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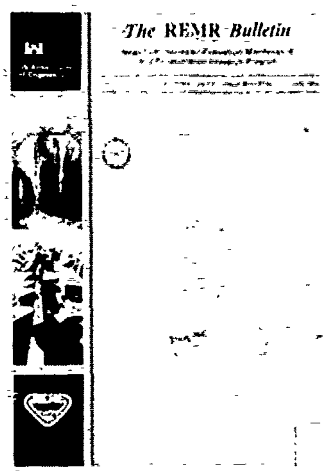

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT SL-REMR-CS-36

EVALUATION AND REPAIR OF CONCRETE STRUCTURES: ANNOTATED BIBLIOGRAPHY 1978-1988

Volume II

by

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HY	Hydraulics	OM	Operations Management
CO	Coastal		

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This bibliography covers the period from 1978 through 1988 and contains 2,062 annotated references on evaluation and repair of concrete structures. The bibliography includes four sections relating to (a) concrete durability and causes of deterioration, (b) procedures for evaluating the condition of existing structures, (c) maintenance and repair materials, and (d) maintenance and repair techniques, and subject and author indexes. Sections a and b are in Volume I, and Sections c and d are in Volume II. The subject and author indexes are included in each volume.

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PREFACE

The work described in this report was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), as part of the Concrete and Steel Structures Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The work was performed at the US Army Engineer Waterways Experiment Station (WES) under Civil Works Research Work Unit 32303, "Application of New Technology to Maintenance and Minor Repair," for which Mr. James E. McDonald (CEWES-SC-R) was Principal Investigator. Dr. Tony C. Liu (CECW-EG) was the REMR Technical Monitor for this work. The annotated bibliography resulting from this study is published in two volumes.

Mr. Jesse A. Pfeiffer, Jr. (CERD-C) was the REMR Coordinator at the Directorate of Research and Development, HQUSACE; Mr. James E. Crews (CECW-O) and Dr. Liu served as the REMR Overview Committee; Mr. William F. McCleese (CEWES-SC-A), WES, was the REMR Program Manager. Mr. McDonald was the Problem Area Leader.

The work was performed at WES under the general supervision of Mr. Bryant Mather, Chief, Structures Laboratory (SL), and Mr. Kenneth L. Saucier, Chief, Concrete Technology Division (CTD), and under the direct supervision of Mr. McDonald, Research Civil Engineer, CTD, who along with Mr. Willie E. McDonald (CEWES-SC-CE), Civil Engineer, CTD, prepared this report.

Commander and Director of WES was COL Larry B. Fulton, EN. Dr. Robert W. Whalin was Technical Director.

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VOLUME II

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acre-feet	1233.489	cubic metres
cubic feet	2.831685	cubic metres
cubic yards	0.7645549	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet	0.3048	metres
gallons (US liquid)	3.785412	cubic metres
gallons (US liquid) per minute	0.00006	cubic metres per second
inches	25.4	millimetres
miles (US statute)	1.609344	kilometres
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres
square yards	0.8361274	square metres
tons (2,000 lb mass)	907.1847	kilograms

* To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) readings, use: $K = (5/9)(F - 32) + 273.15$.

EVALUATION AND REPAIR OF CONCRETE STRUCTURES

ANNOTATED BIBLIOGRAPHY, 1978 - 1988

INTRODUCTION

1. The bibliography contained in two volumes, in essence, is a continuation of the bibliography* previously prepared as part of the Concrete Research Program. The earlier bibliography covered a 51-year** period and contained 826 references. The current bibliography covers the ensuing 11 years; however, it contains 2,062 references. This large number of references reflects the significant increase in concrete evaluation and repair activities during recent years.

ORGANIZATION

2. The bibliography is divided into four sections relating to (a) concrete durability and causes of deterioration, (b) procedures for evaluating the condition of existing structures, (c) maintenance and repair materials, and (d) maintenance and repair techniques. Sections a and b are included in Volume I, and Sections c and d are in Volume II. A reference appears only in the section in which the title is most significantly identified, although the contents of some entries may be associated with two or more sections. Attempts were made to include all references relevant to evaluation and repair of concrete; however, considering the number of references in this broad field, relevant entries may have been omitted.

3. The bibliography contains 461 references in section A on concrete durability and causes of deterioration. The references address a variety of topics including alkali-aggregate reaction, chemical attack, corrosion of

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* Liu, T. C., O'Neil, E. F., and McDonald, J. E. 1978 (Sep). Maintenance And Preservation of Concrete Structures, Report 1, Annotated Bibliography, 1927 - 1977, Technical Report C-78-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS, 409 pp.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

reinforcement, erosion damage, fire damage, and freezing and thawing durability.

4. Section B contains 396 references on procedures for evaluating the condition of existing structures. Many of these references describe non-destructive testing techniques to evaluate the condition of structures. Other major topics include condition surveys, core testing, inspection, petrographic examination, and strength evaluation.

5. Maintenance and repair materials are described in the 495 references contained in section C. These materials include bonding agents, coatings and sealers, fiber-reinforced concrete and mortar, polymer concrete and mortar, polymer-portland cement concrete and mortar, precast concrete, rapid-hardening materials, shotcrete, and silica-fume concrete.

6. Section D contains 710 references on maintenance and repair techniques including bonding new concrete to old, cathodic protection, concrete and masonry cleaning, concrete removal, grouting, overlays, patching, polymer impregnation, polymer injection, strengthening, surface preparation, underwater concreting, and waterproofing. Also, this section includes a number of case histories on maintenance and repair of architectural concrete, bridges, buildings, hydraulic structures, marine structures, pavement, parking structures, and tunnels. References on selection, specification and evaluation of repairs are also included.

7. A complete subject index and author index are provided in each volume as a guide for users of this bibliography.

SECTION C

MAINTENANCE AND REPAIR MATERIALS

and a matching of these needs to a sealant based upon the appropriate design concept. Products such as the semirigid epoxy described in this article are currently available. The designer or buyer should carefully evaluate and be wary of materials that are made to satisfy some other concept of the requirements of a sealant for industrial floors.

C-7 Calvert, G. 1978 (Jun). "Iowa Method of Bridge Deck Resurfacing," Concrete Construction, Vol 23, No. 6, pp 323-329, Cleveland, OH.

Heavy salting of pavements and bridges has resulted in cracking, spalling, and general deterioration of thousands of the nation's bridge decks.

An Iowa research project has developed a practice of using high-strength, low-slump, air-entrained concrete for resurfacing bridge decks. The low-slump portland-cement concrete is used with a sand-cement bonding grout. The only concrete admixtures used are for air entrainment and water reduction. Careful preparation of the old concrete surface, use of high-quality low-slump concrete, and overall good workmanship are essential features of the repair program. While some minor localized failures, have occurred--for example, loss of bond in a spot where an air compressor leaked oil and the saturated concrete was not removed--the vast majority of the 455 bridge decks resurfaced to date have shown no disintegration or other problems.

C-8 Mauritz, W. 1978 (Apr). "Abrasive Wear Problems in Handling and Storage" (in German), Zement-Kalk-Gips, Vol 31, No. 4, pp 180-182, Wiesbaden, Germany.

Abrasive wear occurs as a special case of wear problems. It is characterized by the action of mineral particles which, in performing sliding motions over the surface, tear particles out of the material. The problem can be solved by suitable choice of material, design precautions, and process engineering precautions.

Process engineering and design precautions for combating wear are not always practicable. On the other hand, the choice of material remains possible as a subsequent measure. The training of engineers is directed mainly toward the commonly employed metallic materials. Nonmetallic materials include, for example, mineral and ceramic ones:

- sintered materials such as feldspathic ware, silicon carbide, oxide ceramics;

- cast materials such as cast basalt, cast corundum.

Wear resistance is based on the hardness of various minerals. Abrasive materials which have to be handled are usually softer than the wear-resistant materials, i.e., there is a low level of wear action in respect to the latter. If the material to be handled is harder than the wear-resistant material, a high level of wear actions develops. If possible, conditions should be so arranged that wear is at a low level.

Cast nonmetallic materials can be individually shaped. Some examples of uses for cast basalt in chutes, bunkers, continuous-flow conveyors, cyclones, and separators are given, and cost comparisons are made.

C-9 Rollings, R. S. 1978 (Jun). "Laboratory Evaluation of Expedient Pavement Repair Materials," Report CEEDO-TR-78-44, Civil and Environmental Engineering Development Office, Detachment 1 (ADTC), Tyndall AFB, FL.

Past work and current technical literature were reviewed to determine potential capping materials for expedient repair of small craters (less than 20- by 20-ft repair areas) in airfield pavements. Seven materials identified in the literature review were tested in the laboratory to develop information on strength and cure requirements. Accelerated high alumina cement, magnesium phosphate cement, three commercial asphalt products, and unsurfaced, well compacted aggregate were recommended for field testing as the most promising small crater repair materials.

C-10 "Bibliography on Grouting." 1978 (Jun). Miscellaneous Paper C-78-8, US Army Engineer Waterways Experiment Station, Technical Information Center & Concrete Laboratory, Vicksburg, MS.

This bibliography on grouting contains abstracts of various engineering and scientific publications on both portland-cement and chemical grouts. The technical data cover subjects such as: dams, bridges, buildings, machinery foundations, tunnels - sewers - shafts, silos, roadbeds, pavements, soils, rock bolts, and miscellaneous structures.

C-11 Blankenhorn, P. R., Baileys, R. T., Kline, D. E., and Cady, P. D. 1978 (Jul). "Effects of Linseed Oil on the Compressive Strength of Concrete," Cement and Concrete Research, Vol 8, No. 4, pp 513-515, Elmsford, NY.

Boiled linseed oil/mineral spirits mixtures are being applied to bridge decks as a preventative maintenance procedure by many state highway agencies. Spraying of these mixtures on concrete helps to reduce scaling, but the shallow penetration (about 3 mm) of concrete using the linseed oil mixture has little effect in reducing spalling. Spalling is a major cause of bridge deck deterioration and has been attributed to corrosion of reinforcing steel by deicing chemicals that have permeated the concrete. Recently, research was conducted on relatively deep impregnation of concrete with various linseed oil/mineral spirits mixtures to retard the ingress of deicing salts and water and thereby to alleviate the spalling problem.

When oxygen can reach linseed oil, it polymerizes and forms a film through a series of reactions known as autoxidation. After the deep impregnation of concrete with linseed oil, molecular oxygen probably will be readily available only at the concrete surface. Hence, the linseed oil mixtures in the capillaries will probably remain in the nonpolymerized state for some time. Under these conditions, there is some question as to the effect of linseed oil mixtures on the mechanical properties of the concrete, specifically compressive strength.

C-12 Guenter, R. 1978 (Jul). "Steelfiber Shotcrete for Repair of Prestressed Concrete Structures" (in German), Strassen- und Tiefbau, Vol 32, No. 7, pp 10, 12, Isernhagen, West Germany.

A modern method for concrete bridge repairs by the application of fiber-reinforced shotcrete is described. Definitions are set out and the stress behavior of the composite materials under strain is outlined. The composition of steel fiber-reinforced shotcrete and the main points for using it in repair works is dealt with.

C-13 "Shift Toward Concrete Seen in Minnesota Overlay Test." 1978 (Aug). Engineering News-Record, Vol 201, No. 7, pp 26-27, New York, NY.

Experiments with bonded concrete overlay are under way in a pilot project in Minnesota. Badly spalled pavement and chloride-corroded steel reinforcement is being scarified to create a bonding surface for the 2- to 3-in. nonreinforced overlay.

The bonding agent, a stiff cement slurry, will be hand broomed into the replaned pavement by a crew working less than 100 ft ahead of the paving train. A variety of dense, low-slump mixes--one with a super water-reducing admixture--will be applied in six test sections.

While savings through improved concrete milling methods can be transferred to bituminous overlays. Concrete's cause has also been aided by better slipforming techniques and development of new, quick-set concrete additives.

Test results are still being monitored, but judging from findings, a sand-cement grout applied to a dry surface has produced the most satisfactory bond.

C-14 Paillere, A. M., and Rizoulieres, Y. 1978 (Jul-Aug). "Repair of Concrete Structures by Injection of Polymers: Columns Injectability Tests" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 96, pp 17-24, Paris, France.

Research has led to the development of a relatively simple test which makes it possible to assess the behavior of products during injection. Their differentiation involves the notions of practical duration of utilization, viscosity, and compatibility in a wet medium. This article describes the operational procedure of this test, called the column injectability test, together with the apparatus employed. The results obtained with a fairly wide range of products on the market are given. The test method makes it possible to develop a grout incorporating cement which can be injected into cracks less than 1 mm wide.

C-15 Fowler, D. W., Paul, D. R., and Yimprasert, P. 1978 (Oct). "Corrosion Protection of Reinforcing Provided by Polymer-Impregnated Concrete," ACI Journal, Proceedings, Vol 75, No. 10, pp 520-525, Detroit, MI.

The protection against corrosion provided reinforcing bars by polymer-impregnated concrete (PIC) was investigated. Partially impregnated slabs and fully impregnated piling specimens were used in the investigation. The slabs were sprayed with salt water for 20 months and the pilings were immersed in seawater for up to 28 months.

The bars from the control slabs had about 24 times more surface area corrosion than bars from the treated slabs. The chloride content in the treated slabs ranged from 4.6 percent to 38.2 percent of that in the control slabs.

The bars from the control piles had corrosion ranging from 10 percent to 39 percent over the surface area while the PIC specimens had corrosion over 0.7 percent or less of the bar area. The chloride content of the PIC piles ranged from 3.4 percent to 8.5 percent of the chloride in the controls. In the concrete adjacent to the reinforcing, the chloride contents in the impregnated piles were less than the corrosion threshold.

C-16 Houghton, D. L., Borge, O. E., and Paxton, J. A. 1978 (Dec). "Cavitation Resistance of Some Special Concretes," ACI Journal, Proceedings, Vol 75, No. 12, pp 664-667, Detroit, MI.

The performance of conventional, polymerized, and fiber reinforced concretes subjected to high-velocity water flow with induced cavitation patterns is described. The results, which indicated superior performance of the fiber reinforced and polymer impregnated concretes, are important because of their application to the design of concrete to be used in water passage structures. The materials and techniques tested in this investigation have been used in the repair of prototype structures subjected to high-velocity water flows, and initial results have been promising.

C-17 Stebbins, R. J. 1978 (Dec). "Polymer-Impregnated Concrete at Dworshak Dam," Journal of the Construction Division, Vol 104, No. 4, pp 539-548, American Society of Civil Engineers, New York, NY.

Dworshak Dam is the third highest concrete dam in the United States. After moderate usage, the stilling basin and an outlet suffered serious cavitation and erosion damage. The use of polymer impregnation in the repair of the damaged concrete is explained. Impregnation was performed on conventional concrete, fibrous concrete, dry-pack patches, vertical surfaces, and horizontal surfaces. This was the first major field application of polymer-impregnated concrete. The construction procedures used and the experience gained in the project are presented.

C-18 Clear, K. C., and Chollar, B. H. 1978. "Styrene-Butadiene Latex Modifiers for Bridge Deck Overlay Concrete," Report FHWA-RD-78-35, Federal Highway Administration, Washington, DC.

Styrene-butadiene (S/B) latex modified concrete overlays are being used to protect new bridge decks from rapid deicer-borne chloride intrusion and also in bridge deck rehabilitation efforts. The purposes of this research were to evaluate several commercially available S/B latex modifiers for bridge deck overlay concrete, to develop chemical specifications for the material, a prequalification program to permit evaluation of other S/B latex modifiers which become available, and a certification program to ensure that the user receives a prequalified product.

The chemical and physical properties of the latex emulsions were studied (percent solids, percent butadiene, particle size, surface tension, viscosity, etc.), and the material from each manufacturer was finger-printed using infrared spectroscopy. The physical properties of concrete made with each material were also determined (workability, strength-compressive, flexural and bond, freeze-thaw and scaling resistance, and chloride permeability).

The prequalification procedures given in the report are suggested for use in evaluating other S/B latex emulsions offered by industry. The certification procedures are suggested for use to ensure that each production batch of emulsion is similar to an emulsion which was prequalified.

C-19 Webster, R. P., Fontana, J. J., and Kukacka, L. E. 1978 (Feb). "Rapid Patching of Concrete Using Polymer Concrete," Report CONF-780270-1, Continuously Reinforced Concrete Pavement Workshop, Department of Energy, New Orleans, LA.

One of the major problems confronting the highway industry today is the need for a rapid repair material for deteriorated concrete structures. High maintenance costs and traffic delays have created the need for a long lasting, rapid setting, concrete patching material. The use of polymer concrete (PC) as a repair material is discussed. Materials used to make PC composites are described, as is the procedure for placing polymer concrete patches. The placement of polymer concrete patches in the field by highway maintenance personnel using conventional concrete mixing equipment and techniques is also described.

C-20 Manson, J. A., et al. 1978. "Use of Polymers in Highway Concrete," NCHRP Report 190, Transportation Research Board, Washington, DC.

The major research finding described in this report demonstrates the technical feasibility of field impregnation of structurally sound, salt-contaminated concrete bridge decks with polymer to a depth of 4 in. (10 cm). Following preliminary small field trials in two different locations, using two drying methods and two impregnation methods, the most promising combination was selected and demonstrated in three larger trials. The techniques and principles used are applicable to commercial application, and, although the equipment used was smaller than that proposed for commercial applications, it can be scaled up readily. The specific findings for the various research areas are detailed.

C-21 Everett, A. 1978. Materials, Halsted Press, Wiley, New York, NY.

This book deals with the properties of building materials and materials manufacturing in the factory and on the site. It considers the selection of materials according to performance requirements: economy, deterioration, and maintenance. References to sources of more detailed information are made throughout. Chapters include information on general properties, timber, boards and slabs, stones, ceramic, bricks and blocks, limes and cements, concretes, metals, fiber reinforced composites, bituminous products, glass, plastics and rubbers, adhesives, mortars for jointing, mastics, and gaskets.

Intended for students preparing for professional licensing examinations, this volume may also be used as a reference book for architects, surveyors, builders, and engineers.

C-22 Tyson, S. S. 1978. "Internally Sealed Concrete for Bridge Deck Protection," Interim Report 1, Virginia Highway and Transporation Research Council, Charlottesville, VA.

The study reported herein was performed to examine the use of internally sealed concrete to protect bridge deck reinforcing steel. A laboratory determination of the properties of the wax and concrete used and a field evaluation of a method of heat treatment were made. The experimental structure was a three-span bridge on which internally sealed concrete was applied as an overlay. The concrete mixture had good placement characteristics and resulted in good properties for internally sealed concrete. It had a water-cement ratio of 0.47, a cement content of 752 lb/yd^3 (446 kg/m^3), a wax bead content of 114 lb/yd^3 (68 kg/m^3), and included 4 to 6 percent entrained air. A similar mixture should be used on any internally sealed decks to be constructed. The heat treatment should be modified to prevent thermal cracking by heating entire span lengths and by heating only when ambient temperatures of 60° F (16° C) and higher have been sustained for 1 day. If these recommendations can be implemented, internally sealed concrete should be considered an acceptable system for protecting bridge decks. A decision concerning the use of internally sealed concrete should not be made until further evaluations can be made of pattern cracking that has appeared to varying degrees on both the experimental and control spans.

C-23 Stewart, J. C. 1978. "Internally Sealed Concrete: Wax Beads," Report FHWA-RD-OK-79-02-1, Oklahoma Department of Transportation, Oklahoma City, OK.

This report covers the placement, heating, and testing of two test sites: a salt shed floor and a bridge deck span. Wax beads were mixed with fresh concrete and used as a 1.5-in. (38-mm) overlay on the salt house floor slab. In the construction of the bridge span, wax beads were used throughout the full 9.5-in. (240 mm) depth of the deck to avoid two-stage placing.

Methods of melting the wax are discussed and include: infrared heating, forced air heating, and electric blanket heating. While melting the wax, the maximum allowable surface temperature is 350° F (177° C). A minimum temperature of 185° F (85° C) is required at the reinforcing steel level to melt the wax.

Various tests were run on the slabs. Discussed in this report are: (1) absorption, (2) penetration, (3) chloride analysis, (4) skid resistance, (5) crack survey, (6) compressive strengths, and (7) half-cell. A special provision for internally wax sealed concrete bridge floors is included.

C-24 Rieche, G., and Delille, J. 1978. "Investigation of Temporary Corrosion Measures for Tendons" (in German), Heft 298, Deutscher Ausschuss fur Stahlbeton, pp 5-19, Berlin, Germany.

Temporary corrosion protection measures for tendons are being increasingly used in posttensioned prestressing construction before mortar injection. Temporary anticorrosive agents give only temporary protection, but are normally sufficient for common use in prestressing construction.

Experiments discussed in this article include: testing of the corrosion protection facility, stability in alkaline media, influence of prestressing steel on stress corrosion behavior, compatibility with mortar, and bond behavior. In addition, some characteristic physical properties (viscosity and film thickness) have been determined. These experiments analyze the test procedure and critical examination of temporary anticorrosive agents.

C-25 Fowler, D. W., and Paul, D. R., ed. 1978. "Polymers in Concrete: Second International Congress," University of Texas at Austin, Austin, TX.

This is the published proceedings volume from the 1978 Second International Congress on Polymers in Concrete, sponsored by the American Concrete Institute and the Federal Highway Administration, to provide for the dissemination of information on concrete-polymer materials. The proceedings include papers from worldwide authors which are beneficial to researchers, designers, users, builders, and manufacturers having an interest in the latest developments, existing and potential applications, safety requirements, and economics for polymers in concrete. The table of contents includes such topics as: application of polymers to concrete sea structures, structural use of polymers in concrete, rapid patching of deteriorated concrete using polymer concrete, polymer concrete materials for use in geothermal energy processes, polymer concrete for high-voltage electrical insulation, petrographic identification of polymer in surface-treated bridge decks, and investigation into the use of polymer concrete for rapid repair of airfield pavements. Thirty-nine papers and a discussion section are included in the proceedings.

C-26 "Adhesive Materials, Paints, and Corrosion." 1978. Transportation Research Record 692, Transportation Research Board, Washington, DC.

This report contains six papers on adhesive materials, paints, and corrosion. Subject areas include cement and concrete, general materials, and maintenance. Paper topics are: improving thermoplastic stripe adhesion on concrete pavements; acceptance sampling of structural paints; accelerated performance testing of bridge paints for seacoast environments; measurement of polarized potentials in concrete bridge decks; methods of determining corrosion susceptibility of steel in concrete; and measurement of cement content by using nuclear backscatter-and-absorption gage.

C-27 Cady, P. D., Kline, D. E., and Blankenhorn, P. R. 1978. "Deep Impregnation of Concrete Bridge Decks with Linseed Oil," Transportation Research Record 664, Transportation Research Board, Washington, DC.

The overall objective of the research described in this paper was to evaluate the feasibility of deep (>5 cm) impregnation of concrete bridge decks with boiled linseed oil/diluent mixtures. Impregnation is one of the techniques that is currently receiving considerable attention as a means of improving the longevity of bridge decks by reducing or preventing spalling problems associated with corrosion of reinforcing steel. The choice of linseed oil was based on safety (low volatility and high flash point), cost considerations, and the elimination of the polymerization step required for other polymers. Also, many highway agencies are already familiar with linseed oil, since it is commonly sprayed on bridge deck surfaces periodically to retard surface scaling. The latter procedure results in penetration depths of less than 3 mm and has little or no effect on preventing spalling. Deep impregnation requires a drying step to remove water, followed by sufficient contact with the impregnant to permit penetration to the desired depth. Following a period of preliminary laboratory studies, demonstration impregnations were carried out on 5.6 m^2 areas on two bridge decks. One of the bridges had been subject to three winters of deicer salt application. The other had received no salt. Examination of cores subsequently removed from the test areas revealed that penetration depths ranging from about 5 to 10 cm were obtained.

C-28 McNerney, M. T. 1978. "Investigation of the Use of Polymer-Concrete for Rapid Repair of Airfield Pavements," Report CI 78-112, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH.

An investigation was made to determine the feasibility of using polymer-concrete (PC) for rapid repair of airfield pavements. The PC studied was a mixture of dry aggregate and a methyl methacrylate monomer. Tests were conducted to isolate the variables that affect the strength and polymerization time of PC. Laboratory and field tests were conducted to test the strength, durability, and feasibility of polymer-concrete repairs.

The major variables affecting the polymerization time of PC were temperature and chemical composition. Monomer formulations were developed that permitted polymer-concrete to be polymerized in less than 1 hr at a temperature range of 0 to 100° F.

An investigation into the variables that affect strength resulted in several findings. The tests showed that dry aggregate (less than 1 percent moisture) is very important for strength. The strength of PC increased with stronger aggregate and smaller pore volume. The temperature of the PC affected the strength to a great extent. The higher the temperature the greater the reduction of strength.

Field repairs of interstate highways and a major airport taxiway were conducted successfully. The field repairs demonstrated the feasibility and simplicity of using PC. PC repairs can be made at a cost of approximately $10 per cubic foot for the monomer system.

Laboratory tests on two modeled slabs, 3 by 6 ft with two different thicknesses, showed that PC can resist high stresses successfully under repeated loads of simulated trucks and aircraft. The high stresses successfully sustained by the laboratory slabs seems to indicate a favorable redistribution of stress or plastic behavior compared to conventional concrete.

C-29 Burstrom, P. G. 1978. "Durability and Aging of Sealants," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

The aim of the project has been to examine how fundamental factors causing aging affect mainly the deformation characteristics of sealants. The factors which have been examined are temperature (heat), moisture, alkaline water, ultraviolet (UV) light, and ozone. Furthermore, the effect of natural aging, that is, the effect of natural climate combined with forced joint width variations, has been studied. The effect of the factors has been studied on two polysulfide-based sealants, two polyurethane-based, three acrylic-based, and one oleoresinous-based sealant.

The temperature is the aging influencing factor that has the greatest effect on the deformation characteristics of the sealants. But it is impossible to find a general connection between accelerated aging in heat and natural aging for different types of sealants. Where a couple of the sealants are concerned there are some connections outlined between accelerated heat aging and natural aging. Ozone had a great influence only on the polysulfide-based sealants.

C-30 Pihlajavaara, S. E. 1978. "Background and Principles of Long-Term Performance of Building Materials," Durability of Building Materials and Components, ASTM STP 691. American Society for Testing and Materials, Philadelphia, PA.

A review is presented of historical background information, service life expectations and the need for research in the field of the durability of materials. The necessary procedures and intervals of the maintenance of some building materials also are examined. Information on the performance of materials should be expressed clearly in terms of service years dependent on degradation factors, of degradation effects during lifetime, and of maintenance procedures and intervals.

C-31 Gutt, W. H., and Everett, L. H. 1978. "Durability of Some Common Building Materials," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

In this paper the durability of some materials used in building is considered; in particular, concrete, fibrous composites, surface coatings, and adhesives. For each of these materials, the processes which cause change in the physical, mechanical, or chemical properties are discussed and the deterioration which occurs on aging is reviewed, identifying, where appropriate, the specific environments producing unacceptable loss of function or appearance. Careful selection of the material used in specific applications is considered to be a prime requirement for continued good service and low maintenance.

C-32 Lamberton, B. A. 1978. "Preplaced Aggregate Concrete," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

This article gives a general review of preplaced aggregate concrete technology. Test methods for evaluating the properties of the fresh grout and coarse aggregate fractions employed in this method are described.

C-33 Schutz, R. J. 1978. "Organic Materials for Bonding, Patching, and Sealing of Concrete," Significance of Tests and Properties of Concrete and Concrete-Making Materials, ASTM STP 169B, American Society for Testing and Materials, Philadelphia, PA.

Organic materials which have been used for bonding, patching, and sealing of concrete include epoxy resins, silicones, bitumens, linseed oil, oil-based paints, acrylics, urethanes, polyvinyls, and so-called rubber-based coatings. For these uses the epoxy resin systems have proven to be the most versatile.

1979

C-34 Tabor, L. J. 1979 (Feb). "Concrete Repairs," Precast Concrete, Vol 10, No. 2, pp 65-68, London, England.

Repair of concrete damaged by plastic shrinkage cracking, drying shrinkage cracking, thermal contraction cracking, honeycomb or inadequate compaction, and overloading are discussed. Resin mortars, adhesive bonding of additional steel to existing concrete, and the addition of reinforced concrete are analyzed as remedial actions.

C-35 Fowler, D. W., and Paul, D. R. 1979 (Mar). "Concrete-Polymer Materials for Highway Applications," Report CFHR-3-9-71-114-9F, FHWA/TX-79/03-114-9F, Federal Highway Administration, Austin, TX.

The use of concrete-polymer materials for highway applications has been studied with the objectives of providing durable materials that would reduce maintenance in highway structures. Several significant developments resulted from this research. Partial-depth polymer impregnation was developed for improving durability of bridge decks. The process includes drying the concrete, cooling the surface, applying a low viscosity monomer solution to a sand cover, and permitting it to soak into the concrete, and applying heat to polymerize the monomer in the concrete to a depth of 0.5 in. (1.3 cm) or more. Posttensioned polymer-impregnated beams were made and tested to determine the structural behavior. Beams with an I-shaped cross section and a span of 8 ft (2.7 m) were fully impregnated with a monomer solution. High strength wire tendons were posttensioned and the beams were tested to determine the flexural and shear behavior. Significant increases in strength and stiffness were observed. Time-dependent deflections were reduced by an order of magnitude. Polymer concrete was developed for repairing bridge decks.

C-36 Frey, H., and Wildgruber, J. 1979 (Jul). "Internally Sealed Concrete" (in German), Beton Herstellung und Werwendung, Vol 29, No. 7, pp 243-245, Dusseldorf, Germany.

A new technique for sealing concrete comes from the United States; small wax spheres are added to freshly mixed concrete. After setting, the concrete is heated to about 85° C. This results in the melting of the small wax spheres which then reliably seal the concrete pores.

C-37 Bretz, T. E., Jr. 1979 (Jul). "Properties of Sulfur Concrete," Report AFIT-CI-79-170T, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH.

This report summarizes the state of the art of sulfur concrete. Sulfur concrete is created by mixing molten sulfur with aggregate and allowing the mixture to solidify. Ultimate strength is reached in a short time. It exhibits favorable fatigue properties and has excellent resistance to acids, salts, and many organic compounds. It works well as a rapid runway repair material. Sulfur concrete also has unfavorable properties. It has poor durability when exposed to large temperature change and to wet curing conditions. The material is also brittle. All of these properties are examined in some detail and modifications (dicyclopentadiene and sulfurcrete) are proposed to overcc- the unfavorable properties.

C-38 Brown, R. P., and Kessler, R. J. 1979 (Aug). "Evaluation of Penetrants and Coatings Used on Reinforced Concrete Surfaces," Report RR-207, FHWA/FL-79-207, Florida State Dept. of Transportation, Gainesville, FL.

This report presents a method by which the performance of protective coatings for reinforced concrete in a marine environment can be evaluated. Comparison of properties resulting from an impressed current test is used to establish acceptance limits for qualification of protective coatings to be used on structural concrete in a corrosive environment.

C-39 Seely, T. 1979 (Aug). "Waterproofing Concrete with Wax," Concrete, Vol. 13, No. 8, Aug 1979, pp. 26-27 London, England.

According to recent American research, a dark brown wax extracted from brown coal in East Germany can provide a complete solution to steel reinforcing corrosion in concrete structures. The wax is highly water repellent, is easily molded under the influence of heat, and has high bonding strength and sealing capabilities. It also has a high affinity for concrete, and in its fluid state can wet and penetrate the very smallest capillaries and interstices in a concrete structure.

C-40 Alexander, D. 1979 (Aug). "Substrate Steel Protection in Ferrocement," New Zealand Concrete Construction, Vol 23, pp 29-31, Porirua, New Zealand.

Ferrocement relies on the low permeability of the mortar, the absence of excessive crack widths, and the maintenance of a high alkalinity to protect substrate steel lying with the mortar matrix. The means of achieving these features include the use of fine grained dense mortar with a high cement ratio and a low water-cement ratio in conjunction with chemical protectants such as chromium trioxide for the passivation of galvanized coatings. Crack widths are controlled by adequate subdivision of the reinforcement alone or together with other characteristic bond length determinants, and finally by restricting the working stress levels to prevent crack opening beyond predetermined amounts. In aggressive environments these devices may be augmented by the application of surface protective coatings which may be directly applied to the reinforcing itself or alternatively to the surface of the ferrocement as an initial impervious film. The mechanics of protection, including protection by covers and crack restriction, hydrogen gas evolution fresh cement pastes, and chemical protection of the steel are presented. A discussion includes information on the relative effect of pozzolans to sulfating, crack width, and protective coatings. Crack control comparisons in different forms of ferrocement are also presented.

C-41 Chokshi, C. K. 1979 (Aug). "Shotcrete and Its Uses In Underground Construction," Indian Concrete Journal, Vol 53, No. 8, pp 207-209, 219, Bombay, India.

Shotcrete, which is a modified form of gunite with larger size aggregates, is widely used for repairs and waterproofing of concrete structures. Uses in mines, tunnels, shafts, and other underground structures are discussed. Application systems, properties, and advantages are also presented.

C-42 "To Prevent Corrosion, Stop It Dead In Its Tracks" 1979 (Sep). Concrete Construction, Vol 24, No. 9, pp 591-595, Addison, IL.

Calcium nitrite, a corrosion-inhibiting admixture, can be used in concrete mixes to prevent or greatly delay chloride corrosion of reinforcing steel. The admixture could improve the performance of bridge decks, parking decks, roof decks, marine structures, and other reinforced or prestressed concrete that might be exposed to chlorides. Results of tests show that mixing 2 percent calcium nitrite into the concrete to be used in a bridge deck can increase deck service life by something in the range of 15 to 50 years.

C-43 Master Bond, Inc. 1979 (Sep). "EP41 Solvent-Free, Epoxy-Based Resin Coating System Gives Corrosion Protection Under Severe Exposure Conditions," Plastics Engineering, Brookfield Center, CT.

It has high build, 100 percent solids, and provides air-dry coatings which resist gasoline, oils, lubricants, organic solvents, acids, bases, and salts. It cures quickly and completely at room temperatures. Suggested applications include coatings for CPI uses, finishes for concrete structures pipe coatings, linings, and marine uses.

C-44 Pace, C. E. 1979 (Sep). "The Structural and Durability Properties of Various Concrete Repairs," Miscellaneous Paper SL-79-20, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Many old concrete structures exist and are in need of repair. The structural deterioration will accelerate with advancing age and progressively diminish their service lives. Methods of evaluation and repair are necessary.

Durable concrete can be produced and placed; therefore, the main problem is to have a durable interface between the old and the new concrete. The bonding of epoxy resin, cement mortar, latex polymer mortar, and latex polymer mortar plus fiberglass fabric was tested in a freezing and thawing environment subjected to conditions of complete submergence, one-half submergence, and stress conditions. Many surfaces are subjected to abrasion. The latex polymer was tested to determine if it helped to increase abrasion resistance.

These tests showed that for early ages of repair water will collect at the interface of the old and new concrete and when the water concentration is sufficient and freezing occurs, the overlay will be debonded. The epoxy bond exhibited a constant number of specimen failures with cycles of freezing and thawing. The concrete-to-concrete bonding had more specimens fail at early intervals of freezing and thawing than in later intervals, indicating that as similar characteristics develop between the repair and the aged concrete, less water collected at the interface. All four bonding types had about the same final percent failures in the freezing and thawing environment, which in all probability suggests that the failures due to water collecting at the interface for early ages of repair are essentially comparable.

Specimens which were subjected to freezing and thawing plus stress showed more failures than the unstressed specimens. The specimens which were one-half submerged showed no failure in the freezing and thawing environment.

Epoxy bonding should not be used in a freezing and thawing environment where there is a possibility of water collecting at the interface. The latex polymer showed a considerable decrease in shear strength with cycles of freezing and thawing. The concrete-to-concrete bonding to a dry interface is an acceptable bonding. The fiberglass fabric is a promising material to be added in thin overlays to prevent cracking.

The stressing of the specimens at various intervals of freezing and thawing had an adverse effect on the durability of the shear strength of the repaired interface.

Any eccentricity of the load causing shear at the repair interface produces tension on the interface. Tension was a predominant factor in shear stress failures.

A concrete overlay should be placed on a surface which is surface dry.

C-45 "Protective Materials' (Chessington, England) New Repair Material is for Use on the Exteriors of Buildings, Jetties and Other Concrete Structures." 1979 (Oct). Financial Times, London, England.

The natural concrete gray Epoxy Render provides a method for making permanent repairs to cracked and spalled concrete. After painting on a coat of the firm's Epoxy Tack, Render is applied by trowel. It is easy to use since it should not cling to the tools and consolidates to a dense void free consistency; it also has low slump features making it ideal for repairing vertical or under overhanging surfaces. Render will harden down to 0° C, although full strength will not be achieved until the temperature rises.

C-46 "Indiana Field-Tests New Corrosion-Fighting Deck." 1979 (Oct). Rural and Urban Roads, Vol 17, No. 10, pp 50, 62, Des Plaines, IL.

Concrete bridge decks, modified with a new reinforcing bar rust fighter that promises to end deck spalling, are being tested by the Indiana State Highway Commission under a 5-year research program.

The state placed three new decks containing the additive on three rural bridges located in "snow-belt" areas and subject to deicing chemicals. The use of the additive appeared to have no adverse effect on the concrete.

The additive is a compound of calcium nitrite and water that retards (or stops) the cathodic-generated buildup of rebar rust that spalls decks through volumetric expansion.

C-47 Galler, S. 1979 (Nov). "Polymer Concrete Patching Comes of Age--18 Years Late," Rural and Urban Roads, Vol 17, No. 11, pp 32-33, Des Plaines, IL.

After more than 18 years of successful use in Europe, polymer concrete patching material is gaining acceptance as a road repair material in the US. To compile a track record of its performance, tests and demonstrations are being made. The Federal Highway Administration's sponsored reports on the tested qualities of polymer concrete list these features: good bonding to the original concrete; short cure-time to full load bearing; high chemical and abrasive resistance; minimal permeability to chlorides and water; high physical properties, including higher compression, flexure, and tensile strength than normal concrete; can be ultraviolet ray resistant; can be feather finished; and can be formulated for minimal shrinkage.

C-48 Johnson, H. A., and Chao, P. C. 1979 (Nov). "Rollcrete Usage at Tarbela Dam," Concrete International: Design & Construction, Vol 1 No. 11, pp 20-33, Detroit, MI.

Rollcrete, dry lean concrete placed by earthfill methods, was used as mass fill at Tarbela for rapid repairs of the damages in the intake area of Tunnel 2 and the plunge pool of the Service Spillway. Plant designs and properties of the rollcrete are described. Mix proportions, moisture control, mixing and handling, field density, and compressive strength results are presented.

C-49 Herod, S. 1979 (Dec). "New Weapon Defeats Corrosion In Concrete," Modern Concrete, Vol 43, No. 8, pp 30-32, Cleveland, OH.

A new product, tradenamed Darex Corrosion Inhibitor (DCI), provides a chemical answer to corrosion problems in reinforced concrete. The inorganic compound of calcium nitrate and water is the only product on the market that uses a "fight chemistry with chemistry" approach. Not only does calcium nitrite chemically abort the corrosion process, but tests demonstrate that the additive, which is added to the concrete in liquid form at a ready-mixed concrete plant, also increases compressive strength and accelerating time.

C-50 Bard, R. J. 1979 (Dec). "Teton Dam -- Foundation Grout Testing Program," REC-ERC-79-2, Water and Power Resources Service, US Department of Interior, Washington, DC.

After failure of Teton Dam in Idaho on 5 June 1976, a program was initiated to test foundation grouts similar to those used during construction of Teton Dam. Grouts were to be: made with the same cement, sand, bentonite, and calcium chloride as were used during construction; and made using mix proportions representative of grouts used during construction; and mixed and cured as congruently to field conditions as possible. Bleeding characteristics were also analyzed and a detailed petrographic examination was performed. All grouts exhibited good hydration properties and good physical soundness, adequate strengths, no degradation due to calcium chloride, and low permeability.

C-51 Peschke, H., and Dinitz, A. M. 1979. "Development of Performance Standards and Specifications for Polymer Concrete," Transportation Research Record 713, pp 17-19, Transportation Research Board, Washington, DC.

Eighteen years of experience working with polymers in concrete have shown that early rehabilitation of concrete roadways with polymer concrete will prevent major deterioration problems. Overlays on existing concrete roadways and bridge deck rehabilitation with polymer concrete result in a durable, highly skid-resistant road surface. The use of polymer concrete is also cost effective if all factors are taken into consideration.

Laboratory and field tests can now be performed to determine the true suitability of any proposed polymer concrete material to be used for rehabilitation of concrete roads and bridge decks as well as for the existing substrate.

C-52 Bashore, F. J., and Price, A. W. 1979. "Effectiveness of Neoprene Seals In Preventing Concrete Pavement Contraction Joint Deterioration," Report FHWA/MI-79/2, Michigan Department of Transportation, Lansing, MI.

Over 200 cores were taken from contraction joints sealed with compressible seals on 17 construction projects over a period of 4 years to determine the amount and rate of deterioration of the concrete at the bottom of the joint. Seal performance was rated, chloride content of concrete was determined, and drainability of base material was rated. The study indicates that the neoprene seals are performing well in preventing the entry of incompressibles but permit the entry of liquids into virtually all joints to some degree. Deterioration of the concrete at the bottom of joints is occurring, but at a relatively low rate for most projects. The data include that most of the deterioration occurred during the first 5 years and shows little significant change for the following years. Several modifications in design, construction, and maintenance of concrete contraction joints are suggested.

C-53 Bishara, A. G. 1979. "Latex Modified Concrete Bridge Deck Overlays--Field Performance Analysis," Report FHWA-OH-79-004, Ohio Department of Transportation, Columbus, OH.

Data on field performance of 132 bridge decks overlaid by latex mortar or concrete in Ohio, Michigan, Kentucky, and West Virginia, as well as some data from Minnesota and Vermont, were collected according to a specially designed inspection questionnaire. Common durability distress features and the factors that might influence them were identified. Statistical analysis was performed to determine the set of variables that best explain the variation in the surface distress features among the different latex projects investigated and to quantify the relationship between overlay condition and the pertinent variables through the formulation of regression models. Further assessment of available performance data was conducted to tie the obtained relationships with the limited data on effectiveness of latex overlays in providing corrosion protection to the deck reinforcing bars and to develop hypotheses on the formation and development of various durability deficiency features of latex overlays. The results obtained and the conclusions drawn explain, quantify, and delineate the interrelationship among such factors as years of service, trafficked versus untrafficked decks during placement, continuous versus simply supported decks, thickness of overlay and skid number on the overlay durability and corrosion protection capability.

C-54 Naus, D. J. 1979. "Evaluation of the Effectiveness of Selected Corrosion Inhibitors for Protection of Prestressing Steels in PCPVs," Oak Ridge National Laboratory, Oak Ridge, TN.

The objective of this study was to evaluate the corrosion protection provided prestressing steel by portland-cement-based grout in the presence of sulfide, nitrate, and chloride ion environments. Results were compared to those obtained from selected, commercially available petroleum-microcrystalline waxes (petrolatums) compounded with organic corrosion inhibitors. The investigation as conducted in two phases: (1) a review of literature to establish the mechanisms of prestressing steel in hostile environments and the performance of structures that have utilized nongrouted- or grouted-tendon prestressing systems; and (2) a laboratory study to develop relative performance data for portland-cement grout and selected commercial petroleum-based greases and waxes containing inhibitors. Conclusions derived from the investigation indicate that (1) sulfide, nitrate, and chloride salts must be excluded from prestressing materials; (2) prestressing materials must be continuously protected from inimical environments; (3) the effectiveness of the protection provided by both the organic- and cement-based corrosion inhibitors is reduced unless the steel is completely covered; and (4) both cement- and organic-based corrosion inhibitors completely protect prestressing materials when properly applied.

C-55 Cristman, R., and Lane, K. 1979. "Pavement Recycling--Bituminous Concrete and Concrete Mix Designs," Report FHWA-CT-79-569-1-10, Connecticut Department of Transportation, Wethersfield, CT.

Trial mixes developed from both salvaged bituminous concrete and portland-cement concrete pavement materials were tested in the laboratory. Salvaged materials investigated included crushed and cold-milled bituminous concrete and crushed 40- by 12-ft concrete pavement slabs with wire mesh reinforcing.

Laboratory results indicated the feasibility of full-scale bituminous recycling projects using central-plant mixing of salvaged and virgin aggregate by the heat-transfer method and both in-place full-depth and surface recycling. The concrete tests provided good results in terms of strength properties and demonstrated the potential of concrete recycling. Mesh separation and removal did not present any insurmountable problems.

Experimental design and specifications for full-scale field projects are included for both recycled concrete and bituminous concrete, together with a plan for post-construction evaluation of the various recycled pavements.

C-56 Burstrom, P. G. 1979. "Aging and Deformation Properties of Building Joint Sealants," Report TVBM-1002, Lund Institute of Technology, Lund, Sweden.

A short review of the literature on aging and durability of organic building materials, including sealants, is described. In the experimental part of the report, deformation factors affecting sealant properties are clarified. The effects of thermal, moisture, alkaline water, ultraviolet radiation, and ozone action are considered.

C-57 "Aquatic Structures." 1979 (First Quarter). Construction, Vol 14, No.1, Adhesive Engineering Company, San Carlos, CA.

Several documental case histories in which CONCRESIVE structural adhesive products and the SCB injection process have permanently repaired cracked, leaking, and eroded concrete structures are included in this article.

C-58 Freund, H. T. 1979. "Cementitious Coatings: A Low Cost Alternative," Paintindia, Vol 29, No. 6, pp 27-32, Bombay, India.

The performance of various types of latex modifiers for cement coatings are reviewed. In view of the poor hydrolytic stability of vinyl acetate polymers and the insufficient UV resistance of styrene/butadiene emulsions, acrylic latex modifications were found to give best results. Such systems may be used with advantage in maintenance coatings (exhibiting excellent corrosion control, water and salt resistance), textured coatings, such as waterproof coatings, foam coatings, floor and patio paints, and for steel bar reinforcement coatings.

C-59 Dekker, T. T., Happe, J., and De Jong, J. 1979. "Organic Protective Coatings for Concrete and Asbestos Cement Pipes and Structures Exposed to Sewage Water," Proceedings of the 3rd International Conference on Internal and External Protection of Pipes, London, Vol 2, Paper E3, pp 67-78, England.

Pretreatments and coatings to ensure maximum adhesion to concrete and asbestos cement substrates are surveyed. For example, a sand-filled solvent-free epoxy system on a blast-cleaned surface, followed by a glossy solvent-free epoxy coating, is recommended.

1980

C-60 Plecnik, J. M., Bresler, B., Cunningham, J. D., and Iding, R. 1980 (Jan). "Temperature Effects on Epoxy Adhesives," Proceedings, ASCE, Vol 106, ST1, pp 23-27, New York, NY.

The strength properties of structural epoxy adhesives at elevated temperatures are experimentally determined. Finite element analysis of thermal gradients in typical columns is provided. Both the ASTM E 119 and the SDHI time-temperature fire exposure curves are considered in evaluating the fire ratings of epoxy repaired concrete components. The relationship between strength, duration of fire exposure, and type of fire exposure is provided in both graphical and tabular form.

C-61 Klieger, P. 1980 (Jan). "Something for Nothing - Almost," Concrete International: Design & Construction, Vol 2, No. 1, pp 15-23, Detroit, MI.

This article traces the history of air entrainment in concrete, the development of concepts relative to the characteristics of the air void system, and how air entrainment enhances the resistance of concrete to freezing and thawing. Describes the development of test methods to determine not only the volume of entrained air but also the size and distribution of the air voids. The field performance of air-entrained concrete over the past 30 to 40 years and the recent incidence of poorer performance is discussed. Three broad courses of action are suggested to resolve the reasons for such recent poorer performance.

C-62 "Hi-Performance Patching System Remedies Damaged Concrete." 1980 (Feb). Railway Track and Structures, Vol 76, No. 2, pp 22-25 Chicago, IL.

A multipurpose acrylic reactive resin polymer concrete material (PCM) system employing methyl methacrylate is designed to bond tightly to, to be stronger than, and to outlive the conventional concrete structures it rehabilitates. The polymer concrete mortar system can be applied as a thin, self-leveling overlay or as a matrix for bonding coarse aggregate. Once cured--only 1 to 2 hr after placing--it performs in a manner that not only increases structural strength, but provides durability; imperviousness to deicing chemicals; and resistance to wear, chemical action, and freeze and thaw stresses. The material has a successful track record on European railroads. There, the polymer concrete material solved major problems in bridge bearing shimming operations, high-strength anchor bolt grouting, and in the repair of structurally deteriorated concrete members, ties, and platforms. The solutions to downtime and scheduling problems, mixing variations, and shelf life are described.

C-63 "Cement Composite for Wharf Restoration." 1980 (Feb). Precast Concrete, Vol 11, No. 2, London, England.

A wharf on the River Thames, London, has been successfully reconstructed using a new cement composite called AG-RC. AG-RC is a cement composite reinforced with a combination of alkali-resistant glass fiber and Du Pont's "Keviar" 49 aramid fiber. Regular portland cement is reinforced with 25 mm chopped glass fiber rovings to provide good shear, torsion and compressive strength.

C-64 Burstrom, P. G. 1980 (Mar). "Sealant Between Elements of Aerated Concrete," International Journal of Lightweight Concrete, Vol 2, No. 1, pp 43-47, Harlow, England.

Because of the low tensile strength of aerated concrete, the sealing of joints between such elements causes special problems.

In this paper some main characteristics of sealants for use in aerated concrete joints are discussed. These properties are elongation resistance, elasticity, and aging. The elongation resistance was examined at different rates and different temperatures. The elasticity was determined by measuring the residual deformation after a certain elongation. Storing in heat (40 or 70° C) was used for accelerating aging.

Of ten sealants, only four were found to be suitable in aerated concrete joints. Many of the disqualified sealants showed defective aging properties or high resistance to elongation, which in some cases caused cohesive failure within the aerated concrete.

C-65 Sharma, P. C. 1980 (Apr). "Use of Ferrocement for Waterproofing," Journal of Ferrocement, Vol 10, No. 2, pp 127-141, Bangkok, Thailand.

Waterproofing as a unique application is discussed. Construction notes on this innovative application were presented based on experiences with numerous practical applications of the process described. Economical and functional comparisons of ferrocement waterproofing with other conventional methods of waterproofing were presented.

C-66 Root, C. R., Ismalia, D. A., Locke, C. E. 1980 (Apr). "Polymer Concrete Patching. Volume III. User's Manual," Report FHWA/OK-80/003, Federal Highway Administration, Oklahoma Department of Transportation, Oklahoma City, OK.

Polymer concrete is a quick setting, high-strength, durable patching material used to repair reinforced portland-cement concrete. Cure times of approximately 1 hr can be obtained from 20 to 130° F. The complete patching procedure is discussed including the preparation of the patch, calculation of the amount of materials required, and the mixing and placing of the polymer concrete. Suppliers of the chemicals used are listed. Proper storage, disposal, and safety procedures are also outlined. The cost of polymer concrete is also calculated for the methyl methacrylate (MMA) system used in this study. A materials cost (early 1980) of about $16 per cubic foot or $430 per cubic yard is expected.

C-67 Chandra, S., Berntsson, L., and Anderberg, Y. 1980 (May). "Some Effects of Polymer Addition on the Fire Resistance of Concrete," Cement and Concrete Research, Vol 10, No. 3, pp 367-375, Elmsford, NY.

Some trials have been made under this work to see the influence of small amount (1 to 1.5 percent) of polymer addition on the fire resistance of concrete. Normal concrete plates with and without polymer addition are compared. Lightweight aggregate concrete plates, slabs, and reinforced beams are also tested for fire exposure. Plates of normal and lightweight aggregate concrete have not shown any spalling effect when exposed to fire from one side. Normal concrete without polymer addition resulted in explosive spalling when exposed to fire from two sides whereas no spalling is noticed in all types of concrete tested with polymer addition. A more open structure created in cement paste by polymer addition facilitates the steam transport from the specimens during heating and thus prevents creation of high vapor pressure in the concrete responsible for explosive spalling.

C-68 Mills, D. L., and Campbell, W. A. 1980. "Deterioration of Reinforced Concrete Structures--An Engineering Crisis," Annual Conference - Canadian Society for Civil Engineers, Winnipeg, Manitoba, 29-30 May 1980, University of Manitoba, Winnipeg, Canada.

Mild steel imbedded in alkaline portland-cement concrete is normally not subject to corrosion. However, when concrete is invaded by chlorides, sulfates, and other chemical ions, electrochemical balance shifts to form an active corrosion cell in which steel will corrode and form corrosion products that lead to failure. The paper reviews the failure mechanism. Considering the methods presently available to prevent early corrosion of reinforcing steel and premature failure, the most promising and effective appear to be: epoxy coating of rebar, and corrosion inhibitor addition to the concrete. Each of the two methods offers advantages in cost and application. Fusion bonded epoxy powder coatings have had a successful history in protecting steel against corrosion in chloride environments. There is every reason to believe that a well-formulated and properly-applied fusion bonded epoxy coating will last as long as the concrete structure itself. The method removes application from the site with resulting lower construction costs and superior quality control.

C-69 Van Beemen, J. F. 1980 (May). "Epoxy Resins for Concrete," New Zealand Concrete Construction, Vol 24, pp 4-12, Porirua, New Zealand.

Epoxy resins form a very hard bond with many different materials, have low shrinkage, and can be used in all branches of industry in such products as skiis, spacecraft, bridges, and offshore oil rigs. In the concrete industry, epoxy resin based materials played an important role in the development of new construction techniques and repair methods. Failures due to mixing, temperature, and impurity problems have been reported because the specialized technology and performance specifications of epoxy materials have been neglected.

Epoxy resins have developed since a German patent was awarded in 1934, with further improvements coming from the United Kingdom and the United States. The largest markets are paint and epoxy coatings for concrete members and pavements in particular. Major specialty companies sell preformulated epoxies to customers as well as provide expertise in mixing new compounds for certain applications. Because epoxy resins are thermosetting polymers, they cannot be melted and reused, so the temperature during the reaction with surrounding materials must be strictly controlled. Some formulations are available in summer and winter grades. The working life of the epoxy (the time between mixing and uselessness) depends on the specific formulation and application.

Dilutants, fillers, flexibilizers, fire retardants, modifiers, accelerators, and reinforcers are the major types of epoxy resins. The physical properties of each material, including strength at various temperatures, creep, shrinkage, thermal expansion, and fire resistance, must be considered before each is used as a surface coating, mortar, grout, or adhesive. Various special circumstances in the application, storage, and properties of epoxy resins are also discussed.

C-70 (Deleted)

C-71 "DuPont's Crylon Series 3000 Methacrylate Bonding Agents Provide a Rapid-Setting Polymer Concrete System for Repairing All Kinds of Portland Cement Concrete Structures." 1980 (Jun). Plastic Engineering, Brookfield Center, CT.

The DuPont materials react with a fine aggregate powder and other chemical catalysts to produoe a fast-setting mortar. Average compressive strength is 8,200 psi, versus 4,000 for conventional cement.

C-72 Fowler, D. W., Paul, D. R., McCullough, B. F., and Meyer, A. H. 1980 (Jun). "Methyl Methacrylate Polymer-Concrete for Bomb Damage Repair Phase I," Report AFESC/ESL-TR-80-28, Air Force Engineering and Services Center, Engineering and Services Laboratory, Tyndall Air Force Base, FL.

Methyl methacrylate (MMA) polymer concrete appears to be a material which can be successfully used to rapidly repair bomb damaged runways. A research program is underway to develop monomer formulations, determine engineering design properties, develop repair procedures, conduct field tests, conduct analytical studies, and develop an implementation manual. Research in Phase I has emphasized materials characterization, development of preliminary repair procedures, and analytical and experimental behavior of repairs. Materials characterization studies have determined monomer formulations and polymer-concrete mechanical properties for a wide range of ambient temperatures. Possible solutions for reducing adverse effects on strength of polymer-concrete made with wet aggregate have been studied. The effect of MMA on bond to asphalt has been determined. The effect of aggregate size on mechanical properties has been investigated.

C-73 Selde, V. 1980 (Aug). "Fiber-Latex Approach to Concrete Facing Repair--A Project Report," Construction Specifier, Vol 33, No. 8, pp 52-55, Alexandria, VA.

Lock walls are subject to abrasion and spalling caused by boats and barges banging into them. Damage is also caused by freezing and thawing cycles in the northern latitudes. A practical way to perform essential repairs on lock walls has been developed by the US Army Corps of Engineers. A glass fiber-latex concrete surface coating is sprayed on the walls to prevent further deterioration of the mortar of the concrete. Lock walls at a site in Washington state had to be repaired with a 3-week maximum closure time (conventional repair methods would require several years to complete) and the water-saturated walls could not be dried adequately to use an epoxy concrete overlay, making that repair method impractical. Two groups of three experimental mixes were prepared. One group of three included air entrainment; the other did not. In each group, one mix contained fibers and no latex, one had fibers and latex, and one had neither fibers nor latex. Tests cores taken 1 year after application of the mixes showed the fiber-latex, air-entrainment mixture was the most satisfactory.

Prior to application, the surface was cleaned to remove all loose material and contaminants. An onsite mixing plant was used to prepare the material, which used latex and continuous strand fibers. Since the latex material in the mix cured from the exterior inward, no moist curing was required. Quality control and personnel specifications, contracts, and supervision are outlined in detail. Fiber-latex materials have high tensile strength, impact resistance, and toughness and will have applications in offshore facilities particularly because they prevent intrusion of seawater.

C-74 "Fusion-Bonded Epoxy-Coated Rebars." 1980 (Aug). Concrete Construction, Vol 25, No. 8, pp 587-591, Addison, IL.

This article describes a promising new method for protecting steel reinforcing bars in concrete parking decks and bridge decks. Costs of fusion-bonded epoxy-coated bars are considerably lower than polymer-impregnated or galvanized reinforcing bars.

The rate of deterioration of a concrete deck due to corroding steel, caused by calcium chloride or sodium chloride seepage, increases with time. The iron oxide which forms on the steel increases the volume with the concrete, ultimately causing it to break open in cracks and spall. The loss of large pieces of concrete means greater vulnerability to further corrosive damage.

In a new parking deck in suburban Minneapolis, MN, coated reinforcing bars were used at a cost of $860 per ton, compared to $540 per ton for uncoated bars. In a neighboring project where uncoated bars were used, a $100,000-repair program had to be undertaken after 15 years. The parking deck constructed with coated bars is expected to perform more satisfactorily during the same service life, marking the higher original costs (about 40 cents more per sq ft) worthwhile in terms of better performance.

C-75 Ray, G. K. 1980 (Sep). "How Joint Seals Affect Pavement Performance," Rural and Urban Roads, Vol 18, No. 9, pp 56, 58, Des Plaines, IL.

Joints in concrete pavements are necessary but can be the source of problems and pavement distress if improperly designed, constructed, or maintained. Joint sealants are designed to bond to concrete in the joint and are made to withstand the cycles of tension and compression as the joint opens and closes. Sealants prevent water from entering the subbase and must also resist the intrusion of sand or gravel into the joint reservoir under the seal.

Although there is no complete agreement among paving engineers on the need for sealing all pavement joints, a report by the 16th World Congress of the Permanent International Association of Road Congresses concluded that under certain conditions there is no disadvantage in leaving narrow transverse joints unsealed. The conditions are when: (1) traffic is light, (2) traffic is heavy but climate is dry, and (3) traffic is heavy and climate is wet, but the pavement is doweled. The research noted some improvements in performance when joints were kept reasonably well sealed.

The pumping of soil and water from the subbase under the pavement slab is a cause of deterioration. Pumping at joints, cracks, and pavement edges can also cause failure. Corrosion of the steel reinforcement by deicing salt brine is another form of pavement distress. Properly installed and maintenance joint seals will prevent several major forms of pavement distress. However, overfilling the joints can have a detrimental effect of riding quality.

C-76 "Stadium Steps Repaired with Zero Slump Mortar." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, pp 135-136, Detroit, MI.

The Michigan Stadium steps of the University of Michigan, Ann Arbor, have been repaired and are maintained by an annual program of applying a masonry topping and sealer. An Ann Arbor contractor first removed all loose, deteriorating concrete with chipping guns, cleaned the surface with high-pressure water, applied a coat of inorganic penetrant, then a special mix mortar bond coat, and a final application of a zero-slump top coat of special mix mortar. Within 10 min of final troweling of the top coat, a curing compound was applied to the surface, followed at a later date with a final cleaning and application of an inorganic seal coat.

C-77 Glassgold, I. L. 1980 (Sep). "Shotcrete Repair Saves Baltimore Bridges," Concrete International: Design & Construction, Vol 2, No. 9, pp 120-125, Detroit, MI.

The dry-mix fine-aggregate shotcrete process is still the most widely used shotcrete process for the repair of concrete structures and linings, especially for small patch and thin section repair. Shotcrete repair is extremely effective for variable depth repairs of bridge beams, caps, columns, abutments, wingwalls, and underdeck where deterioration has been accelerated by the introduction of continuous beam design, shallow depth deck slabs, asphalt surfacing, and the heavy use of deicers. Baltimore, MD, has established an annual preventive maintenance shotcrete program to provide emergency repairs and upgrade bridges as the budget allows. The repair program consists of three basic steps: (1) preparation of disintegrated areas; (2) removing bad reinforcing steel and placing galvanized welded wire fabric; and (3) shotcreting.

C-78 Bullock, R. E. 1980 (Sep). "Factors Influencing Concrete Repair Materials," Concrete International: Design & Construction, Vol 2, No. 9, Detroit, MI.

Two very important factors influence the selection of a specific material for a repair program: relative volume change and preparation of the repair interface. Differential volume changes between the repair materials and concrete impose stresses at the interface between the repair and the concrete which may cause cracking in both the sound concrete and the repair material. The most direct method recommended to minimize differential initial shrinkage is to minimize the water content in the replacement concrete.

C-79 "Hi-Performance Patching System Remedies Damaged Concrete." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, Detroit, MI.

A multipurpose polymer concrete material (PCM) can be applied as a thin, self-leveling overlay or as a matrix for bonding coarse aggregate. After a 1- to 2-hr cure, the PCM provides increased structural strength, durability, and resistance against deicing chemicals, wear, and freeze-thaw stresses. In Europe the polymer concrete material solved major problems in bridge bearing shimming operations, high-strength anchor bolt grouting, and in the repair of structurally deteriorated concrete bridge members, ties, and platforms. The techniques in using this material are described.

C-80 Schupack, M. 1980 (Oct). "Divorces and Ruptured Relations Between Epoxies and Concrete," Concrete Construction, Vol 25, No. 10, pp 735-738, Addison, IL.

Epoxy and other polymers are very useful in concrete construction. They are used as coatings, protective armor, bonding agents, for joinery, and for many types of repairs to concrete elements and structures. In many concrete repair jobs, epoxy injection of cracks is the only practical long-term solution. However, when epoxy or epoxy mortar layers have been laminated to concrete in thicknesses of 1/4 in. or more, distress sometimes has occurred. Distress is caused by differences in the shrinkage, thermal, and mechanical properties of the two materials. These differences are much greater in some combinations than in others. A single high thermal shock sometimes can degrade the opposite, as can any of various cyclic changes over a period of time. Some examples of distress include failure of overlay, failure of end cover, and failure of end-block cover.

To avoid eventual distress in a layered system of epoxy and concrete, it is necessary to ensure that the mechanical properties of each material are such that no excessive stresses will be induced by the environment. This is also true of any thicker laminates to concrete such as acrylics, urethanes, and others that have relatively high moduli of elasticity.

C-81 Galler, S. 1980 (Oct). "Bridge Deck Rebar Problem and the Fusion-Coated Solution," Rural and Urban Roads, Vol 18, No. 10, pp 18-20, Des Plaines, IL.

The use of fusion-bonded coating for the protection of reinforcing steel in bridge decks is spreading and is now specified in four states. Definitive tests have underscored the effectiveness of the epoxy-coated reinforcing bar as a corrosion barrier.

After an extensive federally funded study by industry and scientists, it was found that fusing epoxy powder to suitably heated reinforcing bars provided the protection of porcelain and assured long-term protection against the destructive action of roadway deicing salts. As an interface, the coating did not interfere with bonding of the steel to the surrounding concrete, could be applied with few holidays (holes), had tolerable creep characteristics, did not blister, and further, the rod could be bent without rupturing or impairing the coating.

C-82 Sims, F. A. 1980 (Nov). "Use of Resins in Bridges and Structural Engineering in West Yorkshire," International Journal of Cement Composites, Vol 2, No. 4, pp 193-203, Harlow, Essex, England.

This paper covers the application of epoxy resins in segmental beam construction for bridges. The use of epoxy resins in ancillary bridgeworks is discussed, including rock bolting, earth reinforcing straps, expansion joints, and strengthening and repair work. The need for national specifications is stressed.

C-83 Hiranmas, S. 1980 (Dec). "Corrosion of Reinforcing Steel in Sulfur Impregnated Concrete," Dissertation Abstract, Vol 41, No. 6, University of Texas, Arlington, TX.

One of the problems facing reinforced concrete structures in corrosive environments is the corrosion reinforcing steel which subsequently leads to deterioration of the structures. Structures most susceptible to this problem are marine structures and highway bridge decks which are frequently subjected to Cl deicer as a solution to snow and ice problems. Concrete normally provides to embedded steel a high degree of protection against corrosion. This is because steel in concrete is polarized anodically, and because a thin protective film of gamma iron oxide is formed on the steel surface. However, this passivating film is disrupted when the pH value of the moisture in equilibrium with the concrete is reduced by carbonation or when sufficient salt (chloride ions) has penetrated to the steel surface. For this reason, one of the corrosive protection methods is to prevent the penetration of chloride ions to the embedded steel by reduction of the permeability of the concrete cover. Sulfur-impregnated concrete, which is simply a plain concrete with most of its voids filled with sulfur, has been proved to have a very low permeability. The quantities of impregnated sulfur required to completely prevent corrosion of the embedded steel for each concrete mix and the method to approximately predict the length of time the corrosion process takes to cause distress in concrete cover are established.

C-84 Chao, P. C. 1980 (Dec). "Tarbela Dam--Problems Solved by Novel Concretes," <u>Civil Engineering</u>, Vol 50, No. 12, American Society of Civil Engineers, pp 58-64, New York, NY.

While constructing the world's largest embankment dam, Tarbela, in Pakistan, the designers and contractors faced unprecedented flow volumes and velocities causing severe cavitation and erosion. The problems affected the tunnels, one of which collapsed, stilling basins, the flip buckets of both spillways, and the slopes and floor of the two spillway plunge pools. The solutions involved application of special concretes. Record volumes of rollcrete were used to protect the high rock slopes, structures, and foundations, and fiber concrete was used to repair stilling basins and spillways. Epoxy paints or coats were used early on to achieve a smooth, resistant surface, but generally failed within days. They were ultimately replaced by conventional concrete.

C-85 Shimizu, Y., Higashi, Y., and Endo, T. 1980. "Experimental Study on Repaired Reinforced Concrete Wall with Initial Cracks or with Honeycomb," <u>Transactions of the Japan Concrete Institute</u>, Vol 2, pp 415-422, Tokyo, Japan.

The load-deflection behavior of seven epoxy-repaired and nonrepaired reinforced concrete walls is studied. The nonrepaired walls were originally weakened by imperfect construction and subjected to combined axial force, moment, and shear reversals. Observations indicate considerable increase in rigidity and ductility of the repaired specimens compared with the imperfectly constructed weakened specimens.

C-86 Dikeou, J. T. 1980. "Development and Use of Polymer Concrete and Polymer Impregnated Concrete," Progress in Concrete Technology, pp 539-581, Energy, Mines and Resources, Ottawa, Ontario, Canada.

Three categories of concrete which contain polymers are: polymer-impregnated concrete (PIC), polymer concrete (PC), and polymer-portland-cement concrete (PPCC). This paper presents a state-of-the-art review on development and use of PIC and PC in the United States and Canada, with a passing reference to PPCC. As compared to conventional portland-cement concrete, PIC and PC composites can have considerably greater strengths (by a factor of about 4) and are generally much more durable. Engineering design information available on the materials is briefly reviewed. PIC and PC uses in highway related work is rapidly increasing. The greatly improved durability of the materials is the primary benefit from such uses. Polymer impregnation is being used to protect dam structures and to repair deteriorated concrete on highways and in building structures. Other PC applications include precast wall panels, floor blocks, and pipe.

C-87 Mathews, C. W. 1980. "Antifouling Marine Concrete," Report TN-1573, Civil Engineering Laboratory, Port Hueneme, CA.

Various toxic agents were investigated for their ability to prevent the attachment and growth of marine fouling organisms on concrete. Three methods of incorporating antifoulants into concrete were also studied. Porous aggregate was impregnated with creosote and bis-tri-n-butyltin oxide (TBTO) and then used in making the concrete. Cuprous oxide, triphenyltin hydroxide (TPTH), and 2-2-bis-(p-methoxyphenyl)-1,1,1-trichloroethane (methoxychlor) were used as dry additives. Two proprietary formulations were applied as coatings on untreated concrete. Test specimens were exposed at Port Hueneme, CA, and Key Biscayne, FL. Efficacy of toxicants was determined by periodically weighing the specimens and the fouling organisms that became attached. Concrete prepared with an aggregate impregnated with a TBTO/creosote mixture demonstrated the best antifouling performance of those specimens exposed for more than 1 year. The two proprietary coatings and the concrete containing methoxychlor, TPTH, and cuprous oxide as dry additives have exhibited good antifouling properties but have been exposed for a shorter time. Also, the strength of concrete prepared using the toxicants was acceptable, and the corrosion rate of reinforcing rods did not increase. The concentration of organotin compounds was essentially unchanged in a concrete specimen exposed 6-1/2 years in seawater.

C-88 Alberts, C., and Stromberg, U. 1980. "Damage to Concrete Balconies--Follow-up of Previous Repairs" in Swedish, CBI Report 2:80, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

The project provides source material for recommendations for repairing concrete balconies. The state of repairs, carried out on a large number of balconies, has been inspected. The results have been complied in tabular form. Of the repairs carried out more than 5 years ago, only those which were done by specialist firms were in good condition.

Repairs which can be regarded as more or less cosmetic operations and which have been made with cement mortar or plastic have shown particularly poor results. There are numerous examples of repairs which have failed after no more than a couple of years.

Particular attention was devoted to the comparatively new repairs carried out according to accepted practice using conventional concreting methods. All of these were intact after 3 years. The question which now arises is if this repair standard is satisfactory or if more specialized methods, which have proved to be durable for decades in highly exposed positions, should be recommended instead.

Repairs using plastic material have shown widely varying results. Repair work involving, for example, epoxy mortar with satisfactory preparatory work and otherwise executed in a professional manner are still intact after more than 5 years.

C-89 Dunstan, E. R., Jr. 1980. "Possible Method of Identifying Fly Ashes that will Improve the Sulfate Resistance of Concretes," Cement, Concrete, and Aggregates, Vol 2, No. 1, pp 20-30, Philadelphia, PA.

Current methods for determining sulfate resistance of fly ash concrete often require several years of testing. An accepted method that can be used to predict sulfate resistance in a few days does not exist. A hypothesis is submitted as a possible step toward development of a comprehensive theory. The sulfate reactivity of fly ash is characterized by its chemical composition. One high calcium fly ash was shown to react similarly to blast furnace slags. Sulfate resistance of comparable fly ash concretes is shown to correlate with ash composition; therefore, based on chemical composition of fly ash, a sulfate resistance factor is proposed.

C-90 Ohkubo, M., Fukuda, R., and Higashi, Y. 1980. "Application of Shotcrete for Repairing and Strengthening Reinforced Concrete Existing Members," Transactions of the Japan Concrete Institute, Vol 2, pp 383-390, Tokyo, Japan.

Two series of tests investigated the effects of shotcrete sprayed on existing reinforced concrete members for stiffness recovery and improvement of shear capacity. In the tests of cantilever-type slabs, the shotcrete sprayed to the bottom of the slab caused noticeable effects on the stiffness recovery and the reduction of creep deflection in long-term tests. In the tests of shear failure type beams, the shotcrete sprayed to both sides of the beam improved failure mode from brittle shear to ductile flexure in some beams without stirrups.

The shotcrete method was useful for repairing and strengthening existing reinforced concrete members. Diagonal tension cracks occurred in some beams and reduced load capacity, but the improvement in the failure mode clearly showed the effect of shotcrete strengthening.

C-91 Makita, M., Mori, Y., and Katawaki, K. 1980. "Performance of Typical Protection Methods for Reinforced Concrete in Marine Environment," Performance of Concrete in Marine Environment, SP-65, American Concrete Institute, Detroit, MI.

This report describes laboratory and field tests on the corrosion preventive effects of resin coating, galvanizing, cathodic protection, concrete surface coating, and commercial inhibitors used as a protection measures for steel in concrete. The following conclusions were drawn from the test results:

(1) The best in protective performance among the epoxy coatings is the powder epoxy. For protective performance, a coating thickness of 150μm or greater is required, but for good bond to concrete, the thickness of 150μm is considered to be optimum. The liquid type tar epoxy coating is not satisfactory in its protective performance or for bond to concrete.

(2) Galvanization gives good protective performance but is not always satisfactory at the splash zone.

(3) Cathodic protection has an excellent protective effect in the tidal area and in seawater. The voltage to be applied is preferably -1,000 to 1,200 mV. When it is higher than -800 mV, the effect is not satisfactory, and when lower than -1,500 mV, overprotection may result.

(4) Urethane coating over the concrete surface failed to give a satisfactory cutoff effect in the tests and proved to be of no protective value.

(5) Sodium sulfite series inhibitors had no protective effect.

C-92 Ivanov, Y. A., et al. 1980. "Waterproofing Coating for Concrete Surface," Soviet Inventions Illustrated, Vol C, No. 31, Group L, 3, London, England.

Coatings for concrete surfaces are based on epoxy resin, polyethylene/polyamine, shale tar, and stabilized butadiene/styrene latex.

1981

C-93 Reading, T. J. 1981 (Jan). "Durability of Shotcrete," Concrete International: Design & Construction, Vol 3, No. 1, pp 27-33, Detroit, MI.

The low water-cement ratio of shotcrete enhances its durability for most types of exposure. However, some concern has been expressed about its resistance for frost action, even though most service record reports are good, because air entrainment is not normally used, and the findings of previous research are inconclusive.

Samples of shotcrete from several jobs were tested for strength, air content, air spacing factor, and other properties. Most of the specimens performed poorly in the accelerated freeze-thaw test frequently used for conventional concrete. Performance in a less accelerated test--exposure in seawater off the coast of Maine--was much better.

At the present state of the art, it appears that dense shotcrete with a low water-cement ratio should be durable under ordinary freezing and thawing. Caution should be exercised, however, where special mixes are used or the exposure is very severe.

C-94 "Quick-Set Grout/Binder for NEC Bridge." 1981 (Jan). Railway Track and Structures, Vol 77, No. 1, pp 38, Chicago, IL.

A railroad bridge in the Northeast Corridor near Newark, DE, was rehabilitated with polymer concrete used as a selfleveling grout and as a structural concrete binding agent. The polymer concrete was used to both fix and shim new precast concrete ballast-deck panels. Total track outage had to be minimized on the busy Northeast Corridor route, so the grout had to set up within an hour. The project also required the use of a simply mixed and installed grout to save time.

The rail and ties were removed from the bridge, a wooden walkway was dismantled, and a front-end loader was used to remove ballast from the old bridge deck. The old deck was cut away in sections off the steel girder spans. Once the new precast concrete panels were set in place, the grout was fed into the void spaces. The polymer concrete grouting component was easily mixed and the material was sufficiently cured in 45 min. Compressive and flexural strengths met the design requirements.

C-95 Steinegger, H. 1981 (Jan). "Fibre-Reinforced Mortar in Underground Structures" (in German), Beton Herstellung Verwendung, Vol 31, No. 1, pp 9-10, Dusseldorf, Germany.

By using a new glass fiber reinforced rapid-hardening mortar, it is possible to carry out tunnel restoration operations and the temporary support of freshly driven tunnel sections with unsophisticated machinery. Since this work can be done economically and at a steady pace, the material presented in this paper makes a valuable contribution to advanced tunnel repair and lining methods.

C-96 Ruffert, G. 1981 (Jan). "Experience with the Application of the New German Standard DIN 18 551, 'Shotcrete'," Concrete International: Design & Construction, Vol 3, No. 1, pp 107-108, Detroit, MI.

In 1974, the German Concrete Association published the DIN 18 551, "Spritzbeton" (Shotcrete) applying to all shotcrete jobs, especially for tunnel lining and maintenance of reinforced concrete constructions. The use of shotcrete for strengthening and repairing of load-bearing concrete members was regulated in a special appendix to this norm, "Recommendations for the Strengthening and Repairing of Reinforced

Concrete Structures by Shotcrete," published in 1976 by the same committee. The application of this standard has brought a net increase in shotcrete quality as well as in the general use of shotcrete in the last few years in Germany.

C-97 Monahan, A. 1981 (Jan). "Porous Portland Cement Concrete; The State of the Art," Miscellaneous Paper SL-81-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This study investigates the current state of the art relating to the production and use of those porous portland cement concretes that may be suitable for the construction of porous portland cement friction courses. Porous concretes produced by gap grading or elimination of the fine aggregate fraction were found to have been used in both pavement and nonpavement applications with varied degrees of success. Nonpavement applications discussed include: porous draintiles and drains, porous concrete floors in greenhouses, and a porous concrete blanket placed on an earth-fill dam.

Pavement applications discussed include: a no-fines pavement layer, porous portland cement concrete pavements, and porous pavement edge drains or porous hard shoulders.

Evidence as to the suitability of porous portland cement concretes for the construction of porous portland cement friction courses is inconclusive. The successful use of porous concretes in other pavement applications does, however, suggest that porous concretes may be useful in the construction of friction courses.

C-98 Mander, R. F. 1981 (Feb). "Use of Resins in Road and Bridge Construction and Repair," International Journal of Cement Composites and Lightweight Concrete, Vol 3, No. 1, pp 27-39, Harlow, Essex, England.

This critical and practical review of the use of resins focuses on expansion joints, nosings, surfacings, adhesives, and bonded reinforcement. The author begins by cautioning the proper use of resin systems since they are expensive and should be fully exploited if selected.

Bonded nosings, installed correctly, overcome all the difficulties presented by expansion joints in bridge decks. These difficulties are described, and a history of the use of nosings in several countries is outlined. The advantages of epoxy resin mortar nosings were originally seen to be related to the material's toughness and high early strength. Their disadvantages and the causes of nosing failure are described. Hollowness and cracking became a major problem, and a probable mechanism of warping and curling, involving the exotherm, is outlined. Polyester-resin mortar and polyurethane-resin mortar nosings are also discussed. Concrete nosings, though far cheaper than resin systems, must be reinforced, preferably with random fibers.

Resin adhesives are commonly used in segmental construction; they compare favorably with concrete joints. Resin adhesives are also increasingly used instead of welding in secondary connections in structural steelwork. They are also used in the bonding of steel to concrete to provide additional reinforcement for existing structures.

It is emphasized that bonded external reinforcement be used with care since codes and standards do not yet exist for this method, and the long-term behavior of strengthened structures is not known.

C-99 Iwasaki, N. 1981 (Feb). "Properties and Usage of Galvanized Steel Reinforcement" (in Japanese), Concrete Journal, Vol 19, No. 2, pp 3-11, Tokyo, Japan.

Hot-dip galvanizing is evaluated as an effective procedure for preventing corrosion of reinforcing steel both in experiments and in practice. If structures with galvanized steel are designed and constructed in the same way as those with ordinary steel bars, durability will be remarkably improved.

C-100 Chung, H. W. 1981 (Jan-Feb). "Epoxy Repair of Bond in Reinforced Concrete Members," ACI Journal, Proceedings, Vol 78, No. 1, pp 79-82, Detroit, MI.

Pullout specimens and reinforced concrete beams were tested to investigate the effectiveness of epoxy injection in repairing the bond between steel and concrete in reinforced concrete members. The tests results indicate that the bond strength can be restored by the repair process, provided adequate penetration of epoxy resin into the bar-concrete interface can be achieved.

C-101 Rostasy, F. S., Ranisch, H., and Alda, W. 1981 (Apr). "Strengthening of Prestressed Concrete Bridges in the Region of Coupling Joints by Means of Bonded Steel Plates" (in German), Bauingenieur, Vol 56, No. 4, pp 139-145, Berlin, Germany.

Repair of cracks at the coupling joints of prestressed concrete bridges requires an increase of the usually very low reinforcement ratio. This may be realized with epoxy-resin glued steel plates. The report deals with research for solving the problems of design, execution, and efficacy of such a strengthening method.

C-102 "Concrete Repair." 1981. Civil Engineering, Supplement, pp 5-11, London, England.

This article discusses vacuum impregnation, guniting, repair materials, resins, crack injection methods, organic chemical treatment, epoxy adhesives, and admixtures.

C-103 Wehefritz, K. W. 1981 (Apr). "Repair of Reinforced Concrete Structures" (in German), Beton Herstellung Verwendung, Vol 31, No. 4, pp 131-133, Dusseldorf, Germany.

Early and efficacious remedial measures for deteriorations in structures safeguard against more extensive and costly repairs. This applies also to reinforced concrete structures with insufficient depth of concrete cover over steel. Good results are achieved with shotcrete. The article looks at practice-oriented applications.

C-104 Bennington, R., and Emmons, P. 1981 (Apr). "Concrete Repairs to a Water Treatment Plant: Treating Both Cause and Effect," Concrete International: Design & Construction, Vol 3, No. 4, pp 82-87, Detroit, MI.

This article describes the methods used to repair a 50-year-old water plant with concrete walls suffering severe deterioration due to freeze-thaw cycling and exposure to corrosive chemicals. The repairs had to be made while the plant remained in operation. The existing walls of the chlorination tank were encased with a new concrete wall. Deteriorated concrete tie beams were replaced with epoxy-coated steel beams. Exterior face wall repairs were made with shrinkage, compensating cementitious patching mortar, and interior face wall repairs were made with a flexible lining system.

C-105 Wilder, C. R., and Spears, R. E. 1981 (Apr). "Concrete for Sanitary Engineering Structures," Concrete International: Design & Construction, Vol 3, No. 4, pp 29-34, Detroit, MI.

This article is based largely on the report by ACI Committee 350, "Concrete Sanitary Engineering Structures." It describes the desirable properties of concrete in general and the specific properties required of concrete for sanitary engineering structures. It deals primarily with the making of watertight, chemical resistant concrete, with special emphasis on sulfate resistance and how to attain it.

C-106 Kubanick, J. E. 1981 (May). "Catalog of Decorative Barrier Coatings for Concrete," Concrete Construction, Vol 26, No. 5, pp 406-412, 417, Addison, IL.

This article lists some of the most commonly used paint systems which have merit for application to concrete. All of the substances are identified by generic names, and their advantages and disadvantages for use on concrete are outlined on the basis of the present state of the art. However, the rapidly expanding technology of the paint industry in an atmosphere of increasing governmental and environmental regulations brings continuing changes. To keep up to date, a knowledge of current documents is required, supplemented by a working relationship with reputable, technically capable coatings suppliers.

Many decorative paints are applied only for appearance. They offer little in the way of barrier properties and cannot be expected to last very long when subjected to harsh atmospheres or when asked to help protect the concrete substrate from chemical attack. Several of these are included in this "catalog." Coatings listed include latex emulsions, water-based portland-cement paints, alkyds, chlorinated rubbers, phenolics, acrylics, oil-modified urethanes, vinyls, urethane prepolymers, catalyzed epoxies, epoxy esters, two-component urethanes, and polyesters.

C-107 "New Jersey's Pulaski Skyway Gets a New Latex-Modified Concrete Surfacing." 1981 (May). Constructioneer, Vol 35, No. 11, pp 28-30, Chatham, NJ.

A major resurfacing project on New Jersey's 3-1/2-mile long Pulaski Skyway has been completed. In 1979, an $11-million contract was awarded for the repair work. The contract called for removing the existing deck (1-1/2 in. thick) in a continuous deck slab. Another was the use of the first aluminum median barrier curb in the East, along the entire 3-1/2-mile length of the skyway as a safety update, replacing the old steel H-bar type.

A unique feature of the job included the installation of a latex-modified concrete immediately over the main beams which had been cut down to expose the reinforcing steel. The next stage called for drilling 2-1/2-in.-diameter holes, 8 in. deep, down to the beams and removing moisture from the holes with a heavy-duty vacuum cleaner. Stud shear connectors were then welded to the beams using a special foot and chuck adaptor to permit stud welding through the small-diameter holes. When the repaving operation was completed, the stud shear connectors welded to the beams served to tie the fresh concrete to the framework. The steel and concrete combined in a composite action to increase the strength of the deck.

C-108 Fernandez, M., and Soto, M. C. 1981 (May). "Mortars and Concretes with Wax: An Answer to Durability?" (in Spanish), Revista del IDIEM Vol 20, No. 1, pp 9-22, Santiago, Chile.

Water absorption is reduced by impregnation, and, consequently, durability to attacks from salt solutions and to freezing and thawing greatly improves, though strength is impaired. But for wax content up to 25 percent by weight of concrete, the decrease in strength is not significant.

C-109 Reading, T. J. 1981 (May). "Shotcrete for Building Repairs," Concrete Construction, Vol 26, No. 5, pp 379-383, Addison, IL.

Properly placed shotcrete is a superior product for repairs and thick overlays because of its excellent bonding properties.

C-110 Yadav, K. S. 1981 (Jul). "Acidproof Lining for Concrete Surfaces in Chemical Plants," Indian Concrete Journal, Vol 55, No. 7, pp 183-186, Bombay, India.

Concrete is readily attacked by acids and other corrosives. Acid-proof brick lining is recognized as the best and most economical protective lining for use under continuous immersion conditions with strong acids and chemicals at elevated temperatures coupled with moderate abrasive operating conditions. The brick lining consists of a membrane, followed by the actual acid-proof lining.

The types of bricks used and proper acid-proof cements for bedding and mortar purposes are discussed. Use of a special mastic for instances where dry salts are handled is mentioned. Applications of the lining in various circumstances is outlined, and two tables present the consumption of various materials and the general properties of acid-proof cements.

C-111 Buck, A. D., and Burkes, J. P. 1981 (Jul). "Characterization and Reactivity of Silica Fume," Miscellaneous Paper SL-81-13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Silica fume is a fine, siliceous powder that is a by-product of producing silicon metal or ferrosilicon in a reducing environment in an electric furnace. Recent research work on cementitious materials included characterization of such a silica fume from Alabama by chemical, physical, and petrographic tests. In addition, properties of mixtures of this fume with water and calcium hydroxide were studied. Compressive strengths were determined at different ages, and the composition and microstructure of the hydrated material was studied by X-ray diffraction and by scanning electron microscopy.

The results show that the silica fume is characterized by small spheres of high silica content, by very high surface area, and is almost totally amorphous. Physical tests showed that it is a pozzolan, is effective in reducing expansion due to alkali-silica reaction, and increases the sulfate resistance of mortars. Combination of this material with water and calcium hydroxide results in the formation of extremely well crystallized Type I calcium silicate hydrate (CSH-I).

C-112 Moksnes, J. 1981 (Aug). "Resins in Construction and Repair of North Sea Oil Structures," <u>International Journal of Cement Composites and Lightweight Concrete</u>, Vol 3, No. 3, pp 203-211, Harlow, Essex, England.

Typical properties of resin systems are described, and the range of conditions encountered in practice and development of a wide range of epoxy systems for a variety of applications are discussed. Several applications, such as surface and underwater repairs, used as curing membranes, and crack and joint sealing are described in detail. Careful selection of materials and good workmanship are essential to derive maximum benefit from epoxy system use. A wide range of properties can be obtained from epoxies to suit requirements of the designer and contractor.

C-113 Webster, R. P., and Fontana, J. J. 1981 (Aug). "Technology for Improving the Wear Resistance of Aggregates by Materials Impregnation," Report FHWA/RD-81/115, Federal Highway Administration, Washington, DC.

The use of impregnation as a means of improving the wear resistance of natural aggregates was investigated. A series of tests were conducted using 4 aggregates of varying quality, selected from a sampling of 40 different aggregates. Tests performed to evaluate the effect of impregnation on the physical, mechanical, wear resistant and polish resistant properties of the aggregates included: petrographic analysis, Los Angeles abrasion loss, sodium sulfate soundness loss, the British polish wheel, aggregate surface microtexture analysis, and two circular test track studies. The strength of concrete cast with unimpregnated and impregnated aggregate was also tested, as was the affinity of asphalt to bind to impregnated aggregate. Impregnants studied included: MMA-based and styrene-based monomer systems, water-based phenol formaldehyde resin, and sodium silicate. In general, the physical and mechanical properties of natural aggregates can be significantly improved by impregnation. Significant improvements in wear resistance can also be obtained, however, in some instances this improvement is accompanied by a decrease in polish resistance. The use of impregnated aggregate can increase the strength of concrete. Impregnation can also reduce the tendency of some aggregates to strip.

C-114 Hogan, F. J., and Meusel, J. W. 1981. "Evaluation for Durability and Strength Development of a Ground Granulated Blast Furnace Slag," Cement, Concrete, and Aggregates, Vol 3, No. 1, pp 40-52, Philadelphia, PA.

Ground granulated blast furnace slag was evaluated as a 40 to 65 percent replacement for portland cement in mortars and concrete. The study showed that ground slag replacement significantly improved strengths, sulfate resistance, and alkali aggregate reactivity. But slag-cement concrete strength development was more adversely influenced by cold weather conditions than is the strength development of straight portland-cement concrete.

C-115 Palencar, Z. 1981 (Sep). "Concrete Impregnated in Surface Zone" (in Slovak), Stavebnicky Casopis, Vol 29, No. 9, pp 745-756, Bratislava, Czechoslovakia.

Research shows the applicability of impregnants based on pyrolysis oil and epoxide resins. Influence of the technological conditions of impregnation (thinning rate of the agent, time and number of operations) on the watertightness of concrete was assessed. Frost resistance of impregnated concrete compared with nonimpregnated concrete was twice improved. Chemical resistance of the impregnated concrete was determined by electrochemical method. Impregnating concrete in the surface zone with agents containing epoxide resins or pyrolysis oil protects concrete against the corrosive effects of some diluted acids.

C-116 "Spray-On Inhibitor Helps Fight 'Concrete Corrosion'." 1981 (Sep). Engineers Australia, Vol 53, No. 18, St. Leonards, Australia.

This article briefly describes a method to check anodic and cathodic corrosion of steel reinforcing rods and protect the surrounding concrete. Corrosion is detected by sounding hammers and magnetic detectors, the concrete's affected area is chipped away, the exposed section is blasted with fresh water before heating to 105° C, and this section is then sprayed with a bipolar inhibitor.

Air pressure in the hairline cracks is lowered by the heating, reducing surface tension of the inhibitor. After treating the affected section, a mortar mix that consists of 10 percent inhibitor is used to repair the concrete structure. The area is then coated with a silicone-modified acrylic spray.

C-117 Stephens, H. S., and Goodes, D. H., ed. 1981. "Proceedings Conference Papers Presented at the Fourth International Conference on the Internal and External Protection of Pipes," Noordwijkerhout, the Netherlands, 15-17 Sep 1981, BHRA Fluid Engineers, Cranfield, Bedford, England.

The conference proceedings contains 27 papers. The subjects covered include thermostat protective coatings, thermoplastic coatings, durability, quality assurance, cathodic protection, stress effects on pipeline coatings materials, internal protection of pipelines, and high temperature applications. Some papers consider thin film coatings, polyethylene coatings, operations in Saudi Arabia, zinc-based coatings, submarine pipeline concrete quality, low water-cement ratio concrete mixes, hot coating systems, potable water transportation, heat resistant coating materials, external protection tapes, and hot buried flow lines in Holland.

C-118 Grube, H. 1981 (Oct). "Surface Protection of Reinforced Concrete" (in German), Beton, Vol 31, No. 10, pp 379-384, Dusseldorf, Germany.

For most applications, concrete gives itself the best surface protection in terms of durability. However, there are some cases where additional surface protection is useful. For protection right from the start and remedial measures in the event of damage to the surface, the industry offers well-proven products.

C-119 Helminger, E., and Ruhl, K. 1981 (Oct). "Temporary Protection Against Corrosion of Prestressed Steel Tendons in Prestressed Concrete Using Nitrogen" (in German), Bauingenieur, Vol 56, No. 10, pp 395-399, Berlin, Germany.

For various prestressed concrete construction methods, especially in prefabrication of prestressed concrete building elements, prestressing rods may lie in the nongrouted sheaths for a longer time. During this period, condensation water can accumulate inside the sheaths and cause stress corrosion or hydrogen embrittlement of the prestressing rods. Corrosion and damaging mechanisms can be counteracted by using nitrogen, an application which is technically and economically justifiable.

C-120 Pfeifer, D. W., and Scali, M. J. 1981 (Dec). "Concrete Sealers for Protection of Bridge Structures," NCHRP Report 244, Transportation Research Board, Washington, DC.

Concrete bridges in the US are undergoing accelerated deterioration caused by corrosion of embedded reinforcing steel.

The objective of this investigation was to study the effectiveness of different chemical surface sealers when applied on concrete and cracked reinforced concrete subjected to different environmental conditions. Their effectiveness was established by determining if these chemical materials could minimize or prevent the intrusion of salt water into concrete during four different laboratory test phases, including 24 weeks of accelerated northern and southern climate weathering tests. The investigation was aimed at all bridge surfaces except the top surface of the bridge deck, subjected to tire abrasion.

Results show that a wide range of generic types of chemicals are being used to seal concrete bridge surfaces. However, the laboratory performance of these chemical materials in minimizing the intrusion of salt water into concrete was highly variable.

Although significant variations in performance exist, certain chemical materials exhibit very good to excellent performance. These materials are able to reduce the intrusion of chloride by 80 to 99 percent when compared with uncoated concrete. The approximate formulations and infrared spectra for these specific materials are identified in the report. Two test procedures, including limits on chloride intrusion, are suggested for use by chemical manufacturers, highway agencies, and testing laboratories to evaluate the performance of sealers.

Guidance is given on proper application rates for the materials that provide good to excellent results, and on the proper amount of air drying time the concrete should be allowed, after curing or rain, prior to applying these sealers. All specimens received a very light sandblasting to prepare the concrete surface for the sealers.

Although certain sealers can significantly reduce the intrusion of chloride into concrete, the use of properly consolidated and cured low water-cement ratio concrete and deep cover over the embedded reinforcing steel is still needed for long-term protection in severe environments.

C-121 Kaminetzky, D. 1981. "Application of Polymers for Rehabilitation of High-Rise Concrete Structures," <u>Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations</u>, National Science Foundation, Washington, DC.

This paper describes the rehabilitation of two 7-year old highrise 45-story concrete structures using polymer mortars. Time-dependent creep and shrinkage imposed high stresses with resulting damage in the form of shearing and spalling of concrete slabs at a highrise apartment complex. Additional damage was caused by corroding reinforcing bars and "pop-outs" near the exposed concrete surfaces.

In situ stress relief tests using electrical strain gages were performed at various levels and indicated a rather high level of compression stresses. A computer model was analyzed for the effects of dead and live loads coupled with long time creep and shrinkage. The correlation was sufficiently close to establish the main mechanism of damage.

A comprehensive repair program was undertaken. This included the use of polymer powered mortars. The no-water mix was very easy to apply, cured and hardened fast, and resulted in a very hard surface with high tensile and compressive strengths.

The separation of the cladding by introduction of "soft joints" was affected so as to reduce the repetition of development of high stresses.

C-122 Ramakrishnan, V. 1981 (Dec). "The Role of Superplasticized Fiber Reinforced Concrete and Fiber Shotcrete in the Rehabilitation of Bridges," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, Washington, DC.

A significant portion of the nation's highway system consists of portland-cement concrete pavements. Due to increasing heavy traffic, use of deicing salts, freeze-thaw cycles, studded tires, and various other fatigue, surface deterioration and failures are beginning to show up on the pavements. There is a need to determine the most effective and the most economically advantageous means to rehabilitate the distressed concrete pavements.

An investigation sponsored by the Department of Transportation, Washington, DC, has been completed at the South Dakota School of Mines and Technology, to develop a tough, high-strength, high-density, durable concrete for bridge deck construction and a medium-strength flowing structural concrete through the use of superplasticizers and steel fibers. The study was made in two phases. The first investigated the basic properties of concrete made with superplasticizers through the use of experimental mixtures conforming to the requirements dictated by statistically valid factorial designs, so that analysis of variance can be used in the evaluation. The second phase extended the findings into an evaluation of superplasticized concrete containing steel fibers. The study has been completed and the significant results are presented in this paper.

In a corrosive atmosphere, there is extensive damage and deterioration in the beams, piers, columns, and abutments of bridges. The most effective way to rehabilitate these bridges is through the use of fiber shotcrete. A suitable mix, using a new type of steel fibers with deformed ends glued together into bundles with water soluble adhesive, has been developed for shotcrete work. This paper presents the evaluation of the performance characteristics of this fiber shotcrete.

C-123 Iyer, L. S. 1981 (Dec). "Polymer Concrete and Its Application in Bridge Maintenance," Proceedings of an International Conference on Rehabilitation of Buildings and Bridges Including Investigations, National Science Foundation, Washington, DC.

Polymer concrete is a monolithic material composed of aggregates bound together with a polymeric compound. Its chief advantage lies in its quick setting and fast development of strength without any special curing, thereby reducing significantly traffic closure time on busy highways and airport runways.

The paper discusses the development of an optimized polymer mix at South Dakota School of Mines and Technology and its properties compared with the commercial mixes available in USA. Simulated patch work in the laboratory are evaluated for strength properties, finishability, workability, and thermal compatibility with portland-cement concrete. Field application of polymer concrete to maintenance of pavements, runways, and bridge decks are in progress.

C-124 Fontana, J. J. 1981. "Recommended Practices for the Use of Polymer Concrete," Report BNL 29351, Brookhaven National Laboratory, Upton, NY.

Polymer concrete is defined as a composite material in which the aggregate is bound together in a dense matrix with a polymer binder. Special terms used in reference to the discussion of polymer concretes are defined.

Specific instructions for using polymer concrete patching materials and overlays are given. Factors discussed include material limitations, surface evaluation, formwork, tool cleaning, and safety. Use of polymer concrete as a patching material will provide a fast-curing, high-strength material suitable for repairs for portland-cement concrete structures. Polymer concrete overlays make a durable and wear resistant surface for portland-cement concrete. These overlays may also be formulated to provide low water and chloride permeabilities to help prevent concrete deterioration after freeze-thaw cycling or concrete spalling due to reinforcing steel corrosion.

Precast polymer concrete is also discussed. Different applications of precast polymer concrete are listed and proper formwork, vibration techniques, mixer selection, and finishing techniques are described. Appropriate plant design and safety procedures for precast polymer concrete are mentioned.

C-125 "Corrosion Prevention." 1981. Zinc Cadmium Research Digest, Vol 39, pp 44-50, New York, NY.

Progress in applied research aimed at preventing the corrosion of steel by galvanizing is described. Results of testing galvanized and ungalvanized steel rebar in concrete exposed to air, seawater, and chloride solution under dynamic loading are presented. Fatigue life was significantly extended for cold worked and hot rolled rebar. Similar research is reported on an investigation of the use of galvanized steel reinforcement for a variety of concrete structures. Projects to evaluate pretreatments necessary to ensure adequate adherence of paint on galvanized surfaces are discussed.

C-126 Ramakrishnan, V., and Coyle, W. V. 1981. "Superplasticized Concretes for Rehabilitation of Bridge Decks and Highway Pavements," Report DOT/RSPA/DPB-50/81/3, South Dakota School of Mines and Technology, Rapid City, SD.

A two-phase study was initiated to develop guidelines for assuring the trouble-free placement of tough, high-strength, high-density, durable concrete for bridge deck construction through the use of superplasticizers and steel fibers. The first phase investigated the basic properties of concrete made with superplasticizers through the use of experimental factorial designs. This phase is described in the report.

Two mixes, one with medium workability and high cement content suitable for bridge deck replacement, and the other with high workability suitable for structural and pavement concrete, were selected for intensive study. Slump, vibration time, flow table spread, air content, and initial and final setting times are reported for the mixes. The effects of retempering are described. The influence of three types of cements on the properties of plastic and hardened concrete is explained. Results of tests on compressive strength, tensile strength, flexural strength, static modulus of elasticity, dynamic modulus of elasticity, pulse velocity, and dry unit weight at 1, 3, 28, and 90 days curing are given. The selected concretes showed high durability and satisfactory resistance against deicer scaling.

C-127 Fontana, J. J., and Reams, W. 1981. "Repairs with Polymer Concrete," Report BNL-31146, CONF-811244-1, Department of Energy, Washington, DC.

The practicality of using polymer concrete (PC) to repair portland-cement concrete (PCC) bridge decks and pavements has been demonstrated. PC repairs will cure rapidly over a wide range of temperatures (0° to 38° C), develop high strength in a few hours, and bond well to PCC. The use of PC as a thin, permeable, skid-resistant overlay has to date shown outstanding wear characteristics. The practicality of placement is not yet conclusive, but the material promises many advantages.

C-128 Weyers, R. E., Cady, P. D., Blankenhorn, P. R., and Stover, L. R. 1981. "Evaluation of the Bond Durability of Low Slump and Latex-Modified Concrete Overlays on Polymer Impregnated Concrete," Applications of Polymer Concrete, SP-69, American Concrete Institute, Detroit, MI.

Polymer impregnated concrete (PIC) was overlaid with a low-slump dense concrete (LSDC) or a latex modified concrete (LMC). Flexure strength, compressive strength, and freeze-thaw durability data were obtained on the composite specimens. Flexural data indicated a strong bond was established between LSDC, LMC, and PIC. Compressive strength data indicated the bond was weaker for the LMC than the LSDC. Freeze-thaw data showed that a durable bond was established between the PIC and the LSDC whereas the bond failed between the PIC and LMC.

C-129 Meyer, A. H., McCullough, B. F., and Fowler, D. W. 1981. "Highway Pavement Repairs by Using Polymer Concrete," Transportation Research Record 800, Transportation Research Board, Washington, DC.

As traffic, particularly truck traffic, has increased on the primary highway system, the need for rapid repair methods has increased. Polymer concrete (PC) has been used effectively for rapid repair of portland-cement concrete pavements, both jointed and continuously reinforced. Basic formulations for PC are presented and both user-formulated and prepackaged systems are described. Methodology for the repair of cracks, joints, spalls, and punchouts is illustrated. The results of several PC repairs are presented. Deflection measurements that illustrate the restoration of structural integrity, which means a prolonged pavement life, are given.

<u>1982</u>

C-130 "Rapid Hardening Concrete." 1982 (Jan). Federal Laboratory Consortium, Springfield, VA.

This citation summarizes a one-page announcement of technology available for utilization. Deteriorating structures in or out of water can be repaired with rapid hardening concrete that can be formulated on the spot with very little extra cost. In most cases simple calcium chloride will serve as the hardening accelerator. The Navy's Civil Engineering Laboratory has developed the formula for fast-setting and rapid-hardening portland-cement concretes for use in restoring damaged or deteriorated concrete structures. These structures are situated either ashore or in harbor waters at depths to 60 ft, in any geographic region. A data sheet showing the summary of mixtures, proportions, and conditions for use of accelerators may be obtained by requesting information on TECTRA Case W03-10. The data sheet also gives some instructions on which type of accelerator to use (calcium chloride or calcium nitrate) depending upon several stated conditions. These conditions are carefully described.

C-131 Schulz, R. J. 1982 (Jan). "On New ASTM Standards--Epoxy Resins," <u>Concrete International: Design & Construction</u>, Vol 4, No. 1, pp 33-37, Detroit, MI.

This article discusses the use of ASTM standard material specification C 881-78 Epoxy Resin-Based Bonding Systems for Concrete and the ACI standard specifications for use of these bonding systems: hardened materials to hardened concrete, ACI 503.1-79; plastic mortar or concrete to hardened concrete, ACI 503.2-79; producing skid-resistant surfaces on concrete, ACI 503.3-79; and the repair of concrete with epoxy mortars, ACI 503.4-79.

The advantages and ease of using standard material specifications in conjunction with standard specifications describing the work are discussed. The technical reasons for the ASTM standard test methods for epoxy resin bonding systems are also covered.

C-132 Hummert, G. 1982 (Jan). "Repairs with Steel Fiber-Reinforced Shotcrete" (in German), Beton, Vol 32, No. 1, pp 13-14, Dusseldorf, Germany.

Through the constant impact of a grab bucket, the walls of a central refuse incinerator plant in Vienna were damaged over the years and had to be repaired. This was done with steel fiber reinforced shotcrete which, as compared with normal concrete, can absorb higher impacts and thus withstand extreme loads.

C-133 Kuroda, Y., Imaki, J., Ishibashi, S., and Ko-Bayashi, A. 1982 (Feb). "Repair and Strengthening of Reinforced Concrete Viaduct Damaged by Fire" (in Japanese), Concrete Journal, Vol 20, No. 2, pp 27-33, Tokyo, Japan.

This article describes the repair of railway viaduct. Also described are test results on mix proportioning of concrete containing a superplasticizer and an expansive admixture and on composite beams consisting of existing reinforced concrete and shotcrete or newly placed concrete.

C-134 Schwarz, W. E. 1982 (Mar). "Shipyard Piers Undergo Major Restoration," Concrete International: Design & Construction, Vol 4, No. 3, pp 43-46, Detroit, MI.

While examining concrete deterioration to pier support beams and pile caps at the Portsmouth Naval Shipyard in New Hampshire, a contractor found unexpected damage. What appeared to be minor damage turned into a major concrete restoration project using polymer-modified concrete on the piers exposed to seawater. Details of the repairs are discussed.

C-135 Hugenschmidt, F. 1982 (Apr). "New Experiences with Epoxies for Structural Applications," International Journal of Adhesion and Adhesives, Vol 2, No. 2, pp 84-96, Kyoto, Japan.

The properties and testing of structural adhesives are reviewed in relation to such applications as segmental concrete bridge construction and the repair and strengthening of reinforced concrete structures. Criteria for the selection of epoxy adhesives are discussed with particular emphasis on creep deformation, heat stability, moisture resistance, on-site conditions, handling, and field testing. Supportive structural tests for large-scale applications are also described.

C-136 Mays, G. C., and Vardy, A. E. 1982 (Apr). "Adhesive-Bonded Steel/Concrete Composite Construction," International Journal of Adhesion and Adhesives, Vol 2, No. 2, pp.103-107, Kyoto, Japan.

The development of a new form of roadway deck for bridges is described. This consists of a concrete core bonded to a steel soffit plate using epoxy resin adhesive. The durability of structural joints made with a number of adhesives and with steel, concrete, and aluminum adherends was investigated.

C-137 Kordina, K., and Naisacke, J. 1982 (May). "Repair and Protection of Damaged or Unsatisfactorily Executed Concrete Surfaces with Mortars and Coatings Based on or Containing Synthetic Resins: Part 3" (in English and German), Betonwerk und Fertigteil-Technik, Vol 48, No. 5, pp 295-300, Wiesbaden, Germany.

After inspecting a relatively large number of reinforced concrete structures, which were protected for repairs using artificial resins, results of these measures are assessed. Special attention is paid to the physics of these protection or repair materials as well as to their durability.

C-138 Leuchars, J. M. 1982 (May). "Scots College--Strengthening the Main School Building," New Zealand Concrete Construction, Vol 26, pp 12-13, Porirua, New Zealand.

This article briefly describes the method used for strengthening the school building. Some internal brick walls were demolished and replaced by lightweight construction; remaining brick walls were sprayed with up to 150-mm-thick gunite. Steel strapping to assist the timber diaphragms were added to the underside of the floors. Walls were detailed according to current practice for walls of low ductility, and a single layer of reinforcement with diagonal trim bars at all openings was used. No changes were made to the exterior facade or main entrance.

C-139 Howell, R. D. 1982 (May). "Fiber-Reinforced Concrete Proves Worth for Airport Pavements," Civil Engineering, Vol 52, No. 5, pp 52-55, American Society of Civil Engineers, New York, NY.

This article discusses effectiveness of this concrete as a practical and economical material for both overlays and slabs on grade. Basically, two projects are discussed that used a new type of steel high-strength fiber with deformed ends collated and held in packets of 25 fibers by a water-sensitive glue. Deforming the fiber ends improves fiber anchorage and permits use of longer fibers of higher-strength steel.

Fiber-reinforced concrete (FRC) has shown increased flexural strength, fatigue life, and impact resistance over plain portland-cement concrete. Initial construction cost of FRC and conventional heavy-duty portland-cement concrete pavements is approximately the same, with FRC pavement thickness one-half to two-thirds of conventional concrete for given design criteria. FRC's greater tensile strength allows an increased joint spacing, expected to reduce long-term maintenance associated with cracking and spalling concentrated at the joints.

Design considerations when using FRC, including aggregate gradation and straight versus deformed collated fibers, are discussed. Specific concerns of construction using FRC are given. Applications of FRC to industrial slabs, precast structures, moment-resisting ductile frames, shear reinforcing in beams, and impact and blast resistant structures are mentioned.

C-140 Koop, D. E., and Anderson, J. E. 1982 (Jun). "Study of High Density and Latex Modified Concrete Bridge Deck Overlays," Report R82-4(535); FHWA/NE/R-82/4, Federal Highway Administration, Lincoln, NE.

Portland-cement concrete overlay surfacings for bridge decks which will effectively resist deicing salt solution penetration are a major concern. The report compares the relative effectiveness of latex modified concrete and high density concrete overlays. This report is divided into the following chapters; (1) Introduction, (2) Compressive Strength and Air Content, (3) Density of Hardened Concrete, (4) Shear Bond Strength, (5) Chloride Penetration, (6) Roughness, (7) Skid Resistance, (8) Cracking, Delaminations, and Corrosion and (9) Conclusions. From the data it was concluded that the differences in the measurements between the two protective systems are minimal and that both latex modified concrete and high-density concrete overlays provide adequate bridge deck protective systems.

C-141 Bacci, J. A. 1982 (May-Jun). "Polymer Concrete Tests--A Success," The Military Engineer, Vol 74, No. 480, pp 218-221, Alexandria, VA.

This article describes tests in Baltimore that demonstrate the possibility of converting old railroad track on wood ties and rock ballast (in a tunnel with very limited space) to modern high-speed track on concrete ties bonded to an existing concrete invert slab without keeping the track out of service for more than 12 hr per day.

Concrete ties were bonded to a 100-year-old concrete slab using a thin layer of polymer concrete. Details of the practical test apparatus simulating the loads of passenger and freight trains are given. The mixing plant was mounted on a railroad car. Other cars making up the work train were the crane car, equipment car, and a flatcar bearing an industrial vacuum cleaner truck.

C-142 "Epoxy--Polyamide Coatings for Resistance to Atmospheric Corrosion." 1982 (Jul). Material Performance 21, Vol 7, pp. 51-57, National Association of Corrosion Engineers, Houston, TX.

Data on the performance and limitations of epoxy--polyamide coatings used to control atmospheric corrosion are presented. Although there are many epoxy-based coatings available, this discussion includes only the epoxy resins made by reaction of bisphenol-A with epichlorohydrin, the type most commonly used in protective coatings. These epoxy coatings are subdivided further into the following classes: amine-cured (two-component); epoxy esters; thermoplastic epoxy; and epoxy--polyamide (two-component). General data are also given on properties, forms available, effects of compounding, chemical resistance, properties of applied coatings, surface preparation, application details, and experience record. Epoxy--polyamide coatings are among the most widely accepted and universally used industrial maintenance finishes. They can be applied by brush, spray, or roller to metal and concrete structures and are cured at ambient temp. > 50° F to achieve their final properties.

C-143 Plecnik, J. M., et al. 1982 (Aug). "Epoxy-Repaired Concrete Walls Under Fire Exposure," Proceedings, ASCE, Vol 108, ST8, pp 1894-1908, New York, NY.

Strength properties and other important parameters regarding the behavior of epoxy-repaired concrete walls during fire exposure were experimentally determined. Both ASTM E 119 and SDHI time-temperature "pseudo" fire exposures were considered in evaluating the fire ratings of epoxy-repaired concrete walls. Conclusions are provided regarding the interrelationship between fire performance and wall thickness, crack width, duration and intensity of fire exposure, and type of epoxy adhesives.

C-144 Bennison, P., and Duggan, M. 1982 (Aug). "Concreting the Derwent-Wear-Tees Tunnels," Concrete, Vol 16, No. 8, pp 13-14, London, England.

This article describes construction of the smooth concrete lining (minimum thickness 200 mm) of a rough rock tunnel. In Britain's largest water project to date, the finished tunnel is to transfer some 1,100 million liters of water form the £120 million reservoir. Production, transportation, and placing of the concrete are described. A special concrete with greatly enhanced performance was required. Repair of defects with a polymer-modified cementitious mortar is also described.

C-145 Drennon, C. B. 1982 (Aug). "Latex Improvement of Recycled Asphalt Pavement," Report FHWA/OH-82/006, Federal Highway Administration, Ohio Department of Transportation, Columbus, OH

The investigation compared the performance of a single unmodified milled recycled asphalt concrete to milled asphalt concrete modified by addition of three types of rubber latex. Latex was added at 2, 3, 5, and 8 percent latex by weight of asphalt in the asphalt concrete. Latices used were a styrene-butadiene (SBR), a natural rubber (NR), an acrylonitrile-butadiene (NBR), and four varieties of out-of-specification SBR latices. Marshall tests, while indecisive, showed a modest improvement in properties of SBR and NR-added material at 3 and 5 percent latex. Addition of NBR latex caused deterioration in Marshall stability and flow over that of control. Repeated load tests were run using the indirect tensile test, analyzed by the VESYS program, which computes life of pavements. Repeated load tests showed improvement in asphalt concrete life when 3 and 5 percent SBR was added. Improvement was also shown by the out-of-specification SBR. Natural rubber showed no significant improvement, probably due to mixing difficulties. The addition of rubber in latex form to recycled hot-mix as a method to improve pavement characteristics shows promise, but proof of practicality is not yet adequate.

C-146 El-Jazairi, B. 1982 (Sep). "Rapid Repair of Concrete Pavings," Concrete, Vol 16, No. 9, pp 12-15, London, England.

This article discusses the use of a proprietary magnesia-phosphate cement (MPC) for repairing concrete pavements. MPC is a chemical-setting cement, consisting mainly of magnesia, a mixture of phosphates blended with fine aggregates, and packed as a ready-to-use mortar. Mix proportioning and fresh mix properties are covered. Properties of the hardened mortar and concrete including mechanical properties and temperature effect, compressive and tensile strength at 20° C, dimensional stability, durability, and absence of the need for curing are discussed. Typical applications of the patching material are also named.

C-147 (Deleted)

C-148 Sugama, T., and Kukacka, L. E. 1982 (Sep). "Magnesium-Phosphate-Glass Cements with Ceramic-Type Properties," Report PAT-APPL-6-422 510, Department of Energy, Washington, DC.

Rapid setting magnesium phosphate (Mg glass) cementitious materials consisting of magnesium phosphate cement paste, polyborax and water-saturated aggregate, exhibits rapid setting and high early-strength characteristics. The magnesium glass cement is prepared from a cation-leachable powder and a bivalent metallic ion-accepting liquid such as an aqueous solution of diammonium phosphate and ammonium polyphosphate. The cation-leachable powder includes a mixture of two different magnesium oxide powders processed and sized differently. When mixed with the bivalent metallic ion-accepting liquid, the powder provides the magnesium glass cement, consisting primarily of magnesium ortho phosphate tetrahydrate, with magnesium hydroxide and magnesium ammonium phosphate hexahydrate also present. The polyborax serves as a set-retarder. The resulting magnesium mono- and polyphosphate cements are particularly suitable for use as a cementing matrix in rapid repair systems for deteriorated concrete structures as well as construction materials and surface coatings for fireproof structures. (ERA citation 08:054284)

C-149 Broniewski, T., and Macharski, P. 1982. "Aging of Polymers in Concrete Impregnated with Polymethyl Methacrylate," (in Polish), No. 37, Konf No. 7, Wydawnictwo Politechniki Wroclawskiej, pp 18-25, Wroclaw, Poland.

An analysis of the possibility of Polymethyl Methacrylate (PMMA) ageing showed that there is no danger that the properties of concrete impregnated with this polymer may deteriorate since this plastic is one of the most ageing-resistant materials of this type. Very low reactivity of PMMA excludes the possibility that it can be degraded in contact with concrete components despite the largely developed surface of this contact. Further more, the concrete matrix cuts off the polymer from light and other adverse agents such as increased or variable temperature whereby it is protected from their pernicious effects.

C-150 Ellyin, F., and Matta, R. A. 1982 (Sep-Oct). "Bonding and Corrosion Protection Properties of Two Coatings for Prestressing Steels," ACI Journal, Proceedings, Vol 79, No. 5, pp 417-440, Detroit, MI.

Corrosion resistant and bonding properties of two types of coatings were investigated. Cement slurry and coal-tar modified epoxy (resin) were applied on different types of prestressing steels. Twenty pretensioned and posttensioned beams with uncoated, cement-slurried, and resin-coated strands were subjected to the attack of calcium chloride ($CaCl_2$) and sulfur dioxide (SO_2) environments.

C-151 McDonald, J. E., and O'Neil, E. F. 1982 (Oct). "Annotated Bibliography: Polymers in Concrete," Technical Report SL-82-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Included in this bibliography are 1,211 annotated references on polymers in concrete. They cover articles written between 1922 and 1981 on four major areas of polymers in concrete: polymer concrete, polymer-impregnated concrete, latex-modified concrete, and sulfur concrete. A complete subject index and author index are provided.

C-152 Ironman, R. 1982 (Dec). "Polymer Concrete for Swiss Tunnels," Concrete Products, Vol 85, No. 12, Chicago, IL.

This article presents a solution to the problem of concrete spalling in Swiss railroad tunnels. The spalling was caused by the high gypsum and marl content of the rock coupled with heavy rainfall and air pollution. The solution had been to drain water off before it could saturate the concrete and exert pressure to create spalling. In seeking a more efficient and less expensive solution, a system of central drainage channels with high chemical resistance was proposed. Concrete was said to be unsuitable for the system because of its low surface porosity. A "lining" channel of polymer concrete set within a conventional precast reinforced concrete duct was tested and surpassed all values specified.

C-153 Joshi, A. B., Singh, R., and Singh, R. N. P. 1982 (Dec). "Epoxy Resins as Bonding Agent for Concrete Repairs Under Water," Indian Concrete Journal, Vol 56, No. 12, pp 322-323, Bombay, India.

The spillway stilling basin floor of a high gravity dam suffered extensive damage due to the abrasive action of the water. Repairs were unsuccessfully attempted by underwater concreting with anchor road and reinforcing mat. Experimental investigations on the use of epoxy resins were done; the various tests carried out are described. It is shown that epoxy materials can develop a good bond between old and new concrete in underwater conditions.

C-154 Wieczorek, G., and Gust, J. 1982. "Protection of Reinforcing Steel in Carbonized Concrete With a Dikszopt Corrosion Inhibitor" (in Polish), Ochr. Przed Koroz. Vol 25, No. 2, pp 30-34, Poland.

Test results of a Dikszopt corrosion inhibitor for reinforcing steel are discussed. The protective effectiveness of this inhibitor was examined by gravimetric, electrochemical, and ellipsometric methods. The inhibitor effectively inhibits reinforcing-steel corrosion in concrete with a carbonized surface (4.5 times lower rate of corrosion). The effect of the inhibitor in a liquid corrosive environment in concrete, the structure and durability of passive layers on iron, and the permissible degree of anodic polarization at which the inhibitor is effective were determined. The criteria for selecting the cements in respect of application technology were also determined.

C-155 Orgtekhstrom, L. 1982. "Decorative/Protective Coating Composition for Concrete, etc.," Soviet Inventions Illustrated, Vol E, No. 14, Group G, 3, London, England.

Coatings for concrete, which has been preactivated with phosphoric acid prior to application, contain an alumino-borophosphate binder, titanium dioxide, silica, kaolin, chromium oxide, and water. Curing is effected by IR radiation.

1983

C-156 Goldstein, D. 1983 (Jan). "Epoxy Coating Systems," Plant Engineering, Vol 37, No. 2, pp 102-103, Barrington, IL.

There are two basic types of epoxy resins: liquids and solids. Liquid epoxy resins are formulated from 100 percent solids and contain no solvents. They flow well and fill gaps. The solid epoxy resins, on the other hand, must be dissolved in solvents, so their use is restricted to thin coatings. The epoxy group in the basic resin is stable until it is mixed with other types of reactive resins, such as amines, polyamides, and amido-polyamines. Epoxy resin and curing agents are used in flooring applications because of their strength and durability. Systems containing epoxy resins range from low-viscosity, low-solids coatings, to high-solids, high-viscosity bonding agents and heavily filled troweled-on mortars. Applications discussed include coatings for protective and decorative use, acid resistance and slip-proofing, mortars for resurfacing, repairing and grouting masonry, and agents for bonding new concrete to old damaged concrete.

C-157 Hansen, T. C., and Narud, H. 1983 (Jan). "Strength of Recycled Concrete Made from Crushed Concrete Coarse Aggregate," Concrete International: Design & Construction, Vol 5, No. 1, Detroit, MI.

Compressive strength of hardened concretes made from recycled concrete coarse aggregates was studied as a function of compressive strength of original concretes from which coarse aggregates were derived. Also studied were properties of fresh concretes made from recycled aggregates, gradings of crusher products, properties of recycled aggregates, and the amount of old mortar which remained attached to various grades and size fractions of recycled aggregate.

The compressive strength of recycled concrete is largely controlled by the water-cement ratio of the original concrete when other factors are essentially identical. If the water-cement ratio of the original concrete is the same as or lower than that of the recycled concrete, then the new strengths will be as good as or better than the original strengths and vice versa.

C-158 Tabor, L. J. 1983 (Feb). "Concrete Repair: The Role of Resin Compositions," Concrete, Vol 17, No. 2, pp 19-22, London, England.

This article outlines proper use of resin composition in the maintenance and repair of concrete structures. Their complementary role to cementitious materials is stressed. Specific applications of resins to construction faults and service faults are briefly covered.

C-159 Robery, P. C. 1983 (Feb). "Structural Repairs," Concrete, Vol 17, No. 2, pp 23-24, London, England.

This article briefly discusses proper materials and methods for repairs to concrete. Often, cementitious materials (concretes, grouts, and mortars) are preferable to resin-based alternatives due to their structural and thermal compatibility with the parent concrete. Methods that may be used for repair include wet concreting, preplaced aggregate, polymer-modified concrete, sprayed concrete, and underwater placement.

C-160 Kobayaski, K., Itoh, T., and Takewaka, K. 1983 (Feb). "Studies on Epoxy Coated Reinforcing Steel" (in Japanese), Concrete Journal, Vol 21, No. 2, pp 91-106, Tokyo, Japan.

As a means of protecting steel in concrete from corrosion due to chlorides, increasing the thickness of cover may be first considered. But in the case where cover thickness is limited for design reasons and some cracking is unavoidable, it is necessary to adopt a positive corrosion protection method such as providing a barrier layer at the surface of concrete (lining corrosion protection), mixing in a substance such as a polymer to the concrete to lower permeability, and covering the reinforcing bar itself with a corrosion protection material (galvanized reinforcing steel and epoxy-coated reinforcing steel). This study deals with the epoxy-coated reinforcing steel.

C-161 Higgins, D. 1983 (Feb). "Repairs to Cracks in Concrete," Concrete, Vol 17, No. 2, pp 26-28, London, England.

Before repairing cracks in concrete, it is necessary to determine why the cracking occurred and if the structural safety, durability, watertightness, and/or appearance will be affected. Types of cracks are distinguished between (dead, live, and growing), and the basic repair premise suitable to each situation is mentioned. The repair methods of resin injection, vacuum impregnation, polymer emulsions, cement-based materials, stitching, movement joints, bandaging, and surface coatings are outlined.

C-162 Kawamura, M., Koizumi, T., and Hasaba, S. 1983 (Mar). "Some Properties of Slag Cement Concrete Using Polypropylene Polymer Emulsion" (in Japanese), Memoirs of the Faculty of Technology, Vol 16, No. 1, pp 55-60, Kanazawa, Japan.

Because of its high resistance against chemical corrosive action, slag cement is used for concrete structures exposed to seawater. Polymer, added to slag cement, improves its physical properties. Polypropylene polymer emulsion has high water-reducing effect and improves the durability of slag cement concrete.

C-163 "Latex-Modified Concrete in Resurfaced Overpass." 1983 (Apr). Concrete Products, Vol 84, No. 4, Chicago, IL

Concrete modified with synthetic rubber is expected to improve the bridge surface durability of a heavily used overpass serving the industrial section of Sarnia, Ontario, Canada. The concrete surface of the overpass has been deteriorating as a result of the freezing/thawing cycle and the corrosive effects of road salt during the winter. Latex mixed in the concrete forms a barrier that slows the rate of penetration by moisture and road salts and improves the physical properties of the concrete. The material takes about 4 days to cure.

C-164 "Problem-Solving Admixtures Aids Dam Repair Project." 1983 (Apr). Concrete Products, Vol 86, No. 4, pp 28-29, Chicago, IL.

Rehabilitation of the 65-year-old Emsworth Lock and Dam on the Ohio River, 6 miles west of Pittsburgh, Pa., is described. A sulfate-resisting grade of concrete that will not decompose or disperse in river water as it is pumped was used. To maintain pumpability without compromising the sulfate-resistant aspects of the concrete as well as its strength, durability, and overall quality, an admixture was used.

C-165 Perenchio, W. F., and Marusin, S. L. 1983 (Apr). "Short-Term Chloride Penetration into Relatively Impermeable Concretes," Concrete International: Design & Construction, Vol 5, No. 4, pp 37-41, Detroit, MI.

Thin concrete overlays are used extensively in resurfacing concrete bridge decks and parking structures. Even more important than their strength and resistance to wear is the ability of such concretes to resist the ingress of water-borne chloride ions. If water and chloride ions can be largely excluded, embedded reinforcing steel will not be subject to galvanic corrosion with subsequent delamination and spalling of the concrete. This study presents data which shows the amount of water and chloride imbibed by 4-in. (100-mm) concrete cubes. The concrete mixtures included a typical structural concrete, an "Iowa method" low-slump concrete, along with the same low water-cement ratio mixture to which a high-range water reducer was added, two concretes containing synthetic latexes, and one concrete containing an epoxy admixture. The concrete made with the epoxy was the least permeable followed by those containing the latexes, the "Iowa" concretes, and then the structural concrete.

C-166 Jefferson, J. N. 1983 (May). "Contractor Slashes Bridge Redecking Time," Constructor, Vol 65, No. 5, pp 24-27, Washington, DC.

Redecking of the Wilson Bridge, Washington, DC, using a strong, durable, lightweight, epoxy-coated concrete is discussed. The new deck will consist of 46-ft-wide precast roadways constructed of full lane width, transversely posttensioned, lightweight concrete slabs supported by cast-in-place polymer concrete bearing pads on the exterior girder and existing continuous stringers. Construction is proceeding at night to allow passage of rush-hour traffic; specifics of construction are described. Expected completion is for 4 Jan 1984, 120 days ahead of schedule.

C-167 Mikhail, R. Sh., Mousa, A. M., Abo-El-Enein, S. A., and Marie, M. S. 1983 (Mar). "Pore Size Restrictions on Polymer Load and Molecular Weight in Impregnated Cement Pastes," Cement and Concrete Research, Vol 13, No. 3, pp 325-334, Elmsford, NY.

Polymer admixtures are used in portland cement where thin layers of concrete are needed and for patching of cracks since such concrete has better bond strength and durability than conventional concrete. The effect of some structure-forming conditions of pastes on polymer load was investigated, and these conditions include the fineness of the cement, water-cement ratio, and the age of the paste. The variation of the polymer load with sample age is explained on structural basis, and the support is gained from SEM studies. Results of the viscosity average molecular weight of the polymer inside the pore system are also presented, showing their dependence on pore size.

C-168 Alias, J. 1983 (May). "Repairing Underground Structures on French Railways with Gunned Concrete" (in French), Travaux, No. 577, pp 68-75, Paris, France.

A brief overview of the technology of shotcrete is presented. Tests of vaults reinforced with shotcrete are discussed, and examples of some recent jobsites are included.

C-169 Sorokin, I. N., Reikhardt, L. V., Farvazev, R. F., Gur'eva, V. A. 1983 (May-Jun). "Gunited Concrete for Repair of a Blast-Furnace Stack," Refractories, (English translation of Ogneupory), Vol 24, No. 5-6, pp 296-299, New York, NY.

Investigations showed that the gunited concrete coating applied to the circular perimeter of the shaft wore slightly more rapidly than ShPD-41 chamotte parts. The high-alumina cement is suitable for repair of local failure of linings of individual chamotte parts.

C-170 Ruffert, G. 1983 (Jun). "Maintenance of Massive Bridges" (in German), Beton, Vol 33, No. 6, pp 213-214, Dusseldorf, Germany.

As our bridges get older and environmental nuisances increase, the importance and extent of the problems to be solved in the maintenance of bridges are growing. Processes and materials for the protection and rehabilitation of bridges are presented.

C-171 "Ameron's New High-Build, High-Solids Epoxy Coating Serves as a Primer and Topcoat." 1983 (Jul). American Paint & Coatings Journal, St. Louis, MO.

It can be applied by brush, roll, or spray equipment for general maintenance of in-place concrete or steel structures. A 5-mm coat protects against corrosion. Amerlock 400 is available in a variety of colors.

C-172 Shaw, J. D. N. 1983 (Jul). "Use of Polymers in Concrete Repair," Civil Engineering, pp 24-25, London, England.

Continued from the June issue, several repair procedures are discussed including resin bonded external reinforcement, protective coatings, and penetrating in-surface sealers. The author concludes that successful repair of concrete will depend upon a number of factors such as correct diagnosis and careful preparation of the appropriate materials and technique. A guide to the selection of materials for concrete repair is presented.

C-173 Dedic, D. J., and Klaiber, F. W. 1983 (Jul). "High Strength Bolts as Shear Connectors in Rehabilitation Work," Concrete International: Design & Construction, Vol 6, No. 7, Detroit, MI.

In the rehabilitation of composite concrete and steel structures, often inadequate shear connection between the two materials is found. As noted in the statement of research significance, established methods of adding shear connectors by welding are unacceptable since the type of steel in many old structures is unknown. This article presents two methods of using high-strength bolts as shear connectors. Two series of push-out tests involving two different bolt configurations were done; for comparison, a third series of push-out tests with welded steel stud connectors was also accomplished.

C-174 Kahn, L. F. 1984 (Jul). "Shotcrete Strengthening of Brick Masonry Walls," Concrete International: Design & Construction, Vol 6, No. 7, Detroit, MI.

Fourteen 3- by 3-ft (1- by 1-m) single-width panels were constructed to model old, exiting masonry walls. A 1.5-in. (38-mm) or 3.5-in. (89-mm) thick layer of reinforced shotcrete was applied to 12 panels. Brick surfaces were either dry, wet, or epoxy coated. The shotcrete greatly increased the in-plane shear strength of the panels; small amounts of steel reinforcement developed significant ductility in the panels.

The brick surface treatments were about equally effective in developing the full composite behavior and ultimate load.

C-175 Sasse, H. R., and Fiebrich, M. 1983 (Jul-Aug). "Bonding of Polymer Materials to Concrete," Materials and Structures, Research and Testing, Vol 16, No. 94, pp 293-301, Paris, France.

An adhesive is defined as a substance capable of holding materials together by surface attachment. This paper gives basic information about this process and its impact on engineering technology. Resin adherence to concrete is also discussed, with test results for tensile strength, bending strength, shrinkage, and thermal compatibility.

C-176 McBee, W. C., Sullivan, T. A., and Jong, B. W. 1983 (Aug). "Industrial Evaluation of Sulfur Concrete in Corrosive Environments," Report BUMINES/RI-8786, US Bureau of Mines, Boulder City, NV.

Over the past several years the Bureau of Mines has developed a sulfur concrete (SC) technology in which chemically modified sulfur is mixed with suitable mineral aggregates to produce construction materials that are resistant to corrosion by acids and salts. Modified SC materials have been tested in actual operating conditions in 50 corrosive process environments at 40 commercial plants. SC components ranging from small test coupons to 4-ton acid sump tanks were fabricated and installed at plant locations where chemical corrosion was destroying conventional concrete materials. Through cooperative agreements with several companies, floors, retaining walls, and foundations were cast in place using SC materials, then monitored for resistance to corrosion and retention of strength properties.

C-177 Plecnik, J. M., Plecnik, J., Diba, A., Howard, J., and Hiremagalur, J. 1983 (Aug). "Fire Research on Seismically Damaged Concrete Beams Repaired with Epoxy Adhesives," Report NSF/CEE-83218, North Carolina State University at Raleigh, NC.

The behavior of epoxy-repaired concrete beams during fire exposure is discussed. The shear failures in small beams are examined, and it is noted that shear failure generally occurs through epoxy-repaired cracks at temperatures exceeding 150° F. Failure loads decrease with increasing temperature due to presence of shear-type failure mode for epoxied specimens. When epoxy-repaired beams failed in pure flexure, the ultimate strengths were not significantly affected by temperature. Construction, repair, and experimental testing are described for four large-scale specimens: two rectangular and two T-shaped cross sections.

C-178 Dixon, J. F., and Sunley, V. K. 1983 (Aug). "Use of Bond Coats in Concrete Repair," Concrete, Vol 17, No. 8, pp 34-35, London, England.

Experimental repairs on a 20-year-old building are described. Two series of tests were carried out. Split plaques were used, concrete was poured against a wedge without any bond coat. Thereafter, prism specimens were produced by casting concrete against wedges which had received a bond coat containing equal parts of ordinary Portland cement and an SBR polymer.

C-179 Nakano, S., and Kabeya, H. 1983. "Durability Performance of Surface Coating for the Newly Developed Autoclaved Aerated Concrete Components," Conference on To Build and Take Care of What We Have Built with Limited Resources, CIB 83, The 9th CIB Congress, Stockholm, Sweden, 15-19 Aug 1983, Vol 4, pp 423-434, National Swedish Institute for Building Research, Gavle, Sweden.

This paper introduces the process of selecting external surface finishing for the autoclaved aerated concrete components that has been newly developed. Hereby the surface finishing plays a prominent role in view of the performance over time in the total system. A maintenance guideline is also presented which includes the actual measures for repairing and recoating of wall surfaces.

C-180 "Concrete Polymer Composites. 1977-September, 1983 (Citations from the Rubber and Plastics Research Association Data Base)." 1983. National Technical Information Service, Springfield, VA.

This bibliography contains citations concerning the development, the effect on the construction and building industry, and the application of polymer modifiers in concrete. Polymer concrete highway construction and chloride penetration, epoxy resins, unsaturated polyesters, and polystyrene binders for concrete, machinery and equipment used for polymer concrete manufacture, polymer impregnated concrete comparison to conventional concretes, and thermal insulation properties of plastic aggregates in concrete are among the topics discussed. Mechanical properties, performance evaluations and applications for polymer concrete in such areas as pavement, bridge and runway maintenance are included. (This updated bibliography contains 275 citations, 44 of which are new entries to the previous edition.)

C-181 "Epoxy Bonding Buttresses Bridge Repair." 1983 (Sep). Railway Track & Structures, Vol 79, No. 9, pp 51-52, Chicago, IL.

This article discusses epoxy bonding repairs done in 1980 to a concrete pier severed at a disbonded cold joint. The restoration had a higher level of structural integrity than the original concrete composition.

C-182 Hansen, T. C., and Narud, H. 1983 (Sep). "Recycled Concrete and Silica Fume Make Calcium Silicate Bricks," Cement and Concrete Research, Vol 13, No. 5, pp 626-630, Elmsford, NY.

When old concrete is crushed to coarse aggregate for production of new concrete, approximately 20-weight percent of crusher fines are generated. Calcium hydroxide from hydrated cement of such fines reacts in the autoclave with siliceous particles in the fines to give calcium silicate products. Such products are similar in nature to sand-lime bricks. When silica fume is added, the compressive strengths of the products are greatly improved. Crusher fines from recycled concrete do not qualify as hydraulic cements even when ground to cement fineness.

C-183 Fattuhi, N. I., and Hughes, B. P. 1983 (Sep). "Effect of Acid Attack on Concrete with Different Admixtures or Protective Coatings," Cement and Concrete Research, Vol 13, No. 5, pp 655-665, Elmsford, NY.

Different admixtures and coatings were used in an attempt to improve the chemical resistance of a standard concrete mix. The admixtures included pulverized fuel ash, styrene butadiene latex, water-reducing, super plasticizing, retarding, and waterproofing agents. Coatings, including PMMA and polymer emulsions, were brushed onto hardened concrete cubes. Forty 102-mm cubes containing the different admixtures or coatings were immersed in a channel with a 1-percent solution of continuously flowing sulfuric acid. Twenty cubes contained centrally positioned short mild steel bars. The changes in weight with time for each cube were determined continuously up to 172 days exposure, and the condition of the reinforcement was visually examined at termination. The effects of admixture additions of the workability and compressive strength of the concrete were also investigated.

C-184 Holland, T. C. 1983 (Sep). "Abrasion-Erosion Evaluation of Concrete Mixtures for Stilling Basin Repairs, Kinzua Dam, Pennsylvania," Miscellaneous Paper SL-83-16, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The resistance to abrasion-erosion of several concretes made with different coarse aggregates, with and without silica fume as a mineral admixture, was evaluated. Testing was done in accordance with the Corps of Engineers standard test method.

Initially, concretes made with a limestone coarse aggregate (available near the project site) and with two gabbros (from New York and Virginia) were prepared and tested. Although the gabbros were thought to be harder than the limestone, testing revealed very little difference in abrasion-erosion resistance among the three aggregates. The two gabbros did not show a great enough improvement to justify the increased transportation costs necessary for their use.

A polymer portland-cement concrete (epoxy-modified concrete) was also prepared using the limestone aggregate. This material showed very little improvement in abrasion-erosion resistance--certainly not enough improvement to justify the high cost of the epoxy product.

High-strength concretes ($f'_c \approx 7,500$ psi) made using the limestone aggregate and one of the gabbros and containing silica fume and a high-range water-reducing admixture showed improved abrasion resistance. Very high-strength silica-fume concretes ($f'_c = 14,000$ psi) showed excellent abrasion-erosion resistance.

Cores taken from the fiber-reinforced concrete overlay presently in the Kinzua stilling basin were also tested. The cores showed very high abrasion losses, which agrees well with the apparent poor performance of the material in the prototype.

Recommendations were made that either a source of coarse aggregate with better abrasion-erosion resistance be located for use or the use of the very high-strength silica-fume concrete be evaluated further.

C-185 Holland, T. C. 1983 (Sep). "Abrasion-Erosion Resistance of Concrete Made with Two Aggregates, Stonewall Jackson Dam, West Virginia," Miscellaneous Paper SL-83-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The resistance to abrasion-erosion of two concretes made with different coarse aggregates was evaluated. The aggregates used were selected as being representative of those that may be selected for use during construction of Stonewall Jackson Dam.

The two coarse aggregates were limestones from different sources. All other concrete ingredients were identical for the two mixtures. Both concretes showed very high abrasion-erosion losses when tested using the Corps of Engineers standard test method.

A recommendation was made that coarse aggregates with better wear-resistant properties be selected for use in areas of the structure that may be subjected to abrasion-erosion.

C-186 Aikin, H. B. 1983 (Nov). "Shockey Brothers Play Important Role in Major Bridge Renovation," Concrete, Vol 47, No. 7, pp 24-27, Chicago, IL.

This article discusses slab production and redecking of a bridge with stone and concrete. Stone sand is a controlled gradation sand produced from quarried stone that has a sharp, angular particle shape. A 1974 change in ASTM C 33 related to the requirements for fine aggregates has caused increased production and use of stone sand.

C-187 Smith, R. D. 1983 (Nov). "Experimental AC (Asphalt Concrete) Overlays of PCC Pavement," Report TL-633352, FHWA/CA/TL-83/07, Federal Highway Administration, Sacramento, CA.

A series of experimental asphalt concrete (AC) overlays were constructed over an existing distressed portland-cement concrete pavement on Interstate 80 near Boca, CA. The experimental overlays included rubberized dense-graded AC, rubberized open-graded AC, a rubber flush coat interlayer, dense-graded AC with short polyester fibers, and Bituthene interlayer strips. The report presents a description and discussion of AC mix batching, construction observations, laboratory testing, overlay coring, and initial performance evaluation.

C-188 Jimenez, R. A., and Meier, W. R. 1983. "Laboratory Evaluation of Anti-Reflection Cracking Materials," Arizona Department of Transportation, Phoenix, AZ.

This report is concerned with the evaluation of four mixtures of asphalt-rubber to serve as a strain attenuating layer in asphaltic concrete overlays. The four mixtures consisted of two different blends of asphalt-rubber, and the strain attenuating layer was made with and without stone chips. The tests used for the evaluation were developed to simulate certain pavement loadings, and they were classified as repeated vertical shear, horizontal shear, repeated horizontal shear, and flexure fatigue. Calculations were carried out to determine the effects of the strain attenuating layer on stress in the laboratory models and also in flexible layered pavement systems.

C-189 Fowler, D. W., Beer, G. P., and Meyer, A. H. 1983. "Survey on the Use of Rapid-Setting Repair Materials," Transportation Research Record 943, pp 33-37, Transportation Research Board, Washington, DC.

This article reviews the current state of the art for rapid-setting materials used to repair concrete in Texas and other selected states. Texas districts were surveyed for a listing of rapid-setting materials that have been used over the past 10 years. Twenty-seven materials were reported. The districts also provided an evaluation of the materials based on their use in different types of repairs, cost, use in different climatic conditions, durability, bond to concrete, and appearance. Nine states were asked to provide the same information requested of districts; eight responses were received. Districts and states were also asked to provide a ranking of material characteristics and properties.

C-190 McCullough, B. F., Meyer, A. H., and Fowler, D. W. 1983. "Design of Polymer-Concrete Runway Repairs," Transportation Research Record 943, pp 37-42, Transportation Research Board, Washington, DC.

Portland-cement concrete airfield pavements with polymer concrete (PC) repairs were analytically modeled to develop design criteria for determining the required repair thickness. A previously developed computer program for analyzing discontinuous orthotropic plates and pavement slabs was used to analyze the pavement. Two representative aircraft, the F-4 and the C-141, were used. Different repair sizes, support values, and runway thicknesses were tested. A sensitivity analysis was performed to determine which variables have the greatest effect on the stresses.

For the purpose of developing design charts, the critical positions of the wheel loads for the different size repairs were found. The magnitude of the existing runway support outside the repair section had little effect on the stresses in the PC repair, although the existing runway thickness did have a significant effect. Because of the emergency nature of the repairs, the repair support values and thicknesses may be significantly different from those for the existing pavement. Consequently, these values have a significant impact on the repair results. The design charts that were prepared give the flexural stress as a function of repair thickness for three repair sizes, two repair support values, and two runway thicknesses. The allowable stress level for the polymer concrete has been reduced for the number of loading repetitions.

C-191 Meyer, A. H., Fowler, D. W., and McCullough, B. F. 1983. "Field Tests of Rapid Repair Methods for Bomb-Damaged Runways," Transportation Research Record 943, pp 30-33, Transportation Research Board, Washington, DC.

Rapid repair of bomb-damaged runways is of vital concern to the US Air Force. The results of field tests conducted under the direction of the Air Force Engineering and Services Center at Tyndall Air Force Base are presented. These tests were of various rapid repair techniques that use methyl methacrylate polymer concrete. Both spalls and craters were repaired. Full-depth polymer concrete (PC) repairs, at-grade precast units, and precast units with PC caps are reported. The repairs were trafficked with both F-4 (27,000-lb single wheel) and C-141 (144,000-lb dual-tandom wheel) load carts. All of the crater repairs performed satisfactorily, as did most of the spall repairs, which demonstrated the feasibility of using PC methods for the rapid repair of bomb-damaged runways.

C-192 Gemert, D. V., and Maesschalck, R. 1983. "Structural Repair of a Reinforced Concrete Plate by Epoxy Bonded External Reinforcement," <u>International Journal of Cement Composites and Lightweight Concrete</u>, Vol 5, No. 4, pp 247-255, Harlow, Essex, England.

This article deals with the repair of a severely damaged reinforced concrete plate with epoxy bonded steel strips. The method consists of gluing steel elements to the concrete with epoxy glue. Structural damage and the procedure followed in handling the repair are described. Results of laboratory experiments related to the actual repair are given. Other possible applications for the repair technique are indicated.

C-193 McBee, W. C., Sullivan, T. A., and Jong, B. W. 1983. "Corrosion-Resistant Sulfur Concretes," Report of Investigations 8758, US Bureau of Mines, Boulder, City, NV.

Sulfur concretes have been developed as construction materials with physical and mechanical properties that suit them for use in acid and salt-corrosive environments where conventional concretes fail. Mix design methods are established for sulfur concretes using different types of aggregates and recently developed sulfur cements. Bench-scale testing of the sulfur concretes has shown their potential value: corrosion resistance, strength, and durability of sulfur concrete are superior to those of conventional materials.

C-194 Sprinkel, M. M. 1983. "Thermal Compatibility of Thin Polymer-Concrete Overlays," Transportation Research Record 899, pp 64-73, Transportation Research Board, Washington, DC.

Thin polymer-concrete overlays that provide low permeability and high skid resistance can be installed on bridge decks with minimal disruption to traffic and at about one-half the cost of alternative service-life-extending measures such as portland-cement concrete overlays. Laboratory tests have indicated that the temperature changes to which bridge decks are typically subjected are sufficient to cause deterioration and eventual failure of the overlays. The deterioration is caused by the development of stress in the bond between the concrete and overlay that results from differences in the measures of elasticity and the coefficients of thermal expansion of the two materials. Thermally induced cracks have been noted in the overlay, the base concrete, and the bond interface-a majority of them in the medium least able to withstand the stress. Cracks in the overlay increase its permeability, and cracks in the base concrete or the bond interface lead to delamination of the overlay. It is estimated that a properly installed overlay prepared with either of the two polyester resins tested to date will have a useful service life of at least 5 years. A longer service life should be possible if more flexible resins are developed.

C-195 "Special Steels and Systems for Corrosion Prevention in Reinforced Concrete." 1983. Concrete Society Proceedings, The Concrete Society, London, England.

This publication includes six papers presented at a symposium which give an authoritative guide to the available reinforcing materials and systems for avoiding corrosion in reinforced concrete. There is a full record of the discussions together with additional material and illustrations presented by the speakers.

C-196 Moskvin, V. M. 1983. "Water-Repelling Treatment as a Means to Increase Concrete Stability" (in Russian), Beton i Zhelezobeton, No. 8, 1983, pp 7-9, Moscow, Russia.

This article discusses methods and results of treatment of concrete with water-repellent silicon. The possible volume and surface water repelling treatment is shown as well as the limit for an effective similar treatment of concrete to increase its stability and lifetime. Some experiments are also described.

C-197 Gaertig, H. J. 1983. "Silicone Resin/Bitumen Anticorrosive Paints and Coatings for Concrete" (in German), Plaste und Kautschuk, Vol 30, No. 1, pp 46-49, Leipzig, East Germany.

The paints or coatings are made from a fast-curing silicone resin and bitumen. Adhesion, mechanical and gas and water permeability properties have been studied.

1984

C-198 Winters, J., ed. 1984. "International Symposium on Mechanical Properties of Special Concrete," Transportation Research Record 1003, Transportation Research Board, Washington, DC.

This symposium proceedings contains 10 papers. The topics covered include: plastic and steel fiber-reinforced concretes; bridge and pavement rehabilitation; fiber-reinforced superplasticized concretes; epoxy-bonded cementitious overlays; polymer concrete curing; evaluation of rapid-setting concretes; shear transfer in composite systems; precast polymer concrete form applications; and composite concrete pavements.

C-199 Choudhary, M. M., et al. 1984 (Jan). "Epoxy Grouting of Cracks in Concrete," Indian Concrete Journal, Vol 58, No. 1, pp 4-10, Bombay, India.

Epoxy resins have often been used for grouting cracks in concrete. Because of their low modulus of elasticity as compared to concrete, it was thought that the grouted cracks might reopen on application of additional load. Laboratory studies conducted at 29 ± 3° C showed that there is no adverse effect on the load-carrying capacity and deflection of concrete structures treated with epoxy resins having a modulus of elasticity as low as one-fifteenth of that of concrete. This proves the utility of normal epoxy resins for grouting cracks in concrete to restore strength with no fear of the low modulus of elasticity.

C-200 Smith, P. 1984 (Feb). "Combating the Effect of Spalling in Concrete Structures," Anti-Corrosion Methods and Materials, Vol 31, No. 2, pp 11-12, London, England.

A variety of reasons for concrete deterioration are outlined including corrosion of any reinforcements; calcium chloride; restrained movement; chemical attack; and internal corrosion reactions. Resin based, polymer modified cement-based and cement-based repair materials are considered. It is shown that for an effective repair to be undertaken, it is necessary for the repair material to have characteristics as close as possible to the base concrete, so that the properties of the old and new work are compatible, so preventing unnecessary strains being placed at the interface which would diminish the changes of a good bonding being achieved.

C-201 Perkins, P. H. 1984 (Mar). "Use of SBR/Cement Slurry for Bonding Coats," Concrete, Vol 18, No. 3, pp 18-19, London, England.

There are a number of bonding aids on the market, but this article will deal only with styrene-butadiene dispersion/portland-cement slurry. This known as SBR/cement slurry. SBR/cement slurries and mixes have established themselves over the past 15 to 20 years in this country and abroad by consistently good site results. While it is not possible to list all the circumstances where this bond is important, the main locations in construction are listed below: concrete toppings and mortar screed laid on concrete floor and roof slabs; mortar rendering to brickwork, blockwork, and in situ concrete; clay bricks and tiles to concrete; mortar/fine concrete for the repair of concrete members, and daywork joints in in situ concrete construction (also known as 'monolithic' type joints).

C-202 Paillere, A. M., and Guinez, R. 1984 (Mar-Apr). "Seeking a Formulation of Grouts Incorporating Hydraulic Binders for Injecting Fine Cracks and Cavities" (in French), Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 130, pp 51-58, Paris, France.

In many cases cement grouts are used for the repair of concrete or masonry structures. The sand column test developed by the LPC network ensures that epoxy resins can be injected and can be used to test hydraulic cement grouts. Half-scale experiments confirm the indications of this test. This study proves the importance of the fineness of the cement. The tests as a whole show that it is possible to obtain a perfectly injectable cement grout formula provided that the interstices to be injected are 1.5 to 2.3 times as large as the coarsest particles of cement.

C-203 Osen, M. P. 1984 (May). "Degradation and the Use of SBR Polymers," Concrete, Vol 18, No. 5, pp 18-19, London, England.

Concrete has been used as a basic building material for many hundreds of years and will continue to be used because there is no cheaper alternative. It is a stable product but its ability to withstand continued stress depends on physical and chemical changes. Concrete deteriorates either because the quality of the solid components is poor, the degree of compaction is below standard, curing techniques are bad, or the component is stressed beyond limits. There are other causes of degradation, such as carbonation (the effect of carbon dioxide in the air on portland cement); sulfate attack (a process normally associated with below ground structures and sulfate bearing soil); permeabiltiy which may result from lower than usual cement content); poor compaction; "bleeding" or segregation; and mechanical damage (which is more serious and might lead to reconsideration of the original design unless it can be shown that the stress calculations were correct).

Several types of repair mediums are available. The medium should match the quality of the original concrete but with greater adhesive strength and with lower permeability to water. The expansion coefficient and E value should ideally be the same as the concrete, epoxy, or polyester mortars, and SBR modified mixes. SBR modified mixes are highly recommended, and it is anticipated that advances will be made to increase durability beyond the already well-accepted level.

C-204 Kobayashi, K., and Takewaka, K. 1984 (May). "Experimental Studies on Epoxy Coated Reinforcing Steel for Corrosion Protection," International Journal of Cement Composites and Lightweight Concrete, Vol 6, No. 2, pp 99-116, Harlow, Essex, England.

In a severely corrosive environment such as a marine splash zone, it is necessary for thickness of cover to be made fairly large to protect steel in concrete from corrosion. It is also necessary for the crack width to be limited to a fairly small size. However, in addition to adequate cover, the most practical corrosion protection method is that of covering the reinforcing bar itself by a material of a corrosion-inhibiting nature. This paper presents the results of tests on epoxy-coated reinforcing steel with comparative data on untreated and galvanized steel.

C-205 Hill, T. B. 1984 (May). "Underwater Repair and Protection of Offshore Structures," Concrete, Vol 18, No. 5, pp 16-17, London, England.

Structures in the North Sea are subject to weathering, corrosion, and other structural damage. To maintain these structures and their operational life, it is important that practical means are available for their repair and protection. A "package" of epoxy resin and cementitious materials, together with the appropriate application equipment, has been developed for carrying out all types of repair to concrete structures.

Two-part epoxy resins consisting of a base and hardener are particularly suitable for underwater repairs, as they are compatible with wet surfaces. These resins also have a high impact resistance, together with a high flexibility, which allows structural straining without failure of the material of bond. However, there are two restrictions on the use of the resins: (a) the difference in the modulus of elasticity between the cured resin and the concrete makes them unsuitable for repairs where the latter's structural design properties are important, and (b) poor adhesion to the substrate can occur if the surface area-volume ratio of the repair is not high enough to allow the heat generated during curing to be dissipated quickly to the surrounding seawater. The resin developed for the package has a high compressive strength, low permeability, good adhesion, and gives low exothermic peak and smooth temperature gradient. This material may be used for a variety of repairs as it overcomes some of the problems normally associated with resins.

C-206 Carnahan, J. C. 1984 (May). "Repair-Don't Replace-Cracked Sewer Pipe," Civil Engineering, Vol 54, No. 5, pp 56-58, American Society of Civil Engineers, New York, NY.

Circumferential hairline cracks in joints at the bells of concrete sewer pipes required extensive repair. While corrective action in accordance with contract documents called for removal and replacement, its cost would have been tremendous. The contractor requested permission to repair the pipe in place instead. A urethane polymer grout was injected between the bell and spigot of each bad joint. The grout is injected as a liquid but reacts with water to create a foaming action, expanding approximately 10 times the original volume. The grout then sets to form an elastomeric seal, which is resistant to deterioration from expected sewage components. The grout appeared as resistant to deterioration as O-ring gaskets, and it seemed more resistant to hydrocarbons, such as petroleum products, than to synthetic rubber.

C-207 Pfeifer, D. W., and Perenchio, W. F. 1984 (May). "Sealers or Overlays? Concrete Construction, Vol 29, No. 5, pp 503, 505, 507, Addison, IL.

The studies began as an investigation of sealers, mostly proprietary, that are being used to protect new and old highway bridges, parking garages, marine structures, and industrial, commercial, and residential buildings. The authors selected a number of generically different materials that are promoted and used for this purpose, including boiled linseed oil, silane, chlorinated rubber, styrene-butadiene, epoxies, urethanes, methyl methacrylates, sodium silicate, and others. The results of these extensive laboratory studies showed considerable differences among the sealers tested and led to recommendations for the most effective.

C-208 Bennison, P. 1984 (Jun). "Repair and Protection of Reinforced Concrete," Corrosion Prevention & Control, Vol 31, No. 3, pp 5-10, Bucks, England.

Mechanisms are discussed, by which reinforced concrete can deteriorate. It is shown that a very high percentage of all reinforced concrete structures suffers some form of continuous distress during their life. Modern repair materials, either modified cementitious or resin based can now offer an excellent solution for most repair and maintenance problems. It is, though, considerably more economic to protect a structure by regular inspection and maintenance by qualified personnel, than to await advanced costly deterioration before taking any action.

C-209 Ovens, A. 1984 (Jun). "Repair and Protection of Reinforced Concrete in High Rise Buildings (Part II)," Concrete, Vol 18, No. 6, pp 44-45, London, England.

This article outlines the prerequisites and criteria used for selecting the most appropriate protective coating when repairing or refurbishing steel reinforced concrete. Prior to protective coating, the surface to be coated should be completely free of surface defects. All dirt, grease, organic growth, or other contaminants must be removed. It is also advisable to avoid coating over areas of high cement laitance. Blastcleaning is probably the best method of preparing concrete surfaces for coating.

Criteria for selecting the most suitable coating include appearance, resistance to water-moisture ingress, resistance to aggressive atmospheric gases, resistance to water vapor, resistance to ultraviolet light, resistance to abrasion, and ease of maintenance. From these prerequisites and criteria, the performance characteristics of a coating can be listed for each individual project. The most suitable coating can then be selected, with a specific product being chosen for a specific purpose.

C-210 Drennon, C. B. 1984 (Jun). "Use of SBR (Styrene-Butadiene Rubber) Latex for Improvement of Recycled Asphalt Pavement," Report FHWA/OH-84/008, Federal Highway Administration, Columbus, OH.

Styrene-butadiene rubber (SBR) latex was added to cold-milled, recycled hot-mix asphalt concrete to improve the fatigue properties of the mix. Samples were tested by repeated load indirect tensile tests and analyzed by the VESYS Structural Subsystem computer model. Four different pavement materials and two different latices were tested. The basis for comparison is VESYS 'life', a predicted time to reduce predicted present serviceability index to 2.5. Since the major improvement area is reduction of the rutting component of damage, excessive stiffness of the treated recycled mix may remain a problem, but full-scale testing is justified.

C-211 Kostyk, B. W., and Parnell, J. E. 1984 (Jun). "Effective Repair for Leaking Waterstops," Concrete Construction, Vol 29, No. 6, pp 594-596, Addison, IL.

Waterstops in joints in concrete structures perform important functions in protecting the structure, its contents, and its environment from various aggressive effects of water, such as corrosion of steel, mildewing or rotting of organic materials, or eroding the surrounding soil. In water-containing structures, waterstops protect against loss of water. But if for any reason they do not function properly or if they fail, they are usually difficult to repair effectively. Presently, an injection method that uses a specially formulated grout with proven effectiveness makes repair fast and easy. The grout is a liquid resin of relatively low viscosity (300 to 600 centipoise) at ambient conditions. After it is injected into a joint containing water, the resin reacts with the water, begins to foam, and expands in place.

C-212 Cady, P. D., Weyers, R. E., and Wilson, D. T. 1984 (Jun). "Durability and Compatibility of Overlays and Bridge Deck Substrate Treatments," Concrete International: Design & Construction, Vol 6, No. 6, pp 36-44, Detroit, MI.

Freezing and thawing tests were carried out to evaluate the durability and compatibility of composite specimens consisting of treated concrete substrates in combination with three types of concrete overlays. The various substrate treatment-overlay combinations are potential candidates for bridge deck rehabilitation. Substrate treatment consisted of impregnating concrete with corrosion inhibitors, hydrophobic agent, pore sealants, or a water-displacing penetrant. The overlay materials used were latex-modified concrete, low-slump dense concrete, and polymer concrete. Suitable performance relative to both durability and compatibility was obtained only for methyl methacrylate impregnation treatment of the substrate. When used in conjunction with this treatment, all three overlays provided superior performance.

C-213 Holm, T. A., Bremner, T. W., and Newman, J. B. 1984 (Jun). "Concrete Bridge Decks: Lightweight Aggregate Concrete Subject to Severe Weathering," Concrete International: Design & Construction, Vol 6, No. 6, pp 49-54, Detroit, MI.

The influence of the internal structure of lightweight aggregate on the physical and durability characteristics of concretes used in severe weathering applications is examined. Scanning electron microscopy studies on cores from weathered surfaces of mature structures are reported and compared with field experience. Cracking response and other mechanical properties are related to the characteristics of the lightweight aggregate.

C-214 "Sealing Plays Vital Role in Concrete Performance." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 48, Des Plaines, IL.

The benefits of promptly sealing concrete pavement are explained. Sealants are used to prevent intrusion of incompressibles and water into joints. Authorities claim that sealing and resealing can be the most effective means of concrete maintenance available. The three types of sealants, low modulus silicone, liquid joint, and neoprene compression are discussed. Recommendations are given for various application techniques as well as maintenance regularity.

C-215 Stoll, F., and Grein, A. 1984 (Jul). "Possibilities of Surface Protection of Tanks and Structures in Wastewater Treatment Plants" (in German), Zeitschrift fuer Werkstofftechnik/Materials Technology and Testing, Vol 15, No. 7, pp 223-229, Weinheim, West Germany.

The composition of wastewater from chemical plants often requires a suitable surface protection for the steel or concrete substrates of structures in wastewater treatment plants. The use of a suitable protection system will be instrumental in economizing and will enhance the availability of the plant. To study the resistance to chemical wastewater, extensive tests with different corrosion protection systems were carried out under service-life conditions. The most suitable system was a solventless epoxy-polyamine coating. Some examples and experience in service with this protective coating are discussed.

C-216 "New Precast Material Gets Tunnel 'Wear Test'." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 16-18, Des Plaines, IL.

A new precast material, quazite, was tested in a tunnel rehabilitation project. Composed of selectively graded aggregate, polymers, and monomer in a patented mixing and curing process, the quazite was used to repair sidewall deterioration and accident damage. The new material is unaffected by water, salts, deicing chemical, and expansion-contraction resulting from cycles of freezing and thawing. It resists virtually all corrosive acids, chemicals, oils, and is graffiti-proof. The material was precast into lightweight bench panels and reinforced with fiberglass for greater impact resistance. The bench panels were not modified in the field because erection time was so limited. Holes could be predrilled in sidewalks to receive anchors cast into the bottom of the panels. This is the third repair project for the tunnel. Previous repairs were made using concrete panels and ceramic tile facing.

C-217 Meinheit, D. F., and Monson, J. F. 1984 (Jul). "Parking Garage Repaired Using Thin Polymer Concrete Overlay," Concrete International: Design & Construction, Vol 6, No. 7, pp 7-13, Detroit, MI.

Corrosion of deformed bar reinforcement and posttensioned, unbonded tendons of an eight-story parking structure caused concern for the integrity of the slab system of the garage. A condition survey was conducted to locate areas within the garage with the most advanced deterioration. Priority was placed on repairing these areas.

Several alternative repair schemes were considered; clear height limitations within the garage made the use of thin overlay materials desirable.

C-218 Pickard, S. S. 1984 (Jul). "Solving Corrosion Problems with Sulfur Concrete," The Construction Specifier, Vol 37, No. 7, pp 36-42, Alexandria, VA.

A major sulfur concrete project was recently completed in Louisiana. Acid-resistant, high-strength sulfur concrete was used to repair deterioration in a large portland-cement concrete basement containment and sump area. An overlay of 29,000 ft^2 of portland-cement concrete floor with 3-1/2 in. of unreinforced sulfur concrete and a lining encapsulating over 5,700 ft^2 of walls and piers with 4 in. of unreinforced sulfur concrete was placed. A history of sulfur concrete as well as a table illustrating the strength differences between sulfur and portland-cement concretes are given.

Performance criteria were set for the project. Strength, durability, chemical resistance, and shrinkage conditions were met. Preparation, mixing procedures, forming techniques joint design, and placing and finishing are detailed. The sulfur content level and the results from being too high or too low are also explained.

C-219 "New Paving Technologies Get Full-Scale Try-Outs." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 53-56, Des Plaines, IL.

In a 6-month construction project on Wisconsin's Interstate 90/94, epoxy-coated reinforcing steel is being used in a continuously reinforced concrete pavement. The 5,000 miles of epoxy-coated reinforcing bars containing 1/4 percent minimum copper content are being used because of the high chloride content in the old pavement. The reconstruction also makes use of a bonded concrete overlay on a 4-mile section. Billed as one of the largest concrete pavement recycling projects to use recycled concrete in the form of coarse aggregate, all construction is to be completed without a detour. Other specifics of the construction include no more than 1/8-in. deflection in each 10 ft of pavement and a concrete strength measured by a 3,500-lb cylinder break test.

C-220 "Performance of Latex Modified and Low Slump Concrete Overlays on Bridge Decks." 1984 (Aug). Report MCHRP-83-1, Federal Highway Administration, Washington, DC.

A field investigation was conducted in 1982-1983 to determine the performance of 60 Low Slump Concrete, 7 Latex Mortar, and 24 Latex Concrete overlays. The overlays were constructed between 1973 and 1983 with the majority from 1979 to 1981. The investigation included the extent and type of surface cracking, area of debonding and/or delaminating, and area of surface patching. On a limited number of selected bridge structures, voltage potential measurements, chloride ion content, and extent of crack penetration were also included. Data indicated concrete overlays exhibited cracking, debonding, and/or delaminations. Continued use of latex modified and low slump concrete overlays appeared warranted.

C-221 Scarpinato, E. J. 1984 (Aug). "Thin Polymer Concrete Bridge Deck Overlays," Concrete Construction, Vol 29, No. 8, pp 711-715, Addison, IL.

Past failures of bridge deck overlays can be attributed to one or more of the following factors: inadequate surface preparation; far advanced concrete deterioration; dissimilar physical properties of the overlay material and underlying concrete; chemical incompatibility of polymers and concrete; improper proportioning, mixing, or application procedures; and use of less technologically advanced materials. Testing and evaluation programs have identified several properties that bridge deck overlays must possess. They include a modulus of elasticity between 90,000 and 150,000 psi, tensile elongation of at least 30 percent, minimum tensile strength of 2,500 psi, compressive strength between 5,000 and 8,000 psi, long-term flexibility or resistance to age hardening, and aggregates sufficiently tough to withstand impact loads without fracturing, good skid resistance without polishing, and good bond to the polymer used.

Although no single system has yet been proven suitable for all types of bridge deck overlays, development of thin polymer concrete overlays is progressing well. The broom-and-seed and slurry methods, which have been used to apply thin polymer concrete overlays, are briefly described. Polymer concrete is made with an organic polymer binder rather than a hydraulic cement; the overlays are 1/4 to 5/8 in. thick.

Initial cost of the overlays is high, but they are often cost effective in the long term.

C-222 Fontana, J. J., and Webster, R. P. 1984 (Aug). "Electrically Conductive Polymer Concrete Overlays," Report BNL-35669, CONF-850115-5, Department of Energy, Washington, DC.

The use of cathodic protection to prevent the corrosion of reinforcing steel in concrete structures has been well established. Application of a durable, skid-resistant electrically conductive polymer concrete overlay would advance the use of cathodic protection for the highway industry. Laboratory studies indicate that electrically conductive polymer concrete overlays using conductive fillers, such as calcined coke breeze, in conjunction with polyester or vinyl ester resins have resistivities of 1 to 10 ohm-cm. Both multiple-layer and premixed mortar-type overlays have been made. Shear bond strengths of the conductive overlays to concrete substrates vary from 600 to 1,300 psi, with the premixed overlays having bond strengths 50 to 100 percent higher than the multiple-layer overlays.

C-223 Bhaskara Rao, M. V., and Satija, P. D. 1984 (Aug). "Use of Galvanised High-Tensile Steel in Prestressed Concrete Construction," Indian Highways, Vol 12, No. 8, pp 21-24, New Delhi, India.

At present, the corrosion of steel in concrete highway bridges and other structures is receiving the attention of both maintenance engineers and researchers. The objective of the paper is to reexamine the usage of galvanized high tensile wires and to suggest a means to apply zinc silicate coating on nongalvanized steel during manufacture. Zinc silicate paints can be used in place of organic paints as coatings on the reinforcements prior to construction. The techniques is a better alternative to the hot-dip galvanizing method for the protection of reinforcements.

C-224 Schorn, H., and Koehne, D. 1984 (Aug). "Resin-Modified Concretes as Part of a Refurbishment Concept for Structures," Betonwerk Fertigteil Tech, Vol 50, No. 8, pp 571-576, Weisbaden, Germany.

Against the background to the bewildering multitude of commercially available materials and systems, varying greatly in performance, and intended for the refurbishment of reinforced concrete structures, the notion of 'refurbishment' is given a neutral definition, and a proposal for a 'refurbishment concept' is elaborated. For this purpose, the deteriorative damage affecting structures is divided into a number of 'assessment stages' according to the degree of impairment of bond behavior and the time-dependent progress of the damage. A refurbishment method is described which has been developed more particularly for the treatment of most of the kinds of damage currently affecting reinforced concrete structures. It is based on the use of a resin-modified sprayed concrete and on special features of its application. Certain properties of both the fresh and the hardened concrete are so changed to satisfy the requirements of concrete spraying in terms of material properties and of process technique.

C-225 Haynes, J. M. 1984 (Aug). "Stainless Steel Reinforcement," Civil Engineering, pp 23-28, London, England.

The failure of reinforced concrete to meet design life is a major concern. This paper suggests that the worst such maintenance problem is the cracking and spalling of concrete due to corroding reinforcement. The use of stainless steel reinforcement is advocated, especially where corrosion presents serious problems of shortened life, high maintenance costs, or unacceptable safety risks.

C-226 "Oklahoma's I-40 Recycling Project is a Major First." 1984 (Sep). Roads, Vol 22, No. 9, pp 22-23, Des Plaines, IL.

In 1982, Oklahoma accepted bids on a 7.7-mile highway project. The existing 21-year-old plain concrete pavement needed repairs due to D-cracking and deterioration.

A bid for an asphaltic-concrete overlay lost to an alternate, less costly design necessitating removal of 220,382 yd^2 of the old concrete. New plain concrete replaces the old, which is crushed and used as coarse aggregate in the new pavement. A new asphaltic concrete surface was planned for the old soil-cement shoulder base.

C-227 Coleman, S. E., and Diamond, S. 1984 (Sep). "Studies of Low-Porosity Concretes Designed for Bridge Deck Applications (Part I)," Cement and Concrete Research, Vol 14, No. 5, pp 670-678, Elmsford, NY.

A major concrete problem in recent years has been premature deterioration of concrete bridge decks due to corrosion of reinforcing steel. The research reported explores the possibility of eliminating the problem by the use of low-porosity concrete. A brief review of low-porosity cement systems is provided and mix proportioning considerations for these concretes are explored. The results of laboratory trials on rheological and other features of fresh low-porosity concretes are reported, and compressive strength data are provided for several different low-porosity concrete systems.

C-228 Fontana, J. J. 1984 (Oct). "Development of Concrete Polymer Materials," Report BNL-35496, CONF-850497-1, Brookhaven National Laboratories, Upton, NY.

The properties of PC make it suitable for the repair of concrete structures and for the placement of impermeable, skid-resistant overlays. PC patching can be cast in place and will cure rapidly over a wide range of temperatures (20° F to 100° F), develop high strengths in a few hours, and bond well to portland-cement concrete. Two methods of application and several monomer systems have been used with success for the installation of PC overlays. To date, the feasibility of using PC liners for steel pipe, vessels, or tanks to extend their service life in geothermal environments has been confirmed. Aggressive corrosive fluids do not cause deterioration in specially designed PC at temperatures close to 250° C. Commercial methods for the application of such liners have been developed and shown to be cost effective. The insulation of LNG impounding dike installations with IPC composites has been feasible. The safety benefits accrued from such installations will reduce the hazards of explosive mixtures in the event of an accidental LNG spill. The use of IPC as a dike insulation will be implemented as early as spring 1985.

C-229 "Latex-Modified Concrete and Mortar for Repair." 1984 (Oct). Concrete Construction, Vol 29, No. 10, pp 889-892, Addison, IL.

Used primarily for bridge decks, parking ramps, and other large expanses of concrete exposed to extreme weather, latex-modified concrete is resistant to freeze-thaw damage and the effects of deicing salts. When synthetic latexes are added to portland-cement concretes, the resulting mixture develops higher strengths, bonds better to existing concrete, has a higher resistance to chloride penetration, and is more resistant to chemical attack than plain concrete. Recommendations are given for dosage and mix proportions, batching and mixing, and curing procedures.

C-230 "Properties and Specifications for Epoxies Used in Concrete Repair." 1984 (Oct). Concrete Construction, Vol 29, No. 10, pp 873-878, Addison, IL.

This article presents a general discussion of the chemical and physical characteristics of epoxies, and describes specifications and tests for determining performance properties and end uses. ASTM C 881-78, the standard specification for epoxy performance, is described.

C-231 "Acrylic Concrete for Fast Repair." 1984 (Oct). Concrete Construction, Vol 29, No. 10, pp 881-886, Addison, IL.

This article describes repair applications of acrylic concrete (concretes made with methyl methacrylate or a high molecular weight methacrylate and which contain neither water nor portland cement). Though costly, the ability of acrylic concretes to develop compressive strengths of 5,000 to 10,000 psi in 1 to 2 hr makes them ideal for repairing pavements, bridge and parking decks, and warehouse and factory floors that cannot be closed to traffic for longer periods of time. The density and impermeability of acrylic concretes make them highly resistant to water, chlorides, and strong acids, allowing them to be used successfully as protective overlays on portland-cement concretes.

C-232 "Nonshrink Hydraulic Cement Mortars and Grouts." 1984 (Oct). <u>Concrete Construction</u>, Vol 29, No. 10, pp 893-898, Addison, IL.

Describes properties and applications of nonshrink cementitious repair products. Three categories of nonshrink hydraulic cements are discussed: patching mortars and concretes; grouts and anchoring cements; and fibrous patching mortars and concretes. Tables displaying characteristics of hydraulic cement-based products are included.

C-233 Warner, J. 1984 (Oct). "Selecting Repair Materials," <u>Concrete Construction</u>, Vol 29, No. 10, pp 865-871, Addison, IL.

This article presents an overview of the material properties (dimensional stability, coefficient of thermal expansion, modulus of elasticity, and permeability) that must be considered when selecting concrete repair materials. A checklist of questions to aid in the appraisal of application and repair conditions is included.

C-234 "Acrylic Concrete for Fast Repair." 1984 (Oct). <u>Concrete Construction</u>, Vol 29, No. 10, pp 881, 883, 885-886, Addison, IL.

Unlike normal portland-cement concrete, acrylic concrete contains no water and no portland cement. Aggregate is held together instead by an acrylic polymer. Monomer, aggregate, initiator, and promoter may be mixed together in mixers, wheelbarrows, or bags and then placed, or monomer may be poured over a patch area filled with preplaced aggregate. Workers should wear splash-proof goggles and rubberized gloves, boots, and aprons or overalls. They should have respirators they can use for their own comfort, even if concentrations stay within the levels safe for good health. First aid equipment and approved fire extinguishers should be kept on hand, and emergency telephone numbers should be readily availa[illegible] Smoking is absolutely prohibited in any areas where MMA is stored or used.

C-235 Epps, J. A., and Button, J. W. 1984 (Nov). "Fabrics in Asphalt Overlays--Design, Construction and Specifications," Report TTI-2-9-79-261-3F, FHWA/TX-84/59+261-3F, Texas Transportation Institute, College Station, TX.

Recommendations are given to improve design and construction of asphalt concrete overlays containing a fabric interlayer installed to reduce the severity or to delay the occurrence of reflection cracking. Improvements in specifications for fabrics and overlays and construction procedures are given. Methods of determining life cycle costs and selecting the appropriate pavement rehabilitation alternative are discussed.

C-236 Temple, M. A., Meyer, A. H., and Fowler, D. W. 1984 (Nov). "Evaluation of Fiber Reinforced Rapid-Setting Materials for Highway Repair," Report CTR-3-9-82-311-5, FHWA/TX-85/311-5, Center for Transportation Research, University of Texas, Austin, TX.

Using fiber reinforcement with rapid-setting materials is a cost effective and simple way to improve some of the properties of the materials. Whereas the properties of portland-cement concrete with fiber reinforcement and the properties of rapid-setting materials without fiber reinforcement are fairly well known, the effect of fibers on rapid-setting materials has not been fully investigated. The report provides an evaluation of the performance of three different types of rapid-setting materials reinforced with three different types of fibers. Materials tested include gypsum modified portland-cement concrete, magnesium phosphate concrete, and modified portland-cement concrete. Fibers used in the tests were hooked and half-round, crimped, steel fibers and polypropylene lattice bundles. The results of laboratory tests with varied coarse aggregate content and fiber application rates are given. Field repairs made in Paris, TX, with fiber-reinforced materials are described.

C-237 Shanklin, D. W. 1984. "Repair of Concrete Water Resource Structures by Epoxy Materials," Paper 34-2643, American Society of Agricultural Engineers, St. Joseph, MO.

Three concrete spillway systems experiencing problems were repaired satisfactorily by various epoxy materials. Repairs involved underwater examination; cleaning; and use of epoxy mortars, replacement mixes, and injection resin. The projects are located in Arkansas and Oklahoma. All repairs were modest in cost and, to date, they have performed successfully.

C-238 Kapkin, I. A., et al. 1984. "Frost-Resistance of Concrete Impregnated with Polymer," Beton i Zhelezobeton, No. 6, 1984, pp 11-12, Moscow, USSR.

This article discusses requirements of concretes with high strength, corrosion and frost resistance, and low adhesion to ice for use in seawater development works in the northern USSR. The results are presented for tests on concrete surfaces impregnated with methyl methacrylate.

C-239 Ruffert, G. 1984. "Polymer Resins for Concrete Repair" (in German), Kunstst Bau, Vol 19, No. 3, pp 117-119, Germany.

Repair of cracks in load-bearing components and machine foundations using EP resins necessitates - depending on the causes and type of cracking ascertained beforehand - different high or low pressure injection methods.

C-240 Sprinkel, M. M. 1984. "Thin Polymer Concrete Overlays for Bridge Deck Protection," Second Bridge Engineering Conference, Transportation Research Record 950, Vol 1, Transportation Research Board, Washington, DC.

The installation of thin polymer concrete overlays on portland-cement concrete bridge decks during the past 3 years has demonstrated that overlays of low permeability and high skid resistance can be successfully installed with a minimum of disruption to traffic. The initial condition of the overlays has been excellent from the standpoint of permeability, skid resistance, and bond, although some overlays have been better than others.

The potential of thin polymer concrete overlays for extending the service life of bridge decks is discussed. The bond achieved between the overlay and the deck concrete, the protection provided by the overlay, and the tensile properties of the resins and how they affect the performance of the overlays are described. The cost of a polymer concrete overlay is compared with that of a more conventional latex-modified concrete overlay, and insight is provided about when to specify a polymer concrete overlay based on considerations of service life, traffic volume, discount rate, and the value of driving time.

C-241 Apostolos, J. A. 1984. "Cathodic Protection of Reinforced Concrete by Using Metallized Coatings and Conducive Paints, "Transportation Research Record 962, Transportation Research Board, pp 22-29, Washington, DC.

Corrosion-caused distress to reinforced concrete structures is a serious and continuing problem. A practical measure for mitigation is cathodic protection of the embedded reinforcing steel. The results of an ongoing laboratory and field study that tests proprietary conductive paints and flame-spray metallizing as protective coatings and/or anodes are described, and their physical characteristics, behavior, and economics as part of cathodic protection systems are also discussed.

Results to date indicate that several of the paints and most of the metals tested provide adequate conductivity and bond to the concrete, but differ significantly in ease of application, toxicity, aesthetics, and economics. Of the materials tested, zinc metallizing appears to provide the most viable combination of physical characteristics and economics for cathodic protection of concrete reinforcement.

C-242 Munger, C. G. 1984. Corrosion Prevention by Protection Coatings, NACE, Houston, TX.

This book is intended to supply corrosion engineers and others needing to select or apply coatings with the fundamental reasons and philosophy behind selection, application, and use for maximum effectiveness of high performance coatings. Chapters cover corrosion, coating characteristics, types of corrosion-resistant coatings, substrates and surface preparation, application methods, repair and maintenance, coatings for concrete, failures, cathodic protection and coatings, specifications, inspection and testing. In all, it is a comprehensive treatise combining basic and even theoretical information with practical details.

C-243 Pennwalt Corp. 1984. "Adherent, Acid-Cured Resin Protective Coatings for Concrete and Steel," United States Patent US4435472, Official Gazette, 1984, Vol 1040, No. 1.

An acid-soluble substrate such as concrete or steel is primed with acid-stable resin selected from styrene/butadiene (block) or isoprene copolymers, chlorosulphonated polyethylene and chloroprene. This is thickly overcoated with an acid-curable furan or phenolic resin.

C-244 Chemiewerk, N. V. 1984. "Polysiloxane Mixtures Compatible with Organic Coating Solutions," Soviet Inventions Illustrated, Vol 83, No. 51, Group A, 1, London, England.

Silicone resins, compatible with acrylic, polyester and amino resins, or nitrocellulose for use in protective coatings for concrete are prepared by phenylating the distillation residues from methylchlorosilane production and hydrolyzing the product.

C-245 French, E. L., and Robery, P. C. 1984. "Coatings for Concrete," Conference on Coatings for Marine Environments, ITI Consultancy Services/ Steel Structures Painting Council, London, England.

The deterioration of reinforced concrete marine structures occurs mostly in the tidal and splash zones. The protection and repair of chloride-contaminated concrete structures is divided into five distinct levels according to the extent of damage. The use of high-performance coatings is mentioned.

C-246 Barnaby, D., and Dikeou, J. T. 1984. "Applications of Permanent Precast Polymer Concrete Forms for Concrete Rehabilitation," International Symposium on Mechanical Properties of Special Concrete, Transportation Research Record 1003, Transportation Research Board National Research Council, Washington, DC.

Two case studies are presented on the use of precast polymer concrete stay-in-place forms for rehabilitation of transportation structures. The first study is on precast median barrier shells used by the Pennsylvania Turnpike Commission. The new barrier replaced an obsolete, deteriorated 4-ft-wide concrete island. The shells are 1-in.-thick and come in 20-ft-long sections. They are placed on the roadway, aligned, anchored with anchor bolts, then filled with conventional concrete through holes at the top of each section. The system is easily and rapidly installed, and provides a more impact-resistant and durable barrier than conventional concrete barriers. The second study is on precast bench panels that replaced deteriorated bench walls in Boston's Sumner Tunnel. Polymer concrete panels were selected because of their high strength and high modulus, good impact resistance, and their outstanding resistance to deicing salts, chemicals, and freeze-thaw. The work, performed during the night, consisted of placing and anchoring panels, sealing off vent openings to prevent backfill concrete from coming out, then placing concrete behind the panels. In addition to improved performance properties, rapid construction time was a major benefit.

C-247 Stebbins, R. J., Josifek, C. W., and Jeniec, J. D. 1984. "Epoxy-Bonded, Steel Fiber-Reinforced Thin Cementitious Overlay at Orlando International Jetport, Florida," International Symposium on Mechanical Properties of Special Concrete, Transportation Research Record 1003, Transportation Research Board National Research Council, Washington, DC.

The reasons for selecting an epoxy-bonded, steel fiber-reinforced, cement/fly ash, superplasticized thin overlay are discussed. Each project field application procedure from existing concrete preparation through project completion is also discussed. A total of 40,000 ft^2 was applied from 1.5 to 3 in. thick with no signs of delamination or visible cracking evident after testing at maturity of 90 days. To date, this is the largest project of its type in the state of Florida.

C-248 Ramakrishnan, V. 1984. "Superplasticized Fiber-Reinforced Concretes for the Rehabilitation of Bridges and Pavements," International Symposium on Mechanical Properties of Special Concrete, Transportation Research Record 1003, Transportation Research Board National Research Council, Washington, DC.

The most critical problem facing the highway industry is the rehabilitation of its distressed structures, particularly concrete bridge decks and pavements. Various forms of distress have occurred in some of the surfaces and different rehabilitation procedures can be very costly. There is a need to determine the most effective and the most economically advantageous means to rehabilitate the damaged concrete bridge decks and pavements. An investigation sponsored by the US Department of Transportation has been completed at the South Dakota School of Mines and Technology to develop a tough, high-strength, high-density, durable concrete for bridge deck construction; and a medium-strength, flowing, structural concrete through the use of superplasticizers and steel fibers. The study was conducted in two phases. The first phase investigated the basic properties of concrete made with superplasticizers through the use of experimental mixtures conforming to the requirements dictated by statistically valid factorial designs, so that analysis of variance can be used in the evaluation. The second phase extended the findings into an evaluation of superplasticized concrete containing steel fibers. The study has been completed and the significant results are presented in this paper. The addition of the special type of steel fibers (with deformed ends and glued together into bundles with a quick water soluble adhesive) to superplasticized concrete greatly increased its ductility, toughness, impact resistance, ultimate flexural strength, post-crack load-carrying capacity, and shock resistance. The fiber-reinforced superplasticized concrete also had higher freeze-thaw durability and lower permeability. These improvements were achieved without a reduction of workability or the usual balling of steel fibers in the plastic concrete. Therefore, the fiber-reinforced superplasticized concrete is an almost ideal material for the rehabilitation of bridge decks and highway pavements and for construction of other concrete structures.

C-249 Chynoweth, G. L. 1984. "Properties of Latex-Modified Shotcrete Beneficial to Concrete Repairs," <u>International Symposium on Mechanical Properties of Special Concrete</u>, Transportation Research Record 1003, Transportation Research Board National Research Council, Washington, DC.

The inclusion of a latex into a shotcrete mix imparts a new set of mechanical properties to shotcrete and enhances the benefits of shotcrete when used for the repair of concrete. The effects of the polymer binder on the shotcrete matrix are discussed and then related to the mechanical properties of latex-modified shotcrete. The mechanical properties of latex-modified shotcrete are presented along with a discussion of how they benefit the repair of concrete structures that have experienced corrosion or freeze-thaw damage, particularly in environments subject to chloride exposure. The application of latex-modified shotcrete is discussed, and guidelines are provided for preparing the mix proportions and specifications.

C-250 Morgan, D. R. 1984. "Steel Fiber Shotcrete for Rehabilitation of Concrete Structures," <u>International Symposium on Mechanical Properties of Special Concrete</u>, Transportation Research Record 1003, Transportation Research Board National Research Council, Washington, DC.

Steel fiber-reinforced shotcrete (SFRS) was first introduced into North America in the early 1970's. Since that time, it has been used in numerous applications, mainly in new construction or lining rock slopes and underground openings in mines and tunnels. There has been relatively little use of this innovative material for rehabilitation of concrete structures. Some of the mix design, batching, mixing, and placing procedures that have been successfully used in numerous SFRS projects in British Columbia are reviewed. Physical properties of SFRS that make it particularly attractive as a rehabilitation material include its good bond characteristics, flexural strength, toughness, impact strength, fatigue resistance, and durability. These characteristics of SFRS are reviewed. Existing SFRS rehabilitation projects are briefly reviewed and suggestions are made for applications where SFRS could provide a viable alternative to conventional rehabilitation procedures.

C-251 "Chlorinated Polyvinyl Chloride-Based Varnishes and Enamels." 1984. Russian Patent SU1043266, 4 pp, <u>Soviet Inventions Illustrated</u>, Vol 84, No. 23, Group G, 2, London, England.

Use of the coatings for concrete, wood, or metal building foundations and constructions is claimed to provide improved resistance to corrosion and frost.

C-252 Macadam, D., Smith, K., Fowler, D. W., and Meyer, A. H. 1984. "Evaluation of Rapid-Setting Concretes," International Symposium on Mechanical Properties of Special Concrete, Transportation Research Record 1003, Transportation Record Board National Research Council, Washington, DC.

Rapid-setting materials are becoming widely available. Transportation agencies have a strong need for materials that will set rapidly yet provide a durable repair especially in urban areas. There are eight categories of rapid-setting concretes, and these possess a wide range of characteristics and properties. A survey of state transportation departments indicated that there are several preferred properties and characteristics of rapid-setting materials. A test program was conducted to evaluate test procedures for these materials and to determine the properties of a range of rapid-setting concretes. The results of this test program are summarized in this paper.

C-253 MacDonald, C. N. 1984. "Plastic and Steel Fiber-Reinforced Concrete Applications," International Symposium on Mechanical Properties of Special Concretes, Transportation Research Record 1003, Transportation Research Board National Research Council, Washington, DC.

The designed properties of concrete for the use of steel or plastic fiber reinforcement are discussed. The reasons for using fiber reinforcement are cited from experience and case histories at chemical plants in various locations in the United States. The implementation techniques and applications are about repairs and original work with fiber-reinforced slabs, grade beams, and equipment and tower foundations. The benefits of using fiber reinforcement were realized in scheduling, economy, ease of placement, volume constraints, fire resistance, modulus of rupture, fatigue strength, skid resistance, durability, repairability, joint spacing, and deflection control. Histories have shown savings of 10 percent or more on projects bid against alternate designs with conventional reinforcement. Superplasticizer was vital in most cases to ease placement of the steel fiber-reinforced concrete. Field changes in some cases allowed no design changes to the concrete, and the performance has been better than expected with no adverse effects. These applications have high-lighted the successful uses of plastic and steel fiber-reinforced concrete. However, there are risks from the lack of material design information that challenge the normal concrete codes and practices for design.

1985

C-254 "Joint Sealants Prolong Pavement Life." 1985 (Jan). Better Roads, Vol 55, No. 1, pp 20-22, Park Ridge, IL.

Expansion and contraction joints in concrete pavement are designed to extend pavement life by reducing random cracking. However, if joints are improperly sealed, the rate of pavement deterioration can be accelerated by the penetration of air, water, and debris. Joint preparation and sealant installation are the two most important factors affecting sealant performance. A discussion covers the three-step process of sealant application: 1) joint preparation, 2) installation of a backer rod, and 3) sealant application.

C-255 "Joint Treatment with Glass Fiber Stops Reflective Cracks." 1985 (Jan). Roads & Bridges, Vol 23, No. 1, pp 19-20, Des Plaines, IL.

This article briefly discusses an experimental system that combined high-strength woven glass fiber mat reinforcement with a chemically modified asphalt polymer to seal and waterproof surface defects in a 6.4-mile-long expanse of Texas highway. Repair procedures used on cracked pavements and methods for the repair of severely spalled joints and midslab cracks are described.

C-256 Barfoot, J. 1985 (Feb). "Polymer Grids-The Breakthrough Into Concrete," Concrete, Vol 19, No. 2, pp 29-30, London, England.

After 3-1/2 years of research, polymer grids have been introduced as reinforcement for concrete. Due to an inherent resistance to corrosion, the grids found immediate application. The grids are produced by perforating heavy-duty polymer sheet and stretching the perforated sheet to produce an alignment of the long-chain polymer molecules, hence, a dramatic increase in tensile strength.

Used in concrete applications, the grids require a second process in which the uniaxially stretched sheet is gripped between two sets of heavy chains and stretched in the transverse direction to produce a biaxially-oriented product.

In addition to contributing to more economic and durable construction, the polymer-reinforced concrete exhibits freedom from corrosion, high energy absorption, shrinkage restraint, and good crack control properties.

C-257 Asano, A., Nishioka, T., and Minematsu, T. 1985 (Feb). "Repair Works by Shotcreting Using Ultra Rapid Hardening Cement with Steel Fibers" (in Japanese), Concrete Journal, Vol 23, No. 2, pp 28-35, Tokyo, Japan.

An elevated railroad in service was repaired by shotcreting using ultrarapid hardening cement with steel fibers. Results show this to be an excellent repair method. The process used and other matters pertaining to the quality of shotcrete are discussed.

C-258 Furumura, M. 1985 (Mar). "Polymer-Impregnated Concrete Interlocking Blocks: Resistance to Wear, and Applications to City Roads" (in Japanese), Roads and Concrete, No. 67, pp 33-40, Tokyo, Japan.

The author, using methyl methacrylate (MMA) as monomer, developed polymer-impregnated (PIC) interlocking blocks to be used for city roads

Based on the analysis of over 1,600 core samples, the results show that the experimental waterproofing systems outperformed Vermont's standard treatment of tar emulsion.

C-262 "Silane Treatments Fight Bridge Corrosion." 1985 (May). Better Roads, Vol 55, No. 5, Park Ridge, IL.

This article discusses silane treatment of bridges, which prevents bridge deck deterioration caused by concrete corrosion. The potential use of silane treatment is great because almost 45 percent of the United States' 564,499 highway bridges are structurally deficient or functionally obsolete. The silane compound prevents corrosion of the reinforcing bar by penetrating the concrete and producing a chemical reaction with it, rather than just coating the concrete. This forms a protective layer, which renders the concrete salt resistant. Core samples taken from treated bridge decks have shown that the treatment is effective in preventing corrosion for both old and new bridges. Test results from the core samples are discussed, and the application of the silane treatment on concrete surfaces is described.

C-263 Webster, R. P., Fontana, J. J., and Reams, W. 1985 (May). "Electrically Conductive Polymer Concrete Overlays," Report BNL-35036, FHWA/RD-84/033, Federal Highway Administration, McLean, VA.

The development of a built-up, electrically conductive polymer concrete overlay and a premixed, electrically conductive polymer concrete mortar for use on bridge decks and other concrete members, in conjunction with cathodic protection systems, is reported. The research program was divided into two phases. The emphasis of the work performed in Phase One was directed toward the evaluation of the 18 commercially available resin systems and the 16 conductive filler systems selected for consideration. Basic studies also evaluated various parameters affecting the electrical resistivity properties of both the built-up overlay and premixed mortar systems. In Phase Two, extensive evaluation of the physical and mechanical properties of the most promising overlay and premixed mortar systems were performed. In addition, the performance characteristics of the selected overlay systems, when incorporated into active cathodic protection systems, were evaluated.

C-264 Zolotukhin, V. A., and Azimov, F. I. 1985 (May). "Maintenance of Building Structures by Guniting of Concrete Mixes" (in Russian), Beton i Zhelezobeton, No. 5 pp 37-38, Moscow, Russia.

Maintenance and repair of concrete building elements are described. Efficiency of shotcreting of damaged parts with the application of different concrete mixes is analyzed.

C-265 Sudakov, V. B., Ginzburg, TS. G., Morozova, G. V, Bel', A. A., and Miklashevich, N. V. 1985 (Jun). "Use of Combined Surfactant Additives in Concrete of Hydraulic Structures," Hydrotech Construction, Vol 19, No. 6, pp 316-320, New York, NY.

The use of surfactant additives is one of the most effective methods of regulating the structure and properties of concretes. Surfactant additives have (since the 1950's) found wide use in hydrotechnical construction practice. The most common of them are sulfide-yeast waste liquor (SYL), sulfide waste liquor (SWL), and neutralized air-entraining resin (NAR) which have made it possible to save hundreds of thousands of tons of cement and to considerably increase the durability of hydraulic structures. Investigations and long-term experience have revealed, along with the great favorable effect, shortcomings of using individual surfactant additives. Individual additives do not make it possible to act on the entire complex of properties of cement systems in the necessary direction.

C-266 Ramakrishnan, V. 1985. "Steel Fiber Reinforced Shotcrete: A State-of-the-Art Report," pp 7-24, Swedish Cement & Concrete Research Institute, Stockholm, Sweden.

Steel fiber reinforced shotcrete (SFRS) was first experimented in the USA in 1971, and the first major field application was in 1973. Since that time there has been extensive use of this new promising material in all advanced countries of the world. This report traces the history of development of SFRS and describes the laboratory research and successful field applications. SFRS has found its largest application in mining operations for forming linings in various railway, road, and water tunnels. Other applications include rock slope stabilization work, brick bridge arch strengthening, dome structures, canal linings, and repair and rehabilitation of water front structures and other deteriorated concrete structures. The most successful applications are when it has been used in lieu of mesh reinforced shotcrete. Materials, steel fibers, additives, admixtures, mixing and placing techniques are described. Factors affecting rebound are discussed. Physical and elastic properties, particularly the improvements achieved in shotcrete performance due to the addition of steel fibers are described.

C-267 Nojiri, Y., Tazawa, Y., and Nobuta, Y. 1985. "Durability of Lightweight Concrete for Arctic Concrete Structures," Ocean Space Utilization '85, Proceedings of the International Symposium, Vol 2, pp 431-438, Springer-Verlag, Tokyo, Japan and New York, NY.

The experimental results regarding characteristics of lightweight concrete incorporating condensed silica fume are discussed. Many factors such as type and moisture content of lightweight aggregates, dosage of condensed silica fume, air content, water to cement ratio are selected as experimental factors. It was concluded that high-strength and durable-lightweight concrete satisfying requirements for arctic concrete structures could be obtained by using lightweight aggregate with low moisture content and utilizing condensed silica fume as a mineral admixture.

C-268 Haug, W., Ditter, K., and Geiseler, W. D. 1985. "Two Examples for the Regeneration of Cement Concrete and Asphaltic Concrete Linings of Water Storage Reservoirs by Means of Asphaltic Concrete," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Lausanne-Suisse, Paris, France.

After 25 years of use, the cement concrete lining of the Reisach-Rabenleite pumped storage reservoir (Bavarian Forest, Southern Germany) showed first signs of deterioration, repair of which exceeded normal maintenance works. After having taken the decision that asphaltic concrete would be the most suitable material for regenerating the lining, STRABAG BAU-AG carried out a large-scale trial, testing various construction methods and design variations. The works were executed with great success and therewith the owner had reached two aims. The most endangered part of the lining was repaired, and, in case that somewhere larger areas or the entire lining have to be regenerated, a perfect method, tested and proven, is available.

A second example deals with regeneration of an asphaltic concrete lining by means of asphaltic concrete. The aims were the same as previously mentioned, repair of the most deteriorated part of the original lining and finding the most suitable method for larger regenerating later on. In contrary to Reisach-Rabenleite, where the concrete slabs were left in place, at Geesthacht the impervious asphaltic concrete layers were milled off with specially developed machines to a depth where sound and nonaged material was found. On top of the milled surface, a fresh asphaltic concrete layer of 7-cm thickness was placed and partly covered with mastic asphalt. Method, material, and machinery were tested and found suitable.

C-269 Fattuhi, N. I., and Hughes, B. P. 1985 (Jul). "Testing Repair Materials for Concrete Cracks," Durability of Building Materials, Vol 3, No. 1, pp 59-64, Amsterdam, The Netherlands.

This article describes a simple testing technique for evaluating the effectiveness of a repair material in sealing cracks and transmitting tensile stresses across cracks, and also for comparing different repair materials when used under varying conditions. For crack simulation purposes, grooves were formed in concrete beams during casting and filled with different repair materials. The beams were tested in flexure, and the results indicated the relative effectiveness of the repair materials in transmitting the tensile stresses with reasonable accuracy.

C-270 Aitcin, P. C., and Regourd, M. 1985 (Jul). "Use of Condensed Silica Fume to Control Alkali Silica Reaction-A Field Cast Study," Cement and Concrete Research, Vol 15, No. 4, pp 711-719, Elmsford, NY.

In 1980 a sidewalk was built in Becancour, Quebec, with condensed silica-fume concretes containing highly reactive aggregates. Eleven concrete mixes were used with cement quantities from 150 to 405 kg of cement per m^3 and condensed silica-fume substitutions varying from 10 to 40 percent. In spite of the great reactivity of the aggregates, the alkali-aggregate reaction is still under control. Microstructural studies of four particular concretes were made after the first and third winters. No silicate gel was observed in the two leaner mixes, but some has been found in a few locations encircling coarse aggregate particles in the two richer mixes. The severe scaling problem observed in one of the concretes is characterized at the microstructural level by frequent unbonding of coarse aggregates and presence of converging cracks around the aggregates.

C-271 Neal, B. F., and Krauss, P. D. 1985 (Jul). "Experimental Overlays Utilizing Magnesium Phosphate, Methyl Methacrylate and Polyester-Styrene Concretes," Report TL-633352, FHWA/CA/TL-85/19, California State Deparment of Transportation, Sacramento, CA.

Details are listed for pavement overlays less than 1 in. thick. Three different materials were used: magnesium phosphate, methyl methacrylate, and polyester-styrene concretes. Each section is 24 ft wide and from approximately 1,100 to 1,300 ft in length. Construction problems were encountered and are discussed. The polyester-styrene concrete overlay performed best with no delamination. The magnesium phosphate concrete and the methyl methacrylate concrete overlays failed due to debonding. Surface preparation for thin bonded overlays was found to be a significant factor.

C-272 Husbands, T. B. 1985 (Aug). "Repairing Concrete with Polymers," Military Engineer, Vol 77, No. 502, pp 426-427, Alexandria, VA.

This article describes two Army facilities selected to demonstrate current technology using polymeric systems to repair concrete. At Fort Bragg, NC, a water tower with spalled concrete footings was repaired by injecting an epoxy resin under pressure into cracks and areas of delamination. Unsound concrete in a severely spalled footing was removed and restored to its original shape with fresh portland-cement concrete (PCC) bonded to the existing hardened PCC with an epoxy resin. A second Fort Bragg project repaired a multistory concrete building with corroded reinforcing steel, and spalled and cracked concrete. Cracks were routed and sealed with a single-compound polyurethane joint sealant. Reinforcing steel was exposed, sandblasted or wire brushed, and coated with an epoxy resin before patching with latex-modified mortar.

At Fort Ord, CA, the concrete roof decks of two water-storage tanks showed spalling from reinforcement steel corrosion and numerous hairline cracks. Unsound concrete was removed to expose the reinforcement, the roof deck and exposed steel were sandblasted, all spalled areas were patched with a polyester mortar, and the roof deck was given a 3/4-in. coating of polyester resin after sealing with a neat polyester resin.

C-273 Schroder, M. 1985 (Aug). "Fibrous Mortar for Repair Work" (in German), Beton, Vol 35, No. 8, pp 301-302, Dusseldorf, Germany.

This article describes a concrete repair system based on cement mortar reinforced with fibers and modified with synthetic resin for good workability. It will repair large, deeply ruptured surfaces without cracking. The same cement is also used to prevent reinforcement corrosion and as a bonding layer.

C-274 Puech, M. 1985 (Sep). "Protection of Structural Steels, Concrete Reinforcing Bars, and Prestressed Tendons by Hot Galvanization," Annales, Institut Technique du Batiment et des Travaux Publics, No. 437, pp 106-124, Paris, France.

Preventing corrosion is a very important problem in view of the extensive damage caused each year by rust, whether it be on steel or reinforced concrete structures. Possibilities of protection by hot galvanization are presented for structural steel, reinforcement for concrete, and prestressing tendons. Comments on the possibilities of arc-welding of galvanized components, the future of assembly by high-streng .: bolts, and the necessity for homogeneity in the degree of galvanizat'on of components such as girders and bolts in any one construction are given.

C-275 Mansur, M. A., and Ong, K. C. G. 1985 (Oct). "Epoxy-Repaired Beams," Concrete International: Design & Construction, Vol 7, No. 10, pp 46-50, Detroit, MI.

Six reinforced concrete beams, each with a large rectangular opening, were severely damaged during a test program. These beams were repaired by removing loose concrete and replacing it with epoxy mortar and filling the cracks by epoxy injection. The repaired beams were then tested in the same manner as the original beams. A comparison made between the two sets of test data shows the effectiveness of the repair technique.

C-276 Krauss, P. D. 1985 (Oct). "New Materials and Techniques for the Rehabilitation of Portland Cement Concrete," Report TL-633291, FHWA/CA/TL-85/16, California State Department of Transportation, Sacramento, CA.

Details of test installations of overlays less than 1 in. thick are given. Various types of concrete repair materials are discussed along with test procedures developed to evaluate the products. New developments in repair techniques are also described. Specifications for rapid set patching materials and organic polymer concrete overlays are included in the appendices of the final report. Test results of numerous portland-cement-concrete (PCC) patching materials are listed.

C-277 Haston, J. S. ed. 1985. "Developments in New and Existing Materials," Proceedings of a Session in Conjunction with the ASCE Convention, American Society of Civil Engineers, New York, NY.

This session proceedings contains four papers. The topics covered include: bridge deck polymer impregnation tests; silty clay stabilization using type C fly ashes; cement stabilized soil engineering properties; cement concrete and asphaltic concrete pavement overlays

C-278 Schroeder, M. C. 1985 (Oct). "Corrosion and Protective Coatings in the Pulp and Paper Industry," Journal of Protective Coatings & Linings, Vol 2, No. 10, pp 22-28, Pittsburgh, PA.

The pulp and paper industry, where process and exposure conditions are extremely corrosive and where steel structures are often aged and complex, is the ultimate challenge for coating system protection and performance. Successful resistance to the debilitating effects of exposure and operation requires a concerted effort on the part of design and maintenance engineers in solving the problems of corrosion and designing high performance coating systems for both steel and concrete substrates. This paper is an overview of the industry's problems with corrosion and with selecting protective coatings systems.

C-279 Stamatello-Gorska, M. 1985 (Oct). "Investigation of Impregnated and Unimpregnated Ferrocement in Aggressive Environment," Journal of Ferrocement, Vol 15, No. 4, pp 349-357, Bangkok, Thailand.

The aims of the study were to investigate and compare the properties of concrete, plain ferrocement and MMA-impregnated ferrocement specimens exposed to aggressive environment for 1 year. The testing of the specimens consisted of determining changes in tensile strength, absorbability and appearance after 3, 6 and 12 months of exposing the specimens in natural sewage environment. Test results showed that the MMA-impregnated ferrocement specimens in comparison with unimpregnated ones are characterized by a higher tensile strength and four times lower absorbability. The increase in tensile strength with time of impregnated ferrocement and the accompanying absorbability decrease is remarkable.

C-280 Romualdi, J. P. 1985 (Oct). "Pool Relining with Ferrocement," Concrete International: Design & Construction, Vol 7, No. 10, Detroit, MI.

The use of ferrocement in the rehabilitation of water containment structures such as tanks and swimming pools is described. Application to the relining of tunnels, culverts, and chimneys is also discussed. The problem of using multiple layers of conventional mesh to form the reinforcement for the relatively thin ferrocement liner is avoided by the use of one layer of a special three-dimensional mesh originally developed in New Zealand. The advantages and construction sequence for the installation of an unbonded liner using one layer of the new mesh type is described. Examples of successful installations are also provided.

C-281 Turgeon, R., and Ishman, K. D. 1985 (Nov). "Evaluation of Continuously Reinforced Concrete Overlay and Repairs on Interstate Route 90, Erie County, Pennsylvania," Report FHWA/PA-85/007, Pennsylvania Department of Transportation, Harrisburg, PA.

The report covers the construction and maintenance of a CRC pavement over a RCC pavement in Erie County. Various investigation techniques, studies of maintenance materials, and performance of these materials are reported. Failures of the overlay are investigated and patching techniques are tested and evaluated. Deflection equipment performance, crack evolution, and decision processes are discussed and evaluated. Maintenance contracts and repair costs are presented with reference to previous construction activities and decisions.

C-282 Kuhlmann, L. A. 1985 (Nov). "Latex Modified Concrete for the Repair and Rehabilitation of Bridges," International Journal of Cement Composites and Lightweight Concrete, Vol 7, No. 4, pp 241-247, Harlow, Essex, England.

Portland cement modified with styrene butadiene latex has been in use for over 25 years. This paper presents data on the physical properties of latex modified concrete and case histories are cited to show its application and usefulness. Latex modified cement systems are applicable wherever adhesion, durability, and compatibility with the base concrete are required.

C-283 McLean, B. W., and Bridges, A. J. R. 1985. "Fusion Bonded Epoxy Coating for Corrosion Protection of Re-Bars," Vol 2, pp 11-17, Institute of Corrosion Science & Technology, Birmingham, England.

Although much has been reported in the USA on the use of fusion bonded epoxy resin powder coatings for protection of reinforcing bars in concrete, the United Kingdom construction industry has until now not felt the need to introduce this system except in special cases such as the Middle East. The escalating costs of repair for bridge decks and marine environment structures points to the need for such protection. This state-of-the-art review confirms the availability of necessary technology.

C-284 Sims, F. A. 1985 (Nov). "Applications of Resins in Bridge and Structural Engineering," International Journal of Cement Composites and Lightweight Concrete, Vol 7, No. 4, pp 225-232, Harlow, Essex, England.

This paper covers some of the uses of epoxy resins in bridge and structural engineering over the last 2 decades, including segmental construction. Uses of resin in ancillary bridge works are considered, along with deck strengthening, earth reinforcement, and rock bolting. Resin application for the maintenance and repair of bridges and structures is referred to.

C-285 "Cost-Effective Patching." 1985 (Nov). Roads & Bridges, Vol 23, No. 11, pp 27-31, Des Plaines, IL.

Though patching is not a permanent measure, it is an economical way to maintain a reasonably smooth roadway surface. There are four basic options for bridge-deck maintenance: temporary patching, permanent patching, overlaying, and redecking. A rule of thumb is to continue patching until 20 percent of the deck has been repaired, overlay with a modern compound, and continue patching until 20 percent of the overlaid deck has been repaired. After all these measures have been exhausted, redecking should be considered.

The range of patching materials discussed includes blacktop, standard concrete with accelerator, cementitious materials, gypsum-cement blends, magnesium phosphates, and latex-modified and polymer concretes.

C-286 Maslow, P. H. 1985 (Dec). "Sealants, Joints, and Membranes for Concrete," Construction Specifier, Vol 38, No. 12, pp 60-69, Alexandria, VA.

Properly specifying sealants, joints, and membranes can increase the life and functionality of concrete. The four basic types of joints used in concrete discussion defined are expansion, control or contraction, construction, and isolation joints. Low-, medium-, and high-movement capability sealants and caulks are discussed in light of their functioning under joint conditions. Joint materials generally used together with liquid-applied sealants include premolded joint fillers, rubberized asphalt sealing strips, compression seals, waterstops, and parking-deck expansion joints. Overviewed also are waterproofing membranes and the uses and misuses of sealants.

C-287 Popovics, S. 1985. "Modification of Portland Cement Concrete with Epoxy as Admixture," SP-89, pp 207-229, American Concrete Institute, Detroit, MI.

The work presented is a portion of a larger investigation concerning the improvement of durability of concrete structures in seawater. Therefore, as an introduction, the deterioration of reinforced concrete in corrosive environment is discussed followed by a description of two types of polymer modification of concrete. This latter means the addition of a liquid polymer of polymerizable system to the fresh concrete.

The major portion of the paper presents a new investigation concerning the effects of epoxy modification on the properties of concrete, primarily strength. It is demonstrated that the addition of a suitable epoxy to the fresh concrete can increase the concrete strength significantly. This strength improvement can be further increased by the simultaneous use of a compatible superplasticizer, or an accelerator, or both.

C-288 Mendis, P. 1985. "Commercial Applications and Property Requirements for Epoxies in Construction," SP-89, pp 127-140, American Concrete Institute, Detroit, MI.

Almost every structure where concrete or steel is used is vulnerable to the corrosive effects of chemical and environmental attack, as well as mechanical abuse due to stress and vehicular traffic. Severe deterioration of such structures can result in the commercial, industrial, and transportation areas. Epoxy resin based polymer products are used for the rehabilitation, repair, and protection of both existing or newly constructed structures.

C-289 Ohama, Y., Notoya, K., and Miyake, M. 1985. "Chloride Permeability of Polymer-Modified Concretes," Transactions, Japan Concrete Institute, Vol 7, pp 165-172, Japan Concrete Institute, Tokyo, Japan.

Recently the rapid deterioration of various reinforced concrete structures has been a widely recognized problem in Japan. The chloride-induced corrosion of reinforcing steel is the major cause of the deterioration. This paper deals with the chloride ion permeability of polymer-modified concretes which are promising materials for preventing the chloride-induced corrosion. The polymer-modified concretes using commercial polymer dispersions are prepared with different polymer-cement ratios and tested for chloride ion permeability under immersion in substitute ocean water and saturated sodium chloride solution. It is concluded from the test results that the chloride impermeability of the polymer-modified concretes is superior to that of unmodified concrete and is markedly improved with an increase in the polymer-cement ratio.

C-290 Spynova, L. G., and Ivashkevich, I. A. 1985. "Bactericidal Concrete" (in Russian), Beton i Zhelezobeton, No. 8, pp 29-30, Moscow, Russia.

It was shown that concrete and metal corrosion processes are speeded up by the biochemical actions of micro-organisms. To eliminate this drawback without reducing concrete physicomechanical properties, an alkylpyridine-bromide additive was introduced into concrete, improving preventive maintenance, and increasing concrete life. This additive can also be used in plaster and paint composition.

C-291 Shirayama, K., Hiraga, T., Yano, M., Itatani, T. 1985. "Metal Covering for Improving Durability of Reinforced Concrete Structures," Transactions, Japan Concrete Institute, Vol 7, pp 195-202, Japan Concrete Institute, Tokyo, Japan.

In Japan, recently, some reinforced concrete (RC) structures have shown remarkable deterioration, and the durability of them has become one of the most serious problems to be solved. The authors have been trying to improve durability of RC structures by use of several kinds of noncorrosive metal finish on concrete surface. This paper describes test results of the metals themselves, the method of overlaying metals on concrete, and the effect of metal coverings on the durability of RC members.

C-292 (Deleted)

C-293 Kujala, P. 1985. "Polymer Concrete in Facade Repairs" (in Finnish), Betonituote, Vol 55, No. 1, pp 57-59, Helsinki, Finland.

Polymer concrete, with its superior resistance to weather and chemicals and its high mechanical strength, is a good alternative for many uses. Facade panels made of polymer concrete are presented and their assembly is discussed. The material is briefly described.

C-294 Dinitz, A. M., and Ferri, R. 1985. "Polymer Concrete (MMA) for Bridge Rehabilitation Applications," SP-89, pp 141-159, American Concrete Institute, Detroit, MI.

PC (MMA) systems have been in use for over 20 years and have become one of the most promising materials for the rapid repair of concrete, especially bridge deck repairs. The major bridge applications include joint and spall repairs, thin bonded overlays, and deck impregnation. The latest design concept utilizing MMA is for modular bridge deck replacement using the MMA for bearing pads, for joining individual panels, and for contraction joint pours. Prepackaged systems consist of two components, a premixed powder that contains fine aggregates coated with polymers, initiators and pigments and a liquid monomer component (methyl methacrylate).

C-295 Ramey, G. E., Moore, R. K., Parker, F., Jr., and Strickland, A. M. 1985. "Laboratory Evaluation of Four Rapid-Setting Concrete Patching Materials," Transp Research Record 1041, pp 47-52, Transportation Research Board, Washington, DC.

Compressive strength, tensile strength, direct shear, and energy absorption tests were used to evaluate polymer concrete, magnesium phosphate cement, roadpatch with steel fibers, and epoxy-bonded PCC. The split-cylinder tensile bond strengths of the patching materials were comparable to those of the base concrete. The shear bond strengths and energy absorption tests indicated that polymer concrete has good cured properties as a composite patch but may be susceptible to weathering or thermal deterioration. Roadpatch also had satisfactory cured strength properties but had better resistance to decreases in direct shear bond strength and tensile strength when exposed to simulated weathering. Roadpatch appeared to exhibit a good overall combination of characteristics that indicate satisfactory shot-term and long-term durability.

C-296 Tjugum, O. M. 1985. "Latex-Modified Concrete" (in Swedish), Nordisk Betong, Vol 29, No. 2, pp 15-17, Stockholm, Sweden.

Latex-modified concrete overlays have been in service for over 20 years in the United States. Latex as an admixture is now in use in Norway.

The physical and chemical properties of latex modified concretes and their use in practice are discussed.

C-297 Sakuta, M., Yoshioka, Y., and Kaya, T. 1985. "Use of Acryl-Type Polymer as Admixture for Underwater Concrete," SP-89, pp 261-278, American Concrete Institute, Detroit, MI.

The quality deterioration of underwater concretes may be caused mainly by the washout of the cement from the concrete. The addition of an acryl-type polymer to concrete was found to be effective to prevent such deterioration. With the increase of the polymer content, the resistance of the concrete to be separated in water improved. This polymer did not affect the hydration of the cement. A dialdehyde-type auxiliary agent was effective to improve the function of the polymer at a dosage of only 1 percent of the polymer when it was added to the concrete after the addition of the polymer. Due to the high viscosity of the concrete containing the polymer, the cleaning operation of equipment such as concrete pumps and mixers tends to be time-consuming.

C-298 Engelfried, R. 1985. "Preventive Protection by Low-Permeability Coatings," Proceedings Conference on 'Permeability of Concrete & Its Control', pp 107-117, London, England.

The carbonation reaction is described in detail, and the effect of environmental pollution and of the deterioration of concrete are discussed. Studies have shown that the neutralization of concrete by carbon dioxide is much more significant than by sulphur dioxide. The role of coatings in retarding carbonation is considered, and the required properties are given as a completely continuous coating, of good uniformity and adhesion to the surface. In view of the possible diffusion of water vapour, the coating must show good weather resistance to ensure that the diffusion resistance does not decrease due to chalking.

C-299 Richardson, F. B. 1985. "Formulating Water-Based Epoxide Paints," <u>Pigment and Resin Technology</u>, Vol 14, No. 4, London, England.

The use of a proprietary range of polyamide curing agents for epoxy resins, particularly suitable for water-borne coatings for concrete, is described. Pigmentation and other formulation aspects are discussed.

C-300 Bare, F. 1985. "Paints and Coatings for Concrete" (in German), <u>Farbe und Lack</u>, Vol 91, No. 3, pp 195-199, Hannover, West Germany.

Following a review of basic degradation processes (e.g. in the presence of water), paints, transparent coatings, and impregnants are considered. These include silicate, acrylic (optionally combined with siloxanes), epoxy, chlorinated rubber and polyurethane systems and, for moisture protection only, various impregnants based on silicones, silanes, or siloxanes. Criteria for selection and application are briefly indicated.

C-301 Read, R. T. 1985. "Coatings for Concrete," Polymer Paint Colour Journal, Vol 175, No. 4143, pp 343-344, Redhill, England.

A summary of papers given at the paint R.A. Symposium on Coatings for Concrete, Mar 1985, is presented. Subjects ranged from protective and decorative systems for masonry surfaces to preventive and repair coatings for steel reinforcements.

C-302 Jotischky, H. 1985. "Coatings for Concrete: The Market Framework," Polymer Paint Colour Journal, Vol 175, No. 4153, pp 740-742, Redhill, England.

Economic and technical parameters affecting the repair market for reinforced concrete and the market for reinforcement and masonry coatings are surveyed. Major constraints and opportunities likely to affect these sectors include the level of building activity and the changing usage pattern of building materials relating to concrete, brick, and steel. Statistics are presented on the output of various types of cementitious building materials as well as estimates on the scale of repair work.

C-303 Gill, N. W. 1985. "Protective Urethane Coatings for Concrete Floors," Corrosion Abstracts, Vol 24, No. 3, Houston, TX.

Different coating systems for protecting commercial concrete floors against deterioration caused by traffic and soiling are discussed; polyurethane coatings are considered to be superior.

C-304 Kokubu, K. 1985. "Fundamental Study on Freeze-Thaw Durability of Expansive Concrete," Transactions of the Japan Society of Civil Engineers, Vol 15, pp 502-503, Japan Society of Civil Engineers, Tokyo, Japan.

This paper presents the results of laboratory tests on the freeze-thaw durability of expansive concrete affected by micropores. Because of the characteristic microstructure of expansive concrete, the freeze-thaw durability of the expansive concrete is more inferior to normal concrete fundamentally. But the defect of the expansive concrete can be improved substantially by the use of appropriate air-entraining agents and the curing restraint.

C-305 Opoczky, L., and Szekely, I. 1985. "Investigations to Produce Cements with High Sulfate Resistance" (in Hungarian), Epitoanyag, No. 10, pp 292-297, Budapest, Hungary.

Title cements were made using the silica fume formed during the manufacture of ferrosilicon as a by-product. Silica fume has a high surface area (12 m^2/g), contains 85-93 percent active SiO_2, and has a high hydraulic activity. It can be added to cement up to 25 percent. It improves corrosion (especially sulfate) resistance to a high degree. The simultaneous addition of plasticizers is beneficial. The efficiency of silica fume can be explained in two ways: the $Ca(OH)_2$ formed during the hydration of clinker minerals is absorbed by the activity of silica fume, while its high fineness densifies the structure of the cement stone.

C-306 Fontana, J. J., and Reams, W. 1985. "The Effect of Moisture on the Physical and Durability Properties of Methyl Methacrylate Polymer Concrete," SP-89, American Concrete Institute, Detroit, MI.

Dr. D. Fowler et al. report that the presence of water in a polymer concrete mix containing methyl methacrylate monomer reduces the mechanical strength of the composite. With coarse aggregate containing 3 weight percent moisture or higher, the compressive strength of a polymer concrete composite is reduced by 50 percent or more.

This study was undertaken to determine the influence of moisture in the coarse aggregate on the strength and durability of polymer concrete made with a prepackaged two-component methyl methacrylate system developed at Brookhaven National Laboratory for the Federal Highway Administration.

The data generated indicates that the compressive strength of "Fabucrete" polymer concrete composites do decay when water saturated coarse aggregates are used. In addition, some silane coupling agents in the polymer concrete composite in this study obtained somewhat higher compressive strengths when water saturated coarse aggregates were used.

1986

C-307 Ruffert, G. 1986 (Feb). "Shotcrete for Repairing and Reinforcing Bearing Concrete Structures" (in German), Beton, Vol 36, No. 2, pp 53-55, Dusseldorf, Germany.

More than 60 years of experience with the application of shotcrete for reinforcing and repairing reinforced concrete structures and the existing technical regulations based on these experiences and on a great number of fundamental tests allow consideration of the shotcrete method as perfected according to the technical standards. When this special method is applied for repairing bearing structures, it is not sufficient to know the technical regulations, but it also demands especially trained personnel to guarantee the same quality standard for repairing and reinforcing works with shotcrete that is required for new buildings.

C-308 Toyofuku, T., Nishida, I., and Tsurukubo, H. 1986 (Feb). "Crack of Steel Bridge Deck Slabs and that Control by Using Expansive Concrete-Follow-Up Study of Nagasaki Expressway's Tarami Bridge" (in Japanese), Concrete Journal, Vol 24, No. 2, pp 18-19, Tokyo, Japan.

Expansive concrete was applied to prevent further crack damage in the highway bridge reinforced concrete deck slabs on the Tarami bridge along the Nagasaki expressway. Strain, drying shrinkage, and condition of crack production of the concrete deck slabs were investigated over

2-1/2 years. Results are summarized. Consequentially, it was confirmed that expansive concrete deck slabs crack less than those of normal concrete and that the important causes of cracking were the restraint of main girder against the deck slabs warping originating from the temperature change and the drying shrinkage.

C-309 Plecnik, J. M., et al. 1986 (Feb). "Epoxy Penetration," Concrete International: Design & Construction, Vol 8, No. 2, pp 46-50, Detroit, MI.

Epoxy adhesives are widely used in the repair and rehabilitation of concrete structures. The effectiveness of these adhesives is largely dependent on their ability to penetrate cracks. Test results show that epoxy adhesives with a long pot life and low viscosity provide the optimum results for crack penetration and rebonding of reinforcing steel.

C-310 "Fast-Acting Patches Cure Spalls, Scaling." 1986 (Mar). Roads & Bridges, Vol 24, No. 3, pp 49-53, Des Plaines, IL.

Spalling, scaling, and potholes in portland-cement concrete pavements can be repaired with a host of high-tech patching materials that offer a spectrum of solutions varying in utility, durability, and speed of set. Cement-gypsum blends will set in less than 2 hr and expand on setting to create a good bond with existing concrete. Fast-setting magnesium phosphate patching materials offer high early strengths that can permit traffic flow 45 min after placing, are nonshrinking, and provide good freeze-thaw durability. Such proprietary products as polymer concretes and latex-modified concretes have proven effective for patching, spalls, and overlays.

C-311 Bruce, S. M. 1986 (Mar). "A Survey of Some Materials and Methods of Crack Injection for the Structural Repair of Concrete Central Laboratories Report 4-86/1," Ministry of Works and Development, Lower Hutt, New Zealand.

Injection repairs are often required to restore the load-carrying capacity of cracked concrete. Achieving a successful repair relies on the use of an adequate repair material in conjunction with a suitable injection system and repair technique. Details are presented on commercially available epoxy resins suitable for injection and specialists involved in injection repair. Bond strength was determined for three cement grouts with differing water-cement ratios and two epoxy resins.

C-312 "Quick Set Patch Means Quick Fix for Penn DOT." 1986 (Apr). Roads & Bridges, Vol 24, No. 4, pp 32-33, Des Plaines, IL.

This article describes the Pennsylvania Department of Transportation's use of a one-component, fast-setting material for concrete patching and pavement restoration. Two projects are described, one of which was carried out in deep winter.

C-313 Plecnik, J. M., Plecnik, J., Parra, V., and Diba, A. 1986 (Apr). "Fire-Testing Epoxies," Concrete International: Design & Construction, Vol 8, No. 4, pp 29-33, Detroit, MI.

With the increasing use of epoxy adhesives in the repair and strengthening of concrete structures, the risk for elevated temperature or fire exposure on epoxy-repaired concrete elements is also increased. The authors have investigated the effects of fire exposure on epoxy-repaired concrete beams, determined the effectiveness of a plaster coating applied to epoxy-repaired beams, and evaluated deflections and strength.

C-314 Ralston, M. 1986 (Apr). "Thin Polymer Road Overlay Tested," Engineering News-Record, Vol 216, No. 16, New York, NY.

Polyester styrene polymer will be installed as an overlay along 3.6 miles of highway in California's Sierra Nevada mountains, on Interstate 80. The California Department of Transportation hopes that the thin, hard, 3/4-in. overlay will restore the surface and protect existing concrete from further deterioration. The pavement environment in the high Sierras is rough, and in winter the concrete can go through several freeze-thaw cycles a day. It is also subjected to heavy truck traffic, chain wear, and ice-melting salt.

The job requires replacing some badly deteriorated concrete. Special equipment was developed to mix the material, which consists of the polymer, a catalyst, sand, and aggregate smaller than 1/2 in. Preparation of the existing concrete surface is critical. It must be completely free of contaminants. Caltrans is now testing a number of rehabilitation methods for I-80 pavement, as much as 26 years old.

C-315 Roesli, A., Haechler, A., and Peter, G. 1986 (Apr). "Polymeric Coatings for Concrete," Arabian Journal of Science and Engineering, Vol 11, No. 2, pp 193-200, Dhahran, Saudia Arabia.

Polymeric coatings can protect concrete against environmental influences. However, a prediction of their performance in practice, based upon laboratory tests, is difficult. Thus, field studies were undertaken to investigate their long-term behavior and capability in bridging cracks. It is necessary to try to classify the available polymeric coatings in respect to the problem at hand. In this way, the relations between material type, laboratory results, and reliability in practice may be better established.

C-316 "Record-Setting Whitetopping Project in Utah." 1986 (Apr). Concrete Products, Vol 89, No. 4, Chicago, IL.

Possibly the largest concrete overlay project ever constructed in the United States has been completed on an asphalt parking lot at Valley Fair Shopping Mall in Salt Lake City with a slip form paver. The 1,800,000 ft^2 parking lot was resurfaced with white concrete.

A 4-in.-thick overlay, or whitetopping, was slipformed onto the lot. The drive areas were excavated, and 7 in. of concrete was slipformed in those areas. The job was completed in about one-half the usual time through this method. Details of the repair project are given.

C-317 (Deleted)

C-318 Ruffert, G. 1986 (Apr). "Repair of Refuse Storage Containers," Beton, Vol 36, No. 4, pp 151-152, Dusseldorf, Germany.

Today, a high efficient waste disposal system is essential to cope with the ever increasing volume of rubbish. Rubbish incineration plants coupled to thermoelectric power stations have proved to be an ideal solution, particularly in densely populated areas. However, to operate most economically, these plants need to incinerate refuse continually, which can only be achieved by having a large supply of refuse in storage. The wall surfaces of the steel reinforced concrete silos used for this purpose are subjected to extreme mechanical, chemical, and thermal wear and tear. Over the years, shotcreting has proved to be ideal for repairing these surfaces. It enables regular maintenance work, which is absolutely necessary for long-term plant usage, to be carried out, and involves relatively little and very flexible site work with little interference in the running of the plant.

C-319 Radjy, F. F., et al. 1986. "A Review of Experiences with Condensed Silica-Fume Concretes and Products," Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, SP-91, pp 1135-1153, American Concrete Institute, Detroit, MI.

Extensive technical work has established that high-performance concrete and cementitious materials can be proportioned practically and economically by using condensed silica fume additives. These hybrid chemical/mineral admixtures can be used for applications ranging from bridge overlays, concrete roof tiles, and fiber reinforced cements to structural uses, both on land and offshore.

The first significant applications began some 10 years ago in Norway, with cement replacement as the main benefit. While cement replacement still continues as the main end use in the Scandinavian markets, performance enhancement of cementitious and concrete applications is the dominant attraction for users outside of Scandinavia.

After a brief consideration of the history, a range of durability and high-strength applications are reviewed. This range of varied applications is generally driven by particular features of performance enhancement.

C-320 Downey, E. 1986 (May). "Overcladding," Construction Repairs & Maintenance, Vol 2, No. 3, pp 12-14, London, England.

Housing authorities throughout England are discovering serious defects in the thermal walls of high-rise blocks. The owners of commercial and industrial buildings have also encountered problems, and buildings that were expected to last at least 70 years without significant maintenance to the concrete or brick finishes now require urgent attention. Many repairs may be treated locally by removal and replacement of defective concrete, reinforcement, bricks, etc. An attractive alternative is to overclad the entire building after repair of the worst defects in such a way that problems associated with water penetration and deterioration of surfaces may be dealt with in one operation. Overcladding materials include color-coated steel or aluminum, glass-reinforced cement or concrete, and external grade nonmetallic boards.

C-321 LaFraugh, R. W., and Zinserling, M. H. 1986 (May). "Concrete Overlays for Bridges," Report WA-RD-93.1, Washington State Transportation Center, Seattle, WA.

An extensive state-of-the-art review of construction methods and results for latex modified concrete (LMC) and low slump, dense concrete (LSDC) overlays is presented in the report. Recommendations are made for improvements in construction procedures, inspection, and specifications. An analysis and preventative measures for plastic shrinkage cracks in LMC are presented. Other alternate bridge deck protective systems were examined.

C-322 MacInnis, C., and Racic, D. 1986 (May). "Effect of Superplasticizers on the Entrained Air-Void System in Concrete," Cement and Concrete Research, Vol 16, No. 3, pp 345-352, Elmsford, NY.

This article deals with the effect of two different superplasticizers on the air-void parameter systems produced by two different air-entraining agents when the superplasticizer is added 40 min after the concrete has been batched and mixed. A significant drop in air content was observed with corresponding reductions in total air-void surface areas and increases in air-void spacing factors.

C-323 Neisecke, J. 1986 (Jun). "Corrosion Protection of Reinforcement Steel Near the Surface in Concrete Surface Repairs" (in German), Niedersaechsisches Ministerium fuer Wissenschaft und Kunst, Hannover, Germany.

This research project is intended to enquire into the questions of possible corrosion protection effect of coatings for reinforcement steel in concrete repairs and the causes and effects of corrosion along reinforcement steel due to a step change of pH value. The question of the possible corrosion protection effect of coatings was intensively pursued and which coatings are used for corrosion protection of free reinforcement steels. The questions of the cause, effect, and possible avoidance of corrosion along reinforcement steels due to step changes in pH value (for example at the boundaries of old concrete/repair mortar) could only be briefly considered. It was found that coatings on an epoxy resin basis or based on mineral-filled dispersions could give a great deal of protection. The systems on the market are not all of the same value. In both variants (epoxy resin, dispersion) there were materials with quite insufficient protective effect. Failure occurred first on the fins of the reinforcement steel in the form of rusting through. The brief investigations on differently carbonated mortar with built in steel electrodes showed the possibility of corrosion being formed by voltage peaks of up to 50 mV.

C-324 Ohama, Y., Kobayashi, T., Takeuch, K., and Nawata, K. 1986 (May). "Chemical Resistance of Polymethyl Methacrylate Concrete," International Journal of Cement Composites and Lightweight Concrete; Vol 8 No. 2, pp 87-91, Harlow, Essex, England.

Polymethyl methacrylate concrete was prepared using a binder consisting of methyle methacrylate (MMA), polymethacrylate as thickening agent, trimethylopropam trimethacrylate (TMPTMA) as a cross-linking agent, dicyclohexyl phthalate powder of benzoyl peroxide (BPO) as an initiater, and N. N. dimethleaniline (DMA) and N. N-dimethylp tolacidine (DMT) as promotor. This binder was mixed with fine size $CaCO_3$ filler, fine aggregate, and coarse aggregate in proportion 1:1:5:3.

The cured concrete specimens of size 75 by 150 mm were tested for their chemical resistance in 20 percent hydrochloric acid, 20 percent sulphuric acid, 20 percent acetic acid, 45 percent sodium hydroxide, saturated sodium sulphate, saturated sodium chloride, kerosene rapseed oil, toulene, acetone, and tap water. The resistance was measured in terms of weight loss and compression strength at 28 days of immersion in different chemicals.

C-325 Balaguru, P. N., and Ramakrishnan, V. 1986 (May-Jun). "Freeze-Thaw Durability of Fiber-Reinforced Concrete," ACI Journal, Proceedings, Vol 83, No. 3, pp 374-382, Detroit, MI.

Results of an experimental investigation on the freeze-thaw durability of fiber-reinforced concrete are presented. The primary objective of the research program was to determine whether air content is the most significant parameter for the freeze-thaw resistance of fiber reinforced concrete, as is the case with normal concrete. Accordingly, air content in the mixtures was varied from 1.2 percent to 10.8 percent. Based on results that indicate that air content is the most significant factor, it is recommended that at least 8.0 percent air content be specified for concrete structures exposed to severe freeze-thaw loading.

Comparison of fiber-reinforced concrete specimens with plain concrete specimens indicates that their behavior under freeze-thaw loading is essentially similar. For the same air content, freeze-thaw durability is the same for both plain and fiber-reinforced concrete. An increase of cement content and a reduction of water-cement ratio improves the durability. Results also indicate that the toughness index of fiber-reinforced concrete does not change appreciably with freezing and thawing, provided the mixture is designed to prevent deterioration by incorporating sufficient air.

C-326 Diulus, D. 1986 (Jun). "Parking Lot Gets White Top," Civil Engineering, Vol 56, No. 6, pp 65-67, American Society of Civil Engineers, New York, NY.

A concrete overlay was chosen to repave an asphalt shopping mall parking lot in Utah. Although concrete was somewhat higher in first cost, it was considered a better investment because it would last longer and require less maintenance. Whitetopping was chosen because it would require less construction time since the old pavement would not have to be ripped up and because noise and dust would be minimized. A slipform paving train cast unreinforced slabs 4-in. thick in nontruck areas and 7-in. thick where trucks operate. A slab 25-ft wide was cast, then a 25-ft gap was left, and the next slab cast. Three days later, when the existing slabs had cured enough for the paver and trucks to run on them, the alternating strips were cast.

C-327 Apostolos, J. A., Carello, R. A., and Howell, K. M. 1986 (Jun). "Caltrans Studies Spray Metal Cathodic Protection," Roads & Bridges, Vol 24, No. 6, pp 57-64, Des Plaines, NY.

Cathodic protection on reinforced concrete is a relatively new application of an old and established technology. A new technique, coating concrete with zinc metal, has been applied to a pier of a major bridge in San Francisco Bay, California. Description of this type of metallized cathodic protection is described.

C-328 Knight, N. E., and Turgeon, R. 1986 (Jun). "Polymer Concrete Overlays. Construction Report (L.R. 5 and 439, T. R. 11 and 502, Lackawanna County)," Report FHWA/PA-85/048+83-29, Pennsylvania Department of Transportation, Harrisburg, PA.

The objective of the study is to evaluate the performance of a polyester polymer concrete, CVI Industries, CVI Perma Deck II, as a thin overlay for concrete decks. The purpose of using a polymer concrete is to obtain a fast cure and to waterproof the deck. The VCI Perma Deck II was placed on two decks after deteriorated and delaminated areas were repaired. Two aggregate gradations were used and problems were encountered with each gradation. Replacement or repairs of both deck surfaces will be required during the summer of 1986.

C-329 "Focus: Bekaplast Lining Systems Offered in US by Atlas." 1986 (Jul). Consulting Engineer, Chicago, IL.

Atlas Minerals and Chemicals (Mertztown, PA) is commercially marketing Bekaplast lining systems to industries ranging from chemicals and metal producing to electric utilities. Bekaplast lining systems use thermoplastic sheets of either polyethylene, polypropylene, or polyvinyl chloride and a proven anchor and connecting system to protect concrete structures. Applications include trenches, sumps, and storage and make-up tanks in an electrolytic galvanizing process, the walls and floors of an acid containment pit in a shipbuilding and repair facility and waste treatment sumps in pharmaceutical plants.

C-330 Bean, D. L., and Husbands, T. B. 1986 (Jul). "Latex Admixtures for Portland Cement Concrete and Mortar," Technical Report REMR-CS-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A latex used as an admixture in portland cement concrete or mortar is a water-emulsion organic polymer. This polymer emulsion will coalesce to form a continuous film within the matrix of the paste and around the aggregate, thus producing greater tensile and flexural strength and a more durable material (because it acts as a moisture barrier to the entry of liquid water but allows water vapor to migrate out). A literature search was conducted to collect information about latex admixtures and some minor laboratory testing was performed to corroborate some of the literature findings.

C-331 Pashina, B. J. 1986 (Aug). "Crack Repair of Precast Concrete Panels," <u>Concrete International: Design & Construction</u>, Vol 8, No. 8, pp 22-26, Detroit, MI.

Cracking in nonstructural panels due to shrinkage, temperature changes, and handling stresses can be successfully repaired with fiber reinforced mortar. Esthetics, cost, ease of repair, and retention of flexural strength were repair considerations in choosing fiber reinforced mortar.

C-332 Trout, J. F., and Santangelo, S. 1986 (Aug). "Epoxy Injects New Life into Bridge Pier," <u>Concrete International: Design & Construction</u>, Vol 8, No. 8, pp 39-43, Detroit, MI.

Full-depth repairs were made on a bridge pier for a highway linking Wisconsin and Minnesota. Fine cracks in the pier were injected with a low-viscosity epoxy using socket mounting for the nylon injection nozzles. Injection began at the widest, rather than at the lowest, crack. Careful materials handling and equipment maintenance were shown to be keys to success.

C-333 McDonald, J. E., and Logsdon, D. L. 1986 (Aug). "Epoxy Injection of a Gate Pier," <u>Concrete International: Design & Construction</u>, Vol 8, No. 8, pp 34-38, Detroit, MI.

Cracking in the top pier stem supporting the service bridge at Dam No. 20 on the Mississippi River allowed precipitation ponding to infiltrate the mass concrete. Subsequent cycles of freezing and thawing resulted in progressive deterioration of nonair-entrained concrete. As an alternative to conventional repair methods that involve removing unsound concrete and replacing it with air-entrained concrete, a prototype test was conducted to evaluate the potential of epoxy injection for in situ repair of the deteriorated concrete. Materials and techniques for in situ repair in hydraulic structures are being evaluated by the US Army Corps of Engineers.

C-334 Ozaka, Y., et al. 1986 (Aug). "Bond Failure of Reinforced Concrete Members and Effectiveness of Repairs by Epoxy Resin Injection" (in

Japanese), Proceedings, Japan Society of Civil Engineers, No. 372, pp 121-130, Tokyo, Japan.

The objective of this study was to experimentally investigate the effectiveness of repairs by injecting epoxy resin into reinforced concrete (RC) members that have failed due to loss of bond between reinforcement and concrete.

For this purpose, loads were first applied to RC beams having lap splices and RC beams with cutoff of one-half of main tension reinforcing bars. Bond failures were then induced. Subsequently, epoxy resin was injected into the cracks formed using low pressure and as much time as necessary.

Results indicated that, although the behavior modes of members after repairs may be altered, the capacities, deformation, and energy absorptions are not less than those with beams in their original conditions. Accordingly, it may be stated that epoxy resin injection is an extremely effective method of repairing RC members in which bond failure has occurred.

C-335 Castro, E. D. 1986 (Jul-Aug). "Some Investigations on the Efficiency and Durability of Two Treatments Applied to a Limestone" (in French), Materials and Structures, Research and Testing, Vol 19, No. 112, pp 279-283, Paris, France.

A laboratory study is presented on the efficiency and durability of two products for stone treatment: a surface hydrofuge (based on silicone resin) and a surface protection product against atmospheric agents and pollutants (based on an acrylic polymer, a solvent, and a synthetic resin). The stone studied was the Anca limestone, which is widely used in the central part of this country and that poses serious problems as far as the conversation of historical monuments is concerned.

The test methods used in the characterization of the limestone were those recommended by RILEM 25 PEM (Protection and Erosion of Monuments) Committee.

To evaluate the efficiency and durability of acrylic, treated and nontreated samples were submitted to the following tests for comparison purposes: light action, water and light action due to exposure in a carbon-arc weathering apparatus, action of sulphur dioxide, and crystallization test.

The same tests were carried out on the samples treated with the silicone hydrofuge, except for crystallization and sulfur dioxide action tests. Weathering caused by these tests was assessed by periodic visual observation and by determination of contact angle, drop absorption, 48-hour water absorption, water absorption coefficient (capillarity), and water absorption by hygroscopicity. Results obtained are presented.

C-336 Oberholster, R. E., and Davies, G. 1986 (Aug). "Effect of Mineral Admixtures on the Alkali-Silica Expansion of Concrete under Outdoor Exposure Conditions," Report R/BOU-1404, Paper presented at the International Conference on Alkali-Aggregate Reaction (7th), Ottawa, Canada, August 18-22, 1986, National Building Research Institute, Pretoria, South Africa.

The results of experiments to establish the effects of different mineral admixtures on the expansion of concretes, made with alkali-reactive greywacke/hornfels aggregate and high-alkali cement, are discussed. The concrete specimens were exposed outdoors, and the results should be applicable to concrete structures in practice.

C-337 Ionescu, I., and Ispas, T. 1986 (Jul-Sep). "Research and Practical Results in the Field of Concrete Monolith and Precast Members Repair" (in Romanian), Materiale de Constructii, Vol 16, No. 3, pp 155-158, Bucharest, Hungary.

This article briefly discusses the following aspects: laboratory research results concerning the adherence of different concrete classes to polymers, the concrete-polymer concrete adherence, and results obtained in the work performed in view of repairing different monolithic and precast concrete members.

Observations on the behavior of repaired monolithic and precast concrete members within exploitation, over a period of 10 to 25 years, are made. Conclusions are made for future attempts.

C-338 Shindou, T., Naitou, T., and Tsuruta, K. 1986 (Sep). "Study on Durability of Polymer-Impregnated Concrete (PIC) in the Marine Environment," Concrete Society, pp 293-298, London, England.

This report deals with the durability (resistance to salt water and corrosion) of concrete structures using precast polymer-impregnated concrete boards for the protection of the exterior shell. The method is referred to as the PIC Board Construction Method which intends to improve the strength of the structure by reinforcing the exterior shell. Two types of tests were performed to evaluate durability: (1) drying and wetting test; (2) permeability test (in salt saturated water). Three types of specimens, PIC board, mortar board, and original concrete, all containing reinforcing steel were used. The results of the tests are given in this report.

C-339 Carlson, G. 1986 (Sep). "Prestressed Units Solve Case of - 'the Bridge to Nowhere'," Concrete Products, Vol 89, No. 9, pp 32-33, Chicago, IL.

Reports on Oregon's new Hubbard Creek Bridge, the first in the state to use prestressed girders with epoxy-coated strand. During WWII, the bridge was called - "the bridge to nowhere," because the road leading to it was not built yet. The road was built after the war was over.

The steel in the bridge had rusted, and the expansion and contraction caused by the corrosion had blown the concrete off in big chunks. The replacement construction project is described.

C-340 Helmdach, V., and Adler, J. 1986 (Sep). "Solvent-Resistant Epoxy Resin Coatings for Preserving Structures," Kunststoffe German Plastics, Vol 76, No. 9, Munich, West Germany.

Newly developed epoxy resin formulations based on surface-treated silicates make it possible to coat concrete surfaces with reaction resins which are resistant to solvents, and in particular to chlorinated hydrocarbons, such as ethylene dichloride, methylene dichloride, and similar. Results obtained to date show that this new type of solvent-resistant reaction resin system is suited to a broad field of application.

C-341 Hahlhege, R., and Krahling, H. 1986 (Sep). "Repair of Hydraulic Engineering Construction Using Steel Fiber Gunned Concrete," Beton, Vol 36, No. 9, pp 338-340, Dusseldorf, Germany.

Steel fiber concrete or steel fiber gunned concrete is rarely used for construction work in hydraulic engineering. A report on the repair of large sewage works shows, however, that this construction material has the advantage over conventional methods when special material qualities (crack minimization) are required.

C-342 Knight, N. E. 1986 (Sep). "Polymer Concrete Overlays - Flexolith. Construction Report (L.R. 35064, Lackawanna County)," Report FHWA/PA-86/005+83-29, Pennsylvania Department of Transportation, Harrisburg, PA.

The objective of this study is to evaluate the application of Flexolith, a modified epoxy resin, to a concrete filled steel grid deck to impart skid resistance and to obtain a smooth wearing surface. The application was made by the broom and seed method, in three applications, for a total thickness of 3/8 in. The Flexolith was easy to apply and required only a mixer, squeegee, and roller for equipment. An excellent skid resistant surface was obtained by the use of basalt for the cover aggregate.

C-343 Wilson, G. E. B. 1986. "Repair of the Concrete Piles of An Oil Refinery Jetty in New Zealand," Concrete Society, pp 349-360, London, England.

The paper describes repairs to the collars of 174 of the piles which form a jetty built in 1963. Offers were received for construction of collars by shotcrete, cast in situ concrete, and prepacked aggregate concrete. The latter method was the cheapest and was accepted. Piles which did not have cracks were coated with a waterproof coating of Vandex X74 Marine or an epoxy. The tests done on the Vandex coating are described and sections viewed by electron microscope are included.

C-344 Cardon, A. H., and Hiel, C. C. 1986 (Sep). "Durability Analysis of Adhesive Joints," Adhesion between Polymers and Concrete, Bonding Protection and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The analysis of the adhesion quality of an epoxy material to concrete, or other materials, may be defined by the properties and thickness of a transition zone between the bulk adhesive and the pure adherend.

Direct measurements of those properties and dimensions are very difficult without a strong interaction between the measurement technique and the obtained results. Mixed numerical experimental methods seem appropriate to obtain valuable information on the transition zone. A defined quality of adhesion on a test specimen can be compared with real adhesion by dynamic test methods.

The influence of environmental factors on the quality of the adhesion are also measured on a test specimen and are the basis of a durability analysis of an adhesive joint taking into account classical dimensional analysis.

C-345 Gunter, M., and Hilsdorf, H. K. 1986 (Sep). "Stresses Due to Physical and Chemical Actions in Polymer Coatings on a Concrete Substrate," Adhesion between Polymers and Concrete, Bonding, Protection and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Polymer coatings on concrete surfaces repeatedly exhibit blisters, cracks, or delaminations. Various processes had been proposed to explain the causes of such damage. However, the magnitude of stresses acting on the interface between coating and substrate is relatively unknown. This is particularly true for stresses caused by chemical and physical actions. In a theoretical and experimental research program, an attempt is made to quantify such stresses. Two processes causing stresses are described, osmotic pressure and capillary pressure. Two test set-ups were developed to determine the magnitude of such stresses. The results so far show that osmotic processes and capillary suction can result in pressures up to 45 and 2 bars, respectively, acting on the interface between concrete and coating. But also smaller pressures may cause blisters or delaminations due to stress concentrations at local defects.

C-346 Bundies, F. J. 1986 (Sep). "Adhesion of Modern Barrier Coats on Concrete Motorway Bridges and Troughs Under Tarmac," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Concrete slabs of bridges and motorway troughs under tarmac traffic layers are protected against the effects of water and thawing agents by various sealing systems. The results to date have not been sufficiently satisfactory. Modern systems with crack-bridging properties have been formulated paying particular attention to the adhesion between barrier coat and concrete. Adhesion is greatly influenced by water and moisture in the substrate. Rough estimates give an idea of the quantity of water present at the concrete/barrier coat interface. This has to be taken into account when formulating and applying modern nonbituminous systems.

C-347 Czarnecki, L., and Grabowski, L. 1986 (Sep). "Criterion of Cracking Resistance of Glass Fiber Reinforced Resins: A Comparative Study," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The paper presents the analyses of the state of knowledge on the problem of cracking resistance of anticorrosion coatings made of glass fiber-reinforced synthetic resins (mainly polyester and epoxy). This kind of coatings are most often used to protect the concrete substrate in the chemically active environment. The theoretical bases of relation between the coating and concrete substrate properties have been studied. Different models of the relation have been taken into account. The influence of some coating properties (such as thickness, the tensile strength, the modulus of elasticity) on the value of the limit crack width of the concrete substrate have been analyzed. The basic features of the coating which determine its cracking resistance have been found. A review of numerous papers has been presented.

C-348 Xian-Neng, L. 1986 (Sep). "Study on the Use of Crack Resistant Polyester Mortar as Anticorrosion Coating for Outdoor Concrete," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The paper presents preparation of a low shrinkage polyester mortar coating, its physico-mechanical properties and corrosion resistance in various acid media. The coating is made of polyester resin as binder and hollow micropellets in fly ash as powder material. It features extraordinary low shrinkage approaching zero, and low tensile modulus of elasticity. Applied on the surface of portland-cement concrete, it forms a resin mortar coating that is highly adhesive, impermeable, waterproof as well as abrasion-, impact-, weathering- and chemical-resistant. It has been used successfully in southern China under intense heat of summer when temperature on the ground is as high as 70-80° C as well as temperature of several degrees below zero. It has been used with success as a isolation coating for large-sized waste acid reservoirs.

C-349 Fukushima, T., Tomosawa, F., Fukushi, I., and Tanaka, H. 1986 (Sep). "Protection Effects of Polymeric Finishes on the Carbonation of Concrete and Corrosion of Reinforcement," Adhesion between Polymers and Concrete, Bonding, Protection, Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Protection effects of polymeric finishes on the carbonation of concrete and corrosion of reinforcement were experimentally examined by using accelerated carbonation testing (30° C, 60 percent R.H., CO_2; 5 percent; for 8 months) and accelerated corrosion testing (50° C, 95 percent R.H. for 16 months) for test specimens of reinforced concrete with many kinds of polymeric finishes. To evaluate the effectiveness of polymeric finishes as repairing materials for partly deteriorated reinforced concrete and also to obtain basic data for improvement of the durability of reinforced concrete by polymeric finishes, experimental data were systematically analyzed by the least-square method using parabolic law ($\sqrt{t}$ law) involving a constant term, which was theoretically derived for the progress of deterioration of reinforced concrete based upon unsteady state dynamic analysis. Polymeric finishes play the important roles in the retardation of carbonation of concrete and the suppression of corrosion of reinforcement in neutralized concrete with no chloride ions included under ordinary atmospheric environmental conditions.

C-350 Berra, M., and Venesia, S. 1986 (Sep). "Experiments on the Use of Gunite with Resins in the Maintenance of Dam Facings," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The replacement and repair of deteriorated surfaces with gunite is one of the most common operations of facing maintenance for hydraulic works (dams, canals, etc.). However, a certain number of cracking and deteriorated phenomena occurred during these last years, mainly due to temperature and shrinkage problems, to a poor adhesion to the base and, generally, to an objective difficulty of quality control, have lead the Research Center on Hydraulics and Structures (CRIS) of the Italian Electricity Board (ENEL) to study any possible improvement for gunite. For this purpose, the possibility of adding acrylic resins in water dispersion to the gunite during spraying was considered, and its effectiveness was tested through a series of experimental investigations. Besides a small experimental application on a dam facing, a set of specimens of gunite, with and without resins, was prepared on site, under normal operating conditions. Laboratory tests concerned the following properties: compression and bending strength, adhesion, water absorption, porosity, and water permeability. The results obtained do not seem to indicate, however, in the specimens with resins, improvements in the physical-mechanical characteristics such as expected.

C-351 Chorinsky, E. GF. 1986 (Sep). "Repair of Concrete Floors with Polymer Modified Cement Mortars," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The long-term experience with the formulation of repair mortars for concrete, which are exposed to weather and traffic loads, has shown that the adhesion of modified cement mortars can be explained as follows:

Adhesion of cement mortars, which contain oligomeric additives only, is based on cristalline bonding of the cement paste to the old concrete. This bonding cannot be broken by the exposure to water.

Adhesion of polymer cement mortars, formulated with thermoplastic polymer dispersions is based on physical interaction, the chemical adhesion is prohibited by the polymer cover on the cement particles.

Adhesion of epoxy-modified cement mortars on old concrete is based also on physical interaction. But in contrary to the thermoplastic polymer dispersions, the resistance of the epoxy-resin to saponification can be so high that the bonding to the old concrete can be water resistant over a long period of time.

C-352 "Qualification Tests on PCC Systems for the Repair of Concrete Road Bridges." 1986 (Sep). Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

New building materials for repair of concrete structures have to be investigated by qualification tests to estimate their long-term behaviour. This report deals with such tests for polymer cement concrete (PCC) composite repair systems hardening under dynamic loading followed by thermal cycling tests on the cured composite specimens. Test results showed that shrinkage of PCC and/or thermal stressing of the composite system especially in the bonding interface are decisive for durability of PCC layers on concrete, whereas dynamic loading of the fresh composite system seems to be of minor consequence.

C-353 Steiger, R. W. 1986 (Sep). "Unity Temple: The Cube That Made Concrete History," Concrete Construction, Vol 31, No. 9, pp 807-813, Addison, IL.

Unity Temple was designed by Frank Lloyd Wright and constructed in 1905. As time passed, settlement, weathering, and pollution took their toll. The porous concrete, having voids between the particles of pea gravel, allowed the elements to penetrate. Reinforcing bars, too close to the surface, produced rust stains. Cracking and spalling were the inevitable result.

Attempts to repair this deterioration in 1961 were moderately successful, but the resulting surface looked much like stucco and did not match the original finish. Subsequent attempts to patch cracks that kept opening only detracted more and more from the aesthetics of the building. Finally in 1970 it was evident that this piecemeal approach to repair was having a very negative effect on the structure and wasn't really solving the problem. It was decided that shotcreting the entire building would be the best way to restore the integrity and appearance of the original surface.

Pea gravel from the Fox River Valley, similar to that in the original mix, was used with Type I portland cement and number 2 torpedo sand. To complete the mix, 1/8-inch to 1/4-inch flint glacial deposit was added. This mixture closely resembles the original exposed aggregate texture and has covered over the patchwork of previous repair. Finally the surface was sealed with a protective coating of linseed oil, chosen because of its penetrating quality and lack of sheen.

C-354 Judge, A. I., Cheriton, L. W., and Lambe, R. W. 1986 (Sep). "Bonding Systems for Concrete Repair - An Assessment of Commonly Used Materials," <u>Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium</u>, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Commercially available aqueous polymer dispersions of various types are compared with respect to their bonding properties when used to adhere repair mortars to cementitious substrates. Polymer dispersions tested include a number of acrylates and styrene-acrylates, a styrene butadiene, a vinyl acetate, an acrylate versatate, and a vinyl acetate acrylate versatate. A composite bonding aid, an epoxy bonding system, and the use of cement and polymer/cement slurries are also examined. Three different test methods are used to measure bond, and a simple comparative test has been developed to monitor 'grab'. The merits of these tests are discussed. The best all-round performance including tolerance to site use has been found to be given by an acrylate dispersion.

C-355 Letsch, R. H. 1986 (Sep). "Resin Injection of Cracks with Changing Width," <u>Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium</u>, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Cracks in concrete usually have to be closed to make the structure watertight again or to protect the reinforcement against corrosion. Since as many cracks are not stable in their width, a repair is only successful when the injected material can change its volume according to the volume-change of the crack. The volume of gases can be changed to a great amount by applying small external forces. To achieve volume compressibility of an injecting resin combined with watertightness, plastic microballoons or microspheres (average diameter 0.04 mm) are inserted into the resin. Using a rubberlike epoxy resin, volume deformations of more than 50 percent are possible. If the epoxy resin is stiff (modulus of elasticity about 2,000 N/mm^2), forces can be transmitted still allowing a volume change of 10 to 20 percent. The applied deformations are fully reversible.

C-356 Anqi, L., and Ruiyu, C. 1986 (Sep). "Study of 3200 Vinyl Ester Resin Mortar and Its Applications," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair: Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

This paper describes briefly a new type of high molecular material--vinylester 3200 resin mortar, including the characteristics of its formulation, the varieties of performance, and its applications in the field. Experiments show that the vinylester 3200 resin mortar has excellent resistance to cavitation-erosion, abrasion-erosion, chemical-corrosion and freeze-thaw cycling, with long-term durability to weathering and soaking in water, good deformability, and strong adhesion to the surface of concrete and steel as well as low permeability. It has been proven 3200 resin mortar is a new type of abrasion-erosion-resistant material for hydraulic structures and chemical-corrosion resistant material for construction after practical applications.

C-357 Fowler, D. W. 1986 (Sep). "Use of High Molecular Weight Methacrylate for Repairing Cracks in Concrete," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair: Proceedings of an International Symposium, RILEM Technical Committee 52--Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

High molecular weight methacrylate (HMWM) is a relatively new monomer that has many of the advantages of methyl methacrylate (MMA), namely low viscosity, potential for curing over a wide range of temperatures, and good wetting characteristics. However, the HMWM has low odor and a high flash point which are significant improvements over MMA.

HMWM has been used to produce polymer concrete for overlays and other specialty applications. It has very good mechanical and durability properties, and bonds very well to portland-cement concrete.

One of its most important uses, however, is to seal cracks and restore structural integrity of portland-cement concrete. Due to its excellent wetting characteristics, it penetrates even very fine cracks. It has been used for a wide range of crack repair applications in the United States, particularly for bridges.

C-358 Mikami, N., Arai, T., Shirakawa, K., and Koyama, S. 1986 (Oct). "Epoxy-Coated Bars for Concrete Construction" (in Japanese), Journal of the Iron and Steel Institute of Japan, Vol 72, No. 14, pp 1889-1896, Tokyo, Japan.

Epoxy-coated bars have been developed to prevent the deterioration of concrete structures due to reinforcement corrosion. The properties of corrosion resistance, bendability without serious damage of coating, bond strength to concrete, and resistivity to percussion and abrasion are required for the bars. To examine the bars, exposure tests in marine environments, bend tests, pullout from concrete and trial executions were carried out. (1) Epoxy-coated bars did not corrode in crack-induced concrete specimens which were exposed to marine environments for 3 years. (2) Epoxy-coated bars could be bent 180 deg with the radius of twice the diameter of the bars under the ordinary conditions of execution. (3) The reduction of the bond strength of epoxy-coated bars to concrete required 20 percent increase of lap joint lengths. (4) The bars embedded in concrete beams which were subjected to repeated bending stress up to 38 kgf/mm^2 showed no degradation of coatings. (5) Caring for coating protection did not reduce the work efficiency of bending and construction of the bars in practice.

C-359 Mailvaganam, N. P. 1986 (Oct). "Elastomeric Parking Deck Membranes," Concrete International: Design & Construction, Vol 8, No. 10, pp 51-58, Detroit, MI.

To avoid corrosion of the reinforcing steel in concrete slabs in parking garages, the ingress of water and particularly chloride ions has to be avoided. Waterproofing membranes based on thin elastomeric adhesive coatings have been applied effectively in both bridge and parking decks to reduce the rate of deterioration caused by corrosion. This article reviews available information on elastomeric coatings to assist in selection, installation, and maintenance of waterproofing membranes for parking garages.

C-360 Fairweather, V. 1986 (Oct). "Filling the Cracks," Civil Engineering, Vol 56, No. 10, pp 38-41, American Society of Civil Engineers, New York, NY.

Polymer concrete overlays are major contenders for the enormous highway bridge rehab market. The material, although costly, is very strong and is quickly and easily applied. It also contributes little dead weight to a bridge, since it can be as thin as 3/8 in. Several projects using polymer concrete overlays are described.

C-361 Skupin, L. 1986 (Oct). "Use of Plastics for the Restoration of Ancient and Historic Monuments in Czechoslovakia" (in French), Annales, Institut Technique du Batiment et des Travaux Publics, No. 448, pp 70-81, Paris, France.

The cost of repairs and restoration for historic monuments leads all countries concerned to show proof of imagination and innovation in this field, with a restoration philosophy specific to each country. Developments in the use of plastics were particularly encouraged in Czechoslovakia. Injections of organosilicates combined with epoxy resins have been successfully undertaken especially in the repair of masonry in gothic churches deteriorated by excessive overloading.

Resin concrete has also been applied to copy gothic sculptured elements, replacing the original statues, which are then kept protected in museums. The results of theoretical studies and laboratory tests focus on the durability of sandy limestone and sandstone and contribute extensively to the solution of problems linked with impregnation of stone.

C-362 Yuzuqullu, O. 1986 (Oct). "Durability of Sulfur Impregnated Precast Ferrocement Elements," Journal of Ferrocement, Vol 16, No. 4, pp 429-435, Bangkok, Thailand.

This is a study on the effect of sulfur impregnation on the durability characteristics of ferrocement and companion-plain concrete specimens. Altogether 16 specimens, 150 m^2, 10 or 15 mm thick, were prepared and subjected to permeability and sulfuric acid attack tests. Of the 16 specimens, 8 were impregnated with elemental sulfur. Sulfur-impregnated specimens were observed to be practically impermeable with a noticeable increase in strength together with an improved resistance against acid attack. Immersion of oven-dried units in molten sulfur appears to be most suitable for sulfur impregnation in precast ferrocement elements.

C-363 Munn, W. D. 1986 (Oct). "Polymer Concrete Pavements are Coming," Heavy Construction, Vol 129, No. 10, pp 39-41, Toronto, Ontario, Canada.

Borrowing on its growing acceptance as a resurfacing material for bridge decks, polymer concrete is now beginning to appear on the open highway. A full scale 'demonstration' project completed earlier this year along eastbound I-80 near Donner Pass in California may be paving the way for other such projects. Polymer concretes, which are virtually impervious to water and chloride intrusion, cost $45 to $50 per square yard in place on 10,000-sq ft bridge deck projects in California. The much thicker, 70,000-sq yd pavement resurfacing along I-80 cost about $40 per square yard.

C-364 Kuenning, W. 1986 (Nov). "Chemicals for Removing Stains-Part 5," Concrete Construction, Vol 31, No. 11, pp 960-965, Addison, IL.

This last article in a series has a table with chemical names, other common names, potential hazards, and possible sources for chemicals used in cleaning concrete. Cautions in using the chemicals are listed, and additional safety precautions relating to previous articles in the series are given.

C-365 Fattuhi, N. I., and Hughes, B. P. 1986 (Nov). "Resistance to Acid Attack of Concrete with Different Admixtures or Coatings," International Journal of Cement Composites and Lightweight Concrete, Vol 8, No. 4, pp 223-230, Harlow, Essex, England.

Admixtures and coatings were used in an attempt to improve the chemical resistance of a standard concrete mix. The admixtures included styrene-butadiene latex, silica fume, and naphthalene-formaldehyde-based superplasticizer. Coatings were produced by brushing or soaking 100-mm cubes in styrene butadiene latex or hydroxypropylmethyl cellulose solution. The number of coating layers, method of curing, and soaking period were varied. Two separate test series were carried out, and a total of 56 cubes were immersed in a continuously flowing solution of approximately 2-percent sulfuric acid. The changes in weight with time for each cube were determined. The results indicated styrene butadiene coatings can provide good protection to concrete, but only for a limited period of time before maintenance would be necessary.

C-366 Ahlrich, R. C. 1986 (Nov). "Evaluation of Asphalt Rubber and Engineering Fabrics as Pavement Interlayers," Miscellaneous Paper GL-86-34, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Asphalt-rubber and engineering fabric interlayers have been used to retard reflective cracks in asphalt concrete overlays. These materials have generally performed satisfactorily in warm climates; however, performance in cold climates has been less than desirable. The asphalt-rubber and engineering fabric rehabilitation techniques have been used to retard the reflection of cracks in existing asphalt concrete and portland-cement concrete pavements through asphalt concrete overlays. These rehabilitation techniques also decrease the size of cracks that reflect through, thus retarding the amount of water penetrating into the base course and underlying subgrade. Guidance is provided for using asphalt rubber and engineering fabrics to maximize performance in reducing reflective cracking. This study should result in improved performance of overlays and, subsequently, substantial monetary savings to the taxpayers.

C-367 van Eijnsbergen, J. F. H. 1986. "Galvanizing in the Offshore Industries," Galvanizing Into the Next Century--First International Conference on Galvanizing in South Africa, Pretoria, South Africa, 3-6 Nov 1986, Council for Scientific and Industrial Research, Pretoria, South Africa.

Corrosion protection for an ever increasing number of structures requires sophisticated coating systems because of the extreme conditions in the sea, the splash zone as well as the adjoining atmospheric zone above sea level, and also because of the duration of use of oil and gas platforms now being estimated at 30 years. Galvanizing and especially duplex systems have been used successfully. Some examples from practice are given. When ungalvanizable parts have to be coated, arc-spraying of Al, followed by an epoxy-based paint system, offers maximum corrosion protection. Galvanized rebars have been used in various concrete structures, permanently in contact with seawater, to prevent rust and, thus, flaking of the concrete cover.

C-368 Rossi-Doria, P. R. 1986 (Nov-Dec). "Mortars for Restoration: Basic Requirements and Quality Control," Materials and Structures: Research and Testing, Vol 19, No. 114, pp 445-448, Paris, France.

The major problems concerning mortars, grouts, and plasters, as used in the field of conservation of works of art, are discussed. The fundamental requirements of a mortar for restoration are a low content of soluble salts and mechanical, thermal, and structural characteristics as similar as possible to those of the ancient masonries, which are usually composed of natural stones and bricks. In particular, the need for standard methods of analysis and quality control procedures is stressed, and some future developments in this field are defined.

C-369 Kwasny, R., Roosen, A. and Maultzsch, M. 1986 (Dec). "Comparative Investigations on Repair Mortars (PCC)," Betonwerk und Fertigteil-Technik; Vol 52, No. 12, pp 797-803, Wiesbaden, Germany.

Polymer-modified cement mortars and concretes - also known as PCC, short for polymer cement concrete - are used increasingly for building rehabilitation jobs, as industrial floors, road and airport pavements, and in foundations supporting strongly vibrating machinery units, in recognition of the fact that their bending tensile and bond strength, their abrasion resistance, elasticity, and chemical resistance are, in general, superior to those of normal concrete. Increasing use of repair mortars of this type necessitates establishment of specifications and standard procedures for testing to enable long-term and reliable application of PCC. The results of a partial program published here provide a survey of some of the properties the repair mortars offered by the German building materials trade possess. The characterization of the starting systems, that of fresh mortar and ready-mixed mortars are presented.

C-370 Sasse, H. R. (Ed.). 1986. "Adhesion Between Polymers and Concrete: Bonding, Protection, and Repair," Chapman and Hall, London and New York, NY.

This volume includes proceedings of an international symposium organized by RILEM Technical Committee 52-Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees in Paris. Selected individual papers are also referenced herein.

Architects and civil engineers know little about adhesion, but it is necessary to ensure success and durability. Purpose of the symposium was to exchange information on a scientific, technical, and practical level among international experts and to document the work of RILEM Technical Committee 52-RAC. Cooperation among experts for information on adhesion phenomena and practical applications is the aim of the work.

Areas covered include science of adhesion, surface properties of substrate, properties of bonding materials, coating and painting, repair of concrete surfaces, bonding of fresh to old concrete, crack injection, gluing of precast elements, gluing of steel to concrete, and adhesion test procedures.

C-371 Sheppard, W. L., Jr. (Ed.). 1986. "Corrosion and Chemical Resistant Masonry Materials Handbook," Noyes Publications, Park Ridge, NJ.

This volume is directed to those engineers and architects who are charged with designing buildings and equipment that may require chemical resistant masonry materials. It contains the information necessary to select the most appropriate materials, write the specifications and instructions, and draw the details covering them and necessary for their proper installation.

C-372 Emery, H., and Johnston, T. 1986. "Unshrinkable Fill for Utility Cut Restorations," <u>Concrete in Transportation</u>, SP-93, pp 187-212, American Concrete Institute, Detroit, MI.

Utility cut restoration problems (settlements, voids, cracks, and protracted maintenance) have a significant negative impact on pavement serviceability. A recent metropolitan Toronto study quantified this impact and identified unshrinkable fill (very weak concrete) as the preferred solution. In addition to repair costs, road user costs, and nuisance effects, substandard utility cut restorations increase the metro maintenance surfacing costs by some $3 million annually.

Pavement impairment was a function of the large number of utility cuts (about 4,000 per year) and significant noncompliance with specifications covering granular backfill quality and compaction. While tighter granular specifications enforcement was considered, the characteristics of controlled density backfill were assessed to provide a materials approach to improved restorations. The desired controlled density backfill characteristics were: reasonable cost, flowability, pavement structural support, excavatability, wide availability, standard materials without need for inspection, satisfactory long-term performance, and demonstrated use.

Based on long-term Winnipeg experience and utility comments, unshrinkable fill (25 kg cement per m^3, conventional concrete aggregates, 160- to 200-mm slump, usually air entrained, maximum 28 days strength of 0.4 MPa) was subjected to extensive field trials and cost analyses. It was found that unshrinkable backfill meets the technical requirements and is generally cost effective compared to properly compacted and inspected granular backfill. Unshrinkable fill from qualified suppliers is now required for all metro utility cut restorations.

C-373 Scholer, C. F. 1^86. "Thin Mortar Overlay for Restoring Friction on Concrete Pavements," <u>Concrete in Transportation</u>, SP-93, pp 159-168, American Concrete Institute, Detroit, MI.

Vehicle tire friction with pavements is an essential element of highway safety. On concrete pavements this friction depends on the macrotexture of the pavement surface and the composition and texture of the fine aggregate. Some concrete pavements lose enough of their tire friction capacity to cause concern for safety before the pavement's structural life is expended.

This paper describes a technique to apply a thin mortar overlay for friction (TMOFF) to the surface of an existing pavement. Portland cement, especially selected fine aggregate, and a styrene-butadiene emulsion admixture produced a mortar having excellent properties for friction and for adherence to the underlying pavement. Indiana evaluations have shown both blast furnace slag and expanded shale (structural lightweight) aggregate to provide exceptional friction properties even after traffic has severely worn the macrotexture of the pavement.

Recommendations include cleaning pavements with shotblast equipment, then applying a very thin mortar layer having a nominal thickness of 3/16 in. (4.8 mm). A flowable mortar must be brushed into the concrete surface. An asphalt slurry spreader was adapted successfully to both brush and "squeegee" the final surface.

Light traffic could move on the surface within 8 hr but 24 hr were required for heavy, stopping traffic. Cost of materials varies with the cost of the aggregate but is usually between $1 and $1.75 (US) per yd^2 ($1.22 and $2.13 per m^2). Excellent skid numbers were obtained and remain satisfactory after more than 5 years service.

C-374 Marusin, S. L. 1986. "Laboratory Investigation of Conventional and Polymer-Modified Concretes and Their Use for Repairs," Transportation Research Record 1062, pp 76-81, Transportation Research Board, Washington, DC.

Cubes of 4-in. (10-cm) concrete were cast by using conventional portland-cement concretes with a water-to-cement ratio of 0.35, 0.44, and 0.54 and polymer-modified concretes with latex-modified shotcrete repairs in the field. All cubes were immersed for 21 days in a 15-percent NaCl solution and then stored in a controlled-climate room in accordance with test procedures described in NCHRP Report 244. During 21 days of soaking and 21 days of final air drying, weight gains and losses were determined at 3, 7, 14, and 21 days during each period. Following air drying, powder samples were removed by drilling at several intervals of depth from the center of each face to the center of the cube. Then one-half of each cube was crushed to powder and the acid-soluble chloride ion contents of all samples were measured by a potentiometric titration procedure. At a depth of 1-1/2 to 2 in. (37 to 50 mm), the latex- modified concretes had the least amount of chloride.

Laboratory tests of the influence of high temperature and wind on hand-placed and on form-cast large vertical repairs using the modified concretes showed that, under arid conditions, the hand-placed repairs always cracked. Accelerated-wearing tests on small repairs made with the polymer-modified concretes left the repairs intact. On the basis of these test results, the acrylic, latex-modified, cast, in situ concrete was successfully used to repair columns, spandrels, and balcony slabs of a high-rise housing complex, and modified, shotcrete, acrylic latex was used to repair underground garages. Both types of repairs were in excellent condition after 5 years service.

C-375 "Ameron." 1986. Patents & Copyrights, Annual Report, Monterey Park, CA.

Protective Coatings and Linings Products Ameron markets proprietary protective coatings, product finishes, and surfacing systems under the tradenames Amercoat, Amerlock, Amershield, Amerthane, Dimetcote, Nu-Klad, and Tideguard. These products are used as protective and decorative coatings for steel and concrete structures, industrial equipment, and manufactured goods. In addition to developing, manufacturing, and marketing these products throughout the world, the company also offers annual maintenance services, providing coatings and application management services for major facilities.

For high-performance protective coatings systems and maintenance coatings, the company's principal markets are wastewater treatment, chemical processing, power, petroleum, bridges, pulp, and paper, railroads, mining, metal processing, marine and offshore, government, military, and institutions.

In recent years the company has dedicated its research and development to new, easy-to-use, single-coat epoxy, urethane and elastomeric polyurethane coatings. The newest of these to be commercialized is Amershield, the world's first single-coat, high-solids urethane coating. This innovative product combines decorative attractiveness with a level of corrosion and abrasion resistance hitherto unattainable in urethane coatings. With its high-solids formulation, Amershield more than meets Environmental Protection Agency requirements for solvent emissions, thus giving it a market advantage over numerous competitive products which are not Environmental Protection Agency compliant. And because of its low solvent content, Amershield can be applied in a single coating to a thickness twice that of conventional urethanes for longer service life and reduced application costs.

C-376 Janssen, D. J., and Dempsey, B. J. 1986. "Effect of AC Overlays on D-Cracking in PCC Pavements," Transportation Research Record 1062, pp 70-75, Transportation Research Board, Washington, DC.

Durability cracking (D-cracking) is the progressive deterioration of portland-cement concrete (PCC) and is usually caused by winter freeze-thaw cycling. The PCC coarse aggregate source has been identified as causing well-designed mixes to develop D-cracking. A common rehabilitation procedure for D-cracked PCC pavements is to overlay the PCC with asphalt concrete (AC). This renews the surface, but little is known about the long-term effect of AC overlays on D-cracked pavements.

The primary climatic factors responsible for D-cracking are moisture and temperature. Finite-difference transient flow computer moisture movement modeling as well as field instrumentation and laboratory measurements indicate that AC overlays have a negligible effect on the PCC pavement moisture regime. The effect of AC overlays on the PCC temperature regime was evaluated by finite-difference heat transfer computer modeling. AC overlays decreased the number of freeze-thaw cycles and the rate of cooling in PCC pavements. Laboratory freeze-thaw durability tests duplicating field conditions for Interstate 70 near Vandalia, IL, were conducted on PCC samples with AC overlays 0 to 6 in. thick. All the PCC samples cycled to the equivalent of 5 years of winter exposure showed strength loss as determined by split tensile tests. The samples with 4-in. overlays showed the most strength loss.

It was concluded that AC overlays do not prevent the progression of D-cracking in PCC; instead some overlay thicknesses accelerate it. When AC overlays are designed for D-cracked PCC pavements, the effect of decreasing strength of the deterioration PCC should be considered.

C-377 Holland, T. C., et al. 1986 (May). "Use of Silica-Fume Concrete to Repair Abrasion-Erosion Damage in the Kinzua Dam Stilling Basin," Fly Ash, Silica Fume, Slag, and Natural Pozzolans in Concrete, SP-91, pp. 841-864, American Concrete Institute, Detroit, MI.

The stilling basin of Kinzua Dam on the Allegheny River in western Pennsylvania has experienced severe abrasion-erosion damage since the structure was put into operation in 1967. The basin was repaired in 1973-74 using a steel fiber-reinforced concrete overlay. Deterioration continued to the extent that repairs were again necessary in 1983.

A laboratory program was undertaken to evaluate the abrasion-erosion resistance of several concrete mixtures proposed for the 1983 repairs. This program showed that high-strength concrete made with silica-fume and limestone aggregates available near the project site would provide suitable abrasion-erosion resistance at a reasonable price. The Corps of Engineers, owner of the structure, required potential suppliers of silica fume to conduct full-sized placements to demonstrate that this concrete could be made and placed outside the laboratory.

Based upon these demonstrations and the laboratory program, the repair concrete was specified with a compressive strength of 86 MPa (12,500 psi) at 28 days as a means of obtaining the required abrasion-erosion resistance. Approximately 1,500 m^3 (2,000 yd^3) of 250-mm (9-3/4-in.) slump concrete were placed using silica fume delivered as a slurry that included water-reducing admixtures.

The average 28-day compressive strength was over 90 MPa (13,000 psi). Diver inspection of the concrete after 1 year in service, including a period with a very large volume of debris in the stilling basin, has indicated that the silica-fume concrete is performing as intended.

C-378 Jain, R. K., and Asthana, K. K. 1986 (May). "Development of Low Cost Polymeric Systems for Anti-Corrosive Treatment of Building Materials," Workshop on Corrosion of Building Materials in Fertilizer and Chemical Industry; CBRI Roorkee; 6 May 1986, pp 7-11, Uttar Pradesh, India.

A survey of a few fertilizer plants indicated that there is collosal loss of building materials due to deterioration of concrete and reinforcement because of improper choice of materials and faulty workmanship in the absence of standard codes on the aspects of protective coats. CBRI tried to formulate a protective material prepared as a blend of epoxy resin and phenol formaldehyde.

C-379 "Coating Concrete Floor." 1986. Japanese Patents Gazette, Vol 86, No. 32, Group G, pp 25-26, London, England.

Oil-resistant antistatic coatings for concrete comprise a moisture--curable polyurethane resin (I), a coloured, intermediate, inorganic coating containing aggregate, and a topcoat of I.

C-380 Bagda, E. 1986. "Coatings for Reinforced Concrete" (in German), Farbe Lack, Vol 92, No. 2, pp 97-100, Hannover, West Germany.

Carbonation of concrete requires a relative air moisture content of under 60 percent and an iron content of over 90 percent for corrosion. Coatings for reinforced concrete are considered with respect to carbon dioxide permeability, moisture, adhesion, efflorescence, and bridging of cracks. Hydrophobic treatments are also mentioned.

C-381 Richardson, F. B. 1986. "Water-Borne Epoxy Coatings," Paint & Resin, Vol 56, No. 5, 15, Rickmanworth, England.

Formulation, drying, and applications of water-borne coatings based on epoxy resins are outlined. Coatings for concrete, sealer/primers for tar or asphalt surfaces, and specialist applications in nuclear power stations, hospitals, breweries, etc. are some areas of use. The absence of intercoat adhesion problems make them good maintenance coatings.

C-382 "Coating for Repair of Ferroconcrete." 1986. Japanese Patents Gazette, Vol 86, No. 29, Group G, pp 28-29, London, England.

The composition, which may be used as a topcoat or intermediate coat, is prepared by mixing glass flake into a liquid silicone rubber comprising an organopolysiloxane, a cross-linking agent, filler, pigment and solvent. Hard adhesive coatings with reduced gas permeation and good temperature resistance are obtained.

C-383 "Preventing Corrosion of Rebars in Concrete." 1986. Japanese Patents Gazette, Vol 86, No. 1, Group G, p 26, London, England.

Reinforced concrete is coated and impregnated with an aqueous solution of an anticorrosive inorganic salt, e.g. a nitrile, and with an aqueous solution of lithium silicate, followed by coating with a cement composition containing a styrene/butadiene polymer dispersion.

C-384 Zamaitis, Z., Sniuksta, A., and Kudzys, A. 1986. "Anticorrosive Coatings for Reinforced Concrete Structures" (in French), Proceedings International Symposium 'Adhesion between Polymers & Concrete' Aix-en-Provence, pp 177-182, France.

Results are presented of studies on coatings based on a commercial system comprising coumarone/indene, polyester acrylate, and styrene. Properties of the resin system, formulation in coatings, mastics and resin-bound plasters, durability of the coatings obtained, and uses (e.g. on industrial floors and roofs, building facades, agricultural installations, etc.) are discussed.

C-385 Sokalska, A. 1986. "Usefulness of a New Bituminous Epoxy Paint for Protection of Concrete" (in Polish), Materialy Budowlane, No. 11/12, p 18, Warsaw, Poland.

The advantages of bituminous epoxy paint for concrete are discussed, i.e. ease of production, long period of utilization, simplicity of application, and good covering power on wet and dry concrete surfaces.

C-386 "Waterproofing in the Wet." 1986. ICI News for Industry, Vol 1, No. 4, 5, ICI Speciality Chemicals, New Delhi, India.

A series of cement-based coatings for concrete and masonry, which may be applied even in wet conditions, are briefly described. They include a waterproof coating, a flexible high-build acrylic emulsion, and a nonshrink, nonslumping coating for repairing beams, etc.

C-387 "Cathodic Protection Coating Composition." 1986. Official Gazette, Vol 1073, No. 5, Washington, DC.

Cathodic protection systems for reinforced concrete structures comprise a moisture-permeable electrically conductive coating layer having a predetermined resistivity and a source of DC energy connected between the reinforcing steel and the coating layer.

C-388 Clifton, J. R., and Godette, M. 1986. "Performance Tests for Graffiti Removers," Cleaning Stone and Masonry, ASTM STP 935, pp 14-24, American Society for Testing and Materials, Philadelphia, PA.

The defacing of the surfaces of masonry buildings with graffiti has increased substantially during the past decade, with removal cost exceeding several hundred million dollars annually. An assortment of materials have been used to remove graffiti with varying success. This report discusses performance tests developed to form a technical basis for selecting effective graffiti removers. Important considerations in developing the tests and criteria for graffiti removers were effectiveness in removing marks and effects on the appearance of masonry substrates.

In developing performance criteria, "standard graffiti" were produced by applying aerosol paints, crayons, lipstick, and felt-tip pens and markers to the surfaces of brick, sandstone, limestone, and aluminum specimens. The effectiveness of removers and their compatibility with masonry substrates was determined by comparing the color changes of unmarked, marked, and remover-treated masonry surfaces. Test methods were also developed to determine the ability of removers to migrate into masonry.

1987

C-389 Choudhary, M. M., et al. 1987 (Jan). "Epoxy Grouting Technique," Indian Concrete Journal, Vol 61, No. 1, pp 9-17, 22, Bombay, India.

Epoxy resins are often required for grouting cracks in concrete, open joints in masonry, and construction gaps in structures for strengthening. These synthetic adhesive materials require a special technique for grouting. Thorough knowledge of site conditions and proper experimentation are essential when selecting an epoxy system suitable for a specific job. The detailed procedure of epoxy grouting, special equipment used, methods for determining efficacy of grouting, and typical applications are described.

C-390 Popovics, S., Ragendran, N., and Penko, M. 1987 (Jan-Feb). "Rapid Hardening Cements for Repair of Concrete," ACI Material Journal, Vol 84, No. 1, pp 64-73, Detroit, MI.

This paper presents the results of an investigation on very rapidly hardening cements. Rapid hardening cements are those that can develop several thousand pounds per square inch compressive strength within a few hours. Since these cements were developed just recently, very little laboratory and even less practical experience have been obtained with them. Therefore, this paper presents the results of a laboratory investigation on four such cements. These cements are: 1. magnesium phosphate cement for cold and regular weather use (MPC); 2. magnesium phosphate cement for hot weather use (MPH); 3. aluminum phosphate cement (MAP); and 4. regulated set cement (RS). The presented investigation concentrates on the strength development at early ages.

C-391 Ozyildirim, C. 1987 (Jan-Feb). "Laboratory Investigation of Concrete Containing Silica Fume for Use in Overlays," ACI Materials Journal, Vol 84, No. 1, Detroit, MI.

Hydraulic cement concretes containing silica fume were batched and tested in the laboratory to assess their suitability for use in overlays having a minimum thickness of 1-1/4 in. (32 mm). Tests were made for strength, permeability, and freeze-thaw resistance, and the characteristics of air voids in the hardened concrete were determined by petrographic examination. Concretes made with silica fume from two sources at a cement replacement rate of 5 percent by weight and with a water-cement ratio of 0.40 or lower yielded the properties desired for thin overlays. It is thus expected that concretes made with silica fume can provide a cost-effective protective system for bridge decks when placed in overlays having a minimum thickness of 1-1/4 in. (32 mm).

C-392 Maslehuddin, M., Saricimen, H., and Al-Mana, A. I. 1987 (Jan-Feb). "Effect of Fly Ash Addition on the Corrosion Resisting Characteristics of Concrete," ACI Materials Journal, Vol 84, No. 1, Detroit, MI.

Reports results of experiments evaluating the corrosion resistance of plain and fly-ash concrete mixes. Variables were fly-ash additions of 0 to 20 percent as cement replacement and four cement contents. Data were developed both for constant water-cement ratio and constant-workability concrete mixes. The corrosion resistance of concrete samples in which fly ash replaced an equal quantity of sand was also investigated. Samples were immersed in a 5-percent sodium chloride solution for more than 1,000 days, and corrosion resistance was evaluated by monitoring the half-cell potentials and measuring the corrosion rate of embedded steel using electrochemical techniques.

Results show that additions of fly ash are effective in inhibiting corrosion of reinforcing bars. The corrosion resistance of concrete samples in which fly ash was used as an admixture seems to be better than those in which it was used to replace cement. The superior performance of fly-ash concrete samples in inhibiting corrosion of reinforcing steel is attributable to the densification of the cement-paste matrix due to pozzolanic action in the fly-ash concrete mixes.

C-393 Noble, R. A. D. 1987 (Feb). "Digging Up the Past to Stop Problems in the Future," Concrete, Vol 21, No. 2, pp 11-12, London, England.

This article discusses the use of bentonite to waterproof basements and other concrete structures below ground level. Natural sodium bentonite is expansive and swells up to 15 times its dry volume, forming gel that adheres tenaciously even to wet surfaces. Because the gel clings naturally to concrete, it is an ideal material for providing concrete with its own waterproof skin.

C-394 Gustafson, D. P. 1987 (Feb). "Inspection and Acceptance of Epoxy-Coated Reinforcing Bars," Concrete Construction, Vol 23, No. 2, pp 197-201, Addison, IL.

Use of epoxy-coated reinforcing bars has become widespread in recent years. A properly applied epoxy coating will provide protection for reinforcing bars in bridge decks, pavements, parking garages, and other structures exposed to chlorides. If the coating is damaged, however, protection will be less effective. The article explains how to inspect for damage, how to prevent damage at the jobsite, and how to repair the damaged coating.

C-395 Holland, T. C., and Gutschow, R. A. 1987 (Mar). "Erosion Resistance with Silica-Fume Concrete," Concrete International: Design & Construction, Vol 9, No. 3, pp 32-40, Detroit, MI.

The stilling basin of the Kinzua Dam on the Allegheny River in western Pennsylvania and the low flow channel of the Los Angeles River in southern California are two concrete structures that have experienced severe abrasion-erosion damage. Laboratory studies were performed to evaluate several concrete mixtures that were being considered for repairs on these structures.

These investigations showed that high-strength concrete, made with silica fume and local aggregates, would provide the greatest abrasion-erosion resistance for the structures at a cost-effective price. Based on these results, silica-fume concrete was used for the repairs on both structures. Inspection of the Kinzua Dam stilling basin has indicated that the concrete is performing as intended. Because of the nature of the abrasion-erosion-causing mechanism, performance evaluation of the concrete placed in the Los Angeles River low flow channel will require a longer time.

C-396 Vacha, A. 1987 (Mar). "Geomembranes Defeat Moisture in Pavements," Roads & Bridges, Vol 25, No. 3, pp 48-49, Des Plaines, IL.

Transportation agencies have studied extensively the possibility of prolonging pavement life with the use of geomembranes. Geomembranes are impermeable membrane liners and barriers used for geotechnical projects, usually made from synthetic polymers, extruded to form a film. Geomembranes minimize moisture content in underpavement soil and are being used in Texas, Pennsylvania, and other states. Substantial research on physical properties, procedures, and specifications has been done by manufacturers and independent industry experts. Article presents discussion of some experimental sites.

C-397 "Elastomeric Sealants Fill Gap in Southwest." 1987 (Mar). Roads & Bridges, Vol 25, No. 3, pp 74-75, Des Plaines, IL.

New advances in sealants and their application equipment have led to renewed emphasis on crack sealing by street maintenance officials, a practice once dismissed as unnecessary or ineffective. As a result, street and highway surfaces once in need of reconstruction are gaining new life. The key to the change is the availability of elastomeric sealants that claim to provide solid bonding to pavement surfaces while expanding and contracting with climatic conditions. By eliminating the need for frequent retreatment, the process allows street crews to keep up with repairs to the point where major problems can be nearly eliminated.

C-398 Bradbury, H. W. 1987 (Mar). "Grouts and Grouting," Civil Engineering, pp 39-40, 42, London, England.

An introduction to grouts, injection of appropriate materials into soils, rocks, or man-made structures to impart strength and stability, to reduce permeability, and to fill voids, is presented. Advantages to using grouts are outlined. The different types and classes of grouts are explained as are the divisions of the cementitious grouts. The article emphasizes the importance of accurately selecting the best grout for each application.

C-399 Yogendran, V., Langan, B. W., Haque, M. N., and Ward, M. A. 1987 (Mar-Apr). "Silica Fume in High-Strength Concrete," ACI Materials Journal, Vol 84, No. 2, Detroit, MI.

The efficiency of silica fume in influencing the strength of high-strength concrete was studied at different water-cementitious ratios and dosages of silica fume. The results suggest that the optimum replacement of cement by silica fume in high-strength concrete, 50 to 70 MPa (7,500 to 10,500 psi) at 28 days, is 15 percent. Furthermore, the effect of silica fume decreases with increasing cement content and decreasing water-cementitious ratios. At a cement content of 500 kg/m^3 (840 lb/yd^3) and a water-cementitious ratio of 0.28, it was not possible to increase the strength of concrete using silica fume to replace cement. In addition, normal levels of air entrainment were required even in the highest strength mix to ensure adequate performance in rapid freeze-thaw testing.

C-400 "Silica Fume in Concrete." 1987 (Mar-Apr). ACI Committee 226, ACI Materials Journal, Vol 84, No. 2, Detroit, MI.

Silica fume is a by-product resulting from the reduction of high-purity quartz with coal in electric arc furnaces in the manufacture of silicon and ferrosilicon alloys. This report briefly describes the physical, chemical, and pozzolanic properties of silica fume. Methods of using silica fume in concrete are mentioned, and the properties of fresh and hardened concrete incorporating it are described. The durability of silica-fume concrete is discussed, and the limitations of its use in concrete are outlined. The report is concluded by listing research needs.

C-401 Marschall, J., and Milstein, F. 1987 (Mar-Apr). "Thermal Degradation of Polymer Concrete," Construction and Building Materials, Vol 1, No. 1, pp 14-18, Surrey, England.

Polymer concrete (in which polymers, rather than cements, are used as binders of aggregate materials) are being used in an increasingly wide variety of applications. A relatively simple experimental procedure for evaluating the thermal degradation of polymer concrete is described, and the results of testing two distinct polymer concretes (one based on methyl methacrylate and the other on a polyester) are presented. Thermal degradation was determined by measuring the weight loss experienced by samples exposed to various temperatures for different times. In addition, each sample was given a subjective structural integrity rating on a scale of A to D (where A and D, respectively, indicate no observed loss of structural integrity and complete loss of cohesion).

C-402 "Sharp Chemical Develops Polysulfide-Based Paint with High Solid Content." 1987 (Apr), Comline Chemicals and Materials, Tokyo, Japan.

Sharp Chemical Industry Co., Ltd., a sealing material manufacturer, has developed and begun sample shipment of "Thiocoat," apparently the first polysulfide-based paint to be developed to date. The product is a single-component paint with a high solid content of 80 percent. Containing no plasticizers, it has excellent weatherability, excellent chemical resistance, and a predicted durability of 10-15 years.

The company plans to develop the paint for use in corrosion resistant coatings for concrete structures, utilizing the flexibility of the substance to effectively seal cracks occurring in concrete. The paint is easy to work with as it has a low solvent content of 20 percent and is a single-component type. The price is 1,000 yen per kilogram.

C-403 Higgins, R. J. 1987 (Apr). "Fusion Bonded Epoxy Powder Coating Chosen for Rebar Protection in Prestigious New Development in Dubai," Anti-Corrosion Methods and Materials, Vol 34, No. pp 14-15, London, England.

Fusion bonded epoxy (FBE) powder coated rebar has at last come of age in the Gulf region. The prestigious new Diwan complex has specified FBE coated rebar. FBE powder coating offers the design engineer the concept of 'total protection' of the rebar against corrosive elements which may penetrate concrete exposed to hostile conditions. The trend, in reinforced concrete design and construction practices, toward greater recognition of the potential problems of rebar corrosion, and a commitment to preventative measures, all undoubtedly give a permanent place to FBE coating technology in the field of design for maintenance-free concrete structures for the future, even in the most hostile of environments.

C-404 "Andek Chemical Introduces New Urethane Adhesive for Industrial and Construction Applications." 1987 (May), Andek Chemical Corp.

Andek Chemical Corporation, a division of 3 E Group, has introduced Andek 950, a high solids, moisture curing, urethane adhesive for industrial and construction applications. Laminating applications require that Andek 950 is applied to one surface only and placed under pressure for only 45 minutes before stacking. During the curing stage, Andek 950 swells to ensure total contact between the two surfaces regardless of irregularities and unevenness of the substrate. As a structural adhesive for repair of concrete infrastructure, Andek 950 is highly penetrative and will seek minute cracks within a concrete structure including bridges, piers, foundations, etc. Half-inch holes are drilled into the concrete and the adhesive is pumped into the holes at 100 psi. After the adhesive has thoroughly penetrated, it will begin to swell and fill any remaining voids before curing to a hard, structural cement that will restore strength to the weakened construction and prevent water reentry.

C-405 Macgregor, B. R. 1987 (May). "Galvanized Solution to Rebar Corrosion," Civil Engineer, pp 18-19, 21, London, England.

Rust-stained surfaces and cracking and spalling of concrete in recently completed structures demonstrate the need to protect steel reinforcement from corrosion. Serious deterioration, and even failure, as a result of corrosion due to aggressive environments and deficiencies in design or construction can, however, be avoided by proper use of materials. A galvanized coating would last 10 to 150 times as long as uncoated steel in the atmosphere. Immersed in concrete, there is an additional benefit that up to a pH of about 12.5 there is no significant corrosion of zinc. On the acid side, zinc is not so resistant and significant corrosion of zinc can start below about pH5.

C-406 Sakuta, M. 1987 (May). "Use of Acryl-Type Polymer as Admixture for Underwater Concrete," Takenaka Technical Research Report 37, pp 135-144, Takenaka Technical Research Lab, Japan.

The quality deterioration of underwater concretes may be caused mainly by the washout of the cement from the concrete. The addition of an acryltype polymer to concrete was found to be effective to prevent such deterioration. With the increase of the polymer content, the resistance of the concrete to be separated in water improved. This polymer did not affect the hydration of the cement. A dialdehydetype auxiliary agent was effective to improve the function of the polymer at a dosage of only 1 percent of the polymer when it was added to the concrete after the addition of the polymer. By the field test in which concretes containing the polymer were applied to a underwater concrete structure, the performance of the polymer was confirmed.

C-407 Sadegzadeh, M., and Kettle, R. J. 1987 (May). "Abrasion Resistance of Polymer Impregnated Concrete," Concrete, Vol 21, No. 5, pp 32-34, London, England.

This article investigates the use of different polymer solutions to improve the abrasion resistance of concrete floor slabs. Following an extensive mail survey, it was decided to concentrate on two main types of liquid surface treatments, these being surface hardeners and in-surface seals.

C-408 Pigeon, M., Aitcin, P. C., and Laplante, P. 1987 (May-Jun). "Comparative Study of the Air-Void Stability in a Normal and a Condensed Silica Fume Field Concrete," ACI Materials Journal, Vol 84, No. 3, Detroit, MI.

Very little reliable data exist concerning the durability of field-condensed silica-fume (CSF) concrete exposed in service to freezing and thawing in the presence of deicing salts. The data available indicate that CSF concrete without the right bubble-spacing factor performs very poorly, but with the correct spacing factor, it performs satisfactorily in similar climatic conditions.

This paper reports the findings of a research program studying freeze--thaw durability and the stability of the air-void system in a specific CSF mix from batching through placement. Additional test data show shrinkage and compressive strengths.

With proper mixing and placing techniques, the air-void system of CSF concrete was as stable as that of normal concrete. The proper spacing factor was obtained without any problem, and freeze-thaw tests confirmed the durability of the CSF concrete.

C-409 Webster, T. 1987 (Jun). "Polypropylene Fibers May Protect Bridge Decks," Roads and Bridges, Vol 25, No. 6, pp 71-72, Des Plaines, IL.

Research has uncovered that adding polypropylene fibers significantly increases concrete's resistance to early-age plastic shrinking and cracking due to vibrations of the bride deck. These fibers have also increased strain capacity at early ages and tensile strength at later ages. The article also addresses passivation and deicing salts in terms of cracking.

C-410 "Patching at Low Temperatures." 1987 (Jun). Better Roads, Vol 57, No. 6, pp 44-46, Park Ridge, IL.

An experimental investigation has identified four high early-strength materials as suitable for cold-weather patching of concrete pavement and bridge structures. The materials are methyl metacrylate-based polymer concrete, magnesium phosphate-based materials, either water or nonwater activated, and polyurethane polymer concrete. All patch materials were cast and cured at temperatures of 15 and 20° F. The MMA and magnesium phosphate-based materials are superior to the polyurethane in most performance criteria, but an apparent high variability in performance of MMA under fatigue loading requires further investigation.

C-411 Higgins, R. J. 1987 (Jun). "Wide Spectrum Finishes for the Building Industry," Finishing, Vol 11, No. 6, pp 42, 45-46, Rickmanworth, England.

Powder coatings, applied in the factory under quality-controlled conditions, are used to protect and decorate components of virtually every part of a building - from its structural core to its decorative skin. Applications draw on virtually every powder coating chemistry available from the world's powder suppliers. Fushion bonded epoxy (FBE) powder coatings protect steel rebar in reinforced concrete structures. Architectural grade TGIC/polyester and polyurethane powders decorate and protect aluminum and galvanised steel profiles and sheet products for windows, doors, curtain wall systems, cladding, and siding.

C-412 Shimada, H., Kimura, T., Kuga, T., and Kokado, T. 1987 (Jul). "Resistance and Prevention Mechanism of New Type Low Alloy Steel Rebars Against Corrosion Due to Chloride Ion Attack" (in Japanese), Zairyo/Journal of the Society of Materials Science, Vol 36, No. 406, pp 737-743, Kyoto, Japan.

The deterioration of the concrete structure exposed to chloride ion attack is caused by the expansion force of the rust layer growth in the embedded rebars. To prevent such concrete damage, various practical methods have been proposed. We have tried to improve the corrosion resistance of the steel rebar itself and discovered that copper and tungsten or 3-percent nickel should be added to highly purified rebar. To make clear the effect of this steel rebar, electrochemical tests and concrete deterioration accelerated tests using concrete blocks with various rebars were carried out. From the deterioration accelerated tests of concrete blocks, the resistances against rust formation and crack growth of the rebar were excellent. High purified steel rebars containing copper and tungsten or 5-percent nickel are suitable for the concrete structure at seaside.

C-413 Ohama, Y. 1987 (Jul). "Recent Development and Trend of Concrete-Polymer Composites" (in Japanese), Zairyo/Journal of the Society of Materials Science, Vol 36, No. 406, pp 690-696, Kyoto, Japan.

Sufficiently high waterproof, moderate moisture permeability and extensibility are the necessary properties for a coating material to have to prevent the damage of concrete due to the alkali-silica reaction (ASR). A new inorganic coating material having all of these properties has been developed. In the present study, its physical properties were measured first, and then the durability under accelerated ultraviolet light exposure was examined. Lastly, practical performance tests were carried out by using the specimens made of concrete with alkali reactive aggregate and the actually damaged concrete structure due to ASR. As the result, it was confirmed that ASR was prevented for 2 years by coating the new material.

C-414 Mangat, P. S., and Gurusamy, K. 1987 (Jul). "Long-Term Properties of Steel Fibre Reinforced Marine Concrete," Materials and Structures, Research and Testing, Vol 20, No. 118, pp 273-282, Paris, France.

This article presents results from a continuing research program to develop steel fiber reinforced concrete for marine applications and to investigate its durability. A mix of proportions by weight of 1:1.5:0.86 was adopted that was reinforced with three types of steel fibers: low-carbon, corrosion resistant, and melt extract. Prism specimens were cured under marine exposure, both in the laboratory and at Aberdeen beach, for up to 2,000 wet-dry cycles (1,250 days) and were tested at regular intervals of age. Results are given of tests of long-term compressive strength, flexural strength, and ductility as measured from flexural load-deflection curves. The state of fibers with respect to corrosion is also discussed. Results indicate that melt extract fibers, although least effective from the mechanical strength point of view, are the most suitable for marine applications.

C-415 El-Jazairi, B. 1987 (Jul). "The Properties of Magnesia Phosphate Cement Based Materials for Rapid Repair of Concrete," Proceedings of 3rd International Conference on: 'Structural Faults and Repair' London, England.

There is an increased interest in materials for rapid repair of concrete pavements and for other applications where adequate strength at a very early age is required for trafficking or other use.

Magnesia-phosphate cement (MPC) based materials provide the essential requirements for rapid repair of concrete. On mixing with water they provide a workable mix which sets within 15 min at normal temperature and hardens to sufficient strength, over 20 MPa, within 1 hr. Almost the same performance can be obtained at subzero temperatures and in hot weather conditions by using special but simple techniques or by the addition of special admixtures.

In this paper, a brief history of the use of magnesia-phosphate cement (MPC) will be given, its chemical nature and its properties will be outlined and its mode of employment in the repair of concrete pavements will be discussed.

Review of past field experience, 13 years in the USA and 6 years in the UK, will demonstrate that MPC based materials provide, in the long term, durable repair for concrete pavements.

C-416 "Coatings: Underwater Repair Epoxy." 1987 (Aug). Paint and Resin, Rickmanworth, England.

Quentsplass has introduced two new knifing filler underwater-grade epoxy compositions that can be applied to wet surfaces or underwater. The products offer good adhesion to rusted steel, concrete, timber and other structures, resist fresh and waste water, oils, effluents and sewage, and withstand mechanical stress.

C-417 Wallace, M. 1987 (Sep). "For Reinforcing Shotcrete Canadians Prefer Steel Fibers," Concrete Construction, Vol 23, No. 9 pp 775-776, Addison, IL.

Canadian researchers are finding that steel-fiber-reinforced shotcrete (SFRS) performs better than plain shotcrete or mesh-reinforced shotcrete. Canadian applicators choose it because it is easier to place than mesh-reinforced shotcrete. It was first used in western Canada in 1979 to stabilize a railway embankment in Burnaby, British Columbia. Since then, it also has been used to line tunnels and to rehabilitate concrete dams and other deteriorated structures.

C-418 Romualdi, J. P. 1987 (Sep). "Ferrocement for Infrastructure Rehabilitation," Concrete International: Design & Construction, Vol 9, No. 9, pp 24-28, Detroit, MI.

Ferrocement has inherent properties of toughness and crack resistance that make it superior to conventional concrete in some applications, yet its use in the United States has been limited primarily due to a preoccupation with its potential use as a load-resisting structural member. Ferrocement's true value comes forth when it is used as a thin wall liner for rehabilitation. When combined with labor-saving application techniques, it is a cost-competitive solution for many of the nation's critical infrastructure rehabilitation needs.

C-419 Iorns, M. E. 1987 (Sep). "Laminated Ferrocement for Better Repairs," Concrete International: Design & Construction, Vol 9, No. 9, pp 34-38, Detroit, MI.

For conventional ferrocement construction, several layers of mesh are tied to a framework of reinforcing bars and then mortar is impregnated into the steel matrix. Laminated ferrocement production has each layer of mesh separately embedded into preplaced mortar. This laminating process eliminates voids, allows more reinforcing to be incorporated without mortar penetration problems, allows mortar composition and density to be varied, and greatly reduces labor costs. This technique has been used successfully for a wide variety of structural repairs and has proven to be impact and corrosion resistant.

C-420 Azab, M. A., Helwing, R. D., and Malasheskie, G. J. 1987 (Sep). "Heavy Duty Membranes for the Reduction of Reflective Cracking in Bituminous Concrete Overlays: A Follow-Up Report, Report REPT-79-6, FHWA/PA-87/011+79-6, Aug 85 - Sep 87, Pennsylvania Department of Transportation, Harrisburg, PA.

Seven types of heavy-duty membranes were tested to determine their effect on reducing reflective cracks in bituminous overlays of rigid pavement. The final report for the project which was completed in August 1985 indicated significantly better performance of the treated transverse cracks and joints and recommended the approval of four membranes for this specific use. The follow-up report reexamined the ability of these membranes in reducing reflective cracks 6 years after their original application. It is concluded that there is no need for using heavy-duty membranes to treat longitudinal joints and cracks. Based on the analysis of crack data from the survey, it is apparent that the same degree of reflective cracking occurred in the membrane-treated sections as over the untreated joints and cracks if the cracking observed on all the membrane sections is combined together. However, based on individual product section cracking, two types are recommended to remain on the approved list for treatment of transverse cracks and joints.

C-421 Robles-Austriaco, L. 1987 (Sep). "International Ferrocement Information Center," Concrete International: Design & Construction, Vol 9, No. 9, pp 39-41, Detroit, MI.

The International Ferrocement Information Center (IFIC) does much more than just collect, repackage, and disseminate information on ferrocement and related materials. It promotes widespread use of the technology, especially in the developing countries. These objectives are achieved through publications, bibliographic search services, computer software development, inquiry services, formal education, networking activities, and organization of training courses, seminars, study-tours, conferences, and symposia. IFIC has achieved significant goals, and its effectiv~ness can be measured through the growth of ferrocement applications in housing, agriculture, marine transportation, water supply, and sanitation.

C-422 Mangat, P. S., and Gurusamy, K. 1987 (Sep). "Permissible Crack Widths in Steel Fibre Reinforced Marine Concrete," Materials and Structures, Research and Testing, Vol 20, No. 119, pp 338-347, Paris, France.

This article presents some results from a continuing study of the marine durability of steel fiber reinforced concrete. The overall aim of the investigation is to develop the material for marine applications. The results reported here pertain to precracked specimens of steel fiber reinforced concrete that were exposed to wet-dry cycles of marine spray in the laboratory simulating tidal zone conditions of exposure. Two types of concrete mixes were used, one with standard concrete constituents and ordinary portland cement and the second replacing about 26 percent of cement with pfa. The cement content of the mixes was 590 and 435 kg/m^3, respectively. Fiber reinforcement was provided by low carbon steel fibers and melt extract steel fibers. Prism specimens were manufactured and precracked to induce cracks of widths ranging between 0.03 and 1.73 mm. After cracking, both sealed and unsealed specimens were exposed to laboratory marine spray cycles using seawater. Some control specimens were cured in the laboratory air throughout. Based on data on flexural strength, energy absorption capacity, stiffness, and corrosion state of the fibers, recommendations are made regarding suitable permissible crack widths for the design of steel fiber reinforced concrete for marine applications. The results indicate that a permissible crack width of 0.2 mm is satisfactory for concrete reinforced with melt extract fibers. A smaller value is recommended for concrete reinforced with low carbon steel fibers. Complete healing of open cracks of small widths is observed under exposure to marine cycles.

C-423 Bennison, P., and Lloyd, C. G. 1987 (Sep). "Materials for Concrete Repair - 'Innovations'," Construction & Building Materials, Vol 1, No. 3, Reigate, Surrey, England.

The realisation that modern concrete structures are not as durable as was anticipated has caused increasing concern among structural design engineers, site contractors, and materials' scientists alike.

It is accepted that only when the fundamentals of reinforced concrete design and the implications of structural analysis are understood can satisfactory repairs be undertaken to structures suffering from any form of distress. To effect successful repairs, the same degree of professional expertise as the original design required is necessary.

C-424 Dahlquist, M. S. 1987 (Oct). "Use of Fiber-Reinforced Acrylic Polymer Modified Concrete as Repair Material at Lock 2," The REMR Bulletin, Vol 4, No. 2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

During the winter of 1986-87, the US Army Engineer District, St. Paul, used fiber-reinforced acrylic polymer modified concrete (FRAPMC) to repair Lock 2 located on the upper Mississippi River near Hasting, MN. Twenty-eight vertical monolith joints in the lock chamber and selected sections of the lock wall were repaired with this material. This project is the first known application of FRAPMC on such an extensive basis.

FRAPMC was chosen over conventional concrete because of its reported high performance compared to the above criteria and its low shrinkage potential relative to portland-cement concrete. Also, the addition of polypropylene fibers reduced the possibility of shrinkage cracks and crack propagation.

Even though the concrete work at Lock 2 was successfully completed, it will be several years before the long-term performance can be determined. It is highly recommended that trial programs be conducted before FRAPMC is used because local conditions and material availability can affect the performance of the repairs.

C-425 Ohama, Y. 1987 (Nov-Dec). "Principle of Latex Modification and Some Typical Properties of Latex-Modified Mortars and Concretes," ACI Materials Journal, Vol 84, No. 6, Detroit, MI.

Latex-modified mortars and concretes employing various polymer latexes have been developed actively for more than 60 years and widely used as construction materials because of their good performance-cost ratio. This paper reviews the principle of latex modification in the process technology of latex-modified mortars and concretes and discusses their typical properties. Such properties are mainly characterized by a polymer-cement comatrix they form. The formation process of the comatrix is explained by a three-step, simplified model. The possibility of some reactions between polymers, cement, and aggregates is also discussed.

The author proposes a binder-void ratio law for the strength prediction of the latex-modified mortars and concretes, which expands Talbot's void theory. The reviewed typical properties of hardened latex-modified mortars and concretes include strength, adhesion, pore structure, impermeability, and durability (freeze-thaw resistance, chloride penetration resistance, carbonation resistance, and weatherability).

In general, these properties are strongly affected by the polymer-cement ratio.

C-426 Kuhlmann, L. A. 1987 (Dec). "Application of Styrene-Butadiene Latex Modified Concrete," Concrete International: Design & Construction, V. 9, No. 12, pp 48-53, Detroit, MI.

Characteristics of concrete modified with styrene-butadiene latex are discussed, and application techniques are described. Several case histories are presented.

C-427 Mendis, P. 1987 (Dec). "Polymer Concrete Overlay," Concrete International: Design & Construction, Vol 9, No. 12, pp 54-56, Detroit, MI.

The deck of New York City's historic Brooklyn Bridge was resurfaced with epoxy polymer concrete to protect the deck from further deterioration, to provide skid resistance, and to lower the noise level.

C-428 Murray, M. A. 1987 (Dec). "Applications of Epoxy-Modified Concrete Toppings," Concrete International: Design & Construction, Vol 9, No. 12, pp 36-38, Detroit, MI.

Two projects in which thin epoxy-modified portland-cement concrete toppings were applied to concrete decks, a water storage tank and a lightweight concrete parking garage deck, are described. The advantages and disadvantages of the procedures followed in each case are discussed.

C-429 Ramamurthy, K. N. 1987 (Dec). "Fibre Reinforced Concrete for Rehabilitation Works," Proceedings International Symposium on Fibre Reinforced Concrete, 16-19 Dec 1987, Madras; Vol II, pp 6.63-6.67.

Fibre reinforced concrete has large potential as an effective repair material to replace deteriorated concrete from concrete slabs, pavements, bridges, culverts, etc. Investigations show that materials reinforced with fibre are durable.

Repair of masonry walls was undertaken using sulfur reinforced with fibre and treated with a plasticiser by surface bonding technique. The rehabilitated walls were as strong as standard masonry. Portland-cement paste blended with glass fibre can also be used.

C-430 Fidjestol, P. 1987. "Reinforcement Corrosion and the Use of CSF-Based Additives," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1445-1458, American Concrete Institute, Detroit, MI.

Effect of silica addition on the corrosion of reinforcement in concrete is considered. Silica (SiO_2) is added in various forms of refinement; however, when properly executed, the effects of the various means of addition should be similar. It is concluded that the use of silica at the worst will not influence the time for initiation of corrosion attack. In a number of cases though, silica will delay significantly or prevent corrosion attack.

The use of CSF (condensed silica fume) in concrete slows down the rate of corrosion once corrosion is initiated. The only exception to this rule is corrosion in submerged concrete where corrosion rates are extremely small and CSF will make little difference.

This paper discusses the corrosion rates in concrete above water and concludes with a test program that will be performed the results of which will complement the paper.

C-431 Balaguru, P. N., Ukadike, M. M., and Nawy, E. G. 1987. "Freeze-Thaw Resistance of Polymer Modified Concrete," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 863-876, American Concrete Institute, Detroit, MI.

Paper presents the results of an experimental investigation on the freeze-thaw durability of polymer modified concrete (PMC). Basically, prism specimens were subjected to a maximum of 900 cycles of freezing and thawing, using ASTM C 666 Procedure A. Five sets of specimens with various amounts of polymer content were tested. The polymer consisted of a liquid epoxy resin and a curing agent (or hardener). Weight and fundamental transverse frequency were measured at various intervals of freeze-thaw cyclic loading. The results indicate that the freeze-thaw durability of PMC is better than that of nonair-entrained plain concrete. The PMC with polymer-cement ratio of 0.4 or higher can withstand 900 cycles of freezing and thawing.

C-432 Fontana, J. J. 1987. "Electrically Conducive Polymer Concrete Coatings," Polymer Modified Concrete, SP-99, pp 31-50, American Concrete Institute, Detroit, MI.

The corrosion of reinforcing steel embedded in concrete causes cracks and delamination in the concrete. The application of impressed current cathodic protection utilizing electrically conductive polymer concrete to distribute the current across concrete bridge deck surfaces is gradually becoming a standard practice in the highway industry. To protect the bridge substructures, a sprayable electrically conductive polymer concrete coating is being developed. This thin coating has a very low resistivity and can distribute the cathodic protection current across the concrete surfaces that are to be protected.

C-433 Mays, G. C., and Wilkinson, W. B. 1987. "Polymer Repairs to Concrete: Their Influence on Structural Performance," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 351-376, American Concrete Institute, Detroit, MI.

Damage to reinforced concrete structures in the form of spalled concrete may occur either as a result of reinforcement corrosion, impact damage, or from the effects of fire. A widely accepted method of patch repair is by making use of either resin mortars or polymer modified cementitious systems. At the present time the durability of such methods, particularly to chloride attack, is the subject of several independent studies. However, these materials may have very different thermal and time-dependent properties to the steel or concrete to which they are bonded. This aspect of the concrete repair process has so far received little attention.

An experimental and analytical program of research is in progress to evaluate the structural integrity of such patches. The paper describes the initial test series involving patch repairs within both the tension and compression zones of flexural specimens. Repair materials having a wide range of elastic and thermal characteristics have been used in patches of varying shapes and sizes. Their effect of short-term structural performance is assessed and conclusions drawn as to the relative performance on a range of systems.

C-434 Carrasquillo, P. M. 1987. "Durability of Concrete Containing Fly Ash for Use in Highway Applications," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 843-862, American Concrete Institute, Detroit, MI.

The effect of fly ash content on the air entrainment, freeze-thaw durability, abrasion resistance, strength gain, shrinkage, and creep of concrete was studied. Two different fly ashes were used to replace 0, 20, and 35 percent of a portland cement by weight. A blended cement, containing 20 percent fly ash by weight, was also tested. Three different air-entraining admixtures were used.

It was found that the use of fly ash in concrete could reduce the effectiveness of air-entraining admixtures depending on properties of the fly ash, such as loss of ignition (LOI). However, concrete containing fly ash exhibited freeze-thaw resistance equal to or better than that of similar concrete containing portland cement only, provided both that similar entrained air contents. Similarly, concrete containing fly ash showed equal or better resistance to abrasion when compared to concrete of equal strength containing no fly ash.

The strength gain characteristics of concrete containing fly ash are different from those of concrete containing no fly ash. The creep of concrete containing fly ash was less than or equal to that of portland-cement concrete when subjected to equal sustained loads, even though the 28-day compressive strength of the concrete containing fly ash was lower than that of concrete containing no fly ash.

The shrinkage of concrete containing fly ash is highly dependent on the curing given to the concrete and on environmental conditions, such as temperature and relative humidity. Not only is the shrinkage of concrete containing fly ash affected differently by the previously mentioned conditions than that of concrete containing no fly ash, but concrete containing Class C fly ash is affected differently than concrete containing Class F Fly ash.

C-435 Marusin, S. L. 1987. "Improvement of Concrete Durability Against Intrusion of Chloride-Laden Water by Using Sealers, Coatings, and Various Admixtures," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 599-620, American Concrete Institute, Detroit, MI.

Research since 1979 on sealers, coatings, and concrete containing admixtures is summarized. A test procedure developed during a National Cooperative Highway Research Program project, "Concrete Sealers for Protection of Bridge Structures," was used.

This test method uses 10 cm cube specimens, and water absorption and chloride ion penetration is determined after 21 days of exposure to a 15-percent NaCl solution. The study focuses on the minimization of the ingress of chloride-laden water into concrete, the influence of water-cement ratio, the relationship between water absorption and chloride ion content in concrete, and the comparison of the chloride distribution profiles through the conventional portland-cement concrete and concrete containing various admixtures (superplasticizers, polymer emulsions, condensed silica fume).

C-436 Vondran, G. L. 1987. "Making More Durable Concrete with Polymeric Fibers," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 377-396, American Concrete Institute, Detroit, MI.

The use of fibrillated polymeric fibers as secondary reinforcing to improve concrete durability is presented from a wide range of data with the purpose of demonstrating major trends. In this paper, results presented focus on one type of polymeric fiber, a collated fibrillated polypropylene (CFP), at an addition rate of 1.5 lb/yd^3 (0.9 kg/m^3). Tests on qualities that can affect durability illustrated CFP fiber-reinforced concrete increases resistant to: plastic shrinkage cracking, impact, abrasion, shattering, freeze-thaw, deicing scaling, permeability, fatigue, and fire. The toughness index is increased up to 4.9 with the use of this fiber. Polypropylene will not degrade or corrode, and is not negatively affected by an alkaline environment of portland-cement concrete. Much research is being dedicated to the discovery of specific trends through lab testing. Once a trend is established, it is reconfirmed in the lab and then again in field applications. Since most durability properties are long term in nature, and CFP fibers are in their advent, future papers will discuss more conclusive results of research in this field. An attempt is made here to characterize polypropylene fibers and their relative contribution to durability of concrete.

C-437 Kukacka, L. E., and Sugama, T. 1987. "Furfuryl Alcohol Polymer Concretes for Use in All-Weather Repairs of Concrete and Asphalt Surfaces," Polymer Modified Concrete, SP-99, pp 91-112, American Concrete Institute, Detroit, MI.

A furfuryl alcohol-based polymer concrete (FA-PC) has been developed for use as an all-weather repair material for concrete and asphalt surfaces. For this application, the following criteria were established: high-strength at an age of 1 hr, placement of the materials possible during heavy precipitation over temperatures ranging from -32 to 52° C, and the chemical constituents low in cost with long-term stability when contained in a maximum of three packages during storage. A formulation consisting of furfuryl alcohol monomer (FA), α,α,α-trichlorotulene, pyridine, silane, zinc chloride, silica filler, and coarse aggregate meets these requirements.

Optimized formulations were established for use with premixed and percolation placement methods. The premixed formulation meets essentially all of the property and storage criteria and is compatible with moisture contents up to 4 percent by weight of the total mass, which stimulates placement in a 2.54 cm/hr rainfall. The working time for the FA-PC slurry can be controlled at ±15 min over the operating temperature range -20 to 52° C by simply varying the α,α,α-trichlorotoluene catalyst concentration while holding all the other constituents constant. Below -20° C, slight increases in FA and $ZnCl_2$ concentrations are needed to yield optimum properties.

Prototype equipment for the mixing and placement of FA-PC was constructed and used in a series of tests up to a size of 6 by 6 by 0.15 m. The equipment consisted of a concrete transit mix supply of mixed aggregate, a hopper-fed volumetric feed screw that supplied aggregate at a known rate to a mixing screw, a monomer pump, and spray nozzle. The unit mixed and delivered FA-PC at ~ 182 kg/min. The practicability of using equipment currently employed for the continuous placement of conventional portland-cement concrete was proven.

Field tests were performed under rainfall and dry conditions at temperatures ranging from -15 to 35° C. In all of these tests, the mixing and placement equipment performed well and the FA-PC slurries exhibited self-leveling characteristics. Test results from proxy samples prepared during the placement of the patches and cores taken after simulated aircraft trafficking indicated that the property requirements at an age of 1 hr were attained.

C-438 Brown, D. D. 1987. "Proven Seal," Joint Sealing and Bearing Systems for Concrete Structures, SP-94, pp 1009-1016, American Concrete Institute, Detroit, MI.

The neoprene compression seal has now been used commercially in construction projects, including highways and bridges, for more than 20 years. It continues to be today's top method of sealing contraction and expansion joints in highways and bridges, as measured by the footages used annually.

Through the years, there has been continued refinement of the specifications covering this type of sealing so that for practical purposes performance is assured when these specifications are followed. The degree of sophistication inherent in the development of this type of seal exceeds most rubber-like products. Enough time has now elapsed that data on field performance can be related back to the design parameters that were monitored by accelerated laboratory tests and that have been proven correct.

The paper reviews the problems encountered in arriving at a proper seal design, the problems of field installation, and the correlation of accelerated laboratory testing to field results. Included also are remarks concerning the adoption of various special compression seals to specific applications.

C-439 Chin, D. 1987. "Calcium Nitrate-Based, Non-Corrosive, Non-Chloride Accelerator," Corrosion, Concrete, and Chlorides-Steel Corrosion in Concrete: Causes and Restraints, SP-102, pp 49-78, American Concrete Institute, Detroit, MI.

Two important properties of calcium nitrite are that it is an accelerator and a corrosion inhibitor when used as an admixture in concrete. With its performance as an accelerator enhanced, calcium nitrite can be used as an effective non-corrosive, non-chloride accelerator in normal and fly-ash concrete.

The calcium nitrite-based accelerator provides good acceleration in initial setting times of 50 and 72° F (10 and 22° C) and produces a significant improvement in compressive strengths at early ages.

Electrochemical solution tests can be used to conduct a quick screening test to determine the potential corrosivity of a non-chloride accelerator. Potentials and linear polarization resistance measurement tests provide a quick indication of the potential corrosivity of a non-chloride accelerator.

C-440 (Deleted)

C-441 Sri Ravindrarajah, R., Loo, Y. H., and Tam, C. T. 1987 (Dec). "Recycled Concrete as Fine and Coarse Aggregates in Concrete," Magazine of Concrete Research, Vol 39 No. 141, pp 214-220, London, England.

The paper reports the effects of the use of recycled aggregates in both fine and coarse form, upon strength and deformation of concrete by conducting tests in fresh and hardened states.

Materials used were OPC, natural sand conforming to zone 2 and crushed granite of maximum size 20 mm in control mixes as well as in concrete used for producing recycled aggregates. Relevant BS were followed.

The recycled aggregates were produced by crushing 100 mm, about 1-year-old cubes with a strength of about 60 N/mm^2 in a jaw crusher.

C-442 Larsen, T. J., and Armaghani, J. M. 1987. "Draincrete in Pavement Rehabilitation," Transportation Research Record No. 1110, Transportation Research Board, National Research Council, Washington, DC.

Draincrete is an open-graded concrete of relatively low strength with a high void ratio. It is used in pavement construction and rehabilitation where water is to be rapidly removed from the pavement system. For new pavement structures the draincrete is used as a water-transporting layer under a concrete pavement. With the strength often specified at 800 psi, it also serves as a rigid subbase. Its major application, however, has been as a water-collecting medium for edge drains in pavement rehabilitation work. Specification provides for a minimum as well as a maximum strength to avoid confusion with ordinary concrete. As an additional safeguard, requirements are also set to limit its unit weight range to secure sufficient void ratio. Draincrete used for edge drain serves the dual purpose of providing drainage as well as strengthening the subbase where the subbase ledge has been removed to provide the drainage channel. Many miles of edge drain draincrete have been installed on the Florida interstate system. As these installations have only been in place for less than 4 years, their functioning and durability over extended time periods cannot be adequately judged. All indicators suggest, however, that an edge drain system using draincrete, as used in the Florida interstate system, will function for extended periods of time with a minimum of upkeep.

C-443 Nawy, E. G., Hanaor, A., Perumalsamy, N. B., and Kudlapur, S. 1987. "Early Strength of Concrete Patching Materials at Low Temperatures," Transportation Research Record No. 1110, Transportation Research Board, National Research Council, Washington, DC.

Winter repair and maintenance operations of concrete bridge decks and pavement require high early-strength patching materials suitable for application at subfreezing temperatures. An extensive experimental program at Rutgers University has identified four generic materials as potentially suitable to fulfill this role. Early-strength tests included compressive cylinder strength of patching material and slant shear bond strength to existing concrete at 1 day and 7 days, and static and fatigue flexure strength of patched specimens at 7 days. All patch materials were cast and cured at temperatures of 15 to 20° F. The three generically distinct materials identified were: (a) a methyl methacrylate-based material, (b) two types of magnesium phosphate-based materials, and (c) a polyurethane binder. Early strengths ranged from 1,700 psi to more than 8,000 psi. Slant shear bond strengths ranged from 2,000 psi to more than 5,000 psi. Flexural strengths, both in static and fatigue loading, are also suitable, with most materials displaying performance comparable to that of the control (unpatched) specimens. Flexure test results, however, are highly variable. The causes of this variability and ways of reducing it need further investigation.

C-444 Stanfield, R. F. 1987. "Environmental Protection for Concrete," Pigment and Resin Technology, Vol 16, No. 10, London, England

The protective properties of a proprietary pigmented rubber-based emulsion are described. Methods of calculating carbon dioxide diffusion resistance are outlined, and this parameter is evaluated for various generic types of coating. Results are presented from investigations into the prevention of carbonation and control of alkali/silica reaction.

C-445 "Water-Repellent Coating for Concrete Buildings." 1987. Japanese Patents Gazette, Vol 87, No. 20, Group G, 19, London, England.

Water-borne coatings resistant to cracking in the concrete substrate comprise a thickly applied alkyl acrylate polymer undercoat, followed by a water-repellent coating comprising a polymer of Tg below 10° C and specified tensile strength, together with cement, etc.

C-446 "Ageing of Concrete." 1987. Japanese Patents Gazette, Vol 87, No. 16, Group G, 5, London, England.

Concrete surfaces may be artificially aged by means of a water-borne coating containing a water-absorbing polymer and rubber latex. After the water has evaporated from the composition, the coating may be stripped off.

C-447 Bell, Q., and Kubitza, W. 1987. "Polyurethane Coatings for Concrete," Surface Coating Australia, Vol 24, No. 3, 8-11, Balaclava, Australia.

The properties and advantages of polyurethane systems for exterior use on concrete as well as interior use on floors are outlined. High-solids systems are also available; solvent-free systems are forecast for the future.

C-448 Robinson, H. 1987. "Evaluation of Coatings as Carbonation Barriers," Construction Repair, Vol 1, No. 1, 12-8, London, England.

Studies carried out on 71 proprietary coatings systems for protection of concrete, covering gas permeability, water vapour transmission, etc. are described.

C-449 "Forming of Resin Film on Concrete Block Surface." 1987. Japanese Patents Gazette, Vol 87, No. 1, Group G, 2, London, England.

Waterproof coatings with wear resistance are applied to hardened concrete by blasting with steel balls coated with a film-forming resin.

C-450 Leeming, M. B. 1987. "Surface Coatings for Concrete," Construction Repair, Vol 1, No. 1, pp 9-11, London, England.

The different types of coatings available for decoration and protection of (reinforced) concrete are discussed.

C-451 "Providing Waterproof Surface on Building Material." 1987. Japanese Patents Gazette, Vol 87, No. 9, Group L, 8, London, England.

Waterproof coatings for moulded foamed concrete building materials are comprised of solutions or emulsions of acrylic resin, polyvinyl chloride, etc. These are applied to the partly cured moulding, the surface of which is then abraded (e.g. by wire brushing) to remove loose particles which become embedded in the coating during final curing of the moulding.

C-452 Tatro, S. B. 1987. "Performance of Steel Fiber Reinforced Concrete Using Large Aggregate," Transportation Research Record No. 1110, Transportation Research Board, National Research Council, Washington, DC.

Traditionally, steel fiber reinforced concrete has utilized aggregates not exceeding a maximum size of 3/4 to 1 in. The purpose of this investigation was to evaluate the performance of steel fiber reinforced concrete mixes containing an aggregate with a maximum size of 1-1/2 in. Mixes were evaluated using three fiber types and three fiber concentrations. Beams were tested in flexure with load-deflection curves plotted for each specimen. Toughness testing was done in accordance with ASTM C 1018-85. Cylinders were cast to obtain specimens for compressive strength and impact resistance testing. Additional beams were cast for fatigue testing up to two million cycles. Flexural specimens using the longer fibers, 2 in. or longer, showed improved first-crack strength over conventional concrete mixes and displayed good toughness characteristics. The longer fibers significantly improved the impact resistance and the fatigue performance of steel fiber reinforced concrete with 1-1/2-in. maximum-size aggregate. The compressive strength of mixes increased with the addition of steel fibers except when fiber loadings interfered with consolidation of the mix.

1988

C-453 Lavelle, J. A. 1988 (Jan-Feb). "Acrylic Latex-Modified Portland Cement," ACI Materials Journal, Vol 85, No. 1, Detroit, MI.

The term acrylic refers to a large family of materials having a similar chemical structure but a wide range of properties. The paper briefly reviews some basic acrylic chemistry with special emphasis on those features relevant to its use in portland-cement applications. While acrylic latexes have been used to modify portland-cement composites for more than 25 years, many end users have not been aware that some acrylic latex types are not suitable for use with cement. The properties that can be obtained by adding acrylic latex specifically designed for compatibility with portland cement are discussed. A variety of end-use applications are also illustrated.

C-454 Wallace, M. 1988 (Feb). "How Do You Prevent Corrosion?" Concrete Construction, Vol 33, No. 2, pp 125-132, Addison, IL.

Several ways of preventing or stopping reinforcing bar corrosion are described. Some are: watertight concrete and proper cover, nonchloride accelerators, cathodic protection, sealers, polymer concrete overlays, silica fume concrete overlays, epoxy-coated reinforcing bars, and corrosion-inhibiting admixtures. Each is described briefly and includes where to get more information.

C-455 "Friarton Bridge: Replacement Waterproofing." 1988 (Mar). Civil Engineering, pp 36-37, London, England.

Resurfacing plans of the two-deck bridge led to the discovery that the existing mastic asphalt waterproofing layer was cracked and, in areas, debonded from the deck. The criteria for the replacement waterproofing system were stringent and varied. It had to be suitable for a lightweight concrete deck, possibly containing more water vapor than conventional concrete without being adversely affected by the upward movement of moisture vapor. Construction procedures of the new waterproofing are described once the structural design is decided upon.

C-456 Awal, A. S. M. A. 1988 (Mar). "Failure Mechanism of Prepacked Concrete," Journal of Structural Engineering, American Society of Civil Engineers, Vol 114, No. 3, pp 727-732, New York, NY.

Concrete is a multiphase material in which aggregate particles are distributed in the mortar matrix. Since a large volume of the concrete is occupied by aggregate, it is likely that variation in aggregate content will significantly influence the strength and deformation behavior. Prepacked concrete, as it contains a higher proportion of coarse aggregate, shows characteristics in failure that are widely dissimilar from those of normal concrete. This paper presents some aspects of failure mechanism of prepacked concrete observed during testing in compression. Along with the observations, some theoretical considerations are also made and discussed.

C-457 Knab, L. I. 1988 (Mar). "Factors Related to the Performance of Concrete Repair Materials," Technical Report REMR-CS-12, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report provides the status of information, including research needs, on the performance of materials containing polymers used to repair portland-cement concrete. The following types of repair materials were covered: sealant type materials for repairing active cracks; and polymer adhesives, polymer mortars, and concretes; and polymer-modified mortars and concretes for repairing spalls and dormant cracks and for placing overlays. This report is considered a first step in the process of developing performance tests and criteria and is intend d to serve as a guide in selecting performance requirements, degradation factors, properties related to performance, and relevant existing test methods and their parameters.

C-458 Shirley, S. T., Burg, R. G., and Fiorato, A. E. 1988 (Mar-Apr). "Fire Endurance of High-Strength Concrete Slabs," ACI Materials Journal, Vol 85, No. 2, pp 102-108, Detroit, MI.

In recent years, use of high-strength concrete ranging in compressive strength from 8,000 to 15,000 psi has become more prevalent. Concrete structures, such as high-rise buildings, are now using these materials. Most recently, the use of silica fume as a supplementary cementitious material has developed for design of higher-strength concrete mixtures. The objective of this investigation was to develop fundamental information on the behavior of high-strength concrete at elevated temperatures using realistic test specimens.

Scope of the work included a review of available literature on performance in fire tests of specimens fabricated from high-strength concrete mixtures, with and without silica fume. The literature review was followed by laboratory tests of 3- by 3- by 0.33-ft slab specimens with embedded reinforcement. Specimens were exposed to elevated temperatures and monitored for temperature rise and physical integrity.

C-459 Bean, D. L. 1988 (Apr). "Surface Treatments to Minimize Concrete Deterioration," Report 1, Survey of Field and Laboratory Application and Available Products," Technical Report REMR-CS-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

A literature search was conducted for information about materials used to protect concrete. Little information was found concerning field testing and evaluation of these materials. However, there were several reports describing laboratory testing and results of different chemical compounds and brand-name products. Case histories of materials applied on Corps of Engineers projects are documented within.

C-460 Neeley, B. D. 1988 (Apr). "Evaluation of Concrete Mixtures for Use in Underwater Repairs," Technical Report REMR-CS-18, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Concrete mixtures were evaluated to determine which were most suited for placement underwater in thin lifts. The concretes were proportioned to have good workability, good abrasion-erosion resistance, and good resistance to washing out of the cement paste. High-range water reducers (HRWR) were used to increase the workability and permit the use of low water-cement ratios (W/C) to increase the resistance to abrasion-erosion. Low W/C, silica fume, and antiwashout admixtures (AWA) were used to increase the resistance to washout.

A washout test was used to determine the relative amount of cement paste lost when the concrete is exposed to a large volume of water. The two-point workability test was used to evaluate the relative workability properties of each mixture. The slump and air content were also measured for most of the mixtures. The test method for abrasion-erosion resistance of concrete (underwater method) was used to determine the abrasion-erosion resistance of each mixture.

C-461 "Concrete Polymer Composites, Dec 1982 - May 1988." 1988. (Citations from the Engineering Index Database), New York, NY.

This bibliography contains citations concerning concrete polymer composites including both polymer aggregate concretes as well as polymer impregnated portland-cement concretes. Production, hardening, uses, and properties are explored. Studies on applications such as bridge decking, tunnel supports, highway pavements, and bone cements are included. (This updated bibliography contains 260 citations, 60 of which are new entries to the previous edition.)

C-462 King, J. C., and Wilson, A. L. 1988 (Jul). "If It's Still Standing, It Can Be Repaired," Concrete Construction, Vol 33, No. 7, Addison, IL.

Concrete repairs sometimes fail because bond between new and old concrete fails. Although repairs may bond well at first, the new concrete shrinks and puts a strain on the bond face. This strain is often large enough to break the bond. Preplaced aggregate (PA) concrete is an alternative repair material that bonds well but shrinks very little.

C-463 McDonald, J. E. 1988 (Jul). "Evaluation of Vinylester Resin for Anchor Embedment in Concrete," The REMR Bulletin, Vol 5, No. 2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

For the range of parameters in this study (hole condition and test age), results of pullout tests on threaded-rod anchors installed in dry holes were remarkably consistent with an overall average tensile capacity of 105 kips at 0.1-in. displacement and an average ultimate load of approximately 125 kips. In comparison, results of pullout tests on anchors installed under submerged conditions were relatively erratic with an overall average tensile capacity of 36 kips at 0.1-in. displacement and an average ultimate load of 48 kips. Obviously, the tensile load capacity of anchors embedded in concrete with Hilti's HEA vinylester resin capsules is significantly reduced when the anchors are installed under submerged conditions. At a displacement of 0.1 in., the tensile capacity of anchors embedded under submerged conditions was approximately one-third that of similar anchors embedded in dry holes.

Creep tests should be conducted to evaluate the effect of sustained loads on anchor performance prior to the use of HEA vinylester resin capsules for embedment of anchors that will be subjected to long-term loads.

C-464 Williamson, G. 1988 (Jul-Aug). "Waterproofing Multi-Story Car Parks," Construction Repair, Vol 2, No. 4, London, England.

The waterproofing treatments available fall into 4 main categories:

1. Asphalt systems.
2. Nonflexible systems.
3. Sealers.
4. Elastomeric lightweight systems.

These treatments are described and their applications are discussed in this article.

C-465 "Recycled Freeway." 1988 (Aug). Concrete Products, Vol 91, No. 8, Chicago, IL.

Detroit's rebuilt 8.7-mile John C. Lodge Freeway uses crushed concrete recycled from the old roadbed. Through a series of crushing processes, properly sized crushed concrete is ready to go into making new pavement, enabling recycling of the original freeway.

C-466 Pedersen, N. 1988 (Aug). "Wear Resistant Concrete for Pavements," Concrete International: Design & Construction, Vol 10, No. 8, Detroit, MI.

A special test rig that simulates 10 years traffic with 10,000 ADT within 1 week was used to determine factors that strongly influence rutting resistance in concrete pavement, an important consideration in Norway where studded tires are used throughout the long winter season. These factors include concrete strength, aggregate type, sand type, air entrainment, and condensed silica fume. Test are continuing to optimize all variables to achieve the highest possible resistance for the lowest cost.

C-467 Hadchiti, K. M., and Carrasquillo, R. L. 1988 (Aug). "Abrasion Resistance and Scaling Resistance of Concrete Containing Fly Ash," CTR-3-5/9-87-481-3, RR-481-3, FHWA/TX-89+481-3, Federal Highway Administration, Austin, TX.

The durability of concrete containing fly ash subjected to various curing conditions was investigated in the research program. The test results show that strength is the most important factor influencing the abrasion resistance of the concrete. The curing practices were found to influence the abrasion resistance of the concrete in that they affected the concrete strength. No relationship could be established between the deicer scaling resistance of concrete and the water cementitious ratio, the compressive strength, or the curing practices.

C-468 Sadegzadeh, M. and Kettle, R. J. 1988. "Abrasion Resistance of Surface-Treated Concrete," Cement, Concrete, and Aggregates, Vol 10, No. 1, pp 20-28, American Society for Testing and Materials, Philadelphia, PA.

This article describes a laboratory study of surface treatments on the abrasion resistance of concrete. A test method based on rotating steel wheels running in a circular path was adopted to assess the abrasion resistance. The reported data are from a series of tests performed on relatively large slabs so that power trowelling and finishing could be used to produce the test surfaces. These slabs were used to assess the effects of various treatments on abrasion resistance, including both liquid surface treatments and dry shake surface treatments.

Concrete liquid hardeners were more effective in improving the abrasion resistance of mixes with low water-cement ratios than those with high water-cement ratios. Proper curing of the concrete slabs was more effective in improving the abrasion resistance than the application of concrete liquid hardeners. Penetrating sealing and hardening treatments significantly increased the abrasion resistance of all types of concrete mixes. The abrasion resistance obtained by the use of penetrating sealer and hardener treatments ranked highest when compared with other air-cured specimen slabs. The application of these treatments reduced the influence of concrete mix design on the abrasion resistance of the slab.

C-469 "Protecting Concrete by Flexible Waterproofing Slurries." 1988 (Sep). Concrete Precasting Plant and Technology, Vol 54.

Accelerated exposure tests in the laboratory and 5 years field observations of exposed test coatings have demonstrated that flexible waterproofing slurries offer high resistance to weathering and that local mechanical damage does not produce further detrimental effects.

C-470 Kukacka, L. E. 1988 (Sep). "Repair and Rehabilitation with Polymer Concrete," BNL-41960, CONF-8811153-1, Rand Afrikaans University Symposium on Polymer Concrete, 13 Nov 1988, Johannesburg, South Africa.

As a result of their fast setting characteristics and excellent mechanical and physical properties, polymer concretes (PC) are finding ever increasing usage for the repair of deteriorated portland-cement concrete structures. Applications include the repair of highway pavements and bridge decks, airport runways, hydrotechnical structures, tunnels, and industrial flooring. The most commonly used resins and monomer systems for these applications are epoxies, polyesters, and methylmethacrylate. Furfuryl alcohol has been used experimentally, and shows promise for use in making emergency repairs under adverse moisture or extreme temperature conditions. In the paper, repair procedures will be discussed and several case histories given.

C-471 Shah, S. P., Ludirdja, D., Daniel, J. I., and Mobasher, B. 1988 (Sep-Oct). "Toughness-Durability of Glass Fiber Reinforced Concrete Systems," ACI Materials Journal, Vol 85, No. 5, pp 352-360, Detroit, MI.

Glass fiber reinforced concrete (GFRC) panels are being used increasingly by the precast industry for cladding panels of new construction and for retrofit projects (1987 volume of $100,000,000). The widespread development of GFRC has resulted from the development of alkali-resistant glass fibers that have an improved resistance to the alkaline environment that exists in portland cement-based matrices. In spite of the improved alkali resistance, long-term weathering tests reveal that GFRC panels may exhibit reduced tensile strength and a loss of ductility with aging.

C-472 Perenchio, W. F. 1988 (Nov). "Durability of Concrete Treated with Silanes," Concrete International: Design & Construction, Vol 11, pp 34-40, Detroit, MI.

This article examines the available literature on laboratory tests and describes the condition of several bridges in the US and Germany that have been treated with silanes. The conclusion is that the highly unnatural treatment of specimens in some laboratory testing may be responsible for the poor performance sometimes observed in these concretes in contrast to field performance. A theoretical explanation for the difference is given.

C-473 Smoak, W. G. 1988 (Dec). "Polyurethane Injection Stops Water Tunnel Leaking," Concrete Construction, Vol 33, No. 12, Addison, IL.

A valve at the Pacheco Conduit inlet in California lets workers drain the conduit without draining the 5.3-mile-long tunnel that feeds it. During tests after construction in 1986, however, Bureau of Reclamation engineers found a 125-gpm leak at the concrete valve structure expansion joint. Removing and replacing the valve structure concrete would have been too costly. Repair by epoxy injection was rejected because liquid epoxy would penetrate the sponge rubber filler in the expansion joint, gluing the faces together. Therefore, a way to plug the leak while still allowing movement at the joint was needed.

C-474 Blaha, B. 1988 (Dec). "GFRC Process Mimics Originals," Concrete Products, Vol 91, No. 12, Chicago, IL.

Southern California's Mimco Products use glass fiber-reinforced concrete to precast units with the look and feel of the building materials being duplicated. Some of the materials duplicated include stone, wood, stucco, and brick. Materials are duplicated in the exact appearance and detail of the originals.

C-475 McBee, W. C., Weber, H., and Ward, F. E. 1988 (Dec). "Sulphur Polymer Cement for Chemically Resistant Concrete," Construction & Building Materials, Vol 2, No. 4, Reigate, Surrey, England

Composite materials based on sulphur polymer cement (SPC) and mineral aggregate have been developed by the US Bureau of Mines as part of a program to utilize abundant material resources. Goals are to develop durable, chemically resistant construction materials with lowered costs. Chemical degradation of portland-cement concrete (PCC) is a serious problem due to acid and salt attack.

C-476 Oshiro, T., and Tanigawa, S. 1988. "Effect of Surface Coatings on the Durability of Concrete Exposed to Marine Environment," Concrete in Marine Environment-Proceedings of the Second International Conference, St. Andrews, NB, SP-109, pp 179-198, American Concrete Institute, Detroit, MI.

A test building constructed in 1984 was exposed to marine environment under subtropical weather of Okinawa, Japan. Concentration of chloride ions in concrete, changes in the half-cell potentials with time, and protective effects of surface coatings were investigated.

Diffusion of chloride ions was monitored using Fick's law. The diffusion equation was converted to a difference equation and solved under the initial condition in terms of time. These results were compared with those of the field, and the relationships were obtained.

C-477 "Anticorrosive, Waterproof Coating for Concrete." 1988. Japanese Patents Gazette, Vol 88, No. 4, Group L, 4.

The coating system, suitable for concrete structures, tanks, and floors, comprises a water-borne primer containing an ethylene/vinyl acetate copolymer or rubber(/asphalt) emulsion; and a layer of an unsaturated polyester or epoxy resin, filled with, e.g., glass flake, graphite, or mica.

C-478 Stavinoha, R. 1988. "Protecting Concrete from Exposure to Aggressive Chemicals," Journal of Protective Coatings and Linings, Vol 5, No. 2, pp 28-32, Pittsburgh, PA.

Important factors for selecting a suitable protective coating for concrete in aggressive chemical environments are discussed and the relative merits of currently used materials are considered. Commonly used coatings include epoxy, polyester, vinylester, phenolic- and furan-based resins. Chemical resistance and physical characteristics are tabulated for each type.

C-479 "Waterproofing of Lightweight Concrete Panels." 1988. Japanese Patents Gazette, Vol 88, No. 1, Group G, 2, London, England.

Coatings which improve the strength and water assistance of concrete comprise, e.g., a nonwoven fabric bonded to the outer surface with a filled synthetic resin, followed by a decorative coating.

C-480 Gemert, D. V., Czarneckit, L., and Bares, R. 1988. "Basis for Selection of PC and PCC for Concrete Repair," Longman Group, UK Ltd, United Kingdom.

A classification of concrete polymer composites is presented, which takes into account the influence of the solid phases, as well as the composite interaction with a fluid phase, which in the limit will be the ambient environment. The classification is based on a structural model, enabling the qualification and quantification of material properties.

A brief overview of damage and causes of damage to concrete and concrete structures is given. A study of damage and damage causes reveals the requirements, with which the repair materials have to comply. The comparison of both requirements and structural material properties enable the proper choice of the repair material, or indicate the way to proceed in developing repair materials for specific repair jobs.

C-481 "Standard Specification for Packaged, Dry, Combined Materials for Mortar and Concrete." 1988. Designation: ASTM C 387-87, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This specification covers the production, properties, packaging, and testing of packaged, dry, combined materials for concrete and mortars. The types of concrete and mortar covered include high-early-strength concrete, normal-strength concrete, high-strength mortar, and mortars for unit masonry.

C-482 "Standard Specification for Epoxy-Resin-Base Bonding Systems for Concrete." 1988. Designation: ASTM C 881-87, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This specification covers two-component, epoxy-resin bonding systems for application to portland-cement concrete which are able to cure under humid conditions and bond to damp surfaces.

C-483 "Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs." 1988. Designation: ASTM C 928-80, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This specification covers packaged, dry, cementitious mortar, or concrete materials for rapid repairs to hardened hydraulic-cement concrete pavements and structures. Materials that contain organic compounds, such as bitumens, epoxy resins, and polyesters, as the principal binder are not included.

C-484 "Standard Specification for Latex Agents for Bonding Fresh to Hardened Concrete." 1988. Designation: ASTM C 1059-86, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This specification covers latex bonding agents suitable for brush, broom, or spray application to bond fresh concrete to hardened concrete. These bonding agents are intended for bonding new concrete to old concrete such as interior surfaces, floors, roadways, bridge decks, ramps, runways, walks, and curbs.

C-485 "Standard Test Method for Bond Strength of Epoxy-Resin Systems Used with Concrete." 1988. Designation: ASTM C 882-87, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers the determination of the bond strength of epoxy-resin-base bonding systems for use with portland-cement concrete.

This test method covers bonding hardened concrete to hardened or freshly mixed concrete.

C-486 "Standard Test Method for Effective Shrinkage of Epoxy-Resin Systems Used with Concrete." 1988. Designation: ASTM C 883-80 (Reapproved 1983), 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This method covers the determination of the effective shrinkage occurring during the curing of epoxy-resin systems, and is intended for laboratory use. A laminate is constructed of the epoxy resin applied to a glass plate. As the epoxy cures, any shrinkage will cause a bowing of the glass plate. Excessive shrinkage of the resin, as evidenced by fracture of the glass plate, is an indication of probable incompatibility of the epoxy-resin system applied to a concrete substrate.

C-487 "Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay." 1988. Designation: ASTM C 884-87, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers the determination of which epoxy-resin formulations are subject to debonding when used as overlays for concrete when the combination of the two is subjected to temperature changes that may be met in the field. A layer of epoxy-sand mortar is applied to a slab of cured and dried concrete. After the epoxy has cured, the sample is subjected to five cycles of temperature change between 77° F (25° C) and -6° F (-21.1° C). Cracks near the bond line between the concrete and the epoxy mortar constitute failure of the test.

C-488 "Standard Test Method for Bond Strength of Latex Systems Used with Concrete." 1988. Designation: ASTM C 1042-85, 1988 Annual Book of ASTM Standards, Vol 04.02, American Society for Testing Materials, Philadelphia, PA.

This test method covers the determination of the bond strength of latex bonding systems for use with portland-cement concrete. This test method covers bonding hardened mortar specimens to freshly mixed mortar specimens.

C-489 ACI Committee 207. 1988. "Roller Compacted Concrete," ACI 207.5R-80, ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

Roller compacted concrete (RCC) represents a new concept in which concrete of no-slump consistency is transported, placed, and compacted utilizing earth and rock-fill construction equipment. Properties of hardened RCC are the same as conventional concrete of the same water-cement ratio. Mixture proportioning, physical properties, mixing, transporting, placing, consolidating, curing, protection, and design and construction of gravity sections with RCC are discussed.

C-490 ACI Committee 223. 1988. "Standard Practice for the Use of Shrinkage-Compensating Concrete," (ACI 223-83) ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

Shrinkage-compensating concrete is used extensively in various types of construction to eliminate or minimize cracking caused by drying shrinkage. Although its characteristics are in most respects similar to those of portland-cement concrete, the materials, selecting of proportions, placement, and curing must be such that sufficient expansion is obtained to compensate for subsequent drying shrinkage. This recommended practice sets forth the criteria and practices necessary to ensure that expansion occurs at the time and in the amount required. In addition to a discussion of the basic principles, methods and details are given covering structural design, concrete mix proportioning, placement, finishing, and curing. A bibliography of the major references covering expansive cements and concretes is also appended.

C-491 ACI Committee 225. 1988. "Guide to the Selection and Use of Hydraulic Cements," ACI 225R-85, ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

Since cement is the most active component of concrete and usually has the greatest unit cost, its selection and proper use is important in obtaining the balance of properties and cost desired for a particular concrete mixture. Selection should take into account the properties of the available cements and the performance required of the concrete. This report summarizes information about the compositions and availability of commercial hydraulic cements and factors affecting their performance in concrete. Following a discussion of the types of cements and a brief review of cement chemistry, the influences of admixtures (both chemical and mineral) and the environment on cement performance are discussed. The largest part of the report covers the influence of cement on the properties of concrete. Cement storage and delivery and the sampling and testing of hydraulic cements for conformance to specifications are reviewed briefly.

The report will help users recognize when a readily available, general-purpose (ASTM Type 1) cement will perform satisfactorily, or when conditions require selection of a cement that meets some additional requirements. It should also aid cement users by providing general information on the effects of cements on the properties of concrete. Some chemical and physical characteristics of a cement affect certain properties of concrete in important ways. For other properties of concrete, the amount of cement is more important than its characteristics.

The report is not a treatise on cement chemistry nor on concrete. For those who need to know more, the report provides many references to the technical literature, including ACI documents.

C-492 ACI Committee 363. 1988. "State-of-the-Art Report on High-Strength Concrete," ACI 363R-84, ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

Currently available information about high-strength concrete is summarized. Topics discussed include selection of materials, concrete mix proportioning, batching, mixing, transporting, placing, control procedures, concrete properties, structural design, economics, and applications. A bibliography is included.

C-493 ACI Committee 503. 1988. "Use of Epoxy Compounds with Concrete," ACI 503R-80 (Revised 1984), ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

Epoxy compounds have found a wide variety of uses in the concrete industry as coatings, grouts, binders, sealants, bonding agents, patching materials, and general adhesives.

Properties, uses, preparations, mixtures, application, and handling requirements of epoxy-resin systems when applied to and used with concrete and mortar are presented. The adhesiveness of epoxy and its chemical, thermal, and physical properties are given. The modification of the foregoing properties to accommodate given situations is reviewed.

Problems encountered in surface preparation are reviewed and procedures and techniques given to ensure successful bonding of the epoxy to the other materials. Temperature conditioning of the base material and epoxy compound are outlined. The cleaning and maintaining of equipment is reviewed. Procedures to be followed in the application of epoxy compounds in the several use situations are given. The important factors which ensure that the epoxy compound will harden (cure) and therefore perform its function are discussed together with alterations of the hardening rate. The allergenic and toxic nature of epoxies and the chemicals used with them in the industry create a hazard and precautions are detailed throughout the report.

C-494 ACI Committee 506. 1988. "Guide to Shotcrete," ACI 506R-85, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This guide provides information on materials and properties of both dry-mix and wet-mix shotcrete. Most facets of the shotcrete process are covered including application procedures, equipment requirements, and responsibilities of the shotcrete crew. Preconstruction, prequalifying, and acceptance testing of workers, materials, and finished shotcrete are also considered.

C-495 ACI Committee 506. 1988. "State-of-the-Art Report on Fiber Reinforced Shotcrete," ACI 506.1R-84, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This report describes the technology and uses of fiber reinforced shotcretes using steel fibers, glass fibers, and polypropylene fibers. Mechanical properties, particularly ductility, toughness, impact strength, and flexural strength are improved by the fiber addition, and these improvements are described along with other typical properties and proportions of typical mixtures. Batching, mixing, and application procedures are described, including methods of reducing rebound and equipment used to apply fiber reinforced shotcrete. Applications of fiber reinforced shotcrete in North America, Europe, and Scandinavian countries are described. These include rock slope stabilization work, construction, and repair of mine and tunnel linings, bridge arch strengthening, and dome-shaped structures. Available design information is briefly discussed and design references are listed.

C-496 ACI Committee 523. 1988. "Guide for Cast-in-Place Low-Density Concrete," ACI 523.1R-86, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This guide provides information on materials, properties, design, and proper handling of cast-in-place concrete having oven-dry unit weights of 50 pcf (800 kg/m^3) or less. These concretes achieve their low unit weight by incorporating low-density aggregates, air entrainment, or preformed foam. These concretes are most commonly used in roof deck systems, where their advantages include insulating value, the ability to be sloped-to-drain, and improved fire resistance.

C-497 ACI Committee 544. 1988. "State-of-the-Art Report on Fiber Reinforced Concrete," ACI 544.1R-82 (Reapproved 1986), ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

The present state of development of the mechanics for fiber reinforcing of portland-cement concrete by metallic, glass, plastic, and natural fibers is reviewed along with techniques for mixing and mix proportioning, placing, finishing, and actual and potential applications.

C-498 ACI Committee 547. 1988. "Refractory Concrete: Abstract of State-of-the-Art Report," ACI 547R-79 (Revised 1983, Reapproved 1987), ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

Refractory concretes are currently used in a wide variety of industrial applications where pyroprocessing and/or thermal containment is required. The service demands of these applications are becoming increasingly severe and this, combined with the constant demand for refractories with enhanced service life and more efficient means of installation, has resulted in an ever expanding refractory concrete technology. ACI Committee 547 has prepared this state-of-the-art report to meet the need for a better understanding of this relatively new technology.

The report presents background information and perspective on the history and current status of the technology. Composition and proportioning methods are discussed together with a detailed review of the constituent ingredients. Emphasis is placed on proper procedures for the installation, curing, drying, and firing. The physical and engineering properties of both normal weight and lightweight refractory concretes are reported, as are state-of-the-art construction details and repair/maintenance techniques. Also included is an indepth review of a wide variety of applications together with the committee's assessment of future needs and developments.

C-499 ACI Committee 548. 1988. "Polymers in Concrete (Abstract)," ACI 548R-77 (Reapproved 1981), ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

ACI Committee 548 has prepared a state-of-the-art report on polymers in concrete, a comprehensive compilation of information on the current state of knowledge relating to polymers used in concrete, process technology, properties of the various composites of concrete and polymers, structural design information, and applications under study or in use. For detailed information and indepth discussions, the full report should be consulted. The full report has 92 pages and was published in 1977.

C-500 ACI Committee 549. 1988. "State-of-the-Art Report on Ferrocement," ACI 549R-82, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This state-of-the-art report, and publication SP-61, "Ferrocement - Materials and Applications," provide technical information on the mechanical properties, performance, and applications of ferrocement. The intent of this report is to promote the more effective use of ferrocement as a construction material for terrestrial structures in contrast to marine structures, where it has been so far most widely used.

SECTION D

MAINTENANCE AND REPAIR PROCEDURES AND TECHNIQUES

1978

D-1 "NE Corridor Improvement Plan Opens Doors for Concrete Ties." 1978 (Jan). Engineering News-Record, Vol 200, No. 3, p 58, New York, NY.

The Federal Railroad Administrator's (FRA) recent purchase of a $1.9-million track renewal machine to tear up wooden ties and replace them with prestressed concrete ties on 400 miles of track between Boston and Washington may mark the advent of widespread concrete tie use in the United States. The landmark installation of 800,000 to 1,000,000 ties aims at meeting high-speed train requirements under FRA's $1.82 billion Northeast Corridor Improvement program.

Although used extensively in Europe, the availability of sufficient numbers of wooden ties at reasonable cost and the questionable performance of early concrete tie sections slowed their acceptance in the United States. Mass transit systems frequently use them, but concrete ties are rare on major railroads.

D-2 Abraham, T. J., and Sloan, R. C. 1978 (Jan). "TVA Cuts Deep Slot in Dam, Ends Cracking Problem," Civil Engineering, Vol 48, No. 1, pp 66-70, American Society of Civil Engineers, New York, NY.

In 1972, cracking in the curved portion of the concrete dam at TVA's Fontana Project caused TVA to go on a 4-year program of investigation, analysis, and repair. Thermal expansion and some concrete growth caused a longitudinal thrust that cracked the concrete. While investigations were being made into the cause and cure for the problem, water was sprayed onto the concrete to keep it cool, and the cracks were restrained by posttensioned anchor rods and by grouting. The cracking problem was finally solved by a vertical slot cut across the dam to interrupt the longitudinal thrust.

D-3 Janson, L. 1978 (Jan). "Repair of Cracks by Plastic Injection" (in Swedish), Nordisk Betong, Vol 22, No. 1, pp 17-21, Stockholm, Sweden.

The paper describes the injection of plastics into cracks in concrete. It deals with desirable properties of the plastics used for injection, with work procedures, and with control of injection operations. Finally, it gives typical cost values.

D-4 Bailey, M. W., and Collin, W. D. 1978 (Feb). "Sawing and Drilling of Stone and Concrete," Precast Concrete, Vol 9, No. 2, pp 65-68, London, England.

This article discussed the machinery available for drilling stone and concrete. Several types of diamond and synthetic diamond drills were tested for reliability and strength on plain cured concrete. Metal bond type saws were of particular interest in the research.

D-5 "Ready-Mix System Halts Lake Erosion." 1978 (Mar). Concrete Products, Vol 81, No. 3, pp 52-53, Chicago, IL.

A new technique to combat beach erosion involves pumping ready-mixed concrete from trucks into large nylon bags placed on matting along the waterfront, thus forming a breakwater that halts eroding wave action. This stabilizes and encourages beach expansion.

Because concrete hardens underwater, the method improves the earlier practice of using sand-filled bags which often ripped open. The concrete bags can be filled rapidly and independent of the weather conditions. A crew of four workers can construct as much as 360 ft of shore protection in a 10-hr period. The system requires no barges or heavy equipment, and the light house extensions cause no environmental damage to the shore banks.

D-6 Collum, C. E., Denson, R. H., and Hoff, G. C. 1978 (Mar). "Repair and Restoration of Paved Surfaces; Bomb Damage Repair Field Trials, June 1975 - November 1976," Technical Report C-78-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

In response to a request from the Deputy Chief of Staff, Engineer, US Army, Europe (USAREUR), a program was initiated to demonstrate a proposed rapid runway repair procedure using a cellular regulated-set concrete. The work involved the design of a self-contained batching and pumping unit, the training of the military personnel to do the actual work, and a large-scale demonstration of the repair procedure. Due to a restriction on the purchase of equipment, the pumps, as built, were not able to meet the production criteria and resulted in modification of the initial approach of using cellular concrete for the repair. The initial testing of the pumps was accomplished using dug craters in the 100-ft by 200-ft by 12-in. concrete test pad. The failure of the pumps necessitated finding a different method of filling the crater and of making the repair. The new method involved the use of truck-mounted concrete mixers to mix and place the regulated-set concrete in the repair area. Using this procedure, the debris and upheaved concrete are removed from the crater area, the crater area is excavated to a depth of 3 ft below final grade, then the crater is brought up to 12 in. below final grade with crushed aggregate and compacted. A regulated-set concrete cap of 12-in. thickness is placed to bring the crater to final grade. The cap is screeded in a circular fashion using a wooden beam constructed of 2-in. by 10-in. lumber. The beam is pinned in the center of the crater on a concrete pedestal and the free end is pulled with a vehicle around the crater. In addition to the work in the field, various tests were done in the laboratory to supplement the information available from the field. The results of these studies are reported in Appendix A of this volume.

D-7 "Water Blasting Unit Develops 10,000 psi." 1978 (Apr). Modern Concrete, Vol 41, No. 12, pp 48-49, Cleveland, OH.

A new product for variable water pressure blasting is rapidly replacing sandblasting as the surface preparation standby. Several demonstrations by the Michigan manufacturer have shown liquid blasting to be an efficient, nonpolluting, and surface protecting method of cleaning. The pressurized stream of water (up to 10,000 psi) can be used in such varied applications as cleaning tar buildup off trucks or removing barnacles from ocean-going ships. With the use of a high-durability engine, new water blasting equipment will be useful to specialized industrial cleaning contractors.

D-8 Borini, D. 1979 (Apr). "Repair Works on the Up-Stream and Down-Stream Faces of the Morasco Dam (Novara)," (in Italian with English abstract), Industria Italiana del Cemento, Vol 49, No. 4, pp 239-252, Rome, Italy.

The Morasco Dam, 59 m high, with a 565-m crown forms a reservoir containing 17,650,000 m^3 of water. Twenty-five years after its construction the two faces of the dam were seriously damaged. The repair consisted of demolition of the damaged part and reconstruction of the faces. The article is well illustrated by photos, drawings, and tables and examines the characteristics of the new materials used, the concretes, the cement mixes, freeze resistance, the types of mortar used, the anchorages of reinforcements, and describes the entire repair work in general.

D-9 Boult, B. F. 1978 (Apr). "Concrete in Sport--Squash Court Walls," New Zealand Concrete Construction, Vol 22, p 10, Porirua, New Zealand.

Each year many thousands of dollars are spent replastering or patching the playing surface of squash court walls. This appears to be a complex problem since the service expected from the playing surface is clearly too severe for most present plastering practices. This article reviews research in progress on this subject.

The present practice of plastering squash court walls has a basic procedure, although variations occur. A rich cement/sand bond coat is applied to the wall to act as a key for subsequent plaster coats. This mixture is applied to the wall by throwing, hence the common name, splatter coat. A flanking coat is then applied and screeded to take all the irregularities out of the wall to the tolerances of the finished job.

D-10 "NAHB Looks Into Basement Water Leakage Problems." 1978 (Apr). Concrete Construction, Vol 23, No. 4, pp 211-213, Addison, IL.

Several preliminary steps can be made to prevent leakage in concrete basements. Test boring at the site, control of surface water, proper excavation and backfill methods, waterproofing below grade, lowered water pressure under the slab, sumps, and good supervision of the entire job are all elements of a leakage-free concrete basement construction operation.

D-11 Sedlenieks, M. 1978 (May). "Flame Treatment of Concrete for Finishing or Cleaning," Concrete Construction, Vol 23, No. 5, pp 275-277, Addison, IL.

Flame treatment is a relatively new method of cleaning concrete or roughening its surface. The flame treatment for concrete has four main applications: to pretreat the surface to achieve the best possible bond of a paint, plastic, or other applied coating; to clean the surface of oil or other stains; to expose the coarse aggregates for esthetic reasons; and to increase the friction of roads and landing strips.

The process involves moving a special high-temperature multiflame blowpipe with an oxygen-acetylene flame over the surface at a uniform speed. Concrete slabs that are thoroughly soaked with water exhibit uniform removal results. Trained personnel are necessary for the proper execution of flame treating.

D-12 "Waterproofing Concrete." 1978 (May). Civil Engineering, pp 57-59, 71, London, England.

By means of suitable mix proportion, in theory concrete in new construction should be waterproof; this is not so in practice. Modern developments have brought about treatments that nearly achieve this and are compared in this article. To upgrade extensively cracked concrete and masonry structures, laid sheeting such as butyl, hypalon, and polyolefin are often the only solutions and these methods are covered.

D-13 "Stay-in-Place Forms: Protect Bridge Piers." 1978 (May). Highway and Heavy Construction, Vol 121, No. 5, pp 98-99, Cahners Publishing Co., Inc., New York, NY.

Special fiberglass sheets are being used as wraparound forms during the repair of pier columns for a major highway bridge in Illinois, then they stay in place to provide additional waterproofing protection. That process has been used frequently in the repair of docks and other marine facilities, but this is the first known instance of nonmarine application.

D-14 Oosthuizen, A. P. C. 1978 (Jun). "New Method of Repairing Cracks in Concrete," Concrete/Beton, No. 10, pp 18-19, Johannesburg, South Africa.

A method of crack repair utilizing a low-viscosity epoxy-resin compound is described. The method has been successfully applied on a number of construction sites in Germany. The crack is first mitered out on one side of the member and is sealed with an epoxy compound. Injection nipples are then epoxied onto the other side of the crack at intervals approximately equal to the thickness of the member, and the crack is sealed between nipples, thus converting it into a watertight reservoir with numerous inlets/outlets. The epoxy resin compound is injected into the crack with a special electrically operated gun. The advantages of the method are described.

D-15 Berger, R. H. 1978 (Jun). "Extending the Service Life of Existing Bridges by Increasing their Load Carrying Capacity," Federal Highw.y Administration, Report FHWA/RD-78-133, Washington, DC.

A catalog of bridge deficiencies is developed based on the inspection of over 140 deficient bridges located in Illinois, Florida, Pennsylvania, California, and Tennessee. A classification of structure types is developed for concrete, steel, and timber bridges. Deficiencies are related to the structure classification system and a hierarchy of the most common deficiencies established. Techniques presently utilized by state highway departments to correct deficiencies are described and evaluated. Several innovative techniques for increasing the load carrying capacity are also described. Utilizing these techniques, increased capacity values are developed. Cost factors are also analyzed and graphic presentations which show the relative merit of each system are presented. Techniques for increasing load capacity include: (1) Lightweight deck systems, e.g., timber, plate, steel grid, metal; (2) changes in structural system, e.g., develop continuity in simple spans, composite action, posttensioning; (3) member strengthening techniques, e.g., epoxy attached plates, replacement members, supplemental support systems. Techniques developed for improving geometrics include widening concepts for through girder bridges and improved clearance for through truss bridges. The report includes examples of techniques developed as they apply to actual bridge rehabilitation projects. Details are shown illustrating these techniques.

D-16 Epps, J. A., Terrel, R. L., and Little, D. N. 1978 (May-Jun). "Recycling Pavement Materials: An Overview of Alternatives," Rural and Urban Roads, Vol 16, No. 5, May 1978, pp 34-36, and No. 6, Jun 1978, pp 68-71, Des Plaines, IL.

These articles discuss the overall concept of pavement rehabilitation and the fact that recycling is only one of several rehabilitation alternatives is shown. A decision to recycle pavements requires the consideration of several factors: existing conditions, surface condition, roughness, and choice of recycling technique. Surface condition, roughness, deflection, and skid resistance can all be improved through the use of proper rehabilitation methods.

Pavement recycling can be done in several ways: heating and planning of the surface with or without the addition of aggregates; heating and scarifying the surface with or without a thin overlay of aggregate; heating and scarifying with the addition of a thick overlay; and surface milling with no overlay or with a thin or thick overlay.

The advantages of each technique are discussed and associated costs are included for each particular application need.

D-17 Warner, J. 1978 (Jul). "Compaction Grouting--A Significant Case History," Journal of the Geotechnical Engineering Division, Vol 104, No. 7, pp 837-847, American Society of Civil Engineers, New York, NY.

Compaction grouting was used for the soil stabilization phase of settlement repairs to the West Orange County, California, courthouse. The 8-yr-old concrete and masonry structure was founded on a pile foundation 25 to 40 ft (7.63 to 12.20 m) deep with differential settlement. Compaction grouting was selected as the best solution as it affords close control of the zone of grout deposition due to the stiff, mortar-like grout and special injection procedures used. Therein, grout remains in a homogeneous mass, compacting the soil as it expands due to injection pressure. A total of 32,729.36 cu ft (916.5 m**S**3) of grout was injected into 162 holes. Work proceeded from the top down utilizing 1,185 hole stages of about 6 ft (1.83 m) each. Following stabilization, the structure was restored to its proper grade and necessary structural and cosmetic repairs made.

D-18 Brown, D. C. 1978 (Jul). "Tight Race at Starved Rock," Construction Contracting, Vol 61, No. 7, pp 36-37, Bobit Publishing Co., Redondo Beach, CA.

Unusual jumbo positioning and special guiding templates gave this contractor the edge in his race to repair a busy Illinois River lock in 60 days.

D-19 Chung, H. W., and Lui, L. M. 1978 (Jul). "Epoxy-Repaired Concrete Joints Under Dynamic Loads," ACI Journal, Proceedings, Vol 75, No. 7, pp 313-316, Detroit, MI.

Dynamic shear tests were carried out on concrete pushoff specimens which were severely damaged and then repaired by epoxy injection. The test results illustrate the effectiveness of the repair process in restoring the shear strength and the impulse capacity of the damaged joint.

D-20 "Low-Cost Nylon Bag Form Speeds Repair of Borer-Damaged Piles." 1978 (Aug). Engineering News-Record, Vol 201, No. 6, p 16, New York, NY.

A city in the state of Washington recently completed contracted repair work to save a group of historic buildings from sliding into a canal. The Swinomish Channel's salinity has increased since 1960 due to the diking of a major freshwater source. With the saltier water came teredos, marine borers that have caused destruction of the untreated wood piles used to support the historic buildings.

Working either at low tide or in the water, the diving organization that won the contract excavated the piles until sound wood was found, reinforced the deteriorated sections, and placed a tailored water-tight nylon bag around the pile. Spacers hold the bag away from the reinforcing mesh and provide room for the concrete to be pumped into the zippered bags, forming a concrete bandage to protect the piles from marine borers for an indefinite period of time.

The concrete reached a minimum compressive strength of 5,000 psi within 28 days but retained its nylon jacket while the strength increased.

D-21 "Track Rebuilding Behemoth Aims for a Mile-A-Day Pace." 1978 (Aug). Engineering News-Record, Vol 201, No. 6, p. 22, New York, NY.

A gargantuan track-laying machine being used in a railway improvement project in the eastern United States picks up old steel rail in its claws and scoops up worn wood ties as it simultaneously spits out new reinforced concrete ties and plows up undertrack ballast. The concrete-tie track will be suitable for high-speed trains which will be used on the rail corridor between Boston and Washington, DC. Using conveyors to supply concrete ties and take away wood ones, the track-laying machine is proceeding at a mile-a-day pace.

D-22 Madderom, F. W. 1978 (Aug). "Let's Eliminate Scaling of Driveways," Concrete Construction, Vol 23, No. 8, pp 257-458, Addison, IL.

Most contractors and concrete producers agree that the problem of scaling is best eliminated by mutual understanding and cooperation between the two.

The concrete producer must do his part by inspecting his aggregate carefully and frequently, obtaining an optimum air void system in the concrete and using proper mix proportioning and batching techniques.

Even the best quality concrete will not hold up in northern climates unless it is properly handled by the contractor. The contractor must take the responsibility for using a reasonable slump, proper finishing techniques, and adequate curing.

Even if the ready-mixed concrete is of high quality and is placed at a reasonable slump, it is nevertheless possible for the surface to scale if it is overworked with finishing tools too early. Premature finishing causes an excessive amount of fines to make their way to the surface.

Curing is of critical importance for high-performance concrete. Strength development requires water to be present for continued hydration of the cement. Concrete that is not properly cured will dry out and may attain as little as 40 percent of its strength design. Ponding is still probably the best method of curing.

It is best to avoid attacking the concrete chemically with deicers until at least 30 days after curing, or preferably not during the first winter at all.

D-23 (Deleted)

D-24 Ahari, H. E. 1978 (Sep). "Scaled Concrete - The Late Fall Problem," Concrete Construction, Vol 23, No. 9, pp 529-531, Addison, IL.

Concrete placed in late fall will be susceptible to scaling during its first winter if proper procedures are not followed. The occurrence of scaling is a complex problem.

Scaling is the peeling off of the top 1/16 to 1/8 in. of the concrete surface. It is caused by freezing and thawing in damp environments, particularly in the presence of deicing salts.

In such northern states as Michigan, Ohio, and New York, the exposure can be severe due to the prolonged cold winters and the considerable number of cycles of freezing and thawing.

Use of a moderate (3- to 5-in.) slump air-entrained concrete, avoidance of working bleed water into the top surface, and proper drainage achieved by sloping surfaces are some ways to avoid scaling. Adequate curing is also necessary.

D-25 Berger, R. 1978 (Sep). "New Techniques Speed Concrete Pipe Repair and Fabrication," Modern Concrete, Vol 42, No. 5, pp 78-79, Cleveland, OH.

Techniques that take advantage of advances in quick-set patching mortars, cements, and concrete bonding agents are being used regularly to increase efficiency and reduce work time. The techniques also enhance the appearance of pipe and even salvage pipe that might otherwise have to be discarded. The article describes some of the ways quick-set patching mortars, concrete bonding agents, and quick-set hydraulic cements are used for repair, cosmetic improvement, and fabrication at a concrete pipe manufacturing firm in Springfield, VA.

D-26 "Smoothing Adjacent Lanes Aids Concrete Lane 'drop in'." 1978 (Sep). Rural and Urban Roads, Vol 16, No. 9, p 58, Des Plaines, IL.

Dropping in new concrete between an old concrete two-lane pavement and a concrete gutter was helped by a diamond cutter that literally smoothed the way. The 25-year-old street, half asphalt and half concrete, was to be rehabilitated by replacing the asphaltic section of new concrete. Dropping in a new concrete section required smooth, level grades between the old concrete pavement, the existing concrete gutter, and the new pavement. The problem was solved with a "bumpcutter" armed with diamond cutting wheels.

D-27 Liu, T. C., O'Neil, E. F., and McDonald, J. E. 1978 (Sep). "Maintenance and Preservation of Concrete Structures; Report 1, Annotated Bibliography, 1927-1977," Technical Report C-78-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Included in this bibliography are 826 annotated references on maintenance and preservation of concrete structures. They cover the period from 1927 to 1977 on the subjects of durability and causes of deterioration, evaluating the condition of existing structures, maintenance and repair materials, procedures, and techniques. A complete subject index and author index are provided.

D-28 "Drilling and Filling is Key to Cheap, Quick, Bridge Repair." 1978 (Sep-Oct). Transportation Research News, No. 78, pp 7-9, Transportation Research Board, Washington, DC.

The paper reports and discusses the two methods that have been evolved in Kansas for repairing cracks in continuously reinforced concrete-deck girder bridges. The first, simple rebonding, involves an epoxy crack seal and then a surface epoxy injection through the seal into the crack. The second requires supporting the cracked girder with falsework, completely removing the concrete in the area of the crack, adding more reinforcing steel, and repouring the girder to its original dimensions.

D-29 Datta, O. P., and Aggarwal, S. L. 1978 (Oct). "Maintenance and Repair of Concrete Surfaces," Indian Concrete Journal, Vol 52, No. 10, pp 260-265, Bombay, India.

The maintenance and repair of a concrete surface may be necessary due to any one of several causes, such as the effects of normal wear and tear, stresses induced by abnormal differential temperatures, inadvertent errors in design, detailing and construction, and exposure to aggressive environments like fire and earthquake. The paper outlines the agencies and processes which cause the deterioration of concrete surfaces, and describes methods of maintenance and repairs including the removal of stains.

D-30 Stratton, F. W., Alexander, R. B., and Nolting, W. J. 1978 (Nov). "Cracked Structural Concrete Repair through Epoxy Injection and Rebar Insertion," Report FHWA/KS/RD-78-3, Federal Highway Administration, Kansas Division, Topeka, KS.

The objective of this project was to develop a technique for repairing cracked structural bridge concrete. The method developed consists of sealing the crack, drilling holes at 45 deg to the deck surface and crossing the crack plane at approximately 90 degrees, filling the hole and crack plane with epoxy pumped under low pressure, and placing a rebar into the drilled hole in a position to span the crack. The epoxy bonds the bar to the walls of the hole, fills the crack plane bonding the cracked concrete surfaces back together in one monolithic form, and thus reinforces the section. The epoxy injection equipment utilized was developed for hollow plane injection. Injection nozzles were built, and a large vacuum swivel was designed, developed, and built. Drilling to a 7-ft (2.1-m) depth was accomplished in 22 minutes on the first repair, and no significant gain was noted on the second. A total of 220 ft (67-m) of number 4 rebar was epoxy bonded in 55 holes to repair 18 cracks in 8 girders of 2 bridges. The first bridge has been repaired for nearly 2 years, the second 9 months without failure. This test repair cost averaged $2,000 per girder compared to a girder removal and replacement cost of $38,763 in 1975. Further development of implementation has reduced the cost to $1,000 per girder.

D-31 "Building Renovation on Brooklyn Waterfront." 1978 (Dec). Construc-tioneer, Vol 38, No. 24, pp 10-11, Chatham, NJ.

This article describes ongoing exterior restoration of a group of older industrial buildings that are being converted for commercial and office use. The facades had deteriorated badly during their 70-year exposure to waterfront weathering and presented special challenges in the planning of repair and waterproofing techniques.

As sandblasting or steam-cleaning will increase the porosity of the concrete facade and thus accelerate decay, the initial cleaning is accomplished with multiple applications of paint stripper and limestone wash. Patching and preparation of the concrete is accomplished with a brush-applied slurry of patching mortar and acrylic polymer bonding agent. Use of the slurry eliminates the need to prime exposed steel reinforcement in badly damaged sections of the facade. The patches are finally covered with sealant and allowed to cure for 30 minutes before a finishing coat is sprayed on.

D-32 Kruger, J. E. 1978 (Dec). "Protection of Concrete Floors Against Attack by Aggressive Media: Some Basic Design Considerations," Concrete/Beton, No. 12, pp 3-6, Johannesburg, South Africa.

Many a concrete failure occurs because attack by an aggressive medium has not been anticipated, or because the degree of protection is inadequate since the problem has not been defined properly, or because the wrong protection has been chosen. This paper indicates the more important basic design considerations for arriving at a proper choice of protection for concrete floors against attack by aggressive media.

D-33 Pace, C. E. 1978 (Dec). "Tests of Brick-Veneer Walls and Closures for Resistance to Floodwaters," Miscellaneous Paper C-78-16, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Floodwaters are a problem and expense to the owners of many homes and commercial buildings. It is important to determine expedient, feasible, and effective ways of floodproofing buildings which are subject to potential flooding. This study is limited to the common brick-veneer wall.

Important conclusions which were reached while performing this study are:

a. The common brick-veneer wall leaks excessively.

b. The permeability of the wall to water can only be significantly reduced by using a coating which is thick or has body. This type of coating must be applied with great care or leaks in the walls will still exist. This solution was not successfully tested in the laboratory experiments. Because of excessive coating material, time, and care this may not offer a practical solution.

c. For a closure to be watertight, it must have gasket material at its connection to the side walls and bottom and must be bolted in place. The connecting members between the closure and the side walls and floor must be continuous and sealed securely.

d. Water will flow freely through the first layer of a two-layer brick wall and along a water barrier in the wall.

e. A two-layer brick wall will support greater water depths than a one-layer brick wall.

f. A tubular seal and plastic sheet can be used to eliminate water flow through a wall and closure.

The limited tests run show that there are answers to the floodproofing problem and that effective procedures can be established which will allow brick-veneer walls to structurally support any reasonable water depth.

It is not advisable to develop a system for reducing flow of water through walls and depend on it without first testing it for performance.

D-34 Wilson, H. K. 1978 (Dec). "Grouting of Scoured Foundation, Old River Low Sill Structure, Louisiana," Miscellaneous Paper C-78-19, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

In the emergency grouting operations at the Old River Low Sill Structure, Louisiana, in late 1973 and early 1974, the Concrete Laboratory of the US Army Engineer Waterways Experiment Station was responsible for (a) development of a series of grout mixtures for placement in scoured areas, (b) supervision of mixing and placement of the grout mixtures, (c) development of instrumentation for monitoring uplift pressure and grout levels and locations beneath the structure, (d) the actual monitoring of uplift pressure and grout levels during grouting operations, and (e) determining the physical properties of field-placed grout. It is believed, after many check borings, that the physical properties of the field-placed grout closely match the design criteria, and the scoured areas have been successfully replaced.

D-35 Virkler, S. J. 1978. "Maintenance Methods for Continuously Reinforced Concrete Pavements," Report FHWA-RD-78-S0776, Purdue University, West Lafayette, IN.

In late 1974, test maintenance sections were constructed on a section of I-65 south of Indianapolis, IN. The road was stratified into "similar" sections of pavement using deflection, cracking, and breakup as selection criteria. Various types of measures including concrete shoulders, undersealing, asphalt overlay, and installation of drains with various combinations of these methods were applied as a means for strengthening the pavements. In each case the pavement was patched prior to the installation of the maintenance technique.

Since its construction, performance surveys have been made each spring and fall using deflection measurements, crack counts, and a general condition survey of the test pavements. Soil samples obtained during the construction were tested and the soil and subbase characteristics were evaluated. A cost analysis was performed with a time frame of 2 years and an estimated cost for a third year of maintenance of the pavements.

The overlay methods exhibited good behavior over the 2 years of service. The subdrains and concrete shoulder methods produced less than expected performance.

D-36 "Maintenance of Prestressed Concrete Structures." 1978. Publication 15.383, Vol 2, Cement and Concrete Association, Wexham Springs, England.

This report is a first attempt to bring the subject of the maintenance of prestressed concrete structures to prominence. It emphasizes the necessity for systematic inspection so that early knowledge of possible damage can reduce its effect. The publication also aims to provide useful and comprehensive information, based on international experience, for engineers faced with problems related to repair work and which may be outside their normal responsibilities.

D-37 Hellstrom, B., and Jonis, P. 1978. "Part 1--Repair Methods-A Study of the Literature. Part 2--Repair of Balconies-Current Methods" (in Swedish), CBI Research No. 7:78, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

This report contains a study of the literature on current methods for repair of concrete balconies in Sweden. Preliminary recommendations and detailed repair instructions concentrate on the various factors which can affect the quality of the repair work. The recommendations on inspection and repair practices are published in English.

D-38 Dartsch, B. 1978. "Preservation, Restoration, Repair: Technologies for the Repair of and with Concrete" (in German), Beton, Dusseldorf, Germany.

This book discussed all areas of concrete preservation and restoration from the cleaning and painting of concrete surfaces to the evaluation of repairs and the strength qualities of steel reinforcement. Recommended for architects, construction firms, and builders who encounter problems with concrete, the text can also be used as a reference guide for the repair of other types of buildings. Numerous illustrations, graphs, photographs, and verbatim building regulations and directions are included.

D-39 Meyer, A. H., Ledbetter, W. B., Layman, A. H., and Saylak, D. 1978. "Reconditioning Heavy-Duty Freeways in Urban Areas," National

Cooperative Highway Research Program Report 196, Transportation Research Board, Washington, DC.

The object of this report was to develop new technology by which all or part of the pavement structure on a heavily traveled urban freeway could be reconstituted rapidly or replaced (or both) so that the finished product would have a design service life equal to, if not greater than, that of the original pavement. Included in the objective was the restoration of the riding quality and nonskid characteristics of the pavement structure.

Research included an extensive literature search and discussions with contractors, material suppliers, equipment manufacturers, representatives of state highway and transportation agencies, and others having information that could help in solving the many problems involved in reconditioning urban freeways. The end product of the study is a series of detailed rehabilitation schemes for several specific structural conditions. All of the schemes are designed to permit completion of construction activity of 1/4-mile singlelane segments in 48 hr or less without total closure of the freeway to traffic and without significantly raising the elevation of the pavement surface.

D-40 King, R. A., Dawson, J. L., and Gearey, D. 1978 (Feb). "On the Detection, Repair and Prevention of Corrosion of Steel Reinforcements in Marine Reinforced Concrete Structures," Corrosion of Steel Reinforcements in Concrete Construction, Proceedings Conference, pp 135-143, London, England.

The presently available methods for estimating the rate of corrosion of steel in large reinforced concrete structures are reviewed and the disadvantages of these conventional techniques are outlined. A novel method promising to give meaningful comparative measurements of corrosion rates is described and laboratory results of a practical system based on this method are presented. Methods of repairing gross structural damage of reinforced concrete structures caused by corrosion of reinforcement steel are critically reviewed. Factors likely to affect later corrosion performance of repaired areas are detailed. Techniques available to reduce the rate of corrosion of the steel, those applicable at initial construction, and those applicable during service life of the structure are also discussed.

D-41 Stratton, F. W., Alexander, R. B., and Nolting, W. J. 1978. "Repair of Cracked Structural Concrete by Epoxy Injection and Rebar Insertion," Bridge Design, Evaluation, and Repair, Transportation Research Record 676, Transportation Research Board, National Academy of Sciences, Washington, DC.

The objective of this project was the development of a technique for repairing cracked structural bridge concrete. The method developed consists of sealing the crack, drilling holes at 45 deg to the deck surface, crossing the crack plane with epoxy pumped under low pressure, and placing a rebar in the drilled hole in a position to span the crack.

The epoxy bonds the bar to the walls to the hole, filling the crack plane and bonding the cracked concrete surfaces together in monolithic form, which thus reinforces the section. The epoxy injection equipment used was developed for hollow plane injection. A modified injection nozzle was built, and an enlarged vacuum swivel was designed, developed, and built. The hollow-stem carbide-tipped vacuum drill bits were 19.1 mm (0.75 in.) in diameter and up to 2.44 m (8 ft) long. A mechanical-advantage motion detector was designed and built and used to detect fractional vertical and horizontal motions of 1.19 mm (3/64 in.) and record them as 19.1-mm (0.75-in.) motion. Drilling to a depth of 2.1 m (7 ft) required 22 min. Fifteen 0.914-m (36-in.) long rebars were placed in repair zones. All crack injection attempted was successfully completed in 3 working days. Seventeen months after completion of the repair, no motion had been detected and the repair appeared to be permanent.

D-42 Sweeney, R. A. P. 1978. "Some Examples of Detection and Repair of Fatigue Damage in Railway Bridge Members," Bridge Design, Evaluation, and Repair, Transportation Research Record 676, Transportation Research Board, National Academy of Sciences, Washington, DC.

Examples of details that have caused fatigue damage in recently designed railway structures are given. Procedures for arresting crack growth and some repair details are described. Emphasis is placed on damage caused by secondary and out-of-plane effects often not considered by designers.

D-43 Zuckerman, A. I., et al. 1978. "Stiffening the Manhattan Bridge," Bridge Design, Evaluation, and Repair, Transportation Research Record 676, Transportation Research Board, National Academy of Sciences, Washington, DC.

The Manhattan Bridge is a suspension bridge located in New York City. It lower level carries three lanes of traffic at the center of the bridge and two transit tracks on either side. Its upper level carries two lanes of traffic over each set of tracks. The loads are supported by four cables suspended over four stiffening trusses. After the bridge was opened to traffic in 1909, breaks appeared in the upper laterals. Substituted larger members also broke. The broken pieces were hazardous to the trains, which required the removal of the entire top lateral system. The breaks were attributed to torsional stresses induced by eccentric transit loads. Because it has no top laterals, the bridge has little torsional stiffness and large vertical and lateral motions occur between adjacent trusses during passage of trains, which causes many maintenance problems. Load tests for stresses and deflections were performed on the bridge, and a single-plane 50-scale model, 18 m (59 ft) long was constructed to duplicate the motions and stresses of the prototype. Schemes for stiffening the bridge--stays radiating from the tower tops to the stiffening trusses, tie cables that had small sags from anchorage to anchorage, diagonal ties between the cables and the stiffening truss, and side-span supports--were tested on the model. The side-span supports are efficient and economical in reducing deflections at the main-span center and almost eliminate deflections of the side spans. The tower stays and diagonal ties at the center of the main span are effective in reducing deflections of the main-span quarter points.

D-44 Manning, D. G., and Chojnacki, B. 1978. "Concrete Overlays for the Protection of Reinforced Concrete Against Corrosion," Durability of Building Materials and Components, ASTM STP 691, American Society for Testing and Materials, Philadelphia, PA.

Portland-cement and modified portland-cement concrete overlays were placed on reinforced concrete base slabs containing differing quantities of added chlorides. The specimens were ponded intermittently with sodium chloride solution. Concrete overlays were effective in retarding the penetration of chloride ions. Resistance to chloride penetration was improved by decreasing the water-cement ratio of the concrete and by the use of a latex modifier or internally sealing with wax. Initially, high concentrations of chloride ions within the base concrete were redistributed within the base and the overlay. The concrete overlays caused a decrease in corrosion activity of reinforcing steel embedded in concrete containing more chloride than the chloride content threshold. Cracks accelerated the onset of corrosion of intercepted reinforcing bars.

D-45 Schrader, E. K., Fowler, D. W., Kaden, R. A., and Stebbins, R. J. 1978. "Polymer Impregnation Used in Concrete Repairs of Cavitation/Erosion Damage," Polymers in Concrete--International Symposium, SP-58, pp 225-248, American Concrete Institute, Detroit, MI.

This paper discusses the use of polymer impregnation in the repairs of concrete damaged by cavitation/erosion forces at a major dam. Impregnation was performed on conventional concrete, fibrous concrete, dry-pack patches, vertical surfaces, and horizontal surfaces. The project area and damage are described. Preliminary testing which demonstrated the feasibility of impregnating concrete on this large field project is explained. The basic design concept and procedures used to obtain a competent contractor on a low-bid basis are summarized. The construction procedures used and some of the lessons learned are included as the major part of this paper. Approximate cost impregnation depths, and performance are given. To date, this is the largest and most complex known field project of its type.

D-46 "Maintenance of Maritime Structures." 1978. Institution of Civil Engineers, Great Britain.

This publication includes: organization of the systematic underwater inspection and maintenance of offshore facilities; systematic maintenance and inspection of a major port; case histories of repairs of maritime structures; inspection and maintenance of breakwaters; deterioration of concrete structures under marine conditions and their inspection and repair; inspection, maintenance and repair of North Sea concrete structures; and BP West Sole gas field platform structures in the southern North Sea.

1979

D-47 Henel, E., and Sachse, V. 1979 (Feb). "Reconstruction of the Outdoor Swimming Pool Billstedt in Hamburg" (in German), Beton Herstellung und Verwendung, Vol 29, No. 2, pp 59-62, Dusseldorf, Germany.

This article discusses the renovation of an outdoor swimming pool which includes the use of precast concrete units stressed together to form a homogeneous building element. The new swimming pool is also heated.

D-48 "Unique Process for Repairing Concrete." 1979 (Mar). Municipal Engineering, Vol 156, No. 5, pp 154-159, Municipal Engineering Publications, Ltd., London, England.

A trademarked process uses the vacuum principle to introduce polymers into defective areas to effect structural repairs. It has been used on a London highway to fill voids under the road surface, restricting overnight road closure to only 7 hr. Holes were drilled through the pavement to the void area for injection and evacuation pipes. A flexible membrane is sealed to the surface above the void areas. The technique has been used to raise a section of sunken highway. The cost of lifting and grouting was estimated to be one-half that of conventional repair. The article describes how the process can also be used for remedial work on failing grout in tensioning ducts of bridges, beneath crane rails in an automatic warehouse, and a failed bridge bearing pad. It has also been applied to spalled and cracked concrete.

D-49 Schmolinske, A. J. 1979 (Mar). "Well Proven Injection Systems" (in German), Beton Herstellung und Verwendung, Vol 29, No. 3, pp 85-87, Dusseldorf, Germany.

This article lists important injection systems presently used for the closing of cracks in concrete. The article also looks at the main features of each system.

D-50 "Terminal Surfacing -- Bringing the Problems Down to Earth." 1979 (Apr). Cargo Systems International: The Journal of ICHCA, Vol 6, No. 4, pp 92-93, 95, 97, CS Publications Ltd, Surrey, England.

The application of high throughout technology to cargo handling has confronted many terminals with the problem of working surfaces rapidly deteriorating under the increased operational strain, ultimately resulting in serious disruption to services. This dilemma has prompted a great deal of activity especially in the analysis of surface structures and implication to design; work that may prove all the more important in the light of current trends within unitization. The article discusses various types of surfacing materials, including bituminous and concrete, and mechanical properties analyses.

D-51 (Deleted)

D-52 "Concrete Finishing and Related Problems." 1979 (Apr). Concrete Construction, Vol 24, No. 4, pp 247-258, Addison, IL.

Common finishing problems encountered during placing and finishing, their prevention, and remedies are reported. Segregation, excessive bleeding, plastic cracking, surface blisters, pickup or peeling, scaling, dusting, and crazing are surface defects examined in the article.

D-53 "Vacuum--A New Accessory to Repair." 1979 (May). Concrete Construction, Vol 24, No. 5, pp 315-321, Addison, IL.

Onsite repair of deteriorated concrete and stone and other masonry is being done by a new technique developed in Britain. The process uses vacuum to impregnate concrete or friable stone with silane formulations, thus consolidating and weatherproofing it. Defective areas of concrete pavements or structures can be filled and repaired with polymers by this method.

The process involves only a few steps. First, the area or object is covered with polyethylene film. Air is then extracted from the pores or cavities of the concrete or stone by vacuum pumps, creating a low-pressured area. A suitable impregnant is then introduced beneath the polyethylene cover. Normal atmospheric pressure causes the impregnant to penetrate the previously evacuated pores or cavities.

D-54 "Finishing Architectural Concrete." 1979 (May). Concrete Construction, Vol 24, No. 5, pp 319-321, Addison, IL.

Architectural concrete includes all exposed-to-view vertical concrete, soffits, and ledges of any building or structure. Finishes may be smooth or textured. Smooth surfaces are usually obtained with plastic-coated or plastic-laminated plywood forms, steel forms, fiber glass forms or tempered hardboard forms. Textured surfaces generally are achieved by sandblasting, bushhammering, forming with roughsawn lumber, using special form liners, or fracturing the projections of a striated surface. Preparing smooth surfaces for patching and cleandown; preparing, applying, and curing the grout; and finishing textured surfaces are discussed.

D-55 Billington, C. J. 1979. "Underwater Repair of Concrete Offshore Structures," Offshore Technology Conference, Vol 2, pp 927-937, Dallas, TX.

This paper describes a major research program which has been carried out to develop proven underwater techniques for repairing cracked and spalled areas on concrete offshore structures. Materials have been tested and where necessary new materials developed for priming surfaces, for crack sealing prior to injection, for crack injection, for patching and for bonding steel to concrete. Preliminary screening tests on a large number of proprietary materials showed that few form a bond to high strength concrete underwater. Materials developed during the project are described together with tests which demonstrate the superior performance of these materials.

D-56 Hyma, W. R. 1979 (May). "Replacing Timber Decks on Railroad Bridges with Prestressed Concrete Slabs," Concrete International: Design & Construction, Vol 1, No. 5, Detroit, MI.

Thirty-two miles of bridges owned by a major railroad are steel-deck girder spans with timber-ballasted decks. The Atchinson, Topeka, and Santa Fe is emerged in a program of replacing 50- to 60-year-old timber decks with precast, prestressed concrete slabs which are bonded to the steel with an epoxy grout. Transverse joints between slabs also are epoxy-grouted. The result: a monolithic, water-tight deck which protects the steel and should greatly extend the painting cycle.

D-57 Gehring, D. 1979 (May). "Site-Precast Panels Match Intricate Design of An Old Master," Concrete Construction, Vol 24, No. 5, pp 307-308, Addison, IL.

The article discusses the use of custom-made fiber glass form liners to form the exterior surface of structural site-precast concrete panels for an 88-room addition to the Frank Lloyd Wright-designed Biltmore Hotel in Phoenix, AZ. The original building consists of individual hand-cast concrete blocks, many with textured bas-relief patterns, hand-laid in double-wythe grouted masonry wall construction. To match the patterns in the original building visually, yet save both time and labor, the contractor proposed using new fiber glass form liners to form the surfaces in precast concrete panels. The panels could then be erected in large sections.

D-58 Linder, R. 1979 (May-Jun). "Stripping, Cutting, and Demolition of Concrete Elements" (in Spanish), Revista IMCYC, Vol 17, No. 98, pp 23-33, Instituto Mexicano del Cemento y del Concrete, Mexico.

The author deals with techniques used to modify, repair, or eliminate reinforced concrete constructions or parts of them. He defines the stripping, cutting, and demolition operations that are carried out for this purpose and describes the procedures and materials employed.

D-59 Mouton, Y. 1979 (Jun). "Contribution to the Study of the Repair of Cracked Concrete Structures by the Injection of Epoxy Binders" (in French), Rapport de Recherche 86, Laboratoire Central des Ponts et Chaussees, Paris, France.

A study was conducted to evaluate the efficiency of crack repairs in concrete. A complementary study of capillary phenomena shows that the binder advances into the cracks thanks mainly to hydrostatic pressure, and that no phenomenon of a chromatographic type occurs which could interfere with the reticulation of the binder.

D-60 Deskins, R. L. 1979 (Jul). "Cathodic Protection Requirements for Concrete Pipes," Materials Performance, Vol 18, No. 7, pp 50-51, National Association of Corrosion Engineers, Katy, TX.

Difficulties associated with estimating the probability that concrete-coated buried or submerged steel pipelines will corrode are surveyed. A report is made on electrical surveys on 10 concrete-coated pipelines in Southern California buried or submerged in soil or salt/fresh water. Soil resistivities are described. Consequences of corrosion related to soil resistivity are estimated. Methods for determining survey values indicative of corrosion attack and requiring cathodic protection are considered and criteria of protection evaluated. It is concluded that cathodic protection is an effective way to control corrosion of concrete-coated pipelines where active pipe-to-soil conditions or low resistivity soils prevail.

D-61 "New Subbase Crushed from Old Pavement." 1979 (Aug). Construction Equipment, Vol 60, No. 2, pp 46-49, Des Plaines, IL.

Eleven miles of concrete road surface on a Chicago, IL, expressway are being removed, sent through a crushing plant, and then relayed as subbase for a new roadway to replace the old. Deterioration of the original roadway is due to a poor subbase rather than the surface concrete. Removal of the old pavement is complicated by an asphalt overlay. At one point, it was though that the concrete and asphalt could be crushed together for the new subbase material. Engineering tests, however, determined the material to be unsuitable. So the old asphalt is first stripped by bulldozers, then used to form a temporary haul road for the construction project. Later, a portion of it will be picked up and used as part of the new shoulders. Advantages of the recycling project include costs savings due to savings in the purchase of new materials, and speed.

D-62 "New York Tests First Cement Concrete Overlay." 1979 (Aug). Engineering News-Record, Vol 203, No. 9, pp 18-19, New York, NY.

This article describes the New York State Transportation Department's first thin-bonded concrete overlay test. The project, costing $226,860, consists of removing and replacing a 2- to 2-1.4-in. thickness of 5,830 sq yd of badly spalled portland-cement concrete on a section of a state highway.

The field conditions for the test are ideal. Aside from the scaling, the 8-year-old highway is in excellent conditions, carries heavy concentrations of traffic, and is subjected to weather conditions that are variable and intense. If the test is successful, it could literally pave the way for larger scale overlay projects.

D-63 "Cathodic Deck Protection for Bridges Comes Slowly." 1979 (Sep). Engineering News-Record, Vol 203, No. 10, pp 24-24, New York, NY.

The cost of chloride corrosion of reinforcing steel in concrete highways and bridge decks is estimated to be $500 million annually. Most engineers say cathodic protection (CP) is the only sure way to halt this corrosion in an existing slab. The method is cost-competitive with other bridge rehabilitation methods, such as overlays of low slump or latex-modified concrete. However, CP has not been accepted by most state highway agencies, and its development is floundering. This article describes the history of the system, its use, and the problems which may be preventing its acceptance. The use of the system in Ontario, Canada, is also described; the problems found the United States have not been obstacles to the system there, and it is routinely installed.

D-64 Ainsworth, D. L. 1979 (Sep). "Grouting Instrumentation, Old River Low Sill Control Structure," Miscellaneous Paper SL-79-23, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Instrumentation was developed and used in the field to monitor the presence and flow of grout during remedial grouting of the Old River Low Sill Control Structure. Measurements were also made of uplift pressures by means of transducers installed in packers in drilled holes through the slab. This report presents information on the development and field use of instruments to detect the presence of grout, the rate of buildup under the base of the structure, and pressure increase under the slab due to grouting operations. All data were electronically recorded and were used extensively to regulate the grouting operation.

D-65 Harris, P. A. 1979 (Oct). "Use of Grout Bags in Strengthening Reinforced Concrete Bridges," Concrete Construction, Vol 24, No. 10, pp 673-676, Addison, IL.

The Carmarthen Bridge, linking west Wales and the other parts of the country, opened in 1938. The reinforced concrete bridge carries two major highways over a river, a railway, and a road. Recent inspections revealed evidence of distress, because the bridge is now carrying heavier loads than it was designed for.

Traffic was restricted to avoid overloading the bridge, and work was begun to strengthen one traffic lane pending construction of a bypass around Carmarthen. Two methods of strengthening the reinforced concrete beam/slab and slab decks were used. Slabs in public view were to be strengthened with stressed external strand, while other spans were to be strengthened with weathering steel support frames, beams, or towers. The use of grout bags above these steel frames and beams, to take up the variable space and provide uniform support, provided the key to the success of this second operation. Continuous contact was needed between the steel frames and the beams; nylon-reinforced polyvinyl grout bags pumped full of cement-sand grout to fill varying gaps between the frames and beams and the deck soffits were used. The system was easy to install where access was difficult, could take any shape to fill the gap, and also provided enough rigid contact to transmit loads from the concrete deck to the frames and beams.

D-66 Van Gemert, D. 1979 (Oct). "Reinforcement and Repair of Concrete Constructions with Glued Reinforcement" (in Dutch), Cement, Vol 31, No. 10, pp 437-440, 449-451, Amsterdam, The Netherlands.

A method has been developed for repairing concrete structures with impaired bearing capacity. This method is characterized by using (gluing) reinforcing elements such as strips, angled irons, or special flat steel sections. A so-called bicomponent epoxy resin is used as a glue. Various experiments and test loadings are reported. This method is also applicable to constructions which have to withstand heavier loads due to modification.

D-67 Imai, H., et. al. 1979 (Oct). "Method of Repairing and Strengthening of Izumi High School Damaged by Miyagi-Oki Earthquake and Proof of Repairing" (in Japanese), Concrete Journal, Vol 17, No. 10, pp 9-22, Japan Concrete Institute Tokyo, Japan.

A high school building was heavily damaged by an earthquake in June 1978. Among the buildings constructed according to the present standard, the school was the first to sustain heavy damage. This paper discusses the repair methods for the damaged building and the design for aseismic strengthening. The cause of the damage was examined in terms of horizontal strength as well as the ratio of sharing the force of the earthquake. By analyzing the horizontal strength of the building after repairs and strengthening, it was confirmed that the resistance to earthquakes was increased.

D-68 Cantor, I. G. 1979 (Oct). "Renovation: Stripping the Years from Old Buildings," Consulting Engineer, Vol 53, No. 4, pp 74-79, London, England.

The major renovation of an older building is one of the most complex and high-risk construction and engineering projects possible. Unexpected structural problems tend to become routine and no assumptions can be made from existing plans.

Some structural assumptions, however, can be made based on the age of the building. Most buildings erected in the last 16 years are difficult to alter. In general, most modern buildings are engineered solely with their present stress in mind. Stringent cost control analyses and the economics of lighter structures make any other approach to new construction economically unfeasible. Concrete buildings built before 1963 and conceived under the former elastic theory are prime candidates for alteration and/or recycling. These buildings generally have a greater inherent structural capacity to assume heavier loads than newer structures. However, alternations that were not incorporated into the original plans, or changes made in the field during actual construction may vary from the existing plans, complicating renovation work.

A study of the structural condition of the main building on Ellis Island, NY, recycling of buildings for new uses, and recycling buildings for reuse are discussed.

D-69 Chand, S. 1979 (Oct). "Cracks in Buildings and Their Remedial Measures," Indian Concrete Journal, Vol 53, No. 10, pp 268-272, Bombay, India.

Development of cracks in buildings results in loss of strength and stability, causes rain penetration, decreases sound insulation, and affects esthetics and overall efficiency. The paper addresses itself to the task of detecting causes of cracks and suggests remedial measures to combat the situation. Methods of repair and precautions to be taken while repairing the cracks have also been described in detail.

D-70 "Thin-Bonded Concrete Overlay Applied to Busy Road North of Utica." 1979 (Nov). Constructioneer, pp 26-27, Chatham, NJ.

A concrete pavement repair project involving an existing four-lane highway in New York is reported. The original 9-in.-thick portland-cement concrete pavement was built in the early 1970's and over the years several of the panels scaled due to a lack of adequate air entrainment. Because these scaled panels were randomly spaced and not confined to one lane, it was decided to try an "inlay" approach to refurbishing 5,830 sq yd of the pavement. The design called for the mechanical scarification of the panel to a plane 2 in. below the original top surface. In some cases an existing bituminous patch had to be removed. All surfaces were sandblasted and then airblasted to remove any loose debris just prior to grouting. A portland cement-sand grout of stiff slurry consistency was then applied to the dry surface. A Class D mix with water reducer-retarder was then placed on top of the moist grout. Class D mix used a 3/8-in. coarse aggregate and 725 lb of cement per cu yd. This experimental work was essentially an application of the high density, low slump (Iowa) process to roadway surfaces.

D-71 "Urban Expressway Rebuilt on Recycled Concrete Base." 1979 (Nov). Engineering News-Record, Vol 203, No. 22, pp 24-25, New York, NY.

Working against a rigorous schedule and other constraints, a joint venture contractor brought in the first half of a huge Chicago expressway reconstruction job exactly on target. The contract requires completely rebuilding 15 miles of the Edens Expressway in two construction seasons. The 28-year-old highway is the first major urban expressway in the US to be rebuilt entirely. And, because the contractor elected to crush the old concrete pavement, remove its reinforcing steel, and reuse the material as base, it is said to be the world's largest recycling project. On the first half of the job, 97,000 cu yd of concrete, or nearly 200,000 tons, were recycled. Construction details are given.

D-72 Danielsson, J. 1979 (Nov). "Grinding Can be a Routine Floor Finishing Method," Concrete Construction, Vol 24, No. 11, pp 727-733, Addison, IL.

The intentional omission of floating and troweling floors in favor of finishing by grinding is proving a useful method of constructing certain types of concrete floors in the US. The proprietary method involves placing, screeding, and bull-floating the concrete, curing it for 2 to 5 days, and finally using a machine which is a grinder-finisher. The resulting surface is flat and slightly porous with a sanded appearance. It is free of ridges, trowel marks, and other protrusions; and surfaces have closer tolerances than trowel-finished floors. Finishing is usually done at the rate of 4,000 sq ft per man per day. No weak surface film remains. The method produces an excellent base for tile, linoleum, resilient flooring, and carpeting, and is useful in high-rise construction, commercial, and institutional buildings, residential construction, shopping centers, loading docks, and for tilt-up panels that are to be painted. Advantages include big labor savings due to the elimination of waiting time for bleed water to leave the surface before finishing. Finishing procedures and handling special problems are reported.

D-73 Svensson, O., Fagerlund, G., and Petersons, N. 1979. "Repair of Concrete Balcony Slabs," International Conference on Concrete Slabs, CBI Rapport 4:79, pp 25-42, Swedish Cement and Concrete Research Institute, Stockholm.

More than 200,000 concrete balconies in Sweden are badly damaged by frost and corrosion of the reinforcement. Many balconies have been repaired but the repairs, which are normally various types of plastic coatings, have often failed within a few years. This paper describes a research project in which the durability of different repairing systems is studied in the laboratory and in the field. In the laboratory the frost resistance, the thermal gradient sensitivity, and the diffusivity of the repairs are studied. In the field the general behavior of different repairing systems is followed up. The moisture state in the structural concrete slab beneath different repairs is also measured. Some preliminary results are given indicating that it is very doubtful if any repairing system can protect a low grade concrete slab from continuing damage.

D-74 Schnoor, C. F., and Renier, E. J. 1979. "Portland Cement Concrete Overlays of Existing Asphaltic Concrete Secondary Roads in Iowa," Transportation Research Record 702, pp 75-82, Transportation Research Board, Washington, DC.

Forty-two km (22 miles) of existing asphaltic concrete low-volume roads were resurfaced with portland-cement concrete in five counties of Iowa during 1977. In two counties, complete removal of the old asphalt surface was required prior to repaving with portland-cement concrete. In the other three, the old asphalt surface was retained as a base for the new pavement. This paper discusses procedures developed to establish and control grade and portland-cement concrete overlay thicknesses in the cases where the old asphalt was retained. On one project, grade was established and minimum thickness retained by use of a computer. Economics of design and construction procedures were determined by county engineers. Projects were approved by the Iowa Department of Transportation prior to construction. Thickness monitoring and required equipment modification was accomplished by contractor development and cooperation. The resulting pavements show that portland-cement concrete overlays can be successfully constructed over existing asphaltic concrete roads on low-volume secondary systems with a minimum of surface preparation and can contribute a long-term economical solution to the ever increasing cost of maintenance.

D-75 Dreyman, E. W. 1979. "Corrosion Control of Reinforcing Steel by Cathodic Protection," Concrete Industry Bulletin, Vol 19, No. 2, Spring 1979, pp 11-15, New York, NY.

The author reports on corrosion and corrosion control of reinforcing steel in concrete. Remedial measures include such reinforcing bar treatments as inhibitors, coatings, alloying, and cathodic protection.

Cathodic protection reverses corrosion cell action by inducing direct electric current which changes the potential of the structure in a more negative direction. Protection is achieved when a shift of 300 mv is attained or a potential of -0.85 volt to a copper/copper sulfate reference cell is reached.

The corrosion control method is being used to protect dock structures in seawater, pipelines, and many structures imbedded in concrete including reinforced steel concrete pipe. Cathodic protection of bridge decks, power supply, overall costs, potential testing, and recent developments are other areas discussed.

D-76 Kahn, L. F., Will, K. W., and Sanders, P. H. 1979. "Strengthening Existing Bridges by Means of Epoxy Injection," Transportation Research Research Record 711, pp 47-48, Transportation Research Board, Washington, DC.

A low-viscosity epoxy was pressure injected between portions of the concrete slab and steel stringers of a noncomposite highway bridge to determine whether the structure could be strengthened by inducing composite action. The slab was jacked off the girders at different distances to inspect for an acceptable separation for satisfactory flow of the epoxy. After epoxy injection, the slab was cut into sections stripped from the girders. Epoxy did not penetrate between the slab and girder where the slab was not first raised. A 0.8-mm (0.03-in.) shimmed separation was required for flow, and then epoxy covered only 60 percent of the flange surface. Push-off tests of several slab sections showed that the natural bond between the concrete slab and the steel girders was greater than the concrete-epoxy-steel connection. It was concluded that the epoxy-injection technique shows only marginal promise of strengthening existing bridges, but that the natural bond might be inducing significant composite behavior.

D-77 Halstead, W. J. 1979. "Recycled Portland Concrete Pavements--State-of-the-Art Summary--Part II," Report FHWA/VA-80/12, Virginia Department of Highways and Transportation, Richmond, VA.

This report constitutes a review of the literature concerning recycling of portland-cement concrete pavements by crushing the old pavement and reusing the crushed material as aggregate in a number of applications. A summary of the major projects conducted by state transportation departments is included.

Crushed portland-cement concrete has been successfully used in the following applications: (1) graded-aggregate bases; (2) cement-treated bases; (3) asphalt base courses and pavements; (4) portland-cement concrete bases (econocrete) and pavements; and (5) source of supply for independent commercial operations selling aggregate for a variety of applications.

In any given circumstances, the cost and availability of new aggregate and the cost of disposing of the old concrete play important roles in establishing whether or not recycling is a desirable alternative. Consequently, each project or the general situation for a given area must be examined separately and the decision made on the basis of local conditions.

D-78 Eakin, J. H., and McMillen, D. G. 1979. "American Falls Replacement Dam," Transactions, Thirteenth International Congress on Large Dams, New Delhi, India, 29 Oct-2 Nov 1979, Vol 1, pp 1-20, International Commission on Large Dams, Paris, France.

The replacement dam was constructed from 1976 through 1978 on the Snake River in southeastern Idaho. Replacement was required due to excessive cracking and deterioration caused by alkali-aggregate reaction in the concrete. It consists of a structure which attaches to the original dam and incorporates portions and replaces others. Embankment sections at both abutments connect to a central concrete-gravity section that incorporates the spillway, low level outlets and the powerhouse intake structure, and the entire dam is topped with a two-lane highway. The completed project also included construction of a new 92,000 kW powerhouse. Construction of the American Falls Project required maintenance of a tight schedule to provide reservoir storage capacity; permit irrigation releases; maintain highway and railroad traffic across the Snake River, and continue power production at an existing generating plant. Also, the new powerhouse had to be so located that penstocks, the powerhouse structure and the tailrace would fit various constraints discussed in the paper.

D-79 Baccini, S., and Manca, F. 1979. "Damage to the Cuga Dam in Sardinia and Subsequent Repair and Completion Works," Transactions, Thirteenth International Congress on Large Dams, New Delhi, India, 29 Oct-2 Nov 1979, Vol 2, pp 633-649, International Commission on Large Dams, Paris, France.

The dam is a 54-m-high rockfill structure with a reinforced concrete upstream facing. It was built on a complex volcanic formation of lavas and outcropping tuffs which have been subject to more or less intense argillization. During and after construction it was badly damaged mainly by settlement of the foundation soils. Repairs consisted of construction of a rockfill embankment with an impervious silt core, which was built up against the existing dam after the cracks in the concrete facing and cutoff had been treated by laying a coat of semiopen bituminous concrete to act as a filter behind the core and also as a plastic hinge between the old and new structures.

D-80 "Joint-Related Distress in PCC Pavement: Cause, Prevention, and Rehabilitation." 1979. National Cooperative Highway Research Program Synthesis 56, Transportation Research Board, Washington, DC.

This synthesis of design and construction practices will be of special interest and usefulness to pavement designers, materials and maintenance engineers, and others seeking information of the causes and prevention of joint problems in concrete pavements. Detailed information is also presented on the rehabilitation of joint defects. The report reviews the causes of distress and ways in which joint problems might be prevented. Rehabilitation methods and techniques for their selection are also discussed.

D-81 "Failure and Repair and Continuously Reinforced Concrete Pavement." 1979. National Cooperative Highway Research Program Synthesis 60, Transportation Research Board, Washington, DC.

This synthesis will be of special interest and usefulness to highway design and maintenance engineers and others seeking information on the design, construction, maintenance, and repair of continuously reinforced concrete pavement (CRCP). The performance of CRCP has revealed a number of failure modes that are traceable to design, construction, materials, and maintenance deficiencies and such other factors as environmental conditions and traffic loadings. This report includes a review of the cumulative experiences of states that have constructed and maintained CRCP. Guidelines for repair techniques are included, and areas of needed research are identified.

D-82 Zielinski, J. W. 1979. "Methods of Strengthening Foundation and Foundation Footing of Buildings" (in Polish), Prace Instytutu Techniki Bukowlanej, Vol 8, No. 3, pp 39-52, Warsaw, Poland.

A review is presented of procedures in use for protecting buildings during repairs of foundations of existing residential and public buildings under definite technical conditions. The principles are discussed of relieving continuous foundations being strengthened by underpropping the floors, schematics are given of structures relieving the ferro-concrete- and steel columns, as well as of basing the walls on transverse and longitudinal steel beams with the use of lifting appliances or wedges. From among the methods of strengthening foundation sections, the following are singled out: widening the foundations, replacing weaker foundation sections, deepening, as well as transmitting the loads onto piles or wells. The importance is emphasized of a thorough analysis of the condition of the structure and the soil, as well as of an appropriate organization of work and careful workmanship for obtaining proper performance of the foundation systems being strengthened, and of the whole structure.

D-83 Petersons, N., and Johansson, L. 1979. "Flame Cleaning of Concrete," International Conference on Concrete Slabs, CBI Rapport 4:79, pp 15-23, Swedish Cement and Concrete Research Institute, Stockholm, Sweden.

The purpose of flame cleaning concrete surfaces is to improve the bond of various coatings, such as plastics or mortar. Flame cleaning can also be used for cleaning such surfaces as oil-stained concrete floors and to give an esthetically pleasing appearance to concrete facades. Furthermore, flame cleaning can be used to increase friction on concrete roads and landing strips.

Flame cleaning is performed by passing a special multi-flame oxygen-acetylene blowpipe (temperature approximately 3,100° C) at uniform speed over a concrete surface. Depending on the properties of the concrete, a surface scaling or a partial melting of the surface layer is obtained. After flame cleaning, any melt residue or loose particles are removed with ... brush surface scaler or the like.

The studies show that flame cleaning at normal blowpipe speed does not cause any significant deterioration of the basic properties of the concrete. Flame cleaning is a good method for cleaning concrete surfaces.

This paper, published with ... others in this report, was presented at the International Conference on Concrete Slabs in Dundee, 3-6 Apr 1979.

D-84 Uchida, T. 1979 (Oct-Nov). "A Study on Interface of New and Old Concrete, With Particular Reference to the Raising of a Gravity Dam," Thirteenth International Congress on Large Dams, New Delhi, India, 29 Oct - 2 Nov 1979, Vol 1, International Commission on Large Dams, Paris, France.

The Kuroda Dam, to be used as the upper reservoir of the Okuyahagi Pumped Storage Project (the Chubu Electric Power Company began work on this project in 1976 and plans to put it into operation in 1981), is an already existing concrete gravity dam of 35 m and is to be raised by 10.2 m by the addition of concrete on downstream side of the dam, thus having its storage capacity increased.

There are instances of concrete gravity dams having been raised but a special feature of the Kuroda dam operation was that a computer was used. Through simulation the temperature distribution and thermal stress of the dam were calculated to determine the thermal stress in interface of the old and new concrete, and then the results were compared with actual measurements.

D-85 Martensson, G. B. 1979 (Oct-Nov). "New Intake for Extension of Harspranget Power Plant," Thirteenth International Congress On Large Dams, New Delhi, India, 29 Oct - 2 Nov 1979, Vol I, International Commission on Large Dams, Paris, France.

Great difficulties are normally experienced when changes of an existing dam structure is considered. The safety of the dam has to be maintained at the same time as a minimum of disturbance or interruption of the operation of the plant is of great economical importance. An example of this kind of work is the installation of unit No. 5 at Harspranget.

The Harspranget Power Plant is located in the River Stora Lulealv in northern Sweden. The plant was built between 1945 and 1952. The head is 107 m, the turbine discharge 380 m^3/s, and the power output 320 MW. Three units of equal size were installed.

The geology of the area was a critical factor for the location of the dam, as a wide zone of crushed rock passes the dam site east of and parallel to the river. This zone had to be avoided when planning the dam, which was therefore located entirely to the west of it. The rockfill dam consists of a main dam straight across the course of the river, with a maximum height of 50 m, and a lateral dam with a maximum height of 18 m between the crushed zone and the river.

D-86 Shenolikar, A. K., and Apte, S. S. 1979 (Oct-Nov). "Strengthening of Old Gravity Dams in Maharashtra State with Special Reference to Bhatghar Dam," Thirteenth International Congress on Large Dams, New Delhi, India, 29 Oct - 2 Nov 1979, Vol II, International Commission on Large Dams, Paris, France.

In the State of Maharashtra, India, a number of dam structures were built around the beginning of the twentieth century. These structures built with stone masonry in lime mortar having become 40 to 50 years old and because such dams had shown distress elsewhere, the State Government appointed in the year 1964 a "review team" to examine the condition and built-in safety of these old dams and suggest measures for ensuring their safety and satisfactory performance over the years to come. The report of the team covered four dams, namely Bhandardara dam, Bhatghar dam, Radhanagari dam and Darna dam.

D-87 Cole, B. A. 1979 (Oct-Nov). "Repair of Scotts Peak Dam, Tasmania," Thirteenth International Congress on Large Dams, New Delhi, India, 29 Oct - 2 Nov 1979, Vol II, International Commission on Large Dams, Paris, France.

During the period November 1974 to December 1975, a series of underwater repairs was carried out by divers. The main technique was to backfill the wider cracks and holes with crushed rock, sand or mortar filled sacks, and to cover all defects with butyl rubber sheets. Each period of repair succeeded in reducing the leakage temporarily, but soon further cracking occurred and more repairs were required. The behaviour of the dam and the details of the temporary repairs have been described by Fitzpatrick (Discussion on Q. 44, 12th ICOLD 1976, Vol V, p 54).

This paper describes the design and construction of an impervious gravel blanket to provide a permanent seal for the upstream face of the dam.

D-88 Abraham, T. J. 1979 (Oct-Nov). "Analysis and Repair of Cracking in TVA's Fontana Dam Caused by Temperature and Concrete Growth," Thirteenth

International Congress on Large Dams, New Delhi, India, 29 Oct - 2 Nov 1979, Vol II, International Commission on Large Dams, Paris, France.

This paper discusses the causes of concrete expansion resulting in cracking. Three factors were involved in the expansion. Solar heat absorption during the summer through the top surfaces and the downstream face of the dam resulted in a seasonal cycle of considerable temperature deformations. Second, an alkali-silica reactivity within the mass concrete resulted in a moderate long-term concrete growth. The third cause was gradual warming of the interior of the dam from the low initial temperatures due to artificial cooling of concrete during construction. This third factor was most pronounced in the upper part of the dam.

The analyses leading to selection of the wide expansion slot method of repair are described. Also included are descriptions of field procedures for cutting and sealing the expansion slot.

D-89 Howard Needles Tammen & Bergendcff. 1979. "Bridge Deck Joint-Sealing Systems: Evaluation and Performance Specification," National Cooperative Highway Research Program Report 204, Transportation Research Board, Washington, DC.

This report is recommended to bridge design engineers, construction engineers, materials engineers, maintenance engineers, researchers, specification writing bodies, and others concerned with bridge deck joint-sealing systems. It contains the findings of a comprehensive assessment of the performance of currently used systems based on a literature review, a survey of highway agencies, and contact with selected individuals knowledgeable on this subject. A recommended performance specification for joint-sealing systems, accompanied by a commentary, is included in this report.

D-90 Markus, T. A., ed. 1979. "Building Conversion and Rehabilitation," Butterworth Publishers, Inc., Boston, MA.

There is no doubt that the conversion of an existing building to new uses is a growing activity throughout the Western World. Some of the economic, social, architectural, and psychological forces which have brought about this rapid shift from the post-World War II urban development ('destruction', in the eyes of some) are discussed in this book.

The book is the outcome of a Symposium held at the University of Strathclude in May 1977, which took place during an exhibition of executed projects. There was a deliberate attempt to bring together ideas, theories, and experimental techniques, with practice, executed projects, and experience. In architecture this juxtaposition of theory and practice is all too rare and the bridges and continuities which exist in other disciplines are only just being built (or, re-built).

D-91 Bramer, G., and Drobusch, H. 1980 (Jan). "Foundation Reinforcement and Underpinning at the Reconstruction of a Power Station" (in German), Bauplanung-Bautechnik, Vol 34, No. 1, pp 22-24, Berlin, Germany.

The reconstruction of a power plant, which had to be performed without interruption of the operations of the plant, required elaborate planning and technologies. The different methods which had to be used to provide adequate foundations and to prevent uneven settlement are described and illustrated in the article. [R. Fischl]

D-92 "Dam's Renovators Blow Its Top." 1980 (Jan). Engineering News-Record, Vol 204, No. 5, pp 30-31, New York, NY.

To speed work and hold down costs on the renovation of an inadequate dam protecting San Antonio, TX, from flash floods, contractors used explosives to demolish sections of the structure while concrete placement proceeded simultaneously to stabilize the dam and prevent overturning.

Work on the dam includes widening the "footprint" portion of the structure, constructing a spillway, relocating the gate operation room, and raising the nonoverflow sections of the dam on each side of the spillway. In total, 46,000 cu yd of concrete will be placed.

Additional stability in the nonoverflow sections will be provided by drilling holes for and adding prestressing rods through the dam to be anchored to the underlying limestone strata. Two fault zones in the limestone under the dam are being grouted on the upstream side to prevent leakage and erosion problems and to keep water from migrating under the dam. To build the spillway, a series of decorative thin arches on the downstream face of the dam had to be removed.

Prestressing for strengthening the entire length of the dam was ruled out because the underlying limestone in some areas was faulted, soft, and shot through with solutions cavities. By using prestressing in nonoverflow sections and mass concrete in the spillway segment, it was possible to increase the effective deadweight and shift the center of gravity to provide the required stability and sliding resistance at minimum cost.

D-93 Tuthill, L. H. 1980 (Jan). "Performance Failures of Concrete Materials and of Concrete as a Material," Concrete International: Design & Construction, Vol 2, No. 1, Detroit, MI.

A concrete structure does not have to collapse and fall down to be a failure - and one seldom does. But, in any respect that concrete performance as a material falls short of reasonable and potential expectations, it is to that degree a failure. There are so many things that can be done to avoid and prevent such shortcomings and disappointing results that this should never happen. It is the purpose of this paper to review what things can go wrong and what is practical to do to make sure that these things do not go wrong but go as they should for best results.

D-94 Robertson, J. L. 1980 (Feb). "Pavement Recycling Saves Time and Money on Giant Interstate Job," Rock Products, Vol 83, No. 2, pp 52-54, Chicago, IL.

Recycling broken concrete pavement became an accepted construction technique on a major project in Chicago during the summer of 1979. A joint venture of four contractors resurfaced 15 miles of the Edens Expressway, north of Chicago.

D-95 Musannif, A. A. B. 1980 (Feb). "Demolition of Concrete Buildings," Proceedings, Institution of Civil Engineers, Part 1, Design and Construction, Vol 68, pp 91-102, London, England.

Types of firms engaged in demolition and organizations within the industry are outlined. Methods and equipment in current use such as crane and ball, hand-demolition, explosives, thermic boring, diamond drills and saws, busters and excavator-mounted hydraulic concrete-breakers are described and applications are given. Observed cases of total demolition and cutting of concrete in building alterations are described. The importance of safekeeping of "as built" drawings of modern structures to aid in the preparation of demolition schemes when the time comes for these buildings to be demolished is outlined. Recycling of concrete from demolished buildings is discussed.

D-96 "Diamond Saw Speeds Tower Repair." 1980 (Feb). Engineering News-Record, Vol 204, No. 8, pp 18-19, New York, NY.

Repair of a tornado-damaged cooling tower at a nuclear power plant in Mississippi is moving ahead nearly 2 years after high winds sent a tower crane boom inside the structure crashing through its rim. Concrete placement has been initiated to fill in the 70-ft-long, 150-ft-wide gash. The high winds and damage had left the tower with latent structural defects, and any selective repairs to the tower would not be as safe as rebuilding it.

The plant owner decided to repair the tower with a technique devised to cut away the damaged portion in a stepped fashion using a wall sawing rig equipped with a diamond blade. Repair consisted of cutting away and squaring the edges to make a larger, cleaner V-shape notch. The damaged portion is being reconstructed in about 12 concrete lifts of about 6 ft each.

D-97 Madderdom, F. W. 1980 (Feb). "How to Eliminate Concrete Scaling," Concrete International: Design & Construction, Vol 2, No. 2, pp 110-114, Detroit, MI.

This paper presents methods that can be used by specifier, ready-mixed concrete producer, contractor, and owner to help eliminate the scaling problem. It points out that concrete must be treated more carefully and must be demonstrated to be durable. The specifier should take steps necessary to write a tight concrete specification and enforce it by the use of a qualified independent testing laboratory that reports to the owner or owner's representative. The ready-mixed concrete producer must have a quality control program. The need for frequent inspection of the aggregates, the use of proper mix proportioning and batching techniques, and special attention to air contents are all necessary for the production of durable concrete. Air contents must be watched more carefully as many ready-mixed concrete producers have recently noticed rapid and unexplained loss of entrained air. The contractors must do their part in using reasonable slump, timely finishing with the right kind of tools, and early curing. Owners must be careful regarding the use of any deicers, especially those with ammonium sulfate or ammonium nitrate.

D-98 Pinjarkar, S. G., Osborn, A. E. N., Koob, M. J., and Pfeifer, D. W. 1980 (Mar). "Case Study--Rehabilitation of Parking Decks with Superplasticized Concrete Overlay," Concrete International: Design & Construction, Vol 2, No. 3, pp 62-67, Detroit, MI.

This article discusses the use of a low water-cement ratio superplasticized specialty concrete overlay to repair deteriorated parking garage floors. It covers repair procedures, repair specifications, and construction considerations. An example of rehabilitation of an existing 15-year-old reinforced concrete parking structure using a superplasticized fill and overlay concrete is presented.

Data are included concerning the chloride ion content within the deteriorated concrete; the 3- and 28-day compressive strengths of the superplasticized fill and overlay concrete; and the air content and plastic unit weight of the superplasticized concrete.

Material concerning the surface preparation technique for the deteriorated concrete, concrete transportation, technique for adding superplasticizer to a ready-mixed truck, quality control tests, and placing and curing techniques are also presented. Observations concerning experiences gained during the project are also made.

D-99 "Demolition." 1980 (Mar). New Zealand Concrete Construction (Wellington), Vol 24, pp 5-10, Porirua, New Zealand.

Demolition prior to redevelopment can be a costly undertaking, accompanied by some risk to persons in the vicinity, neighboring property, and frequently by objectionable noise, dust, and fumes. Therefore, the sophisticated skills required to demolish obsolete buildings are increasing. The essence of demolition is to reduce the structure into small enough elements to be removed to a dump site. To achieve this process economically and safely, the risk of nuisance, damage to neighboring property, and residues of dangerous material must be minimized. Structural control and basement ground support must also be maintained.

Various tools are used in demolition operations, including diamond or air tools, hydraulic breakers, presplitting tools, "nibbling" tools for thick ground slabs, oxy-acetyline torches, and thermic lances for creating holes in and weakening reinforced concrete. General methods of demolition; pusher arm, demolition ball, and wire rope pulling; deliberate collapse; and explosives. Because contemporary buildings may be used differently in the future or may need to be demolished, the implications of possible demolition on structural design are discussed. British codes of practice for safe demolition are also discussed.

D-100 "Three Steps to Correct Surface Defects." 1980 (Mar). Concrete Construction, Vol 25, No. 3, pp 215-219, Addison, IL.

The amount of work that must be put into the correction of surface defects will depend on how carefully the formwork has been erected and removed and on whether or not the concrete has been placed correctly. Close attention to proper procedures for forming and concreting will unquestionably reduce the effort required for final finishing. If, however, after the formwork has been removed, certain corrective measures must be taken, some suggestions are given.

To remove fins which may have formed in the joints of the formwork or streaks of mortar that have run down the face of the completed surface, rub the area with a fine or medium carborundum stone. This will also serve to fill most of the smaller air holes, if the concrete is no more than a day or two old. It is important to go over a wide area, not just the blemished portion, to achieve good results.

Holes left by form bolts or ties can be filled with mortar, ideally made in the same proportions of cement and sand used in the concrete. To correct honeycombing, cut the concrete as far back as the reinforcement, if necessary, and fill with grout.

In any patching operation, the material must be allowed to cure properly. The patched area must be fog sprayed and kept covered until it has hardened sufficiently. Careful treatment during these finishing stages of producing an almost flawless concrete surface is just as important as it is throughout the entire construction job.

D-101 Kilareski, W. P. 1980 (Mar). "Corrosion Induced Deterioration of Reinforced Concrete--An Overview," Materials Performance, Vol 19, No. 3, pp 48-50, National Association of Corrosion Engineers, Houston, TX.

Magnitude of the steel reinforcing bar corrosion problem in highway bridges is described. Procedures for reducing access of chlorides to the bars and electrophoretic and cathodic protection corrective systems are described, and their effects and probable utility are reviewed. Applicatio[illegible] a[illegible]odic, cathodic, and water-resistant coatings to the steel, and [illegible] [illegible]ts obtained, are considered.

D-102 Knudsen, C. V. 1980 (Apr). "Re-decking a Bridge with Precast Concrete," Civil Engineering, Vol 52, No. 4, pp 75-77, American Society of Civil Engineers, New York, NY.

Redecking a 1,627-ft deck girder bridge on the Pennsylvania Turnpike with precast concrete slabs allowed the bridge to remain partially open to traffic during the entire construction period without interfering with setting concrete. Advantages of this method also include enhanced safety due to absence of dangerous field work normally involved with installing forms for cast-in-place concrete, and quicker construction time. Complete construction procedure is described, with attention to problems of controlling relative motion between adjacent slabs. Final cost of this method was comparable to that for cast-in-place concrete. Case histories of similar smaller-scale projects are included.

D-103 "When Wood Decks Deteriorate, Replace with Concrete." 1980 (Apr). Concrete Construction, Vol 25, No. 4, pp 343-344, Addison, IL.

After extensive research, topping of elevated residential wood walkways with concrete proved to be the perfect solution from the standpoint of economy and long-range freedom from maintenance.

D-104 Coghlan, G. T., and Vanderpoel, A. 1980 (May). "Vesuvius Dam Spillway: A Case History of Concrete Performance, Failure, and Repair," Concrete International: Design & Construction, Vol 2, No. 5, pp 42-44, Addison, IL.

The Vesuvius Dam concrete spillway experienced progressive deterioration. Completed in 1939, minor repairs were made in 1949, 1955, and 1964. Cracking, spalling, raveling of rock pockets, and efflorescence continued. In 1977, it was determined that repairs were needed to preserve the structural integrity. An end-product specification was prepared permitting the prospective contractor to propose the repair material and method. The low bidder proposed dry mixed pneumatically applied mortar or shotcrete. Quality, economical repair of the spillway was obtained using the shotcrete. Smooth finish to repairs larger than 3 ft (1 m) square indicated the need for stage removal and minimum form work. A final cleaning and preservative surface treatment of linseed oil somewhat emphasized the repair areas. Where surface treatments are intended for cosmetic effect as well as weather proofing, trial applications might help establish an effective application rate.

D-105 Heuze, B. 1980 (Mar). "Cathodic Protection on Concrete Offshore Platforms," Materials Performance, Vol 19, No. 5, pp 24-33, National Association of Corrosion Engineers, Houston, TX.

Lessons learned during the past few years on five North Sea concrete platforms where cathodic protection systems were incorporated in the construction design are discussed. A general discussion of corrosion behavior of steel inside and outside concrete in seawater and methods of corrosion control provide a background to an analysis of the protective means and criteria that will provide adequate potential coordination, without interaction hazards, or the concrete support with the external steel equipment. The importance of the duct material in the safeguard of the prestressing tendons, the cathodic protection limitation in case of coating cracking and disbondment, and precautions to be taken against welding stray currents are discussed. Included is an approach to the corrosion prevention of an hypothetic drilling, storage, and production concrete platform. The approach focuses on design philosophy, currently required by the reinforcing bar and well casings, corrosion protection inside J tubes and tunnels, monitoring, lighting protection, and criteria of the cathodic protection system appraisal. The paper is not intended to cover all corrosion prevention, but only to discuss the problem areas that remain and to provide something to guide the design of future concrete platforms.

D-106 Anderson, G. H. 1980 (Jun). "Cathodic Protection of a Reinforced Concrete Bridge Deck," Concrete International: Design & Construction, Vol 2, No. 6, pp 32-36, Detroit, MI.

The placement of a cathodic protection system on a restored reinforced concrete bridge deck is presented as a means of arresting corrosion of the reinforcing steel in a chloride contaminated environment. Necessary inspecting and testing prior to structure selection and restoration are discussed. Consideration is given to the system installation and required level of polarized potentials of the top mat reinforcing steel for cathodic protection. During the past 2 years of observation, the top mat of reinforcing steel has been polarized at 300 to 400 mV more negative than the "static" potentials. Corrosometer probe data indicates that further corrosion of reinforcing steel has not occurred since the system was energized. The power required to maintain cathodic protection has averaged about 50 kW per month. As the humidity increases and deck resistance decreases, more current is required to maintain the "set" potentials. The constant structure-to-reference potential control has proven convenient and effective in maintaining the desired level of cathodic protection under the ever changing environmental conditions of the deck.

D-107 "Control Joints Can Eliminate Leaking Cracks in Basement Walls." 1980 (Jun). Concrete Construction, Vol 25, No. 6, pp 474-476, Addison, IL.

A Michigan company has been installing control joints with water stops in its cast-in-place walls. Since the technique has been employed, the firm has not had to repair a leak problem in a single basement. Control joints are used to prevent cracking, especially in sizable expanses of concrete. Backing each control joint midway in the wall thickness is a plastic water stop that prevents leakage through any crack that may occur in the joint. Complete preparation and installation details are included in the article.

D-108 "Drillers Tap Cracked Dam." 1980 (Jun). Engineering News-Record, Vol 204, No. 24, p 14, New York, NY.

Drilling crews inside Dworshak Dam's drainage and grout gallery have completed the first of a series of pressure relief bores into a 1/10-in. crack evident since 1972 when the 717-ft-high concrete gravity dam began impounding water. It is located 15 ft above the 525-ft-thick base of monolith 35, about one-third of the way from the left abutment. Apparently, the crack is next to and follows the path of a 5-in.-diam vertical drain.

D-109 "Caps Graft New Piers to Old." 1980 (Jun). Engineering News-Record, Vol 204, No. 23, p 18, New York, NY.

When a contractor in Jackson, MS, had to excavate next to a hospital to add a wing now under construction, the excavation threatened the foundation of the existing building by extending below the level of its concrete piers. Instead of choosing a conventional shoring method to relieve the threat, the two engineers devised an underpinning procedure that, though unorthodox, is saving time and money.

D-110 (Deleted)

D-111 "Precast Deck Panels Speed the Update of the Clarks Summit Bridge." 1980 (Aug). Constructioneer, Vol 34, No. 17, pp 27-31, Chatham, NJ.

A Pennsylvania company is redecking a turnpike bridge by utilizing precast reinforced concrete panels and doing it in about half the time required by the conventional method of cast-in-place concrete construction.

The 1,700-ft-long bridge rises 140 ft above the road and railroad tracks. Because it was required to remain open to traffic during the redecking operation, the resulting traffic vibrations would have had a damaging effect on the setting of concrete placed in the conventional way; thus the conventional method was ruled out and the precast plank method selected instead. The old deck was removed, and the structural steel was measured so that the precast concrete planks could be fabricated to conform exactly to the elevation of the steel at the exact point of placement. Each one of the 360 planks was made to fit precisely on the deck. They measure approximately 28 ft 8 in. by 7 ft 6-1/4 in. by 6-3/4 in. deep and weigh about 1,800 lb. The epoxy grout used to secure the planks is placed on top of the original steel and is retained in place with the neoprene strips. Joints between the planks are filled with nonshrink grout.

D-112 "Time and Tide Wait for No Man on Wharf Extension Project." 1980 (Aug). Heavy Construction News, Vol 24, No. 33, pp 8-10, Toronto, Ontario, Canada.

How do you strengthen a 44-year-old concrete wharf so it will be capable of supporting a pair of rail-mounted container cranes which each weigh 545 tons - especially when the wharf substructure is subjected to 6.7-m (22-ft) tides twice every 24-hr day? The article tells how.

D-113 Whitman, R. V., Heger, F. J., Luft, R. W., and Krimgold, F. 1980 (Jul). "Seismic Resistance of Existing Buildings," Proceedings, American Society of Civil Engineers, Vol 106, ST7, pp 1573-1592, New York, NY.

A particular opportunity to upgrade the seismic resistance of existing buildings arises when their lifetime is extended by major renovations. There is lacking, however, a set of guidelines that relates the cost of strengthening a structure to the probable reduction in earthquake-induced damage and life loss. This paper offers a recommendation for strengthening buildings undergoing renovations in zones where intensity of expected seismic shaking is low. Two buildings, one a masonry bearing wall and heavy timber floor warehouse and the other a reinforced concrete flat slab factory, are studied to determine the existence of weak links in seismic resistance and the cost of upgrading such resistance during major renovations. The expected damage from three levels of earthquake for the two buildings is summarized in damage probability matrices; these matrices are then used to compute mean damage ratios (MDR). Each MDR is shown as a function of strengthening cost, providing a means of estimating the reduction in seismic risk of these buildings from their present condition when they are strengthened to a recommended practical level or replaced with new construction.

D-114 Waddell, J. J. 1980 (Sep). "Basic Steps of a Concrete Repair Program," Concrete International: Design & Construction, Vol 2, No. 9, pp 30-33, Detroit, MI.

A basic approach to concrete repair is outlined. The procedure is broken down into six discrete steps: diagnosis, prognosis, scheduling, selection of method, preparation, and application.

D-115 Bobrowski, A. 1980 (Sep). "Prestressed Concrete Steps Modernize Twickenham Stadium," Concrete International: Design & Construction, Vol 2, No. 9, pp 99-101, Detroit, MI.

A repair program has been designed for the reconstruction of damaged concrete steps at the Rugby Football Union Ground in Twickenham, England. The deteriorated steps were cut away from the existing steel support beams. Reinforcing was fixed around the steel beams and new concrete support steps were cast in place. Then, precast, prestressed concrete steps were erected in place to span between the new cast-in-place concrete support steps. All the surfaces were given a waterproofing acid and alkaline resistant final treatment which gave the structure a uniform appearance.

D-116 Delargey, R. P. 1980 (Sep). "Repair of Bascule Bridge Pit Using Epoxy Injection," Concrete International: Design & Construction, Vol 2, No. 9, pp.63-67, Detroit, MI.

A Philadelphia firm used a system of drilling holes into concrete walls and injecting epoxy under 3,000 psi (20.7 MPa) pressure into those holes to repair cracking and deteriorating concrete bridge pier walls at the Water Street Bascule Bridge in Milwaukee, WI. The epoxy was injected from the interior face of the walls against high hydrostatic pressures on the exterior face. The epoxy stopped the infiltration of water through the cracks and cavities in the concrete walls, allowing workmen to remove deteriorated concrete and apply a new interior layer of special mix water-resistant concrete to rehabilitate the wall.

D-117 "Pile Restoration." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, pp 116-117, Detroit, MI.

Several companies have developed concrete pile restoration systems which employ pile jackets that serve as forms for the placement of fresh grout around the deteriorated pile and remain in place permanently. As an example, the patented pile restoration system is described.

D-118 Johnston, F. T. 1980 (Sep). "Fire Damage Repaired in Concrete Silos," Concrete International: Design & Construction, Vol 2, No. 9, pp 130-131, Detroit, MI.

Severe explosions and fire occurred at a Louisiana grain company terminal causing tremendous damage to the concrete slipformed silos. Washington and Illinois firms were contracted to perform visual inspection of the damage, perform tests on concrete and reinforcing, and prepare a report outlining the areas and extent of damage to the silos. A Columbus, OH, company prepared final drawings and specifications for the silo repairs and provided construction management during the actual repairs which included demolition and removal of bad concrete and reinforcement, sandblasting, shotcreting, casting new concrete, and pressure injection of epoxy to repair cracks.

D-119 "Underwater Grouting Stabilizes Bridge Pier Foundations." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, pp 126-129, Detroit, MI.

A United States railway company uses a unique process of inspection and underwater grouting as a part of its railway bridge preventive maintenance and safety program. An Ohio firm of maintenance specialists, trained and qualified to use diving gear, uses its patented "bagpipe grouting" procedure to install grout-filled nylon mesh bags around concrete bridge pier foundations to stabilize the piers against the erosive effects of silt-laden river currents.

D-120 "Concrete Sawing and Drilling." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, pp 46-48, Detroit, MI.

The economics of constructing, repairing, and modifying concrete has changed because of the advancement of diamond saw blades and drill equipment. The Concrete Sawing and Drilling Association, Inc., Moorestown, NJ, was formed in 1972 to represent the interests of this growing industry. The association has developed specifications on various aspects of concrete repair and modification work.

D-121 Mass, G. R., and Meier, J. G. 1980 (Sep). "Investigation and Repair of Hoist Dam," Concrete International: Design & Construction, Vol 2, No. 2, pp 49-56, Detroit, MI.

An investigation was made of the concrete in a 54-year-old gravity arch dam. Visual examination of the structure showed severe concrete weathering and erosion. Depth of deterioration and condition of interior concrete was studied by core drilling. Petrographic examinations and laboratory tests were made on core specimens. Additional information was obtained from a repair program underway by the owner. The study showed that complete restoration would require an average of 1.2 ft of concrete replacement on the upstream face and 2.3 ft of concrete replacement on the downstream face. Replacement was made by the preplaced aggregate concrete method. The interior concrete was not of first quality but when protected from exposure by a high quality concrete exterior further deterioration would be minimized and the structure would be capable of many years of continued service.

D-122 "Frank Lloyd Wright's Fallingwater Home Restored to Original Elegance." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, Detroit, MI.

The elegant fallingwater home designed by Frank Lloyd Wright began to face increased concrete deterioration some 25 years after its construction. It was Wright's appreciation for the natural look of concrete, thus leaving exposed surfaces untreated, that led to the eventual problems of discoloration, pitting, and spalling, among other problems. Restoration consisted of sandblasting the entire exterior concrete surface followed by the application of a fast-setting, nonshrink patching mortar mixed with a bonding agent for repair of the damaged areas. Two coats of a cement-based coating mixed with a bonding agent was then brushed over all exposed surfaces to provide future protection. Finally, an apricot mortar paint which matched the Wright's original color specification was applied.

D-123 "Clark Summit Bridge Redecked." 1980 (Sep). Concrete International: Design & Construction, Vol 2, No. 9, Detroit, MI.

The Pennsylvania Turnpike Commission's Clark Summit Bridge was redecked using a method employing precast concrete slabs. This method offered such advantages as lower cement-water ratio, better vibration, optimum curing, and no deck forms.

D-124 Thome, J. J. 1980 (Sep). "Jefferson Davis Memorial Repaired with Structural Concrete Bonding," Concrete International: Design & Construction, Vol 2, No. 9, Detroit, MI.

The Jefferson Davis Memorial is a 351-ft (107-m) concrete obelisk that suffered from extensive cracking and spalling due to natural weathering and freeze/thaw exposure. Pressured injections of epoxy were used to repair these cracks. Subsequent ultrasonic tests were conducted to determine the effectiveness of the injection procedures. Also, caulking, waterproofing, and epoxy patching repairs were accomplished.

D-125 De Lange, G. 1980 (Sep). "Structural Repair of Fire Damaged Concrete," Concrete International: Design & Construction, Vol 2, No. 9, pp 27-29, Detroit, MI.

An intense fire in the x-ray archives of the St. Elizabeth Hospital in Alkmaar, Holland, caused severe damage to the concrete structure. To determine the stability of the structure, several cores were taken from the beams and ceiling and the columns were tested ultrasonically. The consulting engineers concluded there was no reason to tear down the structure as long as the repairs were made very carefully by specialists in the field. Three repair techniques were used: structural repair of the cracks using epoxy injection, shotcrete repair of damaged concrete surfaces, and stiffening of structural members.

D-126 Stratton, F. W. 1980 (Sep). "Custom Concrete Drill Helps Repair Shear Cracks in Bridge Piers," Concrete International: Design & Construction, Vol 2, No. 9, pp 118-119, Detroit, MI.

The Kansas Department of Transportation now repairs cracked, continuously reinforced concrete deck girder bridges by silicone sealing the crack, vacuum drilling dust-free holes 6 in. (152 mm) apart and 45 deg to the deck surface, crossing the crack plane at about 90 deg, filling the hole and crack plane with epoxy pumped under low pressure, and placing a near full-depth length of reinforcing bar into the drilled hole to span the crack by at least 18 in. (0.46 m). The epoxy bonds the bar to the walls of the hole, fills the sealed crack plane, bonding the cracked concrete surfaces back together in one monolithic form and reinforcing the section.

D-127 McDonald, J. E., and Liu, T. C. 1980 (Sep). "Repair of Concrete Surfaces Subjected to Abrasion-Erosion Damage," Concrete International: Design & Construction, Vol 2, No. 9, Detroit, MI.

A variety of materials including armored concrete, conventional concrete, epoxy resins, fiber-reinforced concrete, and polymer-impregnated concrete were used with varying degrees of success in the repair of erosion-damaged structures. It appears that given appropriate flow conditions in the presence of debris, all of the materials are susceptible to some degree of erosion. No one material demonstrated a consistently superior performance advantage over alternate materials. Improvements in materials should reduce the rate of concrete damage due to erosion, but will not solve the problem. Until the adverse hydraulic conditions that caused the original damage are minimized or eliminated, it will be extremely difficult for any of the materials currently being used in repair to perform in the desired manner. Prior to major repairs, model studies of the existing stilling basin and exit channel should be conducted to verify the cause(s) of erosion damage and to evaluate the effectiveness of various modifications in eliminating undesirable hydraulic conditions.

D-128 Holland, T. C., and Turner, J. R. 1980 (Sep). "Construction of Tremie Concrete Cutoff Wall, Wolf Creek Dam, Kentucky," Miscellaneous Paper SL-80-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Significant leakage was occurring at a Corps of Engineers dam. The cause of the leakage was postulated to be flow through the dam's cutoff trench or through solution cavities beneath the dam or through both. The repair technique selected was to construct a concrete cutoff wall through the earth-fill portion of the dam into the rock foundation using a modification of the diaphragm wall technique often used in foundation construction. Concrete was placed by tremie to construct the individual elements making up the wall. The construction methods, equipment, and materials are described in this report.

The report emphasizes the effort to determine the cause of isolated areas of heterogeneities such as honeycomb and laitance which were found in the completed wall. The apparent cause was a combination of segregation occurring during the fall of the concrete through the tremie, the small diameter of the wall elements, the smooth walls of the casings being used for the elements, and the rapid rate of concrete placement. It is believed that these last three factors inhibited concrete remixing within the wall elements leading to the heterogeneities noted.

Since the problems were confined to cased elements, no detrimental effects on the cutoff wall are anticipated. Overall, the procedure has proved to be an effective cure for the leakage at the structure.

The problems identified also have bearing on other types of deep, confined tremie concrete placements such as cast-in-place piles or piers or the filling of precast concrete elements.

D-129 Ray, G. K. 1980 (Oct). "Quarrying Old Pavements to Build New Ones," Concrete Construction, Vol 25, No. 10, pp 725-729, Addison, IL.

Recycled concrete is old concrete that has been removed from pavement, foundations, or buildings and crushed to produce aggregate. This aggregate can then be used as aggregate in new concrete, in soil cement, or simply as stone for aggregate bases or pavement subbases. Recycled concrete can be used in concrete bases built with concrete mixers and slipform pavers. Before use as aggregate in new concrete pavement, tests must be made to show whether the new concrete made with crushed concrete aggregate will have acceptable strength and durability.

In recycling concrete, reinforcing steel or other embedded items must be removed. Care must also be taken to prevent contamination of the concrete by dirt or other undesirable materials, such as gypsum plaster products from buildings. Sizes of crushed concrete can be specified for the intended use.

The experiences of a number of agencies in recycling highway and airport pavement are summarized in tables, and cost comparisons are made.

D-130 Schrader, E. K., "Repair of Waterstop Failures," Journal of the Energy Division, Vol 106, No. EY2, pp 155-163, American Society of Civil Engineers, New York, NY.

Various methods of repairing failed waterstops or creating new waterstops where the old ones have failed have been examined. The work considered primarily relates to high pressure conditions at working joints such as occurs in dams, but it is also applicable to many other types of structures. Field experience for each repair method is described. A new concept of drilling along a joint and filling the hole with elastic filler to create a cast-in-place waterstop has been used with good success.

D-131 Maidl, B., and Hahlhege, R. 1980 (Nov). "Reinforcement of a Railway Tunnel with Steel Fibre Reinforced Shotcrete" (in German), Beton Herstellung Verwendung, Vol 30, No. 11, pp 413-414, Dusseldorf, Germany.

The railway tunnels of German national railways are regularly inspected for defects on the lining. In older tunnels, there is frequently an internal leaf of brickwork provided with a sealing coat of shotcrete as protection against climatic influences, flue gas, mountain water, and vibrations. Cracks and spallings in this sealing coat must be repaired in such a way that full consideration is given to the operational and technical requirements of the railways. To cause as little obstruction as possible, the repair work is done during the nightly interruptions of the train service, since large amounts of equipment have to be transported to the place of work.

D-132 Carbonara, G. 1980 (Nov). "Ancient Monuments Restored by Using Various Types of Mortar, Grout and Precasting" (in Italian), L'Industria Italina del Cemento, Vol 50, No. 11, pp 1097-1122, Rome, Italy.

The successes and failures of strengthening a dozen churches, bridges, and castles are discussed. It is suggested that the repairs be potentially reversible because of past failures in recognizing root causes of damage.

D-133 Pohlhammer, V. 1980 (Nov). "On-Site Volumetric Proportioning: Key to Successful Bridge Repair," Modern Concrete, Vol 44, No. 7, pp 39-40, 62, Cleveland, OH.

Bridges in Illinois, like bridges almost everywhere in the United States, were suffering a specific type of damage caused by corrosion of the reinforcing steel within the concrete. The corrosion was both induced and accelerated by sodium chloride and other deicing chemicals. Although research programs had developed good cement-rich overlay concrete, the concrete which worked most effectively was stiff and difficult to handle, and could not be mixed in conventional mixers. This article describes the use of the volumetric proportioning unit which solved the mixing problem. The mixer, manufacturing concrete on site, produced and delivered the mixes without difficulty. Moreover, the mixers eliminated waste. The mixers have become such an essential tool that, since 1977, their use has been specified for all major maintenance and rehabilitation projects in Illinois. The stiffness of the mixes was also improved by the development of a latex emulsion consisting of styrene and butadiene plus a combination of surfactants and emulsifiers. The enhanced latex additive crated a highly plastic, almost fluid concrete when placed in an otherwise normal concrete mix.

D-134 Lane, K. 1980 (Nov). "Connecticut-FHWA Demo Job Evaluates PCC Recycling," Rural and Urban Roads, Vol 18, No. 11, pp 31-32, Des Plaines, IL.

The Federal Highway Administration (FHWA) and the Connecticut Department of Transportation teamed up to recycle a 1,000-ft-long section of portland-cement concrete on an interstate highway to evaluate recycling of old concrete for new pavements. Preliminary samples of a 24-year old concrete pavement were analyzed for compressive strength and chloride content. The sample concrete was then crushed, and the resulting coarse aggregate tested according to state standard requirements for soundness, wear resistance, and durability. Tests showed the aggregate was satisfactory. Strength and chloride content of the new concrete mix were then evaluated and found to pass all requirements. Finally the ability to place the material with standard paving machinery was observed, to find whether recycling was practical.

When the project was completed, the work showed that there were no problems in design, proportioning, handling, placement, finishing, or curing. Engineers will now begin checking performance of the pavement in the field.

D-135 Vanek, T. 1980 (Nov-Dec). "Strengthening Existing Floor Slabs" (in English and French), Building Research and Practice, Vol 8, No. 6, pp 360-367, Paris, France.

Techniques for the strengthening of existing reinforced concrete structures in general restoration or as a defect remedy have been developed in Czechoslovakia. Old floor slabs, strengthened by a new concrete layer, are evaluated here.

A change in building use, greater load requirements, or deterioration may cause a need for strengthening work. Different methods are used to strengthen floor slabs, however only the method of an additional concrete layer is considered here. It is important that the old and new layers of concrete interconnect to form a good bond. The most effective thickness of the new layer was found to be 3 to 5 cm, containing a mesh reinforcement. Soiled or oil-coated concrete may not be economical to cover with a new layer, old concrete in this condition is best completely removed. Slackened or hollow areas on the surface of the old slab should be removed also.

The old surface should be kept in a humid state for about 2 hr before concreting and a mortar or epoxy layer can be applied to help bond the old and new slabs. Steel mandrels, metal plates inserted in bored holes of the old slab, and mortar coating assist a good connection under dynamic stress. Mutual bracing by high-strength bolts is also advantageous.

D-136 Winand, A., Paduart, A., and Dubois, P. M. 1980. "Repair of a Railway Bridge in Prestressed Concrete with Three Continuous Spans" (in French), <u>IABSE Proceedings</u>, No. P-27/80, pp 21-35, Zurich, Switzerland.

A railway bridge in prestressed concrete with three continuous spans and in caisson form cross section suffered damage when a road transport collided with it. The present article describes the proceedings of the delicate repair operations carried out by means of prefabricated units as well as the putting into stress by hydraulic jacks.

D-137 "County Bridge Replacement." 1980. Reprint RP252.01E, Portland Cement Association, Skokie, IL.

This article reports an economic, comprehensive bridge replacement program instituted in Graves County, Kentucky. Old bridges are being replaced with prefabricated concrete structures for approximately the same cost as repairing old substandard structures. The program hinges on use of a prefabricated concrete cap and beam combination. Nine forms are used that make bridge sections 3 ft wide and up to 20 ft long. Segments may be shortened by moving a wooden dam inside the form. Skilled welders and machinists are needed for the forms' fabrication; but no special construction skills are required to cast segments and erect bridge sections.

D-138 Raithby, K. D. 1980. "External Strengthening of Concrete Bridges with Bonded Steel Plates," TRRL Supplementary Report 612, Transport and Road Research Laboratory, Berkshire, England.

There are occasions when an existing concrete bridge deck needs local strengthening to improve its serviceability under current traffic loading. The use of steel plates bonded to the surface as additional reinforcement can sometimes be an economically attractive solution. An example of the use of this technique to improve the working load capacity of a group of bridges at a motorway interchange is described. Full-scale loading tests on one of the bridges before and after strengthening demonstrated that the required improvements had been achieved. Results of associated laboratory tests are also given, with some indication of where further research may lead to improvements in performance for future applications. Until the long-term durability of bonded joints in this type of construction has been established, the technique is not recommended for general use but can be considered for certain applications. Exposure tests are in process to determine whether there is likely to be any deterioration of bond efficiency with time.

D-139 "Bridge Deck Renewal with Thin-Bonded Concrete Resurfacing." 1980. Concrete Information Pamphlet No. IS207.01E, Portland Cement Association, Skokie, IL.

Bonded portland-cement concrete resurfacing for bridge deck repair is a proven maintenance procedure. Whether the concrete is high density and low slump or latex modified, the purpose of the resurfacing is the same: to repair deteriorated decks, restore riding quality, and protect the reinforcing steel from detrimental penetration of the chlorides in deicing salts. This pamphlet describes procedures involved in construction of thin-bonded concrete resurfacing for bridge decks with either high-density, low-slump concrete or latex-modified concrete. Details on concrete mix, deck preparation, bonding grout, placing concrete, and curing are included.

D-140 Shanafelt, G. O., and Horn, W. B. 1980. "Damage Evaluation and Repair Methods for Prestressed Concrete Bridge Members," National Cooperative Highway Research Program Report 226, Transportation Research Board, Washington, DC.

Research is described to provide guidance for the assessment and repair of accidental damage to prestressed concrete bridge members, primarily longitudinal girders. Current repair techniques, including splicing, replacement, and epoxy injection, are described with appropriate calculations and data. The accidental damage discussed in this report includes damage by fire, vehicle collision, and during manufacture. Collisions account for over 80 percent of the damages to bridges under traffic.

The lack of published information on the repair aspects of this subject prompted the evaluation of repair methods for suitability and effectiveness. The present practices of replacement or repair are based on the urgency of returning a construction to use. Some repairs have not performed well because they were hurriedly done to restore the facility to service after a collision. These repair decisions, inspection, engineering assessment, and performance are discussed, with the emphasis on collision-damage repair.

Repair-in-place techniques, specifically splice repairs, were evaluated for load restrictions, durability, speed of repair, costs, esthetics, and materials. Some other methods evaluated require further testing or special development to enhance performance and durability characteristics.

The guidelines developed for damage assessment and for selection of repair methods are structured to result in logical and appropriate techniques. A principal finding of the study is that the damage inspection phase should be carefully differentiated and separated from the engineering assessment phase. Inspection should report the damage facts, and the engineering solutions for an effective repair should then be chosen according to the guidelines reported.

D-141 Manning, D. G., and Ryell, J. 1980. "Decision Criteria for the Rehabilitation of Concrete Bridge Decks," Transportation Research Record 762, Transportation Research Board, Washington, DC.

A systematic approach to bridge-deck rehabilitation is presented. Bridge-deck rehabilitation is consuming an increasing proportion of the resources of highway agencies. The nature and extent of deterioration are highly variable so that there is neither a single problem nor a single solution. The requirements for a condition survey are described. The performance of concrete overlays, waterproofing membranes, and cathodic protection applied to existing structures is assessed from field studies and the literature. Decision criteria that can be used to identify the most appropriate method of rehabilitation for any particular structure are given.

D-142 Fromm, H. J. 1980. "Successful Application of Cathodic Protection to a Concrete Bridge Deck," Transportation Research Record 762, Transportation Research Board, Washington, DC.

The effectiveness of the cathodic protection treatment of an Ontario concrete bridge deck after 3 years of service is evaluated. The Duffins Creek bridge was the first Ontario deck to be repaired and treated with cathodic protection. One-half of the deck was treated, and the other half was left untreated. Corrosometer probes were placed in the treated half of the deck. These probes showed that cathodic protection was preventing further corrosion. After 3 years, the deck was stripped and the protected and unprotected sides were compared. It was found that the treated side had much less corrosion than the untreated side. It also became apparent that corrosion had occurred below the rebars, where the epoxy injection technique had been used for repairs. The most current Ontario system of cathodic protection has now been applied to the entire deck.

D-143 Nicholson, J. P. 1980. "New Approach to Cathodic Protection of Bridge Decks and Concrete Structures," Transportation Research Record 762, Transportation Research Board, Washington, DC.

Until now, cathodic protection of bridge decks has been accomplished by installing anodes on the concrete surface or by recessing them into the concrete and covering them with a conductive paving layer to spread the current over the entire surface of the structure to be protected. Tests are reported in which wire anode consisting of platinized niobium was installed in a bridge deck in sawed slots with conductive backfill. Tests to date indicate that if the wire anode is carefully spaced a bridge structure can be protected without using a conductive paving layer. This eliminates to a great extent the cost of conductive paving and of other wearing courses required to protect the conductive paving layer.

D-144 Tracy, R. G. 1980. "Cathodic Protection for Continuously Reinforced Concrete Pavement in Minnesota," Transportation Research Record 762, Transportation Research Board, Washington, DC.

The corrosion of steel in concrete can be suppressed by the use of cathodic protection, which involves applying a low-voltage direct current to the steel from a remote anode so that corrosion is transferred to the remote anode and the steel becomes a protected cathode. The results of the application of cathodic protection to continuously reinforced concrete pavement (CRCP) in Minnesota are presented and discussed. Several segments of CRCP are undergoing rapid, premature deterioration that is directly related to corrosion of the embedded mesh reinforcement. Pavement testing revealed that salt concentration at the reinforcement is high, copper/copper sulfate half-cell potentials indicated widespread corrosion activity. Essential elements from pipeline and bridge-deck applications of cathodic protection were integrated, and a prototype system was installed along a 1,000-ft section of CRCP. Two methods of power (current) application were examined: (a) burying anodes in a trench filled with a conductive aggregate and (b) burying anodes in individual postholes along the pavement shoulder. Both installations were connected to a central rectifier controller, which was interfaced with an automatic device for monitoring and recording the data. An initial data evaluation, expected by late summer of 1980, will provide information on the performance and effectiveness of the system.

D-145 Seeds, S., McCullough, B. F., Hudson, W. R., and De Velasco, M. G. 1980. "Implementation of New Overlay Design Procedure in Texas," Transportation Research Record 756, Transportation Research Board, Washington, DC.

A project is under way in Texas to adapt a version of the rigid pavement overlay design procedure developed for the Federal Highway Administration by Austin Research Engineers, Inc., into standard Texas State Department of Highways and Public Transportation (SDHPT) practice. This project is part of a cooperative research program between Texas SDHPT and the Center for Highway Research at the University of Texas. This paper provides some feedback on the use of this procedure and documents its successful application to an interstate rehabilitation and widening project in San Antonio. This project was unique in the sense that thickness and reinforcement designs were required for five different composite pavement structures that, by their nature, are not suitable for design by past empirical methods. In documenting the designs, the selection of design criteria, characterization of materials properties, and thickness design recommendations for each section within the project are discussed. The paper provides a general description of the design procedure, discussion of the results of the design, conclusions about the applicability of the design model, and recommendations for further work. The validity and practicality of the new procedure, as well as its applicability for nationwide use, are noted.

D-146 Way, G. B. 1980. "Prevention of Reflective Cracking in Arizona," Transportation Research Record 756, Transportation Research Board, Washington, DC.

This report represents the culmination of more than 7 years of careful planning, construction, and objective data analysis. The results should be of value to federal, state, and local agencies concerned not only with the restoration of existing roadways but also with new highway construction. The recommendations contained herein refer to overlays--in particular, thin overlays of 102 mm (4 in.) or less placed over existing badly cracked, rutted, or otherwise distorted bituminous pavements. Overlaying can also improve skid resistance or rideability. However, no one treatment is a cure-all for all roadway conditions. Rather, the recommended crack-preventing treatments should be integrated into a total overlay design that is carefully tailored to the nature of the distress. Five treatments have significantly reduced reflective cracking: (a) asphalt-rubber membrane seal coat under asphalt concrete finishing course (ACFC), (b) asbestos plus 3 percent asphalt, (c) heater scarification with reclamite (surface recycling), (d) asphalt-rubber membrane flushed into asphaltic concrete overlay, and (e) 200/300 penetration ashalt. Application considerations are as follows: (a) one of the preceding treatments should be used in conjunction with a thin overlay of 102 mm (4 in.) or less of asphalt concrete (AC), (b) application of an asphalt-rubber membrane seal coat under the AC or ACFC should be used with chips to provide direct transfer of vertical loads, (c) heater scarification should be to a depth of 19 mm (0.75 in.) or more, and (c) heater scarification should be to a depth of 19 mm (0.75 in.) or more, and (d) the lowest possible viscosity AC asphalt with the slowest aging characteristics should be used. Findings from this project led to the use of thin overlays with special treatments. The thickness of these thin overlays varies from 19 mm (0.75 in.) to 90 mm (3.5 in.). If significant cracking appears on the existing highway before overlay, a special treatment is used. Treatments include either asphalt-rubber or heater scarification.

D-147 "Building Weathertight Concrete Masonry Walls." 1980. <u>Concrete Information Pamphlet No. IS041.03M</u>, Portland Cement Association, Skokie, IL.

Leaky walls occur in all types of masonry construction even when the best materials are used and special care is taken. A large number of masonry walls are weathertight, but nonetheless attention is cast on those that do leak. An important cause of leaks in masonry walls is the haste with which modern buildings are erected. Good workmanship is often sacrificed; good design and materials cannot make up for this sacrifice. Proper design, well-supervised workmanship, and continued maintenance are necessary to prevent leaky walls. Wall types, flashings, mortar joints, and surface coatings are discussed with regard to preventing leaky walls.

D-148 Geymayr, G. W. 1980. "Repair of Concrete in Tropical Marine Environment," Performance of Concrete in Marine Environment, SP-65, American Concrete Institute, Detroit, MI.

Although concrete in tropical marine environment is never exposed to freezing and thawing, high temperature and humidity accelerate corrosion of steel and deterioration of concrete. There are a number of other factors which mak it difficult to obtain a desirable concrete in tropical areas. These factors include quality of aggregates and workmanship, special design requirements for easy-to-build structures and problems related to the remoteness of many jobsites. Corrosion mechanisms are mentioned briefly, repair-methods are explained in detail, beginning with the removal of deteriorated concrete, the restoration of reinforcing steel, replacement of concrete with cement-bound mixtures or epoxide mortars to adequate surface protection. Epoxy mortar placement under water as a repair method for concrete piles is described in detail, using a fluid mix of a high-density epoxy compound, recoverable metal forms and which has been in use for 5 years at the Maraven refinery in Punta Cardon, on the Paraguana peninsula, Venezuela.

1981

D-149 "Use and Maintenance of Concrete in Industry." 1981 (Jan). Concrete Construction, Vol 26, No. 1, pp 7-54, Addison, IL.

This special issue presents a broad overview of the maintenance and repair of concrete in industrial buildings. Nine major articles are included which discuss: (1) tips on design, construction, inspection, and maintenance; (2) preventive maintenance; (3) aids for diagnosing deterioration; (4) secrets of lasting repairs; (5) basic concrete repair; (6) agents that attack concrete and materials for protection; (7) a guide to the proper selection of repair techniques and materials; (8) modern sawing, drilling, grooving, grinding, and flame cutting; and (9) tilt-up construction of industrial plants.

D-150 "Preventive Maintenance." 1981 (Jul). Concrete Construction, Vol 26, No. 1, pp 9, 11-12, Addison, IL.

The article is concerned with maintenance that deals with such practical matters as scaling and dusting of surfaces and joints of the concrete structure.

D-151 Deubel, H., Frank, K. D., and Gunther, L. 1981 (Feb). "Metal Powder Jet-Cutting of Concrete" (in German), Beton Herstellung Verwendung, Vol 31, No. 2, pp 49-53, Dusseldorf, Germany.

The increased use of concrete as a building material and the need for structures to be demolished or to have alterations made to them has led in the past decade to the development of jet-cutting methods which are environmentally acceptable and economical. Indeed, in the case of great concrete thickness and underwater they quite often represent the only way of severing. These methods do not cause vibrations and are practically noiseless. They have been standardized in DIN 32 510.

D-152 Ruffert, G. 1981 (Feb). "Measures to Protect Old Arched Bridges" (in German), Beton Herstellung Verwendung, Vol 31, No. 2, pp 45-46, Dusseldorf, Germany.

With the increasing age of the traffic infrastructure, the problems of maintaining the service life of structures come more and more to the fore. The safeguarding of the serviceability mainly of heavily trafficked structures will play a far more prominent part in future engineering tasks. For repair work, the use of shotcrete has proved successful as is illustrated by the example of two old arched bridges.

D-153 Pfeifer, D. W. 1981 (Feb). "Steel Corrosion Damage on Vertical Concrete Surfaces. Part II--Repair and Restoration," Concrete Construction, Vol 26, No. 2, pp 97-101, Addison, IL.

There is not a large body of information on repair of cracked and spalled vertical surfaces. Methods have been adapted from bridge and parking deck repairs. On corrosion-damaged surfaces that have progressed to spalling, the general procedure is to remove the unsound concrete and expose the reinforcing steel, clean the concrete and steel by sand blasting, restore and protect the reinforcement and add anchorage for patches, patch to original surface level, and apply paint or other appropriate surface coating. Pressure injection of epoxy in structural cracks and corrosion areas may be used where no spalling has occurred.

The restoration phase attempts to remove some of the causes of the corrosion. Materials such as shotcrete, mortars, and epoxies are used in this stage. Following appropriate curing of the patched areas, a protective paint or coating of an acrylic type is applied.

Repairs to vertical surfaces must be done carefully to avoid aggravating corrosion in other members. Failure of the bond between the old concrete and repaired area must also be guarded against. The procedures outlined are believed to be the most effective available today, although their long-term efficacy is not documented.

D-154 "Demolition of the Old Aula Valley Bridge of the A7 Mortorway" (in German). 1981 (Feb). Beton und Stahlbetonbau, Vol 76, No. 2, pp 46-47, Berlin, Germany.

The four-span superstructure of a 245-m-long and 24-m-wide valley bridge with steel main girders and 20-cm-thick in situ concrete deck slab had to be demolished. The article describes the principles of the demolition procedure and outlines the considerations that led to its selection.

D-155 Anderson, A. H., Jr. 1981 (Feb). "Adequate Maintenance to Avoid Deterioration in Concrete Structures" (in Spanish), Revista IMCYC, Vol 18, No. 118, pp 17-28, Instituto Mexicano del Cemento y del Concreto, Mexico.

A rehabilitation and maintenance program that was successfully applied for extending the useful life of a two-story reinforced concrete building is described.

D-156 "Runway Repair Sets Fast Pace." 1981 (Mar). Engineering News-Record, Vol 206, No. 10, pp 34-35, New York, NY.

Rehabilitation of a 39-year old runway in San Diego, CA, used a new system of load transfer devices inserted into vertical holes drilled the full depth of the damaged slabs. The method, that can be applied to other failed airport and highway pavements without a long shutdown, consists of a steel frame bonded to a slab with polymer concrete. The frame has a 2-in. dowel welded to its center. Bonded to the adjoining slab is another frame with a 2-in.-diameter hole positioned to mate with the dowel. A load passing over the slab joint is transferred to the frame and the dowel welded to it. The dowel then transfers the load to the plate with the hole. In turn, this plate conveys the load to its adjoining slab.

The runway was repaired several years ago, only to crack more severely on about 300 of the slabs on the 9,400-ft runway. The problem was obviously a lack of load transfer from slab to slab at the joint. To pinpoint the problems, a slab-seated deflection beam with an electronic gage was placed on each side of a joint. By passing a load over the runway, the movement of one slab with respect to another and the total deflection of the joint were measured. About 15 percent of the joints needed careful installation of the patent-pending load transfer system that was developed. Repetitive loads tests made after installation showed a substantial reduction of slab rocking, the major cause of damage.

The most damaged slabs were removed completely and load transfer devices were used to connect existing slabs to the new precast concrete units that were used as replacements. Crack repairs were made on some slabs with polymer concrete. Even with these special repairs, an overlay of 8-in. of asphalt was needed. This was applied in 1-1/2-in. increments each night to permit uninterrupted operation of the airplanes. Every joint in the concrete was accurately matched on the asphalt and sealed. The seals form joints in these controlled cracks.

D-157 Pickard, S S. 1981 (Mar). "Quaker Square Hilton--The First U.S. Hotel Constructed Out of Abandoned Concrete Silos," Concrete International: Design & Construction, Vol 3, No. 3, pp 13-16, Detroit, MI.

Abandoned concrete silos were reconstructed to form a new luxury conventional hotel, by caustic-soda cleaning, diamond-blade concrete saw-cutting, and casting in place new 7-in. (178-mm)-thick concrete floors.

D-158 Liu, T. C., and Holland, T. C. 1981 (Mar). "Design of Dowels for Anchoring Replacement Concrete to Vertical Lock Walls," Technical Report SL-81-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents the results of laboratory and field dowel pullout tests and shear transfer tests. These tests were conducted to evaluate the pullout performance of dowels and the influence of dowel spacing on the load-carrying capacity of the replacement concrete cast during rehabilitation of vertical walls in navigation locks.

The results of these tests and a review of the existing literature on the interface shear transfer and the dowel action mechanisms were the bases for the development of rational design criteria for dowels for anchoring replacement concrete to vertical lock walls. The design criteria include surface preparation, minimum dowel size, dowel spacing, and anchorage requirements. An example for designing dowels for a typical lock wall rehabilitation project is included.

D-159 "Diamond Drilling, Concrete Sawing." 1981 (Apr). Civil Engineering, Supplement, p 11, London, England.

Diamond drilling, thermic lancing, and concrete sawing are all essential to many structural refurbishment contracts. Drilling produces clean, accurate holes, without spalling in reinforced concrete.

D-160 Gaul, R. W. 1981 (May). "Surface Preparation of Concrete for Paints and Coatings," Concrete Construction, Vol 26, No. 5, pp 401-405, Addision, IL.

Despite the lack of a developed art, a rational approach to surface preparation can ensure that a properly installed barrier material will do whatever job it is capable of doing. Three important considerations are involved: surface condition requirements, evaluation of surfaces, and methods of surface preparation.

For surface condition requirements, strength below the surface of the concrete is the major consideration.

In evaluation of surfaces, surface uniformity, cleanliness, dryness, laitance, and strength are factors.

Methods of surface preparation can involve repair, stopping water, and cleaning. In repair, protrusions such as fins are easily removed by grinding or impact. Spalls and holes, on the other hand, must be filled.

Methods of cleaning include wire brushing, grinding, scarifying, sandblasting, water blasting, acid etching, and chemical cleaning.

D-161 Smith, I. C. 1981 (May). "Engineering the Upgrading of Existing Buildings," New Zealand Concrete Construction, Vol 25, pp 22-26, Porirua, New Zealand.

This article examines the methods and feasibility of structurally strengthening existing buildings to modern earthquake codes rather than replacing the buildings with new structures. The three phases of investigating existing building complexes are detailed. Methods of strengthening, design standards, and other features to consider for possible upgrading are discussed. The proper form of contract for the upgrading process is presented, along with the economic factors which favor the upgrading procedure over new building.

D-162 Davis, C. 1981 (May). "Concrete in the Redevelopment of St. Katharine Docks," Concrete Construction, Vol 26, No. 5, pp 395-398, Addison, IL.

How derelict dockland was transformed with the extensive use of concrete into a popular business, residential, and leisure environment is described in this article.

D-163 Migliarese, J. L., Bonaria, D., Herve, G., and Baylot, M. 1981. "Automatic Deep Water Pipeline Repair System," Proceedings, 13th Annual Offshore Technology Conference, Houston, Tex, USA, 4-7 May 1981, Vol 2, pp 195-206, Offshore Technology Conference, Dallas, TX.

The paper discusses development of a modular end preparation system for deepwater pipeline repair. Operations are automated and remote-controlled through an umbilical from an dynamically positioned drillship. For this system five interchangeable tools have been developed. These tools must be used in conjunction with an adapted H-frame and are designed to remove the concrete and bitumen coating, make the final cut, clean inside, and grind down the longitudinal weld bead of the pipe.

D-164 Warner, R. F. 1981 (May). "Strengthening, Stiffening and Repair of Concrete Structures," IABSE Surveys S-17/81, pp 25-43, International Association for Bridge and Structural Engineering, Zurich, Switzerland.

A survey is made of techniques for strengthening, stiffening, and repairing concrete structures. Such corrective work on existing structures depends for its success on proper planning, and in particular on careful structural assessment. A systematic approach to assessment is suggested, in which the key steps are inspection, diagnosis, and prognosis (i.e., assessment of structural adequacy). A detailed chart is presented as an aid to diagnosis. Methods for strengthening, stiffening, and repairing members and assemblages are briefly described, and references are given for further specialized techniques.

D-165 Ziejewski, S. C. 1981 (Jun). "Eden's Expresway Reconstruction: Model For Future Highway Rehabs," Civil Engineering, Vol 51, No. 6, Amercan Society of Civil Engineers, New York, NY.

This article describes the complete restoration of the 29-year-old Chicago Edens Expressway. The details summarized for the reconstruction project include upgrading the drainage system, construction noise reduction and traffic control, pavement design, and contractural agreements.

D-166 "First Post-Tensioned Concrete Runway Overlay." 1981 (Jun). Highway and Heavy Construction, Vol 124, No. 6, pp 74-76, Cohners Publishing Co., Inc., New York, NY.

A post-tensioned concrete runway overlay, believed to be the world's first, was recently constructed at Chicago's O'Hare International Airport as part of an ongoing runway and taxiway restoration program.

D-167 Post, J. R. 1981 (Jun). "Simplified Repair of Wall Cracks," Concrete Construction, Vol 26, No. 6, pp 491-492, Addison, IL.

A simplified system has been developed for repairing cracks and leaky walls. The system is applicable to residential basement walls and other small structures. The process depends on the use of a small structures. The process depends on the use of a small kit of tools and materials which can be supplied to contractors. The techniques of the repair process can be learned effectively within a few hours.

A pictorial description of the repair method is given. It is based on injection of epoxy resin into the crack, but it has the advantage of using preproportioned packaged resin that can be mixed and injected without machines that require care for cleanup and maintenance.

D-168 Schrader, E. K. 1981 (Jun). "Deterioration and Repair of Concrete in the Lower Monumental Navigation Lock Wall," Miscellaneous Paper SL-81-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Deterioration of navigation lock wall concrete due to freezing and thawing is a serious problem which is usually attributed to the ineffectiveness or lack of a proper air-void system in the concrete. Most of the affected locks were constructed many years ago before air-entrained concrete began to be widely used. However, Lower Monumental Lock, one of the largest locks in the world, has been in service for only 10 years yet has serious surface deterioration.

Depending on the extent of concrete deterioration, conventional techniques for repair of deteriorated concrete surfaces normally require the removal of about 1 ft of face concrete, placing anchors and reinforcing steel mat, and replacing the removed concrete with new high-quality air-entrained concrete. This type of repair is very expensive and can put a lock out of service for a long period of time. At Lower Monumental, the cost of conventional repair was estimated to be prohibitive, and the lock could not be taken out of service for more than a matter of weeks. A coating was needed that (a) could be applied in a short period of time, (b) might prevent continued damage from freezing and thawing, and (c) would be permanent under the adverse service conditions.

Six coatings of various portland-cement and fine aggregate mixtures were pneumatically applied to a section of the lock wall for evaluation. Each was applied at a thickness of approximately 3/8 in. A conventional dry-mix shotcrete was used as the control material and was compared to fiberglass fiber-reinforced mortar applied by the "spray-up" process with and without latex. Air-entraining cement mixtures were also compared to nonair-entraining mixtures.

An accurate account of construction equipment, procedures, and production time was maintained, and "constructibility" by these methods was evaluated. Laboratory evaluation included resistance to oils, permeability at various pressures, absorption, air-void size and spacing, resistance to freezing and thawing, tensile and flexural strength, and impact resistance. The latex-modified fiber-reinforced material had essentially no permeability, high-impact resistance, and very high strength and suffered no damage due to freezing and thawing. Total coating of the interior lock wall with this mixture was performed in March 1980.

D-169 Ortigosa, P., Poblete, M., and Retamal, E. 1981. "Underpinning of Buildings on the Santiago Gravel," pp 139-141, A. A. Balkema, Rotterdam, The Netherlands, and Salem, NH.

The paper discusses the Chilean experience on discontinuous earth-retaining and underpinning structures using reinforced concrete piers, unsupported or supported with steel, wood, or reinforced concrete struts. The main design criteria are included for both static and seismic conditions, and theoretical values are compared with field measurements of the stresses acting in the struts. Based on actual construction costs, a brief economical analysis of this underpinning-supporting approach is presented.

D-170 Dubois, J. 1981 (Jun). "Investigation of the Effect of Injections Made in Cracks Prior to Prestressing" (in French), C.S.T.C. Revue, No. 2, pp 35-47, Brussels, Belgium.

Grouting techniques to repair cracked prestressed concrete generally restore the monolithic character of the cracked element. Tests were carried out to determine the extent to which restoring with grout reestablishes a load distribution corresponding to that of uncracked structures. It was found that grouting brings about an even distribution of loads. Deformations measured on either side of a crack were identical to those of an uncracked beam. But in a 5-cm zone on either side of the crack, some deformations were noted; these are described.

It was concluded that epoxy resins yield better results in repairing cracks up to 5 mm. For cracks less than 1 mm, cement grouts are ineffective since they do not penetrate deep enough. It is cautioned, however, that the use of epoxy resins requires an exact technology with which reinforced concrete specialists are not always familiar.

D-171 "Dartmoor Idyll." 1981 (Jul-Sep). <u>Concrete Quarterly</u>, No. 130, pp 15-17, London, England.

This article describes the award-winning restoration of a group of stone buildings in an English settlement that has remained outwardly much the same sinre the 18th century. Though extensive use was made of local stones and roof slates, concrete blocks were used internally. Since the moorstone of the original buildings had touches of pink, a concrete block with a salmon pink aggregate (which came from nearby Exeter) was chosen.

D-172 "Street Manners." 1981 (Jul-Sep). <u>Concrete Quarterly</u>, No. 130, pp 20-27, London, England.

This article describes a retail store building in Exeter introduced into the center of a conservation area. The structure was built by breaking down the external envelope of old Victorian and Georgian buildings and replacing their facades with brick-faced precast concrete, reconstructed stone, and conventional brickwork, achieving a very high standard of finish. Molds for the intricate classical details were cast from glass fiber reinforced concrete. External walls are of brick and precast concrete panels with a 200-mm inner leaf of lightweight concrete blocks. Though much acclaimed by the public, the building has been criticized by some architects as lacking esthetic integrity.

D-173 "'One-Machine' Concrete-Tie Renewal." 1981 (Aug). <u>Railway Track and Structures</u>, Vol 77, No. 8, pp 38-39, Chicago, IL.

This article, in a special issue on the concrete tie, describes a machine for spot replacement of damaged ties. Formerly, these ties were replaced by a largely manual method involving a crane and a cart. Only about 10 ties a day would be replaced. The new machine inserts 10 new ties in 1 hr.

The unit is capable of swiveling its work head 180 deg while handling the additional weight of the concrete tie. A typical sequence of operations with the machine is described, from removal of the two shoulder clip inserts from a damaged tie to the positioning of a new tie under the rail. A description is also given of the way this unit might function after a serious derailment, when a great number of ties would have to be changed quickly. The machine is also used for wood-tie insertion.

D-174 Henderson, G., Ray, G. K., and Bukowski, J. 1981 (Aug). "Recycling Concrete and Recycling Asphalt," Constructor, Vol 63, No. 8, pp 34-37, Washington, DC.

The advantages of recycling concrete and asphalt pavements are discussed in companion pieces. Also described are recycling processes and equipment, the composition of recycled concrete and asphalt, and uses of these products. The largest concrete pavement recycling project to date--15 miles of six-lane divided pavement--is described. The acceptance of the importance of concrete recycling in providing aggregates is considered of great significance because of the scarcity of aggregates for highway paving. The US Federal Highway Administration has commissioned a research project to develop an acceptable mix design procedure for recycled asphalt concrete.

D-175 Norton, W. S. 1981 (Aug). "House Foundation Failure: Settling or Heaving?," Concrete Construction, Vol 26, No. 8, pp 659-664, Addison, IL.

To correct house foundation failure, it is necessary to determine whether it is caused by settling or heaving. This article describes both processes and the crack patterns characteristic of each. Methods of stopping foundation settlement and of repairing foundations and slabs lifted because of expanding soil are given. It is emphasized that preventive measures against expanding soils are not as difficult as is commonly believed, and these measures are described. A questionnaire to identify expanding soil as the cause of damage is included.

D-176 Humphries, E. F. 1981 (Aug). "Sprayed Concrete--Part 1," Concrete, Vol 15, No. 7, pp 29-30, London, England.

This article defines terms relating to sprayed concrete and describes the two processes. The wet and dry processes are compared and contrasted. Equipment for both processes is outlined, and a description is given of how it works and its maintenance requirements.

D-177 "Sulfur Attacks Causeway Pilings." 1981 (Aug). Engineering News-Record, Vol 207, No. 9, pp 47-48, New York, NY.

Contractors tackling the rehabilitation of a sulfate-attacked causeway on the Texas coast have run into several logistical problems during the work. The whole job is being completed from barges under the causeway to allow for the free flow of traffic on this only hurricane evacuation route to the Texas mainland from Galveston Island. Spoil from each of the 468 new concrete pier shafts also must be taken by barge to the shore, transferred to trucks, and hauled away.

New 106-ft pile shafts are being installed on each side of each existing pile on the 1.6-mile twin causeway. Deterioration of the pile caps had taken place over the years because of sulfur runoff from deposits along the Galveston coast. Patching, repairs, and resurfacing had been inadequate and unattractive.

Although deterioration is not as severe on the northern end of the structure, all piles are being replaced in case damage increases. Concrete was chipped off the existing columns to expose the reinforcing steel for better bonding with the new pile cap. The cap covers the existing pile columns and the two new drilled-in piles that flank it. Load will be transferred to the new piles later. Specifications for the concrete are strict as a precaution against sulfate attack. Ice-cooled low-alkali concrete is being used.

One column per day is drilled and placed. High winds and shifting sandbars in the bay decrease working days. Working began in the deepest part of the water under the middle of the causeway and is progressing to the shallower areas. When work is completed in 1982, the superstructure load will be transferred to the tie beams and then to the new columns.

D-178 "Expansion Joints in Post-Tensioned Parking Structures." 1981 (Aug). Concrete Construction, Vol 26, No. 8, pp 651-653, Addison, IL.

The following failures in expansion joints are described: cracking caused by the sealant's not accommodating the movement of the slab; inadequately sealed joints that leak chloride-laden water; spalling at unprotected bearing surfaces; corrosion-causing drainage resulting from inadequate concrete cover over anchors for post-tensioning tendons.

The article offers design precautions for avoiding problems with expansion joints. Careful estimates of seasonal slab movements must be made and an appropriate sealant selected. In construction, sealants should be applied to all specified joints, and all formwork material removed from slab ends. Once the structure is completed, joints and adjacent elements should be inspected several times a year, especially at the end of each winter. Checkpoints and maintenance recommendations are given.

D-179 "Arch Dam Cracks Repaired." 1981 (Sep). Engineering News-Record, Vol 207, No. 12, p 42, New York, NY.

A description is given of the crack repairs on Canada's Daniel Johnson Dam, a 703-ft-tall multiple-arch structure. Extensive cracks were discovered in three sections of each arch and may have been the result of hydraulic fracturing. A board of experts surmised the cracks could have been caused by high-pressure cleaning of construction debris from face drains or by pressure excursions during grout injection between the vertical columns that make up the arch. Other experts have determined that the cracks were caused by freeze-thaw cycles. The repair program involves either grouting or sealing cracks with epoxy.

D-180 Humphries, E. F. 1981 (Sep). "Sprayed Concrete--Part 2," Concrete, Vol 15, No. 9, pp 35-36, London, England.

This article considers the design aspect and specific applications of sprayed concrete in the second part of a current practice sheet. Strength determination of sprayed concrete is briefly discussed. Different aspects of quality control, including rebound, preconstruction test panels, works test panels, and routine tests on the work, are covered. Proper substrate preparation is indicated, in instances of natural, rock, concrete, brickwork, or masonry surfaces. Proper preparation of surfaces under repair is also included. Use of nonrigid formwork and timber or steel formwork with sprayed concrete is outlined. Specific details of reinforcement in shotcrete and the recommended use of construction joints are given. Specific information on the correct spraying procedure is discussed, including spraying distances and proper angle for the nozzle. Various applications of shotcrete are mentioned.

D-181 Fairweather, E. 1981 (Oct). "Past, Present, and A Future for Grinding," Concrete, Vol 15, No. 10, pp 20-21, London, England.

This article briefly traces development of concrete floor grinders as a needed correction device for surface problems associated with troweling concrete floors. Other purposes for grinding machines are also discussed. The grinder can be modified to take brushes or scouring boxes so that the machine may be used for removal of grease, ice, and other unwanted materials on the concrete surfaces quickly and effectively. High speed deep cut wall grinders have been fitted on flexible shafts to allow easier grinding of irregularities on concrete walls and ceilings. Development of the Early Age grinding technique allows use of a grinding system for the original floating and finishing of a concrete floor. Future developments mentioned include larger machines to cover bigger areas more quickly and use of diamonds as the grinding medium in place of normal silicate carbide.

D-182 Meason, N., and Myers, D. E. 1981 (Oct). "Patching Procedures for Defects in Architectural Concrete," Concrete International: Design & Construction, Vol 3, No. 10, pp 44-49, Detroit, MI.

The patching techniques developed for architectural concrete on the Saudi National Guard Headquarters Complex Project in Saudi Arabia are described. Experimental investigations were conducted to determine the best mix coloring, texturing procedure, and placement method for a variety of concrete defects. The three principal finishes requiring patching were the light abrasive blasted, heavy abrasive blasted, and hammered ribbed form surface. It is concluded that with exacting care and time a patching procedure can be developed which renders the color and texture of the patch very near that of the parent concrete.

D-183 "Turnpike Redecks Bridge With Precast Concrete Slabs." 1981 (Oct). Rural and Urban Roads, Vol 19, No. 10, p 22, Des Plaines, IL.

This article describes how precast reinforced concrete slabs were used to redeck a deteriorated bridge on the Pennsylvania Turnpike. This technique was employed to avoid vibration problems during slab placement. It also allowed the use of a lower water-cement ratio as well as saving time and money.

D-184 Herscovici, I. S. 1981 (Oct). "Pressurized Epoxy," Concrete International: Design & Construction, Vol 3, No. 10, Detroit, MI.

A new tool has been invented to inject pressurized epoxy into gaps that form between embedded steel plates and concrete. Its construction and use are described.

D-185 Sharman, W. R. 1981 (Oct). "Corrosion Resistant Flooring," New Zealand Concrete Construction, Vol 25, pp 5-10, Porirua, New Zealand.

This article describes available methods to protect concrete floors subject to adverse conditions, particularly corrosive environments. Factors that affect flooring include spillage, corrosion, abrasion, and fluctuating temperatures. Slip resistance and hygiene must also be considered. A major problem facing concrete flooring is corrosion when acids, sugars, and some salt solutions react with lime in the cement binder on concrete, weaken the bond to aggregates, and disintegrate the concrete. Final selection of a protective system must include considerations of first cost against maintenance, availability of materials, possible alternative uses of building space, and projected life of the facility.

D-186 Walters, B. 1981 (Nov). "Restoration of Frankfurt's Alte Oper," Concrete, Vol 15, No. 11, pp 12-13, London, England.

The opera house in Frankfurt was completely gutted by fire during an air raid in 1944. Only the brick walls and vaulted basement together with the stone facade remained. The walls could not be used as part of the load-bearing structure so a completely new building was erected within the shell. With the exception of the steel girder framework supporting the roof, almost the entire inner building is of reinforced concrete.

The foundations of the Opera House were inadequate, so it was necessary to provide independent foundations for the new inner building. The brick vaults were largely replaced by concrete columns which strengthened the old part of the building. Existing foundations were reinforced with 18-m-deep piles, each capable of supporting 35 tons.

Concrete pillars, reinforced at regular intervals, carry part of the new building's load. No precast elements were used in the new construction. Both ready-mixed and in situ concrete were used.

D-187 "Concrete-Pavement Recycling Could Slash Rehab Costs 30 Percent." 1981 (Nov). Civil Engineering, Vol 51, No. 11, pp 73-74, American Society of Civil Engineers, New York, NY.

In an interview, Gordon Ray of the Portland Cement Association explains the process and advantages of concrete-pavement recycling. The main advantages of the process are that it solves the solid waste disposal problem of deteriorated concrete pavement and makes good quality aggregate readily available. The latter is especially economical in areas where aggregate sources are far from the construction site.

A brief review of the history of asphalt pavement recycling and concrete pavement recycling in the US and Europe is given. There have been only about a dozen projects so far in the US, but many more are predicted because of the aggregate shortage and because much of the interstate highway system is reaching its design life of 20 years. Several recycling projects around the US are highlighted, with reasons for choosing this process.

D-188 Henderson, G. 1981 (Nov). "Overview of U.S. Concrete Recycling," Rural and Urban Roads, Vol 19, No. 11, pp 20, 25, Des Plaines, IL.

Concrete recycling is a relatively simple process involving the break up, removing, and crushing to a specified size concrete from any satisfactory source, and reusing it as aggregates in new surface courses. The benefits from this process include reduced construction costs, an alternative aggregate source for shortage areas, and a durable aggregate with excellent particle shape. Studies conducted show that as the hauling distance for natural aggregates approaches 50 miles, recycled aggregates gain the economic advantage. The equipment and methods used to recycle concrete are discussed. Some recycling projects undertaken by various states are mentioned.

D-189 Rabe, D. 1981 (Nov). "Maintenance of Concrete and Prestressed Concrete Bridges" (in German), Bauingenieur, Vol 56, No. 11, pp 431-437, Berlin, Germany.

Maintenance of road bridges in Lower Saxony is explained. A systematic order of 133 types of defects and damages along with their percentage number are given as most frequently discovered by main bridge inspections. The condition of concrete and prestressed concrete bridges is described by a single number, the damage index SI, as a function of the age of the bridges. Details are given about the cost of maintenance of the concrete and prestressed concrete superstructure.

D-190 "Panels Would Raise Earth Dam." 1981 (Nov). Engineering News-Record, Vol 207, No. 20, p 43, New York, NY.

To raise a Montana earthfill dam so that it can withstand higher flood flows, the Bureau of Reclamation plans to tie precast concrete panels into compacted fill on top of the 60-year-old structure. The process is expected to cost only one-half as much as alternative dam-raising methods.

D-191 Henderson, G. 1981 (Dec). "An Overview of U.S. Concrete Recycling," Rural and Urban Roads, Vol 19, No. 12, pp 22, Des Plaines, IL.

This article presents a brief overview of several concrete recycling projects throughout the United States Projects cited include a subbase of recycled concrete at Love Field, Dallas, TX, and concrete pavement jobs in Colorado, Connecticut, and Iowa. The cost savings of the largest concrete pavement recycling project to date, Edens Expressway in Illinois, is also discussed.

D-192 Lamberton, H. C., et al. 1981 (Dec). "Underwater Inspection and Repair of Bridge Substructures," Transportation Research Board, National Cooperative Highway Research Program Synthesis of Highway Practice 88, Washington, DC.

Problems with substructures are identified, and procedures, equipment, and techniques currently used for underwater inspection are evaluated. The methods and materials used for maintenance and repair of bridge substructures below the waterline are also described.

D-193 Gupta, D. K., and Patel, M. B. 1981 (Dec). "Rehabilitation of A Historic Manhattan Building Chicago Problems & Impact on Environment," Proceedings of an International Conference on REHABILITATION OF BUILDINGS AND BRIDGES INCLUDING INVESTIGATIONS, National Science Foundation, 21-23 Dec 1981, Washington, DC.

As a part of a rehabilitation project of four buildings in the south side of Chicago, a complete investigation was carried out for the Manhattan Building. This building was built almost a hundred years ago, with a metal frame skyscraper which was revolutionary in the architecture of its time. It was the first building to include internal windbracing. As a historic building, the main goal of the project was to maintain their values, but to renovate them with modern amenities to make them functional for present needs. This paper presents the essential aspects of the project and includes the following aspects: a) history inspection report; b) feasibility studies for different uses; (c) environmental impact; d) design criteria, and e) solution (mechanical, structural and other types). It was shown that the solution was the most viable and beneficial from development point of view.

D-194 Brahma, C. S. 1981 (Dec). "Restoration of Structures with Compaction Grouting," Proceedings of an International Conference on REHABILITATION OF BUILDINGS AND BRIDGES INCLUDING INVESTIGATIONS, National Science Foundation, 21-23 Dec 1981, Washington, DC.

Some of the typical problems associated with tunneling in soft ground and several mechanisms responsible for causing such difficulties have been identified. Various sources of ground movement and methods of effective ground control in tunneling, in general, and restoration in structures with compaction grouting technique, in particular, have been briefly discussed with an illustrative case history. The dynamic application of compaction grouting technique to simultaneous soft-ground tunneling operations eliminated or greatly reduced vertical as well as lateral movements that usually occur on the ground surface one or more tunnel diameters away from the center line.

D-195 Dimmick, F., Sr. 1981 (Dec). "Total Concept for Concrete Rehabilitation," Proceedings of an International Conference on REHABILITATION OF BUILDINGS AND BRIDGES INCLUDING INVESTIGATIONS, National Science Foundation, 21-23 Dec 1981, Washington, DC.

This paper describes different types of concrete deterioration and proven epoxy repair techniques used on concrete structures below and above the waterline for structural rehabilitation prior to selecting the final preservation system. The topics include concrete crack welding processes, hollow plane void repair with a structural welding process, horizontal surface patching, vertical and overhead patching, a pile repairing system for above and below the waterline and the selection of a final protective surface such as deck and pavement epoxy overlayments, build-up epoxy flooring and epoxy coating systems.

D-196 Sabnis, G. M. 1981 (Dec). "Rehabilitation of Structures: Introduction and Overview," Proceedings of an International Conference on REHABILITATION OF BUILDINGS AND BRIDGES INCLUDING INVESTIGATIONS, National Science Foundation, 21-23 Dec 1981, Washington, DC.

This paper presents an overview of rehabilitation of structures. The overview is based on the ideas and views of the author with his experience in the United States; however, it is also applicable to other countries. The main topics addressed are: (a) reasons, (b) problems with materials, stresses and loads, (c) techniques, (d) codes and guidelines, and (e) future potentials for this type of work.

D-197 Gogate, A. B. 1981 (Dec). "Rehabilitation Wins Over Replacement of Water Treatment Plant at Findlay, Ohio," Proceedings of an International Conference on REHABILITATION OF BUILDINGS AND BRIDGES INCLUDING INVESTIGATIONS, National Science Foundation, 21-23 Dec 1981, Washington, DC.

Most well designed structures have a virtually unlimited life if proper preventive maintenance is provided to them. In the case of water and sewage treatment plants, a common form of damage is due to abrasion of the concrete at the waterline. The cost method of rehabilitation of structures and their effective use are the two most significant factors that generally govern the final decision in regard to their rehabilitation. A case history of rehabilitation of a water treatment plant at Findlay, OH, is discussed in this paper. The overall economy of rehabilitation in comparison to reconstruction is demonstrated.

D-198 Martin, L. D., and Scott, N. L. 1981 (Dec). "Use of Precast Concrete Components for Replacement and Rehabilitation of Bridges," Proceedings of an International Conference on REHABILITATION OF BUILDINGS AND BRIDGES INCLUDING INVESTIGATIONS, National Science Foundation, 21-23 Dec 1981, Washington, DC.

Possibly the most pressing need in highway construction today is the repair or replacement of bridges which are structurally deficient or functionally obsolete.

The extent of deficiency to which the results of this study may apply can cover a broad range:

.....Deck surface deterioration requiring the replacement of the upper portion of the deck.

......Deck deterioration or obsolescence which requires the complete replacement of the remainder of the superstructure. This would include, for example, a combined need for deck replacement and widening.

......Deterioration or obsolescence of the whole superstructure, but pier and abutments remain usable.

......Deterioration or obsolescence which requires complete replacement.

D-199 Warner, J. 1981. "Workman, Spare That Slab", <u>Concrete Construction</u>, Vol 26, No. 2, Addison, IL.

Slabjacking offers many advantages over replacing failed slabs including:

- faster and usually less costly than replacement.

- slabjacking can be planned to minimize interferences and can be accomplished at night or off hours.

- grout can be pumped several hundred feet eliminating the need for access to accommodate large equipment.

- surface texture and appearance of the slab remain the same.

D-200 Barnett, T. L., Darter, M. I., and Laybourne, N. R. 1981. "Evaluation of Maintenance/Rehabilitation Alternatives for Continuously Reinforced Concrete Pavement," Research Report 901-3, Illinois Cooperative Highway Research Program, Urbana, IL.

This article discusses an evaluation of several maintenance/rehabilitation methods for an interstate continuously reinforced concrete pavement (CRCP) in Illinois. Maintenance and rehabilitation needs are increasing rapidly due to aging and heavy truck traffic on the interstate system. The design, construction, performance, and costs of several maintenance and rehabilitation methods were evaluated including patching, cement grout, and asphalt under sealing, epoxying of cracks, and an asphalt overlay. Nondestructive testing (NDT) deflections, reflection cracking, cost, and statistical analyses were used to evaluate maintenance and rehabilitation methods. Two experimental patches, one with a reduced splice length, the other with a welded splice, are recommended as alternatives to current patching techniques because they reduced cost and construction time. Cement grout undersealing significantly reduced peak deflections and is recommended for preventive maintenance or rehabilitation on a selective basis to fill voids and reduce pumping. Asphalt undersealing did not reduce deflections, but is encouraged as a preventive maintenance treatment to protect the subbase and reduce pumping. Epoxy use to bond wide cracks failed due to large movement of the CRCP. The asphalt overlay significantly reduced deflections and should extend life for several years. Nearly all wide cracks not patched in the existing CRCP (where some or all reinforcing bars ruptured) have reflected through the overlay after 1 year. The asphalt overlay placed over the most highly distressed portion of the project was a cost-effective method.

D-201 Whiting, D., and Stark, D. 1981. "Galvanic Cathodic Protection for Reinforced Concrete Bridge Decks," National Cooperative Highway Research Program Report 234, Transportation Research Board, Washington, DC.

Whether or not sacrificial anode cathodic protection systems can be applied to actual bridge decks at reasonable cost and yield effective protection from corrosion for the top mat of reinforcing steel is assessed. Two cathodic protection system designs were chosen that could be applied to a reinforced concrete bridge deck without resorting to specialized construction techniques or equipment. The first consists of commercially available ribbon zinc anodes placed in grooves cut into the deck at regular intervals. The second system consists of perforated zinc anode sheets bedded on a lift of similar porous mortar.

The systems provided levels of polarized potential and current density consistent with the various criteria established for adequate cathodic protection. Environmental factors, such as temperature, moisture, and salt content were found to play an important role in functioning of the field systems.

In remote areas where electrical line power needed for impressed current systems is unavailable or too costly to supply, sacrificial anode systems will probably be frequently used. They may also be economically more attractive where current requirements for cathodic protection are relatively low. The simplicity of the systems makes them attractive in areas prone to vandalism. Structures showing low to moderate levels of corrosion and subjected to moderately aggressive environments should be considered as candidates for the systems.

D-202 Hironaka, M. C., Brownie, R. B., and Wu, G. Y. 1981. "Recycling of Portland Cement Concrete Airport Pavements--A State-of-the-Art-Study," Report FAA-RD-81-5, Civil Engineering Laboratory, Naval Construction Battalion Center, Port Hueneme, CA.

This article describes an investigation to assess the state of the art of recycling portland-cement concrete (PCC) airport pavements. Previous laboratory studies have shown that recycling of PCC pavements is technically and economically feasible. This had been demonstrated in airport reconstruction projects at Jacksonville International Airport (Florida.), Love Field (Texas), and Coffeyville Municipal Airport (Kansas), where PCC was recycled into econocrete base and aggregate subbase, cement stabilized base, and part of the aggregate base course, respectively. Recycling of PCC for surface courses in airport pavement construction has not yet been performed, but this should also prove to be beneficial as has been experienced by the Iowa DOT and other state highway agencies who have recycled PCC for surface courses. Equipment for recycling PCC pavements is currently available in the construction industry; however, these along with the technology of PCC recycling could be improved substantially. Recommendations for specific improvements are made.

D-203 "Resurfacing Concrete Floors." 1981. Concrete Information IS144.04T, Portland Cement Association, Skokie, IL.

This article discusses the fundamentals of resurfacing a concrete floor. It describes techniques and materials used for fully bonded and unbonded overlays. The factors that influence the floor's performance are explained. These include slab thickness, surface preparation of the old slab, bonding grout, concrete mixtures, forming, placing and finishing, jointing, curing, and reinforcement.

D-204 "Proceedings - International Symposium on Rehabilitation of Structures." 1981 (Dec). Vol 2, Bombay, India.

This conference proceedings contains 67 papers. They are divided into the following sessions: techniques for inspection of structures during construction, evaluation of damage and rating of structures, techniques of rehabilitation of prestressed concrete and steel structures, and general papers on these subjects. Some topics discussed include historic structures and monuments, use of fibrous concrete, problems in nuclear power plants, structural damage caused by fire, limit state design of roof cladding, stiffening and repair of structures, strengthening of steel conveyor gallery, shiploading facilities, epoxy resins, mitigation of seismic liquefaction, nondestructive testing, and wind damage to buildings. The 35 papers from North America are referenced individually herein.

D-205 Ibrahim, R. 1981. "Removal of Concrete Filled Segments in the Circulating Tunnel by Using Explosives in Building the Irrigation System in the Republic of Peru" (in Slavic), Nase Gradevinarstvo, Vol 35, No. 6, pp 1-10, Belgrade, Yugoslavia.

The use of explosives to demolish secondary concrete in the circulating tunnel of the dam in an irrigation system is a specific application of sapper works (the laying of explosives) in civil engineering. The sappering method used is discussed. With minimal quantities of explosives, the temporary fill of concrete was demolished in the final stage of building the system. The methods described are valuable contributions to sappering techniques.

D-206 McNerney, M. T. 1981. "Research in Progress: Rapid All-Weather Pavement Repair with Polymer Concrete," Applications of Polymer Concrete, SP-69, American Concrete Institute, Detroit, MI.

The Air Force Engineering and Services Center (AFESC) of Tyndall AFB, Florida, is currently engaged in a 7-year research and development effort to rapidly repair bomb damaged concrete runways. Polymer concrete because of rapid cure and high strength is one of the most promising methods of repair. The problems of moisture, temperature extremes and mechanization are all being studied for development of rapid all-weather polymer concrete repair system. Research includes work at the University of Texas at Austin, AFESC, Battelle Columbus Laboratories, Brookhaven National Laboratory, and the BDM Corporation. Polymers being considered include acrylics, epoxies, polyesters, and furans.

D-207 Kuhlmann, L. A. 1981. "Performance History of Latex-Modified Concrete Overlays," Applications of Polymer Concrete, SP-69, American Concrete Institute, Detroit, MI.

Latex modified overlays have been in service for over 20 years. This report summarizes the significant events during the development of this system and highlights data that have recently been generated by State Highway Departments and the FHWA in their continuing studies of field performance. Fifteen reports, covering 184 bridge decks, aged 2 months to 13 years, are reviewed. Specific comments regarding test methods, such as chloride penetration and half-cell potential, to measure performance, are included. Life expectancy, based on the testing done to date, as well as the actual life in the field, is projected to be a minimum of 15-20 years.

D-208 Bhargava, J. K. 1981. "Polymer-Modified Concrete for Overlays: Strength and Deformation Characteristics," Applications of Polymer Concrete, SP-69, American Concrete Institute, Detroit, MI.

Problems such as raised edges, "blow-ups," or even cracking have been observed in concrete overlays cast on precast concrete elements. These failures are due to the shrinkage, creep, and thermal effects in the new concrete. To improve the performance of concrete in such slabs, the tensile and shear strain strain capacity of concrete must be improved.

This report gives the results of different tests made to study the effect of polymer modification on the properties of concrete. Both the strength and deformation characteristics of concrete under different kinds of loading were significantly improved by polymers. With its higher tensile and shear strength, and lower shrinkage, polymer-modified concrete should be a viable and attractive alternative for concrete overlays and similar constructions.

D-209 Fitzpatrick, M. W., Law, D. A., and Dixon, W. C. 1981. "Deterioration of New York State Highway Structures," Transportation Research Record 800, Transportation Research Board, Washington, DC.

The analysis presented here quantifies both the deterioration rate of New York State highway structures and cost of that deterioration. The data used are from two complete cycles of condition inspections. The condition rating for the entire structure was used to estimate an overall deterioration rate, and the inspector's determination of the quantity of nine types of repairs needed was coupled with unit work costs from maintenance records to estimate the cost of all needed repairs. These backlogged repairs totaled $323 million in 1980 and were increasing at the rate of $39 million per year. This means that maintenance work worth at least an additional $39 million per year must be performed on New York State structures to halt the decline of their condition. A model of structure deterioration was developed from the data and used to predict future costs and condition should the current level of maintenance remain unchanged. It was inferred from the data that the rate of deterioration currently being experienced is considerably higher than that which existed before 1960.

D-210 Elkins, G. E., and McCullough, B. F. 1981. "Precast Repair of Continuously Reinforced Concrete Pavement," Transportation Research Record 800, Transportation Research Board, Washington, DC.

An initial investigation into the applicability of repairing continuously reinforced concrete pavement (CRCP) by using precast repair slabs is described. To maintain continuity in the longitudinal reinforcement of CRCP, steel connections at the ends of the repair slab are the critical part of this repair technique. These connections may be made by welding, clamping, or use of commercial rebar connectors. Polymer concrete is a fast-setting material that has excellent properties as a cast-in-place repair material for use around these steel connections. Calculations of volume change indicate the possible development of excessive steel stresses at these connections on slabs longer than approximately 7 ft (2.13 m). This is attributed to the restraint of the concrete after its development of sufficient tensile strength that resists the normal cracking, which occurs early in the age of newly constructed CRCP. The use is postulated of a weakened plane situated in the center of the slab to cause the concrete to fracture before excessive steel stresses develop.

D-211 Darter, M. I. 1981. "Patching of Continuously Reinforced Concrete Pavements," Transportation Research Record 800, Transportation Research Board, Washington, DC.

This paper presents recommendations for the permanent repair of localized distress in continuously reinforced concrete pavements in Illinois. Recommendations for cost-effective patching are provided for selection of patch boundaries, sawing of the concrete, removal of concrete, replacing and splicing the reinforcing steel, preparing the patch area, placement of concrete, and curing of the patch until the area is reopened to traffic. These procedures have been validated through extensive field testing. The procedures reduce costs and lane-closure time by (a) adapting the patch size and type to fit the distress, (b) reducing reinforcement embedment length into the patch, (c) using mechanized equipment for construction, and (d) using concrete additives and curing techniques to facilitate early reopening to traffic.

D-212 Yoder, E. J., Florence, R. H., Jr., and Virkler, S. J. 1981. "Evaluation of Several Maintenance Methods for Continuously Reinforced Concrete Pavement," Transportation Research Record 800, Transportation Research Board, Washington, DC.

Research on continuously reinforced concrete pavement (CRCP) has been going on at Purdue University for the Indiana State Highway Commission since 1971. The primary objective of the overall research program has been to evaluate the performance of CRCP in Indiana and to make recommendations relative to design and construction techniques that might improve the performance of this type of pavement. Primary factors found to contribute to performance of CRCP in Indiana have been subbase type, method of construction, and traffic. The usual method of maintaining CRCP has been to patch failures by using reinforced concrete. This research has been done to evaluate other techniques for maintaining CRCP to determine the most cost-effective method. A test pavement on Interstate-65 south of Indianapolis was used. Maintenance methods investigated included normal concrete patching, bituminous patching, overlay by using asphalt concrete with and without prior undersealing and with and without installation of edge drains, undersealing by using asphalt only, drainage, and concrete shoulders. The results show that overlaying the pavements by using asphalt concrete completely stopped the progression of failures within the time frame of this research. Undersealing by using asphalt was also effective. The edge drains and concrete shoulders were not effective. The performance data were also analyzed in light of the cost of maintenance.

D-213 McGhee, K. H. 1981. "Patching Jointed Concrete Pavements," Transportation Research Record 800, Transportation Research Board, Washington, DC.

The experiences of the Virginia Department of Highways and Transportation in the repair of jointed concrete pavements over the past 10 years are summarized. Persons involved in pavement repair are cautioned to give careful consideration to pavement geometrics and dynamics. Also emphasized is the need for proper consolidation, adequate quality-control procedures, and care in the selection of repair materials. The conclusion is that serviceable repairs to concrete pavements can be achieved if these factors are given full consideration.

D-214 Chong, G. J., Phang, W. A., and Jewer, F. W. 1981. "Choosing Cost-Effective Maintenance," Transportation Research Record 800, Transportation Research Board, Washington, DC.

A project is described that was conducted under the Pavement Maintenance Strategies Task Force of the Ontario Ministry of Transportation and Communications. Its objectives were (a) to develop guidelines for corrective pavement maintenance to be used by maintenance patrol staff that suggest a method for evaluating pavement distress and the appropriate cost-effective and practical maintenance treatment alternative and (b) to conduct a pilot test of the developed guide to verify the procedures to be carried out in full later. The guidelines were developed from existing standards for pavement maintenance quality and related management systems data combined with the judgment of individuals experienced in the fields of pavement design and evaluation, construction, and maintenance. Emphasis was on the collection of subjective performance data on various maintenance treatments through personal interviews with experienced maintenance personnel. This material was incorporated into a working copy of the pavement maintenance guidelines. The pilot test was based on the working copy and a combination of an audiovisual presentation and individual instruction of selected maintenance patrol staff. This was followed by a return visit to patrols for interviews to obtain comments on the usefulness, ease of use, and validity of action levels described in the guidelines. The pilot test was conducted in 14 patrols in the five regions of the province. The results obtained confirmed that the working copy of the pavement maintenance guidelines could, with some minor changes, be adopted for full use in the province.

D-215 Bergren, J. V. 1981. "Bonded Portland Cement Concrete Resurfacing," Transportation Research Record 814, Pavement Management and Rehabilitation of Portland Cement Concrete Pavements, Transportation Research Board National Academy of Sciences, Washington, DC.

The experiences of the state of Iowa in developing and refining the process of resurfacing concrete pavements by using portland-cement concrete (PCC) are described. The methods of evaluating the condition of the underlying pavement and determining the thickness of the resurfacing layer are discussed. Several projects that used PCC resurfacing to satisfy different roadway needs are described. Several methods of surface preparation, the methods of bonding, and the bond test results are included and discussed. It is concluded that bonding a layer of PCC 50-75 mm (2-3 in.) thick to an existing concrete pavement is a viable alternative to bituminous resurfacing for the rehabilitation and restoration of concrete pavements.

D-216 Zegeer, C. V., Agent, K. R., and Rizenbergs, R. L. 1981. "Economic Analyses and Dynamic Programming in Resurfacing Project Selection," Transportation Research Record 814, Pavement Management and

Rehabilitation of Portland Cement Concrete Pavements, Transportation Research Board National Academy of Sciences, Washington, DC.

The objective of this paper was to develop a dynamic-programming procedure by using economic analyses to assist in optimizing expenditures in pavement-resurfacing programs. Benefit relationships were determined from expected accident reduction, improved comfort, and savings in time, fuel, and maintenance. The only cost input to the program was the resurfacing cost of each project. Dynamic programming was adapted to the selection of projects for resurfacing in Kentucky. More than $8.4 million of additional user benefits would have been realized in 1976 if dynamic programming had been used in selecting projects. The benefit-cost ratio of sections selected for resurfacing by the current procedures was 3.21 compared with one of 4.22 if dynamic programming had been used.

D-217 Barenberg, E. J. 1981. "Rehabilitation of Concrete Pavements by Using Portland Cement Concrete Overlays," Transportation Research Record 814, Pavement Management and Rehabilitation of Portland Cement Concrete Pavements, Transportation Research Board National Academy of Sciences, Washington, DC.

Overlays of portland cement concrete (PCC) are growing in popularity with paving engineers. This shift away from asphalt to concrete as an overlay material is due in part to some recent shortages in asphalt cement and the concomitant increase in cost of asphaltic concrete materials. Also, some engineers simply prefer concrete surfaces to asphalt for certain applications. PCC overlays are classified as bonded, partially bonded, or unbonded. Within these three classifications are continuously reinforced concrete, jointed concrete, and fibrous concrete overlays. Posttensioned prestressed slabs have also been used as overlays. Not all combinations of overlays and levels of bonding are compatible with all pavement types and all levels of distress. Thus each job must be evaluated as a separate project that uses the appropriate constraints. To evaluate the relative merits of the different types of overlays, a systematic approach to decision making must be used. The limitations and constraints of the different types of PCC overlays are discussed and a possible decision-criterion approach is described for use in evaluating the best overlay alternative.

D-218 Tyner, H. L., Gulden, W., and Brown, D. 1981. "Resurfacing of Plain Jointed-Concrete Pavements," Transportation Research Record 814, Pavement Management and Rehabilitation of Portland Cement Concrete Pavements, Transportation Research Board National Academy of Sciences, Washington, DC.

In 1975, the Georgia Department of Transportation placed a 1-mile concrete overlay test section on I-85, north of Atlanta, which has a high volume of truck traffic. The test area consists of 7.6-cm (3-in.) continuously reinforced concrete (CRC), 11.4-cm (4.5-in.) CRC, 15.2-cm (6-in.) CRC, and a 15.2-cm (6-in.) portland-cement concrete (PCC) overlay. The primary objective was to determine the performance of various concrete overlay systems over a faulted jointed-concrete pavement. Some 16 asphaltic concrete overlay sections that had various thicknesses and treatments were placed adjacent to the PCC section in 1976. The performance obtained to date has indicated the importance of treatment of the existing pavement prior to placement of an overlay. Stabilization of moving slabs, replacement of fractured slabs, and patching and spall repair of the existing pavement are essential to the performance of the overlay. In addition, a level platform must be provided by grinding at the joints or by placement of a leveling course to prevent the overlay from being locked into the existing pavement by the faulted joints. Both 15.2-cm CRC and PCC sections, which have 4.6-m (15-ft) joint spacing, are performing well at this time. The 15.2-cm thickness of concrete overlay should be considered minimum for resurfacing over concrete when there is heavy truck traffic. The results from the asphaltic concrete test sections indicate that the use of a waterproofing membrane or fabric with a 10.2-cm (4-in.) asphaltic concrete overlay will reduce the occurrence and the severity of reflection cracking from the underlying joints.

D-219 Arntzen, D. M. 1981. "Prestressed Concrete Overlay at O'Hare International Airport: In-Service Evaluation," Transportation Research Record 814, Pavement Management and Rehabilitation of Portland Cement Concrete Pavements, Transportation Research Board National Academy of Sciences, Washington, DC.

A 240-m (800-ft) prestressed concrete overlay was placed on the 27L end of runway 9R-27L at Chicago O'Hare International Airport. The overlay consisted of two 120- by 46-m (400- by 150-ft) sections 20 or 23 cm (8 or 9 in.) thick. The pavement was posttensioned by using a fully bonded bar system. Conventional paving and tensioning equipment was used, and the cost and time of construction were comparable with those of conventional paving systems of portland-cement concrete.

D-220 Lindsell, P. 1981. "Demolition Techniques for Concrete Structures," Adhesion Problems in the Recycling of Concrete, pp 201-215, Plenum Press, New York, NY, and London, England.

Conventional methods for demolition are discussed and their performance compared in terms of their efficiency, safety, and general levels of noise, vibration, and dust produced. More recent techniques for the cutting and fragmentation of concrete structures and pavements are reviewed, and the relative advantages and limitations for their use in the demolition industry are examined. It is concluded that more research into the use of explosives and bursting techniques for partial demolition of both reinforced and prestressed concrete members could lead to considerable savings in time and reductions in demolition costs.

D-221 Lindsell, P. 1981. "Demolition of Prestressed Concrete Structures," Adhesion Problems in the Recycling of Concrete, pp 201-215, Plenum Press, New York, NY, and London, England.

Controlled dismantling of prestressed concrete structures requires adequate knowledge of the design calculations and construction details. The sophisticated techniques now being employed in prestressed concrete construction have created structures which will require elaborate planning and detailed calculations when the time arrives for demolition. For complex structures, it is suggested that designers simultaneously prepare a "demolition sequence" for the benefit of future generations.

Various techniques may be used for relieving the tension in prestressed concrete structures and the suitability of these methods is discussed with reference to the basic forms of prestressing. Investigation of alternative demolition techniques and systematic recording of case histories are suggested as a means of improving the present lack of general knowledge in this field.

D-222 Molin, C. 1981. "Explosives for Localized Cutting in Concrete," Adhesion Problems in the Recycling of Concrete, pp 201-215, Plenum Press, New York, NY, and London, England.

Full-scale field tests recently carried out by the Swedish Cement and Concrete Research Institute and the Nitro Nobel group in an old concrete building indicates that blasting with explosives is technically and economically feasible even for ordinary walls and slabs thicker than 150-200 mm. Small charges 10-20 g, placed at 250-300 mm distance in both directions can be used for those thin constructions. Heavily reinforced slabs, 300 mm thick, demand bigger charges, probably three times as much. The distance can be increased to 300-350 mm.

D-223 Etienne, C. F., et al. 1981. "Corrosion Protection of Unbonded Tendons," Heron, Vol 26, No. 3, pp 74, Delft, The Netherlands.

Besides damage due to anchorage failure, faulty design, or careless execution, corrosion of prestressing steel is a potential hazard to prestressed concrete structures with unbonded tendons. Exclusion of moisture is essential: if no moisture can penetrate to the prestressing steel, no corrosive attack will occur. Then normal corrosion, stress corrosion, or hydrogen embrittlement will not cause tendon fracture.

With the aid of literature research and experimental research, including 4 years of exposure tests, CUR-VB Committee studied how prestressed concrete construction with unbonded tendons may be carried out in view of corrosion protection. Attention was focused particularly on the grease applied to the tendons, tendon sheathing, and the method of finishing the anchorages.

Proposals are made for an intermittent immersion test in which the moisture impermeability of greases can be tested with the aid of small steel plate specimens coated with grease, for a stress corrosion test on a tensioned unbonded tendon with a view to ascertaining that the grease employed does not contain harmful constituents. Both these functional tests are to be considered important for the certification, if subsequently introduced, of unbonded tendon systems.

<u>1982</u>

D-224 "Sawing and Drilling Achievements." 1982 (Jan). <u>Concrete Construction</u>, Vol 27, No. 1, pp 81-84, Addison, IL.

This article discusses various projects involving difficult cutting of materials during repairs. Described are: the sawing of 12-ft-wide, 24-in.-thick damaged runway slabs around furnaces, with high-voltage bus bars 6 in. below the bottom surface of the slabs; sawing 2,800 lin ft of concrete at a cooling tower, requiring workers and equipment to be carried nearly 500 ft to the top; and other complex cutting procedures.

D-225 Lamberson, E. A. 1982 (Jan). "Prestressed Concrete Runway for Chicago's O'Hare Airport," <u>Concrete International: Design & Construction</u>, Vol 4, No. 1, Detroit, MI.

A pilot research project was conducted which included the construction of a 2-way posttensioned concrete pavement overlay for a runway at Chicago's O'Hare International Airport. This article describes the construction of the new posttensioned runway and the monitoring of the runway's performance.

D-226 Price, W. H. 1982 (Jan). "Control of Cracking of Concrete During Construction," <u>Concrete International: Design & Construction</u>, Vol 4, No. 1, Detroit, MI.

This is a report on the kinds of cracks that appear in different types of concrete: their causes, and the steps that can be taken to reduce or eliminate them.

D-227 "Fixing Cracked Sewer Pipes." 1982 (Jan). <u>Engineering News-Record</u>, Vol 208, No. 3, pp 62-63, 71, New York, NY.

This article describes cost-effective rehabilitation alternatives to sewer pipe replacement. Measures to combat inflow and infiltration involve lining pipes with a resin coated polyester sleeve and chemical grouting.

D-228 Scheffel, C. W. 1982 (Mar). "Repair of Piles Using Fiber-Reinforced Jackets," <u>Concrete International: Design & Construction</u>, Vol 4, No. 3, pp 39-42, Detroit, MI.

Concrete piles typically deteriorate in water as a result of exposure to both wetting and drying cycles and salt or otherwise aggressive water. To repair the pile and protect its structural integrity, a fiberglass reinforced jacket is placed around the pile, creating an annular void between the jacket and the pile. Either epoxy or a combination of epoxy and concrete, depending upon the amount of section loss, is used to fill the annular void.

D-229 Lamberson, E. A. 1982 (Mar). "Post-Tensioned Concrete Overlay of Airport Runway," Concrete Construction, Vol 27, No. 3, pp 261-266, Addison, IL.

This article describes a test project at Chicago's O'Hare Airport that evaluates costs and performance of the use of a rehabilitative post-tensioned concrete overlay for a runway. Although concrete is relatively strong in compression, it is weak in tension. Prestressing involves inducing an initial compressive stress in the pavement during construction to make the pavement more capable of withstanding destructive tensile forces caused by heavy aircraft.

Specifics of overlay construction and post-tensioning are discussed. Appropriateness of a prestressed concrete strengthening overlay is indicated by extent of airfield pavement deterioration, type and amount of traffic, allowable construction time, and possibility of an asphalt overlay being more suitable and economical.

D-230 "Resurfacing Completed on New York Section of I-81." 1982 (Mar). Constructioneer, Vol 36, No. 5, pp 12-13, Chatham, NJ.

This article describes the application of a thin bonded portland-cement overlay on 18 lane miles of highway, the first time this process was used in a major resurfacing project in the East. The 24-year-old pavement required 127,000 sq yd of milling, sometimes to a 3-in. depth. Sand blasting and hand grouting followed before application of 10,000 cu yd of concrete. A 1-mile test section of the portland-cement overlay used instead of blacktop will be reanalyzed every year.

D-231 Glassgold, I. L. 1982 (Mar). "Repair of Seawater Structures--An Overview," Concrete International: Design & Construction, Vol 4, No. 3, pp 47-56, Detroit, MI.

Repair of concrete structures in a marine environment has been a serious and difficult problem since the discovery of portland cement. The advent of reinforced concrete technology has further complicated the situation. A discussion and brief history of the problem and it causes are presented as an introduction to the subject. This is followed by an evaluation of the procedures required to determine need, specify technique, and implement repair. The characteristics of the various zones of repair are described according to their position relative to the tide. The types of concrete distress, classified as cracking, spalling, and decomposition, are explained and their presence in the various repair zones outlined. The two basic environments for the repair of marine structures--"dry" or "wet"--are described. Types of repair procedure available for each condition, "wet" or "dry," are analyzed and applied to each of the repair zones. In addition to technique, required special equipment and materials are also described.

D-232 (Deleted)

D-233 Schupack, M. 1982 (Mar). "Design of Permanent Seawater Structures to Prevent Deterioration," Concrete International: Design & Construction, Vol 4, No. 3, pp 19-27, Detroit, MI.

When designers conceptualize a reinforced concrete sea structure, they need to fully consider the construction methods of reinforcement details. Several prefabrication systems are cited that give excellent uniform behavior. Detail considerations and suggestions are given based on long-term observation of test beams placed in severe tidal exposure in Maine. A unique system of protecting posttensioning tendons, where small concrete cover is used, is also described.

D-234 "Nonexplosive Demolition of Concrete and Rock." 1982 (Apr). Concrete Construction, Vol 27, No. 4, pp 366, Addision, IL.

This article discusses a nonexplosive demolition agent composed of both inorganic and organic compounds, without harmful chemicals. The agent is mixed with water, poured into holes drilled into the rock or concrete to be demolished, and left to generate cracks. These form within 10 to 20 hr, after which the rock or concrete can be removed with a pick breaker, pneumatic breaker, excavator, or other means. Spraying the surface with water after crack initiation will speed cracking and increase crack width. Three grades of the agent designed for various temperature ranges of material to be cracked are described. An expansive stress more than 4,300 psi can be generated after 24 hr; however, if water ratio is varied above or below 30 percent, expansive stress is lowered.

D-235 "I-81 Connector Rehabilitated." 1982 (Apr). Constructioneer, Vol 36, No. 7, pp 60-61, Chatham, NJ.

This article briefly describes reconstruction, including a precast concrete replacement bridge, for Route 49 in Oswego County, New York. A new 24-ft-wide pavement with 10-ft shoulder on each side was constructed in five stages, delayed by settlement requirements for a number of sand drain areas.

The new bridge had a lightweight fill with a 4-ft surcharge layer at both ends in the abutment areas. After 5 months the surcharge was removed, and two concrete abutments and piers were installed to support the superstructure. The piers and abutments are supported by steel H-piles; 39 percent concrete beams were used for the superstructure.

Approximately 300 cu yd of concrete were used on the substructure, with another 200 cu yd on the 6-in. deck and walls. Approach slab and deck concrete was pumped into place.

D-236 "Highway Maintenance Management." 1982 (Apr). Civil Engineering, pp 23-25, London, England.

Recounts a meeting where US highway maintenance procedures were outlined. A brief discussion of skid resistance methods is also included.

D-237 Flaate, K. 1982 (Apr). "Cold Regions Engineering in Norway," Civil Engineering, Vol 52, No. 4, pp 68-69, American Society of Civil Engineers, New York, NY.

Damage from frost heaving, icing of roads, water pipe freezing, and reduced bearing capacity of subsoil are common in Norway and elsewhere. Norwegian engineers have conducted research and devised practical solutions to these problems with excellent results. Discussed are: road pavement design, strengthening of existing roads, insulation of railroad tracks and road tunnels, and housing utilities.

D-238 Campbell, R. L., Sr. 1982 (Apr). "A Review of Methods for Concrete Removal," Technical Report SL-82-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The purpose of this report is to aid the engineer in his selection of applicable means of removal of distressed or deteriorated concrete for maintenance and preservation work at Corps projects. The report reviews methods of concrete removal and the particular devices that are presently being used or have potential for use in removal of distressed or deteriorated surfaces from mass concrete structures. The report presents the main advantages and disadvantages of each of the following means:

a. Acetylene-air rock-breaker
b. Concrete spaller
c. Concrete splitter
d. Diamond saw
e. Electric-arc equipment
f. Explosive blasting
g. Expansive agent
h. Hand-held breaker
i. High-pressure carbon dioxide blaster
j. High-pressure water jet
k. Hydraulic rock-breaker
l. Powder lance
m. Powder torch
n. Thermal lance
o. Vehicle-mounted breaker
p. Water cannon

Also reviewed is a borehole notching technique that appears to enhance the performance and crack control for some means, such as explosive blasting and the use of an expansive agent, that require boreholes.

Of the removal means reviewed, explosive blasting is considered to be the most cost-effective and expedient for surface removal of large volumes of material from mass concrete structures. In situations where explosive blasting cannot be used, the following have potential as alternates:

a. Acetylene-air rock-breaker.
b. Concrete splitter
c. Expansive agent
d. High-pressure carbon dioxide blaster
e. High-pressure water jet (in situations where reinforcement is to be preserved for reuse)

It is recommended that a field comparison study of these potential alternates, including an evaluation of the borehole notching technique, be carried out as part of the schedule repair and rehabilitation work at a Corps project. The principal determinations to be made for comparison should be:

a. Cost
b. Rates of removal
c. Extent of damage to concrete that remains
d. Problem areas

D-239 "Olmos Dam Modifications." 1982 (Jun). Civil Engineering, Vol 52, No. 6, pp 54-55, American Society of Civil Engineers, New York, NY.

This article describes modifications of a 5-year-old dam in Texas. An innovative combination of prestressing and adding mass concrete proved the minimal cost solution to avert potential overtopping or structural failure.

Design considerations are discussed. Among solutions detailed are (1) providing an ogee spillway section with flip bucket; (2) removal of a roadway across the top of the dam; (3) situating a new gate operating room atop the nonoverflow section; (4) adding mass concrete and increased "footprint" to the spillway portion; and (5) vertical prestressing of the nonoverflow portion.

D-240 Reddy, K. C. 1982. "Strengthening of 62 M High Stone Masonry Dam," Fourteenth International Congress on Large Dams, Rio de Janeiro, Brazil, 3-7 May 1982.

Talakalale Dam, a stone masonry gravity dam in lime surki mortar is 62.48 m high above deepest foundation forming the balancing reservoir in the Sharavathi Valley Hydro Power Project in Karnataka State. Soon after the commissioning of the dam in 1964, heavy leakage of water was observed on the downstream face of the dam and in the drainage gallery. Along with the seepage/leakage of water, solids in the mortar was also observed to be removed from the masonry and was being deposited in the gallery.

In view of the unacceptable state of health of the dam, the stability of the dam was reviewed during 1975, and it was considered necessary to strengthen the dam.

Various alternative methods of strengthening were considered and it was found that providing an earth-backing on the downstream was technically and economically feasible. The original spillway in the centre with two gates of 10.06 by 7.32 m was plugged and a new spillway has been provided on the left flank adjacent to the dam.

The paper deals with the details of the earth-backing. The work of earth-backing and construction of new spillway is complete. Earth pressure cells installed at the interface of the masonry dam and earth-backing "at rest" indicate that "at rest" earth pressure coefficients (Ko) varying from 0.45 to 0.65 are realized as compared to the Ko value of 0.5 considered in the design of earth backing. Thus, it is considered that ample support is given to the dam from the downstream earth-backing. Monitoring of the embedded instruments and seepage is being continued to study the behavior of the dam.

D-241 "Epoxy--Polyamide Coatings for Resistance to Atmospheric Corrosion." 1982 (Jul). Materials Performance, Vol 21, No. 7, pp 51-57, Houston, TX.

Data on the performance and limitations of epoxy--polyamide coatings used to control atmospheric corrosion are presented. Although there are many epoxy-based coatings available, this discussion includes only the epoxy resins made by reaction of bisphenol-A with epichlorohydrin--the type most commonly used in protective coatings. These epoxy coatings are subdivided further into the following classes: amine-cured (two-component); epoxy esters; thermoplastic epoxy; and epoxy--polyamide (two-component). General data are also given on properties, forms available, effects of compounding, chemical resistance, properties of applied coatings, surface preparation, application details and experience record. Epoxy--polyamide coatings are among the most widely accepted and universally used industrial maintenance finishes. They can be applied by brush, spray, or roller to metal and concrete structures and are cured at ambient temperature > 50° F to achieve their final properties.

D-242 "Bridging Stormy Waters." 1982 (Jul). Engineering News-Record, Vol 209, No. 2, pp 22-26, New York, NY.

This article describes the replacement of a section of the Hood Canal floating bridge near Seattle with precast concrete elements. Sonar and computer systems supporting a winching arrangement accurately landed twenty-six 1,500-ton concrete anchors on the canal bottom in water up to 340 ft deep. Twelve 360 by 60 by 18 ft pontoons are to be cable-fastened to the anchors; they will support a two-lane roadway 20 ft above the water that can be modified later to take four-lane traffic. Specifics of the winching operation and production casting of the pontoons are given. Four of the twelve pontoons have been towed to the project site.

D-243 "New Tower Shoots Up Inside Existing Building." 1982 (Jul). Engineering News-Record, Vol 209, No. 2, pp 27-29, New York, NY.

This article describes the progress of a concrete-framed structure that is being built by major alterations from within an old building on the site. The project is adding 27 new floors on top of an existing eight-story building, using existing slabs as formwork for new slabs. The ultra fast-track schedule was implemented to take advantage of a zoning code that was due to be replaced by new zoning rules.

Using the old floors as forms, the design calls for new columns through the building to new foundations. Punched shearwalls are erected next with forms of the large-section exterior walls placed by crane and smaller interior wall forms placed by hand. Holes cut in the floor for column insertion are filled with concrete; hanger assemblies will be inserted, like stirrups around existing floor beams, also extending to the new floor slab. Voids will be placed for the new 18-in.-deep waffle slab, then reinforcing bars, and finally concrete.

The old structural system provides support until the concrete gains sufficient strength. At this point, almost all old interior columns will be cut out and removed.

Influences on the upper building, excavation, and foundation from earlier structures on the site are also discussed. Completion is set for spring 1983.

D-244 Barton, R. E. P, Saunders, D. H., Summers, D. A., and Raether, R. J. 1982 (Aug). "Cutting Concrete with Water Jets," Concrete, Vol 16, No. 8, pp 19-21, London, England.

Parts of two papers delivered at a conference on jet cutting are presented: "Trails with Entrained Abrasives" and "Comparative Use of Intermediate Pressure,"

D-245 "Project Seeks Paving Alternates." 1982 (Aug). Engineering News-Record, Vol 209, No. 6, p 31, New York, NY.

In trying to develop alternatives to standard asphalt resurfacing of existing roads, a highway authority put down overlays of unbonded concrete and a variety of asphalt mixes on a 4-lane, 10-mile stretch of highway. A comparative analysis of the concrete and asphalt roadways based on 20 years of service indicates that some correction would be necessary on the asphalt (like to a thin overlay), but only minor crack repairs on the concrete. Thus the overlays would have the same value after 20 years.

D-246 Perkins, P. H. 1982 (Aug). "Improving the Corrosion Resistance of Concrete," Concrete, Vol 16, No. 8, pp 29-30, London, England.

This article briefly describes methods of protection against chemical attack. The focus is on admixtures or techniques for modifying the concrete to reduce its vulnerability to attack.

D-247 Takewaka, K. 1982 (Aug). "Protection of Steel-Reinforced Concrete Structures Against Corrosion" (in Japanese), Cement and Concrete, No. 426, pp 20-29, Tokyo, Japan.

This article presents prevalent points of view on the problem of protecting steel reinforcement against corrosion. Results of exposure tests carried out in a marine environment are provided. Details are given, particularly on the neutralization depth and chloride content of concrete and conditions of corrosion on nonprotected steel reinforcement. Anticorrosive effects of several methods used for protecting the reinforcement against corrosion (epoxy resin covering, galvanization, and corrosion inhibitors) are discussed.

D-248 Hubler, R. L., Jr. 1982 (Sep). "Niagara Falls Control Dam Restoration," Engineering Digest, Vol 30, No. 8, pp 27-28, Toronto, Canada.

Because of the critical need to check and repair accelerating concrete deterioration of the hammerhead pier caps on the International Control Dam at Niagara Falls, the 30-year-old structure popularly known as the Horseshoe Falls is being restored. Using a highly effective epoxy bonding agent and pumped, superplasticized, air-entrained concrete, the project is effectively countering the destructive combination of freeze-thaw action and the effects of deicing salts on the pier caps. Without such remedial action, the worsening damage would have undermined the structural integrity of the pier-supported precast concrete service roadway on top of the dam.

D-249 Pace, C. E. 1982 (Sep). "Evaluation of Three State-of-The-Art Water-Jet Systems for Cutting/Removal Concrete," Miscellaneous Paper SL-82-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report documents a demonstration project conducted at the US Army Engineer Waterways Experiment Station to evaluate the capability of three water-jet systems for cutting or removing concrete or both. The Corps of Engineers is interested in the potential of this technology for such applications as rapid cutting of bomb-damaged sections of airfield pavement and removing of deteriorated sections of concrete structures at Civil Works projects. Because water-jet systems are capable of transmitting, without mechanical constraint, all of the available horsepower of their power sources into the concrete cutting/removing operation, they may prove to be an extremely efficient means of conducting such operations.

Representatives of the University of Missouri at Rolla and the Colorado School of Mines demonstrated systems employing relatively low water pressures (10,000 psi). A representative of IIT Research Institute demonstrated a system employing a relatively high water pressure (40,000 psi). The demonstrations were conducted on a 12-in.-thick airfield pavement test section containing a chert aggregate and in which the concrete compressive strength was 8,000 psi.

The low-pressure water jets were able to cut a 6-in. slot in the concrete for a distance of 1-1/2 ft in a period of 14 min (a rate of 6.4 ft per hour). The relatively high-pressure water jet cut at rates of 9.6 ft per hour for shallow cuts (less than 5 in.) and 3 ft per hour for deeper cuts (greater than 5 in.). In addition, one of the low-pressure systems was used to remove some surface concrete.

The results of this evaluation indicate that, although these water-jet systems did not demonstrate a capability for efficiently cutting concrete airfield pavements, the technology has potential. The low-pressure system demonstrated a capability for removing surface concrete efficiently.

D-250 "Restoration of the Jediah Hill Covered Bridge." 1982 (Sep-Oct). Journal, Prestressed Concrete Institute, Vol 27, No. 5, pp 131-135, Chicago, IL.

Precast prestressed concrete voided box beams were effect- ly used to restore the Jediah Hill covered bridge near Cincinnati, OH. Use of the concrete beams allowed the preservation of the bridge's historic appearance while providing the reliability of a modern bridge.

D-251 "Delaware River Bridge Deck Replacement." 1982 (Oct). Constructioneer, Vol 36, No. 20, pp 16-17, Chatham, NJ.

This article provides an overview of the replacement of a 29-year-old reinforced concrete deck slab on the bridge. Precast concrete deck is being used in the 34,700 ft^2 replacement area. Little damage of the structural steel was found.

D-252 Price, W. H. 1982 (Oct). "Control of Cracking in Mass Concrete Dams," Concrete International: Design & Construction, Vol 4, No. 10, pp 36-44, Detroit, MI.

This article covers the development of construction practices during the past 67 years for the control of cracking in massive concrete dams which have led to the use of special cements, pozzolans, air-entraining admixtures, water-reducing admixtures, controlled mixing and placing of concrete, precooling of materials, and postcooling of concrete after placing in the dam. The importance of low cement contents is stressed and methods for accomplishing the low contents are discussed.

D-253 Hagen, M. G. 1982 (Nov). "Bridge Deck Deterioration and Restoration," Report INVESTIGATION-639; FHWA/MN/RD-83/01, Minnesota Department of Transportation, St. Paul, MN.

This report reflects the results of a comprehensive research program in response to the problem of bridge deck deterioration. This program placed emphasis on protecting newer decks as well as repairing damaged ones Two basic approaches were applied to protecting bridge decks: (1) Prevention of the penetration of chloride ions to the rebars by using special concrete overlays, deck sealers, and waterproof membranes; and (2) Use of galvanized or epoxy coated rebars to protect the steel after chloride ions have contaminated the surrounding concrete. Bridge decks were constructed or repaired using the systems mentioned above. The decks covered by this study were built or repaired from 1974 to 1978 and were tested annually through 1981. Testing consisted of visual observations, electrical potential corrosion measurements, measuring depth of concrete cover over rebars, delamination detection, and determining chloride ion content.

D-254 "Ohio Seminar Shows Cost-Saving CPR Techniques." 1982 (Dec). Concrete Products, Vol 46, No. 8, pp 32-34, Chicago, IL.

This article describes the Concrete Pavement Restoration (CPR) system presented at an Ohio seminar. Highway repair techniques discussed and described include undersealing of concrete pavement, full-depth slab replacement, partial-depth spall repair, diamond grinding, and load transfer. Also discussed is diamond for highway grinding as an ideal material for use in resurfacing concrete pavement.

D-255 Higgins, D. 1982 (Dec). "Repairs to Reinforced Concrete," Concrete, Vol 16, No. 12, pp 36-37, 39-40, London, England.

Reinforced-concrete structures are inherently durable and normally give long maintenance-free service. However, problems are not totally unknown and concrete in such structures occasionally cracks and subsequently spalls as a result of corrosion of the reinforcing steel. This damage is usually a consequence of design or construction inadequacies and can be alarming to those responsible for the structure. This article discusses various agents of the title subject, including reinforcement protection, investigation aims and techniques, analysis of heat results, structural implications of deteriorated concrete, repair techniques and materials.

D-256 Povetkin, B. P., and Sovazov, I. G. 1982. "Concrete Surface Treatment by a Vibratory Removal Method" (in Russian), Beton i Zhelezobeton, No. 11, pp 10-11, Moscow, USSR.

This article describes the process as well as physical processes occurring in concrete during the treatment. Test results are presented and show that concrete has improved strength, wear resistance, and watertightness.

D-257 "Cement-Grout Subsealing and Slabjacking of Concrete Pavements." 1982. Concrete Information IS121.01P, Portland Cement Association, Skokie, IL.

This article reviews these methods of repairing deteriorated concrete highway pavement. Various types of grout are discussed as well as cement-grout subsealing, slabjacking and plugging, cleanup, and traffic reapplication.

D-258 "Rehabilitation and Replacement of Bridges on Secondary Highways and Local Roads." 1982 (Dec). National Cooperative Highway Research Program Report 243, Transportation Research Board, Washington, DC.

Many bridges on secondary highways and local roads are in need of replacement or major structural repair. Although most are not frequently traversed by heavily loaded vehicles, these structures are vital to the efficient movement of agricultural and other commodities and provide an important transportation link for rural America's population with centralized educational centers. The National bridge inventory shows that, of the more than 500,000 bridges in the United States, 98,000 are structurally weak or unsound and another 102,000 are functionally obsolete because of inadequate alignment, widths, clearances, or load-carrying capacities.

This report contains information that local highway agencies can apply immediately to the repair, improvement, or replacement of deficient bridges on secondary and local road systems. This project had four major objectives: (1) to identify common deficiencies found on bridges on secondary highways and local roads throughout the US, (2) to evaluate feasible corrective procedures that have been successfully employed for these deficiencies, (3) to evaluate economical replacement systems for bridge structures for which repair or rehabilitation is not feasible, and (4) to develop a simple procedure to assist engineers in making decisions involving repair or replacement.

The major portion of the report consists of a manual of recommended practice--comprising 34 procedures for repair, rehabilitation, and retrofit of bridges and 27 available systems for use in replacing bridge components or complete structures. The manual is intended to be used by engineers responsible for bridges on secondary highways and local roads. Its goal is to provide enough information to alert the engineer to his options when dealing with certain bridge deficiencies and direct him to the proper sources for more detailed information required for a final design.

The second phase of the reported project was initiated in June 1980 to expand the manual to include procedures directed at the problems of fatigue cracking of steel bridge members, scour, bridge deck deterioration, seismic damage, and damage due to accidental impacts. Useful information both on repair and rehabilitation procedures that can be applied to bridges with such problems and replacement systems that are also available for immediate application is also given.

D-259 Schupack, M. 1982 (Dec). "Protecting Post-Tensioning Tendons in Concrete Structures," Civil Engineering, Vol 52, No. 12, pp 43-45, American Society of Civil Engineers, New York, NY.

Electrolyte presence, oxygen availability, portland-cement passivation damage by contaminants, or steel exposure to aggressive chemicals will lead to corrosion of prestressing steels. Properly protected tendons with contaminants excluded from the surrounding concrete should not corrode. Reasons for corrosion of bonded and unbonded tendons along with proper protection measures are discussed. Signs and actions of corroded bonded and unbonded tendons are given. Use of an electrically isolated tendon, encapsulated and end to end with plastic, is suggested, backed by favorable test results.

D-260 Rygh, J. 1982. "Cleaning High Stress Areas of Complex Offshore Structures for Inspection Using Remote Operated Waterjetting Tools - Experiences from Sea Trials," Norwegian Maritime Research, Vol 10, No. 4, pp 37-41, Selvig Publishing, Oslo, Norway.

As part of the attempts to improve underwater inspection of offshore structures, IKU carried out a series of sea trials during the summer 1981. The main purpose of the project was to clean and inspect high stress areas of concrete offshore structures using the ROV which was equipped with specially designed waterjetting tools for this purpose. Two cleaning methods were tried, using a frame for cleaning large areas and a manipulator for spot cleaning. The cleaned surfaces were inspected in detail. In this article, equipment and methods are described, and the experiences gained in the sea trials are reported. On the basis of these experiences, improvements are suggested. It is argued that cleaning and inspecting offshore constructions with properly outfitted ROV's will have considerable advantages with regard to cost efficiency and safety.

D-261 Gregory, J. M. 1982. "Continuously Reinforced Concrete Overlay on Trunk Road A3 at Horndean," Transportation Research Record Laboratory Supplementary-742, Transportation and Road Research Laboratory, Crowthorne, England.

Concrete Overlays have been extensively used in the USA and Belgium to extend the lives of existing roads, a number of overlays being constructed of continuously reinforced concrete (CRC). This report describes the design, construction, and early performance of a CRC overlay on the A3 road at Horndean in Hampshire, England, involving 110-mm- and 130-mm-thick sections and 7.05-kg/sq m steel reinforcement. Transverse cracking and longitudinal/reflective cracking occurred. A 5-m length was replaced as a trial of repair techniques; many cracks were sealed by 'banding'. Regular inspection procedures are described.

D-262 Lizzi, F. 1982. "The Static Restoration of Movements," Sagep Publishers, Genova, Italy.

The static restoration of monuments particularly for those situated in seismic areas, is nowadays a matter of the greatest interest. This text is directed to those mainly concerned in the field of practical application and has been subdivided into four chapters as follows:

o The first chapter deals with the static restoration of monuments (foundation and superstructure).

o The second chapter deals with the strengthening of the subsoil in urban areas.

o The third chapter deals with the restoration of structures (monumental or not) damaged by seismic events.

o The fourth chapter deals with the strengthening of towers and tall structures.

This book, far from the usual academic schemes, has the essential purpose of offering material for reflection and guidance to those who are engaged in the study and in the practical application of this difficult and fascinating subject.

1983

D-263 "Strengthening, Repairing of Structures" (in French). 1983 (Jan-Feb. Annales, Institut Technique du Batiment et des Travaux Publics, No. 411, pp 1-112, and No. 412, pp 61-124, Paris, France.

This article presents precedings of a symposium held 15-16 Dec 1981. The four main topics were discussed in 22 papers. Topics include repairing and strengthening structures, why and how; present day techniques for repairing and strengthening; use of sprayed concrete (shotcrete and gunite) for concrete masonry structures and tunnels; and strengthening of steel structures. Panel discussions and general reports follow after each of the four themes.

D-264 "Is Your Parking Garage Having a Midlife Crisis?" 1983 (Jan). Construction Specifier, Vol 36, No. 1, pp 78-83, Alexandria, VA.

This article describes a renovation solution for damaged 12- to 25-year-old parking garages. A hammer or rod is used to "sound" the surface to identify hidden delaminations while horizontal cracks along a beam face and vertical cracks near columns also indicate damaged areas. Boundaries of the unsound areas are sawcut to a 1 or 1-1/2 in. depth; hammers with chisel point tips are used to remove delaminated concrete. The reinforcing bars are then visually inspected for rust or damage and sandblasted immediately before patching to ensure material bonding. Cavities are also sandblasted and then airblasted clean before patching.

A polymeric or polyacrylic concrete or mortar is placed immediately after mixing, struck off 1/2 in. above finished grade, and then consolidated and finished to grade with vibrating devices. The patch is covered with wet burlap and protected by a thick polyethylene sheeting for 24 hr.

The sealer system prevents future penetration of water, oil, grease, salt, deicer chemicals, and acids.

D-265 "Tentative Recommendations for the Corrosion Protection of Unbonded Tendons." 1983 (Jan-Feb). Journal, Prestressed Concrete Institute, Vol 28, No. 1, pp 41-49, Chicago, IL.

This report recommends procedures which will ensure the long-term durability of the prestressing tendon and its anchorages. Local protection from corrosion is usually provided by cement grout; with unbonded tendons some other form of corrosion protection must be provided. This report deals only with unbonded tendons which are preformed and placed in position prior to concreting.

D-266 Jordan, F. E., and Hasbrouck, R. C. 1983 (Feb). "Recent Developments in Pavement Skid Resistance," Civil Engineering, Vol 53, No. 2, pp 64-67, American Society of Civil Engineers, New York, NY.

This article describes various methods and their applications and briefly covers their advantages and disadvantages. The sprinkle treatment method involves applying a thin layer of asphaltic concrete (AC), which is then sprinkled with durable, polish-resistant aggregate particles and rolled into the AC surface layer. Some of these particles project above the surface, creating a rough macrotexture increasing friction and allowing water to drain out beneath vehicle tires.

Portland-cement concrete (PCC) overlays with a low water-cement ratio and high cement content concrete has been used over worn pavement. Advantages of the PCC overlays include longer life than conventional AC overlays and asphalt conservation, yet additional steps and expertise are required to install them.

Polymer overlays can produce a higher strength pavement, improve durability, and improve aggregate retention. These overlays can be applied quickly, minimizing downtime and making them particularly suitable for bridges. Flammability and toxicity, and the high price of some resins are major disadvantages of the method.

Milling, removing a layer of pavement surface to expose underlying material and increase surface texture, is a relatively low-cost method that does not increase the pavement lift. Drawbacks are the big consumption of energy and production of noise and dust.

Emulsified slurry seals provide an inexpensive treatment with a short lifespan of 1 to 3 years. Grooving of existing PCC pavements has proved effective in reducing skidding accidents yet may cause discomfort to passengers of light autos and motorcycles, and produce tire noise, especially with transverse grooving. Using steel tines to texture plastic concrete pavements is also a possibility.

D-267 Scanlon, J. M., Jr., et al. 1983 (Feb). "REMR Research Program Development Report," US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Development of the US Army Corps of Engineers' Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program is documented in this report. This program will involve research and, where available, the collection and synthesizing of research results on repair, evaluation, maintenance, and rehabilitation of existing Civil Works projects. Primary research problem areas which will be addressed are: Concrete and Steel Structures, Geotechnical, Hydraulics, Coastal, Electrical and Mechanical, Environmental Impact, and Operations Management. This research program will:

a. Permit the Corps to perform its REMR activities in a rapid, quality-oriented, and cost-effective manner.

b. Increase the service life of all Civil Works projects for as long as they are performing their intended purposes and that intended purpose is still being economically accomplished.

c. Correct operational deficiencies in such a way that they will not recur within the near future.

d. Furnish knowledge to all Federal agencies, state governments, and private concerns involved in related REMR activities.

e. Modify where appropriate existing design and construction procedures so that future REMR problems associated with new facilities will be reduced.

Section A of the report recounts the background of the program and the development of the research problem areas and summarizes program objectives and funding. Section B is a detailed identification and assessment of the problems in each problem area. Section C presents the details of the recommended research program. Section D discusses technology transfer. A synopsis of the August 1981 REMR Workshop in Arlington, Va., at which many of the REMR problems/needs were identified and assigned to problem areas, is included as Appendix A.

D-268 Blaha, B. 1983 (Apr). "Woolworth Building in New York Gets a Face-Lift in Precast," Concrete Products, Vol 86, No. 4, pp 16-19, Chicago, IL.

Precast concrete has helped to gain a new lease on life for the 70-year-old Woolworth Building, New York City's famous Gothic-style skyscraper. Nearly 25 percent of 45,000 ft^2 of the richly decoated terra cotta facade has been replaced with pieces of precast concrete that are identical in shape, texture, and color to the originals. The casting job stretched over a three-year period; 30,072 duplicate pieces were molded.

D-269 "Problem-Solving Admixtures Aids Dam Repair Project." 1983 (Apr). Concrete Products, Vol 86, No. 4, pp 28-29, Chicago, IL.

Rehabilitation of the 65-year-old Emsworth Lock and Dam on the Ohio River 6 miles west of Pittsburgh, PA, is described. A sulfate-resisting grade of concrete that will not decompose or disperse in river water as it is pumped was used. To maintain pumpability without compromising the sulfate-resistant aspects of the concrete as well as its strength, durability, and overall quality, an admixture was used.

D-270 Slater, J. E. 1983 (Apr). "Role of Cathodic Protection in Preventing Corrosion of Prestressing Steel in Concrete Structures," National Association of Corrosion Engineers, Katy, TX.

The concept of cathodic protection applied to conventionally reinforced concrete bridge decks is an accepted method of halting deterioration of the structure due to chloride-induced corrosion of the embedded steel and is being considered for application to other reinforced concrete structures. Many structures, however, contain high-strength prestressing steel in addition to the conventional reinforcing steel. While the application of cathodic protection to such structures may halt general or localized corrosion of the prestressing steel, it raises the possibility of initiating hydrogen embrittlement of such steel. Current knowledge of hydrogen embrittlement of such prestressing steels is evaluated, this data are compared with field observations of stress corrosion cracking and how current practice of cathodic protection of conventionally reinforced concrete structures may have to be modified to lessen the risk of damage to prestressing steel is discussed.

D-271 "Techniques: Combating Bridge Ailments with Innovation." 1983 (Apr). Construction Equipment, Vol 67, No. 4, pp 42-47, Des Plaines, IL.

This article presents innovative techniques for renovating and repairing bridges which are damaged because of old age, abuse, and neglect. Problems such as concrete deterioration, due to deicing salts; water erosion of concrete foundations and subbase materials; overload stress; inadequate clearances and narrow decks; as well as other problems are addressed.

D-272 Irwin, R. W. 1983 (Apr). "Repair of Concrete Structures in Marine Environments," New Zealand Concrete Construction, Vol 27, pp 19-22, Porirua, New Zealand.

Normal concrete repair techniques cannot be used successfully in tidal zones and below water. Physical phenomena such as repeated wetting and drying, and warming and cooling of the concrete necessitates careful choice of repair material and application method. The combined effects of thermal coefficient of expansion, elastic moduli, and shrinkage of the repair material and the original concrete must be taken into account. Problems of underwater repairs are identified, and repair techniques are illustrated.

D-273 Moreadith, F. L., and Pages, R. E. 1983 (May). "Delaminated Prestressed Concrete Dome: Investigation and Repair," Journal of Structural Engineering, Vol 109, No. 5, pp 1235-1249, American Society of Civil Engineers, New York, NY.

Discovery of the delamination of the 3-ft (76 m)-thick concrete dome portion of a nuclear power plant containment is described. An investigation was made as to the causes of the delamination, the strength of the delaminated structure, and repair techniques. Repairs were made consisting of epoxy injection of cracks in the lower 2 ft (51 m) of the dome, providing radial anchors between the lower portion of the dome and the upper cap, the delaminated portion, which was removed and replaced with new concrete.

D-274 "Correcting Concrete Defects." 1983 (May). Rock Products, Vol 86, No. 5, pp 52A-52E, 52H, Chicago, IL.

This article discusses proper precasting methods which will minimize concrete surface problems and provide longer lasting, better-looking concrete.

D-275 Ota, M. et al. 1983 (Jun). "How to Preserve Concrete Structures Durability" (in Japanese), Cement and Concrete, No. 436, pp 20-26, Tokyo, Japan.

Observations made on methods adopted in West Germany for preserving durability in concrete bridges and repairing the damaged ones were studied. The data obtained allowed a comparison with the main damage occurring on concrete structures in Japan. The problems raised at the stages of planning, construction, maintenance and control, and problems to be solved in the near future for improving of durability concrete structures are also detailed.

D-276 Rodway, L. E. 1983. "Restoration of Concrete Snowsheds in Glacier National Park, B. C.," pp 1, 81-1, 90, Canadian Society for Civil Engineering, Montreal, Quebec, Canada.

During the Spring of 1979 concrete cracking was noted in a number of the columns comprising a portion of five separate snowsheds protecting the Trans-Canada Highway in Glacier National Park, British Columbia, and specifically near the summit at Rogers Pass, British Columbia. The problem was identified as corrosion of reinforcing steel in the columns due to the action of deicing salts used to assist in clearance of ice and snow from the highway surface during the annual battles to keep the Pass open year-round to vehicular traffic. Recommended remedial measures included removal of the cracked cover concrete, cleaning of the exposed reinforcing steel, application of an epoxy bonding agent, patching with polymer concrete mortar and finishing with an epoxy sealer. The repair work was begun and completed in the Spring of 1980. After 2 years service, the repairs were inspected in the summer of 1982. The repaired columns had performed satisfactorily.

D-277 (Deleted)

D-278 Maw, G. 1983 (Jul). "Rebuilding a Century Old Bridge," Concrete International: Design & Construction, Vol 5, No. 7, pp 32-34, Detroit, MI.

As an aftermath of the Industrial Revolution, England has been left with one of the oldest road and rail systems in the world. Interwoven into a nationwide network, these systems have required constant maintenance and rebuilding of thousands of nineteenth and early twentieth century bridges. The rebuilding of one of these spans, located south of London, is described.

D-279 Warriner, P. C. 1983 (Jul). "Rehabilitation of the High Street Overhead," Concrete International: Design & Construction, Vol 5, No. 7, pp 53-57, Detroit, MI.

The High Street Overhead is a 1,750-ft (533 m)-long structure located on a heavily traveled freeway in San Francisco, CA. The 30-year-old concrete deck of the southbound truck lane had suffered severe deterioration due to heavy truck traffic, age, and a poor choice of structural details. Freeway operational requirements called for rehabilitation work which would not restrict rush-hour traffic. An overnight construction sequence was used consisting of removing the existing deck and railing for one span, erecting the new deck section and rail, completing the splice and attachment work, and opening the new section to evening rush-hour traffic within a 20-hr period. Precast deck elements and rapid setting calcium aluminate cement concrete were used in the project.

D-280 Sokol, D. R., and Choate, L. C. 1983 (Jul). "Polymer Modified Cement Overcoatings for Pipelines," Materials Performance, Vol 22, No. 7, pp 20-24, Houston, TX.

A study was performed on the extent of damage to fusion bonded epoxy coatings during transportation, handling, concrete overcoating, and installation. Polymer modified cement overcoating provides protection in addition to preventing slippage of concrete sleeves during offshore lay operations. These overcoatings also have potential for onshore applications such as rock shielding and bore crossings of roads and waterways.

D-281 Wicke, M. 1983 (Jun). "Some Long-Term Experience with Concrete Bridges in Austria" (in German), Beton Und Stahlbetonbau, Vol 78, No. 7, pp 202-205, Berlin, Germany.

The faults and defects of execution and the grouting of prestressing tendon ducts are dealt with. Defective sealing against the ingress of surface water and inadequate discharge are considered. The effects of these defects of the strength, serviceability, and durability of the structure are assessed. Appropriate preventive measures applicable to new structures and the remedial measures applicable to damaged existing ones are described.

D-282 Whitcher, D. J. 1983 (Jul). "Grinding and Grooving," Concrete International: Design & Construction, Vol 5, No. 7, Detroit, MI.

Grinding and grooving are operations that restore concrete pavements to a high degree of usefulness. Grinding is the term used to describe the removal of the surface of concrete slabs. Grooving refers to the cutting of parallel channels of a certain depth and spacing in the surface of concrete slabs. At one time grinding had a negative connotation. It was considered a corrective measure and implied faulty construction. Now these operations are valuable techniques of concrete rehabilitation.

D-283 Grattan-Bellew, P. E. 1983 (Jul). "Preventive Measures to Counteract Expansion of Concrete Containing Alkali-Reactive Aggregates," Durability of Building Materials, Vol 1, No. 4, pp 363-376, Amsterdam, The Netherlands.

Alkali-aggregate reaction causes expansion and cracking of concrete structures exposed to high humidity. Deterioration is much exacerbated if deicing salts are used on the concrete. The expansion, caused by reaction between the alkaline pore solution and certain minerals in the aggregate, can be prevented or minimized by a number of methods. The best solution is to use an alternative, nonreactive aggregate. Beneficiation of the aggregate by selective quarrying is often effective in eliminating reactive material, particularly in horizontally layered carbonate quarries.

D-284 Richter, B. 1983 (Aug). "Surface Preparation for Underwater Inspection and Corrosion Protection" (in German), MT Meerestechnik, Vol 14, No. 3, pp 105-110, Germany.

Fixed marine structures and port installations must be inspected and serviced at regular intervals. This normally requires removal of marine fouling. The paper introduces the different cleaning methods and discusses the surface quality required subject to the inspection method applied. In the underwater region renewal of coatings is not adequate, since application of cathodic protection is easier. In the splash zone of steel and concrete structures passive protection has to be repaired from time to time. This is done by appropriate blasting methods and coating materials.

D-285 Hertting, H. 1983 (Aug). "Lock Wall Repairs Without Interrupting Ship Traffic" (in German), Bauplanung-Bautechnik, Vol 37, No. 8, pp 363-364, Berlin, Germany.

To repair an inclined chamber wall without dewatering the lock and interrupting the ship traffic, a special caisson was designed which can be moved from one working area to another. Ballast is provided by concrete and water tanks which, when emptied, serve as floating bodies. Rubber bands with shock absorbers serve as insulation against the wall. The steel caisson weighs 9.3 metric tons. The work space is 4 m long. Detailed operating instructions are required to maintain stability and floating capacity at each phase of changing water level.

D-286 Degeimbre, R. 1983 (Aug). "Criteria for the Choice of Materials and Systems Used for the Reinforcement, the Restoration and the Protection of Buildings and Structures," pp 529-539, National Swedish Institute for Building Research, Gavle, Sweden.

A program of agreement or qualification tests for formulations based on reactive resinous binders, used for repairing or reinforcing concrete constructions is presented. This program is divided into four sections, which correspond to the four following testing categories: identification tests; applicability tests; performance tests; and durability tests. The tests of applicability, performance and durability are again divided into subsections, specific to the following applications: crack injection; concrete splash repairing; sticking steel-concrete or concrete-concrete.

D-287 Slavis, C. 1983 (Jul-Aug). "Precast Concrete Deck Modules for Bridge Deck Reconstruction," Journal, Prestressed Concrete Institute, Vol 28, No. 4, pp 120-135, Chicago, IL.

Precast concrete deck modules have been used successfully for replacement of deteriorated bridge decking. Primary advantages of the precast modules include economy, safety, and very short construction time.

Variations in connection techniques and other details have been field--tested, and the outlook is good for more widespread use of this design option in the future.

D-288 "Ostarr Corp America's Port and Plug Assembly Can Help Repair Cracks in Concrete Structures." 1983 (Sep). Plastics Engineering, Society of Plastics Engineers, Inc., Brookfield Center, CT.

Rods are inserted into a crack at intervals, with the rods extending outward. A surface seal is applied into the crack near the outer surface of the structure from which the rods extend and to the surface adjacent to the cracks and around the rods. The surface seal now acts as a surface barrier for the filler to be injected. Port members, each having a hollow shank and flange, are placed over the rods, the flange approximately adjacent to the outer surface of the structure. The flange is embedded in the surface seal. When the surface seal cures, forming a surface barrier for the filler, the rods are removed from the crack, so the ports are able to communicate with the crack cavity behind the surface seal. When the surface seal cures, a filler is injected through the port members and into the crack cavity, and the port members are plugged.

D-289 Meyer, A. H., and McCullough, B. F. 1983 (Sep). "Precast Repair of CRC Pavements," Journal of Transportation Engineering, Vol 109, No. 5, pp 615-630, American Society of Civil Engineer, New York, NY.

Conclusions presented include: 1) use of precast panels for the repair of continuously reinforced concrete (CRC) pavements is a viable alternative, 2) repairs can be made with less than a 6-hr lane closure time, and 3) the method is cost effective when user delay costs are included.

D-290 O'Neil, E. F. 1983 (Sep). "Preventative Measures to Limit Stress Corrosion Cracking in Prestressed Concrete," Miscellaneous Paper SL-83-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

In the past decade, the most significant advances in the area of protection of prestressing steel from stress corrosion cracking have come in the fields of metallurgy and concrete materials. These efforts have developed from a more precise understanding of the mechanisms that cause stress corrosion cracking in prestressing steel, and development of concreting materials that provide greater protection for these steels. This reports deals with two aspects of steel protection. First, with respect to the steel itself, new insights into the structure of the prestressing steels have shown metallurgists the conditions under which stress cracks form and advance, as well as ways to modify the physical properties of the steel to minimize the possibility of crack formation and advancement. Secondly, in the field of concrete materials, the emphasis on prevention of corrosion to steel has been in the area of durability of the concrete that protects the steel. Lower water-cement ratios and concretes with lower permeability exclude deleterious materials from the surface of the steel. New materials and procedures are discussed that have been designed to limit the penetration of corrosive elements that may attack the steel at the grain boundaries and initiate brittle failure.

D-291 Heuze, B. 1983 (Oct). "Corrosion and Cathode Protection of Marine Structures of Reinforced Concrete" (in French), Travaux, No. 481, pp 103-114, Paris, France.

A considerable portion of reinforced concrete pipes exposed to extremely corrosive groundwater require cathodic protection. The directive system for the cathodic protection of a double-walled conduit of prestressed concrete is described along with the average degree of corrosion of steel in various types of concrete.

D-292 Fert, C. 1983 (Oct). "Special Repair Techniques" (in French), Travaux, No. 581, pp 99-102, Paris, France.

Reconstitution of deteriorated concrete is discussed. The requirements in terms of durability, structural injection, materials, and products, and new two-component materials are also discussed.

D-293 "Roadway Resurfacing Lincoln Tunnel's Center Tube." 1983 (Nov). <u>Constructioneer</u>, Vol 37, No. 22, pp 34-35, Chatham, NJ.

Major reconstruction of the Lincoln Tunnel's centertube roadway is being done at night to lessen the impact on motorists. The heavily used tunnel accommodates up to 100,000 vehicles on a typical weekday. Over the years the concrete deteriorated and a shear plane developed between the reinforced concrete and the steel beams, weakening the composite action. The new structural system now being installed is designed to eliminate this problem. The new structural system and construction procedures are discussed.

D-294 Conner, B. G., and Bennett, V. P. 1983 (Dec). "Precast Concrete Boxes Replace Old Bridges," <u>Concrete Pipe News</u>, Vol 35, No. 6, pp 3-4, Vienna, VA.

Old bridges on a very important farm-to-market road in southwest Iowa needed to be replaced. A fast construction schedule was required to prevent extended detours for area residents. Several different alternatives were considered for the replacement of the old bridges, but box culverts appeared to be the best option to meet the criteria of site conditions, hydraulics, and road profile.

D-295 "Repair and Renewal of Buildings." 1983. Thomas Telford Limited, London, England.

This publication contains six papers and discussions from a conference held in London, Nov 1982. The first paper deals with an overview of the subject of cladding repair and shows how overreaction has led to higher repair costs than necessary. Engineering judgement concerning the need to preserve the maximum amount of the original structure versus considering only economic considerations is discussed. Two papers consider the restoration projects of the Malting Concert Hall at Snape and the Victorian building, Lloyds Arch, Cornhill, Ipswich. Various methods of underpinning, framing, jacking, and moving projects is discussed in another article, showing that major improvements in amenity and strength of buildings can be achieved with a minimum of damage while retaining the essential character of the building. The last paper identifies common defects in 20th century building and suggests appropriate repair methods.

D-296 Purvis, R. L., and Berger, R. H. 1983. "Bridge Joint Maintenance," Transportation Research Record 899, Transportation Research Board, pp 1-10, Washington, DC.

Damage to bridges in the United States related to the deck expansion joint totals million of dollars each year. This includes both damage to the joint and the portion of the bridge beneath the opening exposed to debris and contaminants. The magnitude of the problem is documented by engineers involved in the National Bridge Inspection Program. The number of deficient structures is growing faster than replacement is possible. Administrators are seeking methods to preserve and extend the service life of their bridges.

There are a variety of deck joints currently in service that depend on the age of the bridge and the type and magnitude of the movement. The earlier designs provided little or no protection to prohibit passage of deck drainage and debris. More recently flexible materials are used to seal the opening. Although some perform better than others, none of the designs have succeeded in eliminating the problems. Engineers and suppliers continue to develop devices and materials intended to improve serviceability. The goal is to have a joint that is watertight, capable of accommodating the movement, as durable as the adjacent deck, and maintenance free.

D-297 Obuchowski, R. H. 1983. "Construction of Thin Bonded Concrete Overlay," Transportation Research Record 924, Transportation Research Board, pp 10-15, Washington, DC.

In 1981 a bonded concrete overlay 3 in. thick was placed on a six-lane divided interstate highway that has an annual average daily traffic of 23,000 with 8 percent trucks. The existing concrete pavement was resurfaced for a length of 3 miles in all northbound and southbound lanes. Two lanes in each direction were closed to traffic while the overlay was placed. Traffic was maintained on the third lane and a thickened asphalt-concrete shoulder. The concrete overlay was placed to remedy widespread longitudinal and transverse joint deterioration caused by porous coarse aggregate in the existing concrete pavement. The freezing and thawing of water in the coarse aggregate caused a surface spalling problem and layered cracking beneath the surface similar to D-cracking. Deteriorated pavement at the joints was removed to a 3-in. depth by using a milling machine. A nominal 3-in.-thick concrete overlay was bonded to the existing pavement with a cement-sand grout after scarification, sandblasting, and cleaning. The resulting 6-in.-thick lift of concrete at the deteriorated joints was designed to bridge the deterioration and provide a long-lasting overlay. Pavement blowups were occurring on the 23-year-old existing pavement, which dictated the installation of pressure relief joints before overlaying.

Surface preparation and cement-sand grout have resulted in an adequate bond. The thicker concrete overlay is bridging the deterioration. Shrinkage cracking, which developed during paving in hot weather, and reflection cracks over existing pavement cracks have not resulted in performance problems to date. Dust control during surface preparation needs improvement. Pavement friction generally is adequate but needs further study. Overall rideability is excellent.

D-298 Calvert, G. 1983. "Portland-Concrete Inlay Work in Iowa," Transportation Research Record 924, Transportation Research Board, pp 15-18, Washington, DC.

High maintenance costs and continuing inconvenience to the traveling public have forced Iowa to take drastic measures in resolving a long-standing problem on Interstate 80 in western Iowa. It was necessary to remove a section of asphalt and replace it full width with a portland- cement concrete section 10 in. deep. The removal and replacement operation led to the conclusion that in the future major problems could be corrected by replacement of the 12-ft travel lane only. Construction of the 12-ft travel lane proved to be cost effective and no major problems were encountered. Through traffic was maintained in the normal passing lane and the contractor was limited to use of the 10-ft outside shoulder only. Included are details of the reasoning leading to the decision to reconstruct the travel lane only. Minor problems associated with smoothness of ride were corrected by use of a heavier finishing machine.

D-299 Gregory, J. M. 1983. "Continuously Reinforced Concrete Overlays of Flexible Pavements on Trunk Road A2," Transportation Research Record Laboratory-Supplementary-803, Transportation and Road Research Laboratory, Crowthorne, England.

The design and construction of continuously reinforced concrete (CRC) overlays on flexible pavements on Truck Road A2 are described. The existing pavements were dual carriageways on flexible construction built in 1975-76; isolated sections had failed completely and the whole length was approaching failure. Three 1-km and one 0.9-km CRC overlays were constructed during 1981. These overlays are all of nominal 200-mm thickness and have a steel content of 0.65 percent; anchorages are provided at both ends of each overlay.

D-300 Makinen, M., and Tanskanen, K. 1983. "Use of Concrete in Rehabilitation of Buildings. Preliminary Study" (in Finnish), Research Report 237, Technical Research Centre of Finland, Espoo.

This report is concerned with a study of basic repairs and renovation and especially with the present and future uses of concrete in the renovation of buildings. In renovation, concrete is used for basic repairs in earth construction, foundations, load-bearing structures, surface layers, and structural members. The applications for which it is used largely depend on each separate case. Typical measures are the strengthening of block rubble foundations, the construction of stair and lift wells, the replacement of wooden floor slabs by concrete floor slabs, the manufacture of beams, and the repair of rendering. The information presented in this report is based on a study of the literature, interviews, and visits to construction sites. A program for further studies is also presented.

D-301 Littlejohn, G. S. 1983. "Grouting of Platforms and Pipelines Offshore," pp 205-216, A. A. Balkema, Rotterdam, The Netherlands.

This paper describes a wide range of grouting applications and techniques which have developed recently in relation to the installation, strengthening, protection and repair of offshore platforms and pipelines. Examples include underbase grouting of concrete gravity structures, pile annulus grouting of steel jackets, strengthening of steel legs by grouted aggregate concrete infilling, sleeve protection of pipes by using flexible formwork, saddle weight coating of gas lines, free span support of pipelines and their crossings, and repairs to noded joints.

D-302 Arioglu, E., Anadol, K., and Candogan, A. 1983. "An Underground Shopping Center Fire and After-Fire Repair Project," Fire Safety of Concrete Structures, American Concrete Institute, Detroit, MI.

In this article, a fire which took place in the largest underground shopping center of Istanbul, Turkey, and its after-fire repair and strengthening project prepared by the authors are reported. First the structural system of the shopping center is described and information is given on the fire. After-fire surveys and main features of the repair and strengthening project are then summarized. In the conclusions, general concepts related to fire effects on reinforced concrete structures and observations made during the study are discussed.

D-303 Heyde, K. H., and Herz, G. 1983 (Dec). "Improvement of Skid Resistance of Old Concrete Pavements," Strasse und Autobahn, Vol 34, No. 12, pp 495-500, Bonn, West Germany.

Evaluations of the necessary repairs or replacement of 15- to 20-year-old concrete pavements must be made on the basis of examination of defects and by weighing costs and benefits. Skid resistance and accident reports also have to be considered. Methods of improving skid resistance include: treatment of surfaces with sand, steel and flame jets, milling, grinding, chipping, or coating with cement or reaction resin mortar, bituminous layers, or surface treatment. The techniques and devices for different procedures are described. Three methods have been used in Rhineland. Treatment of concrete pavements with surface milling is preferred.

D-304 Manson, J. A., et al. 1983. "Long-Term Rehabilitation of Salt-Contaminated Bridge Decks," National Cooperative Highway Research Program Report 257, Transportation Research Board, Washington, DC.

This article reports on experimental work conducted on new methods for the rehabilitation of salt-contaminated bridge decks. Emphasis was given to improving techniques for the impregnation of concrete with polymethyl methacrylate and to the concept of scarification to remove the top layer of concrete, followed by impregnation with a polymer or corrosion inhibitor, and resurfacing with a low-permeability concrete. Experimental research on the electrochemical removal of salts was also conducted.

1984

D-305 Wels, W. 1984 (Jun). "Safeguarding of the Kaiser-Wilhelm-Gedachtnis Church with Shotcrete" (in German), Beton, Vol 34, No. 1, Dusseldorf, Germany.

The ruin of the Kaiser-Wilhelm-Gedachtnis church tower in Berlin is at present surrounded by scaffolding while repairs are made. The structures is being supported by an inner layer of shotcrete, and renovations executed on the sandstone facade.

D-306 "New Era in Bridge-Rebuilding." 1984 (Jan). Engineering News-Record, Vol 212, No. 1, pp 36-39, New York, NY.

The Surface Transportation Assistance Act, put into law the first week of January 1983, responded to the nation's infrastructure needs. The act provided billions for highway work and revived the expiring bridge-replacement and rehabilitation program. But despite a strengthened federal commitment and increasing state support, the billions of dollars spent on rehabilitation over the next 3 years will only scratch the rusty, spalling surface of the nation's problem. Bridge deck deterioration caused by corroding reinforcing bars is the most common problem. Some innovative techniques and cost effective procedures of rehabilitation are presented.

D-307 "Redecking with Precast Keeps Traffic Moving." 1984 (Jan). Civil Engineering, Vol 54, No. 1, pp 46-50, American Society of Civil Engineers, New York, NY.

This article describes the redecking of a well-used bridge with precast lightweight deck slabs. Using innovative construction and precast slabs not only kept traffic going through peak periods but also cut costs and 7 months from the schedule.

Special attention is paid to design and construction of the bridge, with several diagrams.

D-308 Whittington, K. 1984 (Feb). "The Airey House Problem," Concrete Plant and Production, Vol 2, No. 2, pp 63-66, Amersham, England.

Post WWII, prefab housing became a necessity in many European cities. Revolutionary in design, they were built of concrete or asbestos-cement cladding panels fixed to steel, concrete, or timber frames.

One of these houses and the repairs to the corroded steel tubing in the concrete columns are described. Surveys and tests on the house are included, with special details devoted to column repair.

D-309 Brown, R. W. 1984 (Feb). Residential Foundations: Design, Behavior and Repair, 115 pp, Van Nostrand-Reinhold Co., Inc., New York, NY.

This study defines the causes of foundation failure and gives suggestions for diagnosis, repair, and prevention. The text presents a background on foundations and also looks at how various foundations react with different types of soils. Other factors that affect foundations such as climate and construction are also considered. Photographs are provided to help familiarize readers with foundation failures. The primary methods of repair, underpinning and mud-jacking, are presented. Included for less common foundation problems are such approaches as deep grouting and French Drain installation. A chapter focusing on such procedures as proper maintenance, watering, drainage, and vegetation, outlines preventive measures for avoiding foundation failures.

D-310 Lohmeyer, G. 1984 (Feb). "Watertight Concrete Units - Remedial Measures in the Case of Moisture Penetration" (in German), Beton, Vol 34, No. 2, pp 57-60, Dusseldorf, Germany.

Though watertight building parts of precast reinforced concrete manufactured under ideal production conditions should not be defective, in practice defects do occur which allow moisture penetration. Proven techniques for the eradication of such defects are presented.

D-311 Ducker, H. P. 1984 (Mar). "Structural Alteration of a Prestressed Concrete Bridge" (in German), Beton, Vol 34, No. 3, pp 91-94, Dusseldorf, Germany.

This article details structural alteration of an overhead highway originally built in 1965. The alteration involved the destruction of two bays, which were then regraded and replaced with two parallel roadways.

D-312 "Damaged Bridge Returns to Health in Delicate Repair," Engineering News-Record, Vol 212, No. 12, pp 26-27, New York, NY.

By mid-March, Michigan's Zilwaukee Bridge's repairs should be almost complete. Plagued by problems since construction began in 1979, the repairs included work done on a cracked pier footing, involving an extremely difficult ground freezing project. Photographs included trace progress of the repairs.

D-313 Kurome, M., Satoh, Y., and Sakurai, T. 1984 (Apr). "Pavement Repair Work on Run-Way Under Operation by Placing Prestressed Concrete Precast Panels in Chitose" (in Japanese), Concrete Journal, Vol 22, No. 4, pp 29-35, Tokyo, Japan.

This article describes the research, evaluation of pavement, planning, design, and construction concerning the night-time repair work of a military airport runway. The Sapporo Defense Facilities Administration decided to replace the damaged concrete pavement panels with new prestressed, precast concrete panels without interrupting the daily operations of the Air Self-Defense Force at Chitose Air Base. The night-time construction process is discussed in detail.

D-314 Dhir, M. P. 1984 (Mar-Apr). "A Study of the Effect of Temperature Variations on the Bonding of Concrete Overlays," ACI Journal, Proceedings, Vol 81, No. 2, pp 172-179, Detroit, MI.

Preventive strengthening of existing concrete pavements with bonded concrete overlays leads to economy. With the background of observations of areas of loss of bond on some projects, this study was undertaken to assess the adverse effects of large temperature variations that occur when overlaying is done in intemperate weather. An insulation covering was used to try to counteract these weather effects. Panels were also overlaid in temperate environs with shear pegs and epoxy bonding for comparison. Temperature and data developed in interior, edge, and corner portions of panels in different cases are given.

Areas of inadequate bond result along panel peripheries when concreting is done under large temperature variations. This can be effectively counteracted with the insulation covering.

D-315 Halmos, E. E. 1984 (Apr). "Precast Deck Sections Achieve Overnight Success on Potomac River Bridge," Concrete Products, Vol 87, No. 4, pp 24-25, 44, Chicago, IL.

A six-lane bridge was successfully renovated with the use of precast tensioned and posttensioned concrete. Due to an overload of traffic and suspected insufficient air entrainment in the concrete, the 21-year-old Potomac River bridge became a hazard. To repair the deck of the 5,900-ft-long bridge without shutting the structure down, construction was limited to nights and the traffic rerouted. At dawn, the six lanes were restored to handle rush-hour traffic.

Concrete slabs weighing 27 tons each, averaging 46.6 ft in length, were precast, posttensioned, covered with an epoxy-sand wearing surface, and shipped to the bridge site. The slabs contained a mixture of cement, expanded slate, crushed limestone sand, an air-entraining agent, and a retarding water-reducing agent. The panels designed for placement on eight spans on the west side of the bridge had to be tapered slightly to ensure proper fit.

Each night a large section of the original cast-in-place deck was cut out and replaced with the precast sections. Diamond tipped saws were used to remove the old decking. After the underlying pier caps, outer girders and stringers were cleaned, the new slabs were laid, posttensioned in groups, and rebolted into place. The joints between the slabs were filled with quick setting polymer concrete. The project also made use of bearings and tie-downs which fasten the slabs to the girders and stringer. This prevents stresses in the steel from shrinkage of creep.

D-316 "Vital Pittsburgh Span Restored." 1984 (May). Constructioneer, Vol 38, No. 10, pp 12, 16-17, Chatham, NJ.

The rehabilitation of Pittsburgh's Liberty Bridge cost $31.6 million. The 56-year-old Liberty Bridge crosses the Monongahela River, connecting downtown Pittsburgh with the South Hills area, and is a major link with state Routes 19 and 51S. The structural steel of the bridge began to deteriorate rapidly when the original drainage system ceased functioning properly several years ago. The bridge was actually rebuilt one-half at a time while maintaining traffic on the other half. The renovation of the 16-span deck truss and multi-girder bridge included removing and disposing of portions of the existing bridge superstructure including the deck, buckle plates, sidewalks, handrails, splashguards, curbs, wearing surface, expansion dams, lighting system, and a host of other operations.

D-317 "Westinghouse Bridge Reopened to Traffic." 1984 (May). Constructioneer, Vol 38, No. 10, pp 26-28, Chatham, NJ.

Pittsburgh's Westinghouse Bridge, carrying Route 30 over Turtle Creek Valley between East Pittsburgh and North Versailles, is open to traffic again after an $11.4 million facelift. The five-span reinforced concrete structure was built in 1932. Sidewalks were closed in 1974; two outside traffic lanes were closed in 1976; without action the 1,524-ft-long bridge would no longer be functional.

Rehabilitation included replacing portions of the existing structure including the bridge deck superstructure, expansion dams, drainage system, and approved slabs, as well as repairing portions of the substructure. A major operation on the rehabilitation project was the removal and replacement of the reinforced concrete deck, plus restoration of the sidewalk supports and jack arches. To prevent a repeat of the deterioration problem caused by salt used to combat winter ice and snow, epoxy-coated steel reinforcing bars were incorporated into the new deck. Details of the project are discussed.

D-318 Passage, J. T., and Plump, J. H., Jr. 1984 (May). "River Lock Rehab: A Winter's Tale," Civil Engineering, Vol 54, No. 5, pp 44-47, American Society of Civil Engineers, New York, NY.

The cost efficient rehabilitation project of two locks and an overflow dam involved winter construction under an insulated enclosure and incorporated use of controlled blasting. The entire investigation and restoration process took five winters to complete and involved placing a new filling and emptying system, installing posttensioned anchors through the lock walls for stability, and replacing operating machinery and the power supply and control system.

D-319 Moore, W. 1984 (May). "Frozen Ground Key to Delicate Bridge Repair," Construction Equipment, Vol 69, No. 5, pp 69-71, Des Plaines, IL.

This article briefly outlines a ground freezing technique used to prevent ground loss during caisson construction and ensure stability of a span while repairs to the foundation of the Zilwaukee Bridge proceeded. Soil surrounding the foundation consisted of 90 ft of soft clay, running silts, and sand, which could have caused collapse of the tilted span above the caisson installation if ground loss had occurred.

D-320 Long, W. B. 1984 (May). "Repairs to Fire Damaged Structures," Concrete, Vol 18, No. 5, pp 13-14, London, England.

The assessment of the fire history and residual strength of a structure is complex and requires skill and experience to achieve. The normal purpose of a repair is to restore the structure to the performance it had before the fire, both in strength and fire resistance. The effect of high temperatures must also be considered on both structural materials and elements. This article examines the effect of fire on structural materials and structural members, repair specifications, repair materials, and methods of placing the repair materials, which are recasting in formwork, spraying (guniting), or hand-applied mortars. Each method will give satisfactory results, providing the specification, materials, and techniques are appropriate and the work competently done by experienced operatives.

D-321 Drisko, R. W. 1984. "Maintenance of Waterfront Structures," Western States Corrosion Seminar 18, pp 30, 1-30, NACE, Houston, TX.

Waterfront structures composed of wood, steel, concrete, rock, and plastic materials abound along the hundreds of miles of shoreline of the United States. Each of these materials has special uses in marine shore structures and each is subject to deterioration in harsh marine environments. A knowledge of the manners in which they deteriorate and the best methods to control their deterioration is necessary to maintain them efficiently.

D-322 Franchi, O., and Petroselli, U. 1984 (May). "Reinstatement of the Gerber Bearings of the Marconi Bridge Over the River Tiber in Rome" (in Italian), Industria Italiana del Cemento, Vol 54, No. 5, pp 324-333, Rome, Italy.

This article examines the techniques used in the reinstatement and restoration of the reinforced concrete deck of the Marconi bridge in Rome, in particular the repair of the Gerber bearings, which had undergone displacement. To reach the area to be repaired, the bridge deck was lifted by about 2 m by special hydraulic jacks. To avoid interrupting traffic, the work was programmed in successive stages. The reinstatement envisaged demolition and reconstruction of damaged concrete, widening of the contact area, substitution of the deteriorated supports with steel and teflon supports and the substitution of the previous road joints with completely waterproof joints.

D-323 Ovens, A. 1984 (May). "Repair and Protection of Reinforced Concrete in High Rise Buildings," Concrete, Vol 18, No. 5, pp 21-11, London, England.

This article discusses the concepts and current state of the art in concrete repair and refurbishment. The advances in concrete technology would also appear not to have been matched by equivalent advances in site quality control.

Numerous techniques are available, but the basic areas of a correct approach are survey, diagnosis, removal of damage, replacement, and future protection. Adopting the cheapest proposal and the use of laboratory methods unproven in long-term practical applications must be avoided. This report discusses the basis of a correct approach, in relation to the most common and widespread concrete damage in high-rise buildings, that is, those that due to inadequate quality or thickness of concrete cover over the steel reinforcement, result in loss of passivating alkalinity, active corrosion of the steel, and eventual spalling of the concrete. Structural defects, high chlorides, ASR, and other such problems require more individual investigation and solutions.

D-324 Keeney, C. A. 1984 (May). "Prototype High-Pressure Waterjet Cleaning System," Report NCEL-TR-R-909, Naval Civil Engineering Laboratory, Port Hueneme, CA.

Inspection, maintenance, and repair of waterfront facilities require an efficient method of removing marine fouling and corrosion from underwater structures. The Naval Civil Engineering Lab (NCEL) conducted an evaluation of commercially available methods of underwater surface cleaning on waterfront structures. Based upon the results of the tests, it was concluded that no single system possessed the necessary combination of safety and operational characteristics needed to meet the Navy's waterfront structure cleaning requirements. Therefore, in 1981 a prototype high-pressure waterjet cleaning system was developed that incorporated the best features identified during the commercial system evaluations. In 1982 and 1983 the prototype waterjet cleaning system was tested, modified, and field-evaluated. It was determined that the high-pressure waterblaster was best suited for cleaning steel underwater structures, particularly in limited access areas, while on concrete underwater structures the best cleaning tool was the Whirl Away rotary abrading hydraulic tool. Both concrete and steel underwater structures can be effectively and efficiently cleaned using the NCEL system, since one power source can drive both the Whirl Away hydraulic tool and the NCEL waterjet pistol.

D-325 Lutz, J. G., and Scalia, D. J. 1984 (May-Jun). "Deck Widening and Replacement of Woodrow Wilson Memorial Bridge," Journal, Prestressed Concrete Institute, Vol 29, No. 3, pp 74-93, Chicago, IL.

This article describes the rehabilitation of the bridge, which included several innovative construction techniques when replacing the deck of the Woodrow Wilson Bridge. The deck was constructed with full roadway width, precast, transversely posttensioned, lightweight concrete panels, longitudinally posttensioned in place into segments of generally the same length as the continuous girder units. Polymer concrete and mortar were used within the deck system because of structural properties, placement characteristics, and rapid setting time over a wide temperature range. They were approved after extensive testing by the Maryland and Federal Highway Administrations.

To guard against intrusion of water and salt into the completed deck system and the subsequent corrosion of embedded steel, multiple protective measures were employed. A two-coat epoxy-sand membrane was applied to the top surface of the panels for protection during construction and under the asphaltic concrete wearing surface. Posttensioning was used in both directions to provide crack control, and all embedded reinforcing steel, prestressing hardware, studs, etc., were epoxy-coated. All stressing strands were sheathed in plastic, and multiple strand duct were grouted.

D-326 Chou, G. K. 1984 (Jun). "Cathodic Protection: An Emerging Solution to the Rebar Corrosion Problem," Concrete Construction, Vol 29, No. 6, pp 561-566, Addison, IL.

Cathodic protection, an electrical means to reverse the direction of the mechanism that causes steel to rust in concrete, is being used to combat deterioration of steel reinforcements.

Corrosion is the spontaneous tendency for iron to return to its natural oxidized state. In the normally alkaline concrete environment, a passivating oxide layer forms over the steel reinforcement. This layer prevents the corrosion reaction from proceeding. However, when salt is present in the concrete, the chloride ions break down this passivating layer, and the reinforcement is unprotected against corrosion. The steel that is more positive (anodic) corrodes while the steel that is more negative (cathodic) does not corrode. The rust occupies a larger volume than the original steel, thus producing force that causes the concrete to crack. By using an electric current, corrosion is prevented by imposing an overriding potential that forces all the reinforcement bars to act as cathodes.

Installment of this system, as well as alternative placement of a platinum or carbon fiber overlay is discussed. The design of control systems to simplify installation and operation of cathodic protection and a financial perspective regarding corrosion prevention is also covered.

D-327 "Pavement Joint Sealing-How to do it Right." 1984 (Jun). Concrete Construction, Vol 29, No. 6, pp 579-582, Addison, IL.

Procedures that will extend the life of joint seals are presented. Factors of prime importance include cleaning the vertical faces of the joint by sandblasting, inspecting the joint faces, maintaining the cross-sectional shape of the sealant, and keeping the sealant hot. A new type of applicator wand featuring a temperature gage, a supporting wing for the tip, and a cutoff valve located only 6 in. above the nozzle is recommended.

D-328 Lwin, M. M., and Gloyd, C. S. 1984 (Jun). "Rebuilding the Hood Canal Floating Bridge," Concrete International: Design & Construction, Vol 6, No. 6, Detroit, MI.

The west half of the original Hood Canal Floating Bridge was destroyed in a severe storm in 1979. Careful planning, innovative construction methods, and a staged construction program combined to replace this major transportation link in Washington state.

D-329 Dobrowolski, J. A., and Scanlon, J. M. 1984 (Jun). "How to Avoid Deficiencies in Architectural Concrete Construction," Technical Report SL-84-9, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report documents the results of a task force assessment of deficiencies in architectural concrete construction being performed for the Corps of Engineers. A field survey of various civil works and military projects revealed 29 repetitive deficiencies for which causes are cited. Recommendations for prevention and possible repair procedures are presented in a series of fact sheets included in the report.

D-330 Ribar, J. W., and Scanlon, J. M. 1984 (Jun). "How to Avoid Deficiencies in Portland-Cement Plaster Construction," Technical Report SL-84-10, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report documents the results of a task force assessment of deficiencies in portland-cement plaster construction for the Corps of Engineers. A field survey of various civil works and military projects revealed 28 repetitive deficiencies for which causes are cited. Recommendations for prevention and possible repair procedures are presented in a series of fact sheets included in the report.

D331 "Concrete Resurfacings Demonstrate Cost-Effectiveness." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 37-38, Des Plaines, IL.

Although repairing roads with portland-cement concrete is not a new procedure, improvements in equipment and reinforcing techniques have made concrete resurfacing more desirable. Resurfacing projects using concrete have extended life and increased load-carrying capacity of existing pavements. The performance of concrete resurfacing, however, is influenced by the condition of the existing pavement. Depending on the pavement type, resurfacing is classified as bonded, partially bonded, unbonded, and white topped. The specifics of each interface treatment are detailed along with examples of applications. Considerations are given to resurfacing with alternate types of concretes as well.

D-332 "Recycling Shifts to High Gear for PCC Pavements." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 42, 44, Des Plaines, IL.

Recycling concrete is a successful reconstruction technique. Until recently, this process which conserves material, energy, and money, was thought of only in regard to asphalt concrete pavement. The process has been extended to PCC pavement as a variety of emerging technologies and has allowed this reclamation procedure to be just as successful. While recycling the PCC pavement involves basic steps--breaking, crushing, and removal of imbedded steel-reinforced bars and mesh--the equipment and applied techniques can vary. Projects using the recycled concrete aggregates can diversify as well, ranging from airport runways to porous concrete shoulders. Strength capacity appears to be a major factor for using the recycled concrete on runways and shoulders. Recycled "D" cracked concrete is less susceptible to "D" cracking. This is a result of the air which has been entrained in the original concrete to the smaller particle size that results from crushing. With great durability benefits and low construction costs, expanded applications of recycled PPC concrete are expected.

D-333 Klein, G. J., and Gouwens, A. J. 1984 (Jul). "Repair of Columns Using Collars with Circular Reinforcement," Concrete International: Design & Construction, Vol 6, No. 7, pp 23-31, Detroit, MI.

Concrete collars can be used in several ways to repair and strengthen concrete structures. In most applications, the critical function of the collar is to transfer vertical load to the column.

Reinforcement encircling the column can be used to transfer load through shear friction. This article presents the theoretical normal force and appropriate friction coefficients for circularly reinforced collars. Load tests simulating actual repair installations verify the theoretical capacity.

D-334 Gaul, R. W. 1984 (Jul). "Preparing Concrete Surfaces for Coatings," Concrete International: Design & Construction, Vol 6, No. 7, pp 17-22, Detroit, MI.

While great care is usually taken in selecting and installing coatings (barrier systems) to protect concrete from aggressive environments, insufficient attention is given to the concrete surface to which the barrier system will be attached. Merely specifying a clean, dry, and sound surface is inadequate because these terms do not precisely define requirements. To ensure optimum barrier system performance, a systematic approach is necessary to identify surface condition requirements for each barrier material, evaluate the existing condition of the surface to be protected, and use proper methods to correct deficiencies in that surface.

D-335 "Diamond Grinding Brings PCC Surfaces Back to Life." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 50-51, Detroit, MI.

Diamond grinding a concrete surface during rehabilitation adds to the serviceability of the pavement. By creating a smooth surface, diamond grinding adds years of life to pavements and provides a quiet, skid-resistant ride. The procedure of diamond grinding is explained as well as how the process provides safer roadways. Guidelines for grinding indicate that the process must meet friction tests, blade spacing, and depth averages. The popularity of this method has spread to the restoration of millions of yd^2 of concrete.

D-336 "Seven Techniques of CPR." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 46-47, Detroit, MI.

Concrete Pavement Restoration (CPR) uses seven techniques that combine for a total PCC pavement system. CPR looks at the several interlocking causes of concrete deterioration, beginning with restoration of structural integrity. Conditions for replacements slabs, reestablishment of load transfer, and slab stabilization are discussed. After defective areas are identified, they are sawed out with diamond sawblades. Other repair procedures are presented. The article concludes with methods of joint resealing and maintenance tips to preserve the restored concrete structure.

D-337 Steele, G. W., and Gunderman, W. G. 1984 (Jul). "Roads-Keystone of the Infrastructure," Standardization News, Vol 12, No. 7, pp 13-18, Philadelphia, PA.

Maintenance needs of the roads system are discussed. A search for better materials, equipment, and processes and the development of standards to define them have been supported by federal, state, and private sector funds. Primary causes responsible for maintenance inefficiencies were found to be the patronage system, the lack of maintenance management research, inadequate maintenance data, lack of uniform standards, ineffective procedures for planning and scheduling, and overstaffing to meet emergencies.

The increasing cost of maintenance is caused by two unrelated matters. A large portion of recent expenditures are now being attributed to goals not in effect in earlier years. These are traffic service items including snow removal, ice control, and traffic control. Secondly, the approaching end of the design life of existing roads is being accelerated by the increasing volume of traffic. Driving on deficient roads not only adds to the maintenance costs of the road system, but to those of the driver as well.

The success of improving these deficient roads while minimizing rehabilitation costs and labor is discussed. The effects of statutes, standards, and regulations on the allocation of funds for road construction and maintenance is considered. Afterward, the assurance of quality construction is covered, recognizing the need for extended research as well as the development of processing, sampling, testing, and inspection standards that provide a performance based quality level corresponding to what has been judged desirable in existing work.

D-338 "Concrete: Could be the Best Buy Per Mile." 1984 (Jul). Roads (formerly Rural & Urban Roads) Vol 22, No. 7, pp 31-34, Des Plaines, IL.

The latest advancements in the use of concrete indicate that emphasis today is placed on rehabilitation projects. Changes in the industry include undersealing, production diamond grinders, and new sealants.

Using several sources, the most efficient methods of design and pavement selection are chosen along with cost analyses of each.

Interest rates are of great importance and are used in funding analysis to account for factors such as depreciation, estimated inflation, and expected long-term increases in materials costs.

Concrete is compared to asphalt for efficiency. The time needed for construction and maintenance costs are also mentioned.

D-339 "Kansas Fights Thermal Cracking with 'White-Top'." 1984 (Jul). Roads (formerly Rural & Urban Roads), Vol 22, No. 7, pp 14-15, Des Plaines, IL.

When thermal cracks appeared on portions of Interstate 70, the Kansas Department of Transportation (KDOT) decided to resurface the asphalt with concrete pavement. The 10-in.-thick asphalt was repaired with an 8-in. concrete overlay. The KDOT decided to mill off 4 in. of asphaltic concrete and then place the 8-in. of concrete.

The recycled asphalt was used on shoulders and ramps. Westbound traffic was switched "head to head" and construction of the eastbound lane was completed in less than 20 working days, returning traffic to its normal four lanes. Upon asphalt removal, soft spots were uncovered. Plywood sheets were placed to minimize additional cracking.

After skewed joints were sawed off at 15 ft spacings, the joint was sealed with silicone. The paving train was headed by a spreader to allow greater uniformity of movement of the slipform paver. Prior to tining, a 4-in.-wide canvas webbing was placed on a skew to prevent texture on the surface where joints would be sawed.

D-340 McCabe, C. 1984 (Jul). "Diverless Repair System Ready for Deepsea Tests," Ocean Industry, Vol 19, No. 7, p 94, Gulf Publishing Co., Houston, TX.

The prototype for a robotic deepsea pipeline repair system has completed land tests in Nantes, France, and is scheduled to undergo deepwater tests. The diverless system is intended to prepare the severed ends of a damaged section of pipeline for reconnection at depth without direct human intervention. Operating under remote control from the surface, the system will employ various tool packages to remove concrete, where necessary, and anticorrosion coating, cut the pipe end, and brush and clean the inside of the pipe.

D-341 "Caisson." 1984 (Jul). Civil Engineering, Vol 54, No. 7, p 48, American Society of Civil Engineers, New York, NY.

Damaged by deterioration and an explosion, New York's Jamaica Bay Water Pollution Plant desperately needed repair. This article describes the restoration steps taken, including replacement of digestion tanks and thickener equipment. The project, however, was highlighted by the sinking of a new concrete caisson pumping station. The caisson placement was accomplished by constructing four walls and removing the earth from the caisson's center. Concrete sealer was placed over the caisson's bottom at 56 ft. After hardening, the site was rewatered by pumping down to basement level. The plant remained in operation during construction and now meets federal standards for B.O.D. sewage treatment removal.

D-342 "Rehabilitation of the Blaine Hill Viaduct." 1984 (Jul-Aug). Journal, Prestressed Concrete Institute, Vol 29, No. 4, pp 13-138, Chicago, IL.

After approximately 46 years of service, the Blaine Hill Viaduct in east central Ohio needed rehabilitation. Precast and precast prestressed concrete were selected to upgrade the bridge's load-carrying capacity from 7,800 to 12,480 vehicles per day by the year 2000. The total length of the structure is 1,015 ft, including the length of slab-on-grade for the approaches. Four concrete arch spans and seven concrete beams are the main components of the structure. Rehabilitation procedures, materials, and costs are discussed.

D-343 "Cathodic Protection: Black Magic or Blue Ribbon Solution?" 1984 (Aug). Roads (formerly Rural & Urban Roads), Vol 22, No. 8, pp 26-29, Des Plaines, IL.

To electrical engineers, the theory of cathodic protection is well accepted. To many civil engineers, contractors, and highway officials, however, the concept is as yet unproven. The principle of cathodic protection is that by running electricity through a reinforced concrete structure, corrosion disappears. The pipeline industry has been employing the process of adding electrical current to reinforced concrete to arrest corrosion in reinforcing bars for more than 30 years.

The principles of cathodic protection are described and a brief history is given. Installation costs vary from \$2 to \$4 per ft^2 depending on the system, labor rates, and other factors. Several systems on the market are described, and present attitudes and future trends are discussed.

D-344 Stratton, F. W., and Crumpton, C. F. 1984 (Aug). "Kansas Bridges Renovated by Post Reinforcement and Thin Bonded Concrete Overlay," Concrete Construction, Vol 29, No. 8, pp 705-709, Addison, IL.

This article details the process of postreinforcement, a repair method for girder bridges that increases the girder's shear capacity. The four basic steps are: 1) seal all cracks in the girder with a silicone sealant; 2) vacuum drill 1-in.-diam clean, dust-free holes at a 45-deg angle to the deck near the girder center line in the pattern specified in the engineering plans; 3) pump epoxy into drilled holes and into cracks intercepted by these holes; and 4) insert a #6, Grade 60 reinforcing bar cut 3 in. short of full-hole depth into each hole.

A three-span bridge can be completely postreinforced in less than 1 week if the repair crew is efficient, and traffic can usually be maintained on one lane of the bridge during the repair. The technique raises the girders' shear capacity to 10 percent above 1981 AASHTO requirements. In some cases, the final step is construction of a thin bonded overlay if the bridge deck is in poor condition.

D-345 Kendall, K. 1984 (Sep). "Cathodic Protection of Reinforcing Steel," Civil Engineering, pp 57-58, London, England.

This article considers the use of cathodic protection to control corrosion of reinforcing steel in concrete. The discussion focuses on the lack of exact assessment methods for monitoring the process and on the absence of adequate criteria by which to judge the success or failure of an installation. It is concluded that, due to the lack of direct experience, the use of cathodic protection should be considered a promising experimental procedure in need of serious study.

D-346 Miller, D. O., and Beckman, R. D. 1984. "Renovation of the Third Avenue Bridge in Minneapolis," Transportation Research Record 950, Vol 1, pp 150-156, Transportation Research Board, Washington, DC.

Built in 1918 this reinforced concrete structure had deteriorated to the point where it needed major renovation or replacement, Howard, Needles, Tammen, & Bergendoff, Architects, Engineers, and Planners did a detailed inspection and evaluation of the bridge. They recommended replacement of the entire deck including roadway, barriers, sidewalks, railings, and lights; the spandrel caps and the upper portions of the spandrels; the entire approach spans, including the bents; and even the abutments and wing walls. An incentive clause was added to the contract. Construction brought additional problems. The condition of the bridge was worse than expected. Decisions about the extent of the repairs had to be made daily.

D-347 "Mothballed Hotel Comes to Life." 1984 (Oct). Engineering News-Record, Vol 213, No. 16, pp 47, New York, NY.

This article describes the renovation of the 80-year-old Willard Hotel in Washington, DC, and construction of an adjacent 12-story office building. The hotel has been closed since 1968. The detailed limestone and brick facade of the hotel will be recondition, and the first floor will be restored. Extensive load tests determined that existing footings could support a new interior and that some steel columns needed strengthening. The interior of the hotel was essentially gutted except for the historic rooms and the terra-cotta brick subfloors throughout. At the same time, adjacent excavation began for the office building. Existing hotel footings had to be underpinned to 30 ft below grade, the depth of the new structure. The office building is a conventional reinforced concrete, flat-slab structure; its combination of granite, limestone, and precast facade will complement the hotel exterior. Like the hotel, it will have a mansard roof, but instead of slate, it will be of sheet metal covering precast panels. The Willard is set to open in mid-1986.

D-348 "Proceedings for the Tri-Regional Pavement Rehabilitation Conference Held at Oklahoma City, Oklahoma on 14-17 May 1984." 1984 (Oct). Report FHWA/TS-84/223, Federal Highway Administration, Washington, DC.

This conference provided a forum for practicing engineers, administrators, and industry representatives to discuss and demonstrate both proven and the most promising technology available for the evaluation and rehabilitation of our Nation's pavement systems. Topics covered included asphalt distresses (rutting, stripping and thermal cracking), design of asphalt overlays, special AC rehabilitation techniques, CRCP rehabilitation, PCC overlay design and construction, and special PCC rehabilitation techniques. Both rigid and flexible pavement evaluation techniques were discussed. FHWA and AASHTO viewpoints on selection and design of rehabilitated projects were presented.

D-349 Smyers, W. L. 1984 (Sep-Oct). "Rehabilitation of the Fremont Street Bridge," Journal, Prestressed Concrete Institute, Vol 29, No. 5, pp 34-51, Chicago, IL.

This article presents the design and construction details that were employed in rehabilitating the Fremont Street Bridge, a 50-year-old concrete arch near Pittsburgh, PA. Precast decking and a two-piece precast floor beam assembly were among the construction techniques used to repair the bridge while maintaining uninterrupted traffic. A step-by-step account of the design and repair techniques is given along with illustrative photographs and drawings.

D-350 Glassgold, I. L. 1984 (Oct). "Repair of Concrete Structures in Marine Environment" (in Spanish), Revista IMCYC, Vol 22, No. 162, pp 21-33, Instituto Mexicano del Cemento y del Concreto, Mexico.

The repair of concrete structures in a marine environment has been a serious and difficult problem since the discovery of Portland cement. The advent of reinforced concrete technology has further complicated the situation. A discussion and brief history of the problem and its causes are presented as an introduction to the subject. This is followed by an evaluation of the procedures required to determine need, specify technique, and implement repair. The characteristics of the various zones of repair are described according to their position relative to the tide.

D-351 "Wisconsin Takes Rebar a Long Way." 1984 (Nov). Engineering News-Record, Vol 213, No. 19, pp 36, 41, New York, NY.

This article describes one of the largest highway rehabilitation projects to be completed in the United States. The $70 million rehabilitation project of 32 miles of continuously reinforced concrete highway includes 64 lane-miles of new pavement, 128 miles of new shoulder, and replacement of approximately 112 lane-miles of deteriorated pavement with recycled aggregate.

The Wisconsin interstate highway was built 23 years ago with most of the pavement being 9-in. steel-mesh-reinforced concrete with doweled joints every 80 ft. Severe weather and deicing salts combined to destroy these sections of pavement, but not the 4-mile stretch with 8-in. continuously reinforced concrete. This original stretch of pavement served as the model for the rehabilitation project, and because it met current standards for new pavement, the pavement was merely strengthened with an overlay, which is expected to last another 30 years.

D-352 "IRM/AODC Conference, 5th Offshore Inspection Repair and Maintenance Conference." 1984. Vol 2, Offshore Conference & Exhibition Ltd., Kingston upon Thames, London, England.

This conference is published in 2 volumes and contains 22 papers. The subject matter is primarily concerned with the repair, maintenance, and inspection of offshore structures such as marine platforms, production platforms, concrete structures, and other subsea structures. Methods of defect sizing, underwater welding, and nondestructive examination are discussed. Analysis is given for cost accounting of repair and maintenance procedures.

D-353 Drachnik, K. J. 1984 (Nov). "Application of a Polymeric Anodemesh for Cathodic Protection to a Reinforced Concrete Structure," Corrosion Effect of Stray Currents and the Techniques for Evaluating Corrosion of Rebars in Concrete, Williamsburg, Virginia, USA, ASTM STP 906, pp 31-42, American Society for Testing and Materials, Philadelphia, PA.

A cathodic protection system using a mesh of polymeric anodes to protect the reinforcing steel in a concrete substructure is described. The aboveground structure was actively corroding as indicated by a preinstallation potential survey and analysis of chloride concentrations in the concrete. Gunite was used to permanently attach the anodemesh to the concrete and to provide an electrolyte for distribution of the cathodic protection current. Two criteria were used to determine the level of cathodic protection current required to inhibit corrosion of the reinforcing steel. Test results indicate that the steel has been polarized 300 mV cathodic of its native potential and that the structure is well protected. The system continues to perform as expected after 10 months of continuous operation.

D-354 "Fighting Bridge Decay from Within." 1984 (Nov). Better Roads, Vol 54, No. 11, pp 32-34, Park Ridge, IL.

Recently, cathodic protection has generated interest as a technique to stop rebar corrosion in salt-contaminated concrete structures. Part of the appeal of cathodic protection is that it attacks the underlying cause of most concrete deterioration: corrosion of the steel reinforcement. Materials such as epoxy-coated rebar resist corrosion. Cathodic protection, however, stops the mechanism of corrosion - the electrochemical oxidation-reduction reactions. This article discusses traditional remedies for the problem, cathodic protection, and commercially available protection systems.

D-355 Sinh, P. 1984 (Nov). "Scope for Better Road Maintenance in India," Indian Concrete Journal, Vol 58, No. 11, pp 316-318, Bombay, India.

The scope for improving road maintenance in India is immense. The poor condition of the roads emphasizes the need for preventative, corrective, and timely road maintenance. A well-planned maintenance strategy would keep road pavements in efficient service with minimum overall expenditure, the least inconvenience to traffic, optimal fuel consumption, and minimized incidence of road accidents. While emphasizing the need for maintenance, the paper draws attention to the inadequate allocation for it and by pointing out major deficiencies in present-day maintenance, suggests some corrective measures.

D-356 Somerville, G. 1984 (Nov). "Interdependence of Research, Durability and Structural Design - Concrete," Conference on Design Life of Buildings, Cement & Concrete Assoc, London, England, 1984 Nov 26-27, pp 233-250, Thomas Telford, London, England.

This paper reviews existing practice for designing concrete structures to ensure adequate durability. Based on this review, a scheme is suggested for consideration in the future which would require cooperative effort from research workers, designers, and builders. In summary, we need to know more about how structures really perform in service, including the determination of actual environmental effects. Based on this knowledge, it is then necessary to set down design lives for structures and to determine appropriate performance criteria.

D-357 Standig, K. F. 1984 (Dec). "Rehabilitation of the Delta Dam," International Water Power and Dam Construction, Vol 36, No. 12, pp 21-24.

Delta dam, a 70-year-old concrete structure located in New York State, was one of nearly 3,000 dams found to be deficient after the Corps of Engineers sponsored inspections of non-Federal dams. Concrete deterioration had been a problem for years, and the inspection findings indicated that stability of the structure during peak design floods did not meet modern safety criteria. Measures now being taken to correct both conditions are discussed in this article.

D-358 "From a Locomotive Shop...A Bridge." 1984 (Dec). Railway Track and Structures, Vol 80, No. 12, pp 28-29, Chicago, IL.

This article discusses the project to replace a deteriorating ballasted deck on a Pennsylvania railroad bridge with precast concrete slabs. The original 8-in.-thick reinforced concrete deck and ballast retainers, constructed in 1931, were deteriorating due to age and salt spray from the highway traffic below. It was decided to replace the old deck with precast, doubly reinforced 8-in.-thick concrete slabs with monolithic ballast retainers. Using precast slabs minimized interruption to railroad and highway traffic.

The new slabs were designed to support a load with full impact and to resist the stresses that would occur when lifting and placing the slabs. A total of 61 yd^3 of concrete, 7,500 lb of epoxy-coated reinforcing bars, and 4,500 lb of uncoated reinforcing bars were used in the slabs. Compressive strength requirements and other engineering specifications as well as placement of the new slabs are discussed.

D-359 Beauverd, J. 1984 (Dec). "Concrete Pavement Reconstruction on Geneva-Lausanne Motorway No. 1" (in French), Travaux, No. 594, pp 19-22, Paris, France.

This article describes reconstruction techniques used to restore damaged pavement on a Swiss motorway. Safety features of cement concretes and bituminous concretes are compared.

D-360 Moore, W. 1984 (Dec). "Oklahoma Bridges Get Cathodic Protection," Construction Equipment, Vol 70, No. 6, pp 101-102, Des Plaines, IL.

This article describes the design of two turnkey cathodic protection systems to counteract corrosion of steel reinforcing bars in two highway bridges. Both systems employ platinum-clad and carbon strand anodes sealed in the bridge decks by highly conducive concrete. The current to be distributed throughout each deck is supplied by rectifiers.

On one of the bridges, deterioration of the concrete surface required the design of an "overlay" cathodic protection system, which seals anodes to the existing deck surface and overlays them with a new, conductive concrete wear surface. The soundness of the deck surface of the second bridge allowed installation of a more cost-effective system, wherein anodes are placed into slots sawed in the bridge deck and the slots filled flush with a conductive polymer concrete.

D-361 Som, N. G., Dutta, A., and Dasgupta, A. 1984 (Dec). "Rehabilitation of Damaged Articulation on Bridge Over L.B.M.C. Durgapur at Ch 65.00

West Bengal," Bridge & Structural Engineer, Vol 14, No. 4, pp 15-28, New Delhi, India.

Reinforced concrete was introduced in construction as early as 1940. With virtually no maintenance, these structures performed their function for 30 to 40 years. Lately, some of these structures are showing signs of distress due to corrosion of reinforcement that might have been due to bad workmanship or some lacuna in design. Apart from this, the degree of distress also varies with the location of the structure. The structures are also distressed or damaged due to natural calamities like earthquakes, floods, fire, etc. The repairs to these structures are becoming necessary to avoid much costlier replacements. These repair works require a high degree of skilled and technical innovations with a clear conception of structural behavior.

D-362 "Special Fasteners, Rehab Methods for Transit Bridge Track." 1984 (Dec). Railway Track and Structures, Vol 80, No. 12, pp 20-25, Chicago, IL.

Each year the span and tracks of the Benjamin Franklin bridge across the Delaware river are inspected. In 1980, the rail transit structure's concrete ballast decks were determined to be seriously deteriorated and removal of the deck was recommended. Deterioration was caused by the impregnation of deicing salts sprayed from the adjacent highway as well as by the return current that going to ground from the transit track's running rail on the bridge. This electrolysis problem would be alleviated with the design of the new bridge track.

Designers decided to remove the concrete ballast deck from all approaches and not replace it, thereby leaving the track support open. Removal of the deck concrete and reconstruction of the trackbed are discussed in detail.

D-363 Kailasananthan, K., McCullough, B. F., and Fowler, D. W. 1984 (Dec). "Study of the Effects of Interface Condition on Thin Bonded PCC (Portland Cement Concrete) Overlays," Report CTR-3-8-83-357-1; FHWA/TX-85/45+357-1, Center for Transportation Research, Federal Highway Administration, Austin, TX.

The purpose of the study was to verify the feasibility of using thin bonded PCC overlays and to evaluate their performance when exposed to traffic and environmental conditions in Houston. Laboratory experiments were performed and a test section was constructed; cores were taken and analyzed to determine the correlation between laboratory findings and findings from the field for useful conclusions that would enable the Texas State Department of Highways and Public Transportation to Design Overlays for Future Rehabilitation Programs on CRCP.

D-364 Heystraeten, G. V. 1984. "Waste Concrete Recycling in Road Construction" (in French), Technique Routiere, No. 4, pp 9-31, Brussels, Belgium.

This article focuses on the problems of waste-concrete recycling in road construction. The following aspects are discussed: origins of waste concrete, reasons for recycling, demolition, processing of waste concrete in crushing plants to produce recyclable aggregates, use in road construction, and economic and financial considerations.

D-365 Kloj, G., and Tittel, G. 1984. "Thermal and Mechanical Cutting of Concrete and Steel," Report EUR-8633, Commission of the European Communities, Luxemburg, Belgium.

Various thermal and mechanical processes for dismantling radioactive large components and concrete structures were investigated to determine the optimal handling conditions and their respective efficiency. For the thermal processes, the separation of heavy concrete and steel components by means of oxygen lances, powder cutting, ocyacetylene cutting, and plasma cutting processes were tested. To gain the necessary data for designing filtering equipment with regard to use in nuclear power stations, the amount of dust deposition and particle size distribution for these thermal processes were measured. For the mechanical processes, stationary saws were used. Due to the large dimensions of the components which are to be found in a nuclear install-tion, it is not possible to use such saws for the initial dismantling. These saws can be used for both low-alloy and austenitic types of steel, and for separating materials not containing iron. To compare the efficiency of the saws with that of the thermal processes, to some extent the same test pieces were used that were used for the thermal tests. The advantage of the saw technique in comparison to the thermal separation processes lies in that next to no gas or dust contamination can become released. Also, the amount of shavings produced (secondary waste) is low. Furthermore, some of the saws can be used under remote control.

D-366 Park, S. H. 1984. Bridge Rehabilitation and Replacement (Bridge Repair Practice), S. H. Park, Trenton, NJ.

This book provides common causes of bridge defects and deterioration along with countermeasures for repairs, rehabilitations, retrofits, and replacements. It also covers a wide range of bridge related problem areas and exposes potential conflicts in engineering, design, materials, construction, and fabrication. Beside engineering and design procedures, this book offers an overview of all areas of funding, environmental requirements, FHWA rules, selection of schemes, permits, and utility involvements. The most difficult problem faced by bridge engineers today is the tendency to be involved in bridge design only while bridge projects require more general engineering, administration, and communication skills. Current rapid development and use of microcomputers and CADD systems open a new door for bridge engineers. Wide use of the computer frees us from routine detailing work and leads us to visualize the structural behavior of the bridge in three dimensions instead of conventional two-dimensional approach. This helps us to understand the structural need of a particular bridge and to provide better repair schemes and designs.

D-367 "Cathodic Protection of Bridge Substructures: Burlington Bay Skyway Test Site, Design and Construction Phases." 1984. Transportation Research Record 962, pp 29-37, Transportation Research Board, Washington, DC.

The design and construction phases of a research program to develop an effective cathodic protection system for use on bridge substructures are described. Construction of four experimental systems on columns of the Burlington Bay Skyway Bridge was completed in 1982. One sacrificial anode system and three impressed-current systems were installed, each covering approximately 38 m/SUP/2 of column surface. The sacrificial anode system used zinc ribbon anodes with a shotcrete overcoat. A conductive polymer concrete was used as the primary anode in all the impressed-current systems. In System 1 the anodes were used with a shotcrete overcoat. System 2 consisted of the primary anodes with an exposed secondary anode of conductive paint. System 3 employed a secondary anode network of multifilament carbon strand, also with a shot overcoat.

D-368 Logie, C. V. 1984. "Drilled Pier Foundation Rehabilitation Using Cement Grouting," Innovative Cement Grouting, SP-83, American Concrete Institute, Detroit, MI.

Results from load testing of 1-meter-diameter drilled concrete piers showed that the majority of the piers designed as foundation support for the 37-story Jakarta Mandarin Hotel failed to meet load test criteria. The potential causes for load test failure and the load deflection characteristics of the piers were investigated. A layer of unconsolidated sediment of varying thickness was encountered between the pier tips and the bearing strata. Extensive coring through the pier shafts was undertaken to develop data to statistically characterize the thickness and spatial distribution of the unconsolidated sediments. A rehabilitation technique was developed which consisted of flushing the sediments from the pier tips utilizing high pressure water jets followed by subsequent cement grouting of the resulting voids. The technique was developed so that production rehabilitation could be practically and reliably achieved.

D-369 Weyers, R. E., and Cady, P. D. 1984. "Development: Deep Grooving - A Method for Impregnating Concrete Bridge Decks," Transportation Research Record 962, pp 14-18, Transportation Research Board, Washington, DC.

A laboratory investigation was performed to develop a simplified system that will reduce the impregnation time, simplify the equipment needs, and mitigate the potential fire hazards by deep grooving the concrete. The monomer used was an MMA-TMPTMA-AZO system. The laboratory results indicate that the impregnation time can be significantly reduced by optimizing the groove width, depth, and spacing. Optimum drying (by using infrared heaters) and polymerization conditions for the grooving conditions are also presented. The results of the laboratory study demonstrate the feasibility of the method and the need for a full-scale field trial to demonstrate its applicability to field conditions.

D-370 Byfors, K. 1984. "Prevention of Corrosion" (in Swedish), Nordisk Betong, Vol 28, No. 2, pp 27-30, Stockholm, Sweden.

Various methods used to prevent the corrosion of reinforcement are briefly described. If the risk of corrosion is anticipated, many possibilities exist to prevent damage to reinforcement. Further research is required to form guidelines for evaluation the residual useful life of structures already weakened by corrosion.

D-371 van Heummen, P. H. 1984. "Half-Century Experience with Precast Reinforced-Concrete Box Sections for Culverts and Storm Drains in the Netherlands," Symposium on Durability of Culverts and Storm Drains, Transportation Research Record 1001, Transportation Research Board National Research Council, Washington, DC.

Because of the typical geographical and hydrological situation in the Netherlands, a complex system of water level control has been established. Under varying aggressive conditions, there are tens of thousands of culverts and other structures that make up this system. For more than half a century most of these culverts have been constructed in precast reinforced-concrete box sections. On the basis of practical experience, the real service life, even under severe conditions, amply meets the design service life. In this paper these conditions, and the achievement in manufacturing strong and durable concrete sections, are described.

1985

D-372 Dawes, R. 1985 (Jan). "Preservation and History of the Cleft Ridge Span: Restoration of the Span," Concrete International: Design & Construction, Vol 7, No. 1, pp 14, 16-20, Detroit, MI.

The Cleft Ridge Span in Prospect Park, Brooklyn, which was placed on the National Register of Historic Places in 1980, is believed to be the earliest example of a precast concrete structure in the United States. It is an all-masonry arch vault which carries a vehicular roadway overhead. Today the bridge suffers from severe deterioration, vandalism, and years of neglect. The preliminary estimate for the cost of restoration is approximately $800,000. Taking the structure's historical significance into consideration, the architecture's aim is to save as many original elements as possible. This article discusses problems and solutions connected with the restoration, including a lack of reference material, masonry repair and replacement, surface treatment, vault ceiling and floor, and the foundation.

D-373 "How to Fix Cracks." 1985 (Jan). <u>Concrete Construction</u>, Vol 30, No. 1, pp 37-44, Addison, IL.

Successful crack repair procedures must be based on the cause and condition of the crack. Cracks caused by drying shrinkage are likely to stabilize, while those caused by foundation settlement will continue to grow.

The following crack repair methods and their appropriate applications are discussed: epoxy injection, routing and sealing, stitching, adding reinforcement, drilling and plugging, grouting, flexible sealing, drypacking, polymer impregnation, and overlays and surface treatments. Each repair method is described and examples of where it might be useful are included. Autogenous healing is also described and discussed.

D-374 Allen, H. S. 1985 (Jan). "Methods and Materials for Reducing Crack Reflectance," MN/DOT-INVESTIGATION-202; FHWA/MN/R[illegible]-84/09, Minnesota Department of Transportation, St. Paul, MN.

This study was initiated to study methods, procedures and/or materials that may reduce premature pavement failures of asphaltic concrete overlays on pcc pavement caused by excessive reflective cracking. Methods included in this study were reducing the existing pcc pavement panel size by saw cutting, full coverage fabrics, strip fabrics and Rubber-Asphalt Interlayer as a stress absorbing membrane interlayer (SAMI).

D-375 Engelke, P., and Ivanyi, G. 1985 (Feb). "Injections of Epoxy Resins Under Pressure into Cracks of Concrete Bridge Structures," <u>Beton - und Stahlbetonbau</u>, Vol 80, No. 2, pp 29-35, Berlin, Germany.

Two-component cold-hardening epoxy resins with low viscosity have been used for injections under pressure into cracks in concrete structures.

The purpose of such repairs is to ensure the corrosion protection of the reinforcement and to regain the structural stiffness of the uncracked state. The efficiency of repairing structural cracks by injections of epoxy resins depends mainly on the kind and intensity of stresses acting on the structure, as well as on climatic conditions, the state of crack faces and the properties of the used resins.

D-376 Kaminetzky, D. 1985. "Rehabilitation & Renovation of Concrete Buildings," pp 68-83, American Society of Civil Engineers, New York, NY.

The various steps required during the process of rehabilitating an existing concrete structure are described. The condition assessment, which includes field observations and recording, destructive and nondestructive tests, and which must be thoroughly performed to assess the required rehabilitation, its procedure and its costs, is reviewed. Repair and rehabilitation methods and techniques are discussed. Proper maintenance is emphasized as an important way of reducing the need for restoration. Future research needs to further improve this process are identified.

D-377 "Rehabilitation, Renovation, and Reconstruction of Buildings." 1985. Conference Proceedings, Feb 14-15, American Society of Civil Engineers, New York, NY.

This workshop proceedings contains nine papers. The topics discussed are: building condition assessment; revitalization of existing buildings, evaluation and modernization of Veterans Administration facilities; changing priorities in United Kingdom construction research; renovations of a New Zealand city; research needs for extant iron and steel buildings; rehabilitation and renovation of concrete buildings; masonry rehabilitation; and reconstruction of building cladding.

D-378 Cosgrove, T. 1985 (Feb). "New York Rescues Aging East River Bridges," Construction Equipment, Vol 71, No. 2, pp 122-126, Des Plaines, IL.

This article discusses the repair work planned for the Queensboro, Williamsburg, Manhattan, and Brooklyn bridges in New York. For the Queensboro bridge, most of the structural steel and the concrete decks will be replaced, leaving only the original truss. All main cables on the Williamsburg Bridge will be replaced, which will include anchorage and tower rehabilitation. A 72-ft section of the upper roadway on the Manhattan Bridge has already been rebuilt as a torque tube with the placement of 1-in.-thick steel beams in a diagonal configuration between the trusses under the roadway. Aside from some truss reinforcement work, the biggest problem with the 103-year-old Brooklyn Bridge is the four anchorages. A fiber-optic inspection revealed that all the lower splays were damaged and that the lower shoes were badly corroded. Since the anchorages are not waterproof, these splays and the shoes that anchor them have been perpetually underwater. This resulted in the development of mechanical clamps that fit over the splays and attach to the anchor shoes. Additional work being done on the four East River bridges is discussed.

D-379 "Undersealing Pavement Cuts Noise, Vibration." 1985 (Mar). Roads & Bridges, Vol 23, No. 3, pp 28-29, Des Plaines, IL.

Thin, sometimes widespread voids often develop beneath pavements at transverse joints and shoulders. Complete filling of all voids is necessary to reestablish contact with the subgrade and to provide support for the pavement. A solution to these problems is undersealing, the process of injecting a fluid grout slurry composed of cement, fly ash, and water into small-diameter holes drilled through the pavement slabs and into the thin voids beneath. The successful renovation by undersealing of concrete roads in Minnesota provides an illustration of a solution to noise and vibration problems.

D-380 "Repairs to Concrete." 1985 (Mar). New Zealand Concrete Construction, Vol 29, pp 5-18, Porirua, New Zealand.

Good performance of concrete depends on good designs, details, materials, and workmanship. Unsatisfactory performance could arise as a result of faulty design, use of unsuitable materials, improper workmanship, undue exposure to aggressive environments, excessive structural loadings, or any combination of such factors. This article considers some of the defects that occur and the established methods of correcting them. The article does not cover treatment to remove stains or to restore discoloration. Neither is it possible to explore in any depth design aspects of strengthening structures that are sometimes associated with repair work.

D-381 Simon, J. E. 1985 (Mar). "Repair of the Levallois Bridge, Strengthening of Concrete Arches of the Access Viaduct" (in French), Travaux, No. 597, pp 35-40, Paris, France

The foundations of the piers of the access viaduct underwent significant settlement, causing considerable damage in the concrete arches. An original approach was found for the strengthening of this structure. It consists in precasting a 14-m-diam and 22-cm-thick reinforced-concrete shell that is placed against the defective arch.

D-382 Hosoi, T. 1985 (Mar). "Corrosion in Reinforced Concrete and Its Prevention" (in Japanese), Rust Prevention Control, Vol 29, No. 3, pp 88-94, Japan.

Degradation of reinforced concrete is caused by corrosion of Fe due to carbonation and chloride ions contained in concrete and the reaction of concrete with alkaline aggregates. The process developed by Onoda Co. for prevention of corrosion especially in existing reinforced concrete structures is described. The process consists of desalting by impregnating a corrosion inhibitor into concrete, restoring carbonated areas to alkaline condition by impregnating a specific alkaline aqueous solution and applying polymer cement to prevent further carbonation. The materials used for the process, their corrosion-preventing effect and the procedure for applying the process to existing building structures are described.

D-383 Parr, W. E. 1985 (Mar). "Mining Tool Adapted to Concrete Removal for Lock Wall Rehabilitation Project," The REMR Bulletin, Vol 2, No. 1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Rehabilitation of lock walls at Brandon Road Lock on the Illinois Waterway near Joliet, IL, was the first known application in the Midwest of a highly effective concrete removal device - the Cutter Boom. Manufactured by Excavation and Tunneling Equipment (ETE) Corporation, State College, PA, the Cutter Boom is a modified piece of mining equipment having a rotary head cutter with a series of carbide-tipped teeth that grind away at the concrete.

The primary application of this equipment was to scale the lock walls following the heavy removal work accomplished by blasting.

In addition to the scaling operation, the contractor used the Cutter Boom to effectively grind out soft pockets or honeycombed areas in the concrete structure which were detected by Corps and contractor quality control inspectors sounding the walls. In addition, deeper cuts were easily made by the Cutter Boom to accommodate steel appurtenances such as lock chamber exit ladders and line hook fixtures requiring deeper embedment in the new structure than was afforded by the standard removal line.

While actual cost comparisons of manual removal of concrete versus removal by the Cutter Boom are not available to the author, the Cutter Boom was an obvious success at Brandon Road, where a compressed work schedule was in effect.

D-384 Emery, J. A. 1985 (Apr). "New Techniques in Non-Man Entry Sewer Renovation," Civil Engineering, pp 19-21, London, England.

After finding that some of the city's older sewers needed repairs and replacement, the Luton Borough Council and Thames Water Authority implemented innovative rather than conventional sewer renovation techniques on a 467-m section of a 300-mm-diam sewer. Details of the experimental techniques used in lining a section of an old sewer are provided. Some of the practical difficulties that are applicable to all nonexcavation, nonman entry sewer renovation are described.

D-385 Shimogori, K., Satoh, H., Furuya, T., Tsubono, H., Kodama, K., and Ikeda, K. 1985 (Apr). "Performance of Polymer Cement Grout for Corrosion Protection of Galvanized Steel Wire" (in Japanese), Research and Development, Kobe Steel Ltd., Vol 35, No. 2, pp 71-74, Kobe, Japan.

A cement grouting method between galvanized steel wires and the polyethylene tube top cover is described that increases the durability of the bridge cables. A polymer cement, which is prepared by adding polyacrylic acid ester to portland cement, was applied and the galvanic corrosion protection of this polymer cement against galvanized steel wire was investigated. The polymer cement provided a high degree of protection to the galvanized wire during and after curing.

D-386 Knutson, M. J. 1985 (Apr). "Innovative Demo Tests CPR Techniques, Materials," Roads & Bridges, Vol 23, No. 4, pp 18-20, 22-24, Des Plaines, IL.

This article discusses a concrete pavement restoration (CPR) demonstration project in Des Moines, IA. The objective was to demonstrate various CPR techniques, to develop specifications, to evaluate various materials used, and to develop visual aids to educate those responsible for maintenance of roads, streets, and airports. The project consisted of full-depth patching, partial-depth patching, slab jacking, grinding of pavement, resealing of joints and random cracks, and a bonded bridge approach to resurfacing. The observations concluded from this project are detailed.

D-387 Smith, R. D. 1985 (May). "California Implements Crack-and-Seat Strategy," Roads & Bridges, Vol 23, No. 5, pp 30-33, Des Plaines, IL.

This article describes the California Department of Transportation's crack-and-seat rehabilitation strategy used to repair cracked, spalled, and faulted portland-cement concrete (PCC) freeways.

The procedure entails breaking the damaged PCC slabs into approximately 4-ft-square sections and then using compaction equipment to seat the pieces against the roadway subgrade. An asphalt concrete overlay is then placed over the cracked and seated 8- to 9-in.-thick PCC with an interlayer of reinforcing fabric. Edge drains are installed to help drain water from under the PCC slabs.

Cracked-and-seated highway rehabilitation projects demonstrate good performance after 3 years of service, proving the procedure to be a technically sound, cost-efficient strategy for rehabilitation.

D-388 Slavis, C. 1985 (May). "Bridge Redecking with Precast Components," Better Roads, Vol 55, No. 5, pp 22-24, Park Ridge, IL.

This article discusses techniques used to reduce on-site forming of concrete to lower the cost of concrete bridge construction. The first method involved the use of precast, prestressed girders. Now precast superstructure components are replacing the practice of casting bridge decks in-place with wooden forms between the girders. Precast deck panels are being used as stay-in-place forms or as the total deck thickness.

During redecking of the Kansas River Bridge near Leavenworth, precast deck panels were used as stay-in-place forms for a composite deck. The precast, prestressed panels were 7-1/2 by 8 ft and 3-1/2 in. thick. Temporary falsework was not needed because the panels spanned from girder to girder. Prestressing strands in the panels provided the structural equivalent of a bottom layers of reinforcing steel.

The Kansas River Bridge project used a composite of precast and cast-in-place concrete to replace the deck. Other projects are discussed where precast panels are being used for full-depth deck replacement.

D-389 Hurd, M. K. 1985 (May). "Pavement Rehabilitation with Portland Cement Concrete," Concrete Construction, Vol 30, No. 5, pp 413-425, Addison, IL.

This article outlines construction options for pavement rehabilitation using portland-cement concretes (PCC). Methods reviewed include: concrete pavement restoration (CPR) techniques; bonded, partially bonded, and unbonded overlays; inlays; and PCC recycling.

D-390 Ray, G. K. 1985 (May). "New Pavement from Old Concrete," Civil Engineering, Vol 55, No. 5, pp 56-58, American Society of Civil Engineers, New York, NY.

Recycled concrete pavements look like virgin pavements, may be stronger, conserve raw materials, and solve the problem of disposing of large amounts of pavement in an environmentally acceptable manner. Those who work with recycled concrete offer but a few caveats. Among them are precautions for removing steel reinforcing bars, proper grading of crushed material, and preventing chemical contamination of the crushed aggregate. Life cycle estimates for recycled portland-cement concrete range from 20 to 35 years. Recycled coarse aggregates may be more durable than they were originally. Recycling methods, equipment, and applications are discussed.

D-391 Pomeroy, C. D. 1985 (May). "Requirements for Durable Concrete," Conference on Improvement of Concrete Durability, Proceedings of the Seminar 'How to Make Today's Concrete Durable for Tomorrow', London, England 1985 May 8, pp 1-27, Thomas Telford, London, England.

Some of the basic requirements that must be taken into account if durable concrete structures are to be designed, specified, and construction are discussed. The changes in material properties and in construction practices during recent years are taken into account and the principal requirements for an adequate long term structural performance are highlighted.

D-392 Clear, C. A. 1985 (May). "Effects of Autogenous Healing Upon the Leakage of Water Through Cracks in Concrete," Technical Report 559, Cement & Concrete Association, England.

An investigation is reported which shows that autogenous healing reduces the flow of water through cracks in concrete at rates dependent primarily on the initial effective widths. The mechanism of healing was found to be a combination of mechanical blocking and chemical precipitation of calcium carbonate. The characteristic surface width can be used to estimate the initial effective width if the crack is nominally parallel-sided or if the variation in width along the flow path is known. The watertightness requirements of BS 5337:1976 are not consistent with the consequences of the design method. The report clearly demonstrates that the BS 5337:1976 requirements for crack sealing should allow for the natural closure of cracks with time as a consequence of water leakage.

D-393 Pace, C. E. 1985 (May). "Systems and Materials to Prevent Floodwaters from Entering Buildings," Miscellaneous Paper SL-85-5, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Systems were tested that will protect homes and buildings from floodwaters up to a safe water height. There are many pitfalls which must be watched for and guarded against or leaks will develop in the flood-resistant system. A drainage system with a sump and pump is useful behind the water-resistant system to take care of any leaks which may occur.

D-394 Ota, M., Numata, A., and Kondo, S. 1985 (Jun). "Life Time Test of Prestressed Concrete," Ocean Space Utilization '85, Proceedings of the International Symposium, Tokyo, Japan, Jun 1985, Vol 2, pp 463-467, Springer-Verlag, Tokyo, Japan and New York, NY.

The Japanese Prestressed Concrete Contractors Association (JPCCA) has developed a study of highly advanced corrosion preventive technology intended for oceanic structures, especially the concrete structures constructed in splash zones, as well as long-term durability evaluation. The study reported is a joint work by Public Works Research Institute, Ministry of Construction, and JPCCA with the Research and Development Laboratory of The Cement Association of Japan. Study results are discussed.

D-395 Katawaki, K., and Makita, M. 1985. "Developments of Protection Technologies for Concrete Structures in Marine Environment," Ocean Space Utilization '85, Proceedings of the International Symposium, Tokyo, Japan, Jun 1985, Vol 2, pp 469-475, Springer-Verlag, Tokyo, Japan and New York, NY.

The corrosion of reinforcing steel in concrete structures built in an environment subjected to the influence of seawater as in or on the sea, induces cracks and delamination of the concrete. However, the corrosion behavior of reinforcing steel in concrete as related to the cement paste quality, coverage over steel, and presence of cracks have not been clarified. To prevent such deterioration, the reinforcement should be covered with good quality and thick cement paste, and the generation of crack must be controlled perfectly, or directive protective methods. The protection technology for concrete structure is required. This paper summarizes previous Public Works Research Institute works related to concrete deterioration and describes the current status of corrosion and protection technology for improving durability of concrete structures.

D-396 Donker, B. 1985 (Jun). "Underwater Sandblasting for Surface Treatment of Submerged Steel and Concrete Structures," First International Conference on Surface Engineering, 25-28 Jun 1985, Brighton, UK, Vol 3, Cambridge, England.

Inspection, maintenance, and repair methods are essential for constructions in harbour and coastal engineering, and especially for offshore structures, to ensure that they remain functional during long-life times. Underwater work is necessary to detect and to repair damage caused by wear, corrosion, and unexpected heavy impacts. An underwater working procedure for adequate surface preparation--cleaning and treating--has been developed by GKSS-Research Centre, Geesthacht in close cooperation with the industry. Development requirements and function of the equipment are described. Extensive tests of the underwater sandblasting method have been performed in water depths down to

50 m in the North Sea and Baltic as well as in splash zones. In these tests, mainly standard steel specimens and concrete models were used. In addition, underwater sandblasting with compressed air has been well proven in large scale tests and by industrial application. Operational experience and typical values for blasting capacity and abrasive consumption are given.

D-397 "Cathodic Systems Still Guard After Five Years." 1985 (Jun). Roads & Bridges, Vol 23, No. 6, pp 42-43, Des Plaines, IL.

This article reviews efficiency of cathodic protection systems installed on two Akron, Ohio, bridges. The first system, installed in 1979, is an overlay system using cast iron "pancake" anodes, a 4-in. layer of coke breeze, an asphalt overlay, and a standard rectifier. It has successfully protected the bridge deck from any further deterioration from reinforcement corrosion. In 1981, a second bridge system was installed on a bridge deck in sound condition. This time a slotted system embedding platinum-clad niobium anodes was used. Slots were filled flush to the roadway surface with a highly conductive polyester resin. As with the earlier overlay system, no damage due to reinforcement corrosion has occurred.

D-398 Goddard, W. 1985 (Jun). "Boxes Replace Deteriorating Bridge," Concrete Pipe News, Vol 37, No. 3, pp 8-9, Vienna, VA.

This article describes replacement of a 22-year-old bridge by a triple 7- by 5-ft precast box structure. The timber substructure had deteriorated badly, but the original precast deck showed no signs of decay. The contractor was thus able to remove and reinstall the slabs on new abutments at another location approximately 1 mile away from the bridge site.

D-399 Stenko, M. S., Dinitz, A. M., and Bilotti, J. P. 1985 (Jun). "Modular Bridge Deck Systems for Redecking or New Bridge Construction," pp 43-46, Engineers' Society of Western Pennsylvania, PA.

The transportation community recognizes the need to have methods of rapid replacement for deteriorating bridges and elevated structures throughout the infrastructure. Bridge engineers have developed several new modular systems to permit major rehabilitation and rapid new construction with minimal traffic interruption.

D-400 Cosgrove, T. 1985 (Jun). "Rebuilding America's Highways. Contractor Races Clock on Interstate Rehab," Construction Equipment, Vol 71, No. 7, pp 78-81, Des Plaines, IL.

Phase I of an Illinois program to upgrade Interstates 94, 90, 290, and 294 began in 1984. Phase II began in 1985 in the Chicago area. The job calls for the stripping of the old asphalt on about 8 miles of eastbound I-290 and the selective patching of the underlying concrete pavement. When the patching is completed a 4-in. layer of asphalt will be put down. The decks are being replaced on four bridges along the stretch and the sewer and drainage system is being rebuilt and extended. Once work is completed on the eastbound stretch, the work will be repeated on the westbound side.

The Illinois DOT wanted this job to be finished on schedule because the stretch of freeway handles about 190,000 vehicles per day. As incentive to bring the job in on schedule, the contractors will be penalized $7,000 for each day the project runs over schedule and rewarded with a $3,500 bonus for every day work is completed ahead of schedule. The innovative techniques used to complete construction on schedule are discussed along with the equipment used.

D-401 Budweg, F. M. G. 1985 (Jun). "Rehabilitation of the Rasgao Dam," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

The Rasgao Dam on the Tiete river, in the immediate vicinity of the city of Sao Paulo, Brazil, was built in 1924/25. It is an arched gravity structure of about 130 m in crest length, 22 m high above the lowest foundation level. During the late seventies, careful investigation of evidence of deterioration revealed that the chemical action of the heavily polluted river water, seepage and weathering of the upper layers of foundation rock had seriously affected the dam's structural stability. The calculated factor of safety against sliding was equal to about 1.0. Spillway and bottom outlet gates were heavily corroded and in precarious operating conditions.

An initial study of the possible rehabilitation of the dam resulted in the recommendation of heavy foundation grouting, the construction of a drainage gallery for uplift pressure relief, shotcreting of the dam's upstream face, and replacement of the mechanical equipment.

For economical reasons and taking into account the possibility to reduce the construction time schedule, it was later decided to substitute posttensioned anchoring of the dam into sound foundation rock, for the proposed drainage gallery.

Several restricting conditions imposed by operational and environmental requirements led to the design of a somewhat complex river diversion scheme. Key structure of this scheme is a temporary reinforced rockfill overflow spillway.

D-402 Matsumoto, N. 1985 (Jun). "Repairing the Concrete Facing of Minase Rockfill Dam," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

Minase Dam is a 66.5-m-high rockfill dam with a concrete facing for the impervious membrane. The thickness of the facing slab varied with depth below the crest form 0.3 m to 0.6 m. The slab was reinforced with steel. Large rock, averaging in diameter about 300 mm, was compacted with sluicing water.

In December, 1962, the dam was completed, and the reservoir was first filled with water. The additional settlement of about 100 mm occurred due to the weight of the water on the facing and the compaction of the rockfill itself. Leakage amounted 200 l/s at the high-water level. After dewatering the reservoir, damaged portion of joints of the concrete slab were repaired. Leakage increased about 5 percent due to the 1964 Niigata earthquake. Leakage showed gradual increase, and the amount was 400 l/s at the maximum.

Investigations for the causes of leakage were conducted. Both the foundation and concrete slab were suspected of the passes for the leakage at first. As the results of investigations, it was concluded that the leakage was caused by the damage of joints of concrete slab mainly due to the settlement of the rockfill. Therefore, in place cast asphaltic gravel mastics were selected as the remedial construction materials for the damaged concrete slab.

Remedial works were successful and leakage decreased to nil. The dam was shaken by the 1983 earthquake (magnitude 7.7 on Richter scale); however, the repaired membrane functioned satisfactorily and no leakage was observed.

D-403 Tovar, M. S. 1985 (Jun). "Strengthening the Estangento Dam," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

This report describes the strengthening works carried out on the Estangento dam, a masonry arch-gravity structure, 20 m high, which was built in 1914. The dam will be used as the upper storage reservoir of the "Estangento-Sallente Pumped Storage Station," currently under construction, which will be completed at the end of 1985.

The works were started in the summer of 1983 with the purpose of improving the dam's stability with regard to the new working conditions: daily reservoir draw-down and fill, unfavourable thermic effects with temperatures down to minus 20° C, and uplift. The work included a low concrete wall anchored to the upstream face, a drainage and inspection gallery in the left arch, the highest area of the dam, with vertical drain holes and monitoring equipment for seepage and uplift control.

D-404 De Oliveira, A. R. 1985 (Jun). "Case Histories of Repairs of Concrete Surfaces Subjected to Water Erosion," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

Procedures adopted by CESP, Companhia Energetica de Sao Paulo to inspect concrete structures subjected to water erosion, are described.

ase histories of erosions by cavitation and by abrasion found in concrete surfaces of 8 of the 17 dams built by CESP are presented. It is note that most of the erosions occurred in draft tubes, however structures such as spillways and diversion tunnel have also shown significant ones.

Procedures of repair works are described, involving cement mortar, epoxy mortar, and protection with steel plates, as well as, the structures where each one of these materials were used.

The need of periodic inspections to guarantee the structure durability, elimination or minimization of adverse hydraulic conditions, and the use of adequate materials and techniques are the paper's conclusions.

D-405 Datta, O. P. 1985 (Jun). "Repairs of Bhakra Dam Spillway Apron," Fifteenth International Congress on Large Dams," 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

Bhakra Dam on river Sutlej is a 225.55-m-high concrete gravity dam, with live storage capacity of 7,436 × 10^6 m^3. A centrally located overflow spillway with 6,776 m^3/s capacity has been provided for flood disposal. The spillway has a fall of 152 m which discharges the overflow into a 128.02-m-long stilling basin (Fig. 2). A central wall divides the spillway and stilling basin into two equal compartments for ease of repairs. Apron concrete depth varies from 6.10 m to 12.20 m.

Apron erosion of such high head spillways being an expected phenomenon, underwater survey of the apron was frequently done and underwater repairs, using 48 N/mm^2 concrete, were done with the help of divers for deeper patches. The spillway was operated for 78 days in the wet year of 1978 with maximum releases of 2,830 m^3/s. Inspection by divers and apron surveys later indicated a general increase both in depth and extent of erosion. Various alternatives including underwater concreting, pressure diving bell, open vertical circular shaft, pneumatic caisson, ship-type caisson, rockfill cofferdam, and sheet pile cellular cofferdam, etc., were considered for repairs. After detailed studies, it was decided to repair the apron in dry condition by dewatering half of the spillway using sheet pile cofferdam or by creating almost dry conditions in local area by pneumatic caisson. Some modifications in the sequence of operation of spillway gates & river outlets have also been carried out to achieve more uniform flow conditions.

D-406 Alvarez, A. 1985 (Jun). "Strengthening of Some Existing Dams," Fifteenth International Congress on Large Dams, 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

The present report describes an analysis of dam safety conditions, on the basis of the examples offered by three dams which, in actual fact, were strengthened.

After overcoming the important problem posed by the existing karstified limestone, the 151-m-high Canelles arch dam was strengthened, with particular emphasis being placed on its right abutment.

In the case of the 75-m-high Mequinenza gravity dam, extensive strengthening work was undertaken when the construction of the dam was, in fact, already almost complete.

When the El Sancho gravity dam had to be heightened by 5 m, it was decided to strengthen the foundations at the toe, and the work was duly performed.

Some observations are made in connection with the fact that, before the safety of a dam can be defined, it is necessary to comprehend the interrelations existing between the various different factors that contribute toward dam safety, as well as the subsequent repercussions if any one of these factors were to become subject to variation.

D-407 Pepper, A., and Anderson, D. 1985 (Jun). "Chichester Dam Rehabilitation," Fifteenth International Congress on Large Dam, 24-28 Jun 1985, Lausanne-Suisse, Switzerland.

Chichester Dam is a 41-m-high curved gravity dam in cyclopean concrete which was constructed in the early 1920's. It normally provides about half the annual water supply to a population of approximately 411,500 in. and adjacent to Newcastle on the east coast of New South Wales, Australia. Its section was not designed to resist uplift pressures. These were to be handled by ensuring a tight cut-off at the upstream face and the provision of downstream drains in the mass concrete. The spillway consisted of an overflow section in the crest toward the left abutment with capacity of 567 m^2/s and a downstream training wall which turned its flow across the face of the dam.

Following a flood in 1957 which exceeded the capacity of the spillway, investigations into possible uplift pressures and lack of adequate drainage led to a recommendation that remedial work on the dam was required. As a result, progressive cutting down of the spillway by 2.7 m and drilling of additional drains from the downstream toe was completed by 1969. These were regarded as temporary measures.

Following the setting up of the New South Wales Dams Safety Committee in 1979, it examined the situation, investigated various alternatives, and recommended that the spillway capacity should be increased and the stability improved by posttensioning with restressable tendons.

A contract for the rehabilitation works was let in early 1982. These works comprised a total reconstruction and extension of the spillway to provide a 2,400 m^3/s capacity, and installation of 93 restressable posttensioning cables along the axis of the dam to provide greater resistance to uplift. All holes for the posttensioning cables were inspected by TV camera and recorded on video tapes, which indicated that the condition of the concrete was good and the geology of the foundations generally as expected. Water levels in the holes indicated that drainage may have been more effective than anticipated and efforts were made to retain this situation in installing and grouting the posttensioning cables. Construction was designed to ensure that existing factors of safety were maintained at all stages of construction, and has been successful in bringing a 60-year-old dam up to modern design standards.

D-408 Temple, W. H., and Cumbaa, S. L. 1985 (Jul). "Thin Bonded PCC Resurfacing," Report RR-181; FHWA/LA-85/181, Federal Highway Administration, Baton Rouge, LA.

After the successful experimentation in Iowa with thin-bonded concrete overlays as an alternative to bituminous overlay, the Louisiana DOT decided to resurface a short section of US 61, north of Baton Rouge, using this technique during April 1981. The resurfacing concrete mixture contained 5.8 bags of cement and limestone aggregate. The minimum thickness of the concrete overlay was 3 in. The new overlay increased the serviceability index of the pavement from 2.3 to 4.0 and increased the skid resistance from 36 to 62. Approximately 16 percent of the exterior slab corners have experienced varying degrees of disbondment, resulting in a minor degree of cracking. Deflection measurements indicate that the overlay has maintained much of its initial gain in structural capacity. Recommendations are made relative to construction of future thin-bonded PCC overlays.

D-409 Ruffert, G. 1985 (Aug). "Repairing Old Reinforced Block Floors" (in German), Beton, Vol 35, No. 8, Dusseldorf, Germany.

In steel-reinforced floor blocks. the filler block is needed for stress diversion as well as hollow filler. The reinforced block was often placed as hollow floor filler in houses in the 1940's. Increasingly, these floors require repair because of inadequately remedied war damage and because of deterioration from exposure to weather.

D-410 "Harvard University Stadium Renovation." 1985 (Jul-Aug). Journal, Prestressed Concrete Institute, Vol 30, No. 4, pp 142-145, Chicago, IL.

This article discusses the structural renovation of Harvard University's historic collegiate football stadium in Cambridge, MA. The major portion of the project involved the removal of existing L-shaped precast seats and cast-in-place stairs and their replacement with new precast units. Also included in the renovation was the rehabilitation of the deteriorated structural steel framework and other cast-in-place units. While demolition crews worked to dismantle the old stadium, new precast components were manufactured and delivered to the site as needed. The end result of this renovation project, completed in the spring of 1984, was the harmonious blend of the new and existing structures.

D-411 "Thirties Restoration." 1985 (Jul-Sep). Concrete Quarterly, No. 146, pp 6-9, Wexham Springs, England.

Dudley Zoo is a unique example of prewar reinforced concrete design. Although the 15 buildings comprising the zoo complex were constructed at great speed under difficult site conditions, and some of the reinforcement did not receive as much concrete cover as would be required today, the Zoo has survived remarkably well.

The first effort in the long-term zoo restoration effort is the Tropical Birdhouse. There has been extensive concrete repair to remedy the inadequate reinforcement cover and to apply a waterproof elastomeric membrane to the upper surface of the circular terrace.

D-412 Rhodes, N. F. 1985 (Sep). "Unbonded Concrete Overlay May Fix Recurring Problems," Roads & Bridges, Vol 23, No. 9, pp 22-24, Des Plaines, IL.

This article describes repair of a Fayetteville, AR, street with one of the first unbonded concrete overlays used in the US. Twice before, Maple Street had been resurfaced with asphalt overlays. For the third renovation, asphalt's poor performance record suggested .e use of an unbonded plain concrete overlay.

The project encompasses 2,070 linear ft of 5-in. unbonded concrete overlay 25 ft wide. The concrete mix design provided a minimum 4,000-psi high-strength concrete. The expected service life of the new overlay is estimated at 30 to 40 years, and the only maintenance required is periodic cleaning and refilling of the contraction joints.

D-413 Witterhold, F. G. 1985 (Sep). "Demolition of Reinforced Concrete by Blasting Techniques," Tiefbau, Ingenieurbau, Strassenbau, Vol 27, No. 9, pp 512, 515-516, 518-520, Guetersloh, West Germany.

The characteristic feature of the demolition of reinforced concrete structures by blasting is the concentration of high energy and impulse density for a short time in a limited space. The short waves and falling debris create dangers in built-up areas. Various safety measures to prevent extensive damage to the surrounding buildings and harm to the population are described. It is found that reinforced concrete structures can be demolished by blasting even under difficult conditions of confined space in built-up localities if appropriate precautions are taken.

D-414 Fairweather, V. 1985 (Sep). "Clearing the Decks," Civil Engineering, Vol 55, No. 9, pp 56-59, American Society of Civil Engineers, New York, NY.

This article explores using cathodic protection systems to rehabilitate deteriorating bridge decks. Most state highway departments have adopted a system that embeds anodes in slots about 3/4 in. deep and wide, which are then filled with a conductive polymer backfill. A variation on this method is the mound system, where anodes are laid on the deck surface, embedded in a mound of conductive polymer concrete, and overlaid with concrete. Other new developments in cathodic protection described are flexible conductive-polymer mesh distributed anode systems and protective coatings for the undersides of bridges.

D-415 Tanis, D. 1985 (Sep). "New Technique for Waterstop Replacement Used at Pine Flat Dam," The REMR Bulletin, Vol 2, No. 3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

At Pine Flat Dam, California, failed waterstops between monoliths have been successfully replaced using a new type of resin-encased grout plug. Gelco Grouting Service of Salem, OR, was the lower bidder and began work on the project in February 1985. Gelco used a patented system based on techniques used for in-situ relining of pipelines. First, grout from an old repair was removed by drilling with a tri-cone drill bit. The resulting 6-1/2-in.-diam hole was then filled with a liner bonded to the surfaces of the drill hole. The liner was essentially a tube consisting of a thin polyurethane membrane with an underlayer of felt approximately 1/4 in. thick. Prior to installation, water-activated polyurethane resin was poured into the tube to saturate the felt lining.

The tube was then inserted into the drill hole using water pressure to turn the tube inside-out as it was being forced down the hole. Internal air and water pressure pressed the resin-impregnated felt tightly against the concrete surface, and water inside the drill hole activated the resin creating a bond between the liner and the drill hole. After the resin had cured, the center of the tube was filled with grout to form a strong yet flexible core.

A-416 Verhee, F., and Griselin, J. F. 1985 (Sep-Oct). "French Situation of Drainage Trenches Utilization for Existing Concrete Pavements," Bulletin de Liaison des Laboratoires des Ponts et Chaussees, No. 139, pp 25-38, Paris, France.

French concrete pavements, in particular old ones built on erodible subbases, sometimes undergo a rapid modification linked with the presence of water between the concrete slab and the subbase. Since 1973 experiments have been performed with lateral drainage trenches in porous materials to evacuate infiltrated water. The earliest on-site experiments on deteriorated pavements showed that when the pavement has become modified beyond a certain limit, the setting in place of lateral drainage can accelerate deterioration. Subsequent experiments showed the value of lateral drainage. On the other hand, when the subbase is very erodible or when deterioration is already considerable, a drain trench is not a suitable remedy. The cost of drainage trenches is low compared to other maintenance procedures.

D-417 "Replacement of Coal Storage Retaining Walls." 1985 (Sep-Oct). Journal, Prestressed Concrete Institute, Vol 30, No. 5, pp 162-167, Chicago, IL.

This article discusses the construction of two precast prestressed concrete retaining walls at Indianapolis Power & Light Company's generating station in Petersburg, IN. The precast prestressed concrete components, in addition to being durable, economical, and saving erection time, provided a functional and safe wall system at this generating station.

D-418 Perenchio, W. F., et al. 1985 (Oct). "Cathodic Protection of Concrete Bridge Substructures," National Cooperative Highway Research Program Report 278, Transportation Research Board, Washington, DC.

Research was directed at developing a suitable cathodic protection system for steel reinforcement, excluding the top reinforcement in bridge decks and reinforcement below soil or water. Laboratory investigations were conducted to choose a material for use as a secondary anode in the cathodic protection system. Based on these tests, a conductive coating was selected, and a cathodic protection system was applied to an actual bridge pier. Three variations of primary anode placements were also incorporated into the eventual cathodic protection system that was evaluated.

D-419 Szychlinski, G. 1985 (Oct). "Burning Through Concrete," Concrete International: Design & Construction, Vol 7, No. 10, pp 51-54, Detroit, MI.

Cutting concrete in tight or inaccessible locations, or when the concrete is very hard or heavily reinforced, can be accomplished with the thermal lance. This technique uses burning oxygen and a pipe packed with steel wire to perforate even the strongest concrete. The thermal lance has been used in Poland with great success.

D-420 Ray, G. K. 1985 (Oct). "Overview of Overlays," Concrete International: Design & Construction, Vol 7, No. 10, pp 23-27, Detroit, MI.

This article discusses the renewed interest in concrete resurfacing, which was probably increased by the federal funding now available for 4R projects: restoration, rehabilitation, resurfacing, and reconstruction.

D-421 Malerbi, E. 1985 (Oct). "Automatic Drypacking," Concrete International: Design & Construction, Vol 7, No. 10, Detroit, MI.

An alternate method of concrete repair by drypacking a no-slump mixture into the damaged area by hand is an automated drypacking machine. The dry-pack material is rammed into the repair area in thin layers thus providing a very dense and high-strength repair. High-pressure air is used to apply a slightly premoistened sand and cement mixture. This method is also readily adaptable to larger jobs.

D-422 Neginsky, I. 1985 (Oct). "Stories Stack Up," Concrete International: Design & Construction, Vol 7, No. 10, Detroit, MI.

To convert an existing supermarket and two-story building into two high-rise structures presented a number of challenges for the designers which required implementation of innovative techniques for accomplishment. As part of the solution, a "bookshelf" structure with the side walls serving as supports and the "shelves" serving as additional floors was proposed.

D-423 "Refacing for Uniformity." 1985 (Oct). Concrete International: Design & Construction, Vol 7, No. 10, Detroit, MI.

A major addition to the 18-story Marriott Hotel in Stamford, CT, involved upgrading a 10-year-old existing tower. Originally designed as a multifamily housing facility and converted to a hotel, upgrading included expansion of existing rooms, the addition of a revolving restaurant on top of the tower, and refacing the exterior to provide continuity between the existing and upgraded construction.

D-424 "Repairing a Parking Structure." 1985 (Oct). Concrete International: Design and Construction, Vol 7, No. 10, Detroit, MI.

The rehabilitation of a two-story US post service parking garage was undertaken. Installation of a cathodic protection system to combat accelerated galvanic corrosion in the steel reinforcement bars was the main rehabilitation task. Additionally, repairs to concrete beams, patching, epoxy injections into cracks, removal of spalled concrete and installation of addition steel reinforcement were accomplished in the rehab project.

D-425 "Precast Screed Rail Joins the Navy." 1985 (Oct). Concrete International: Design and Construction, Vol 7, No. 10, Detroit, MI.

As part of the rehabilitation of the physical education facilities at the naval academy, a new concrete overlay was installed as a subbase for the athletic playing surface. A precast concrete screed rail was used to ensure flatness tolerances for the overlay. The rail also became a part of the floor system by forming an interlocking joint.

D-426 Viladas, P. 1985 (Nov). "Invisible Reweaving," Progressive Architecture, Vol 66, No. 11, pp 112-117, Stamford, CT.

This article describes successful restoration of a textile-block house designed by Frank Lloyd Wright in 1923. The house is constructed of plain and patterned precast concrete blocks "woven" together with vertical and horizontal reinforcing steel. Previous repair attempts had replaced deteriorating blocks or patched them with smooth, cold-gray concrete that did not match the original color or texture; other blocks were badly weathered. Some of the original plain blocks were found buried on the grounds and 50 new patterned blocks were cast from a metal mold found in the garage. To match the color and texture of the new block to the old, an extensive trial-and-error effort culminated in using Wright's original sand-to-cement proportions for the concrete, with the addition of decomposed granite found on the site. The restoration produced nearly seamless results.

D-427 "Texas Overlay Experiment." 1985 (Nov). Engineering News-Record, Vol 215, No. 22, pp 33, New York, NY.

A thin-bonded concrete overlay being applied to more than 7 miles of 48-ft-wide continuously reinforced concrete pavement in Houston, TX, includes some experimental approaches designed to provide new ideas on maintaining the state's heavily traveled highways. After repairing roadways, the contractor will apply a 4-in. concrete overlay reinforced by 4-in. welded wire mesh. Six bridges will receive a 2-in. nonreinforced overlay.

The contractor is using a new type of paving equipment which speeds production and provides a uniform surface without labor intensive manual finishing. To get further experience with materials being tested as part of a highway department research program, two four-lane sections of overlay will be experimental. One will use crushed limestone as the coarse aggregate for 1,000 ft, while the other calls for steel fibers as reinforcement for 2,500 ft.

D-428 "Replacing Rural Roads." 1985 (Nov). Roads & Bridges, Vol 23, No. 11, pp 51-55, Des Plaines, IL.

Research on short span design (up to 25 ft) has produced a precasting technique that promises to cut costs, speed construction of replacement bridges, and enable the bridges to carry heavier loads. A system of prefabricated, reinforced concrete beams using a modified double-T cross section can be placed side by side and bolted together to achieve the desired roadway width.

Benefits of this system include substantially reducing material costs and construction time. Beams built during slow times can be stockpiled to haul later to sites after old bridges have been removed and new abutments completed.

D-429 "Lock Wall Restored by Crash Repair Job." 1985 (Nov). Engineering News-Record, Vol 215, No. 20, New York, NY.

The partial collapse of a lock wall in Canada's Welland Canal on 14 Oct might have shut down ship traffic into and out of the Great Lakes for the rest of the season, but 2 days after the collapse a round-the-clock repair effort had ships locking through again in just over 3 weeks. The cavern left by the partial wall collapse was filled with 2,500 yd^3 of new concrete. In the completed job, 480 ft of the wall was posttensioned by five rows of high-strength steel bars.

D-430 "High Pressure Water Pulverizes Bad Concrete." 1985 (Nov). Better Roads, Vol 55, No. 11, pp 28-29, Parkridge, IL.

Hydrodemolition technology was used to shatter delaminated concrete decks on two three-lane highway bridges on Interstate 635 in Kansas City, KS. Using a controlled stream of high-pressure water to pulverize bad decks offered inherent advantages over traditional methods, including raising productivity, lowering noise, eliminating rebar damage, and less vibrating than with rototilling or jackhammering. Hydrodemolition of the decks on I-635 allowed the contractor to keep the renovation of the 3,540 ft long decks on schedule while keeping lanes open for traffic.

D-431 Ducrot, B., and Pfister, P. 1985 (Nov). "Rehabilitation of the Khashm El Girba Dam" (Sudan). Travaux No. 604, pp 15-20, Paris, France.

The sluices of Khashm El Girba dam, in Sudan, had to be completely rehabilitated after 20 years of use. This applied mainly to the area near the gate sills. The works include grooves in the old concrete, anchorage drillings, reinforced concrete pouring, and use of epoxy concrete and antiabrasion coating layers of brai-epoxy mortar to replace the former steel plates. The working conditions on the site proved to be extremely difficult.

D-432 "Bridge Designs to Reduce and Facilitate Maintenance and Repair." 1985 (Dec). National Cooperative Highway Research Program Synthesis Highway Practice 123, Transportation Research Board, Washington, DC

Specifications and manuals outlining structural design criteria are constantly being updated to improve bridge performance. The systematic development of design criteria, concepts, and details can result in designs that reduce and facilitate maintenance and repair. Maintenance manuals have been developed to improve inspection and rating procedures and to identify problem areas. Material selection plays an important role in designing maintainable bridges. Steel and concrete are the principal structural materials used for bridge construction. Procedures and specifications are required to ensure quality control of all bridge materials. Deterioration from corrosion is documented. Corrosion protection for bridges had mainly been in the form of paint, and other special coating systems. Some cathodic protection systems have been developed and successfully installed. The required continued use of a bridge while rehabilitation is performed is also documented. The cooperative effort required to improve maintainability will be enhanced by more effective communication channels.

D-433 "Diamond Saws Prove Efficient, Quiet for Hotel Remodeling." 1985 (Dec). Concrete Producer News, Vol 49, No. 8, Chicago, IL.

Use of a diamond saw to remove balcony ledges from a hotel facade as part of a renovation project is described. A 400 Hz hand saw with a 14-in.-diam diamond blade was used to remove the ledges, which were approximately 13 ft long, 16 in. wide, and 5-1/2 in. thick and contained seven and eight No. 4 and No. 6 reinforcing bars; respectively. Within 60 days two men removed 355 ledges with no inconvenience to hotel guests.

D-434 Pasko, T. J., Jr., Virmani, Y. P., and Jones, W. R. 1985 (Dec). "Polymer Concrete Used in Redecking a Major Bridge," Public Roads, Vol 49, No. 3, pp 78-89, New York, NY.

The six-lane bridge, which spans the Potomac River and connects Maryland with Virginia, was kept open to traffic during rush hours. At night, one-half of the width was cut in sections, removed, and hauled away by barges. Replacement sections of precast, prestressed concrete, approximately 10 ft (3 m) long and 47 ft (14 m) wide, were lifted into place. About eight sections were placed per night, and 129 nights were needed to place the 1,026 sections. Intermittently, the sections were posttensioned together in the longitudinal direction. The uniqueness of this project comes from a combination of factors: The long length of the bridge, the six-lane width, the high traffic volume, the night construction while maintaining traffic flow, the opening of all lanes to traffic during rush hours, and the use of polymer concrete and other innovative construction techniques to speed construction.

D-435 Darter, M. I., Barenberg, E. J., and Yrjanson, W. A. 1985 (Dec). "Joint Repair Methods for Portland Cement Concrete Pavements," National Cooperative Highway Research Program Report 281, Transportation Research Board, Washington, DC.

Developing effective guidelines and criteria for repairing and preventing deterioration of joints and cracks in portland-cement concrete and jointed reinforced pavements was the objective of this report.

In accomplishing this, it was necessary to identify the most promising techniques used to repair and prevent the deterioration of joints and cracks. Seven techniques were chosen for further consideration. Design and construction procedures were then developed using the current state-of-the-art methods, analytical analyses, and experience of numerous engineers from federal and state governments and from industry (contractors and material suppliers).

The seven repair methods used in the project were: full-depth repair of joints, cracks, and shattered slabs; partial-depth repair of spalls; subsealing of voids (or slab stabilization); restoration of load transfer of joints and cracks; diamond grinding of faults at joints and cracks; resealing of joints and cracks; and slab edge support improvement.

D-436 Young, P. M. 1985 (Dec). "Coating Concrete," Construction Specifier, Vol 38, No. 12, pp 52-58, Alexandria, VA.

Successful application of coating systems to cementitious surfaces depends on careful planning and specifying. Because concrete often comes into direct contact with aids, oils, grease, chemical fumes, and other contaminants, a protective coating is often needed to help resist deterioration. Topics considered here include preparing surfaces, correcting surface imperfections; treating old concrete to make it receptive to new coatings, selecting coating systems, and techniques for applying coatings.

D-437 Bean, D. L. 1985 (Dec). "Epoxy-Resin Grouting of Cracks in Concrete," Miscellaneous Paper SL-85-18, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Cracked concrete can be successfully repaired by epoxy-resin grouting if it is performed properly, using the correct materials. Epoxy resins can be pressure grouted in cracks of different sizes in concrete at different temperatures, even if the concrete is damp or underwater. A literature search was conducted and manufacturers were contacted to obtain the latest information about materials, methodology, and equipment for epoxy-resin grouting.

D-438 "Concrete Bridges-Investigation, Maintenance, and Repair." 1985. The Concrete Society, London, England.

Proceedings of a 1-day symposium are presented. Maintenance of the bridge stock, which includes over 50,000 concrete bridges in the United Kingdom, is a major undertaking. The conference discussed the engineering and managerial problems associated with this subject. The proceedings comprise eight papers from the UK, Germany, and the US on: identification and interpretation of problems; developments in research; the joints on bridge decks; German and North American experience in concrete bridge deterioration and maintenance; repair of concrete viaducts and posttensioned structures; contractor's view of repairs; specifications; proprietary materials; access for repairs; and durability of repairs.

D-439 Hover, K. C. 1985. "Cathodic Protection for Reinforced Concrete Structures," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

The use of Cathodic Protection, or the application of an electrical potential difference to reinforcing steel in concrete, has proven to be an effective means of controlling the corrosion of the steel and the subsequent deterioration of the concrete. Although this method has been successfully applied to metal structures of many types including offshore structures, the hulls of ships, and buried pipelines, the use of cathodic protection in reinforcing steel is a relatively new approach. Part I of this paper traces the development of cathodic protection, and describes the principles behind the method. Part II describes the installation, monitoring and evaluation of a cathodic protection system installed over a 14,000 ft^2 (1,300 m^2) portion of a reinforced concrete parking garage in 1977.

D-440 Marsh, D., Simonsen, W. J., and Fowler, D. W. 1985. "Machine Application of Polymer Concrete for Highway Repairs," Polymer Concrete: Uses,

Materials, and Properties, SP-89, pp 1-17, American Concrete Institute, Detroit, MI.

Polymer concrete has been used for years to repair portland-cement concrete. A monomer system is mixed with well-graded aggregate and placed in the repair area. After the monomer cures, a strong durable material is produced which bonds well to portland-cement concrete. Special mixing and placing equipment was developed for a large pavement repair job in Houston. Longitudinal cracks, longitudinal lane-shoulder joint separations, spalls, punch-outs, and other types of damage were repaired.

D-441 (Deleted)

D-442 Tsui, S. H. 1985. "Restoration of a Concrete Clarifier Structure," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

This paper reports the structural investigation, concrete testing, and rehabilitation program for a concrete clarifier in a water treatment plant at Belle River, Ontario, Canada. This plant was constructed in 1945 with nonair entrained, site mixed concrete. Extensive concrete scaling and spalling, traces of leakage and random cracking were observed on the tank wall surfaces. Both analytical methods and in situ testing were employed to evaluate the structural adequacy of the clarifier. Remedial works involving removal of deteriorated concrete, construction of an exterior semicircular protective concrete wall with buttresses plus repairs to the interior wall were completed in Jul 1981.

D-443 Nene, R. L. 1985. "Repairs and Restoration of Reinforced Concrete Columns," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

An effective method of repairs and restoration of reinforced concrete column is presented. Guniting, although good enough to arrest disintegration, tends to show distress after ageing. The article compares the salient features of the method and presents two instances where this method was adopted.

D-444 Prudon, T., and Stockbridge, J. 1985. "Renovation of the Facade of the Woolworth Building," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

The 53-story Woolworth Building in New York was designed by Cass Gilbert. Significant deterioration in the highly ornamental terra cotta facade necessitated the extensive renovation program which was completed in 1981.

Extensive field and laboratory testing developed the optimum repair scheme. The precast concrete system selected utilized units formed in molds taken from impressions of the actual facade pieces.

D-445 Marusin, S. L. 1985. "Repairs of Concrete Columns, Spandrels, and Balconies on a High-Rise Housing Complex in Chicago," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

A large complex of exposed-frame reinforced concrete high-rise apartments began to exhibit severe deterioration after 18 years of service. Tests on concrete extracted from the exposed columns, spandrels and balcony slabs confirmed that large amounts of chloride ions were present in the areas of deterioration. The concrete deterioration related to the corrosion of the embedded reinforcing steel of these structures. Following laboratory tests to develop appropriate repair materials and repair techniques, acrylic modified cast-in-place portland-cement concrete and hand-placed epoxy mortar were selected as the restoration materials. The repair techniques used in the restoration are described.

D-446 Gross, J. G. 1985. "Improving Building Regulations for Rehabilitation," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

This paper provides an overview of building regulations applied to rehabilitation. Constraints due to regulation, technical activities to improve regulations, and research needed to effectively use the existing building stock are covered. Progress has recently been made toward removal of regulatory constraints. Many technical problems remain to be solved through research which needs support from both the public and private sectors. The analysis of numerous studies indicates a strong need for technical evaluation techniques to assist decision making for building rehabilitation.

D-447 Gregorian, Z. B. 1985. "Evaluation, Rehabilitation, and Innovative Design Procedures for Masonry Structures--Case Studies," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

This paper discusses the investigation, renovation, and restoration of ancient masonry as well as the design of modern reinforced brick masonry structures.

Two categories, (a) ancient brick and stone masonry structures and (b) modern reinforced brick masonry structures, are discussed. Relationship between modern shell theory formulas are derived. A practical procedure which has been used for constructing modern reinforced brick structures is outlined for category b structures.

Case studies are discussed for category a structures for ancient buildings such as the Soltanieh Mosque being restored by ISMEO, and the

Golestan Palace which has been redesigned and restored under the supervision of the author, applying the shell theory as presented in this paper. The paper also contains case studies for two category b structures, "Iran Center for Management Studies in conjunction with Harvard University," and the "Bu Ali Sina University," which are designed in accordance with the criteria mentioned above for the design of modern reinforced brick masonry structures.

D-448 Bresler, B. 1985. "Essential Steps in Adaptation of Old Buildings," Rehabilitation, Renovation, and Preservation of Concrete and Masonry Structures, SP-85, American Concrete Institute, Detroit, MI.

Essential steps in modifying structures for the purpose of adapting old buildings to new use are discussed in this paper. Eight basic steps are described: (1) preliminary site visit, (2) documentation of original design and construction, (3) identification of desired changes in the building, (4) identification of code requirements applicable to building alterations, (5) development of structural modification scheme preliminary cost estimates, (6) verification of "as is" condition, review of adequacy of proposed modification scheme and estimated cost, (7) completion of design and construction documents, including drawings and specifications, and (8) coordination of engineering design with construction quality control and accommodation of possible need for design changes during construction.

D-449 Smoak, W. G. 1985. "Polymer Impregnation and Polymer Concrete Repairs at Grand Coulee Dam," Polymer Concrete Uses, Materials and Properties, SP-89, American Concrete Institute, Detroit, MI.

Polymer impregnation and polymer concrete were used to repair the concrete roadway over the Bureau of Reclamation's Grand Coulee Dam. The equipment, materials, and processes used on this project are discussed in depth. The report includes data on the costs of the project.

D-450 "Design, Construction, and Maintenance of Concrete Storage Structures." 1985. The Concrete Society, London, England.

The proceedings of a two-day symposium, held Dec 3 and 4, 1984, at Newcastle upon Tyne, include 19 papers from the UK, Europe, and the US on materials and design, silos and other storage structures, and flow of contained materials. Subjects covered by the papers are: the role of the concrete in storage structures; partial prestressing; intrinsic cracks; sprayed concrete tanks; wall-to-base connections; sealants; cryogenics; effect of hot crude oil; reservoirs; reinforced earth structures; low friction lining materials; mechanical handling equipment; air cannons; silo design; silos for difficult materials; and bunker silos.

D-451 Fargeot, B. 1986 (Jan). "Repair of Buildings and Structures" (in French), Travaux No. 606, pp 106-114, Paris, France.

Details of the repair projects on the roof of a [illegible] broadcasting station and several bridges are given. The station roof is made of a thin concrete shell 80 m long and 40 m wide, bearing on a ring supported by 57 columns. The first repair was made necessary after a shell was destroyed during construction.

Corrosion effects appeared 25 years later, and a renovation of the structure was made necessary. To achieve the repair, the six transverse ties, locally corroded, were replaced by external ties made of 19 T 15 tendons under two concentric tubes; the external steel tube sustains the compressive force during construction. The tendons were protected by cement grouting. After their prestressing, the existing forces within the old ties were released progressively by heating the wires one by one with a flame.

Reinforced and prestressed concrete bridges have been repaired or strengthened, using new methods or materials. Methods of curing cracks and cleaning and repairing concrete include the use of resins, mortar with compensated shrinkage, and shotcrete. Vacuum grouting has been used on Battant Bridge, where arches have also been raised with specially conceived wedge-jacks.

Repair of concrete, reconstruction using shotcrete, and achievement of a watertight coating have been done on the Fourneau and Veauche Bridges. External prestressing and shear keys in cracks have been introduced in the latter bridge.

Arles Bridge on the Rhone River has been strengthened with external prestressing, and cracks have been cured at Saint-Bernard Bridge, when some parts have been reconstructed.

D-452 Godwin, L. N. 1986 (Jan). "Cracking and Seating of Portland Cement Concrete Pavement Prior to Asphalt Concrete Overlay; Facilities Technology Application Test, Fiscal Year 1984," Miscellaneous Paper GL-86-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Asphalt concrete overlays of a jointed or cracked portland-cement concrete (PCC) pavement can develop reflective cracking because of either horizontal or vertical movement of the PCC. One method that can be used to reduce the reflective cracking is cracking and seating of the PCC prior to placement of the asphalt concrete overlay. The PCC is cracked into approximately 18-in. pieces, after which a heavy pneumatic-tired roller is used to seat the pieces of concrete to prevent rocking or movement under traffic. This report provides guidance for the application of the cracking and seating method for reducing reflective cracking.

D-453 Witte, O. 1986 (Jan). "Frank Lloyd Wright Bridge Reconstructed by Suburb," Roads & Bridges, Vol 24, No. 1, pp 98-99, Des Plaines, IL.

In Glencoe, IL, the only bridge designed and built by Frank Lloyd Wright has been reconstructed and reopened to traffic after having been closed since 1977. The bridge, built in 1915, displays elements of Wright's design concepts in its strong horizontal lines, as etrical balance, creative use of cast-in-place concrete, and canti. .ed sidewalk. Because of the close proximity of private homes, dem ition and reconstruction was done one section at a time. The contractor designed and built special forms to replicate the bench pedestals and other special features of the original bridge.

D-454 Kuhne, V. 1986 (Feb). "Recycling of Demolition Materials" (in German), IABSE Proceedings No. P-95/86, International Association for Bridge and Structural Engineering, pp 17-28, Zurich, Switzerland.

Earth's natural resources are in limited supply and are being rapidly depleted as a result of our ever increasing demand for raw materials. Within the building industry as a whole, therefore, the recycling of waste building materials can help us exploit the existing resources more carefully than in the past. Depending on the required material quality, various technical solutions for recycling plants are available whereby economic considerations considerably narrow the choices.

D-455 Wood, J. G. M. 1986 (Feb). "Refurbishment and Renovation of Bridges," The Structural Engineer, Vol 64A, No. 2, pp 57-59, 77, London, England.

The paper reviews classic examples of historic bridge refurbishment and considers some of the difficulties that are arising in the refurbishment of the postwar concrete and steel bridge stock. From this the needs for research and development on the assessment of deterioration and on the strength and durability of remedial works are identified. Some suggestions for bridge designers are made.

D-456 Renier, D. 1986 (Feb). "Synthetic Resins in the Maintenance of the Dams of Electricite De France," Travaux, No. 607, pp 72-73, Paris, France.

Information is given on the materials and processes currently used on EDF structures for the waterproofing of the upstream facings of concrete dams as well as for foundation treatment and protection against water abrasion. Experience acquired with several waterproof facings makes it possible to estimate approximately how long these materials will last.

D-457 "Concrete Repair After Rebar Corrosion." 1986 (Jan-Feb). Civil Engineering, pp 38, 41, 43, London, England.

This article summarizes explanations for reinforcing bar corrosion and repair methods as they appeared in the Concrete Society's authoritative guide on the subject. The most frequent sources of damage due to corrosion of reinforcement are low cover steel, permeable concrete, and high chloride levels. In approaching repairs it is recommended that 1) sufficient investigation be carried out to determine the reasons for and the extent of the problem; 2) the effect of the method of repair on structural aspects and operational procedures be considered; and 3) a full specification for the work be prepared. Some repair methods and details are included.

D-458 Somerville, G. 1986 (Feb). "Design Life of Concrete Structures," Structural Engineer, Vol 64A, No. 2, pp 60-71, London, England.

The life of concrete structures in service depends not only on the production and placing of durable concrete, but also on proper design, detailing and construction methods, and on appropriate levels of maintenance. Past and present procedures for achieving this are reviewed, shortcomings identified, and suggestions made for improvement in the future, in particular. It is argued that there is no single condition called 'durability', and that aggressive actions must be identified and quantified prior to dealing with them in a manner similar to that for the provision of strength, stiffness, stability, and serviceability. It is further argued that enough information exists to permit the derivation of such procedures to begin, but that a prerequisite to this is the definition of design lives for structures - analogous to the approach to fire design (an extreme case of durability).

D-459 Degerlund, C. 1986 (Mar). "Solving the Problem," Civil Engineering, pp 38-39, London, England.

A friction clamp, developed for use during the refurbishment and repair of reinforced concrete buildings, is described. The clamps can be used to transfer loads from the foundations of large columns subjected to working loads over 200 tons, and have been designed so they do not damage the columns and can be removed after use. Concrete hinge durability is discussed.

D-460 "Thin Three-Layer Highway Overlay Resists Abuse." 1986 (Feb). Engineering News-Record, Vol 216, No. 8, New York, NY.

This article describes the rehabilitation of a test section of deteriorated portland-cement concrete pavement with a thin three-layer overlay sandwiching a stress-absorbing, asphalt-rubber membrane between layers of gap-graded asphaltic concrete. The system, which costs about one-third as much as grinding, has provided good rideability, is very stable, and retards reflective cracking at joints.

D-461 "Undersealing, Jacking Ensure Slab Utility." 1986 (Mar). Roads & Bridges, Vol 24, No. 3, pp 58-59, Des Plaines, IL.

Maintaining rigid concrete pavements poses some tasks completely unrelated to routine flexible pavement maintenance.

Cement-grout subsealing introduces a cement grout mixture under pressure to fill voids and depressions under the slab, displacing water and reducing deflection. The mixture is introduced through holes drilled in the slab, which is stabilized without being raised.

Slabjacking is the actual raising of a depressed section of rigid pavement by forcing a cement mixture under it and restoring the slab's original elevation.

D-462 "Recycling Concrete for Motorway Construction." 1986 (Mar). Civil Engineering, London, England.

A method of recycling crushed concrete subbase and asphalt and road surfacing for use as a lower subbase on motorway construction is being pioneered by a contractor in conjunction with the Kent County Council and Department of Transport. Recent examination of the motorway by the council revealed signs of slippage in the cutting slopes along a 4.5-km stretch of the westbound carriageway, together with deterioration of part of the carriageway itself. Recycling details are described.

D-463 Berry, B. 1986 (Mar). "Repair of Reinforced Concrete Structures," Construction Repairs & Maintenance, Vol 2, No. 2, pp 13-14, London, England.

The Concrete Society held a 1-day seminar 23 Apr at the East Midlands (Jesse Boot) Conference Center, Nottingham. Two effective and proven concrete repair systems for repairing damaged areas of reinforced concrete units were discussed.

Both systems are widely used in the construction and civil engineering industry for repairing spalled and damaged reinforced concrete, such as beams, columns, underside of reinforced floors and deck slabs, etc.

D-464 Broomfield, J. 1986 (Mar). "'Testing the Water' on Cathodic Protection," Construction Repairs & Maintenance, Vol 2, No. 2, pp 15-16, London, England.

Field trials are being undertaken by an engineering firm to test the effectiveness of a cathodic protection system to prevent deterioration of concrete structures. Severe cracking on two legs of a water tower has been caused by the addition of calcium chloride to the cement mix during construction, an accepted practice in the 1960's and 1970's.

The Property Services Agency has awarded an engineering firm a contract to install an impressed current cathodic protection system on a multistory, reinforced concrete building in Southend, Essex. Concrete spalls are visible on some of the precast reinforced concrete elements of this building, and deterioration is thought to arise from the addition of a calcium chloride accelerator during manufacture.

D-465 Tritton, P. 1986 (Mar). "On the Right Track," Construction Repairs & Maintenance, Vol 2, No. 2, pp 17-18, London, England.

Gantry crane rails will crack when their concrete track beds collapse beneath them, but a project at a container terminal at Teesport has shown how the beds can be rebuilt to prevent this damage. Engineers designed a new type of track bed that first required the complete removal of the original grout, box sections, and sole plates. The massive concrete beam cast over the site 15 years earlier when the terminal was constructed on land reclaimed from the River Tees, was then exposed.

The beam needed minor repairs, and a new 60-mm-deep concrete base for the rails had to be laid over it. The project required a material much stronger than ordinary concrete, impermeable to water and oil, and capable of developing its full strength within a few days of being placed. The specification was met by a special epoxy resin concrete containing aggregates graded from 9 mm down to fines to give consistent strength and creep resistance. Its compressive strength (80N/mm^2 3 days after casting) is three times greater than that of ordinary concrete.

D-466 Barfoot, J. 1986 (Mar). "Cutting Out the Problem," Construction Repairs & Maintenance, Vol 2, No. 2, pp 20-21, London, England.

The techniques of drilling, sawing, and cutting concrete, which have become a sophisticated and vital technology in the last 40 years, are discussed. Particulars of repair and refurbishment are given. Ten percent of cutting, drilling, and sawing of concrete is devoted to demolition work, and the rest is concerned with repairs and alterations, it is reported.

D-467 Robison, R. 1986 (Mar). "Parking Problem," Civil Engineering, Vol 56, No. 3, pp 68-71, American Society of Civil Engineers, New York, NY.

This article discusses the widespread problem of corrosion and lack of maintenance in United States parking facilities. Various methods are discussed for protecting reinforcement from corrosion by deicing salts.

D-468 Tritton, P. 1986 (Mar). "Repairs to Historic Ferro-Concrete Building Enter Final Phase," Construction Repairs & Maintenance, Vol 2, No. 2, pp 11-12, London, England.

Repairs to the King Edward Building, which houses the Post Office in the City of London, are outlined. Despite its classical portland stone facade and the ornate plasterwork in its public areas, the building was, in Edwardian times, a highly innovative building because its floor and roof slabs, walls, beams, and columns were constructed from cast-in-situ Hennebique ferro-concrete.

One of Britain's oldest reinforced concrete buildings, it was completed 75 years ago as an extension to the London General Post Office.

Considering its age and the fact that it was constructed at a time when reinforced concrete technology was in its infancy, the King Edward Building has stood up well to the natural stresses imposed on building structures, and also to unnatural forces. But in the late 70's, cracks and spalling became evident in the floors, and the external reinforced concrete walls began to suffer from extensive spalling. The 6-1/2-year repair program, divided into four phases, is described.

D-469 Danby, J. 1986 (Mar). "Preserving Integrity and Appearance," Construction Repairs & Maintenance, Vol 2, No. 2, pp 6-8, London, England.

Repairs to a masonry arch bridge, both a vital highway link and a scheduled ancient monument in Invernessshire, are described. Lovat Bridge is a five-span masonry arch bridge of red sandstone that crosses the River Beauly. Constructed about 1814, two of the spans were rebuilt in 1894 following the collapse of one pier during severe flooding.

It had been known for some time that there was significant cracking and spalling in the arch barrels of the three original spans, and a program for repair works and deck waterproofing was prepared by the Highland Regional Council and carried out in the summer of 1985. The deterioration of the structure and the problems of carrying out repairs to reinforced concrete are described.

D-470 Ralston, M., and Reinhardt, W. G. 1986 (Mar). "Bodybuilding to Beef Up Old Dam," Engineering News-Record, Vol 216, No. 12, pp 62-63, New York, NY.

Flood control demands are being imposed on the Bureau of Reclamation's 262-ft-high masonry Theodore Roosevelt arch dam, so the Federal dam builders propose to heighten it by 68 ft to increase its flood storage potential. They also want to expand its river outlet capacity from 1,800 to 14,000 cfs so they can draw down the reservoir, slice off the top of the dam, and add 240,000 yd^3 of new concrete, covering most of the visible portion of the 1,180-ft-long gravity arch. When completed, the central 72 ft of Roosevelt will be a curved gravity-type dam flanked by 230-ft-long straight gravity sections incorporating the spillways. The crest will be 7 ft thick.

D-471 Kennedy, J., and Clark, A. J. 1986 (Mar). "Reconstruction Trials for East Sussex County Council of Mix-in-Place Recycling with Cement and Glass-Fibre-Reinforced Surface Dressing," Technical Report No. 565, Cement and Concrete Association, Wexham Springs, England.

The reconstruction trials carried out on two rural roads in East Sussex during the latter half of May 1985 are described. The purpose of the tests was to assess whether the combination of mix-in-place recycling with cement of the existing pavement structure, followed by the application of a glass-fiber-reinforced double surface dressing, is a viable technique for the rehabilitation of structurally failed/failing "flexible" roads. One test was a full-width reconstruction conducted under a road closure, while the other involved sectional repairs conducted between traffic lights. The trials are reported from inception to visual inspection during the months immediately following the reconstruction work. No attempt is made to compare the technique, either technically or economically, with other methods of reconstruction.

D-472 Anderson, B. 1986 (Mar). "Waterproofing and the Design Professional," Construction Specifier, Vol 39, No. 3, pp 84-97, Alexandria, VA.

Water-related problems in buildings and below-grade structures are a leading cause of lawsuits and a basis for claims and damages assessed against contractors and design professionals. Knowing the right questions to ask can help the specifier choose among the myriad products on the market. Longevity, crack bridging, elastic properties, resealability, leak-localizing capability, resistance to chemicals, hydrostatic pressure resistance, permeability and breathability, freeze-thaw resistance, shrinkage, safety, warranty programs and cost effectiveness are some of the topics discussed.

D-473 "Modules Find New Life." 1986 (Apr). Engineering News-Record, Vol 216, No. 17, New York, NY.

Partially decayed concrete guest-room modules, that sat on an airstrip in Mobile, AL, for 15 years, are being refurbished to create the 592-room Hotel Parkway. The hotel is being built adjacent to Walt Disney World, Orlando, FL. Most of the modules were precast for use in Gambia and Saudia Arabia, but the projects were abandoned. The 23-ton modules, 13 ft wide, 27 ft long, and 9 ft high, will be stacked to form three 5-story sections, two 8-story sections, and three 10-story core areas.

Potted drywall in some of the modules' bathrooms had to be replaced, others covered with mildew had to be lightly sandblasted but not replaced. Because the original module-to-module connections had weathered beyond use, the units are being tied together horizontally with U-shaped metal clips grouted in place.

D-474 Appleman, B. M. "Hap," and Fitzhugh, D. 1986 (Apr). "Essential Requirement for Lowest Maintenance and Repair Costs," Concrete Products, Vol 89, No. 4, pp 27-29, 42, Chicago, IL.

The secret of lowering maintenance and repair costs is preventive maintenance (PM). Breakdown maintenance, on the other hand, is very expensive because component failure often results in adjacent component damages. The authors have implemented over 75 preventive maintenance and repair programs in ready-mixed concrete and aggregate companies, and monitored maintenance costs of thousands of mixer trucks, road tractors, trailers, block trucks, dumps, forklifts, loaders, etc. The experience and data analysis has enabled them to prove that a good PM program is essential to minimizing total maintenance and repair costs.

A good PM program will save at least 20 percent on maintenance costs, on a 5-year average basis, compared with the breakdown method of maintenance.

D-475 Preuss, K., Baderschneider, H., and Muhsam, H. 1986 (Apr). "Restoration of the Wittelsbacher Isarbridge in Munich" (in German), Bauningenieur, Vol 61, No. 4, pp 161-169, Berlin, Germany.

The Wittelsbacher Isarbridge in Munich was built between 1904 and 1905. Consisting of four flat three-centered concrete arches with braced spandrels, the bridge sustained damages in the damp-proofing and spandrels, necessitating a fundamental restoration. According to the restoration concept, the deck, including the spandrels, was removed and replaced by a new reinforced concrete-cored slab construction. The arch and substructures, including their foundations, are in good condition and need no restoration. A temporary steel bridge had to maintain the traffic during restoration. The construction period was restricted to less than 1 year.

D-476 Kuennen, T. 1986 (Apr). "'Fast Track' Overlay Pits Concrete Against Asphalt," Roads & Bridges, Vol 24, No. 4, pp 26-27, Des Plaines, Il.

This article describes the Iowa Department of Transportation's plans for an experimental resurfacing project using high early strength concrete. The goal is to open the road to traffic the same day the concrete is placed. If this and similar projects are successful, concrete will become a viable design alternative for both new and overlay projects requiring rapid completion and the resulting competition would serve to hold down construction costs.

D-477 Arnold, C. J. 1986 (Apr). "Salvaging the Zilwaukee," Civil Engineering, Vol 56, No. 4, pp 46-49, American Society of Civil Engineers, New York, NY.

When a failed pile cap tilted a cantilever out of place in Michigan's Zilwaukee Bridge, work platforms and other heavy equipment had to be removed before the bridge could be stabilized. Main repair was a new footing cast around the damaged pier cap, tied and posttensioned to the columns. Temporarily freezing the earth around and beneath the fractured footing helped stabilize the structure, allowing new caissons to be sunk to bedrock and the new footing to be cast around the top of the failed pile cap. Later, bearings at the column tops were replaced.

D-478 Specht, M., Schade, K., and Nehls, P. 1986 (Apr). "Restoration of Two Chimneys Consisting of Alumina Concrete in Berlin," Bautechnik, Vol 63, No. 4, pp 109-116, Berlin, Germany.

The power plant chimneys with structures of alumina concrete showed an alarming decrease of strength and had to be restored. In the beginning all the knowledge pointed toward a tear off and a new construction which implied a long and expensive shutdown of the power plant. Additional investigations resulted in an economy-priced restoration. The existing structure has been strengthened by means of cross section add ons. The suitable requirements have been: 1. Considering certain conditions the alumina concrete would not suffer any strength decrease. 2. The flue, consisting of brick lining, is in good shape. The most important advantages in using the described restoration has been that all the construction work could be done without a total or temporary shutdown of the power plant operation.

D-479 Setzer, S. W. 1986 (Apr). "Renovating Holland's Tunnel," Engineering News-Record, Vol 216, No. 17, pp 30-31, 34, New York, NY.

The 1.6-mile twin-tube under the Hudson River between Manhattan and New Jersey, opened in 1927, is undergoing major renovation after almost 60 years. Named after chief engineer Clifford M. Holland, the tunnel, with a system of removing auto exhaust by forcing fresh air in at the roadway and drawing off exhaust through the ceiling, became a model for vehicular tunnels throughout the world.

Most of the original components of the tunnel are still sound, but the cumulative effect of 80,000 vehicles per day is taking its toll. Originally, cast-iron segments lined each of the 30-ft-diam tubes. A concrete internal lining, followed by a thick concrete floor slab and ceiling panels, completed the basic structures. Now exhaust has blackened the original ceiling. Seasonal flexing and normal stress produced cracks in the 5-in.-thick concrete ceiling panels. A survey showed that the 1/16-in. reinforcing steel mesh in the concrete was corroded completely through in some sections. The Port Authority of New York and New Jersey will spend $80 million on the project.

D-480 Ojha, S. K. 1986 (Apr). "Rehabilitation of a Parking Garage," Concrete International: Design & Construction, Vol 8, No. 4, pp 24-28, Detroit, MI.

Extensive cracking in the floors of a seven-story parking structure was cause for concern for its structural integrity. A structural capacity evaluation revealed undercapacity in beams and slabs and a load posting was recommended. The cracked floors were repaired by epoxy resin injection. The repairs are standing up well.

Condition evaluation of the floors indicated some potential for corrosion of reinforced steel. The floors are proposed to be protected partly by applying penetrant sealers and partly by installing a waterproofing membrane system.

D-481 Barlow, P. 1986 (Apr). "Repairing a Major Concrete Navigation Lock," Concrete International: Design & Construction, Vol 8, No. 4, pp 50-52, Detroit, MI.

Epoxy injection was used extensively in the structural repair of the John Day Dam and Navigation Lock on the Columbia River between Washington and Oregon. The repairs have been successful, and the outward rotation of the lock wall has stopped. Design methods and techniques are described.

D-482 De Andrade, W. P., Paulon, V. A., and Saad, M. N. A. 1986 (Apr). "Repairing Concrete Erosion," Concrete International: Design & Construction, Vol 8, No. 4, pp 46-49, Detroit, MI.

Three large Brazilian dams developed problems with concrete erosion from abrasion and cavitation caused by high-water velocity. Different techniques were used to make the repairs, depending on the type and extent of the damage. This article describes the damage observed, its causes, the repair work conducted, and the performance of the repairs over time.

D-483 Mainar, J., and Arenas, J. J. 1986 (Mar-Apr). "Renovation of the Historic Maria Cristina Bridge," Journal, Prestressed Concrete Institute, Vol 31, No. 2, pp 20-39, Chicago, IL.

Completed in 1905, the Maria Cristina Bridge is composed of three vaults with 24-m (79-ft) spans, two 3-m (10-ft) wide central piers, and two massive abutments. The total width of the bridge is 20 m (66 ft), including 3.5-m (11-ft 6-in.) sidewalks, four traffic lanes totaling 12 m (30 ft), and heavily decorated parapets. Renovation of the famous structure is described including the conceptual plan, component design, and reinforcement, and structural analysis, together with the precasting and construction techniques used.

D-484 McKeen, R. G., Pavlovich, R. D., and Cassino, V. 1986 (Apr). "Asphalt-Rubber SAMI (Stress-Absorbing Membrane Interlayers) Field Evaluation," Report No. NMERI-WA5-7(5.06); AFESC/ESL-TR-86-02, New Mexico Engineering Research Institute, Albuquerque, NM.

This report documents the investigation of asphalt-rubber mixtures for use as stress-absorbing membrane interlayers (SAMI's) for airfield pavements. The project was initiated in 1977 as a state-of-the-art review. That study concluded that use of SAMI's was promising for improving the performance of asphalt-concrete overlays on airfield pavements. A following study addressed material characterization and development of a proposed construction specification. This report covers follow-on monitoring of the performance of an experimental pavement project at Kirtland AFB, Apron A; construction and performance monitoring of two trial sections located at Williams AFB and Coolidge Field in Arizona; and the design and construction of a field experiment at Peterson AFB, Colorado. Based on the results obtained to date, the performance observed cannot be related in a meaningful way to the material characteristics. This results from the small time elapsed since construction of the pavements under observation. Based on experience, a revised proposed construction specification is included in the current report. Continued performance monitoring is recommended to obtain the benefit from the investment made in the initial construction documentation.

D-485 Husbands, T. B. 1986 (Apr). "Facilities Technology Application Tests; Concrete Repair," Miscellaneous Paper SL-86-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The Office, Chief of Engineers, through the Facilities Technology Application Tests Program, requested that the US Army Engineer Waterways Experiment Station demonstrate some of the latest technology in the use of polymeric systems for repairing concrete. Two US Army facilities were selected for the demonstrations, Fort Bragg, North Carolina, and Fort Ord, California.

Two sites at Fort Bragg were chosen for repair, a water tower and a multistory building. The six concrete footings around the base of the water tower contained numerous cracks, with some spalling and delaminated areas. One of the footings was severely scaled. The concrete balconies and support columns of the building contained numerous spalls and cracks. The cracks and delaminated areas in the footings were repaired by pressure injection of epoxy resin. The severely scaled footing was repaired by overlaying with freshly mixed concrete. The spalls were repaired with a latex-modified concrete. The spalls located on the balconies and columns of the multistory building were repaired using an epoxy-resin paste and a latex-modified concrete. The cracks were sealed with a one-component polyurethane.

The concrete roof decks of two water storage tanks at Fort Ord were repaired. Both roof decks had exhibited the same problem; the concrete around the steel reinforcement had started to spall due to corrosion of the reinforcing steel, and some cracking of the roof deck was apparent. The roof decks were repaired by removing all of the unsound concrete and patching these areas with a polyester concrete. The entire roof was then cleaned and sealed with a polyester sealer followed by overlaying with a thin (3/8-in.) coating of the polyester concrete. The old joint sealant material was removed and replaced with a new joint sealant and new air vents were installed.

D-486 Carr, F. H., and Reinhardt, W. G. 1986 (May). "Inscrutable Rock Tests Power Tunnel Grouters," Engineering News-Record, Vol 216, No. 18, pp 22-23, New York, NY.

Virginia Power of Bath County began an extensive program of very high-pressure grouting to seal rock around the lower power tunnels in one of a pumped-storage project's three power tunnels. Engineers had found that water, at 825 ft of head, was flowing through the unreinforced concrete lining in tunnel one and into the mountain. The technique used to solve the problem is described.

D-487 "Concrete Paves the Way for the Next Generation." 1986 (May). Engineering News-Record, Vol 216, No. 20, pp CS-38-CS-42, New York, NY.

Many communities are turning to concrete for street paving and concrete overlays for deteriorating streets. Concrete pavements minimize maintenance. Examples of concrete streets providing long years of service while needing only negligible upkeep are given.

The long-term economy of concrete pavement is also endorsed in a special report by the New York State Department of Transportation's Engineering Research and Development Bureau entitled "A Life-Cycle Cost Analysis for Asphalt and Concrete Pavements."

Among the report's conclusions was the fact that very few concrete pavements need overlay before 20 years, and most survive beyond 25 years before requiring an overlay. It was also shown that the expected life of concrete rural interstate pavements varied from 13 to 30 years, while that of asphalt pavements ranged from 6 to 20 years.

D-488 "Progress in Paving Equipment and Construction Methods." 1986 (May). Concrete Construction, Vol 31, No. 5, pp 439-445, Addison, IL.

A new market for concrete has come in the 4-R program under the guidelines of the Federal Highway Administration (FHWA)-the restoration, rehabilitation, resurfacing, and reconstruction program. This has now grown to be as big as the new construction program in both federal and local funds. Concrete pavements are being restored in imaginative, ingenious ways that are permitting state, county, municipal, and airport engineers to increase the years of satisfactory pavement performance at low annual costs. Concrete resurfacing of both asphalt and concrete pavements is proving to be the best life cycle cost alternative for increasing the load-carrying capacity and improving the riding qualities and safety of many roads, streets, and airport pavements.

D-489 Barfoot, J. 1986 (May). "Cutting a 50-Metre-Long Joint," Construction Repairs & Maintenance, Vol 2, No. 3, pp 23-24, London, England.

Describes the modification of a standard floor saw to make it into a self-climbing diamond wall saw that could be operated from a cradle. Equipment comprised a diesel-operated power pack in the cradle, connected by flexible hoses to the hydraulic motor driving the sawblade through a gearbox. The blade itself was fixed to the wall using a toothed rack, and this was controlled from the cradle with a long handle connected to the gearbox.

D-490 Wilcox, G. 1986 (May). "A Repair Method for Cornish Unit Housing," Construction Repairs & Maintenance, Vol 2, No. 3, pp 25-26, London, England.

After 25 to 35 years, major degradation is occurring to the concrete elements of Cornish Units, as well as many other types of precast reinforced concrete buildings. A survey of 25 percent of the units determined levels of carbonation, chloride content, and average cover over the reinforcement. The survey revealed that it would be necessary to repair all those areas showing spalling, cracking, and delamination, and that the life expectancy of the structures as a whole could be improved by the application of a suitable surface coating. The method of repair adopted was a system of concrete restoration and protection that does not rely solely on the pacification effect of high alkalinity in the repair mortar, but also offers a high degree of protection for the reinforcement from an epoxy coating.

D-491 Bausch, D. 1986 (May). "Runway Repairs Governed by Extremely Short-Term Completion Dates" (in German), Beton, Vol 36, No. 5, pp 175-178, Dusseldorf, Germany.

A unique achievement in concrete surfacing was accomplished during repair work to the runway of Stuttgart airport. Within 126 hr, 8,300 m^2 of concrete surfacing had to be broken up, 7,000 m^3 of superstructure excavated, and 700 m^3 of mineral base course and 2,300 m^3 of hydraulically bound base course had to be laid before the most up-to-date carriageway surfacing equipment could complete the 8,300 m^2 surfacing project. Because of adverse weather conditions, both the hydraulically bound base course and the surfacing concrete had to be heated to 15 and 20 C, respectively. For this, a generating unit with an output of 6,000,000 watts was required.

D-492 Wixson, G. E. 1986 (May). "Concrete Pavement Restoration-A Long-Range Solution," Concrete International: Design & Construction, Vol 8, No. 5, pp 49-51, Detroit, MI.

Concrete pavement restoration-a series of techniques including full-depth slab replacement, partial depth-spall repair, undersealing for slab stabilization, diamond grinding, joint sealing, and shoulder rehabilitation-is discussed as a cost-effective pavement management tool. Engineering concerns about the United States' aging road system are also addressed.

D-493 Cremaschi, J. 1986 (May). "Polymer Concrete Bridge Overlays," Concrete International: Design & Construction, Vol 8, No. 5, pp 58-60, Detroit, MI.

The serious deterioration of concrete roads and bridges has created a need for a practical alternative to tearing up and replacing existing bridge decks. This paper discusses the use of polymer concrete bridge overlays as a faster, less expensive alternative that protects bridge decks while offering good wear resistance and skid resistance.

D-494 Tayabji, S. D. 1986 (May). "Bridge Deck and Garage Floor Scarification by Hydrojetting," Concrete International: Design & Construction, Vol 8, No. 5, Detroit, MI.

Construction Technology Laboratories conducted an investigation to evaluate the effectiveness of the Conjet concrete removal system. The system uses a high pressure jet of water to rapidly remove unsound concrete at the surface of bridge decks, parking garage floors, and pavements.

A full-scale bridge deck panel was obtained for use in demonstrating the effectiveness of the hydrojetting system. The demonstration project included scarification of the deck panel to various depths using the system, construction of six sections of bonded overlays on the prepared surfaces, and determination of shear strength at the interface between the overlay and base concrete. Test results verify that the system did effectively scarify the deck to provide a surface that enabled excellent bonding to take place between the overlay and base concrete.

D-495 Van Doorn, L., Mulders, P., and Van Der Vloedt, Y. 1986 (Jun). "Strengthening an Old Viaduct by External Reinforcement" (in Dutch), Cement, Vol 38, No. 6, pp 22-27, Hertogenbosch, The Netherlands.

If it becomes apparent that an old concrete civil engineering structure is no longer capable of bearing modern traffic loads, external reinforcement-by bonding steel strips to the structure-is a good method of reconstruction. This technique was used for the first time in the Netherlands on a viaduct over the Mass Route in Noord-Brabant, near Drunen. Choice of this repair method is explained and the execution is described. As well as being strengthened on its underside, the viaduct was strengthened on top with an extra layer of structural concrete.

D-496 "Hydraulic Breakers Make Quick Work of Bridge Deck." 1986 (Jun). Roads & Bridges, Vol 24, No. 6, pp 73-74, Des Plaines, IL.

An $8.5-million rehabilitation project, on the 16th St. Viaduct in Milwaukee, is described. The 3/4-mi-long, four-lane bridge was built in 1929 to connect the north and south sides of Milwaukee, split by the Menomonee River Valley.

The first phase of the job was to break out 4- by 10-ft sections of concrete roadway and load them onto trucks for removal.

D-497 "Excavator/Hammer Allows One-Pass Deck Demolition." 1986 (Jun). Roads & Bridges, Vol 24, No. 6, pp 75-76, Des Plaines, IL.

Demolishing of a twin two-lane deck of the original Burlington Bay Skyway bridge near Hamilton, Ontario, included removing 14,000 yd^3 of concrete and reinforcing bars, 500 18-in. floor beams, 41 steel expansion joints, and more than 3 miles of steel safety railing.

The project is to remove a major source of traffic congestion on the Queen Elizabeth Way, to and from Toronto. It includes a new $38-million concrete bridge, which was recently erected next to the 30-year-old original bridge.

D-498 Hooker, W. H., and Lutz, R. 1986. "New Development in Bridge Cathodic Protection," pp 161-163, Engineers' Society of Western Pennsylvania, Pittsburgh, PA.

The increasing knowledge and recognition of the long-term effectiveness and favorable economics of cathodic protection have resulted in the development of new techniques, materials, instrumentation, and equipment. This progress is being accomplished cooperatively by federal, state, county, and municipal agencies and is evidenced by the National Association of Corrosion Engineers' efforts over a 2-year period to prepare a Standard Recommended Practice for Cathodic Protection of Reinforcing Steel in Concrete Structures. This paper focuses on: development of several alternative techniques and materials for bridge deck cathodic protection systems; and application of cathooic protection to concrete bridge substructures. The cathodic protection systems are given.

D-499 Monti, R. M., and Eglot, J. M. 1986 (Jun). "Tunnel Ceiling Replaced Over Traffic," Civil Engineering, Vol 56, No. 6, pp 80-83, American Society of Civil Engineers, New York, NY.

This article describes the installation of new, largely precast ceilings in the two tubes of the Holland Tunnel linking New York City and New Jersey. The old cast-in-place concrete is being replaced with precast panels finished with plant-installed ceramic tile, minimizing construction time and field labor costs. A dense concrete with a low water-cement ratio and superplasticizers is being used. The steel reinforcement is epoxy coated, and steel inserts for the supporting brackets near the tile surface are stainless steel. These measures were required to prevent metal corrosion, which could lead to delamination of the concrete and popping off of the tiles.

D-500 Gupta, A. K. 1986 (Jun). "Cement-Based Waterproofing Treatment: Failures and Remedies," Indian Concrete Journal, Vol 60, No. 6, pp 162-163, 168, Bombay, India.

Certain deficiencies are sometimes observed in the cement-based waterproofing treatment, mainly as a result of poor workmanship. These deficiencies may range from superficial cracks and delaminations to deep cracks that reduce the effectiveness of the waterproofing treatment, even leading to its failure. The article describes the failure mechanism of the waterproofing treatment and suggests certain remedial measures. The remedial measures, when applied to the damaged terraces of some telephone exchanges in Gujarat, were found to be very economical.

D-501 "Back on Track?" 1986 (Jun). Engineering New-Record, Vol 216, No. 26, New York, NY.

Detroit, MI, officials say the extent of repairs required on the 67 cracked guideway girders in the 2.9-mile elevated people mover will be much less than originally feared, estimating that repairs will be completed for $200 million, $10 million less than earlier estimates. The problem of girders that had cracked on their inner faces will be solved by installing cast-in-place concrete ribs inside the box girders.

D-502 Kuenning, W. 1986 (Jun). "Removing Stains From Concrete: Part I," <u>Concrete Construction</u>, Vol 31, No. 6, pp 539-545, Addison, IL.

Information on removing stains from concrete is presented. Common offenders in staining concrete include iron rust, oil, chewing gum, and dirt. Chemical agents needed are presented and safety of workers is discussed.

D-503 Kenney, A. R., and Kenney, B. P. 1986 (Jun). "Problems and Repairs in Tilt-Up Construction," <u>Concrete International: Design & Construction</u>, Vol 8, No. 6, pp 41-50, Detroit, MI.

Most common problems in tilt-up construction involve either structural repairs or surface blemishes. Structural repairs are necessary for problems such as edge chips and spalls, honeycombing, or handling cracks. Surface blemishes on architectural tilt-up panels vary with the type of finish, which can be as simple as a broom finish or as extensive as intricate textured liners or exposed aggregate. These panels may require skilled finishers to make effective repairs, but the repairs are not complicated. With proper training, and by carefully following planned repair procedures, any good finisher can achieve satisfactory results.

D-504 Barbaux, S. H., and Zollman, C. C. 1986 (May-Jun). "Rehabilitation of the Boivre Viaduct-A Multispan Prestressed Box Girder Bridge," <u>Journal, Prestressed Concrete Institute</u>, Vol 31, No. 3, pp 22-47, Chicago, IL.

This article describes the steps taken to rehabilitate a 7-span, 951-ft-long continuous prestressed box girder bridge 180 miles southwest of Paris. Evaluation of the distressed structure was accomplished over a 4-year period through both instrumentation and visual inspection. The final corrective measures required the development of new materials and procedures along with a high level of quality assurance controls to ensure a successful project. The complete bridge resulted in a substantial savings of time and money.

D-505 "Illinois Improves Patching Procedures for Continuously Reinforced Concrete Pavements." 1986 (May-Jun). <u>TR News</u>, No. 124, pp 8-9, Transportation Research Board, Washington, DC.

This article describes development of smaller, more efficient patch techniques for continuously reinforced concrete pavements than those previously used by the Illinois Department of Transportation. A study resulted in the development of two distinct patching techniques: the first technique incorporated a shorter-tied overlap of existing steel and new steel and provided a shorter working area in the center of the patch; the second technique shortened the overlap of steel even more by welding the existing steel to the new steel and using a tied-lap splice in the center of the patch to avoid potential buckling of the reinforcement.

However, field experience with the welded patch indicated that the quality of the welds was difficult to determine and the use of welds was replaced with mechanically coupled reinforcement. Tests have indicated that mechanically coupling the new reinforcement to the exposed reinforcement at the ends of the patch is a satisfactory alternative to tying the reinforcing bars.

D-506 "Methods of Removing Some Specific Stains from Concrete: Aluminum to Finishing Discoloration." 1986 (Jul). <u>Concrete Construction</u>, Vol 31, No. 7, pp 655-661, Addison, IL.

Part 2 of a series, this article focuses on methods, agents, and equipment for removing specific stains from concrete. The stains treated are: aluminum; asphalt; various beverages; blood; bronze and copper; candy and confectionery; caulking compound; chewing gum; clay; coal tar; creosote; curing compounds; dirt; efflorescence; epoxy coatings and adhesives; and finishing and curing discolorations.

D-507 Loewald, R. 1986 (Jul). "Cologne Relieves Tired Arches," <u>Engineering News-Record</u>, Vol 217, No. 4, p 25, New York, NY.

West German engineers are widening a railroad bridge over the Rhine River. Destroyed 41 years ago and since rebuilt, the 75-year-old Hohenzollern bridge has become a bottleneck for rail traffic.

Two existing piers were widened 46 ft, with the extended portions found partly on caissons from the original pier construction and partly on new foundations. Since the old piers were more reinforced, the contractor divided 23 holes horizontally through each of the old piers to line up with sleeves cast on the new piers for prestressing tendons to tie them together. Drilling was complicated by unexpected steel in the old piers, and the porosity of the concrete made it necessary to grout the tendon sleeves inside and out.

D-508 Perez, A. 1986 (Jul). "Patching Architectural Concrete," <u>Concrete Construction</u>, Vol 31, No. 7, pp 623-629, Addison, IL.

Even when the best materials and construction methods are used, architectural concrete is likely to have imperfections and defects. Some imperfections are acceptable as part of the character and nature of concrete; however, objectionable defects require corrective action. When not to patch; patch mix design, color section, and mixing; application and initial texturing; curing; and finishing are considered.

D-509 Somerville, G. 1986 (Jul). "Useful Life of Concrete Structures" (in Spanish), <u>Revista IMCYC</u>, Vol 24, No. 182, pp 15-32, Instituto Mexicano del Cemento y del Concreto, Mexico.

The life of concrete structures in service depends not only on the production and placing of durable concrete, but also on proper design, detailing and construction methods, and on appropriate levels of maintenance. Past and present procedures for achieving this are reviewed, shortcomings identified, and suggestions made for improvement in the future.

D-510 Wu, G. Y. 1986 (Aug). "Heat-Resistant Concrete Pavements," The Military Engineer, Vol 78, No. 509, pp 487-489, Alexandria, VA.

Military jet aircraft create concrete erosion and spalling on airfield pavements because portland-cement concrete begins to disintegrate at about 662° to 752° F due to dissociation of hydrated lime into quicklime and water. The Naval Civil Engineering Laboratory undertook a study to identify materials and construction technology for heat-resistant pavement. The results obtained from the jet engine exhaust blasts were used to design a full-scale V/STOL test pad at MCAS Cherry Point for field performance evaluation.

D-511 "Epoxy Injection Offers Strength to Substructures." 1986 (Aug). Roads & Bridges, Vol 24, No. 8, pp 34-38, Des Plaines, IL.

This article describes epoxy injection techniques for repairing cracks and filling voids in concrete bridge decks and substructures. Methods described include preparing cracks, drilling port holes for injecting, selecting ports, sealing cracks, selecting epoxies for injection, injecting, finishing the repaired structure, and test cores.

D-512 "Methods of Removing Some Specific Stains from Concrete: Fire and Soot to Moss (Part 3)." 1986 (Aug). Concrete Construction, Vol 31, No. 8, pp 736-743, Addison, IL.

Cleaning agents and methods for removal of specific stains from concrete are described. Stains covered are fire, pitch, wood tar, fruit stains, graffiti, grease, slag discoloration, gypsum plaster, ice cream, ink, iodine, rust, joint sealant, mildew, and moss.

D-513 Guedelhoefer, O. C., and Krauklis, A. T. 1986 (Aug). "Crack Repair Techniques: To Bond or Not to Bond," Concrete International: Design & Construction, Vol 8, No. 8, pp 10-15, Detroit, MI.

This article presents methods for repairing cracked concrete that have been applied successfully to a damaged reinforced cooling tower. Five types of cracking requiring repair are discussed with recommendations for repair methods, specifications, and quality assurance/quality control procedures to ensure repair quality and durability. Conceptual guidance is provided to those involved in designing or constructing concrete crack repairs.

D-514 Sees, M. R. 1986 (Aug). "Underground Detention Saves Money on Urban Road Improvement," Concrete Pipe News, Vol 38, No. 4, pp 3-5, Vienna, VA.

Report is given of Illinois Transportation Department's widening of Charleston Avenue through Matton, IL. The project consisted of widening the existing facility of four 10-ft lanes with curb and gutter to four 12-ft lanes, with an additional 12-ft turn lane. The area had a history of drainage problems during heavy storms.

The method chosen was a system that could make use of existing outfall pipes by using concrete pipe for underground storage, with the detained water being metered into the existing system after the peak flow period had passed. Thirty-six-inch reinforced concrete pipe was used for the detention part of the system. To make the system function, the manholes from the 36-in. concrete pipe act as a metering device between the new and old systems.

D-515 Waring, S. T. 1986 (Aug). "Chemical Grouting of Water-Bearing Cracks," Concrete International: Design & Construction, Vol 8, No. 8, pp 16-21, Detroit, MI.

Materials and application techniques for the repair of water-bearing cracks in concrete by chemical grouting is discussed and several dam and lock repair projects are described.

D-516 Little, D. 1986 (Sep). "Effective Repair and Protection of Concrete," Construction Repairs & Maintenance, Vol 2, No. 5, pp 23-25, London, England.

A repair system is outlined that was designed to combat both carbonation and chloride attack. Possible weaknesses, assessment of problems, and conclusions are listed for reinforcing bar priming, concrete substrate priming, repair mortar, and impregnating surface coatings.

D-517 "Underpinning Alternative." 1986 (Sep). Civil Engineering, pp 50-53, London, England.

This article describes the use of a new technique to stabilize failed foundations. The method consists of casting a concrete beam around the building and posttensioning it. The stress distribution under the foundation then alters and the building is said to be better able to resist differential movement.

D-518 Allen, R. T. L. 1986 (Sep). "Choosing a Concrete Repair System," Construction Repairs & Maintenance, Vol 2, No. 5, pp 10-12, London, England.

Reasons for repair of a concrete structure and choice of materials are discussed. Different methods of repair are described, including resin-based mortars, corrosion inhibitors, polymer bonding agents, and sprayed concrete.

D-519 Hansen, K. D., and France, J. W. 1986 (Sep). "RCC: A Dam Rehab Solution Unearthed," Civil Engineering, Vol 56, No. 9, pp 60-63, American Society of Civil Engineers, New York, NY.

Roller-compacted concrete (RCC) is gaining popularity as a dam rehab material. It has properties equal to conventional unreinforced concrete. It is cheaper, can be placed more quickly, and is as reliable as more traditional rehab choices. Several applications are described, and design considerations are outlined. Design details for RCC dams require careful attention, particularly at the crest, downstream slope, and downstream toe.

D-520 Adachi, I., and Kobayashi, K. 1986 (Sep). "Construction Joint of Concrete Structures Using Shot Blasting Technique" (in Japanese), Proceedings, Japan Society of Civil Engineers, No. 373, pp 64-73, Tokyo, Japan.

This article reports the results of basic research conducted as an essential step in applying shot blasting, which is conventionally used for the treatment of metallic surfaces, to the construction procedures for bonding new concrete to hardened concrete structures.

Experiments were conducted to accumulate data by varying the many factors concerned, such as the ratio of water to cement for concrete, types of coarse aggregate, size of the shot (round particles) and grit (angular particles), blasting velocity, and blasting density.

Studies were mainly conducted by a method providing quantitative evaluation of the degree of concrete surface treatment. The tests also aimed to establish a method for treating concrete structures to attain the required strength in construction joints using shot blasting.

D-521 "Rehabbing Research." 1986 (Sep). Civil Engineering, Vol 56, No. 9, pp 55-57, American Society of Civil Engineers, New York, NY.

Corps of Engineers research is swinging toward operation and maintenance and rehabilitation because its civil works inventory is aging. Areas of study and new applications described include concrete removal, new anchor installation, crack repair, and placement of new concrete underwater.

D-522 Jirsa, J. O. 1986 (Sep). "Repair and Strengthening of Reinforced Concrete Structures," Revista IMCYC, Vol 24, No. 184, pp 57-64, 66-72, 74-79, Instituto Mexicano del Cemento y del Concreto, Mexico.

The results of an experimental project involved with repairing and strengthening reinforced concrete structures are described. The project was divided into phases involving (1) basic studies to determine efficient procedures for attaching new concrete or steel elements to existing concrete members, (2) encasing members to improve shear capacity, and (3) loading strengthened 2/3 scale two-story structures to failure.

D-523 Coote, A., McKenzie, S., and Treadaway, K. 1986 (Sep). "Repairs to Reinforced Concrete in Marine Conditions," Construction Repairs & Maintenance, Vol 2, No. 5, pp 18-22, London, England.

To gain an understanding of repair systems, an experiment was designed to study the effectiveness of various repair formulations when applied to concrete in a marine environment. This article describes the method of exposure and repair of prisms exposed in the tidal zone for 4-1/2 and 6-1/2 years. It was concluded that the criteria for selection of appropriate repairs in marine conditions should include ease of application, both with substrate and resistance to cracking, dimensional stability, resistance to environmentally induced damage, and protection of the steel. Rapid-setting systems have not proven successful in the long run. In addition, repair systems based on epoxy or styrene butadiene plus glass fiber formulations are adequate only for short-term protection. For long-term protection an OPC or OPC-SBR modified mortar is more effective.

D-524 Gemert, D. V., and Bosch, M. V. 1986 (Sep). "Long-Term Performance of Epoxy Bonded Steel-Concrete Joints," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The technique of strengthening reinforced concrete structures by means of epoxy bonded steel plates becomes more and more familiar in renovation industry. It shows to be a reliable and fast repair method, not only under normal laboratory conditions but also under atmospheric and sustained loading conditions. The creep effects in the epoxy joint are very limited, without affecting the mechanical strength of the connection. The preparation of the elements and the execution of the repairing operation turns out to be of great importance. At high temperatures, a weakening of the epoxy-joint appears which calls for insulating measures.

D-525 Cleland, D. J., Naderi, M., and Long, A. 1986 (Sep). "Bond Strength of Patch Repair Mortars for Concrete," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

When diagnosing a faulty concrete structure, the cause of the fault or deterioration should be established so that the most appropriate solution to the problem can be selected. For example, if corrosion of the reinforcement is the main cause of deterioration, then one might call for an impermeable or less permeable repair system which may be among the resinous system. However one should always bear in mind the compatibility of the system with the old or deteriorated concrete structure.

No matter what repair system is chosen one of the requirements of a repair system is the ability to provide an adequate bond between the repair and the old concrete. Ideally the bond strength should be such that the composite structure behaves as monolithial.

The factors which in the authors' view play an influential role in creation of bond between the repair and old concrete, has been examined in this paper and some comparison is made between the different repair systems.

D-526 Silfwerbrand, J. 1986 (Sep). "Bonding Between Old and New Concrete in Structures Loaded at Static and Time-Dependent Load," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Concrete bridge decks often show extensive damages caused by wear, deicing salts and freeze-thaw cycles. The damaged concrete has to be removed and replaced by a new-cast concrete topping.

The bonding between old and new concrete has been studied by tests with composite concrete beams. The beams were composed of old concrete with a stripped, rough interface against a new concrete topping.

In one investigation composite concrete beams were loaded by a single load at the center of the beam. Both static and fatigue tests were carried out. The results show good bonding in both cases.

In a second investigation the effect of differential shrinkage was studied. The composite concrete beam in the tests could resist the residual stresses caused by differential shrinkage without cracks along the rough interfaces or in any of the parts of the beams. The stress relief caused by the creep, which is simultaneous to the shrinkage, is the main cause of the resistance of the concrete beams to residual stresses caused by the differential shrinkage.

D-527 Grosskurth, K. P., and Perbix, W. 1986 (Sep). "Improvement in the Durability of Cracked Concrete Elements Injected with Synthetic Resin by Optimizing the Bond Behaviour," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Cracked building elements are increasingly being repaired by the injection of reactive resins. The success of a repair not only depends on the choice of the right injection material, but rather it is also influenced in a complex way by many practical construction conditions. This includes the nonpositive injection of wet crack surfaces. At present very little information is available about the influence of processing and material-related parameters on the bond behaviour. The cause of premature bond failure must be sought in the microregions of the adhesive areas, wherefore the application of scanning electron microscopy is indispensable. The influence of different boundary conditions on the bond behaviour of the injected resin systems was investigated in several tests. In the first test unit with building elements, it could be shown that dry crack injection at a temperature generally presents little difficulty. The investigation of 25° C carbonated injected crack surfaces also presented positive results. However, the presence of water during the injection and the curing phase resulted in a reduction in the bond tensile strength. In cooperation with the chemical industry, the adhesive properties of some wet injected resins have been improved considerably.

D-528 Keer, J. G., and Emberson, N. K. 1986 (Sep). "A Theoretical and Experimental Study of Concrete Members Repaired by Resin Injection," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Simple analytical models are presented which are used to examine the theoretical behaviour of an axially reinforced concrete prism under tension pre- and postrepair by resin injection. The effect of repair on the steel strain at the crack and the crack movement has been derived in terms of the resin modulus and the original crack width. The load sustained postrepair before recracking has been shown to be dependent upon the load at which repair is carried out and on the previous load history of the member. The experimental work was conducted using axially reinforced concrete prisms loaded in tension and monitored for strain. Plan and ribbed reinforcements were used. A novel part of the test program was that the repair and resin curing period of some members was undertaken while they were held under load, rather than at zero load. Most members tested were able to support, following repair, substantial proportions of the original cracking load before recracking occurred, although for ribbed bars, the postrepair load increment is sensitive to the success in repairing secondary cracking.

D-529 Theillout, J. N. 1986 (Sep). "Repair and Strengthening of Bridges by Means of Bonded Plates," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

The design of concrete strengthening by the application of steel plates bonded to the concrete surface requires a very good knowledge of the mechanical behavior of the strengthened structures. The paper deals with the following aspects of the behavior of bonded steel plates:

(a) Local behavior of a bonded steel plate in the vicinity of a crack. This study reveals local bending of the plate. The influence of the different parameters has been investigated.

(b) Study of assembly failures. It is possible to predict the failure of repaired structures strengthened under normal force, bending moment, and with regard to shearing force when using the concepts of brittle fracture mechanics. Some experimental determination of the energy release rate is presented.

(c) Distribution of deformations between reinforced bars and bonded steel plates. Calculations carried out on a numerical model of a reinforced concrete tie member show that the hypothesis of plane deformation is not verified. These partials results need.to be confirmed by experience.

D-530 Jones, R., Swamy, R. N., and Bloxham, J. 1986 (Sep). "Crack Control of Reinforced Concrete Beams Through Epoxy Bonded Steel Plates," Adhesion between Polymers and Concrete, Bonding, Protection, and Repair; Proceedings of an International Symposium, RILEM Technical Committee 52, Resin Adherence to Concrete and Laboratoire Central des Ponts et Chaussees, Paris, France.

Strengthening of concrete structures in situ by bonding steel plates to concrete surfaces using epoxy resins is now recognized to be an effective and convenient method of improving their performance under service loads or to increase their ultimate strength. The main advantages of the technique are that the operation can be carried out relatively quickly and simply even while the structure is in use. Although the technique has been widely used in various parts of the world, there is very little systematic information on the service load behavior of plated beams, particularly in relation to cracking.

In this paper comprehensive test data are presented on the effect of glued plates on the cracking behavior of reinforced concrete beams strengthened with such plates. The variables studied in this project include plate thickness, glue thickness, layered and lapped plates. The structural behavior of these beams was closely monitored during testing to destruction, and extensive crack measurements were made to evaluate the effectiveness of the glued plates on crack spacing and crack width.

The paper will present a detailed analysis of the cracking data. It will be shown that maximum crack widths are substantially reduced in the plated beams compared to unplated beams. The test results are compared to existing crack width equations in design codes. New equations are developed to predict crack width in plated reinforced concrete beams.

D-531 Van Heummen, H., Bovee, J., Van Der Zanden, H., and Bijen, J. 1986 (Oct). "Study of the Durability of Materials in the Causeway Connecting the Saudi Arabia to Island of Bahrain" (in Italian), Industria Italiana del Cemento, Vol 56, No. 10, pp 762-778, Rome, Italy.

Considering the highly aggressive environment for a prestressed and reinforced concrete structure sited in the Persian Gulf, the materials to be used were investigated carefully: from the type of concrete to the reinforcing steel, in order to obtain the best durability in the course of time. A special commission has prepared a document concerning design problems and the construction procedure to be adopted. We publish here the chapter on 'Materials and Durability' where the various technological conditions such as the concrete mix, the reinforcing steel protection, the different types of mortar, constructional characteristics, and concrete linings are examined thoroughly.

D-532 McDonald, J. E. 1986 (Nov). "Repair of Waterstop Failures: Case Histories," Technical Report REMR-CS-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Nearly every concrete structure has joints that must be sealed to ensure its integrity and serviceability. This is particularly true for monolith joints in hydraulic structures such as concrete dams and navigation locks. Embedded waterstops are generally used to prevent water passage through the monolith joints of such structures. A waterstop failure can result in various problems ranging from minor leakage with cosmetic concern to significant hydraulic forces and structural overloading which could threaten the stability of a structure.

The primary objective of this study was to identify materials and techniques which have been used in repair of waterstop failures. Also, based on a review and evaluation of current practices, a secondary objective was to identify those areas where research is needed to supplement existing technology.

Although the information obtained from the various sources varied widely from project to project, attempts were made to obtain (a) a description of the project, (b) cause and location of the leakage, (c) descriptions of repair materials and techniques, and (d) results of follow-up evaluations. Sufficient information to prepare a case history was obtained from 20 projects, several of which involved multiple repairs. In addition, limited information on three other repair projects is included.

Leakage through monolith joints reported herein ranged from minor flows to more than 600 gal/min. In general, leakage was the result of waterstop defects including (a) excessive movement of the joint which ruptures the waterstops, (b) honeycomb areas adjacent to the waterstop resulting from poorly consolidated concrete, (c) contamination of the waterstop surface which prevents bond to the concrete, (d) puncture of the waterstop or complete omission during construction, and (e) breaks in the waterstop due to poor or no splices.

More than 80 different materials and techniques have been used, individually and in various combinations, to repair the waterstop failures reported herein. Some appear to have been successful, while many have failed. Because of a lack of appropriate test methods and equipment, most materials have been used in prototype repairs with limited or no laboratory evaluation of their effectiveness in the particular application. A definite need exists for development of testing procedures and equipment to allow systematic laboratory evaluation of waterstop repair techniques prior to application in prototype structures.

D-533 Arasawa, H., Matsumoto, K., Yamaguchi, S., and Sumita, K. 1986. "Controlled Cutting of Concrete Structure with Abrasive Water-Jet," pp 211-218, British Hotelier and Restaurateur, Kent, England.

Some results of our recent experimental study on cutting conditions and cutting method with abrasive water-jet for various test blocks are introduced. The test blocks were the same as a part of a concrete construction. Steel reinforcing bars (29 mm in diameter) were used in all blocks, and some of these blocks were covered with steel plate. The investigation showed a possibility of a controlled cutting and dismantling of concrete structures, especially a decommissioning of nuclear power plants.

D-534 deGraaf, F. F. M. 1986. "Special Repair Underwater and Repair of a Coastal Concrete Structure in a Tidal Area," pp 361-372, Concrete Society, London, England.

In this paper special aspects of underwater repair of concrete and, in particular, the execution of repair of some damage to a coastal structure in a tidal area will be considered. It concerns damage of a few of the piers of the storm surge barrier in the Eastern Scheldt in the Delta area. First the general aspects of underwater repair will be considered. Further a description will be given of the investigations and tests that have been done to obtain the desired quality. An explanation will be given of the construction methods and the auxiliaries that were necessary for executing the required repair in the existing hydraulic conditions.

D-535 Ackermann, C. J., and Youdale, J. E. 1986. "Rehabilitation and Upgrading of Terminal 5 Wharf, Port of Seattle," pp 383-391, Concrete Society, London, England.

Terminal 5 is one of Seattle's major container facilities. The wharf was constructed in three phases form 1961 to 1969 as a general cargo berth. During construction of the second phase in 1965, the berth was damaged by an earthquake. Repairs were carried out at that time and some further modifications were undertaken. Continued increases in traffic have dictated that modern, larger container cranes be installed, heavier mobile equipment be used, and the berth be extended. The structure consists of prestressed concrete piles, cast-in-place pile caps, prestressed haunched deck panels, and a steel sheet pile bulkhead. The terminal 5 wharf structure is an example both of the durability of concrete structures in a marine environment and of the ability to modify such a structure to accommodate significant changes in use at reasonable cost.

D-536 Reilley, K. T., Saraf, C. L., McCullough, B. F., and Fowler, D. W. 1986. "Laboratory Study of the Fatigue of Bonded PCC (Portland Cement Concrete) Overlays," Report CTR 3-8-86-452-2; FHWA/TX-87/29+457-2, Federal Highway Administration, Austin, TX.

Bonded concrete overlays are a new method of pavement rehabilitation and the effect of long-term repeated loadings is not yet known. A laboratory study, using accelerated repeated loadings, was performed to enable a prediction of long-term results in a relatively short time period. In the laboratory, four model pavement slabs were tested. Results from the study showed differences in the behavior of CRCP and JCP slabs.

D-537 Wagh, V. P. 1986 (Oct). "Bridge-Beam Repair," Concrete International: Design & Construction, Vol 8, No. 10, pp 43-50, Detroit, MI.

On a concrete arch bridge rehabilitation project in Pittsburgh, a precast posttensioned floor beam cracked 6 to 7 weeks after grouting of the posttensioning duct. The cracking occurred due to freezing of water trapped in the posttensioning duct as a result of improper grouting procedures. After detailed investigation and analysis, an auxiliary support beam was constructed to take the full load in case of failure of the damaged floor beam. The experience emphasizes the importance of proper procedures in grouting of a tendon duct in posttensioned structures.

D-538 Cochrane, D. J. 1986 (Oct). "Caledonian Canal-Repairs to Locks at Fort Augustus," Proceedings, Institution of Civil Engineers, Part 1, Vol 80, pp 1363-1383, London, England.

The sills of the Fort Augustus five-lock staircase on the Caledonian Canal had deteriorated and replacement of the bottom three, in concrete, was necessary. These three sills, however, are lower than low-water level in Loch Ness and consequently cofferdams and a diversion of catchment runoff were required for the works to be carried out in the dry. The size of the sills meant that a considerable amount of heat would be generated during construction and it was thus necessary to monitor temperatures within the concrete. Monitoring procedures formed an important feature of the work as strain gages were used to identify structural movement and noise measurements were taken to ensure compliance with the parameters of a noise consent. The works costs approximately £360,000 (1983 prices) and included pressure pointing of lock walls. They were completed in 18 weeks to minimize canal closure.

D-539 Greve, H. G. 1986 (Oct). "Precast for Terra Cotta," Concrete International: Design & Construction, Vol 8, No. 10, pp 20-25, Detroit, MI.

During the turn of the century architects decorated buildings with ornamental stone, terra cotta, and metal trimmings. As beautiful as these buildings are, time has taken its toll and today's architects and engineers are faced with major damage to building facades. Precast concrete replacement units perform well as substitutes for the original broken and damaged terra cotta units and can be cast to duplicate the original decorative ornamental forms.

D-540 Fritsche, A. O. 1986 (Oct). "Demolition of Concrete Structures with Explosives" (in Spanish), Revista IMCYC, Vol 24, pp 31-41, Instituto Mexicano del Cemento y del Concreto, Mexico.

This paper consists mainly of a description of the demolition works with explosives on concrete structures. Since it is a technology almost unknown in Mexico, information provided has been gathered through demolitions made in Mexico City as a result of September 1985 earthquakes.

D-541 Jain, K. C., and Milne, R. J. 1986 (Oct). "Crack Repair at a Chlorine Plant," Concrete International: Design & Construction, Vol 8, No. 10, pp 26-28, Detroit, MI.

The subject of this study was a caustic/chlorine plant in the midwestern United States. The reaction cells, weighing 100,000 lb (45,400 kg) each, were directly supported by reinforced concrete structures: the cells rested on beams and the beams carried the loads to foundations through cylindrical columns. The concrete deterioration problem was discovered 5 years ago. Cracks were common throughout the structure, but more predominant at the cell extremes, which were unprotected from the weather. The erosion of the concrete on some portions of the cantilever beams was so extensive that about one-half the concrete was eroded away. There has been little research in this area, hence, no specific repair technique could be guaranteed effective. We recommended the following solutions are viable. All cracks must be chipped back to sound concrete, then pressure grouted. If the footings are adequate and the foundations can take the added load, additional reinforced concrete columns could be installed on the same foundations. Fiberglass reinforcement is ideal for such conditions.

D-542 Suprenant, B. A., and Malisch, W. R. 1986 (Nov). "Equipment for Cleaning or Preparing Concrete Surfaces for Repair," Concrete Construction, Vol 31, No. 11, pp 927-934, Addison, IL.

When concrete flatwork has to be resurfaced, the first steps in the process are often the most critical. Deteriorated concrete must be removed and the surface scarified and cleaned. Scarifiers, scabblers, abrasive blasters, and waterblasters are some of the machines used for surface preparation. These types of equipment are discussed in depth, and tips are given to help choose the right equipment for the job.

D-543 "Rehabilitating with Skid-Resistant Surfaced Aluminum Decks." 1986 (Nov). Better Roads, Vol 56, No. 11, pp 34-36, Park Ridge, IL.

The Federal Highway Administration has reported that 45 percent of the 565,000 bridges in this country need repair. The cost of the repair, according to FHWA estimates, is $48 billion. It is also estimated that 65,000 of the bridges have structural deficiencies, which would benefit from the replacement of their heavyweight decking with a lighter weight decking. The light weight of aluminum decking is suited for this application, since the weight savings compared to a conventional concrete deck is in the range of 6:1 to 8:1. Aluminum decking also has a political and sociological advantage. The time required to install aluminum is much shorter than many other types of decks, according to a technical report from Alcoa. Shop fabrication is the reason. The use of aluminum decking greatly relieves the problems of detour inconvenience, delays in fire protection and ambulance service, and loss of business by local firms.

D-544 Kendell, K. 1986. "The Cathodic Protection of Reinforced Concrete Using Polymeric Anodes in the European Context," Cathodic Protection: Corrosion Science: Materials Selection, Vol 2, pp 39-51, The Institute of Corrosion Science and Technology, Birmingham, UK.

Until recently, experience of the cathodic protection of reinforced concrete structures has been largely confined to bridge decks in North America. This paper presents European experience in this field by describing cathodic protection systems based on polymeric anodes which have been applied to deteriorated reinforced concrete structures in Europe. The subjects covered include: the design philosophy adopted, the selection and use of materials with particular emphasis on installation details, operating criteria, and results. This information is supplemented with case histories of actual installations currently in operation in Europe. The range of structures covered in these case histories includes horizontal and vertical surfaces of structures in both land and marine based sites.

D-545 Olesen, S. O. 1986 (Dec). "Danish Approach to Solving Concrete Durability Problems," Nordic Concrete Research, No. 5, pp 101-107, Oslo, Norway.

During the late 70's an increasing number of durability problems were registered in Danish concrete structures. The expenses for repair and maintenance increased accordingly, and the reputation of concrete as a durable building material and, thus, its suitability for a number of important purposes was seriously questioned. A number of Danish Research Institutes and private companies have participated in a 4-year (1982-86) campaign to obtain a longer durability of new concrete structures and to promote a higher degree of maintenance of existing concrete structures. The content of the campaign is described.

D-546 Higgins, R. C., Jr. 1986 (Dec). "Repairing and Restoring Steel Reinforced Concrete," The Construction Specifier, Vol 39, No. 12, pp 64-70, Alexandria, VA.

The article addresses the importance of evaluating data and potential problems before selecting materials and procedures to repair or restore steel reinforced concrete structures.

D-547 McDonald, J. E., and Best, J. F. 1986 (Dec). "Results from TVA Testing of Grouting Systems for Concrete Anchors," The REMR Bulletin, Vol 3, No. 3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The purpose of this investigation was to evaluate the effectiveness of cement, epoxy, and polyester-resin grouts used to embed reinforcing steel bars in hardened concrete under a variety of placing and curing conditions. Pullout strength tests were conducted under wet and dry conditions at eight different ages ranging from 1 day to 32 months.

Beyond 1-day age, all grouts developed pullout strengths approximately equal to the ultimate strength of the reinforcing-bar anchor when the grouts were placed under dry conditions, regardless of curing conditions. With the exception of the polyester-resin grout placed under submerged conditions, pullout strengths were essentially equal to the ultimate strength of the anchor when the grouts were placed under wet or submerged conditions.

The overall average pullout strength of polyester-resin grout placed and cured under submerged conditions was 35 percent less than the strength of the same grout placed and cured under dry conditions. The largest reductions in pullout strength, approximately 50 percent, occurred at ages of 6 months and 16 months. Also, the overall average pullout strength of polyester-resin grout placed and cured under submerged conditions was approximately one third less than the strength of epoxy and cement grout placed under wet and submerged conditions, respectively, and cured under submerged conditions.

Polyester-resin-grouted anchors exhibited significantly higher creep than that exhibited by epoxy- and cement-grouted anchors under both wet and dry conditions. Consequently, creep data should be considered in the selection of an anchorage grout where the frictional resistance and bond between the surfaces of the two masses to be anchored together are important.

D-548 McDonald, J. E. 1986 (Dec). "Remedial Waterstop Installation at Pine Flat Dam," Video Report REMR-CS-1, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This 13-minute video report demonstrates a new method of remedial waterstop installation which was used to repair three leaking joints at Pine Flat Dam, California, in 1985. Gelco Grouting Service of Salem, OR, performed the repair using a patented system in which they cleaned the drill holes to remove grout from a previous unsuccessful repair, inserted a polyurethane liner which bonded to the surfaces of the 6-1/2-in.-diam hole, and filled the hole with elastic grout to form the core of the waterstop. The new waterstops were still functioning effectively 1 year after completion of repairs.

A-549 Fwa, T. F., and Sinha, K. C. 1986. "Analysis of Routine Maintenance Effects on Rigid Pavements," Concrete in Transportation, SP-93, American Concrete Institute, pp 39-56, Detroit, MI.

A concept of measuring the effects of routine maintenance on rigid pavement performance is presented. Adopting this proposed concept, a methodology is developed for evaluating such effects based upon pavement performance data and pavement routine maintenance expenditure information. An application of the methodology is presented where the rigid pavements of six interstate highways in Indiana are analyzed.

D-550 Bargagliotti, A., Caprile, L., Piana, F., and Tolle, E. 1986. "Plasma Arc and Thermal Lance Techniques for Cutting Concrete and Steel," Report EUR-10402, Commission of the European Communities, Luxembourg.

The plasma arc technique is used today in industrial practice for any metal but mainly for cutting stainless steel, carbon steel, and aluminum. In air the maximum thickness that was cut in the performed tests was 150 mm, both with ferritic and austenitic steel. Underwater the maximum thickness cut was 103 mm. The two types of torch used in the tests are those used today: the plasma-shaped electrode torch (WIPC) and the pointed electrode torch (DMC-GRUEN). Two different types of gas were compared: an argon-nitrogen mixture and an argon-hydrogen mixture. The second mixture adopted results in less dust emission. The production of dust and aerosols also depends on the cutting speed, on the kind of steel, but mainly on the environmental conditions; it is reduced up to 500 times underwater. Dust and aerosols can jeopardize the efficiency of the system; moreover, the ambient air can have high-level radiation fields. Indirect and direct protections are needed (shields, remote control, robots, etc). Tentative procedures for dismantling two types of BWR reactor are examined. Two series of tests demonstrated the feasibility of cutting the most geometrically difficult parts of the reactor internals. The thermal lance technique is used in industrial practice mainly for dismantling large reinforced concrete structures. This technique can be applied to dismantle nuclear facilities, even though it can cause some problems due to the gases, fumes and lapilli produced. In addition, the cost of this technique seems to be generally higher than the cost of other techniques. From the analyses done, the conclusion seems that both the above techniques are feasible for dismantling a nuclear power plant (NPP). The best solution is probably to analyze the different dismantling possibilities and problems of each case.

D-551 Chase, G. W., and Lane, J. 1986. "Thin Bonded Portland Cement Concrete Overlay as a Solution to Interstate Highway Restoration," Concrete in Transportation, SP-93, American Concrete Institute, pp 89-106, Detroit, MI.

Interstate 80, which traverses Iowa in an east-west direction, has been showing various signs of deterioration because of heavier-than-anticipated truck traffic, both in volume and in truck weight. Several solutions have been tried, including complete replacement by a new inlay, full-depth patching, asphalt overlay, and portland-cement concrete (PCC) overlay. Several factors favor PCC overlay, including economics, construction time, increased load capacity of the new pavement, and the need to minimize the consumption of new resources. The design provides for a 4-in. (10.2 cm)-thick PCC overlay over the old 10-in. (25.4 cm)-thick pavement. Preparation for the overlay required numerous full-depth patches of deteriorated joints, followed by shotblasting, milling where needed, and the application of a cement-water grout. This paper discusses the design, contract requirements, construction procedures, and pavement performance to date.

D-552 Manning, D. G., and Schell, H. C. 1986. "Cathodic Protection of Bridges," Concrete in Transportation, SP-93, American Concrete Institute, pp 585-608, Detroit, MI.

The corrosion of embedded reinforcement caused by the presence of chloride ions in the concrete causes serious deterioration in highway structures. Cathodic protection is the only method presently available of arresting active corrosion. It consists of applying sufficient electrical current to the surface of the reinforcing steel to prevent it from discharging ions so that corrosion does not occur.

The technology for the cathodic protection of steel in concrete is relatively new. Ontario is the only jurisdiction to use cathodic protection as a routine procedure, and has done so since 1978. The system that is used on bridge decks consists of cast iron anodes positioned in recesses on the deck and a secondary anode of electrically conductive bituminous concrete over the entire deck surface. Current is supplied to the deck anodes by a transformer-rectifier.

Research studies were initiated in 1981 to develop a viable method of applying cathodic protection to bridge substructure members. Eight experimental systems were installed in 1982-83, two larger demonstration projects in 1984, and one system in 1985. Several of the systems were found to be effective in stopping the corrosion and work is now underway to improve the long-term durability of the components.

D-553 Bada, N. P. 1986. "Repairs to International Control Dam-Niagara Falls," Concrete in Transportation, SP-93, American Concrete Institute, pp 609-636, Detroit, MI.

Several of the bridge non-air-entrained concrete bearing seats on the International Control Dam have concrete deterioration from the application of deicing salts. A 410-ton beam and deck slab assembly was raised by 12 hydraulic lift climbing jacks assembled to a singled-span Bailey Bridge Structure. The concrete repair consisted of removing the deteriorated concrete, application of an epoxy bonder, wood forming, and placing of good quality concrete. The 410-ton beam and deck slab was lowered onto new elastomeric bearing pads to its original location. The paper details the construction procedures and methods of repair to concrete in spans 2 and 4.

D-554 Tarroni, G., Melandri, C., De Zaiacomo, T., Lombardi, C. C., and Formignani, M. 1986. "Characterization of Aerosols Produced in Cutting Steel Components and Concrete Structures by Means of a Laser Beam," Journal of Aerosol Science, Vol 17, No. 3, pp 587-591, Pergamon Press, Inc., Elmsford, NY.

The technique of cutting based on the use of a laser beam is studied as a possible method in nuclear plant dismantling. The technique implies a relevant problem of contamination due to high aerosol production. The high temperature value locally reached in the cutting zone causes material vaporization with emission of very fine primary particles. In such conditions aerosol coagulation is very fast and leads to aggregates. Direct investigation on the primary particles is impossible at the moment due to the short life-time involved. The research discussed has been aimed at finding the characteristics of the aerosol removable from the cutting zone by ventilation and evaluating the morphology of the particles that diffuse at approximately 50 cm from the generation point, or settle on the cutting-box base.

D-555 Clifton, J. R., ed. 1986. "Cleaning Stone and Masonry," ASTM STP-935, American Society for Testing and Materials, Philadelphia, PA.

Five sections contain papers presented at a past ASTM symposium on cleaning stone and masonry. Text focuses on selecting methods and materials for cleaning, historic structures, case studies, and ways to determine the effects of cleaning.

D-556 Gunnyon, G. K., and Morgan, D. R. 1986. "Evaluation and Epoxy-Injection Repair of the Pier B-C Structure at Canada Place, Vancouver, B.C., Canada," Concrete in Transportation, SP-93, American Concrete Institute, pp 507-524, Detroit, MI.

The Pier B-C structure in the inner harbor area of Vancouver was selected as the site for construction of the Canada Place trade and convention center. The project includes a five-berth cruise ship facility and a major 514-room hotel. The original Pier B-C was constructed by Canadian Pacific Railway between 1923 and 1927 and consisted of a central berm projecting 330 m (1,080 ft) from the shore, surrounded by a reinforced concrete deck supported by approximately 6,000 precast reinforced concrete piles driven into the berm. A detailed assessment of the structure showed that it was suitable, after rehabilitation of deteriorated areas, for use as the substructure for the Canada Place project.

As construction progressed, substantial additional damage was done to the pier because of movements caused by installation of additional precast concrete piles and steel caissons to support the new structures. This paper describes the original assessment of the pier structure, evaluation of construction damage, and preparation of repair specifications. While extensive repair by shotcreting procedures was required, this paper concentrates on the epoxy-injection repair aspects of the remedial work. Epoxy injection was used to achieve structural repair of reinforced concrete beams, piles, pilecaps, seawalls, and deck slabs.

D-557 Gauri, K. L., Holdren, G. C., and Vaughan, W. C. 1986. "Cleaning Efflorescences from Masonry," Cleaning Stone and Masonry, ASTM STP 935, American Society for Testing and Materials, pp 3-13, Philadelphia, PA.

Salt efflorescences attack masonry in all parts of the world, but in the arid regions they are the major cause of masonry decay. The efflorescences crystallize repeatedly from saturated solutions and become hydrated, generating, in the confined pore space and under surface crusts, pressures large enough to overcome the strength of the masonry material.

Common methods for removing these salts are washing with water and application of surface-active poultices. These methods have their shortcomings: the first tends to transport salts into deeper regions by capillary action while removing some salts from the surface; the second method, besides being highly cumbersome, may result in masonry damage due to the salt crystallizing at the poultice-masonry interface.

This paper describes two suction techniques, one of which appears to eliminate these shortcomings while promising maximum removal of salt from large surfaces in the shortest possible time.

D-558 Boyer, D. W. 1986. "Masonry Cleaning - The State of the Art," Cleaning Stone and Masonry, ASTM STP 935, American Society for Testing and Materials, pp 25-51, Philadelphia, PA.

Development of safe and effective cleaning techniques for older masonry structures has been an objective of numerous contracting and manufacturing firms for many years. A wide variety of effective cleaning techniques have resulted from this development. Unfortunately, many applicators are unaware that cleaning agents and techniques that prove effective for application to some masonries may prove ineffective or too harsh for application to adjacent or dissimilar masonries.

Improper application of "proven" cleaning systems to stained masonry surfaces, without adequate pretesting and thorough evaluation of the masonry and staining conditions, has resulted in severe and often irreparable disfigurement and discoloration of scores of masonry buildings and monuments.

The intention of this paper is to review the variety of cleaning materials and techniques available to masonry cleaning contractors and building conservators. Emphasis is placed on chemical-assist, water washing techniques as they apply to the restorative cleaning of older, exterior masonry surfaces.

Illustrations of field and laboratory testing procedures required for development of cleaning programs to remove surface and subsurface staining - without damage to the masonry and surrounding nonmasonry surfaces - are presented.

D-559 Jones, L. D. 1986. "Criteria for Selection of a Most Appropriate Cleaning Method," Cleaning Stone and Masonry, ASTM STP 935, American Society for Testing and Materials, pp 52-67, Philadelphia, PA.

Historic preservation guidelines are becoming an increasingly larger factor in the commercial construction industry, thanks to the Economic Recovery Tax Act of 1981 and an emerging social attitude that older buildings have intrinsic value. In other words, historic preservation is going "mainstream," and is no longer restricted to museums and other nonprofit applications.

The Secretary of the Interior's Standards for Historic Preservation state that "surface cleaning of structures shall be undertaken with the gentlest means possible. Sandblasting and other cleaning methods that will damage the historic building materials shall not be undertaken," The guidelines for application of the standards make reference to the more detailed preservation briefs for additional guidance.

Preservation Brief No. 1, "The Cleaning and Waterproof Coating of Masonry Buildings," discusses various cleanir~ methods, but without definitive conclusion. While the brief pr. des the reader with valuable information, there is still a need for ıurther information in determining what constitutes "the gentlest means possible."

It is the purpose of this paper to equip the reader with adequate information and a procedure for selecting the most appropriate cleaning method for a given project in terms of adherence to historic preservation standards. This will include an amplification on the role and merits of "water-safe" cleaning technology.

The principles described are exemplified in terms of specific projects undertaken by Clean-America, Inc., and are illustrated by means of photographs and data relating to specific details.

D-560 Rudder, T. H. 1986. "Chemical Cleaning of Historic Structures - A Practical Approach," Cleaning Stone and Masonry, ASTM STP 935, American Society for Testing and Materials, pp 71-82, Philadelphia, PA.

The aesthetic appeal of a building's facade is the visual vanguard of the entire building. Chemical cleaning of a building's exterior, if approached intelligently, can result in the building's substrate being returned to its original condition.

This paper outlines a step-by-step procedure that should be followed by the five key parties who share the responsibility for the cleaning of an historic structure. The duties and obligations of the building owner, the architect, the local preservation officer, the manufacturer of cleaning products, and the contractor are explored and some of the common pitfalls are explained.

The appendix includes a sample set of exterior building cleaning specifications.

D-561 Roth, J. W. 1986. "Cleaning the Masonry Interiors of Public Buildings," Cleaning Stone and Masonry, ASTM STP 935, American Society for Testing and Materials, pp 83-95, Philadelphia, PA.

Problems in the design, operation, and management of public buildings are discussed in the context of cleaning masonry in monumental and historic structures, particularly those subject to intense impacts by casual visitors. Design details, patterns of usage, cleaning standards, products, and procedures are considered. Information is derived from architects' observations and assessments; from comments of operations staffs; and from construction specifications, custodial handbooks, and Historic Structure Reports. The paper concludes with a summary of illustrative examples and factors that determine the effectiveness of cleaning programs.

D-562 Mack, R. C. 1986. "Cleaning and Waterproofing of Historic Masonry Buildings," Cleaning Stone and Masonry, ASTM STP 935, American Society for Testing and Materials, pp 96-104, Philadelphia, PA.

This paper discusses the cleaning and water-repellent coating of historic masonry buildings from a generalist's point of view. Topics discussed include project planning, the three basic types of cleaning, testing cleaning procedures, and application of water-repellent coatings. A case study of the Minneapolis Grain Exchange Building summarizes the material.

1987

D-563 Hudgins, H. T. 1987 (Jan). "Demolition of Concrete Structures," Concrete Construction, Vol 32, No. 1, pp 24-31, Addison, IL.

Most contractors, even though they are not demolition specialists, will have to demolish portions of structures as part of their repair and remodeling business. Knowing which method or combination of methods to use for demolition of reinforced or prestressed concrete structures is essential for a safe and profitable job. Several methods of demolition are described, including the ball and crane, dismantling, pneumatic and hydraulic breakers, pressure bursting, and explosives. A safety checklist is included.

D-564 Chou, G. K., and Hover, K. C. 1987 (Jan). "Cathodic Protection for Prestressed Structures," Concrete International: Design & Construction, Vol 9, No. 1, pp 26-30, Detroit, MI.

Cathodic protection for reinforced concrete structures has been developed during the past 20 years and demonstrated to be successful on many full-scale projects. In light of this success, cathodic protection is being considered for control of corrosion in prestressing steel. The differences between conventionally reinforced structures and prestressed structures, in terms of the properties and arrangement of the materials, complicates the design of cathodic protection systems for prestressed structures. Significant issues include the lack of electrical continuity in prestressing steel, the danger of hydrogen embrittlement, difficulties in monitoring corrosion activity and system performance, assuring the distribution of a protective current, and the development of appropriate performance criteria. Currently, due to the variety and unique characteristics of prestressing systems, the applicability and design of cathodic protection systems must be evaluated specifically for each structure.

D-565 Knutson, M. J., and Riley, R. 1987 (Jan). "Fast-Track Concrete Paving Opens Door to Industry Future," Concrete Construction, Vol 32, No. 1, pp 4-13, Detroit, MI.

A bonded concrete overlay was placed on a highway in Iowa and the road was opened to traffic within 24 hr. Pavement width was also increased during resurfacing. The key to the success of fast-track concrete was the development of economical concrete mixes that can provide high strengths at 24 hr or less. The contractor on this project used a mix with 640 lb of Type 3 portland cement and 70 lb of Class C fly ash with a water reducer. The application on the Iowa highway is described.

D-566 Cady, P. D., Weyers, R. E., and Manson, J. A. 1987 (Jan). "Field Performance of Deep Polymer Impregnation," Journal of the Transportation Engineering Division, Vol 113, No. 1, pp 1-14, American Society of Civil Engineers, New York, NY.

A test installation of deep polymer impregnation was applied to an 8-yr-old, heavily traveled bridge deck in Bethlehem, PA, in 1975. While no surface spalls existed, the chloride contents at the level of the top reinforcing mat exceeded the corrosion threshold values. The deep polymer impregnation process involved drying the concrete, impregnating it to a depth of 7.6-10.2 cm (3-4 in.) with a catalyzed acrylic monomer, and thermally polymerizing the monomer. Detailed field and laboratory examination after a 9-year service revealed excellent performance from the impregnated concrete. Fracture planes and spalls were absent. Surface wear was reduced by 65 percent. Half-cell corrosion potentials revealed active reinforcement corrosion outside the test area, but not within. Chloride contents were significantly lower in the test area. Preexisting corrosion cells within the test area were arrested.

D-567 Murray, M. A. 1987 (Jan). "Epoxy Injection Welds Cracks Back Together," Concrete Construction, Vol 32, No. 1, pp 45-49, Addison, IL.

Within minutes, epoxy can be injected 9 ft deep into cracks as small as 0.002 in. wide. Within hours, this same epoxy will surpass the compressive and tensile strengths of the surrounding concrete. Epoxy injection is one of the most common ways of repairing narrow cracks. This article explains the procedure.

D-568 Havens, J. H., Hopwood, T., and Courtney, E. E. 1987 (Jan). "Bridge Decks and Overlays," UKTRP-87-1, Federal Highway Administration, Kentucky Division, and Kentucky Transportation Cabinet, Frankfort, KY.

The report presents a historical perspective of bridge deck construction and maintenance efforts directed toward increasing bridge deck durability. Bridge decks crack in specific patterns that primarily depend upon bridge designs. Normal deck cracking is due to load-induced and thermal effects. Each type of cracking has a distinct pattern. One-hundred and nineteen experimental bridge deck overlays were inspected. Included were 9 membrane bridges, 87 latex concrete overlays, and 23 low-slump overlays. The overlays had been placed originally on both new and exiting bridge decks on various routes throughout the state. Most of the overlays were rated in good to excellent condition. None of the overlay methods was discernibly superior to the others.

D-569 Coomber, D. 1987 (Jan-Feb). "Restoration of Quay Wall," <u>Civil Engineering</u>, pp 8-9, 51, London, England.

Restoration of Liverpool's Brocklebank Dock, a quay wall, using jet grouting is described. The contractor's plan to underpin the existing wall with jet-grouted columns and then anchor the structure to the seabed, the most inexpensive of those proposed, was comprised of three steps. Another site investigation was completed, the wall's fabric was repaired, and a toe protection mattress was placed. Jet-grouted columns were also installed beneath the wall's base and united the structure with stressed anchors.

D-570 Wallace, M. 1987 (Feb). "Concrete Rescues a Masonry Church," <u>Concrete Construction</u>, Vol 32, No. 2, pp 203-209, Addison, IL.

St. Anastasia Church in Waukegan, IL, was only 22 years old, but the bricks that made up its beautiful masonry arches were falling out. With the columns of the arches exposed to weather on all four sides, water was penetrating behind the brick, causing it to crack and pop out. The rectangular church has 12 towers that flank each side. Three towers create a front entrance and two large towers rise from the roof. To repair the church, arches for the roof tower were rebuilt out of concrete. For the remaining towers, only the brick facing was removed and replaced with concrete.

D-571 Moore, W. 1987 (Feb). "Fast-Tracking in Iowa," <u>Construction Equipment</u>, Vol 75, No. 2, pp 108-111, Des Plaines, IL.

One rehabilitation technique, the thin-bonded concrete overlay, has gained acceptance with many specifying agencies in recent years. Resurfacing old concrete pavements with several inches of new concrete creates a smooth new roadway, and bonding the overlay to the existing pavement creates a thicker monolithic slab with increased strength. However, the technique usually disrupts traffic for 5 to 10 days while the concrete cures. The Iowa Department of Transportation, in cooperation with the concrete paving industry, fast-tracked a bonded overlay on a 7.5-mile stretch of highway. One lane was prepared for resurfacing, the overlay was installed, 2 ft were added to the lane's width, and joints were cut in the new concrete, with traffic allowed back on the pavement within 24 hr.

D-572 Carr, F. H. 1987 (Feb). "Swing Bridge's Fast Fix Saves Water, Road Jam," Engineering News-Record, Vol 218, No. 8, New York, NY.

Within 2 weeks of finding structural problems in a 200-ft-long center pivot swing bridge, the Corps of Engineers sent down divers to inspect the trouble, drew up construction plans and specifications, solicited bids, and awarded a construction contract to complete repairs. The bridge was repaired within 45 days. The pivot pier consisted of an 18-ft-diam concrete pile cap 6.5 ft thick, extending 2 ft below the waterline, on top of twenty four 18-in. reinforced concrete piles. The 40-ft-long piles are embedded 2.5 ft in the pile cap. Concrete around the points of pile embedment had spalled. The emergency repairs consisted of sequentially driving 1,050 linear ft of H-piles around the existing pier, constructing a sheet pile coffercell, using pressurized grout to fill voids in the existing pier cap, and placing rebar and concrete around the existing pier.

D-573 Lankard, D. R., Clear, K. C., and Schull, T. 1987 (Feb). "Cathodic Protection for Overhead Construction," Concrete Construction, Vol 32, No. 2, pp 193-195, Addision, IL.

The bottom steel in the waffle slab of a 23-year-old underground parking structure was severely corroded in some areas. A trial cathodic protection system was installed on the top of the parking deck in an attempt to prevent any further corrosion. Installation of the system is described.

D-574 "Maintenance Spending Up, Exclusive Survey Indicates." 1987 (Mar). Roads & Bridges, Vol 25, No. 3, pp 28-34, Des Plaines, IL.

A new awareness of the importance of pavement maintenance is sweeping the nation. Pavement engineers now agree that the care, treatment, and preservation of the first several inches of a road's surface can restore years of service and postpone costly reconstruction. A survey to determine the state of pavement maintenance in the United States was conducted; initial results from the project are presented.

D-575 Baty, G. 1987 (Mar). "Surface Voids in Concrete: A Report on What Causes Them and Some Pointers on How to Eliminate Them," Concrete Products, Vol 90, No. 3, pp 14-15, Chicago, IL.

Minimizing the holes or cavities that are cast in the surfaces of concrete can be done without changing concrete design characteristics or costing more money. Using different materials and techniques help solve this problem.

D-576 Schrader, E. K., and Tatro, S. B. 1987 (Mar). "Cavitation and Erosion Damage to Concrete in Dams," Concrete International: Design & Construction, Vol 9, No. 3, pp 15-23, Detroit, MI.

Cavitation and erosion experiences within one geographic area are summarized to illustrate the prevalence of this type of damage. Examples of similar experiences at other projects for various owners world-wide are included for general information. A project is often considered to be without damage simply because thorough inspections to identify damage have not been performed or published. Until recently, the 'state-of-the-art' methods used to design, model, inspect, and construct concrete outlets, stilling basins, and similar structures throughout the world have not been adequate to categorically eliminate the possibility of damage. Newer projects with sufficient time and funding to develop, model, and construct an adequate air-entrainment system have successfully dealt with the cavitation problem.

D-577 Burgi, P. H., and Eckley, M. S. 1987 (Mar). "Repairs at Glen Canyon Dam," Concrete International: Design & Construction, Vol 9, No. 3, pp 24-31, Detroit, MI.

Colorado River runoff at the Glen Canyon Dam in northeast Arizona was 180 percent of normal in the summer of 1983. This extreme condition made it necessary to use both of the 41-ft-diam tunnel spillways at the 710-ft-high dam. Operating these spillways for 2 months produced such extensive damage to the concrete liner and foundation rock that 2,810 yd^3 (2,150 m^3) of concrete and rock were scoured from the tunnels. A number of construction techniques were required to backfill the eroded cavities in the foundation rock, repair and tunnel liners, and construct the large aeration slot needed to each tunnel to prevent cavitation-initiated damage in the future.

D-578 Ray, G. K. 1987 (Mar). Evolving Technology Aids Joint Sealing Practice," Roads & Bridges, Vol 25, No. 3, pp 40-43, Des Plaines, IL.

Joints serve several different functions in concrete pavement. Most significantly, joints are put in pavements to control cracking. They also serve many other functions of load transfer, stress reduction, construction, and providing a reservoir for a sealant. A controversial issue is whether seals are necessary in pavement joints. Some agencies do not seal joints, but most experience with pavements has shown that pavements lacking joint seals or possessing unsatisfactory seals do not provide the good performance and long service life anticipated at the design stage. This article presents an overview of new methods of sealing joints, as well as improvements in preparation, equipment, and materials aid performance.

D-579 Mefford, B. W., and Muller, B. C., Jr. 1987 (Mar). "Cavitation Damage and Repair of Stampede Dam Outlet Works," Concrete International: Design & Construction, Vol 9, No. 3, pp 49-54, Detroit, MI.

Severe cavitation damage occurred to concrete in the outlet works at Stampede Dam during flood control releases in the 1982 runoff season. Air slots installed to reduce cavitation damage potential performed poorly during the 1983 runoff season, so a model study was conducted. From the model study, an air slot was designed that provided sufficient air to the flow boundary interface under the high tailwater conditions encountered.

D-580 Fairweather, V. 1987 (Mar). "Stopping Seepage," Civil Engineering, Vol 57, No. 3, pp 44-46, American Society of Civil Engineers, New York, NY.

The combination of seepage, jointed rock foundation, and erodible core materials could cause the 24-year-old Navajo Dam in New Mexico to fail. This article describes the design of a concrete cutoff wall that will reach down to a record-breaking 398 ft within the dam's left abutment. A combination tunnel and filtered borehole drainage system will be used on the right abutment. The concrete cutoff wall will be 450 ft long, extend from the crest elevation 6,108 ft (above sea level) to el 5,710 ft, and extend into the left abutment at least 50 ft to encompass the area of concentrated relief jointing. Height varies from 60 to 400 ft. The cutoff wall is being built by slurry wall construction methods.

D-581 "Pavement Maintenance: How Effective is CPR?" 1987 (Mar). Better Roads, Vol 57, No. 3, pp 38-41, Park Ridge, IL.

Jointed concrete pavement can be rehabilitated cost effectively, according to a recent research project. Pavement grinding of the projects evaluated is expected to provide good ride quality for many years. Improved, full-depth patch design and procedures have resulted in greatly improved performance. Important features of the improved design are the use of 10 dowel bars per joint, which are 1.5 in. in diameter, the use of a sawed-and-sealed joint, and a minimum patch length of 6 ft. The improved design is expected to give about 10 years of service.

Another important requirement of full-depth patching is the close inspection of dowel bar grouting. Partial-depth patching has performed exceptionally well, but there is a need to locate and patch potential areas of spalling delaminations to reduce pavement maintenance cost after rehabilitation. Underdrains will remove water from the pavement. The research project is described.

D-582 "Reinstatement of Concrete Structures Damaged by Fire." 1987 (Mar). Indian Concrete Journal, Vol 61, No. 3, pp 57-58, Bombay, India.

Techniques used to reinstate fire-damaged concrete structures are somewhat similar to those employed for general repairs. If the assessment of a structure after fire shows minor damage, no structural remedial measures need be taken. In such a case, the approach to reinstatement work could be on the following lines: surfaces blackened by smoke and soot are first sandblasted lightly; minor spalls are then treated by applying a suitable mortar mix, bonding agent, and cement wash; the more deeply spalled areas are repaired by providing fine welded-wire mesh, latex bonding agent, and mortar in thin layers until the specified profile is attained. To replace the spalled concrete, three methods are commonly used, namely, hand-applied mortar, concrete cast in formwork, and gunite. In addition, two modern reinstatement methods are also discussed: the use of resins and polymer-modified mortars.

D-583 Carr, F. H. 1987 (Mar). "Mixed Methods Aid in Redecking," Engineering News-Record, Vol 218, No. 12, pp 72-73, New York, NY.

A Maryland contractor is mixing modern technology with age-old, labor-intensive techniques to redeck half of a 4-mile-long span of the Chesapeake Bay Bridge. The contractor is cutting out the old cast-in-place concrete deck and replacing it with a precast deck. The new deck is expected to last 25 to 30 years without additional major repairs.

D-584 Hopping, P. N., and Mass, G. R. 1987 (Mar). "Cavitation Damage on the Karun Dam," Concrete International: Design & Construction, Vol 9, No. 3, Detroit, MI.

The Karun Dam project includes a chute spillway containing three 60-ft (8-m)-wide bays. At the normal reservoir elevation of 1,740 ft (530 m), the gross head at the flip bucket lip is about 426 ft (130 m). Seasonal flood releases in December 1977 resulted in severe cavitation damage to 7,530 ft^2 (700 m^2) of the concrete surface in the lower chute panels and bucket of all three bays. This paper describes the extent of cavitation damage, subsequent repairs performed during 1978 and 1979, and cavitation damages which have occurred following this repair. Causes of cavitation, rate of cavitation erosion, materials and construction methods used in repair, and techniques used to control surface smoothness are also discussed.

D-585 McDonald, J. E., and Liu, T. C. 1987 (Mar). "Repair of Abrasion-Erosion Damage to Stilling Basins," Concrete International: Design & Construction, Vol 9, No. 3, Detroit, MI.

The exit channel downstream of a stilling basin is a primary source of riprap, boulders, and similar debris which cause abrasion-erosion damage. Successful stilling basin repair depends on correcting the adverse conditions which caused the original damage and using repair materials which are least susceptible to erosion. Hydraulic model or prototype tests should be conducted prior to any major repair, and potential repair materials should be tested and evaluated.

D-586 Renier, E. J. 1987 (Apr). "Concrete Overlays Challenge Asphalt," Civil Engineering, Vol 57, No. 4, pp 54-57, American Society of Civil Engineers, New York, NY.

When a pavement needs more than repair but not total replacement, bonded and unbonded concrete overlays are becoming increasingly popular choices. As this still-evolving technology becomes perfected, no longer will lanes have to be closed for days or weeks. The concrete industry believes its overlays will soon be a viable competitor on even the busiest of highways, where closing lanes for long periods of time causes unacceptable traffic congestion. The author discusses the options of concrete overlay jobs.

D-587 Simpson, J. D. 1987 (Apr). "Pier Protection Cell Installed During Bridge Rehabilitation," World Dredging & Marine Construction, Vol 23, No. 4, pp 20-21, Symcon Publishing Co., Irwine, CA.

The John D. Simpson Construction Company recently completed a bridge rehabilitation project at the 65-year-old Jefferson Street Bridge in Joliet, IL. Bridge piers are vulnerable to downstream barge traffic, and the original concrete had deteriorated badly over time. As a part of the rehabilitation, the marine contracting company installed a pier protection cell to make the bridge safer from a direct barge hit. The author describes the installation of the pier protection cell in detail.

D-588 "Successful CPR Repairs Reflect Good Management." 1987 (Apr). Roads & Bridges, Vol 25, No. 4, pp 38-42, Des Plaines, IL.

Concrete pavement restoration (CPR) is a system of rehabilitation techniques that repairs both the roadway surface and structural defects occurring beneath concrete pavement as the result of heavy traffic, temperature extremes, and the action of water. Some repair techniques fix only the surface, but often underlying structural problems can again create new damage. CPR can offer the potential of longer-lasting repairs because it addresses structural as well as surface problems. In the long run, CPR can be less expensive than other surface improvements. This paper addresses the technique of CPR and discusses a few solutions to common road problems.

D-589 "Effective Corrosion Control." 1987 (May). Better Roads, Vol 57, No. 5, pp 30-31, Park Ridge, IL.

New methods are being used for bridge corrosion control as options to the traditional approaches like cathodic protection and the conductive asphalt system. Corrosion studies are under way at the Federal Highway Administration (FHWA), as well as in western European countries, Turkey, Japan, Australia, and Canada, with results of a major study slated for publication this fall. The article presents discussion of said methods, focusing on innovative solutions.

D-590 Jungwirth, D. 1987 (May). "Conserving and Strengthening Prestressed Concrete Structures," IABSE Proceedings No. P-112/87, pp 81-92, International Association for Bridge and Structural Engineering, Zurich, Switzerland.

Conserving and strengthening civil structures offer a multitude of interesting engineering tasks extending from material technology, nondestructive testing, and designing up to execution. The various steps involved are explained fully by an example of a prestressed concrete bridge. In conclusion, questions of cost effectiveness and decision aids are discussed, and mention is made of quality assurance and control systems. In addition, questions relating to insurance have been considered.

D-591 Saucier, K. L., and Neeley, B. D. 1987 (May). "Antiwashout Admixtures in Underwater Concrete," Concrete International: Design and Construction, Vol 9, No. 5, Detroit, MI.

This article describes a two-phase study undertaken by the US Army Engineer Waterways Experiment Station to evaluate the use of antiwashout admixtures in concrete for underwater repair of stilling basins. The first phase consisted of laboratory evaluation of five antiwashout admixtures using two-point workability apparatus and the washout test. The second phase involved placement of selected mixtures underwater by three different methods.

D-592 "Cathodic System Placed in Iowa Bridge Deck Rehab." 1987 (Jun). Roads & Bridges, Vol 25, No. 6, pp 73-74, Des Plaines, IL.

Cathodic protection was used for the first time to eliminate bridge deck deterioration in Cedar Rapids, IA. After an extensive investigation into existing concrete and cracks, subsurface delaminations, corrosion, and the strength and chloride ion content, deterioration was due to the corrosion of reinforcing steel caused by chloride ions, in addition to the combination of salt concrete steel, moisture, and oxygen. The result of these factors is an electrochemical process leading to the corrosion and rusting of reinforcing bars. The cathodic system used on the deck greatly reduces the need for future repair work and is projected to extend the bridge life another 15 to 20 years.

D-593 Roman, R. J., Darter, M. I., and Snyder, M. B. 1987 (Jun). "Optimum Time to Restore Concrete Pavement," Concrete International: Design & Construction, Vol 9, No. 6, pp 65-71, Detroit, MI.

Pavement restoration is defined as returning a pavement to a sound structural and serviceable condition to extend its service life without costly resurfacing, recycling, or reconstruction. Deciding when to perform restoration and what techniques to use is a real problem. This article provides the practicing highway engineer with guidance in determining the optimum time to apply restoration techniques to jointed concrete pavement.

D-594 Sisinyak, M. J. 1987 (Jun). Concrete and the Infrastructure," Concrete International: Design & Construction, Vol 9, No. 6, Detroit, MI.

This article describes a Corps of Engineers research program - Repair, Evaluation, Maintenance, and Rehabilitation - initiated to identify and develop cost-effective technology to maintain and/or extend the service life of the infrastructure. Studies of several problem areas involving concrete structures and technology transfer efforts are highlighted.

D-595 Liersch, K. 1987 (May). "Repair Work on Outer Walls" (in German), Beton, Vol 37, No. 5, pp 195-197, Dusseldorf, Germany.

One of the most important tasks in building construction is the improvement of building protection of the outer walls. In the majority of cases, nonexistent or inadequate protection against dampness is the cause of repair work being necessary. Without protection against dampness, however, heat insulation cannot be achieved. For this reason, improvement of heat insulation can only be carried out in conjunction with an improvement in protection against rain and condensation. The ventilated curtain wall introduced in the paper fulfills these requirements.

D-596 Mohn, D. E. 1987 (May). "Golden Gate Bridge Improvements," Civil Engineering, Vol 57, No. 5, pp 50-51, American Society of Civil Engineers, New York, NY.

Improvements made to the Golden Gate Bridge during the past 50 years are outlined. The article specifically addresses repairs to the suspender ropes and their connectors, viaduct structures, and roadway slab.

D-597 Webster, R. P., and Kukacka, L. E. 1987 (May). "In Situ Repair of Deteriorated Concrete in Hydraulic Structures: Feasibility Studies," Technical Report REMR-CS-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Presented are the results of a program conducted to identify the repair methods and materials currently being used to repair and rehabilitate concrete structures deteriorating as a result of cracking and spalling. These repair methods and materials were evaluated for their applicability to the in situ repair of concrete hydraulic structures. From this evaluation, the following three repair techniques were identified as best suited for in situ repair procedures: pressure injection, polymer impregnation, and addition of reinforcement. Case histories illustrating the application of each technique are presented. Recommendations are made for work to be performed to make these systems more applicable to the repair of hydraulic structures.

D-598 Ellingson, D. 1987 (May). "Tunnel Linings Slotted to Prevent Damage," Engineering News-Record, Vol 218, No. 20, pp 26-27, New York, NY.

Colorado River floodwaters hurtled down Hoover Dam's 50-ft-diameter spillway tunnels twice, in 1941 and 1983, but both times the 120-mph surge caused severe damage. The Bureau of Reclamation expects an $8-million "aeration slot" job to prevent future trouble. The 18-month job involved blasting out a size 1,884 shirt collar around the inside of each spillway, one through the abutment on the Arizona side of the river and other in the Nevada bank, 30 miles south of Las Vegas. The deceptively simple plan caused headaches for the contractors. The dense concrete of the dam demanded that a special dynamite be developed for delay blasting, to avoid excess vibration.

D-599 Gallegos, H., and Quesada, G. 1987 (Jun). "Corrosion Case: Repair Procedure," Concrete International: Design & Construction, Vol 9, No. 6, pp 54-57, Detroit, MI.

Corrosion of steel bars in reinforced concrete structures is a problem that is demanding increasing attention worldwide. In Peru, steel-in-concrete corrosion has not been unusual in structures in areas near the sea and in offshore structures. What is new is corrosion of structures in climates that are not particularly aggressive. A case in point is a structure about 3 miles from the sea in the capital city of Lima, where climatic conditions are mild: 65 percent average relative humidity and 15 to 20° C (59 to 77° F) extreme yearly temperatures. This article reports on the causes of corrosion and describes the procedures employed to repair the structure and to stop the corrosion process.

D-600 Gore, I. W., and Bickley, J. A. 1987 (Jun). "Big Eddy Dam," Concrete International: Design & Construction, Vol 9, No. 6, pp 32-38, Detroit, MI.

Big Eddy Dam had severely deteriorated since its construction between 1918 and 1922. A variety of repair methods had failed to arrest the deterioration of the concrete and the extensive seepage of water through the dam. Investigation of the dam and its foundations are described, along with the various remedial measures taken to improve the dam's overall stability, reduce seepage, and replace surface concrete in critical locations.

D-601 Ray, G. K. 1987 (Jun). "Repairing Concrete Pavements," Concrete International: Design & Construction, Vol 9, No. 6, pp 24-28, Detroit, MI.

Repairing and maintaining concrete pavements has become even more important than new construction. This article discusses the types of distress that may occur and considerations to be taken in the design of repairs to ensure that concrete durability and structural integrity are maintained for the pavement's full service life.

D-602 Murillo, J. A. 1987 (Jul). "Scourge of Scour," Civil Engineering, Vol 57, No. 7, pp 66-69, American Society of Civil Engineers, New York, NY.

The article proposes two approaches to alleviating the problem of scour-erosion of streambeds and banks caused by running water. The first method involves spanning the waterway, thus eliminating scour concerns in the design of the structure, which must be located so as to keep the waterway clear of constrictions that might impede flood waters. The second approach calls for placing the piers in the river but protecting them from general and local scour.

D-603 Kuennen, T. 1987 (Jul). "Lodge Freeway Recycling: Nine Miles in Eight Months," Roads & Bridges, Vol 25, No. 7, pp 44-45, Des Plaines, IL.

In just one construction season, the Michigan Department of Transportation has removed, recycled, and replaced more than 550,000 yd^2 of 10-in. concrete pavement on one of Detroit's busiest highway stretches.

D-604 Scholer, C. F. 1987 (Jul). "Contractor Innovation Speeds Pavement Overlay Project," Concrete International: Design & Construction, Vol 9, No. 7, pp 62-64, Detroit, MI.

A project to restore safe pavement friction to a series of bridge decks and to several lane miles of high-volume expressway pavements was completed speedily and economically when the contractor used a triple-toothed rotomill to prepare the original surface.

D-605 "Tips on Cutting Concrete." 1987 (Jul). Concrete Construction, Vol 32, No. 7, pp 626-628, Addison, IL.

This article enumerates ways to avoid problems when cutting concrete, including planning for mobilization, good practice, and equipment maintenance.

D-606 ABAM Engineer, Inc. 1987 (Jul). "Design of a Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation," Technical Report REMR-CS-7, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

The general approach to lock wall rehabilitation has been to remove 1 to 3 ft of concrete from the face of the lock wall and replace it with new air-entrained concrete. One of the most persistent problems using this approach is cracking in the replacement concrete. It has been postulated that by using precast concrete as a stay-in-place form for the replacement concrete, cracking problems can be eliminated. This report describes the design of such a forming system.

A range of design alternatives was evaluated through a process of value engineering, and horizontal precast panels constructed of conventional precast quality concrete were selected for detailed quantitative investigation. The panels are tied to the lock monolith along the top and bottom edges using form ties designed to support the loads of the infill concrete placement.

The precast concrete stay-in-place forming system is a viable method for lock wall rehabilitation. In addition to providing a concrete surface of superior durability with minimal cracking, the estimated construction cost is about 15 percent less than conventional forming and concrete placement. Another advantage of the system is the potential reduction in the length of time that a lock must be closed to traffic during rehabilitation. With proper detailing, sequencing, and scheduling of work activities, the rehabilitation work may be accomplished with minimized impact on normal lock traffic.

D-607 "Precast Concrete Beams Survive Bridge Collapse." 1987 (Aug). Roads & Bridges, Vol 25, No. 8, pp 72-73, Des Plaines, IL.

Although the North Dakota Apple Creek Bridge's prestressed concrete deck fell into the creek, the precast concrete structural deck beams were salvaged and were used in two new bridges-saving a great deal of money.

D-608 Kuennen, T. 1987 (Aug). "Schoharie Demolition First Step to New Bridge," Roads & Bridges, Vol 25, No. 8, pp 56-57, Des Plaines, IL.

The April collapse of the bridge crossing the Schoharie Creek has prompted the speedy removal of fallen spans. A self-propelled concrete saw is being used to remove deck concrete before removing the structural steel.

D-609 "Hydrodemolition for Restoration." 1987 (Aug). Concrete International: Design & Construction, Vol 9, No. 8, pp 59-61, Detroit, MI.

Contractor expertise combined with hydrodemolition ensured the timely completion of a large parking structure restoration project in Detroit.

D-610 Blanusha, J. 1987 (Aug). "Dan Ryan Elevated Lanes to Get $183 Million Rehab," Roads & Bridges, Vol 25, No. 8, pp 52-54, Des Plaines, IL.

The Illinois Department of Transportation has planned the rehabilitation of the Dan Ryan Expressway in Chicago-one of the world's busiest stretches, frequently sustaining very heavy traffic. The project requires pier restoration and replacement, new decks, and lane additions.

D-611 Jones, J. P., and Gibson, R. F. 1987 (Aug). "Concrete Arch Bridges Get Total Restoration," Roads & Bridges, Vol 25, No. 8, pp 58, 67-68, Des Plaines, IL.

Two historic Fort Worth, TX, concrete arch bridges received steel retrofits, high-tech patching, and epoxy injections to repair failure yet maintain the unique original designs.

D-612 Buttfield, A. 1987 (Aug). "Cathodic Protection-Arresting Active Corrosion," Civil Engineering, pp 39, 41-42, London, England.

Several methods exist for repairing defective concrete, but clearly, unless the repair provided stops reinforcement corroding, the exercise achieves little. Reinforcement corrosion occurs when the passivation film over the steel surface is destabilized by the presence of chloride ions, which reduce its pH level. Cathodic protection systems set out to reverse this corrosion reaction by reducing the anodic current in the cathodic direction to a very low value - causing an electropotential shift, in other words. In practice, this means that by connecting the steel reinforcement as the cathode to a small DC current and introducing anodes on or within the concrete surface, oxidation of the steel is stopped. The steel cage, being forced to behave as a cathode, no longer corrodes.

D-613 Webster, R. P., and Kukacka, L. E. 1987 (Sep). "In Situ Repair of Deteriorated Concrete in Hydraulic Structures," International Congress on Polymers in Concrete, Brighton, UK.

Presented are the results of a laboratory-scaled test program designed to experimentally evaluate new methods and materials for use in the in situ repair of cracked concrete hydraulic structures utilizing pressure injection and polymer impregnation repair techniques. In general, the test results indicate that pressure injection can be used to effectively restore and integrity of air-dried and water-saturated cracked concrete. Polymer impregnation can be used to improve the quality of the concrete surrounding the crack network. However, its effectiveness in sealing the crack network is dependent upon the viscosity of the impregnant being used. The two methods can be used in conjunction to effectively repair and improve the overall quality of the structure to be rehabilitated.

D-614 Diao, K., Kelly, J., and Suros, O. 1987 (Oct). "Strengthening LaGuardia's Decks," Concrete International: Design & Construction, Vol 9, No. 10, Detroit, MI.

The runways at LaGuardia Airport needed to be strengthened to support new heavier aircraft. A strengthening scheme was developed where grooves were cut in critical areas between existing reinforcing steel and additional steel was installed. To gain insight into the structural response to service loads and overloads, load testing was performed and modifications were made to the computer models used to evaluate the structural behavior of the overhangs.

D-615 Keeney, C. A. 1987 (Nov). "Procedures and Devices for Underwater Cleaning of Civil Works Structures," Technical Report REMR-CS-8, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Civil works structures must be continually evaluated for structural safety, stability, and operational adequacy. Proper inspection and evaluation of them to identify deficiencies will usually require some type of cleaning of the structure. A wide variety of underwater cleaning tools and methodologies have been developed and are currently in use in the offshore oil industry and by the US Navy. These tools range from hand-held scrapers to powered tools and high-pressure waterjets. Several tools have been specifically designed for removal of underwater debris. These tools include jet eductors, dredges, and air lifts.

This report summarizes underwater cleaning procedures and devices that are appropriate for use on civil works structures. The application, advantages, disadvantages, and operation of each type of equipment are discussed, along with recommendations for those tools best suited for specific conditions.

D-616 Lewis, R., and Brockman, L. 1987 (Nov). "Chemical Grout Used to Stop Water Leakage in Control Towers and Conduits," The REMR Bulletin, Vol 4, No. 3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

US Army Engineer District, Louisville, personnel at both the Buckhorn Lake Dam and the Barren River Lake Dam successfully eliminated water leakage in the control towers using a hand-operated pump (Alemite, model 7181) and TACSS-020 NF, a chemical grout manufactured by De Neef America, Inc, of St. Louis, MI. The grout is a hydrophobic polyurethane liquid that reacts with water to form a tough, rigid, closed-cell foam. The general procedure followed in both repair operations included:

- o Drilling a hole or holes into the point of leakage.
- o Installing copper tubing in the holes to serve as injection ports for the grout. (A cutoff valve should be installed on the tubing to stop leakage just before connecting the pump.)
- o Packing the area around the tubing with oakum.
- o Sealing the area around the copper tubing with hydraulic cement (if required).
- o Pumping the TACSS-020 NF into the opening.
- o Allowing sufficient gel time before chiseling the ports off flush with the surface of the concrete.
- o Coating the surface with a quick-setting hydraulic cement to provide protection of the repaired area.

D-617 Wickersham, J. 1987 (Dec). "Concrete Rehabilitation at Lock and Dam No. 20, Mississippi River," The REMR Bulletin, Vol 4, No. 4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Major rehabilitation of the lock wall surface was begun in 1986. The deteriorated concrete was replaced with conventional air-entrained concrete.

Cracking in the replacement concrete on lock walls, a persistent problem, was significantly less in the refaced walls at Lock and Dam No. 20 than at most other rehabilitation projects within the US Army Engineer District, Rock Island. The reduced cracking may be the result of a combination of factors including lower cement content, larger maximum size coarse aggregate, lower placing and curing temperatures, smaller volumes of placement, and close attention to curing.

D-618 Federal Highway Administration. 1987 (Dec). "Field Inspection Guide for Restoration of Jointed Concrete Pavements," Demonstration Projects Program, Washington, DC.

For the last several years, highway engineers have accelerated their search for a cost-effective and structurally adequate method to restore or rehabilitate PCC pavements. Complete pavement replacement or thick overlays can and do provide long-term solutions. However, many existing portland-cement concrete (PCC) pavements are basically sound and do not require this level of rehabilitation. Thin lift asphalt concrete overlays can be placed for a reasonable initial cost. However, they do not correct the problems that led to the distress and are usually short-term solutions. An alternative that has gained widespread attention is concrete pavement restoration (CPR).

CPR includes seven integrated repair techniques: (1) full-depth slab repair, (2) partial-depth slab repair, (3) slab stabilization, (4) diamond grinding, (5) joint and crack resealing, (6) shoulder repair, and (7) drainage improvements.

When used at the proper place at the proper time, and most of all with good inspection, CPR can be a cost-effective process that will extend the life of our Nation's concrete pavements.

D-619 Bugler, J. 1987. "Problems and Solutions Pertaining to Rigid Pavement Joint Resealing," Joint Sealing and Bearing Systems for Concrete Structures, SP-94, pp 975-996, American Concrete Institute, Detroit, MI.

This paper describes field application problems experienced during the execution of a joint resealing program initiated within the limits of Region 10 (Nassau and Suffolk Counties) in the early 1980's. It describes what was done to overcome these problems. Solutions to such problems involved equipment modification and improved inspection techniques. These modifications resulted in the virtual elimination of joint overfilling and a 10-fold performance improvement with regard to first-year intermittent bond adhesion failure. Worker safety and protection are discussed.

D-620 Stratfull, R. F. 1987. "Maintaining Your Structure with Cathodic Protection," Lewis H. Tuthill International Symposium on Concrete and Concrete Construction, SP-104, pp 323-346, American Concrete Institute, Detroit, MI.

The results of approximately 30 years of pioneering efforts in the design, installation, and maintenance of cathodic protection to reinforced concrete bridge structures are reported. Some of the more important elements in testing and reasons for the performance of cathodic protection systems on reinforced concrete bridges are described both from the technical and operating viewpoints. The paper is not one of findings but a presentation and compilation of those variables that affect the design and performance of cathodic protection systems for atmospherically exposed reinforced concrete structures. The performance of cathodic protection on a bridge structure is significantly different than that obtained for underground and underwater structures.

D-621 Hugenberg, T. L. 1987. "Alkali-carbonate Rock Reaction at Center Hill Dam, Tennessee," Concrete Durability-Katharine and Bryant Mather International Conference, SP-100, pp 1883-1902, American Concrete Institute, Detroit, MI.

Expansion of the concrete at Center Hill Dam during its 38-year service life resulted in binding of the spillway gates and closing of the expansion joints in the bridge spans in 1983. An extensive laboratory and field investigation identified an alkali-carbonate rock reaction as the cause of expansion. Shortening of the spillway gates and bridge spans in 1985 remedied the operational deficiencies.

D-622 Lehmann, J. A. 1987. "Cathodic Protection (Corrosion Control) of Reinforced Concrete Structures Using Conductive Coatings," Corrosion, Concrete, and Chlorides-Steel Corrosion in Concrete: Causes and Restraints, SP-102, pp 127-142, American Concrete Institute, Detroit, MI.

Usually concrete is an ideal environment for steel, and reinforcing steel in most concrete structures is not subject to corrosion. However, when salts (chlorides or sulfates) penetrate concrete and reach steel reinforcing bars, corrosion becomes active. Rust takes up a larger volume than the iron from which it is formed, developing pressures as great as 5,000 psi within the concrete. This pressure causes cracking and spalling. Ultimately, failure occurs and major repair or replacement is needed.

Once salts (from deicing, bleaching, marine environment, foreign aggregates, and other phenomena) contaminate concrete, corrosion progresses rapidly. Penetrants, sealants, surface coatings, and membrane barriers are useless in combatting the effects of slats already in concrete.

The use of cathodic protection to control corrosion on reinforcing steel in concrete is relatively new. Although cathodic protection has been employed on pipelines, offshore platforms, ship hulls, buried tanks, and such for more than 40 years, its use on concrete bridge decks was initiated only in the early 1970's. Since the development of conductive coatings (1980-82), the effectiveness of cathodic protection has been enhanced. It has becomes easier to install and is now applicable to many different types of concrete structures (i.e., docks, harbor facilities, marine terminals, bulkheads, parking garages, industrial water, and waste treatment plants, tunnels, coastal buildings, and bridge substructures such as piers, pier caps, and beams). As the acceptance of "conductive-coating cathodic protection" continues to grow, new applications develop. This new form of an established technique holds extraordinary promise for the large-scale preservation of concrete structures.

D-623 Blair, L. A., and Born, R. A. 1987. "Albuquerque Channel Joint," Joint Sealing and Bearing Systems for Concrete Structures, SP-94, pp 419-436, American Concrete Institute, Detroit, MI.

Numerous failures and high repair rates of flood control channel joints resulted in the design of a new channel joint. This joint capitalizes on research done on proper shape factors, state-of-the-art materials, and field applications. Four years of experience indicates the design and materials are highly satisfactory.

D-624 Jungwirth, D. 1987 (Dec). "Corrosion Protection in Prestressed Concrete" (in German), Beton, Vol 37, No. 12, pp 481-485, Dusseldorf, Germany.

Early carbonation, cracks, faulty injection methods, and the influence of salt in wintry conditions can lead to corrosion of reinforcement and retarded cracks under static and dynamic loading if concrete is worked badly. With only a little additional expenditure, such damages can be prevented in prestressed construction, for example, by the use of fatty strand systems or epoxy-coated stretching steels. In the anchor technique, a double corrosion protection can be achieved with PE or PVC sheaths.

D-625 Stachon, A. 1987 (Dec). "Maintenance with Breeze Concrete," Beton, Vol 37, No. 12, pp 477-480, Dusseldorf, Germany.

The bridge crossing the river Lahn near Runkel was built around 1440 and survived 5 centuries without damage, but high sulfur dioxide concentrations in the air, stress caused by dew salts, and increasing traffic had damaging effects on the natural stone masonry. A complete overhaul with structural breeze concrete and a simultaneous increase in the load capacity from bridge class 18 to 30 will preserve the structure for future generations.

D-626 ABAM Engineers, Inc.. 1987 (Dec). "A Demonstration of the Constructibility of A Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation," Technical Report REMR-CS-14, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

One approach to minimizing the cracking problem in lock wall resurfacing is to use precast panels as stay-in-place forms. A precast panel rehabilitation system was designed by ABAM Engineers, Inc., in Phase I of a contract with the Waterways Experiment Station (WES). Phase II was a constructibility demonstration in which eight panels were precast and erected on two one-half scale simulated lock wall monoliths at WES. The purpose of the demonstration was to evaluate the feasibility of the stay-in-place forming system without the risk and investment of undertaking a full-scale lock rehabilitation.

The concrete form panels of varying sizes were precast in Colorado and shipped by truck to the installation site at WES. Typical lock hardware incorporated into the precast panels included horizontal armor, vertical corner armor, and a one-half scale line hook. One panel was essentially prototype size (6 ft by 30 ft) and weighed approximately 15,500 lb.

D-627 McDonald, J. E. 1987 (Dec). "Rehabilitation of Navigation Lock Walls: Case Histories," Technical Report REMR-CS-13, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Approximately one-half of the US Army Corps of Engineers' 269 navigation lock chambers were built prior to 1940. Consequently, the concrete in these structures does not contain intentionally entrained air and is therefore susceptible to deterioration by freezing and thawing. Since more than three-fourths of these older structures are located in the Corps' North Central and Ohio River Divisions, areas of relatively severe climatic exposure, it is not surprising that the concrete in many of these structures exhibits significant freeze-thaw deterioration. Depending upon exposure conditions, depths of concrete deterioration can range from surface scaling to several feet.

The general approach in lock wall rehabilitation has been to remove the deteriorated concrete and replace it with concrete or shotcrete. Explosive blasting has been used successfully at several Corps projects and appears to be the most cost-effective and expedient means for removing large quantities of concrete. Once the deteriorated concrete has been removed, conventional cast-in-place concrete has been used as the replacement material in most lock wall rehabilitation projects. Other replacement systems that have been used or proposed include shotcrete, preplaced-aggregate concrete, and precast concrete stay-in-place forms. In addition, several materials including latex-modified concrete, polymer mortars and grouts, conventional shotcrete, and latex-modified, fiber-reinforced shotcrete have been used as thin overlays on existing lock walls. Applications of the various rehabilitation systems and their performance to date are described in selected case histories.

D-628 Uddin, W., Carmichael, III, R. F., and Hudson, W. R. 1987. "A Microcomputer Program to Evaluate Cost-Effective Alternatives for Computer Pavement Restoration," Transportation Research Record 1109, Transportation Research Board, National Research Council, Washington, DC.

A methodology for evaluating cost-effective alternatives for rehabilitation of pavements that was developed for microcomputer applications is described. The life-cycle cost-1 (LCC1) microcomputer program is designed for comprehensive economic evaluation of competing alternatives provided by users. The LCC1 program is unique for life-cycle cost analyses because of its flexibility and the options it offers users: it creates and saves multiple input files and provides default data, manipulates input data without going through an entire session, offers seven available optimization options for rank ordering the strategies, and considers multiple maintenance and rehabilitation treatments. The user inputs an array of design strategies (for initial construction or rehabilitation design). Several cycles of maintenance and rehabilitation actions can be included in a single strategy. Peripheral cost items like moving guide rails and adjusting drainage structures are also considered. The LCC1 methodology is capable of computing user operating costs and added user costs due to traffic delays during rehabilitation and reconstruction. The present worth or the annualized equivalent annuity method can be used to establish ranking of alternatives. Applications of the LCC1 program to the analysis of various alternative strategies for concrete rehabilitation are presented in this paper.

D-629 McCullough, B. F., and Uddin, W. 1987. "A Systems Approach for Design and Evaluation of Alternatives for Concrete Pavement Rehabilitation," Transportation Research Record 1109, Transportation Research Board, National Research Council, Washington, DC.

To design and evaluate concrete pavement rehabilitation alternatives effectively it is necessary to consider the existing condition of pavements and to establish decision criteria for triggering the necessary pavement maintenance or rehabilitation actions. A methodology based on a systems approach to designing and evaluating cost-effective alternatives for concrete pavement rehabilitation is presented. The Pavement Rehabilitation Design System (PRDS-1) computer program incorporates this methodology. The program uses mechanistic analysis to generate numerous rehabilitation design alternatives and perform economic evaluation. The evaluation technique is sensitive to both the performance and the cost of the competing alternatives. Resurfacing alternatives include bituminous concrete, jointed portland-cement concrete, and continuously reinforced concrete. The PRDS-1 program was used to evaluate typical concrete pavements for overlay thicknesses and associated life-cycle costs. A comparison of resurfacing alternatives with several restoration alternatives indicates that in certain cases restoration alternatives are more economical.

D-630 Johnston, D. 1987. "Construction of a Thin-Bonded Portland Cement Concrete Overlay in South Dakota," Transportation Research Record 1110, Transportation Research Board, National Research Council, Washington, DC.

In the early summer of 1985, a thin-bonded concrete overlay was placed on a badly deteriorated stretch of SD-38A near Sioux Falls, SD. The 1.74-mile-long project consisted of two experimental sections, 3 and 4 in. thick. In addition, a 500-ft test section was included where no bonding grout was used before overlaying, as well as another 500-ft test section where a 6-in.-wide tape was placed over the old transverse joint instead of inserting backer rod into the joint. Four different methods of reinforcement stabilization of severe cracks were tried on the project, ranging from bars inserted in sawed slots in the old pavement to bars placed on chairs. The project exhibited over 5,800 ft of random center-line cracking immediately after construction due to a combination of factors. Very little random cracking has occurred at transverse joints and the degree of reflection cracking exhibited by the project after 1 year of service is minimal. Although the unit cost of $25.14/yd^2$ is somewhat excessive, the excellent performance of the project since construction, as well as the dramatic decrease in pavement deflection and roughness and increase in skid resistance, show this method of rehabilitation to be a viable alternative to asphalt overlays or complete reconstruction.

D-631 Miller, K., Majidzadeh, K., Abdulshafi, A., and Kaloush, K. 1987. "Comparison of Concrete Pavement Rehabilitation Techniques in Ohio Demonstration Program," Transportation Research Record 1110, Transportation Research Board, National Research Council, Washington, DC.

Cooperative study initiated in 1983 by the Federal Highway Administration and the Ohio Department of Transportation is described in this paper. Its purpose was to establish cost and performance data for various rehabilitation strategies in Ohio. The study consisted of 10 projects: 4 concrete overlays, 1 modified concrete pavement restoration, 3 thick asphaltic concrete overlays constructed over cracked and seated portland-cement concrete pavements, 1 thin asphaltic concrete overlay constructed on an undersealed concrete pavement with newly added concrete shoulders, and a 6-in. asphaltic concrete overlay constructed over a badly D-cracked pavement with minimal joint repair. The construction operations have been documented and the performance of each project is being monitored periodically. Monitoring includes condition rating, cracking survey, Dynaflect testing, and roughness measurements. However, only projects with concrete overlay and concrete shoulders are of relevance to this paper and will be discussed.

D-632 Ulberg, J. C. 1987. "Montana's Experience with and Strategies for Concrete Pavement Rehabilitation," Transportation Research Record 1110, Transportation Research Board, National Research Council, Washington, DC.

The first concrete pavement rehabilitation project in Montana presented a unique challenge for all those involved. Outlined in this paper are the background, planning, and design processes involved in the project and the recommendations made. Although concrete pavement rehabilitation may not be the salvation for all concrete pavement, it does provide solutions and repair strategies for some, when appropriate procedures are followed. Even though concrete pavement rehabilitation was not ultimately selected as the treatment of choice for this project, the process of analyzing the project and sustaining the final decision was valuable and will provide a useful basis for future concrete pavement evaluations. Future projects will be selected and designed based on cost-effective analyses and proven performance of the many techniques now being used and those yet to be discovered.

D-633 Voigt, G. F., Darter, M. I., and Carpenter, S. H. 1987. "Field Performance of Bonded Concrete Overlays," Transportation Research Record 1110, Transportation Research Board, National Research Council, Washington, DC.

Bonded concrete overlays provide two improvements to an existing pavement: increased structural capacity and a new riding surface. The importance of these benefits and improved construction technology have encouraged several states to construct bonded concrete overlays over the past several years to evaluate this type of rehabilitation. A fair amount of performance data have accumulated so that an initial evaluation of this rehabilitation technique can be conducted. The University of Illinois is currently conducting a study for the Federal Highway Administration (FHWA) entitled Determination of Rehabilitation Methods for Rigid Pavements. One objective of this study is to improve design and construction procedures for selected rigid pavement rehabilitation techniques. Field performance data has been collected on more than 150 projects in 24 states for the following rehabilitation techniques: (a) full-depth repair, (b) partial-depth repair, (c) diamond grinding, (d) crack and seat and overlay, (e) tied concrete shoulders, (f) joint load transfer, and (g) bonded and unbonded concrete overlays.

D-634 Manning, D. G. 1987. "Rational Approach to Corrosion Protection of the Concrete Components of Highway Bridges," <u>Concrete Durability--Katharine and Bryant Mather International Conference</u>, SP-100, pp 1527-1548, American Concrete Institute, Detroit, MI.

The deterioration of highway structures, primarily as a result of the corrosion of embedded reinforcement, has resulted in changes in materials, design, and construction techniques with the intent of improving durability. This paper traces the development of corrosion protection requirements in Ontario over a 30-year period. The methods of achieving positive protection for superstructure and substructure components are presented, including warrants for the use of epoxy-coated reinforcement, the use of increased concrete cover, the adoption of higher qualities of concrete, and increases in member thickness. The result of implementing these changes has been the evolution of a rational approach to durability of highway bridges, of which corrosion protection is a vital component. Corrosion protection is provided in individual components according to the severity of the service environment and, in the most severe exposure conditions, includes multiple protection systems such that redundancy is provided.

D-635 Allen, R. T. L., and Edwards, S. C. ed. 1987. Repair of Concrete Structures, Blackie, Glasgow, Scotland.

Structural concrete, although durable, often needs repairing. Impact, abrasion, overloading, fire, and aggressive environments all cause damage, and cracks appear due to errors in design or specification and faulty construction. This book enables the engineer to diagnose the cause of a fault, choose the appropriate remedial technique, and ensure that the repair work is completed satisfactorily. Twelve chapters cover damage occurring during construction, investigation and diagnosis, cements and aggregates, polymers for concrete repair, repairs to cracked concrete, spalled concrete, sprayed concrete, large-volume repairs, leak sealing, surface coatings, underwater repairs, and floor repairs.

D-636 Lippert, D. L. 1987. "Performance Evaluation of Jointed Concrete Pavement Rehabilitation without Resurfacing. Transportation Research Record 1109, Transportation Research Board, National Research Council, Washington, DC.

The results of a research project that was conducted to evaluate the effectiveness of concrete pavement restoration (CPR) on jointed portland cement concrete pavement are described. The CPR methods evaluated were pavement grinding, grout undersealing, installing underdrains, retrofitting double-vee load transfer devices, and pavement patching. Five construction sections, located on Interstates in Illinois, were selected for evaluation. The original pavement sections were constructed between 1960 and 1963, then rehabilitated in 1983 and 1984. All pavements were of the same design: a 10-in. slab over a 6-in. granular base and a joint spacing of 100 ft. The evaluation began just before rehabilitation of each section and continued until May 1986. Evaluation was done using crack surveys, destructive testing, and nondestructive testing. Performance factors monitored were faulting, pavement cracking, pavement roughness, skid resistance, deflection, load transfer void development, and drainage. A great deal of emphasis was placed on grout undersealing and doweled patching in laboratory and field experiments. Effectiveness of undersealing was determined by deflection testing using a Dynatest 8002 falling weight deflectometer and a Road Rater 2008. Another field experiment was conducted to investigate the effects of dowel bar size and number of dowels on full-depth patch performance. Several different techniques for dowel bar grouting were tested in the laboratory to establish grouting procedures. The findings of this research resulted in improvements in full-depth patch design, improved construction procedures, and proper use of undersealing.

D-637 McDonald, J. E. 1987. "Repair and Rehabilitation of Civil Works Concrete Structures," Concrete Durability: Katharine and Bryant Mather International Conference, Publication SP 100, American Concrete Institute, Detroit, MI.

Approximately one-third of the locks and dams owned and operated by the US Army Corps of Engineers are more than 40 years old. Many of these structures are well beyond their original design life and with the relatively limited number of new construction starts anticipated, the number of projects in this category will continue to increase. In response to this situation, the Corps initiated the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program to develop effective and affordable technology for maintaining and, where possible, extending the service life of civil works structures. The research program is divided into seven problem areas of which Concrete and Steel Structures is the largest representing approximately 30 percent of the total research effort. Results to date of 13 individual research studies within the problem area that relate to concrete are described herein.

1988

D-638 Schoenberner, R. A. 1988 (Jan). "Down the Hole," Concrete Construction, Vol 33, No. 1, pp 18-19, Addison, IL.

Many construction methods had to be adapted to this hard-to-access project. The reinforced concrete walls of the sumps had been attacked by chemicals used to change the water in the sumps. Simply getting to the walls was a challenge. The 20- by 18- by 30-ft-deep and 12- by 15- by 15-ft-deep sumps could only be entered by a 2.5- by 2.5-ft opening at the top. After entering through this small opening, workers restored the deteriorated concrete surface with dry-mix shotcrete. They had to adapt construction methods and materials to the small access hole, limited air flow, and heavy moisture conditions.

D-639 "Exodermic Deck Used on New York Bridge." 1988 (Jan). Better Roads, Vol 58, No. 1, pp 42-43, Park Ridge, IL.

Rehabilitation project includes the first use of exodermic bridge deck for a complete bridge. This design combines steel grid and reinforced concrete to maximize concrete's compressive strength and steel's tensile strength. Factors behind the decision to use this design and how it will be constructed are included. A sidebar entitled "What is an exodermic deck?" accompanies the article.

D-640 Campbell, R. L., Sr., and Bean, D. L. 1988 (Jan). "Repair of Dam Intake Structures and Conduits: Case Histories," Technical Report REMR-CS-16, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Based on a survey of inspection reports, 29 percent of the maintenance and repair problems at Corps dams were observed in intake structures and conduits. Repairs to these structures did not perform as desired in better than 40 percent of the reported efforts and with better than 21 percent reported as failed. A number of products whose manufacturer's literature indicated that their products were suited for application in a wet environment such as that found in intake structures and conduits failed. In some instances, the repair technique was at fault. In others, the product failed to perform as indicated.

This report documents selected repair efforts to intake structures and conduits and presents them in a case history format that includes a project description and a history of the repair efforts. The project description identifies principal project features and gives a detail description of the deficiency being repaired to include its history and cause (if known). The descriptions of repair efforts are presented chronologically for each project and include a detailed description of the repair products and techniques used and the performance of the repair (if known).

D-641 Webster, R. P., and Kukacka, L. E. 1988 (Jan). "In Situ Repair of Deteriorated Concrete in Hydraulic Structures: Laboratory Study," Technical Report REMR-CS-11, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Presented are the results of a laboratory-scaled test program conducted to evaluate the effectiveness of (a) pressure injection, and (b) polymer impregnation repair techniques for use in <u>in situ</u> repair of cracked concrete hydraulic structures. In general, the test results indicate that pressure injection can be used to effectively restore the integrity of air-dried and water-saturated crack concrete. Polymer impregnation can be used to improve the quality of the concrete surrounding the crack network. However, its effectiveness in sealing the crack network is dependent upon the viscosity of the impregnant being used. The two methods can be used in conjunction to effectively repair and improve the overall quality of the structure to be rehabilitated.

D-642 Bhuyan, S. 1988 (Feb). "Repairing Concrete Parking Structures," <u>Concrete Construction</u>, Vol 33, No. 2, pp 97-106, Addison, IL.

To correct problems and restore structures, owners must develop a program for evaluating conditions, making repairs, and setting up maintenance procedures that extend the life of the facility. Article includes specifics on condition appraisal: describing observed distress, identifying causes of deterioration, determining distress severity and repair costs; repair methods: selecting the repair materials and methods, and repair approaches; repair documents; and maintenance programs.

D-643 "How Do You Prevent Corrosion." 1988 (Feb). <u>Concrete Construction</u>, Vol 33, No. 2, pp 110, 125, 127, 129, 131, and 132, Addison, IL.

This paper summaries the latest information available on the subject. It deals with watertight concrete cover, chloride-free accelerators, cathodic protection sealers, polymer concrete overlays, latex-modified concrete, silica-fume concrete, epoxy-coated rebars, stainless steel and galvanized steel reinforcements, and corrosion inhibiting admixtures.

For watertight concrete covers, concrete has to be impermeable and for that water-cement ratio has to be minimized and concrete has to be compacted and cured properly. Water-reducing admixture or superplasticizers with adequate cement content will make the concrete impermeable. Prestressing or use of fibre reinforcement can also be considered.

D-644 Fontana, J. J., Reams, W., and Elling, D. 1988 (Feb). "Electrically Conductive Polymer Concrete Overlay Installed in Pulaski, Virginia," Technical Symposium on Polymers in Concrete, Orlando, FL.

We report the development of a premixed electrically conductive polymer concrete overlay for use on bridge decks and other concrete members, in conjunction with cathodic protection systems. The development of a conductive overlay culminated in the installation of such an overlay on a full-bridge deck in Pulaski, VA; the active cathodic protection system has operated for 8 months and is being monitored on a monthly basis. The monitoring shall continue for about 18 months.

D-645 Arnold, C. J. 1988 (Mar). "Recycling Concrete Pavements," Concrete Construction, Vol 33, No. 3, pp 320, 322, 324, 326, Addison, IL.

Key reasons for recycling concrete pavements are cost savings and reduced environmental impact. High-quality, new aggregates may be scarce or costly to transport. Hauling away removed pavement material adds to the cost. Also, finding a disposal site for removed material near the paving project is difficult, especially in urban areas. Besides saving money, recycling old pavement on site reduces the environmental effects of waste hauling and disposal. The article describes methods of recycling pavement, removal, crushing, uses of recycled materials, and paving.

D-646 "Wet Shotcreting Machine Gives Nozzleman Total Control." 1988 (Mar). Concrete Construction, Vol 33, No. 3, Addison, IL.

Wet-mix shotcrete is more commonly used for high-production shotcreting applications than for repair jobs. But a Chicago-area contractor has designed and produced a wet method shotcrete machine specifically for repair work. Materials are mixed at the jobsite only as needed. There's no ready mix truck waiting and no waiting for ready mix trucks.

D-647 Martin, B. L. 1988 (Mar). "Improved Cathodic Protection System," Concrete Construction, Vol 33, No. 3, pp 340, 342, Addison, IL.

Even in salt-contaminated concrete, cathodic protection stops corrosion and eliminates the need for periodic patching or deck replacement. Improved materials and methods have reduced costs and simplified installation of cathodic protection systems. The article explains how these systems work and the improvements that have been made. Installation methods and a short overview of a project using cathodic protection are included.

D-648 Barfoot, J. 1988 (Mar). "Jetty Repairs Cope with Time and Tide," Concrete, Vol 22, No. 3, pp 25-26, London, England.

The repair of a concrete jetty on the estuary of the River Severn, where the tides are phenomenally high, presents a challenge. Work comprised patch repairs to the trestles, together with repairs to, and extending the cover of, the in situ concrete plinths at the base of the trestles. Work had to be done to suit changing tides. Because of the varied tides, the amount of and type of work varied each day. This work is described.

D-649 Ruffert, G., and Holler, H. 1988 (Mar). "Conversion in Lieu of Demolition" (in German), Beton, Vol 38, No. 3, pp 91-94, Dusseldorf, Germany.

From 1954 to 1956 the Dommel Building was built as one of the Dusseldorf's first high-rise office buildings. With a height of 46 m and 15 stories, it rose well above all new buildings of that time. The state of the facade and the reinforced concrete support structure, as well as the new technical and functional demands of the present, required extensive restoration work. The new Immermann Tower demonstrates clearly that administration buildings dating back to the '50's can be adapted well to the state of the art of current technical construction standards.

D-650 "Assessment of Crack Injection Repair of Reinforced Concrete." 1988 (Apr). Concrete Plant and Production, Vol 6, No. 4, Amersham, England.

This article summarizes a research report on repair of cracked reinforced concrete-assessment of injection methods. The report describes comparative studies of this type of repair.

D-651 Morschauser, G. B., Schidrich, P. M., and Banks, S. C. 1988 (Apr). "Rehabbing the Underground Railroad," Civil Engineering, Vol 58, No. 4, pp 56-59, American Society of Civil Engineering, New York, NY.

Engineers are coping with 19th century structures and materials while renovating the Metro-North rail tunnel in New York City. Demolition and reconstruction have to be done from inside the tunnel without disrupting vehicular traffic on the street. There were two other considerations: the design of the new roof structure had to be concrete or precast for long life and minimal maintenance, and all construction has to be done during off-peak commuting hours, and/or while taking only one track out of service at a time.

D-652 Bickley, J. A., and Liscio, R. 1988 (Apr). "Repair and Protection Systems for Parking Structures," Concrete International: Design & Construction, Vol 10, No. 4, pp 21-28, Detroit, MI.

Overview of repair and protection systems for parking structures covers concrete removal, surface preparation, bonding agents and bond testing, and repair materials, as well as protection by sealers, waterproofing systems, and overlays. Cathodic protection systems are discussed, as are environmental modifications and life expectancy.

D-653 Andrews, G., and Sharma, A. K. 1988 (Apr). "Repaired Reinforced Concrete Beams," Concrete International: Design & Construction, Vol 10, No. 4, pp 47-51, Detroit, MI.

Rectangular reinforced concrete beams were tested to failure, then repaired using two different methods (conventional and ferrocement). The repaired beams were tested to failure, and the strength and deformation characteristics of the repaired beams compared with the original beams.

D-654 Harte, R., and Kratzig, W. B. 1988 (Apr). "Rebuilding of the Congress Hall in Berlin-Stability of the Inner Shell Roof" (in German), Bauingenieur, Vol 63, No. 4, pp 153-156, Berlin, Germany.

The rebuilt congress hall in Berlin-Tiergarten is composed of two separate shell roofs: the completely new, outer prestressed lightweight concrete shell giving the architectural shape, and the inner roof bedded upon the present walls of the auditorium. The inner roof was concreted directly upon the old roof to carry its weight after hardening.

Because of the relatively weak boundary conditions-due to the damaged supports--and because of the considerably large measured imperfections, a possible loss of stability of the inner shell roof had to be taken into consideration. The results of the author's stability investigation include large deformations, which are reported.

D-655 Pearson, R. I. 1988 (Apr). "Seattle Sewer Rehabilitation," Concrete International: Design & Construction, Vol 10, No. 4, pp 29-32. Detroit, MI.

Cellular foam concrete grout was pumped a record distance in the rehabilitation of a 95-year-old double-brick lined sewer tunnel.

D-656 Bradley, J. F. 1988 (Apr). "Hydrodemolition Speeds Bridge Deck Rehabilitation," Concrete International: Design & Construction, Vol 10, No. 4, Detroit, MI.

Hydrodemolition helped a New Jersey company realize the maximum bonus for its early completion of bridge deck rehabilitation on heavily traveled I-80 in northern New Jersey. The recently completed work is the first half of a 2-year $19,328,000 contract that includes the rehabilitation of 10 bridges. Rehabilitation was necessary because the decks were heavily contaminated with chlorides and large areas were delaminated. Following concrete removal, the decks were brought back to original grade with 5,000-psi concrete. After the concrete had cured for 3 days, a 1.25-in. overlay of latex-modified concrete was placed.

D-657 McDonald, J. E. 1988 (Apr). "A Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation," REMR Video Report CS-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

This 20-min video report summarizes a new method of minimizing cracking in lock wall resurfacing through the use of precast panels as stay-in-place forms. A precast panel rehabilitation system was designed by ABAM Engineers, Inc., in Phase I of a contract with WES. Phase II was a constructibility demonstration in which eight panels were precast in Colorado and erected on two one-half scale simulated lock wall monoliths at WES. The purpose of the demonstration was to evaluate the feasibility of the stay-in-place forming system without the risk and investment of undertaking a full-scale lock rehabilitation.

D-658 Dinardo, C., and Ballingall, J. R. 1988 (May). "Major Concrete Repairs and Restoration of Factory Structures-Uniroyal Ltd., Dumfries, Scotland," Structural Engineer, Vol 66, No. 10, pp 151-160, London, England.

The first ferro-concrete factory erected in Britain was in need of extensive renovation and repair work. The external frame suffered severe deterioration, and spalling of concrete had occurred in varying degrees to most perimeter members. In a number of cases, the spalling resulted in exposure of the main bottom reinforcing bar along the full length of beams. The extent of damage was such that there were areas of potential structural instability.

Two alternative repair schemes were developed, allowing factory production to continue. These were a partial replacement and a grafted structural skin over the member profile. The former involved cutting out all unsound concrete and reinstating corroded reinforcement. In considering flexure and thermal movements, it was essential to use a cementitious repair compound rather than an epoxy-based material.

The total estimated volume of concrete to be reinstated is 175 to 200 m^3, and this is reflected in the value of the works. The scale of this project has made it probably one of the largest current repair projects undertaken in the UK.

D-659 "Zilwaukee Bridge." 1988 (May). Concrete International: Design & Construction, Vol 10, No. 5, pp 68-75, Detroit, MI.

The new eight-lane Zilwaukee Bridge in Michigan replaces an aging four-lane drawbridge that was a hazard to both navigation and freeway traffic. The new posttensioned, segmental, precast concrete box-girder structure [actually two bridges, each measuring 1.5 miles (2.4 km) long and 125 ft (38 m) high] was constructed using the balanced cantilever method.

D-660 Pearson, R. I. 1988 (May). "O'Hare Airport Departure Ramp," Concrete International: Design & Construction, Vol 10, No. 5, Detroit, MI.

When the City of Chicago expanded the departure ramp at O'Hare Airport they specified a latex modified concrete overlay for the deck. Their decision was based on the excellent performance of the 10-year-old latex modified concrete topping on the original deck.

D-661 ACI Committee 325. 1988 (May-Jun). "Texturing Concrete Pavements," ACI Materials Journal, Vol 85, No. 3, pp 202-211, American Concrete Institute, Detroit, MI.

The importance of the need for skid-resistant pavement has been known for many years. Increased traffic volumes and speeds have increased the need for an improved skid-resistant surface. The emphasis has been to improve skid resistance by creating new surface textures that increase the "macrotexture" of the concrete pavement. These textures are created by forming the deeper textures in the plastic concrete during the finishing operations. Skid resistance has also been improved in existing concrete pavements by sawing grooves in the hardened concrete with cutting heads composed of a number of circular diamond saw blades. The traveling public may better understand this as a process of placing a "tread" in the pavement surface, which complements the tread on the car tires, and stops the vehicle without skidding or loss of control of permitting the rapid escape of water.

D-662 McDonald, J. E. 1988 (Jun). "Precast Concrete Stay-In-Place Forming System for Lock-Wall Rehabilitation," Concrete International: Design & Construction, Vol 10, No. 6, pp 31-37, Detroit, MI.

This article describes a precast concrete-stay-in-place forming system for lock-wall rehabilitation. In addition to providing a concrete surface of superior durability with minimal cracking, the estimated construction cost is very competitive with the cost of conventional forming and concrete placement. Also, the system has the potential for eliminating the need for dewatering the lock chamber during wall resurfacing and could allow intermittent operation of the chamber during rehabilitation.

D-663 Mullen, T., Ichniowski, T., and Soast, A. 1988 (Jun). "Maryland Closes Long Bridge to Reinforce Concrete Pier Caps," Engineering News-Record, Vol 220, No. 26, pp 6-8, New York, NY.

Structural deficiencies may be the cause of cracks in the pier caps of an 11-year-old bridge recently closed by the Maryland State Highway Administration (SHA). One million dollars of emergency work has begun on the 1.4-mile-long Governor Thomas Johnson Bridge near Chesapeake Bay. The bridge is built with steel girders on 58 concrete piers spaced from 75 to 451 ft apart. Only the eight central piers are being strengthened. The SHA plans to correct the flaws by installing high-strength steel support systems around the pier caps. The hairline cracks are also thought to be caused by temperature changes.

D-664 Bischoff, J. A., Wong, N. C., Orduz, F., and Johnson, D. H. 1988 (Jun). "An Innovative Approach to the Strengthening and Raising of Gibraltar," Sixteenth International Congress on Large Dams, San Francisco, CA.

Analyses were carried out to assess the stability of Gibraltar Dam under two extreme loading conditions, namely the Probable Maximum Flood and the Maximum Credible Earthquake (MCE). The results of the analyses indicate that the 59.3-m (194.5-ft)-tall concrete arch dam would be overstressed in tension and could suffer cracking during the MCE. Alternative remedial measures were developed to strengthen the dam. These include: (1) addition of a roller-compacted concrete (RCC) gravity buttress section; (2) a reinforced rockfill buttress; and (3) strengthening using steel fiber reinforced shotcrete. RCC proved the most effective and flexible alternative, especially in light of the fact that it could allow for future raising of the dam. This paper describes the alternative evaluation which led to selection of the RCC strengthening and raising alternative.

D-665 Hoy, V. S., and Abele, R. H. 1988 (Jul). "Fragile Face-Lift," Concrete Construction, Vol 33, No. 7, Addison, IL.

Salty sea air made the rebar corrode in decorative precast concrete balcony facings of an 18-story coastal condominium in La Jolla, CA. The facings cracked and spalled. Reconstruction accomplished included:

- o Remove nearly 400 balustrades, which weighed up to 1,900 lb each.
- o Repair the cast-in-place concrete balconies.
- o Install new windows.

D-666 Suprenant, B. A. 1988 (Jul). "Bonding New Concrete To Old," Concrete Construction, Vol 33, No. 7, Addison, IL.

Bonding fresh, plastic concrete to old, hardened concrete increases the strength of the composite material. Fresh patches, concrete adjacent to construction joints, and overlays all benefit from bonding to the hardened concrete substrate. Bond is not, however, guaranteed. It must be ensured through proper surface preparation, material choice and use, and curing. Ignoring one of these components does not mean a one-third decrease in bond; it may result in the total loss of bond.

D-667 Meyers, J. G. 1988 (Jul). "Slabjacking Solutions For Settled Slabs," Concrete Construction, Vol 33, No. 7, Addison, IL.

Concrete slab settlement causes problems: poor drainage, tripping hazards, rough floors, unsightly cracks, equipment malfunctions. But slabjacking, properly done, solves the problems permanently.

It is faster and much less costly to raise a concrete slab than to replace it. In our area most residential slabs are raised in a few hours, at a cost less than $500. Plantings near the area are not affected, with even the sod staying in place. And the restored slab can be walked on or driven on almost immediately after it is raised. Patched drill holes are the only evidences of slabjacking.

D-668 Couch, D. G., and Beck, A. F. 1988 (Jul). "Texas City Places PCC Thin Bonded Overlay," Roads & Bridges, Vol 26, No. 7, pp 36-37, Des Plaines, IL.

In 1987, Richardson, TX, constructed a thin-bonded concrete overlay on a street serving a light industrial park. A bonded overlay is one in which the overlay material attaches itself to the base pavement. Interest in this type of overlay stemmed from citizen complaint about asphalt overlays, which had always been used previously.

The concrete mix used was composed of six sacks of cement per yd^3, contained a maximum of 6 percent entrained air, and had a slump varying from 2.75 to 6 in. The street was milled first and all loose particles were removed. Next, a wood form was attached along the center line of the street at the height of the overlay. A bridge screed was to ride on this form. Concrete was poured on the dry pavement surface and screeded off. Contraction joints were then sawn within 24 hr in the overlay. Recommendations and costs are also mentioned.

D-669 Hurd, M. K. 1988 (Jul). "Structural Rehabilitation of Concrete Lighthouse," Concrete Construction, Vol 33, No. 7, Addison, IL.

One of several working lighthouses in the Delaware Bay, Brandywine Shoal Lighthouse, stands 7 miles west of Cape May, New Jersey. It is the first reinforced concrete structure of its kind located on a submarine site in the continental United States. The historic structure was recently rehabilitated with several types of concrete to ensure its ongoing serviceability in a harsh environment.

D-670 Smit, J. 1988 (Jul-Aug). "Starting From The Shell," Construction Repair, Vol 2, No. 4, Palladian Publications Ltd, London, England.

An 18-century riverside wine warehouse, which was partially damaged by fire, is being reconstructed to add to Docklands ever-increasing wealth of up-market residential property. The reconstruction included extensive excavation to facilitate pile driving and foundation restoration and placement of reinforced concrete.

D-671 Jaffe, J. M. 1988 (Aug). "Recurring Residential Concrete Problems," Concrete Construction. Vol 33, No. 8, Addison, IL.

Concrete call-backs are more frequent in the residential market. This is not surprising, since there is generally no inspector, architect, engineer, or testing lab agent involved. What is surprising is that the same mistakes recur season after season, job after job. Careful planning and good workmanship can eliminate these mistakes and cut the number of call-backs.

D-672 "Repair and Rehabilitation of Bridges-Case Studies I." 1988 (Aug). IABSE Structures No. C-46/88, pp 41-63, International Association for Bridge and Structural Engineering, Zurich, Switzerland.

The repair or rehabilitation of 11 bridges around the world is described in some detail. Included are structures in Canada, Austria, Denmark, Finland, France, Japan, Yugoslavia, and India. Of greatest interest is the description of a 35-year-old bridge in Denmark, which was reinforced by gluing steel strips to the underside of the concrete deck with epoxy. Strain gages were used to verify complete adhesion and shear transfer. Design and construction details were emphasized in the reports on all structures. Simplified plans, construction photographs, and photos of the completed repairs accompany interesting and technically detailed text written by thoroughly knowledgeable authors.

D-673 Pearson, R. I. 1988 (Aug). "Recycling Detroit's Lodge Freeway," Concrete International: Design & Construction, Vol 10, No. 8, Detroit, MI.

Recycling of the old reinforced concrete pavement provided more than enough coarse aggregate for the new concrete placed during reconstruction of 8.7 miles (14 km) Detroit's John C. Lodge Freeway in 1987.

D-674 Norman, C. D., Campbell, R. L., Sr., and Garner, S. 1988 (Aug). "Analysis of Concrete Cracking in Lock Wall Resurfacing," Technical Report REMR-CS-15, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

An aging constitutive model for concrete including creep, shrinkage, and cracking is used in a general-purpose heat transfer and structural analysis finite element code to predict the response of concrete overlays placed on lock wall surfaces. Model predictions corresponded well with test results. The model was used to predict the response of concrete overlays with varying thicknesses and placement conditions. In all of the analyses, shrinkage had a dominant effect on cracking. Ambient temperature, thickness of overlay, and use of a bond breaker also significantly affected cracking. Recommendations include careful curing procedures and the use of mix proportions that minimize shrinkage and emphasize the importance of early-time materials property tests in predicting stresses and cracking.

D-675 Gerwick, Ben C., Inc. 1988 (Sep). "Review of the State of the Art for Underwater Repair Using Abrasion-Resistant Concrete," Technical Report REMR-CS-19, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Concrete hydraulic structures that are subjected to severe abrasion require periodic inspection, evaluation, and repair. Not only are these procedures costly and sometimes disruptive, but repeated repairs also make guaranteeing the integrity of the underlying layers difficult. This review was conducted, on an international level, to identify new techniques and potential areas of research that might lead to more abrasion-resistant materials and more effective repair methods and that would avoid the high cost and disruptions associated with dewatering.

Topics of study in this review include: (a) underwater inspection, (b) concrete mixtures, (c) underwater placement of concrete, (d) underwater compaction of concrete, (e) polymer concretes and coatings, (f) surface preparation, and (g) support vehicles.

D-676 "Try Saw Cutting Cleanout Holes." 1988 (Sep). Magazine of Masonry Construction, Vol 1, No. 6, p 251, Addison, IL.

This article describes a procedure for saw cutting cleanout holes for small reinforced concrete masonry projects. The holes are saw cut in the concrete block before they are laid; then the cut-out plugs are placed back into the holes before the cores are grouted.

D-677 Williamson, C. 1988 (Sep). "Remedial Grout Injection of Buildings," Construction & Building Materials, Vol 2, No. 3, Reigate, England.

Grouting, the introduction into a structure of a material in liquid form which subsequently cures or sets into a durable solid or gel, has been used for the repair of masonry structures for over a century. Early works were carried out using hydraulic limes or pozzolans, but today a wide range of cementitious materials in aqueous suspensions, and resin and chemical solutions, are available.

D-678 Smit, J. 1988 (Sep-Oct). "Working To Combat Corrosion," Construction Repair, Vol 2, No. 5.

The Corrosion and Protection Centre Industrial Services (CAPCIS) are international leaders in the field of corrosion technology. This organization was formed, in part, out of an increasing need for specialist corrosion advice in civil engineering structures, in particular, cathodic protection.

D-679 Blaha, B. 1988 (Sep). "Architectural Precast Job Is Blending of New and Old," Concrete Products, Vol 91, No. 9, Chicago, IL.

San Francisco Federal Savings and Loan Building features a combination of new tile faced and restored terra-cotta faced precast panels. To do this, the decorative terra-cotta was taken off the building piece by piece, identified with brass plugs and subsequently reassembled on new precast panels.

D-680 Popovic, P. L., and Klein, G. J. 1988 (Oct). "Shear Collars Save A Parking Garage Slab," Concrete Construction, Vol 33, No. 10, Addison, IL.

During an inspection of the elevated deck for a 16-year-old parking garage we found extensive cracking above all 14 interior columns. The typical crack pattern included cracks up to 1/16 in. wide above the column perimeter and narrower radial cracks. At some locations the radial cracks originated at perimeter cracks. This cracking pattern indicated a deficiency in shear or flexural capacity that could lead to collapse of a large portion of the deck.

D-681 McDonald, J. E., and Liu, T. C. 1988. "Evaluation and Repair of Concrete Navigation Structures," Concrete in Marine Environment-Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 321-338, American Concrete Institute, Detroit, MI.

The US Army Corps of Engineers currently operates and maintains 269 navigation lock chambers along inland and coastal waterways. Approximately one-half of these structures were built prior to 1940. Consequently, the concrete in these structures does not contain intentionally entrained air and is, therefore, susceptible to deterioration from cycles of freezing and thawing. In response to a need for improved technology in evaluation and repair of such structures, the Corps of Engineers initiated the Repair, Evaluati‹ , Maintenance, and Rehabilitation (REMR) research program. The objective of this comprehensive program is to develop effective and affordable technology for prolonging the service life of existing civil works structures. Individual REMR research studies, which relate to the evaluation and repair of concrete in a marine environment, are described in this paper. Results to date indicate that techniques and equipment are available for underwater evaluation and repair of concrete structures without the necessity of dewatering.

D-682 Gilbride, P., Morgan, D. R., and Bremner, T. W. 1988. "Deterioration and Rehabilitation of Berth Faces in Tidal Zones at the Port of Saint John," Concrete in Marine Environment-Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 199-226, American Concrete Institute, Detroit, MI.

Concrete berth faces (wharves) in Saint John, New Brunswick, are subject to a tidal range of 8.5 meters and over 200 freezing and thawing cycles a year. This location and application is perhaps one of the most severe tests for concrete, and when failure of the in situ concrete occurs, repairs must be made in adverse circumstances.

For repairs to be effective, the underlying cause for the initial deterioration must be understood so that it will not adversely affect the repair procedure. The wharves in Saint John are showing distress as evidenced by concrete spalling predominantly in the saturated area of the tidal zone. This deterioration is attributed to concrete breakdown caused by freezing and thawing actions, as well as expansion from alkali-aggregate reaction and reaction with marine salts.

The method of surface preparation used and the repair method selected are described. The tidal cycles had a profound effect on the site schedule and construction details. Repair costs are also discussed. To evaluate the effectiveness of the repairs and determine the properties of the wet-mix shotcrete, a comprehensive preconstruction testing program was adopted.

D-683 Burkowsky, B., and Englot, J. 1988 (Nov). "Analyzing Good Deck Performance on Port Authority Bridges," Concrete International: Design & Construction, Vol 10, No. 11, pp 25-33, Detroit, MI.

This article examines roadway deck structures on four Port Authority of New York and New Jersey bridges. It describes design, concrete formulation, and placement attributes contributing to better performance. Conclusions are drawn and conjecture offered about potential misleading test results.

D-684 Babaei, K., and Hawkins, N. M. 1988 (Dec). "Evaluation of Bridge Deck Protective Strategies," Concrete International: Design & Construction, Vol 10, No. 12, Detroit, MI.

This article documents existing knowledge on the effectiveness of different common strategies for protecting bridge decks against deterioration caused by deicing salts. The strategies considered are increased cover to the top bar; low-slump, dense concrete overlay; latex-modified concrete overlay; interlayer membrane/asphalt concrete system; and epoxy-coated bars. Performance information was expressed in terms of the deck durability, effectiveness in preventing reinforcing bar corrosion, and concrete cracking. The information was analyzed for factors affecting the likely service life of a protected bridge, for costs to achieve a 50-year deck life, and for the relative effectiveness of a certain strategy.

D-685 Cole, R. G., and Horswill, P. 1988 (Dec). "Alkali-Silica Reaction: Val de la Mare Dam, Jersey, Case History," Proceedings, Institution of Civil Engineers, Part 1, Vol 84, pp 1237-1259, London, England.

Val de la Mare dam is a mass concrete structure constructed from 1957 to 1962. In January 1971, the dam suddenly exhibited movements that could not easily be explained. There followed a period of intensive investigations and research leading to the conclusion that alkali-silica reaction had occurred principally due to the combination of chalcedony vein material in the local coarse aggregates and the high alkali content of the imported cement. Remedial works to the worse-affected monoliths were undertaken, and a program of monitoring and further studies was developed to ensure the future safety of the dam. This program has continued since 1975, during which time the reservoir has operated normally.

This paper describes the early events and the remedial works up to 1975. It then considers the performance of these works and describes the monitoring and studies subsequently undertaken, considers the results, and assesses their effectiveness. Problems associated with long-term monitoring of internal uplift pressures and predicting the remaining serviceable life of the dam are also discussed. The costs of the studies, the monitoring, and the remedial works are summarized.

D-686 Sims, G. P., and Evans, D. E. 1988 (Dec). "Alkali-Silica Reaction: Kamburu Spillway, Kenya, Case History," Proceedings, Institution of Civil Engineers, Part 1, Vol 84, pp 1213-1235, London, England.

The Kamburu hydroelectric scheme forms an important part of Kenya's electricity supply system. The spillway, built in 1974, began to show unusual deformations 8 years after completion. Extensive cracking and deformations large enough to prevent the full operation of the spillway gates were found. Laboratory and site investigations confirmed that the concrete was affected by alkali-silica reaction arising from two sources: a reaction from an opal contaminant of the coarse aggregate and a less expansive reaction with the strained quartz of the gneiss bedrock, used as coarse aggregate. Other potential factors examined included rock wedges in the abutment rock, swelling clay, and collapsible soils in a fault underlying the left abutment. The remedial work described has four principal aims: to restore the spillway gates to full operation; to reduce the rate at which the alkali-silica reaction proceeds by controlling the access of water to the concrete through measures including surface sealing, grouting, drainage, and diversions; to install adjustable rock anchors to strengthen the rock within the abutments; and to install a comprehensive array of instruments. The management of the structure in the future will depend largely on data derived from the instruments. They will, for example, shed light on the relative importance of the factors contributing to the observed behavior and will provide useful information on the progress of the reaction itself.

D-687 Martin, B. L. 1988 (Dec). "Mesh-based Cathodic Deck Protection," Concrete International: Design & Construction, Vol 10, No. 12, Detroit, MI.

Upon completion of a bridge modernization and improvement program in late summer of 1988, the 30-year old Jones Falls Expressway (JFX) in Baltimore, MD, became--to our knowledge--the largest bridge deck in the world to employ cathodic protection (CP). The six-lane expressway carries Interstate 83, and is a vital commuter artery serving the almost 95,000 cars travelling daily between Baltimore's northern suburbs and its downtown city center.

D-688 Nanni, A., and Lista, W. L. 1988 (Dec). "Concrete Cracking in Coastal Areas: Problems and Solutions," Concrete International: Design & Construction, Vol 10, No. 12, Detroit, MI.

This article discusses cracking of reinforced concrete (RC) structures in coastal zones where the aggressive action of salt-laden air is the primary cause of concrete deterioration. Case studies are presented, along with discussion of possible remedies including local demolition/reconstruction and epoxy injection.

D-689 Khanna, J., Gilbride, P., and Whitcomb, R. 1988. "Steel Fiber Reinforced Concrete Jackets for Repairing Concrete Piles," CANMET/ACI International Conference, SP-109, American Concrete Institute, Detroit, MI.

Starting in 1984, steel fibre reinforced concrete (SFRC) jackets have been placed around distressed hollow core octagonal concrete piles at the Rodney Terminal wharf, Saint John, New Brunswick. The placement has been by pumping the SFRC into steel forms around the piles.

The pumping and pipeline equipment, steel fibres, and concrete admixtures have evolved over the years to solve problems, initially with the placement by pumping over a long pipeline and subsequently with the control of air to provide acceptable strength and air void parameters for freeze thaw resistance.

This paper describes the experience with this unique method of repairing piles and concludes that, in spite of requiring constant attention to quality control, this is a simple method of repair.

D-690 Vilnay, O. 1988. "The Analysis of Reinforced Concrete Beams Strengthened by Epoxy Bonded Steel Plates," Longman Group, United Kingdom, Ltd.

An analytical method for the elastic analysis of the interaction between a concrete beam and a steel plate bonded to it by epoxy adhesive is presented. The shear and the peeling distributed forces induced into the epoxy are formulated. It is observed that large shear and peeling distributed forces are induced into the epoxy at a small region at the edges of the steel plate. The cases where large tensile distributed peeling force is induced are discussed.

D-691 ACI Committee 210. 1988. "Erosion of Concrete in Hydraulic Structures," ACI 210R-87, ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI.

This report outlines the causes, control, maintenance, and repair of erosion in hydraulic structures. Such erosion occurs from three major causes: cavitation, abrasion, and chemical attack. Design parameters, materials selection and quality, environmental factors, and other issues affecting the performance of concrete are discussed.

Evidence exists to suggest that given the operating characteristics and conditions to which a hydraulic structure will be subjected, it can be designed to mitigate future erosion of the concrete. All too often, however, operational factors change or are not clearly known and hence erosion of concrete surfaces occurs and repairs must follow. This report briefly treats the subject of concrete erosion and repair and provides numerous references to detailed treatment of the subject.

D-692 ACI Committee 224. 1988. "Control of Cracking in Concrete Structures," ACI 224R-80 (Revised 1984), <u>ACI Manual of Concrete Practice</u>, Part 3, American Concrete Institute, Detroit, MI.

The principal causes of cracking in concrete and recommended crack control procedures are presented. The current state of knowledge in microcracking and fracture mechanics is discussed. The control of cracking due to drying shrinkage and crack control for flexural members, layered systems and mass concrete are covered in detail. Long-term effects on cracking are considered, and crack control procedures used in construction are presented. Information is provided to assist the engineer and the constructor in developing practical and effective crack control programs for concrete structures.

D-693 ACI Committee 224. 1988. "Causes, Evaluation, and Repair of Cracks in Concrete Structures," ACI 224.1R-84, <u>ACI Manual of Concrete Practice</u>, Part 3, American Concrete Institute, Detroit, MI.

The causes of cracks in concrete structures are summarized. The procedures used to evaluate cracking in concrete and the principal techniques for the repair of cracks are presented. Evaluation techniques and criteria are described. The key methods of crack repair are discussed, and guidance is provided for their proper application.

D-694 ACI Committee 303. 1988. "Guide to Cast-in-Place Architectural Concrete Practice," ACI 303R-74, <u>ACI Manual of Concrete Practice</u>, Part 3, American Concrete Institute, Detroit, MI.

This report presents recommendations for the production of cast-in-place architectural concrete. The importance of specified materials, forming, concrete placement, curing, additional treatment, inspection, and their effect on the finished produce is discussed. The report deals primarily with requirements for architectural concrete over and above normal requirements outlined in existing ACI standards.

D-695 ACI Committee 304. 1988. "Guide for Measuring, Mixing, Transporting, and Placing Concrete," ACI 304R-85, <u>ACI Manual of Concrete Practice</u>, Part 2, American Concrete Institute, Detroit, MI.

This guide presents information on the handling, measuring, and batching of all the materials used in making normal weight, lightweight-structural, and heavyweight concrete. It covers both weight and volumetric measuring, mixing in central mix plants and truck mixers, and concrete placing using buckets, buggies, pumps, and conveyors.

Underwater concrete placing and preplaced aggregate concrete are also covered. The guide outlines procedures for obtaining good quality concrete in completed structures.

D-696 ACI Committee 308. 1988. "Standard Practice for Curing Concrete (ACI 308-81)," ACI Manual of Concrete Practice, Part 2, American Concrete Institute, Detroit, MI.

Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties may develop.

Basic principles of curing are stated; commonly accepted methods, procedures, and materials are described. Requirements are given for curing pavements and other slabs on ground; for structures and buildings; and for mass concrete. For each of these categories, methods, materials, time, and temperature of curing are stated. Curing requirements for precast products, shotcrete, preplaced-aggregate concrete, refractory concrete, plaster, and other applications are given.

D-697 ACI Committee 325. 1988. "Design of Concrete Overlays for Pavements," ACI 325.1R-67, ACI Manual of Concrete Practice, Part 2, American Concrete Institute, Detroit, MI.

This report up-dates the 1958 report and presents further information on bonded concrete resurfacing. Consideration is also given to concrete overlays on flexible pavements. Design procedures which will give dependable results in situations evaluated by mature engineering judgment are presented; however, note is made that they are subject to further refinement.

D-698 ACI Committee 332. 1988. "Guide to Residential Cast-in-Place Concrete Construction," ACI 332R-84, ACI Manual of Concrete Practice, Part 3, American Concrete Institute, Detroit, MI.

The quality of residential concrete is highly dependent on the quality of job construction practices. This guide presents good practices for the construction of foundations, footings, walls, and exterior and interior slabs-on-grade. The concrete materials and proportions must be selected with reference not only to design strength but workability and durability.

The principles and practices described here pertain to: site preparation; formwork erection; selection and placement of reinforcement in walls, slabs, and steps; joint design, location, construction, and sealing; use of insulation; wall concreting practices and safe form stripping; slab finishing practices; curing in all types of weather; and repairing of defects.

D-699 ACI Committee 345. 1988. "Standard Practice for Concrete Highway Bridge Deck Construction," (ACI 345-82), ACI Manual of Concrete Practice, Part 2, American Concrete Institute, Detroit, MI.

The durability and maintenance costs of concrete highway bridge decks are highly dependent upon the care exercised during the construction phase, including attendant activities during the preconstruction and postconstruction periods. Recommendations relative to these periods are presented covering the areas of design considerations, inspection, preconstruction planning, falsework and formwork, reinforcement, concrete materials and properties, measuring and mixing, placing and consolidation, finishing, curing, postconstruction care, and the use of overlays.

D-700 ACI Committee 345. 1988. "Routine Maintenance of Concrete Bridges," ACI 345.1R-83, ACI Manual of Concrete Practice, Part 2, American Concrete Institute, Detroit, MI.

Various potential sources of distress and the possible areas affected in the roadway, superstructure, substructure, approaches, slopes, and channel of a bridge are described. Guidance for avoiding or correcting such troubles is also provided in the form of a day-to-day maintenance and preventive maintenance guide. The report is directed to the local maintenance supervisor who has responsibility for routine bridge maintenance.

D-701 ACI Committee 357. 1988. "Guide for the Design and Construction of Fixed Offshore Concrete Structures," ACI 357R-84, ACI Manual of Concrete Practice, Part 4, American Concrete Institute, Detroit, MI.

The report provides a guide for the design and construction of fixed reinforced and/or prestressed concrete structures for service in a marine environment. Only fixed structures which are founded on the seabed and obtain their stability from the vertical forces of gravity are covered.

Contents include: materials and durability; dead, deformation, live environmental, and accidental loads; design and analysis; foundations; construction and installation; and inspection and repair. Two appendixes discuss environmental loads such as wave, wind, and ice loads in detail, and the design of offshore concrete structures for earthquake resistance.

D-702 ACI Committee 357. 1988. "State-of-the-Art Report on Offshore Concrete Structures for the Arctic (Abstract)," ACI 357.1R-85, ACI Manual of Concrete Practice, Part 4, American Concrete Institute, Detroit, MI.

The report brings together the relevant experience currently available in designing and building offshore arctic concrete structures. Design criteria have been highlighted, problem areas discussed, and future research needs identified. The document is aimed principally at the arctic and subarctic areas bordering the United States and Canadian coastlines.

The arctic environment and its influence on structure are identified. Typical environmental and geotechnical conditions, types of ice features and efforts on ice surveillance and ice measurements are discussed.

Existing and proposed forms of arctic structures are described. Design criteria, materials durability in the arctic environment and effects of coatings on reducing ice adhesion and friction are discussed together with special considerations for structural and foundation design.

Construction methods, materials, and special features of recently completed arctic structures have been described. Marine operations associated with the safe transport and installation of arctic concrete structures are addressed. Maintenance, inspection, and repair techniques which may be used in relation to arctic structures are discussed. Finally, research and development needs to further improve the design of arctic concrete structures are identified.

D-703 ACI Committee 362. 1988. "State-of-the-Art Report on Parking Structures," ACI 362R-85, ACI Manual of Concrete Practice, Part 4, American Concrete Institute, Detroit, MI.

Repeatedly, parking structures have strength, serviceability, and durability problems associated with their unique structural requirements and exposure to the elements. Many parking structures that are exposed to a deicer environment show very early signs of corrosion, scaling due to cyclic freeze-thaw damage, and through-slab water penetration. Special considerations are discussed to address the repeating problems resulting from design, construction, maintenance, and user practices. Methods used to evaluate conditions of existing structures are reviewed as well as the strategies employed for their future use. A breadth of maintenance, repair, and protection methods are discussed.

D-704 ACI Committee 503. 1988a. "Standard Specification for Bonding Hardened Concrete, Steel, Wood, Brick, and Other Materials to Hardened Concrete with A Multi-Component Epoxy Adhesive," ACI 503.1-79, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This specification describes the work of bonding hardened concrete, steel, wood, brick, and other materials to hardened concrete with a multi-component epoxy adhesive such as defined for this purpose in ASTM C 881. It includes controls for adhesive labeling, storage, handling, mixing and application, surface evaluation and preparation, as well as inspection and quality control.

Repair materials given primary consideration are conventional portland-cement mortars and concretes, and those using latex, epoxy resins, or methyl methacrylate. Only techniques that have been documented and used extensively are included. Guide recommendations are those considered necessary for severe exposure conditions.

D-715 ACI Committee 548. 1988. "Guide for the Use of Polymers in Concrete," ACI 548.1R-86, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This guide presents information on the use of polymers in concrete to improve some characteristics of the hardened concrete. Recommendations are included for polymer impregnated concrete (PIC), polymer concrete (PC), polymer portland-cement concrete (PPCC), and safety considerations for the use of polymers in concrete. Information is provided on types of materials and their storage, handling, and use, as well as concrete formulations, equipment to be used, construction procedures, and applications. A bibliography of major references covering polymers in concrete and a glossary of terms are appended.

D-716 Al-Rabiah, A. R., Baggot, R., and Rasheeduzzafar. 1988. "Construction and Durability Considerations for King Fahd Causeway--A Case Study," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 705-734, American Concrete Institute, Detroit, MI.

This article describes the construction of the 25-km King Fahd Causeway in the Arabian Gulf. On the basis of a review of the performance of marine structures elsewhere in the world, the paper outlines the salient features of concrete deterioration in seawater and discusses the durability requirements for concrete construction in marine environment. Concrete durability considerations for the causeway are outlined in selection of concrete materials and mixes. The durability monitoring of the causeway is being carried out in two phases. Phase I involves continuous visual inspection of the structure, and Phase II includes long-term investigations on concrete specimens exposed to submerged, tidal, and atmospheric zones of the Arabian Gulf.

resealing. Finally, improvements needed to ensure better joint sealing in the future are indicated.

New developments in field-molded and preformed sealants and their use are described together with means of measuring joint movements. Appendix C provides a list of specifications and their sources.

D-709 ACI Committee 506. 1988a. "Specification for Materials, Proportioning, and Application of Shotcrete," ACI 506.2-77 (Revised 1983), ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.
This narrow-scope specification is a reference standard which the engineer or architect may make applicable to any building project by citing it in the project specifications. It may be supplemented as needed by designating or specifying individual project requirements.

The standard, which is written in the three-part CSI format, covers materials, proportioning, and application of shotcrete. Provisions governing testing and evaluation of materials and procedures and of the resultant shotcrete are included. A specifier's guide is included as a preface to assist the specification writer in properly choosing and specifying the necessary supplementary requirements for the project specification.

D-710 ACI Committee 506. 1988b. "Guide to Certification of Shotcrete Nozzlemen," ACI 506.3R-82, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This is a guide for a means of certifying wet-mix and dry-mix shotcrete nozzlemen for application of several but not all types of shotcrete. Certification procedure includes a learning and training period, a written/oral examination, and a workmanship demonstration.

D-711 ACI Committee 515. 1988. "A Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete," ACI 515.1R-79 (Revised 1985), ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This guide updates and expands the scope of the committee report "Guide for the Protection of Concrete Against Chemical Attack by Means of Coatings and Other Corrosion Resistant Materials," which appeared in the December 1966 ACI Journal. The previous guide has been revised and is found in Chapter 6 of this guide entitled "Protective Barrier Systems." In addition, there are new chapters on "Waterproofing Barrier Systems," "Dampproofing Barrier Systems," and "Decorative Barrier Systems." A separate chapter on conditioning and surface preparation of concrete is included because it is relevant to all the other chapters.

This guide is not to be referenced as a complete unit.

D-712 ACI Committee 543. 1988. "Recommendations for Design, Manufacture, and Installation of Concrete Piles," ACI 543R-74 (Reapproved 1980), ACI Manual of Concrete Practice, Part 4, American Concrete Institute, Detroit, MI.

This report presents recommendations to assist the design engineer, the manufacturer, the field engineer, and the contractor in the design and use of most types of concrete piles for many kinds of construction. An introductory chapter provides a description of the various types of piles, definitions used in this report, and a list of reference material.

The section on design discusses factors that should be considered in the design of piles and pile foundations, and presents data to assist the engineer to evaluate and provide for these factors that affect the load carrying capacities of different types of concrete piles.

A chapter on materials lists the various materials and makes recommendations regarding their effect on the quality and strength of concrete. Reference is made to applicable existing codes and specifications. Minimum requirements and basic manufacturing procedures for precast piles are stated so that design requirements for quality, strength, and durability can be achieved. The concluding chapter sets forth general principles for proper installation of piling so that the structural integrity and ultimate purpose of the pile are achieved. The wide variety of installation methods used, and many new techniques are outlined.

D-713 ACI Committee 544. 1988. "Guide for Specifying, Mixing, Placing, and Finishing Steel Fiber Reinforced Concrete," ACI 544.3R-84, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

This guides describes the current technology in specifying, mixing, placing, and finishing of steel fiber reinforced concrete (SFRC). Much of the current conventional concrete practice applies to SFRC. The emphasis in this guide is to describe the differences between conventional concrete and SFRC and how to deal with them. Guidance is provided in mixing techniques to achieve uniform mixtures, placement techniques to ensure adequate compaction, and finishing techniques to ensure satisfactory surface textures. Sample mix proportions are tabulated. A listing of references is provided covering proportioning, properties, refractory uses, shotcrete technology, and general information on SFRC.

D-714 ACI Committee 546. 1988. "Guide for Repair of Concrete Bridge Superstructures," ACI 546.1R-80, ACI Manual of Concrete Practice, Part 2, American Concrete Institute, Detroit, MI.

Repair techniques for concrete bridge superstructures are described. This includes pier caps, beams, decks, curbs, sidewalks, and rails. Special emphasis is placed on decks. Recommendations for evaluation of damage, selection of repair method, and surface preparation are given.

Repair materials given primary consideration are conventional portland-cement mortars and concretes, and those using latex, epoxy resins, or methyl methacrylate. Only techniques that have been documented and used extensively are included. Guide recommendations are those considered necessary for severe exposure conditions.

D-715 ACI Committee 548. 1988. "Guide for the Use of Polymers in Concrete," ACI 548.1R-86, ACI Manual of Concrete Practice, Part 5, American Concrete Institute, Detroit, MI.

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D-716 Al-Rabiah, A. R., Baggot, R., and Rasheeduzzafar. 1988. "Construction and Durability Considerations for King Fahd Causeway--A Case Study," Concrete in Marine Environment--Proceedings of the Second International Conference, St. Andrews, NB, 1988, SP-109, pp 705-734, American Concrete Institute, Detroit, MI.

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