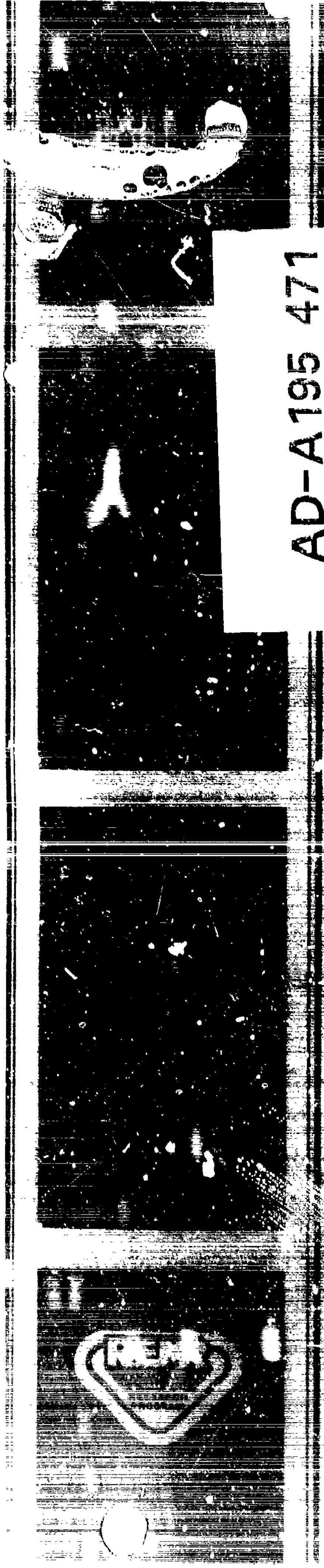

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-CS-14

A DEMONSTRATION OF THE CONSTRUCTIBILITY OF A PRECAST CONCRETE STAY-IN-PLACE FORMING SYSTEM FOR LOCK WALL REHABILITATION

by

ABAM Engineers, Inc.
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December 1987

Final Report

Approved For Public Release, Distribution Unlimited

Prepared for DEPARTMENT OF THE ARMY
US Army Corps of Engineers
Washington, DC 20314-1000

Under Contract No. DACW39-86-C-0014
(Civil Works Research Work Unit 32273)

Monitored by Structures Laboratory
US Army Engineer Waterways Experiment Station
PO Box 631, Vicksburg, Mississippi 39180-0631

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

AD-A195 471

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188
Exp. Date: Jun 30, 1986

1a. REPORT SECURITY CLASSIFICATION: Unclassified

1b. RESTRICTIVE MARKINGS:

2a. SECURITY CLASSIFICATION AUTHORITY:

2b. DECLASSIFICATION / DOWNGRADING SCHEDULE:

3. DISTRIBUTION / AVAILABILITY OF REPORT: Available for public release; distribution unlimited.

4. PERFORMING ORGANIZATION REPORT NUMBER(S):

5. MONITORING ORGANIZATION REPORT NUMBER(S): Technical Report REMR-CS-14

6a. NAME OF PERFORMING ORGANIZATION: ABAM Engineers, Inc.

6b. OFFICE SYMBOL (If applicable):

7a. NAME OF MONITORING ORGANIZATION: Structures Laboratory, US Army Engineer Waterways Experiment Station

6c. ADDRESS (City, State, and ZIP Code): 33301 Ninth Avenue South, Federal Way, WA 98003-6395

7b. ADDRESS (City, State, and ZIP Code): PO Box 631, Vicksburg, MS 39180-0631

8a. NAME OF FUNDING / SPONSORING ORGANIZATION: US Army Corps of Engineers

8b. OFFICE SYMBOL (If applicable):

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER:

8c. ADDRESS (City, State, and ZIP Code): Washington, DC 20314-1000

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
			32273

11. TITLE (Include Security Classification): A Demonstration of the Constructibility of a Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation

12. PERSONAL AUTHOR(S):

13a. TYPE OF REPORT: Final Report

13b. TIME COVERED: FROM ______ TO ______

14. DATE OF REPORT (Year, Month, Day): December 1987

15. PAGE COUNT: 206

16. SUPPLEMENTARY NOTATION: A report of the Concrete and Steel Structures problem area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number): Concrete design; Constructibility demonstration; Lock wall rehabilitation; Precast concrete; Stay-in-place forms

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

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.

20. DISTRIBUTION / AVAILABILITY OF ABSTRACT: ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: Unclassified

22a. NAME OF RESPONSIBLE INDIVIDUAL:

22b. TELEPHONE (Include Area Code):

22c. OFFICE SYMBOL:

DD FORM 1473, 84 MAR — 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

19. ABSTRACT (Continued).

Work associated with installation of the precast panels included surface prepa[illegible]ion on the test monoliths, erection and alignment of the panels, and welding tie connections. The panels were attached to the test monolith with epoxy-grouted, weldable-grade reinforcing steel which was welded to steel plates embedded in the panels.

All aspects of the installation are described herein, and a reassessment of the cost and schedule developed during Phase I is provided. As-built measurements are provided to demonstrate the ability of this repair procedure to meet the required tolerances. Improvements to the precast forming system that will benefit future work are identified, and additional features that require more research and final design have been noted.

Results of this work demonstrate that precast concrete stay-in-place forming system is a viable method for lock wall resurfacing. 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, this repair system can be implimented with intermittent lock openings which would eliminate the lengthy and continuous closures required for conventional repairs.

PREFACE

The study reported herein was authorized by Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32273, "Rehabilitation of Navigation Locks," for which Mr. James E. McDonald is Principal Investigator. This work unit is part of the Concrete and Steel Structures Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program sponsored by HQUSACE. The Overview Committee at HQUSACE for the REMR Research Program consists of Messrs. James E. Crews and Bruce L. McCartney, and Dr. Tony C. Liu. Technical Monitor for this study was Dr. Liu.

The study was performed by ABAM Engineers Inc., under contract to the U.S. Army Engineer Waterways Experiment Station (WES). The contract was monitored by a Technical Review Board consisting of Dr. Liu; Mr. Thurman Gaddie, Ohio River Division; Messrs. Don Logsdon and Denny Lundberg, Rock Island District; Mr. Roy Campbell, Sr., WES; and Mr. McDonald, Chairman. Principal investigators for ABAM Engineers Inc. were Messrs. Charles W. Dolan, Donald D. Magura, Terry A. Nettles, David C. Koski, and Elmer W. Ozolin.

The study was conducted under the general supervision of Mr. Bryant Mather, Chief, Structures Laboratory (SL), and Mr. John W. Scanlon, Chief, Concrete Technology Division (CTD), and under the direct supervision of Mr. James E. McDonald, Research Civil Engineer (CTD), who was the Contracting Officer's Representative. Program Manager for REMR is Mr. William F. McCleese, CTD. This report was edited by Ms. Nancy Curtis, SL.

COL Dwayne G. Lee, CE, was Commander and Director of WES during the publication of this report. Dr. Robert W. Whalin was Technical Director.

CONTENTS

CONTENTS (continued)

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
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
inches	25.4	millimetres
kips (force)	4.44822	kilonewtons
kip-inches	112.9848	newton-metres
kips (force) per square inch	6.894757	megapascals
kips (force) per square foot	47.88026	kilopascals
ounces (avoirdupois)	0.02834952	kilograms
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic yard	432.49842	kilograms per cubic metre
square feet	0.09290304	square metres

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* 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 $K = (5/9)(F - 32) + 273.15$.

A DEMONSTRATION OF THE CONSTRUCTIBILITY OF A PRECAST CONCRETE STAY-IN-PLACE FORMING SYSTEM FOR LOCK WALL REHABILITATION

PART I: PROGRAM SUMMARY

1. The Corps of Engineers currently operates and maintains 133 navigation locks which were built prior to 1940. The concrete in these structures is not air entrained and, consequently, has been susceptible to damage from freezing and thawing. More than 75 percent of these older locks are located in regions of the country that have severe exposure to freezing and thawing. Many of these structures currently exhibit significant degrees of surface deterioration. In fact, some of the high locks constructed after 1940 have surface deterioration even though they were constructed with air-entrained concrete. Past rehabilitation efforts have included removing 1 to 3 ft of deteriorated lock surface and replacing the old concrete with new, conventionally cast-in-place, air-entrained concrete. These repairs have not been entirely successful; they resulted in cracking of the new concrete and required complete lock closures while the repairs were in progress. Other lock repairs have included overlaying the deteriorating surface with shotcrete. These repairs have not been entirely successful either because of areas of delamination between the old concrete and shotcrete.

2. In an effort to develop a repair method that would overcome the problems identified with previous repairs, the Corps of Engineers initiated a research effort which utilizes precast concrete stay-in-place form panels to repair deteriorating mass concrete gravity structures. This effort was conducted in two phases. During Phase I, a wide range of possible precast concrete forming options was evaluated and an optimum system was selected. Cost and schedule assessments were performed on this optimum system, and a detailed design was completed for a demonstration of the system. The Phase I effort, including the criteria used to design the form panels and the materials used in the construction, is described in Technical Report REMR-CS-7 (ABAM Engineers Inc., 1987). Familiarity with the Phase I report would be beneficial in the reader's

understanding of the Phase II constructibility demonstration, which is the subject of this report.

3. The demonstration was completed at the Waterways Experiment Station in Vicksburg, Mississippi, on two half-scale lock wall monoliths supplied by the government. Dimensions of each monolith segment were 15 ft wide by 20 ft high by 6 ft thick. Concrete for the monolith construction was specified with a strength f'_c = 3000 psi; however, test cylinders revealed that the actual strength was in excess of f'_c = 7000 psi. An exposed aggregate finish was applied to the monolith surface. Figure 1 shows the monoliths prior to installation of the precast panels.

4. The specifications and drawings that were used for the demonstration are contained in Appendixes B and C of the Phase I technical report, REMR-CS-7 (ABAM Engineers Inc., 1987). The specifications were developed specifically for the demonstration. For full-scale lock repairs, these specifications should be used in conjunction with the applicable Corps' guide specifications. Appendix A of this report contains a copy of the original specifications but with revisions which incorporate the experience gained during the construction of the demonstration. Additions to the original specifications have been underlined, and deleted sections have been lined out. In addition, a double asterisk has been provided in the right margin to identify these revisions. For reference, the drawings have been included in Appendix B, but have not been modified. It is recommended that the reader familiarize himself with Drawing A86029-1, Sheet 1 of 5, which shows the entire arrangement of the installation.

5. The purpose of the Phase II construction was to demonstrate the feasibility of using this concept to repair deteriorating navigational lock walls without the risk and investment of undertaking a full-scale lock repair. The demonstration contained many of the features which would be included in a full-scale rehabilitation that used precast stay-in-place concrete form panels. As a result, modifications or improvements that would benefit full-scale rehabilitations were identified. The information gained during the construction activities was extrapolated and used to check the validity of cost and schedule data developed during the Phase I effort. The Phase I estimates were based on an assumed 30-ft-wide by 40-ft-high monolith.

6. Work associated with actual construction of the demonstration commenced in October 1986 and was completed by the end of January 1987. All phases of the work were videotaped by Corps personnel. Contributors to the successful completion of the demonstration are the following:

- a. Program Management: Waterways Experiment Station, Structures Laboratory.
- b. Prime Investigator: ABAM Engineers.
- c. General Contractor: Premier Waterproofing.
- d. Subcontractors: Metal Fabricators, Inc. (armor fabrication); Stresscon, Inc. (precast panel fabrication); Colorado Test Center, Warren County Engineers (miscellaneous inspection services).

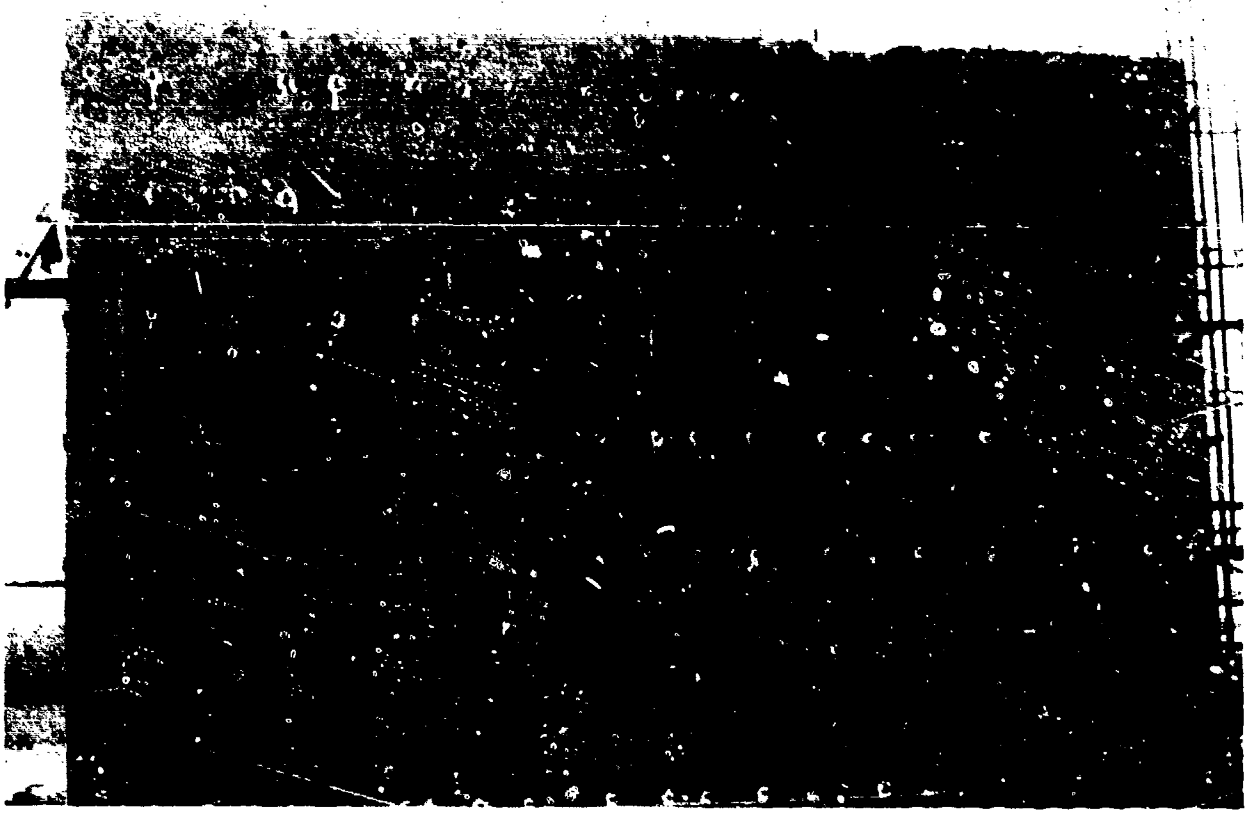

Figure 1. Test section, one-half scale lock wall monolith prior to attaching precast form panels

PART II: CONSTRUCTION GUIDE

7. The repair of deteriorating navigational lock walls with the use of precast stay-in-place concrete form panels has not been undertaken by the Corps to date. Because of this lack of experience, a construction guide that describes most of the activities required to successfully implement and complete a full-scale repair with precast concrete stay-in-place forms has been developed. These activities include the planning, engineering, and actual construction tasks required in the course of the project. Typical uses for this document may be as a guide for performing the design, a checklist for developing the specifications, or as an outline for discussions during prebidding conferences with potential contractors.

8. The construction guide was based on the Phase I concept development work and updated as a result of the experience gained during the demonstration. Input from the demonstration general contractor has been included. The construction guide is contained in Appendix C of this report.

PART III: PRECONSTRUCTION SUBMITTAL REQUIREMENTS

9. The submittals required by the specifications for the demonstration have been summarized in an index of submittals, contained in Appendix D, Part I. The submittals included shop, handling, and erection drawings; work procedures; material certificates; certificates of compliance; catalog information; inspection reports; and as-built measurements. A number of submittals required review by the engineer for compliance with the contract requirements prior to commencing with construction. These were returned to the contractor with status "Reviewed without Comment," "Disapproved," or "Reviewed with Comment." Submittals reviewed with comment or disapproved were returned to the contractor for the incorporation of changes. These were resubmitted until "Reviewed without Comment" status was achieved, at which time construction was allowed to proceed. All other submittals were submitted for documentation purposes; it was the contractor's responsibility to check these for conformance with the required specifications or for accuracy. All construction-related submittals were received before materials were ordered or construction was begun.

10. Appendix D contains sample submittals for the demonstration. These include form tie and dowel pullout test procedures and results, precast panel and cast-in-place concrete mix inspection reports, weld procedure and welder qualification test results, and as-built measurements of the completed installation.

PART IV: STEEL EMBEDMENT HARDWARE

11. Approximately 4800 lb of fabricated steel was incorporated into the installation. The fabricated steel served two purposes: (1) to demonstrate the practical installation of full-size typical lock hardware into the precast panels and (2) to provide a means for erecting panels and support during construction. All fabrications are shown on Drawing A86029-5, and quantities are summarized below.

12. Typical lock hardware included the following:

a. Horizontal lock armor, 60 lin ft (Figure 2).

b. Corner armor, 50 lin ft (Figure 2).

c. One-half-scale mooring hook, 1 piece (Figures 3 and 4).

13. Erection hardware included the following:

a. Vertical alignment screws, 8 pieces (Figure 5).

b. Vertical alignment screw receptacle, 8 pieces (Figure 6).

c. Tie weld plates, 110 pieces (Figure 7).

d. Alignment angles, 7 pieces at 15 lin ft each (Figure 8).

e. Shear key plates, 9 pieces.

14. All steel hardware was fabricated with ASTM A 36 or equivalent steel with the exception of the line hook pin, which was ASTM A 572, Grade 50 or equivalent steel. After fabrication, all steel surfaces were sandblasted, and the exposed surfaces of the lock hardware were coated with a zinc-rich, rust-inhibitive primer.

15. All of the typical lock hardware pieces included curved sections. Because the fabricator's rolls lacked sufficient capacity to bend 3/4-in. plate to the required radius, he elected to cut the curved sections from pipe with the required radius. The corner armor, which required a 4-1/2-in. radius, necessitated the use of a 9-in.-outside-diameter (OD) pipe. (Pipe of this size is not commonly stocked.) The corner armor was a full 90-degree segment of the pipe and had adequate stiffness over its 15-ft length without the need for auxiliary stiffening. A minor amount of bowing and twisting resulted because the sections were flame cut with a gas torch, but the armor was easily straightened and secured to the required alignment after it was placed into the formwork.

16. The horizontal armor was an approximate 40-degree sector cut from an 8-in.-OD pipe. This cut resulted in a shallow, flexible section which necessitated the addition of two 3/8-in. by 1-1/2-in. flat bar

stiffeners to the back side of the armor. The stiffeners were continuously welded to the top and bottom edges of the armor (Detail 1, Drawing A86029-5), as shown in Figure 2. The welding introduced residual stresses, which caused the armor to bow. Because of the stiffness of the pipe and stiffeners, the armor piece had to be heated and placed in a 400-ton hydraulic press for straightening. In the future, the welding distortion can be controlled by staggering the welds in lieu of the continuous welds used for the demonstration.

17. The alignment angles (Detail 6, Drawing A86029-5) were continuous over the full length of the panel, as shown in Figures 8 and 9. The horizontal leg of the angle was cast into the panel while the vertical leg extended from the lower edge of the panel and was used for aligning the upper panel with the lower panel. To accommodate form ties, the vertical (alignment) leg had a series of 6-in.-wide notches, which made the angle very flexible. The fabricator elected to tack weld a continuous bar across the notched angle leg in order to stiffen the angle until it was cast into the panel. The stiffener bar was removed at the erection site.

18. All fabricated elements had either headed weld studs (ASTM A 108) or weldable deformed bar anchors (ASTM A 496) for anchorage into the panel. The anchors were attached to the hardware with automatically timed stud welding equipment. One exception was the alignment angle which had one row of deformed bar anchors manually welded with a flare bevel groove weld.

19. A total of six weeks was required to complete and deliver the hardware to the precaster. This time can be itemized into the following periods:

a. Two weeks -- preparation of shop drawings including review by the engineer.

b. One week -- material procurement.

c. Two weeks -- fabrication.

d. One week -- sandblasting and painting.

20. The actual cost of the fabricated steel was about $2.22 per pound, which includes an allowance for the general contractor's markup for general overhead and profit.

Figure 2. Horizontal armor shown at left, corner armor shown at right

Figure 3. One-half scale mooring hook as would be seen from front face of panel

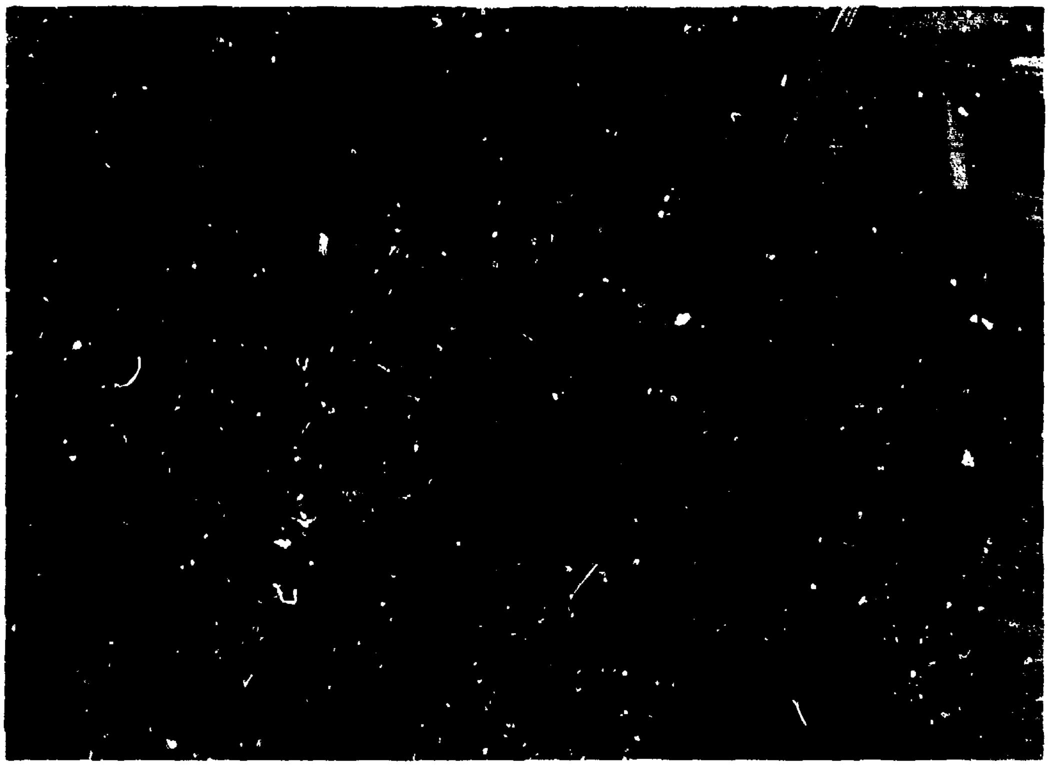

Figure 4. View of back side of mooring hook, which is embedded in infill concrete

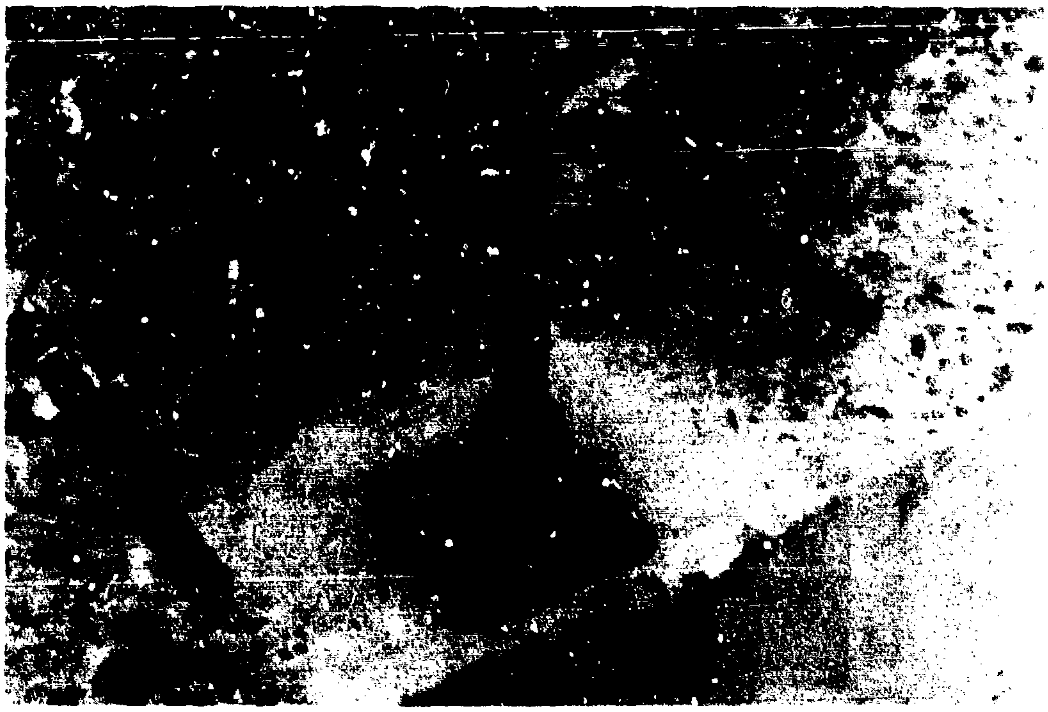

Figure 5. Vertical alignment (leveling) screw

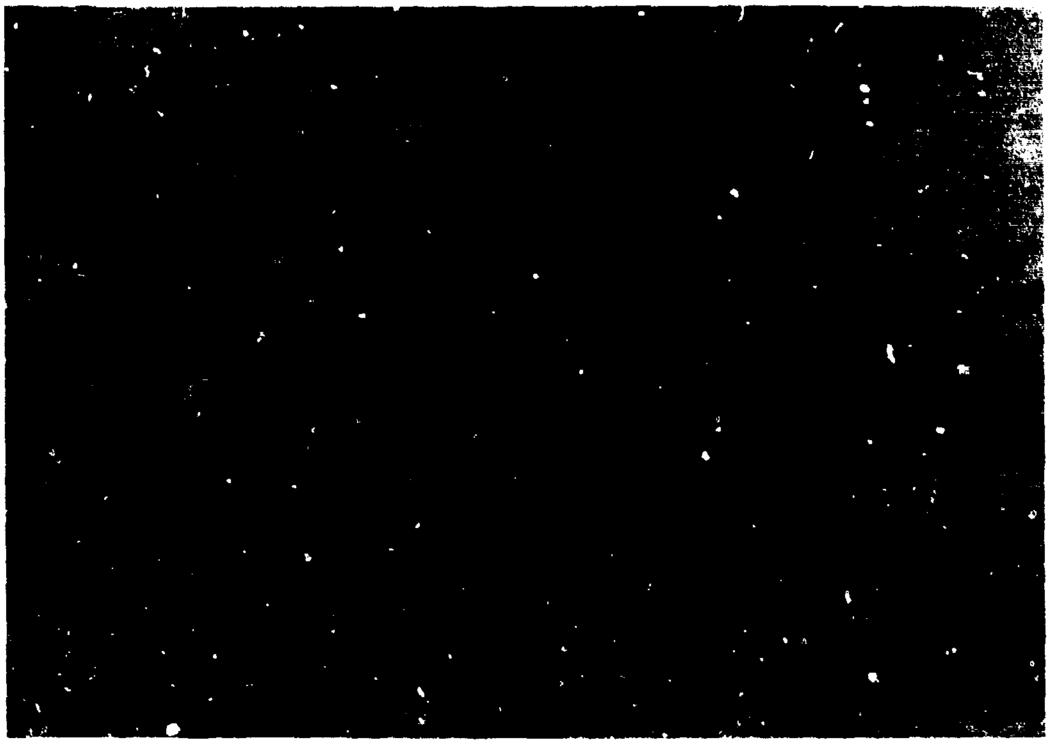

Figure 6. Receptacles for alignment screw (these are cast into lower edge of bottom panel)

Figure 7. Weld plates which are used to attach form ties

Figure 8. Alignment angles showing reinforcement across notches

Figure 9. Alignment angles as cast into bottom edge of panel

PART V: PRECAST PANEL PRODUCTION

Introduction

21. The demonstration included a total of eight different size precast panels, as shown in Elevation 1 on Drawing A86029-1. All panels were constructed at the precaster's facility in Colorado Springs, Colorado, and shipped by truck to Vicksburg, Mississippi. Key data relative to each panel are itemized in Table 1.

Formwork Preparation

22. The panels were cast on an existing steel form bed which was typically used to cast general flatwork products such as columns. The form bed was elevated above ground and enclosed with side panels extending to grade. Hot water pipes were located within the enclosure beneath the form bed for heat curing products cast on top of the bed. A pump and boiler were used to heat and circulate the water in the pipes. A thermostat was located within the enclosure to maintain the temperature at 150 degrees. The resulting product temperature was typically 140 to 145 degrees, which the precaster found optimum for strength gain and economy of boiler use.

23. The only forms that had to be specially built were for the panel edges. The two vertical side edges were flat, and top and bottom edges had matching shear keys. To accommodate the tight tolerance fit between the shear keys and to enable several reuses, the edge or bulkhead forms were fabricated with 12-gage steel plate. The plate was fabricated by bending to the required dimensions of shear key, as shown in Figure 10.

24. The bulkhead forms were accurately positioned to the panel dimensions and tack welded to the form bed. The upper shear key required notches at weld plate/tie locations. These nothces were created by the use of individual blockout forms fabricated from folded, 12-gage sheet metal. The blockout forms were attached to the bulkhead forms with C-clamps. Steel embedments were also attached to the bulkhead forms with C-clamps. The exposed faces of all panels except P-5 and P-8 were cast against the steel form surface. Panels P-5 and P-8 contained horizontal armor which projected approximately 5/8 in. beyond the face

Table 1

Panel Weights and Dimensions

Panel	Size	Weight (lb)	Date Cast	Avg Comp Strength f'_c at 28 days (psi)	Date Erected	Date Infill Placed
P-1	6 ft wide x 30 ft long	15,500	22 Dec 86	9070	19 Jan 87	20 Jan 87 left 27 Jan 87 right*
P-2	3 ft wide x 15 ft long	4,000	16 Dec 86	9180	21 Jan 87	21 Jan 87
P-3	3 ft wide x 15 ft long	4,000	17 Dec 86	9195	21 Jan 87	22 Jan 87
P-4	3 ft wide x 15 ft long	4,000	18 Dec 86	8455	22 Jan 87	23 Jan 87*
P-5	3 ft wide x 15 ft long	5,200	23 Dec 86	9695	23 Jan 87	23 Jan 87*
P-6	3 ft wide x 15 ft long	4,200	15 Dec 86	9175	24 Jan 87	27 Jan 87*
P-7	6 ft wide x 15 ft long	9,500	19 Dec 86	9285	26 Jan 87	27 Jan 87*
P-8	3 ft wide x 15 ft long	5,800	24 Dec 86	8235	26 Jan 87	27 Jan 87*

* Placed in one lift

Curing: All panels were covered with insulating blankets and subjected to radiant heat for approximately 12 hours. Panels P-2 and P-6 had a membrane-curing compound applied to the exterior face after they were lifted from the forms. No other curing measures were employed. See also paragraphs 22 and 31.

of the panel. The precaster placed 5/8-in. plywood against the form surface in the space between the armor strips to produce the required projection.

25. Both mild steel reinforcing bars and welded wire fabric were used to reinforce the panels. Mats consisting of No. 4 or No. 6 reinforcing bars were placed 2 in. from the exterior panel face, whereas 6 x 6 W2.9 x W2.9 wire fabric was placed 3/4 in. from the interior face. Reinforcing bars for the mat were placed piece by piece into the formwork and tied in place. Stainless steel chairs were used to support the mat and wire mesh at the required locations. Prior to placing concrete, the precaster's project engineer performed a quality control inspection to verify the dimensional accuracy of the formwork and to determine that all required embedments and reinforcing were secured and in the required locations. A form ready for concrete placement is shown in Figure 11.

Concreting Activities

26. The concrete mixture used for the panel construction was developed by using trial batches. The three trial batches are itemized in Appendix D, Part II. Mixture Design 3, consisting of an eight-sack mixture containing high early strength (Type III) cement, was selected for this project. Other features of the mixture included a maximum aggregate size of 3/4 in. and use of admixtures for air entrainment, water reduction, and superplasticizing. The constituent materials were computer batched, with the exception of the superplasticizer, which was manually dispensed. Mixing was performed by a central mixer. A special truck (Sidewinder) with a 4-cu-yd hopper and auger dispenser was used to transport and discharge the concrete into the forms.

27. The resulting 28-day concrete strengths for the individual panels are summarized in Table 1. As noted in the table, the panels were cured overnight with radiant heat. Average concrete strength for all panels is 9036 psi. The standard deviation for this concrete based on the limited data is 1650 psi, which is higher than would be expected or desired for a full-scale production process. Concrete testing was performed by an independent testing agency, and its inspection reports are included in Appendix D, Part II. Additional concrete testing was

Figure 10. Lower shear key form

Figure 11. Reinforcement and embedments installed in the form

performed by the precaster. Separate concrete cylinders were cast and cured with the panels and broken to verify panel strengths prior to lifting the panels out of the forms. Overnight strengths ranged between 5500 and 6865 psi.

28. Concrete was discharged directly into the forms from the delivery truck and consolidated with both a pencil vibrator and a full-sized vibrator. Figure 12 shows concrete placement activities. The pencil vibrator was used around the perimeter of the panel, primarily to consolidate the concrete in the vicinity of the shear key and embedments. Its use was initiated when the first panel cast contained air bubbles or "worm holes" along the sloping surface of the key. These defects were caused by the escape of entrapped air, and their presence was reduced for subsequent panels with the more thorough and careful vibration in the immediate vicinity of the shear key.

29. After consolidating the perimeter of the panel with the pencil vibrator, the remainder of the panel was consolidated with the full-sized vibrator. The vibrator was placed into the concrete along a uniform grid spaced about 1-1/2 ft on center. This consolidation procedure produced a very dense exterior panel face with only a few visible surface imperfections such as air bubbles.

30. The concrete was screeded to the required thickness and then floated with magnesium floats. A set retarder/water solution was sprayed on the panel to assist in the floating operation. During the floating operation, the C-clamps which were used to secure the embedments were removed and the resulting depressions were filled. After being floated, the concrete surface was raked to obtain a roughened surface consistent with the requirements of the specifications.

31. The newly cast panels were immediately covered with insulated tarps in preparation for the heat-curing cycle. Curing commenced approximately 4 hours after finishing was completed. Temperatures within the panel were monitored by a thermocouple in order to determine whether adjustments to the curing procedure were required. Initial temperatures of the concrete mixture were 61°F to 65°F. After approximately 8 hours of curing, the panel reached the 140- to 145-degree range. A constant temperature was maintained thereafter until the following morning when the tarps were removed. The ambient overnight

temperatures during the curing cycle were normal for the area during the time of precasting, with lows in the mid to upper 20-degree range.

Finishing, Storage, and Shipping

32. The bulkhead forms were stripped immediately after removal of the curing tarps while the panels were at or near their maximum curing temperature. Where embedded steel is welded to forms, rapid removal of the bulkhead forms is necessary to prevent the buildup of restraining forces as the panels cool and contract. Otherwise, restraint forces could potentially cause cracking. The panels were then lifted off the form bed with a travel lift crane which included a spreader assembly. All panels except P-1 had four lifting loops which were installed for handling panels in the flat or face-down position. The lifting loops were made from prestressing strand, a common practice in the precasting industry. Panel P-1 had eight such lifting loops. Similar strand lifting loops were provided in the upper shear key for handling the panel in a vertical position, as required for erection. Panel P-1 had four loops and the remainder had two.

33. After being lifted off the form bed, the panels were held by the crane while their edges were stoned to remove concrete fins and high spots. No other post-casting finishing measures were required (repair of rock pockets, honeycomb, etc.). The panels were then moved to the storage yard and all but P-1 placed in a horizontal position with the exterior face down. Two large timbers were placed so that the negative moment at the support point equaled the positive moment at the center of the panel. This arrangement minimized deflections and the potential for an adverse permanent set. Because of the length and flexibility of Panel P-1, it was supported in a vertical position. Prior to being stored, Panels P-6 and P-2 had a membrane-curing compound applied to the exterior face as a trial measure.

34. All panels were inspected and measured by the general contractor prior to their being loaded for shipment to Vicksburg. No cracking was observed, as noted on the contractor's inspection report, which is contained in Appendix D, Part III. Tolerances for the precast panels are contained in paragraph 2.2.4 of the specifications. The

predelivery measurements, in conjunction with the as-built measurements, confirmed that all of the required tolerances were achieved.

35. A typical flatbed truck was used to ship all panels because the total weight was below the legal load limit. Panels P-1 and P-7 were placed in a steel yoke frame and shipped in the vertical position. The remaining panels were stacked flat, one atop another, and placed on the base of the yoke assembly to provide additional stability for Panels P-1 and P-7. The panels were also lashed to the truck with slings and come-alongs. Figure 13 provides a view of the shipping arrangement. Upon arrival in Vicksburg, the panels were unloaded and inspected for possible damage during shipment. A careful review failed to disclose any cracking, although some minor localized spalling occurred between Panels P-1 and P-7 and their contact points with the lashing and yoke assembly.

Schedule and Costs

36. The construction activities related to precasting commenced in mid-November 1986 with development of concrete mixtures and preparation of shop drawings. The last panel was cast on 24 December 1986. Precasting started on 15 December 1986, and one panel per day was produced. Typically, a two-person crew performed most of the work. Form stripping commenced at approximately 7:00 a.m., and by 8:30 a.m. the panels were usually stored. Form cleaning and setup for the next pour required approximately 1-1/2 hours, while 3 hours were required to set the embedments and install the reinforcement. The forms were usually ready for the next concrete placement by noon. Concrete placement and finishing required approximately 1-1/2 hours, and another 1/2 hour was required to enclose the panel for curing.

37. The unit price of the eight precast panels, FOB Vicksburg, Mississippi, was approximately $1575/cu yd, which includes an allowance for the general contractor's overhead and profit.

Figure 12. Concrete placement activities (delivery truck chute shown in background)

Figure 13. Panel shipping arrangement

PART VI: DEMONSTRATION CONSTRUCTION

Introduction

38. The work associated with installation of the precast panels included preparation of the test monolith surface, erection and alignment of the panels, welding tie connections, preparation of formwork for cast-in-place (CIP) concrete, and placement and curing of CIP concrete. All of this work was completed at the Waterways Experiment Station in Vicksburg, Mississippi, during January of 1987. Temperatures during the construction period are tabulated in Appendix D, Part VIII. The general contractor used a basic three-man crew throughout the full construction period. The crew included a general superintendent, a carpenter, and a laborer. This crew was supplemented during the actual erection period with a welder and a crane operator.

Monolith Preparation

39. As-built measurements of the test monolith which impact the precast panel installation were obtained at the onset of the work and are shown in Appendix D, Part IV. The key dimensions include the elevation of the support ledge and the overall width of the monolith. The measurements revealed that the height of the support ledge varied by 1/2 in. over its length. The width of the monolith varied from 30 ft 1/8 in. at the base of the monolith to 30 ft 2-1/2 in. at the top. As a result, a tapered offset was visible between the edge of the precast panels and the monolith. A minimal offset was also apparent along the lower panel (P-1) ledge and the support ledge face, which was attributed to the test monolith formwork.

40. The first construction task was to establish a reference grid for tie and dowel holes and to locate the outline for the mooring hook excavation. The reference point selected for locating these points on the monolith was the lower right edge of the wall (west face) and support ledge intersection. The elevation datum selected was this same point, but on top of the support ledge. As-built measurements and reference point locations are contained in Appendix D, Part IV, Figure D1.

41. Holes were initially drilled in the monolith wall with an electric Hilti drill, but this equipment proved too time consuming because of the high strength of the monolith concrete. Approximately 30 minutes was required to drill each 1-1/2-in.-diameter by 15-in.-deep hole for the ties and dowels. As a result, a pneumatic rotary percussion drill was used, thereby reducing the drilling time to approximately 3 minutes per hole. The rough texture of the exposed aggregate surface caused the drill bit to wander, so a small hand chipping gun was used to form a starter pocket. This approach allowed the holes to be drilled to an approximate tolerance of ±1/4 in. The drilling procedure required two men, one to guide and position the drill bit and one to operate the drill, as shown in Figure 14. To aid in handling, the drill was supported by a rope and pulley arrangement extending from the top of the monolith. A total of 120 tie holes and 32 dowel holes was required. All holes were drilled horizontal. Rather than drilling an inclined hole to retain the epoxy, the contractor developed the procedure discussed in paragraph 45.

42. An additional 6 holes were drilled for three test ties and three test dowels. The test ties and dowels were installed and tested prior to installation of the production ties and dowels. A description of the pullout tests and test results is contained in Appendix D, Part V.

43. Approximately 16 cu ft (0.6 cu yd) of concrete was removed for the mooring hook excavation. To assist in the excavation process and to delineate the plane of the excavation, vertical holes were drilled from the top of the monolith. Concrete was removed with a small, hand-held air-chipping gun. Approximately 30 man-hours were required to complete the excavation. This amount of time could have been significantly reduced by the use of a more suitable chipping hammer.

44. After drilling was completed, the form ties and dowels were installed. Form ties were No. 7 weldable grade reinforcing steel conforming to the requirements of ASTM A 706. Dowels were No. 6 mild reinforcing billet steel conforming to the requirements of ASTM A 615. A two-component epoxy grouting material, Concresive 1441, was used to embed the tie or dowel into the monolith. The epoxy was packaged in two premeasured containers which, when mixed together, produced approximately 1 gallon of epoxy. The mixture proportions were two parts A to one part B. When thoroughly mixed, the white Part A and black Part B

produced a uniform gray color. Mixing was accomplished by the use of a paddle attachment on a 3/4-in. hand-held electric drill with a 4- or 5-minute mixing period.

45. The tie and dowel installation procedure included several preparatory steps. First, the ties and dowels were fitted with 14-gage wire tie loops which served as chairs to support the bar in the required position within the hole. To aid in locating ties or dowels, a string line was extended over the full width of the monolith 3/4 in. above the theoretical centerline and at the required tie projection. The final step was to clean the holes with oil-free compressed air. The first step in the actual installation procedure was to inject a small amount of epoxy into the hole and then butter the hole surfaces with a stick. Next the hole was filled with epoxy with a conventional caulking gun as shown in Figure 15. The hole was filled from the back forward to within 3 in. of the face of the wall. The tie or dowel was carefully inserted into the hole; care was taken to make sure that the chairs were facing downward. The bar was inserted within 2 in. of the final position and a plastic retainer disk (Williams form collar) was slipped onto the bar. The collar was held flush against the face of the monolith while the bar was tapped with a hammer to the required projection. Usually, the chairs held the bar above the required centerline and slight tapping with the hammer was sufficient to set the vertical elevation. For the few bars which were low, the disks were removed and shims installed under the bar. Figure 16 shows the tie installation.

46. Approximately 25 to 30 ties were installed on a given day, which required about 2 to 2-1/2 hours. This time included epoxy mixing and cleanup at the conclusion of the work. The corresponding installation rate is 4 to 5 minutes per bar. One gallon of epoxy was sufficient to install 13 to 14 bars.

47. Temperatures during the majority of epoxy work ranged in the mid-40s. Pot life of the epoxy was sufficiently long to allow for final adjustments to the installed bar locations. The epoxy appeared to have completely cured by the next morning, although no pullout tests were performed for confirmation. The corresponding curing time is approximately 18-hours. Ambient temperatures during the construction period have been included in Appendix D, Part VIII.

Figure 14. Tie hole drilling procedure

Figure 15. Epoxy grout injection procedure

Precast Panel Erection

48. The contractor had anticipated using a 30-ton crane during the project planning stages, but one could not be located in the Vicksburg area. Subsequently, a 15-ton-capacity Galion hydraulic crane was located and used to erect all panels. Weights and dimensions of individual panels are summarized in Table 1.

49. Panel P-1, the largest panel erected, represents the prototype panels for full-scale installations. The combination of panel weight and restricted crane working radii necessitated several crane relocations to move Panel P-1 into final position for erection. With each relocation, the panel was temporarily disconnected from the crane and stored while the crane and cribbing for the outriggers were moved.

50. Rigging for Panel P-1 is shown in Figure 17. Two nylon slings were connected to the four erection lifting loops along the top edge of the panel. These, in turn, were connected to a wire rope sling which was attached to the crane hook. The elasticity of the nylon slings was beneficial in compensating for impact loads during handling, but the slightest crane adjustment during final positioning induced some minor panel movements.

51. Panel P-1 included two unique features which led to complications during erection. First, the ties which extended beyond the back face of the panel were welded directly to the weld plates located along the top and bottom panel edges. Second, Panel P-1 contained eight alignment screws which were used to level the panel. Because of the projection of the ties, the panel could not be lowered vertically into position but had to be moved in sideways. There was insufficient space between the monolith ledge and the bottom edge of the panel to install the alignment screws with the panel erected. As a result, the alignment screws had to be installed prior to the erection of the panel. After several trials, a means of supporting the alignment screws within the receptacles by wrapping tie wire around the perimeter of the panel was developed.

52. The close proximity of the monolith wall made sliding the panel sideways into final position using the crane boom impossible. A sill or kicker plate was nailed to the concrete slab in front of the monolith and timber braces were wedged against the panel face in order

Figure 16. Tie installation with two ties in place
(note wire chairs on horizontal tie)

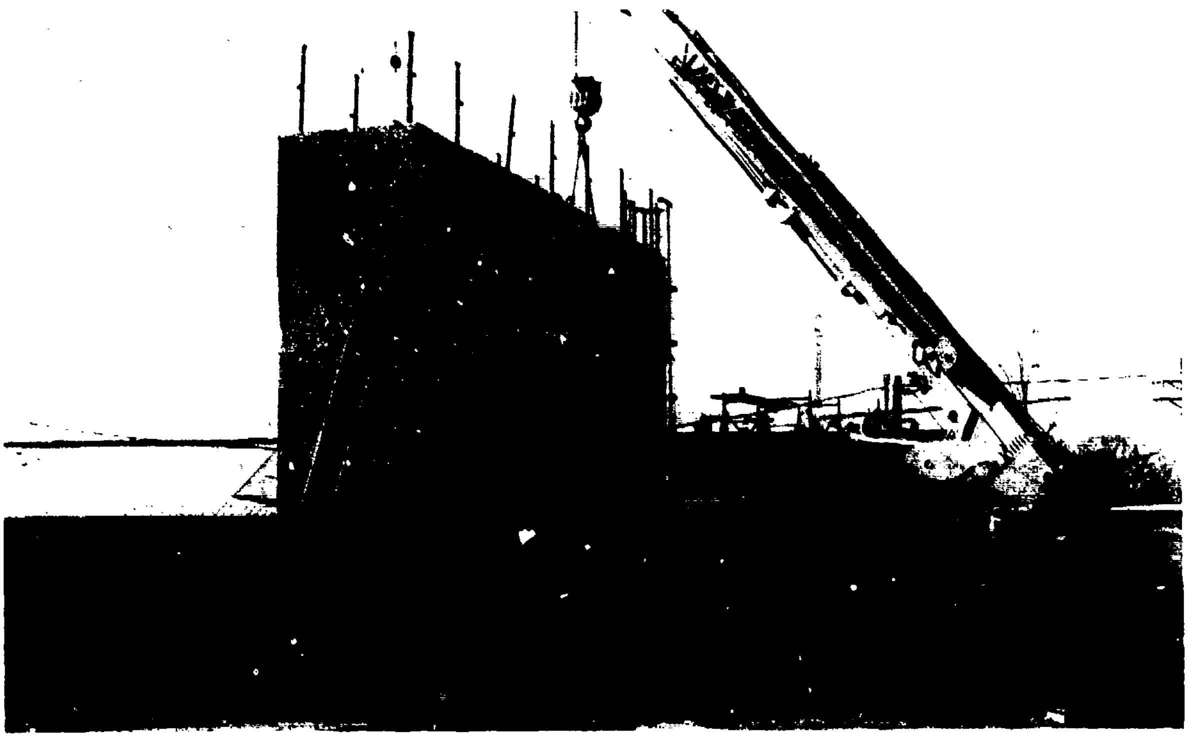

Figure 17. Crane and rigging used for erecting Panel P-1

to obtain the leverage to move the panel. The wedges were then driven with a sledge hammer to move the panel into place. The upper ties were approximately 1/4 in. low at several locations and blocked the panel. These bars were field bent to enable the completion of the erection.

53. The alignment screws were used to level the panel vertically. Elevations were checked at the two corners of the upper shear key face with a surveyor's level. The two outer corner screws were adjusted until the required elevation was achieved. The remaining screws were turned until snug to enable sharing load from additional erected panels. This feature of the precast system worked very well in the overall installation scheme.

54. The remaining panels, with the exception of P-7, were erected with a single crane pick. Because Panel P-7 required the crane to be repositioned once, the panel had to be temporarily stored. All remaining panels were picked with the wire rope sling in conjunction with the two lifting loops in the upper edge of the panels.

55. Several steps were required to prepare a panel for erection. Neoprene seals had to be cemented to the lower panel bearing surface, shims installed, nonshrink grout buttered onto the sloping shear key face, and the back face of the panel washed with a high-pressure water spray. A shear key ready for installation of the upper panel is shown in Figure 18. In addition to these planned tasks, two other preparatory steps were required. These unplanned tasks were the result of oversights during precasting. The rake finish on the back of the panel was extended to the top of the shear key, causing an uneven bearing surface for the alignment angle. Also, the shear keys extended to the edge of Panels P-1, P-6, and P-7, where they conflicted with the vertical corner armor for the panel above. These conditions were corrected by bush hammering and grinding the back face of the shear key along the bearing surface and by locally chipping the shear key with a masonry hammer to clear the armor.

56. Several hours of effort were required to rectify the shear key contact surface. The surface was initially removed with an electric Hilti bushhammer and then ground with an abrasive wheel and an electric grinder. A plywood gage was used to determine the amount of concrete to remove. Although the surface was checked frequently during the work, high spots which prevented a flush fit between the upper and lower

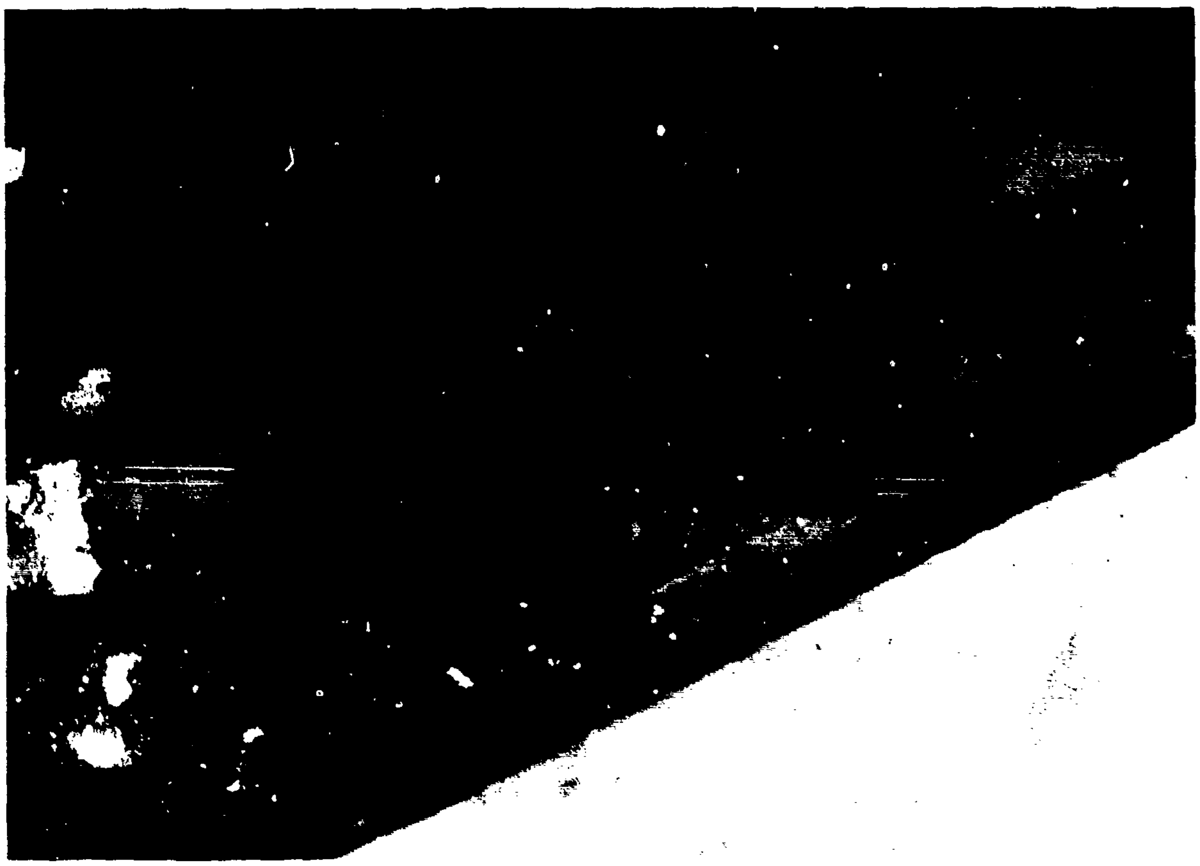

Figure 18. Shear key preparation -- skim, neoprene seal, and nonshrink grout

panels existed. These high spots were located only after a panel was erected and were removed by hand chiseling. This task delayed erection for up to an hour on several panels.

57. Horizontal joints between panels contained 5/16-in.-thick 50-durometer neoprene seals. Because of the low temperatures during the erection (approximately 40 degrees average), the neoprene seals were bonded to the lower panel with conventional contact cement rather than epoxy as required by the contract documents. The cement was applied to both the shear key surface and the seal surface. After the cement dried, the seal was pressed firmly against the panel. No displacement of seals was encountered during erection or infill concrete placement. The use of contact cement rather than epoxy would be sufficient for full-scale repairs and should be specified in lieu of epoxy.

58. The seals were sized to compress in excess of 1/16 in. under the weight of the 6-ft-wide panels and, subsequently, 1/4 shims were required to maintain the 1/4-in. joint width. However, the seals did not fully compress along the full length of the shear key for 3-ft-wide panels, and cement paste leaked through the joint at several locations. At two joints with 3-ft-wide panels, the seals were cut in half (1/2 in. wide) and thinner shims used to obtain greater compression, but there were still areas where the seals did not make full contact. This lack of contact was then attributed to the presence of slight bowing of the formwork during precasting, which can be seen in Figure 10.

59. Two other factors contributed to panel misalignment during erection: (1) slight displacement of the embedded weld plates and (2) displacement of several of the shear key plates along the top of Panel P-6. These displacement may be attributed to insufficiently securing the embedments to the formwork during precasting or to the premature removal of the C-clamps which held these in place. These problems were remedied by grinding the required weld plate corners and trimming the shear key plates with a gas torch. Again, both of these activities delayed the erection.

60. As mentioned in paragraph 55 and shown in Figure 18, the sloping face of the shear key was buttered with a nonshrink grout prior to the erection of the upper panel. The grout was provided as another measure to obtain a watertight joint. The grout was mixed to a sour-cream-like consistency and trowelled onto the joint. It was expected

that the grout would flow under the pressure of the upper panel and redistribute to fill all voids. However, several passes with the trowel were required before the grout stiffened sufficiently to remain on the shear key face. At this point, the grout did not flow under the pressure of the upper panel as expected and actually caused some minor amount of panel misalignment. As a result, the application of the grout was discontinued after the first two joints.

61. Auxiliary measures were employed to assist with panel alignment. These included use of come-alongs and the driving of wedges to push or pull panels into the required vertical alignment. The need for these actions was attributed to the unfinished shear key contact surface and the misplaced steel armor. No special measures were attempted to maintain levelness of the panel as the erection proceeded upward. However, the elevation of panels appeared to gain approximately 1/16 in. per joint relative to the tie location, and the cumulative effect required the field bending of ties to enable completing welds, as discussed in paragraph 70.

62. The three critical as-built tolerances (panel plumbness, horizontal alignment along vertical edges, and the panel-to-panel offset across joints) are summarized in paragraph 2.2.4 of the specifications. These tolerances were checked during the demonstration using a transit to establish reference planes parallel to the front face and both ends of the monolith.

63. The panel plumbness and panel-to-panel offset measurements are summarized in Appendix D, Part IV, Figure D2. A plane parallel to the lower two corners of Panel P-1, noted RP1 and RP2, was established and measurements relative to these points are noted. The maximum out-of-plumb readings occur along the outer edge of Panels P-7 and P-8, but the 7/16-in. measurements are within the 1/2-in. tolerance. It is worthy to note that Panel P-7 was the most difficult panel to erect from an alignment standpoint because of the misplaced shear key plates at the top of Panel P-6. The misplaced plates likely contributed to the magnitude of the out-of-plumbness.

64. The greatest panel-to-panel offset, which is 1/4 in., occurs between Panels P-6 and P-7. The specifications required 1/8-in. tolerance. Again, the misplaced shear key plates are a contributory factor. Several

other joints had 3/16-in. offsets, but the majority of the measurements were within the required tolerance.

65. The panels were erected to provide a uniform vertical joint so the offset was measured along the outer panel edges. These measurements are noted in Appendix D, Part IV, Figure D3. The maximum misalignment is 5/16 in., which is within the 1/2-in. specified tolerance. This sheet also shows the variation of the panel elevation at the top, which is a 1/8-in. maximum difference. The elevation of the panels was checked with a surveyor's level at the top of the monolith and, although very little effort was expended to maintain constant elevation, the panels were erected virtually level over the full height and width of the monolith.

66. Appendix D, Part IV, Figure D4, contains the horizontal measurements across the width of the refaced monolith at the base, midheight, and top. These measurements varied only by 1/8 in. from the theoretical 30-ft width.

67. Several unexpected features were encountered during the erection which were detrimental to good alignment. Nonetheless, the overall installation was successful. The detrimental features can be corrected for future installations, and panels should be erectable to the tolerances required.

Panel-to-Tie Welded Connections

68. Welded connections were used between the precast panels and No. 7 weldable grade form ties. Three different welded connections were used. The connections to Panel P-1 were as shown in the drawings (A86029-4, Details A and B); the tie is welded directly to the weld plates embedded in the panel. The top and bottom welds required different weld procedures because the bottom weld was performed in an "overhead" position. All remaining connections were revised during the planning stages of the Phase II work to a finger plate type connection, as shown in Figure 19. With this connection, the reinforcing bar does not project into the plane of the back face of the panel; therefore, panels could be erected by being lowered vertically. A similar detail is also recommended for the top connection of the bottom panel instead of the ones used on Panel P-1. Figure 20 shows the original tie

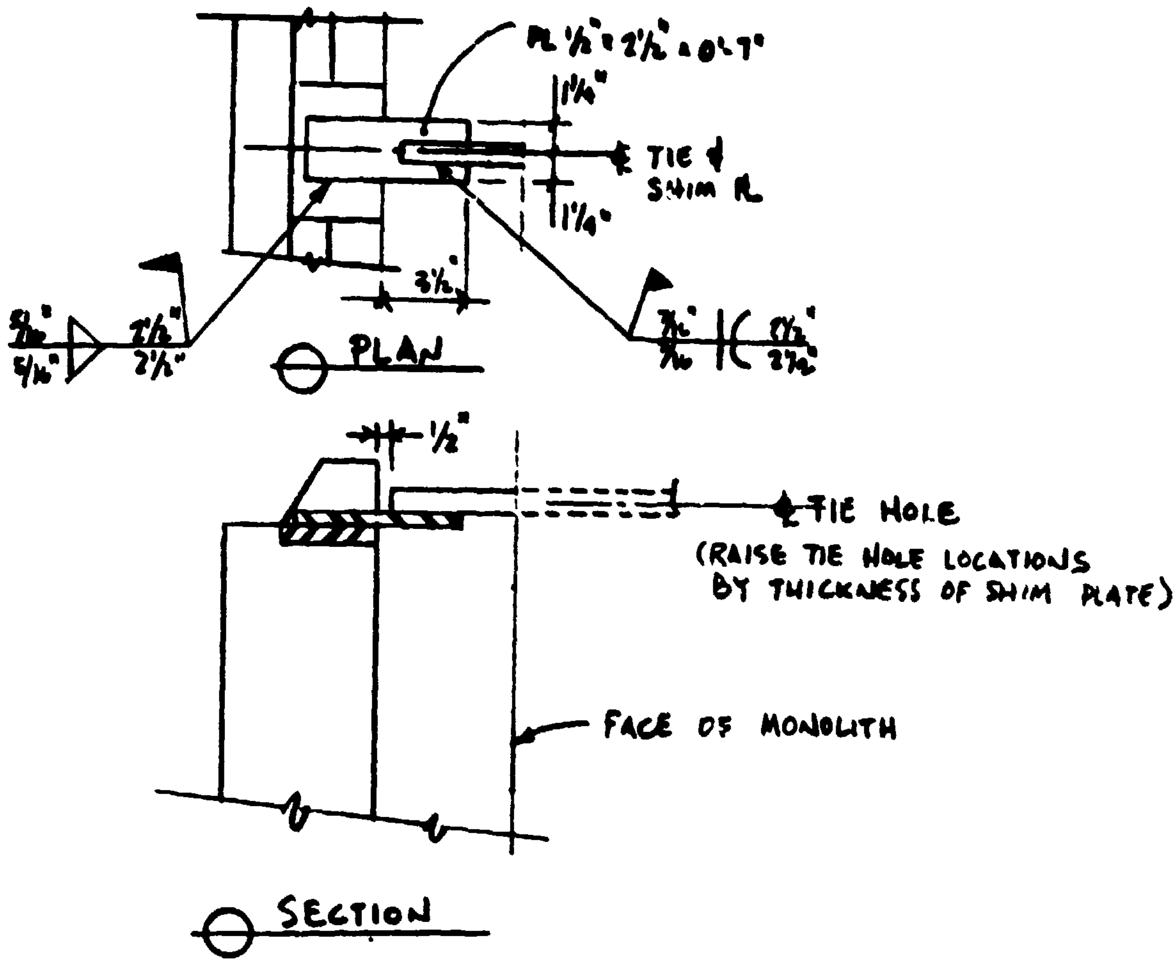

Figure 19. Tie connection using finger plate

connection detail, which is welded directly to the embedded plate, whereas the connection that uses the finger plate is shown in Figure 21.

69. The weld procedure and welder were qualified as required by the applicable welding code, AWS D1.4 (American National Standards Institute, 1979). Weld coupons were performed in Vicksburg by the welder selected for this work and tested in Denver because of the unavailability of a qualified local agency. The weld procedure and results of the weld qualification tests are contained in Appendix D, Part VI.

70. The amount of time required to complete the three different welds is summarized below. This estimate includes time spent bending bars that did not align with the weld plate, flame heating the bar with a gas torch to rebend the bar into contact with the weld plate, and completing welding and cleaning of welds.

Panel P-1 bottom (direct) connection	15 to 20 minutes
Panel P-1 top (direct) connection	10 to 15 minutes
Finger plate (typical) connection	20 to 25 minutes

71. More time was needed to complete the bottom welds for Panel P-1 than the top welds because of the "overhead" position. Because smaller weld rods had to be used, a greater number of passes were required to obtain the same effective throat size. The limited amount of space (2-3/4 to 3 in.) in which the weld had to be completed and the welder having to do this work while kneeling on the ground also increased the time needed to complete the bottom welds. For these reasons, the bottom connection presents a potential problem for full-scale repairs if the joint is located at or near the low pool elevation and a welded connection is used. More time was needed to complete the finger plate (typical) connections as compared to the direct connection because of the extra welding required to attach the finger plate to the embedded weld plate. There was sufficient access from the scaffolding for welding all panel top connections. Scaffolding that provides similar access for full-scale repairs can be developed without significant effort.

72. Heat buildup during the welding process was a problem. Numerous fine cracks occurred at the base of the shear key near the top welds along the left half of Panel P-1. These cracks were caused by expansion of the embedded steel plate. This expansion was not as pronounced for the typical connection because a smaller weld was used

Figure 20. Welded connection to Panel P-1, tie welded directly to embedded plate

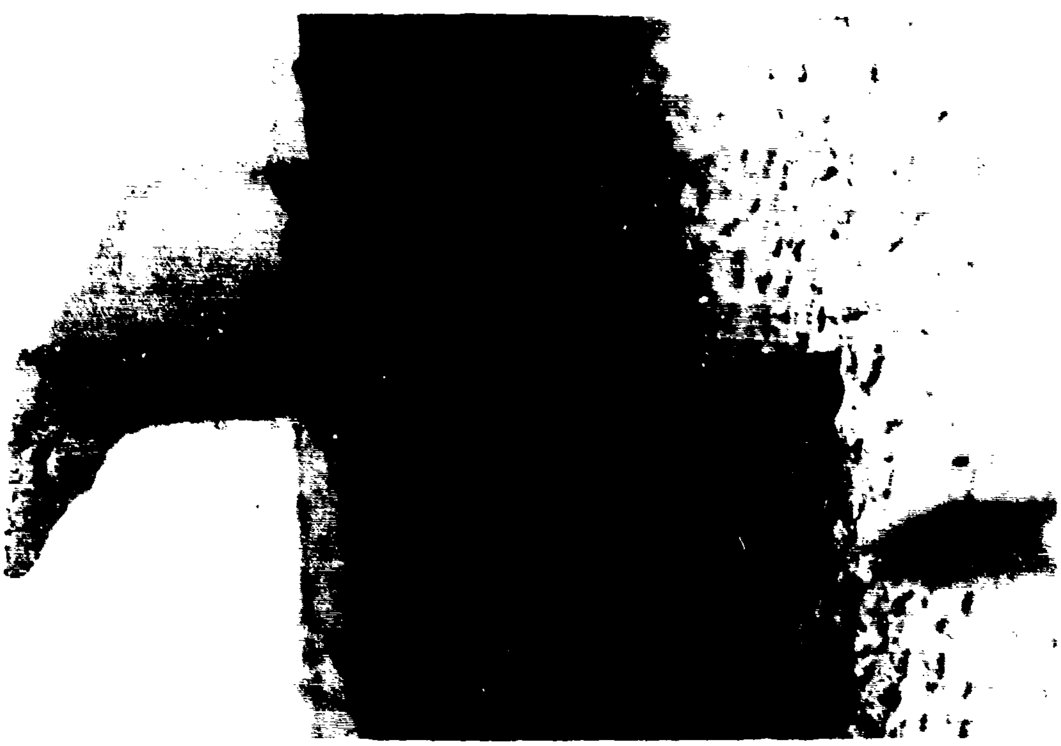

Figure 21. Welded connection utilizing finger plate detail

between the embedded weld plate and the finger plate. However, the cracking problem was eliminated by limiting the welder to single passes for each tie prior to moving to the next tie. Because the spacing of ties for the demonstration was only 15 to 24 in., there was no time penalty as a result of the staggered weld procedure.

Cast-in-Place Concrete

73. The design for the demonstration resulted in a 5-1/2-in. space between the back of the panel and face of the monolith. This space was filled with cast-in-place (CIP) concrete after all panel weld connections were completed and formwork was installed. For panels erected on the east monolith, P-1 (left side) to P-5, the specifications and drawings required that the infill CIP concrete be placed in single lifts coincident with the panel heights. CIP concrete was infilled the full height of the west monolith coincident with Panels P-1 (right side), P-6, P-7, and P-8.

74. No extraordinary mixture requirements were imposed for the infill concrete. The strength of the specified mixture was f'_c = 3000 psi with a water/cement ratio of 0.5 and air entrainment of 3 to 5 percent. The concrete mixture submitted by the ready-mix supplier is included in Appendix D, Part VII. Superplasticizer was submitted as an option if concrete could not be batched to a workable slump within the limiting water/cement ratio and, subsequently, was not needed for the installation.

75. A limited amount of formwork was required for the installation. The following exposed CIP concrete surfaces required forming:

a. Along the lower edge of Panel P-1 and the base of the monolith. (A similar condition will exist for full-scale repairs and will have to be incorporated in the construction.)

b. The exposed surface of the 5-1/2-in. infill concrete between the panel ends and monolith.

c. Along the centerline of the monolith to separate the stepped concrete placements from the full-height placements.

d. Forms for the CIP closure pour at the top of the panels.

76. Although limited formwork is required for the infill concrete for the precast panel repair concept, design and installation of the

temporary forms must not overlook that the same concrete pressures will be exerted on the temporary forms as on the precast panels. For the demonstration, the concrete placement pressure was limited to 1.25 ksf. Attempts were made to quantify the pressures during the full-height placement by Waterways Experiment Station Structural Laboratory (WESSL) personnel through the installation of pressure and strain gages. In addition, panel movements were measured before and after concrete placement in an attempt to extrapolate pressures through panel deflections. These measurements are summarized on Figure D4.5 of the as-built measurements in Appendix D, Part IV. The measurements suggest a slight movement of the entire panel but no absolute deflection at midheight of the panel. A 1/8-in. theoretical deflection was computed for the 125-ksf design pressure at the center of a 6-ft-wide panel. The WESSL measurements are not contained in this report.

77. All formwork for the CIP concrete was constructed from plywood. The bottom forms were braced to kickers nailed to the concrete slab in front of the monolith. The bottom edge was also nailed to the monolith. Side forms were tied with 9-gage wire to either the No. 7 form ties or form straps remaining from construction of the monolith. Attempts were made to drill expansion type inserts into the panels and monolith for holding the forms; however, the drilling near panel edges caused cracking and was discontinued. The top closure pour forms were secured with all-thread rods tack welded to the No. 6 dowels and she-bolts clamped to the exterior face of the forms. The corner armor was supported at the required elevation by a series of bolts through the formwork and a series of steel bars tack welded to the dowels. A small hydraulic jack was used to assist with straightening the armor and forms.

78. Concrete for the single-panel-height placements was deposited from a bucket onto a plywood chute and shoveled into the void, as shown in Figure 22. After a 1-1/2- to 2-ft lift, the concrete was consolidated with a 2-in.-diameter electric stinger. The level of the concrete was stopped about 4 in. below the top of the shear key to prevent interference with the alignment angle for the next panel to be erected. The time required to place and consolidate concrete ranged from 30 minutes to 1 hour for the 3- and 6-ft placements, respectively. Curing measures included the use of moist burlap placed over the exposed concrete and

followed by covering both the burlap and panel with an insulated curing blanket.

79. Concrete for the full-height placement was deposited with a hopper and an 8-in.-diameter trunk, as shown in Figure 23. Although the work was satisfactorily completed, several events occurred which delayed or made the work more difficult than needed:

a. Concrete arrived at the site with an approximate slump of 2-3/4 in. Water was added to increase the slump to 4 in. prior to starting the work. Water was again added after the concrete clogged in the trunk. The resulting concrete had a 5-in. slump, which was a workable mixture for the selected placement procedures and equipment. Water was added to the truck only after verification that the concrete mixture was within the specified water/cement ratio.

b. Form ties used in the construction of the test monolith projected from the face of the monolith. Spacing of the No. 7 form ties and monolith form ties was staggered and therefore reduced the available clear space in which to drop the trunk. The end of the trunk had to be closely observed so that it would not wedge against the monolith form ties and become blocked.

c. Twice during the concrete placement, the end of the trunk became submerged and had to be pulled out with the crane. The first occurrence happened during the use of the stiffer 4-in. slump concrete. The second time appeared to be caused by the trunk's wedging against a monolith form tie. A bright light source was needed to see the end of the trunk during concrete placement and the positioning of the stinger during consolidation. The light was also needed to reposition the trunk. For the demonstration, a mirror was used to reflect sunlight into the bottom of the void.

80. Despite these delays, the 18-ft-high lift was completed in approximately 2-1/2 hours. This schedule corresponds to an average placement rate of 7.2 ft/hour. The concrete temperature at delivery was measured as 57 degrees. Based on the guidelines contained in the formwork design standard SP-4 (Hurd, 1979), this results in a form pressure of 1.27 ksf, which is almost exactly the design pressure.

81. Infill concrete was batched at a computer-controlled batch plant and was truck mixed. The size of the batches varied between 1 and 5.75 cu yds. Because of the insensitivity of the hoppers, aggregate and cement could not be batched accurately for the smaller batches. As a result, slumps were generally too low. It was verified that the actual water/cement ratio was well within the limiting water/cement ratio so

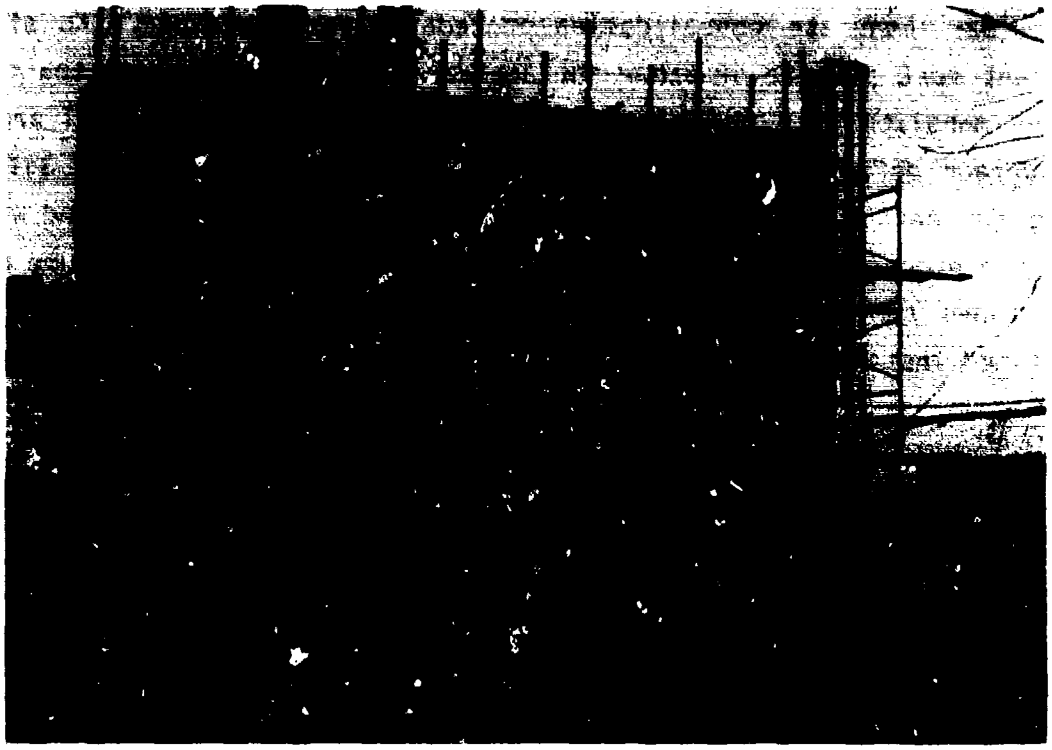

Figure 22. Concrete placement procedures for limited height placement

Figure 23. Full-height infill concrete placement using hopper and trunk

water was added on site to obtain the required slump. Concrete inspection reports for the CIP concrete are included in Appendix D, Part VII.

82. Concrete consolidation procedures were adequate. No significant rock pockets or other surface defects were present on the side of the monolith with panel height concrete lifts. Several small areas of surface defects were present on the side of the full-height lift along the bottom edge below Panel P-1. These areas were repaired with suitable procedures. In addition to these repairs, the CIP closure pour was stoned and sacked for improved appearance. Figure 24 shows the completed installation.

Post-Construction Cracking Investigation

83. One of the primary objectives of this developmental work was to identify a repair procedure that eliminates or minimizes the cracking experienced with the conventional cast-in-place repair procedure. The goal during Phase I was to select a stay-in-place forming system that achieved this objective by the use of the least complicated and costly construction features.

84. The success of this repair concept at achieving this objective was determined by performing a detailed crack inspection six months after completing the demonstration. The results of this investigation revealed the presence of numerous fine cracks. Because the crack widths are extremely narrow, they were not noticed during the precasting operation or during erection. They were detected only after the panel surface was thoroughly wetted and allowed to dry. The additional moisture stored within the cracks caused them to dry slower, leaving a visible trace on the surface. Once located, the cracks are visible to the naked eye when viewed from 6 to 12 in. from the surface. Because the cracks were not noticed earlier in the construction, detailed inspections were not performed; therefore, determining the exact cause of the cracking is more difficult.

85. Figure 25 locates the majority of cracks and provides crack width measurements. The widest crack measured in the precast panels is approximately 0.0025 in. and occurs in Panel P-7 (Figure 26). Core No. 2 was taken at this location to obtain additional information about the crack. All other cores obtained during the investigation are also

Figure 24. Test monolith as completed

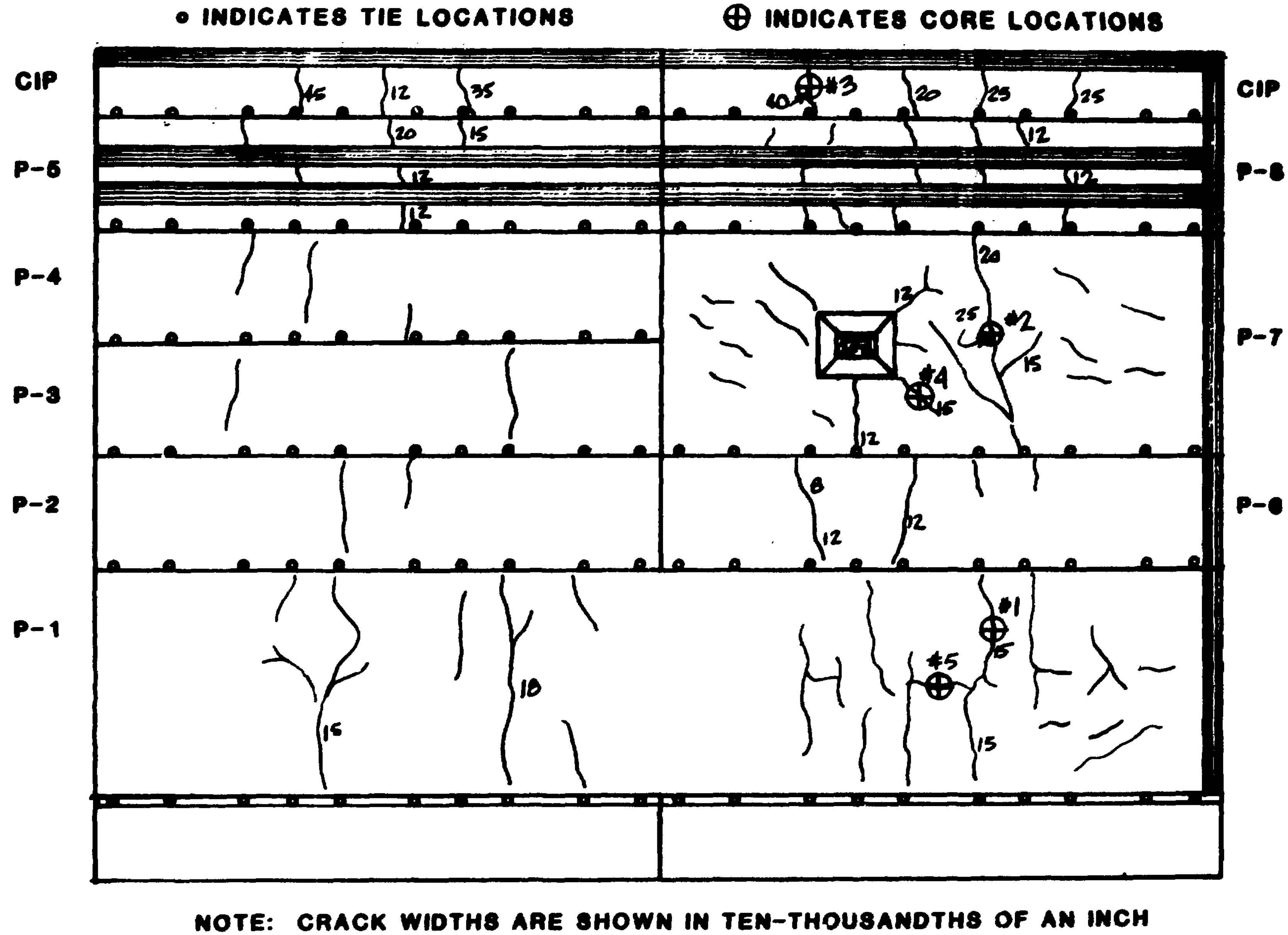

Figure 25. Post-construction crack map

Figure 26. Cracking in Panel P-7 in vicinity of Core No. 2

shown in Figure 25, and a description of each core is contained in Table 2. The largest crack for the demonstration is 0.004 in. wide and occurs in the cast-in-place closure above Panel P-8. This width corresponds to the crack widths reported in the navigation locks previously repaired by the conventional cast-in-place repair procedure.

86. Most of the cracks in the precast panels are less than 0.002 in. wide. The cracks were measured with a pen gage, which magnifies the cracks by a factor of 20. To accurately measure cracks less than 0.002 in. wide requires more sophisticated laboratory equipment so the values shown in the figure are a best estimate. The measurement of cracks this small on a production basis is rarely performed in the concrete industry because this size crack is beyond the normal range where structural or durability problems would arise. The concrete industry standard, ACI 224 (American Concrete Institute, 1980), contains guidelines for tolerable crack widths for various exposure conditions. For example, a tolerable crack width of 0.006 in. is suggested for concrete exposed to seawater or seawater spray under alternate drying and wetting conditions and 0.004 in. for water-retaining structures. The cracks in the precast panels are within these guidelines so their presence will be primarily an aesthetic rather than a structural or durability problem.

87. The cracking in the precast panels can be categorized into four broad groups. The first group consists of the finest (smallest) cracks that actually resemble a surface crazing rather than conventionally perceived cracks. Their appearance can be compared to a spider's web or starburst pattern. The crazing is visible with the naked eye only when viewed within several inches of the surface. The second group includes vertical cracks that extend over the majority of the panel width. The third group consists of horizontal cracks that extend in the longitudinal direction of the panels. These are relatively short with a maximum length of approximately 4 or 5 ft. The last group of cracks occurs in the vicinity of the line hook embedment and is caused by the stress concentrations at the reentrant corners of the line hook assembly.

88. The surface crazing probably occurred during the early stages of the panel precasting. The crazing may be the result of one or more of the following factors: too much heat used in the curing process,

Table 2

Core Descriptions

Core Number	Location	Type	Crack Width @ Surface	Depth of Crack*	Core Size and Description	Rebar Notes
1	Panel P-1	Vertical	0.0015"	Short side 0.06" Long side 0.75" Average 0.41"	o 3" diameter x 15" long o Removed in two pieces, 8" and 7" long, respectively, measured from the panel surface toward the lock wall o Interface joints visually appeared sound o Core break was uneven with rubble waste	Face mat was on extreme periphery of core. Only shaved edge of vertical bar. About midway into panel two bars were cut. These bars did not extend through core. Also cut welded wire fabric.
2	Panel P-7	Vertical	0.0025"	Short side 2" (+ 3½") Long side 2" (+ 4½") Average 2" (+ 4")	o 3" diameter x 15" long o Removed in two pieces, 12" and 3" long, respectively, measured from the panel surface toward the lock wall o First interface joint visually appeared sound o Core broke at infill and lock wall joint o Core break was clean	Face mat vertical bar was on vertical axis of core. The 2" of visible crack runs from face to the rebar. The crack visible with water runs to the back face of the panel.
3	CIP closure pour	Vertical	0.0035"	Short side 3" (+ 7") Long side 3" (+ 7") Average 3" (+ 7")	o 3" diameter x 16" long o Removed in three pieces, 2½", 10", and 3½" long, respectively, measured from the panel surface toward the lock wall o First break was at a cluster of vertical dowels and ties, cut three bars o Second break appeared to start at interface and continued into lock wall	The exterior surface rebar (dowels and tie laps) were ±2½" below the surface. The crack appears wider between the surface and rebar than between the rebar and lock wall interface.
4	Panel P-7	Reentrant corner	0.0015"	Short side 0.00" - 0.03" Long side 0.00" - 0.03" Average 0.00" - 0.03"	o 3" diameter x 16" long o Removed in two pieces, 7" and 9" long, respectively, measured from the panel surface toward the lock wall o Interface joints appeared sound	A horizontal bar was cut and exposed on the core periphery. Welded wire fabric was cut.
5	Panel P-1	Horizontal	0.0008"	Short side 0.00 Long side 0.00 Average 0.00	o 3" diameter x 17" long o Removed in three pieces, 7", 4", and 6" long, respectively, measured from the panel surface toward the lock wall o Core break between first and second pieces was uneven with rubble waste o Interface joints appeared sound	Horizontal and vertical bars were cut.

* Depth of crack visible with the naked eye. Additional length shown in parentheses (e.g., + 3") indicates a continuation of the crack which is visible only after soaking core in water and allowing it to dry.

heat applied too rapidly, a reaction with the form oil, or the introduction of thermal strains immediately after removing the panels from the forms. As discussed previously, the panels were removed without a "cool-down" period, and the exterior faces may have lost heat more quickly than the interior of the panel, thus creating tensile strains in the face of the panel. Subsequent strains resulting from shrinkage and external loads such as handling, transportation, and infill concrete pressures would contribute to the irregular surface crazing to form a discrete or better defined crack.

89. The panels were one month old at the time of the infill concrete placement, at which time approximately 40 to 50 percent of the long-term shrinkage would have occurred. The remaining shrinkage is restrained by the infill concrete, thus creating the potential for tensile shrinkage strains. Although there will be shrinkage in the infill concrete, the rate will be much slower than for the panels because of the slower rate of drying. The vertical cracks, particularly in the 3-ft-wide panels and cast-in-place closure, are attributed to shrinkage. Panels P-5 and P-8 contain large pieces of horizontal lock armor which prevent the normal shrinkage from taking place. The horizontal cracks near the right side of Panels P-1 and P-7 may also be attributed to the proximity of the vertical armor.

90. More cracks are present for the right (west) half of the monolith where the infill concrete was placed in one lift and the concrete placement pressures were higher. Also, more cracks are present for the 6-ft panels (P-1 and P-7), which have more total load. In addition, the vertical cracks generally coincide with the tie locations. These observations indicate that the load on the panels definitely contributes to the cracking in the panels. However, if the cracks were caused exclusively by the infill pressures, then they would be in the horizontal direction, very regular, and probably continuous over the full length of the panel. A similar reasoning would apply to cracks caused by handling or shipping stresses; however, these would be in the vertical direction. The general cracking pattern, as shown in Figure 25, is very irregular.

91. It may be postulated that the demonstration panels, with their higher strength (9036 psi average versus specified strength of 6500 psi) may exhibit less cracking than would be realized for prototype

panels, which are closer to the specified strength. However, because the cracking appears to be initiated in the early stages of precasting, the initial strength of the concrete and the curing practices are more critical to the level of cracking than the 28-day strength.

92. In summary, the cracking appears to have been initiated in the early stages of the precasting, possibly resulting from curing procedures. With the subsequent shrinkage strains and external loads from handling, shipping, and infill concrete pressures, the cracks have increased in size and become more noticeable. However, they are within industry guidelines relative to the potential for corrosion of the reinforcing steel and do not pose structural concerns. The concrete mixture has an air void system that should provide sufficient durability to resist deterioration from freezing and thawing action.

93. Nonetheless, there are several steps that can be taken that would reduce the overall level of cracking in the precast panels. The most direct modification is to include a nominal amount of prestressing in the design of the precast panels. However, the prestressing is cost-effective only in the longitudinal direction and would be advantageous in eliminating cracking caused by shrinkage strains and handling and transportation loads. The prestressing would increase the precasting costs, but the amount would be tempered by a reduction in the amount of mild steel reinforcing. Other steps are available to reduce the amount of cracking without changing the existing design. These include modifications to construction procedures, such as a more gradual application of heat during curing, the use of less heat, the use of steam rather than radiant heat, an increase in the length of time between casting and erection to enable more drying shrinkage to occur before the panels are restrained, and to cool the panels closer to the ambient temperature before removing them from the forms. Most of these modifications would have little or no impact on the costs.

PART VII: EVALUATION OF THE DEMONSTRATION INSTALLATION

Summary

94. During the Phase I study, a panel configuration consisting of tied, flat panels, constructed of precast quality concrete and oriented in a horizontal arrangement, was selected as the optimum system to repair deteriorating navigational lock walls. The criteria used to select this optimum system include durability, functionality, constructability, and cost/schedule. These are summarized in Part II of the Phase I technical report, REMR-CS-7 (ABAM Engineers Inc., 1987). The Phase II installation was undertaken to physically demonstrate the ability of this proposed system to satisfy these criteria. Based on the experience gained during the construction, the following conclusions can be drawn:

- a. The panels can be fabricated without undue complications with the required concrete mixture criteria, which were specifically selected to provide a durable navigation lock surface.
- b. Although fine cracks are present in the precast panels subsequent to the construction, the sizes are such that they should not pose structural or durability problems. Several design and construction features have been identified which will significantly reduce or possibly eliminate the cracking for future applications.
- c. The panels can be precast with typical lock hardware embedded.
- d. The panels can be erected to reasonably close tolerances, thus limiting the potential damage at panel-to-panel joints.

In summary, the results of the demonstration have shown that the optimum stay-in-place form system can be successfully implemented and will satisfy the evaluation criteria.

Cost and Schedule Assessment

95. The projected cost of this repair procedure in the Phase I report was estimated as $119/sq ft of lock wall face as compared to $137/sq ft estimated for a conventional CIP repair. The actual cost of the demonstration was approximately $151/sq ft, but this cost included

only a minimal amount of concrete removal. The small scale of the demonstration results in higher unit costs to absorb mobilization, general administrative, and engineering costs, some of which will not be proportionately higher for a full-scale repair.

96. In addition, the demonstration did not utilize the equipment size or number of workers that would be optimum for a fullscale installation. For example, a preferred sized crane could not be located, and the use of a smaller crane restricted several of the lifts. Form tie welding was the critical path activity, but only one welder was used. This approach resulted in considerable standby time for the crane and operator. Forms for the CIP concrete were used only once but could have been reused several times, reducing the forming costs had this been a full-scale repair.

97. The actual cost of precast concrete was less for the demonstration than was estimated during the Phase I work. This difference is attributable to the use of an existing precast plant. The $1850/cu yd Phase I estimate included developing a casting yard at the lock site. Shipping costs are reflected in the $1575/cu yd price and possibly suggest that existing precasting facilities within several hundred miles of the repair site may be competitive with an on-site casting facility.

98. In summary, the estimated cost for the precast repair has been validated by the demonstration, and it appears to be very competitive with the costs of conventional CIP repairs.

99. The estimated schedule for a precast panel repair developed during the Phase I effort is shown on Figure 27. Activities 4 through 10 were included in the demonstration and have been reassessed. It is estimated that form ties will be spaced at a minimum of 2 ft on center for the full-scale repair, or 16 ties per panel will be required. Seven panels are required for a 40-ft-high monolith, for a total of 112 ties. The previous estimate of 4 to 5 minutes to set a tie was for small batches and included hand equipment. With larger batches and mechanical equipment, the time to install ties for a full-scale installation could be reduced to 3 to 4 minutes. On this basis, the total time required to drill and set ties, assuming two crews for drilling and two for installing ties, will be approximately 4.5 hours. This schedule assumes tie setting commences 1 hour after the start of drilling, and that it takes 3.5 minutes to install a tie. A total of 28.5 hours is required before

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STAY-IN-PLACE FORM LOCK REHABILITATION

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Activity                               Duration (hours)
                          1       10       20       30       40       50       60       70
 1. Line drill & saw cut  ==========
 2. Load holes & shoot              ======
 3. Clean-up & dental work                ========
 4. Drill for form ties                       ============
 5. Set form ties & cure                       ========================
 6. Set panels                                                   ========
 7. Fabricate p'cast panels ================================
 8. Set forms & appurt'ces                                           ========
 9. Place concrete                                                           ====
10. Strip forms & clean-up                                                       ====

     ------Mon "V"---->&lt;------------------------60 hours  - Monolith "X"-------->&lt;------Mon "Z"------
     -----------------Mon "W"-------------------->&lt;------------------Mon "Y"-----------------------
                                                          &lt;---16 hours--->
                                                            Lock closure
```

Bases:
- Typical monolith segment is 30'W x 40'H
- Typical monolith segment includes ladder, line hooks, mooring bitt and armor
- Assumes 50% overlap on multiple monolith segments of lock chamber work
- Approximate progress based on 8 hour shift = 3.75 days per monolith segment

Figure 27. Schedule for full-scale lock repairs

the epoxy has cured, assuming a full 24-hour curing period, which compares to the 25 hours estimated during Phase I.

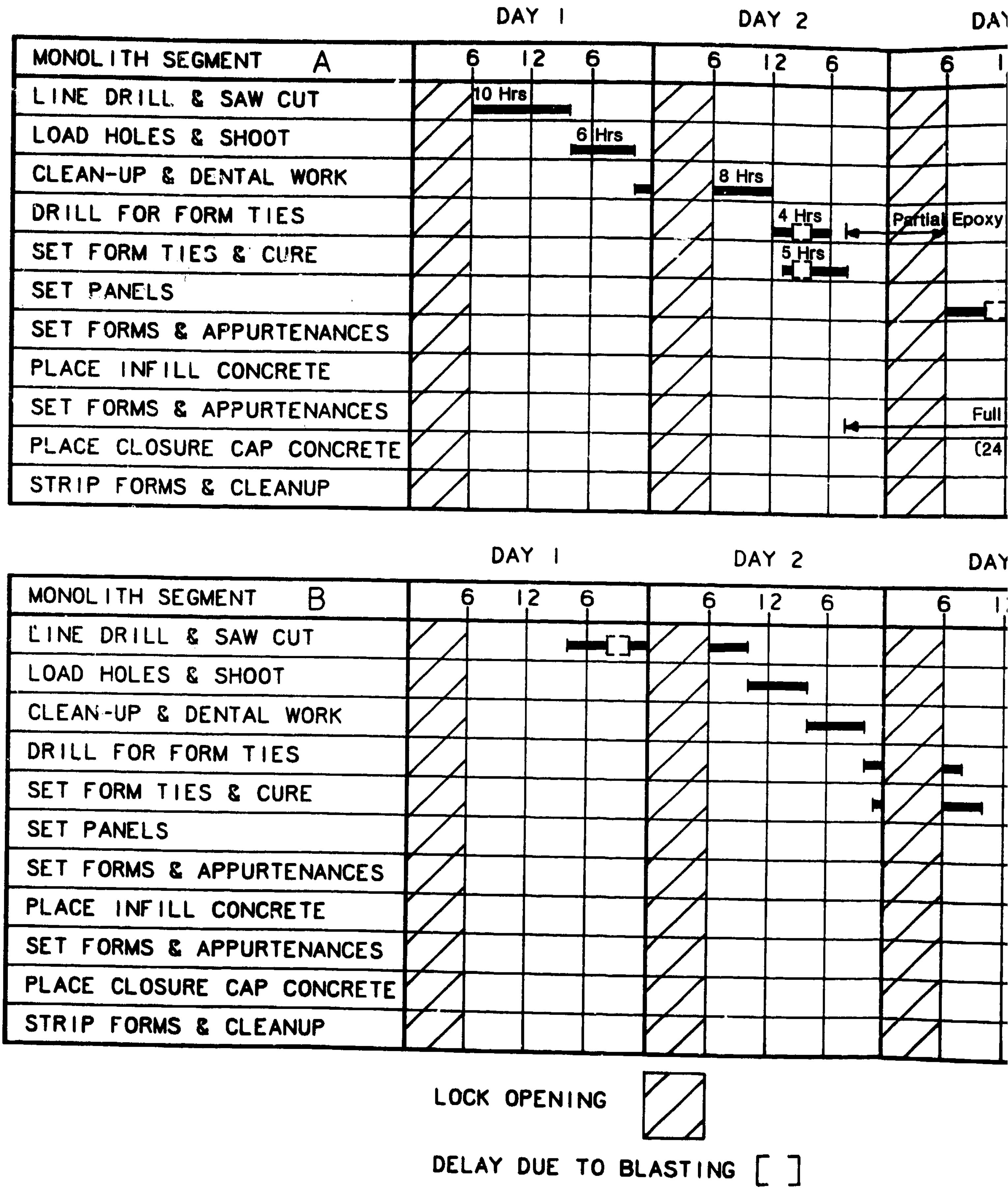
100. Based on the experience of the demonstration, it is estimated that one panel per hour can be erected. If four welders are used for a full-scale installation and 20 minutes is required to complete a weld, 1.33 hours would be required to complete the welding and enable erecting the next panel. A total of 16 hours is, therefore, required to erect all seven panels for one 40-ft-high monolith, if the erection and welding crews are not working concurrently on adjacent monoliths. Approximately 8 hours was estimated during the Phase I work, as shown in Figure 27. Some of this extra time can be recaptured by starting the work before the full 24-hour curing period has occurred, thus extending the previous estimate by approximately 4 hours only.

101. In summary, the experiences gained during construction of the demonstration confirmed that the schedule developed during Phase I is realistic.

102. Figures 28 and 28A have been prepared from experience on the demonstration to illustrate the probable impact on the construction schedule of daily planned lock openings necessary to maintain ship traffic. These figures include a daily 6-hour lock opening which was arbitrarily chosen for demonstration purposes. Required lock openings will be site specific and may require more or less time, depending upon in-depth lockage time studies. These studies will have to determine if the lock is usable with restricted operational lock widths because a minimum clearance from the construction may have to be imposed.

103. In Figures 28 and 28A, the sequence of work is shown for four consecutive monoliths if one composite work crew is performing the work. Additional crews would be working on other monolith sections in the lock. One other assumption incorporated in this estimated schedule is that demolition will be done by blasting; the lock would have to be cleared of workers for approximately 2 hours during the actual blasting.

104. As can be seen in Figures 28 and 28A, the disruptions from planned lockages and sequential blasting will require more time to complete one monolith section. Depending upon the timing of the lock openings and the shutdown for blasting, the gross time to complete one monolith ranged between 98 hours for Monolith A and 116 hours for Monolith C. The total elapsed time to complete all four sections is


DAY 1
DAY 2
DAY
MONOLITH SEGMENT A
6 12 6
6 12 6
6 1
LINE DRILL & SAW CUT
10 Hrs
LOAD HOLES & SHOOT
6 Hrs
CLEAN-UP & DENTAL WORK
8 Hrs
DRILL FOR FORM TIES
4 Hrs
Partial Epoxy
SET FORM TIES & CURE
5 Hrs
SET PANELS
SET FORMS & APPURTENANCES
PLACE INFILL CONCRETE
SET FORMS & APPURTENANCES
Full
PLACE CLOSURE CAP CONCRETE
(24
STRIP FORMS & CLEANUP
DAY 1
DAY 2
DAY
MONOLITH SEGMENT B
6 12 6
6 12 6
6
LINE DRILL & SAW CUT
LOAD HOLES & SHOOT
CLEAN-UP & DENTAL WORK
DRILL FOR FORM TIES
SET FORM TIES & CURE
SET PANELS
SET FORMS & APPURTENANCES
PLACE INFILL CONCRETE
SET FORMS & APPURTENANCES
PLACE CLOSURE CAP CONCRETE
STRIP FORMS & CLEANUP
LOCK OPENING
DELAY DUE TO BLASTING [ ]

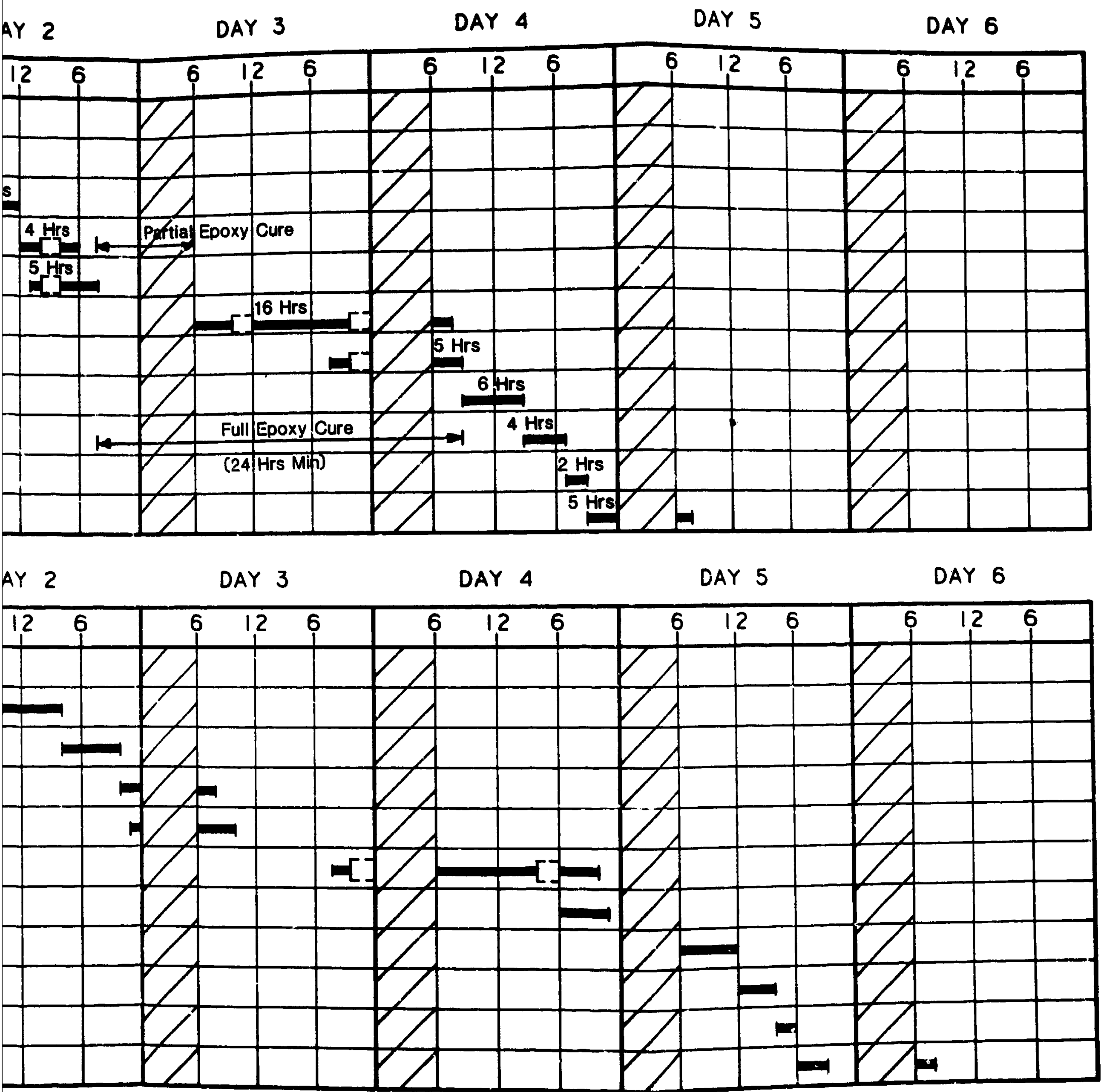
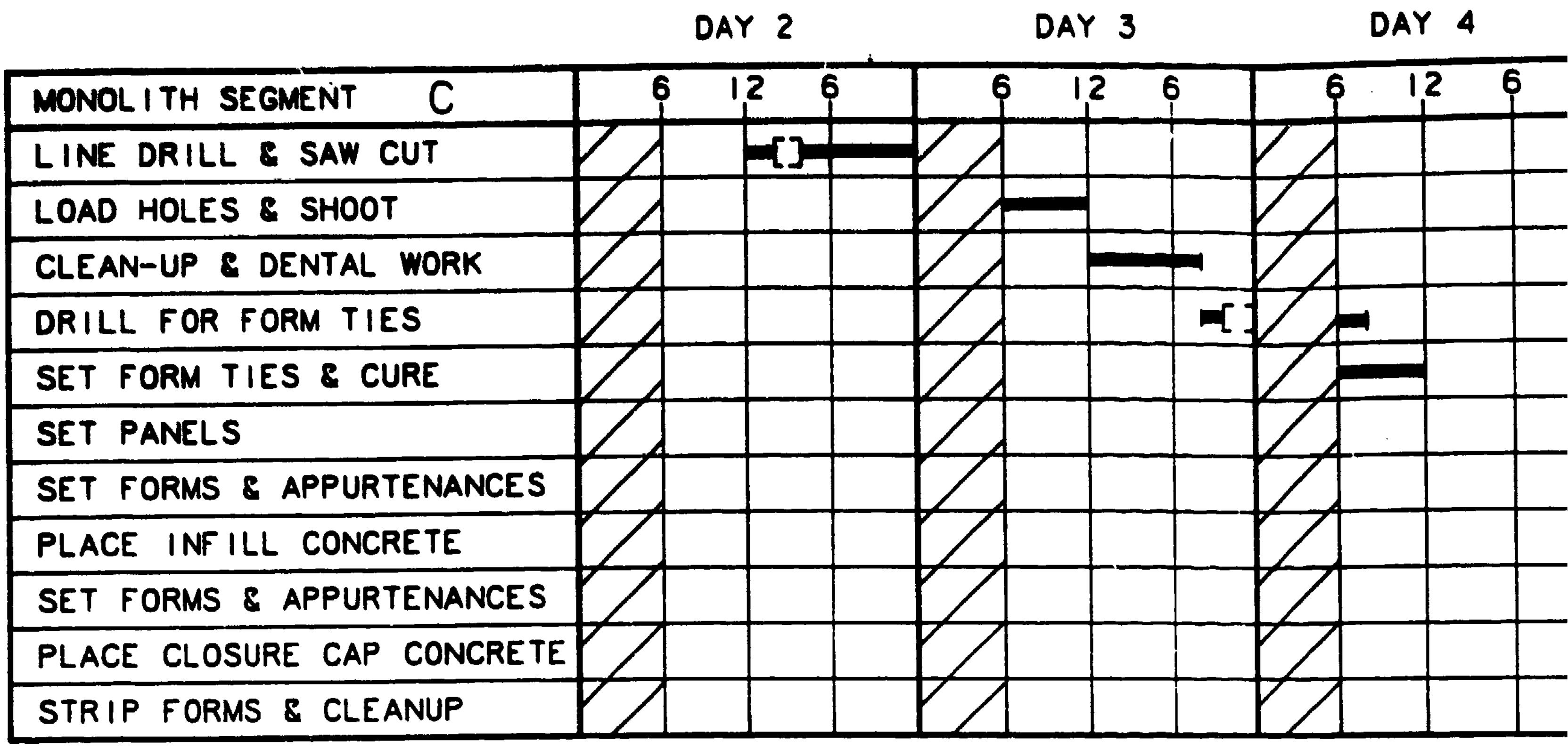
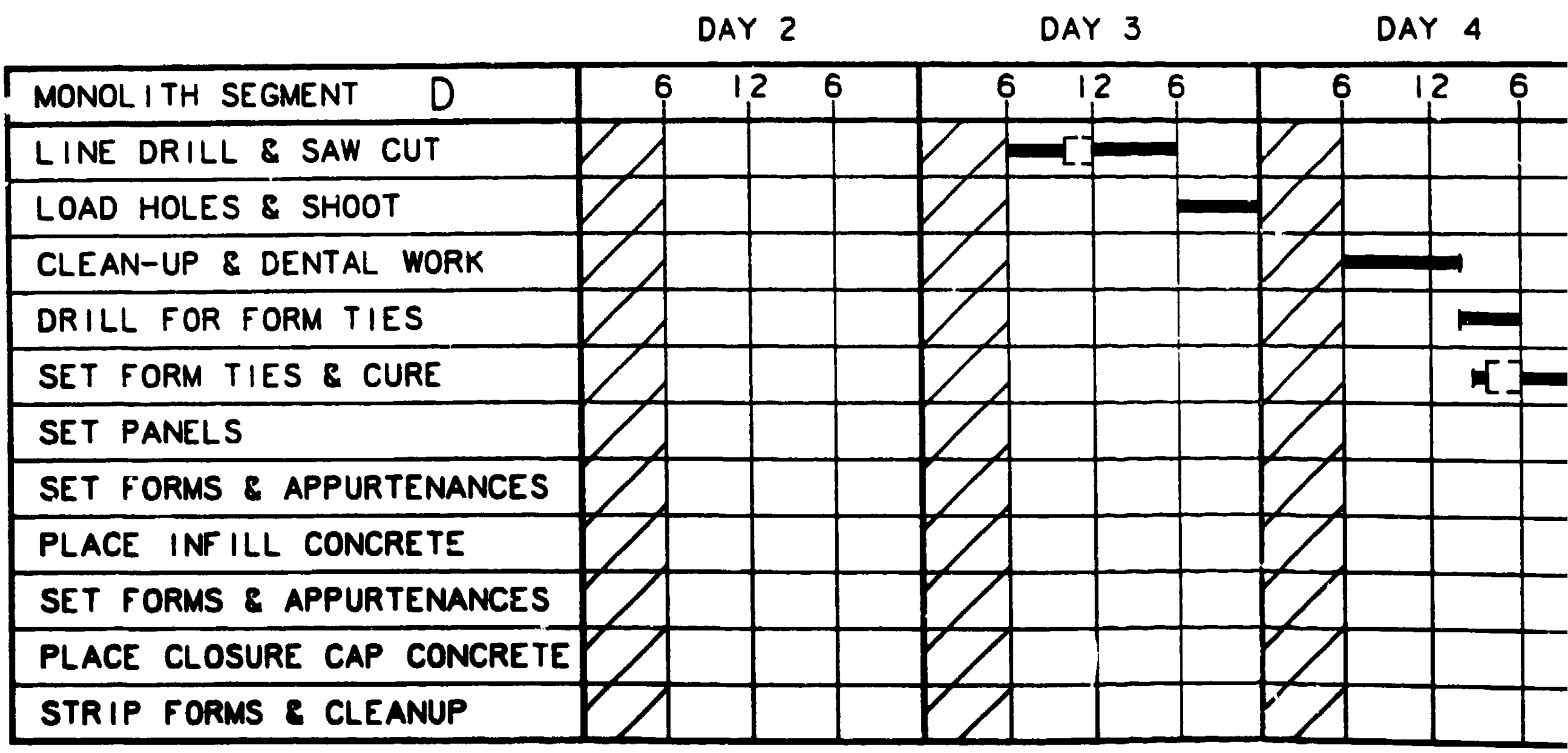


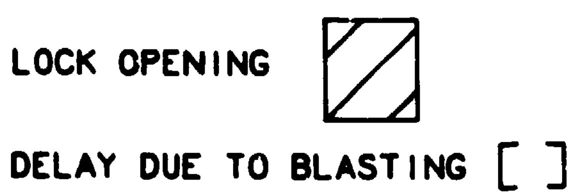
FIGURE 28
REPAIR SCHEDULE IN
AN OPERATIONAL LOCK



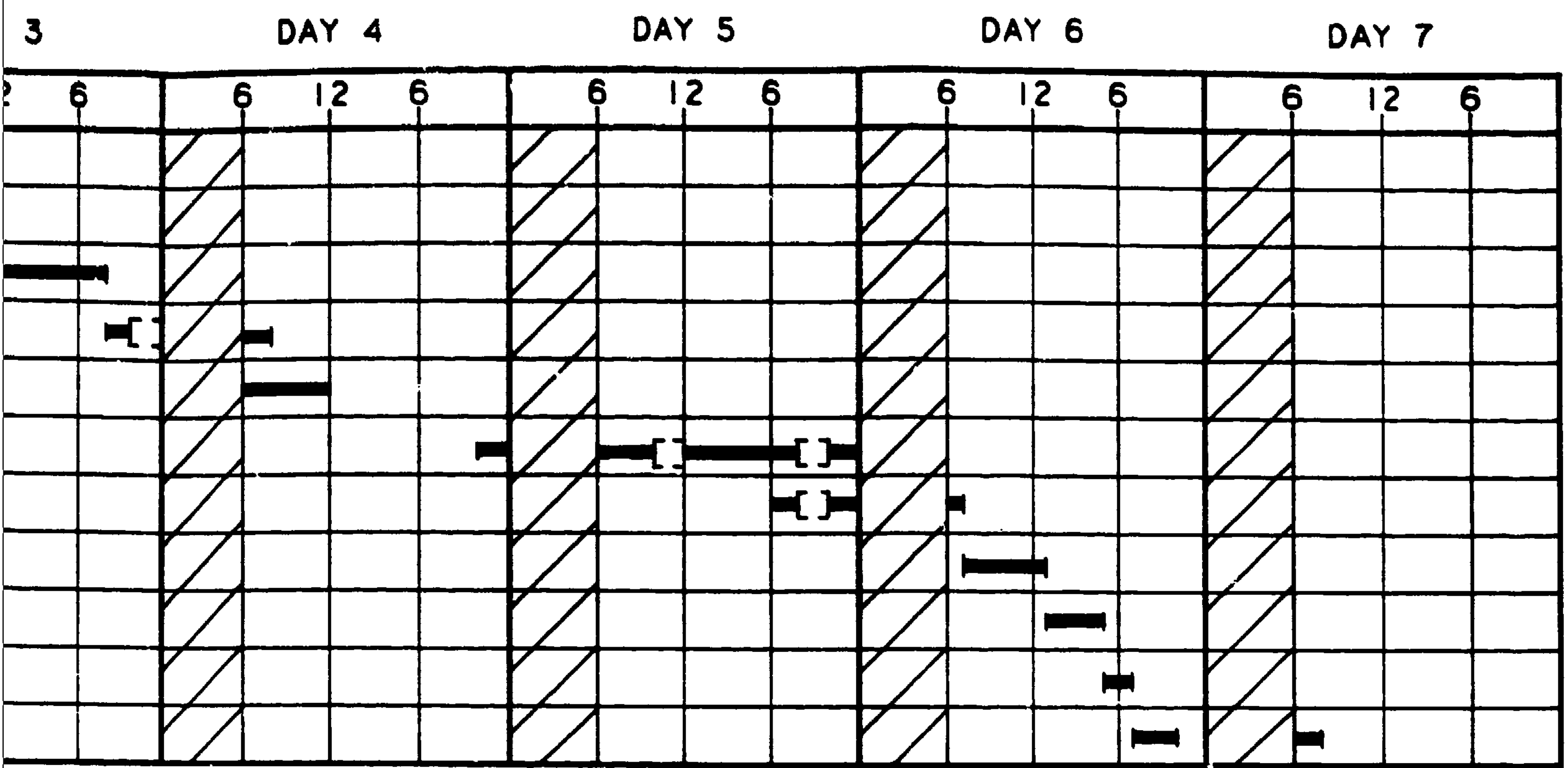
DAY 2
DAY 3
DAY 4
MONOLITH SEGMENT C
6 12 6
6 12 6
6 12 6
LINE DRILL & SAW CUT
LOAD HOLES & SHOOT
CLEAN-UP & DENTAL WORK
DRILL FOR FORM TIES
SET FORM TIES & CURE
SET PANELS
SET FORMS & APPURTENANCES
PLACE INFILL CONCRETE
SET FORMS & APPURTENANCES
PLACE CLOSURE CAP CONCRETE
STRIP FORMS & CLEANUP



DAY 2
DAY 3
DAY 4
MONOLITH SEGMENT D
6 12 6
6 12 6
6 12 6
LINE DRILL & SAW CUT
LOAD HOLES & SHOOT
CLEAN-UP & DENTAL WORK
DRILL FOR FORM TIES
SET FORM TIES & CURE
SET PANELS
SET FORMS & APPURTENANCES
PLACE INFILL CONCRETE
SET FORMS & APPURTENANCES
PLACE CLOSURE CAP CONCRETE
STRIP FORMS & CLEANUP



LOCK OPENING
DELAY DUE TO BLASTING [ ]



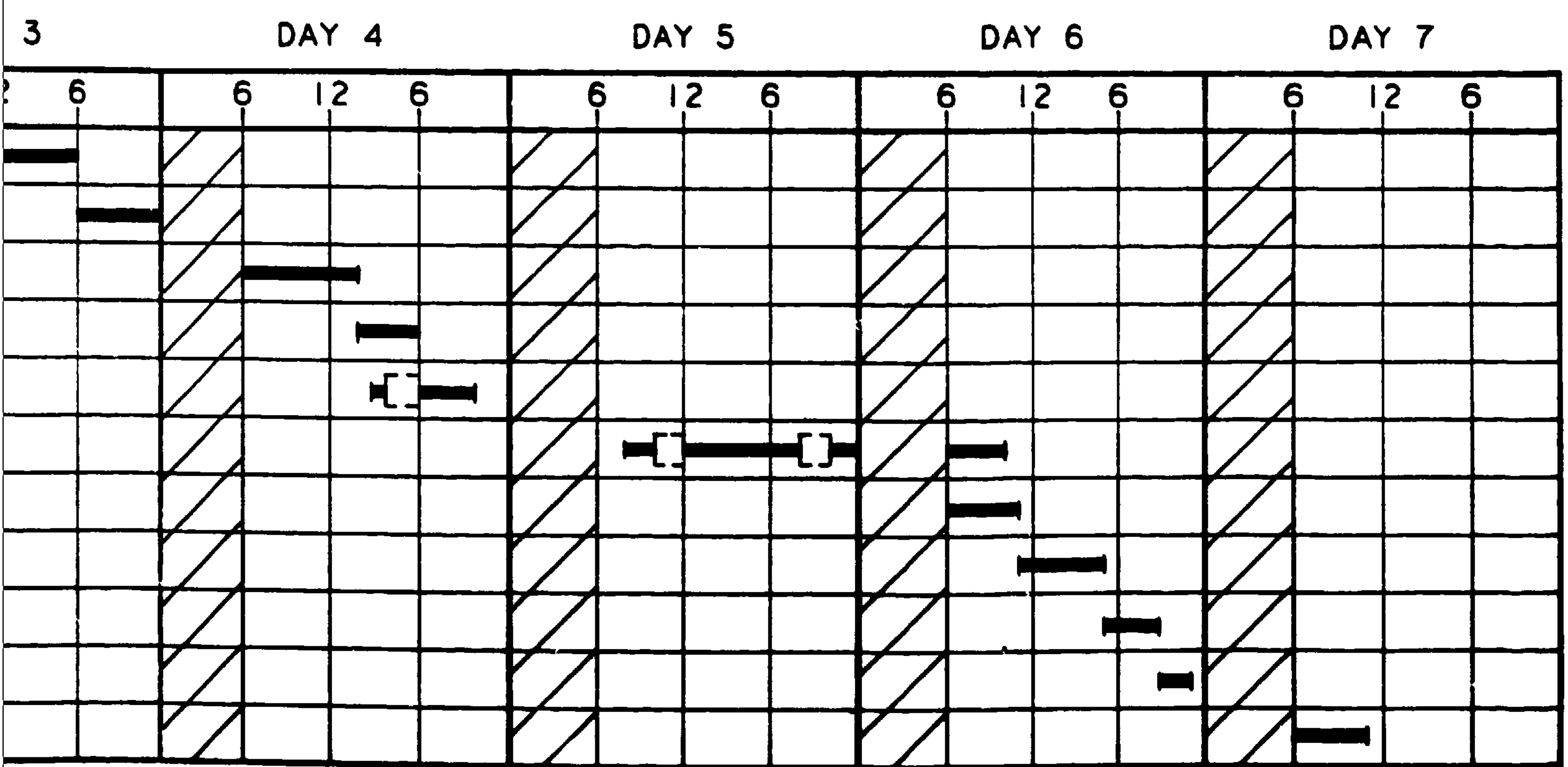


FIGURE 28A
REPAIR SCHEDULE IN
AN OPERATIONAL LOCK

148 hours or 37 hours per monolith. Figure 28A can be aligned below Figure 28 to follow the work sequence.

Future Enhancements

105. The demonstration not only provided an evaluation of the overall repair concept but also enabled a review of the performance of specific details incorporated into the work and the efficiency of various work procedures. A number of features which can enhance both the cost and schedule impacts if they are incorporated into future full-scale lock rehabilitations were identified. The following is a compilation of these features:

- a. The rake finish on the interior face of the panel should be stopped short of the bearing surface for the alignment angle. The bearing area should be finished to a high tolerance.
- b. During precasting of the panels, steel embedments must be more positively attached to the forms through use of bolts, drift pins, or welding. If clamping is used, adequate force should be applied and the clamps should remain in place until the concrete has sufficiently stiffened.
- c. Shear key forms should be constructed from thicker steel and stiffened to maintain true alignment through repeated use.
- d. The lifting loops along the interior face of the panel should be removed prior to the placement of infill concrete unless they can be oriented in line with the ties. Otherwise, they congest the space available for trunks, pump hoses, and stingers used in placing and consolidating the infill concrete.
- e. Any inserts necessary for erection or for holding formwork should be cast into the panels. No drilling should be allowed in the precast panels near corners or edges.
- f. The shear keys should be stopped short at ends of panels that contain corner armor; otherwise, there will be an erection conflict. Also, the alignment angle should be stopped approximately 2 in. short of the panel end if there is a case where the side of the panel and infill concrete are exposed.
- g. The details of the alignment screw receptacle cast into the panel should incorporate a means of holding the alignment screw in place while the panel is erected.

h. The projection of the ties should be stopped 1/2 in. behind the back face of the panel in order to allow the panels to be erected vertically.

i. The thickness of the finger plate for the welded tie connection should be oversized by approximately 1/4 in. This would enable using a thinner plate if the height of the panels creeps upward. Bending reinforcing bars should be avoided regardless of whether they are bent cold or heated.

j. A welding procedure must be developed that does not overheat embedded plates and cause expansion and cracking along the shear key. Single-pass welding may be required. An alternate detail may be to wrap foam tape around the embedded plate, which will accommodate the expansion of the steel without cracking the panel.

k. Separate mechanical ties which could be used to assist with panel alignment would be beneficial at the corners of the panel.

l. Faster curing epoxy formulations which would reduce the required curing time are available.

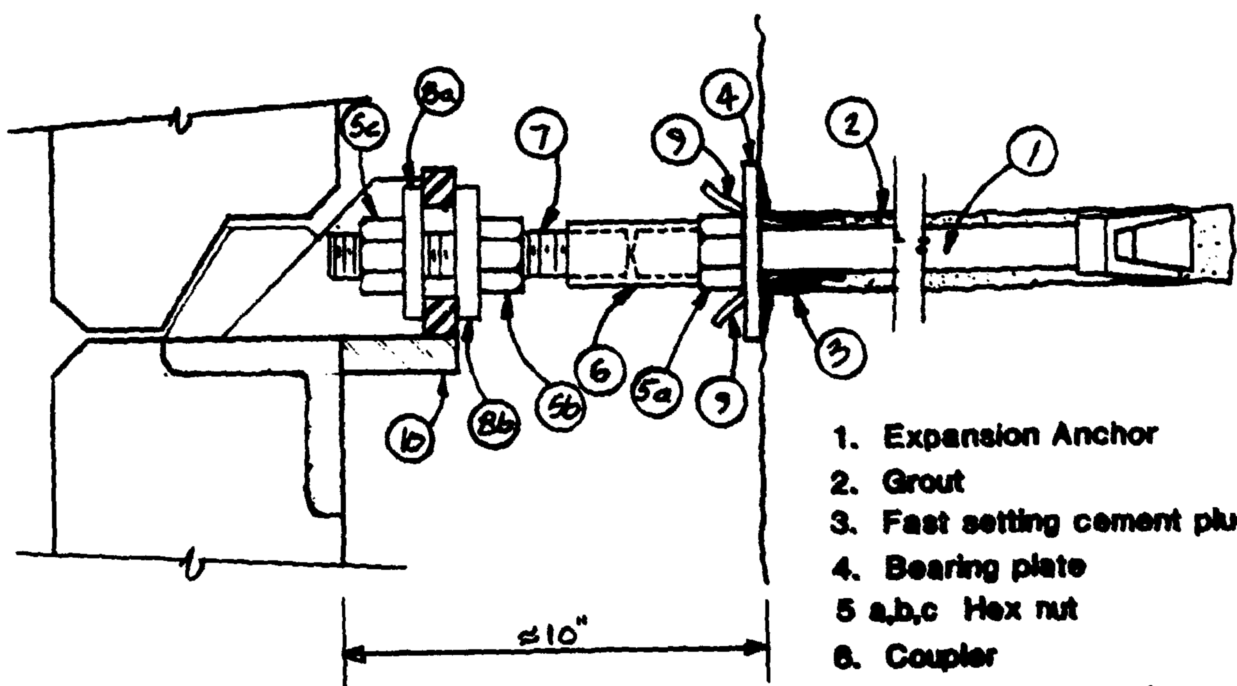
m. To eliminate the curing period for the epoxy grout, a rock anchor or expansion bolt may be considered for the tie which can be loaded immediately after the expansion wedge is seated. The void can be grouted at any time to provide corrosion protection. Details that incorporate tolerance on the installation and attachment to the panel have been conceptually shown in Figure 29. An approximate 10-in. space is needed behind the panel to incorporate all components of the tie as compared to the 5-1/2-in. space for welded ties. A cost/schedule comparison must be made to determine whether welded or expansion anchor ties are the optimum means of attaching panels to the monolith. As an alternative, several tie options can be incorporated with the contract documents, and the contractor can be allowed to select the one that results in the most favorable cost and schedule.

n. The use of a more compressible neoprene seal should be considered to overcome some of the potential unevenness of the shear key form and to prevent cement paste leaks during placement of the infill concrete. One possibility is to cast half-round voids in the upper and lower panels and to use a hollow neoprene tube.

o. If completely watertight joints are desired, the use of grout tubes in conjunction with the neoprene seals should be considered. The grout would be injected subsequent to the placement of the infill concrete. The Corps has successfully used a system manufactured by de Neef to seal vertical joints. The nonshrink grout installed during the demonstration did not appear to provide a watertight joint and should be eliminated for the full-scale repair. Another system manufactured by

FEATURES

1. Ties can be loaded immediately
2. Grout is provided for corrosion protection only
3. Ties can be installed in the wet
4. Tolerance on hole location 1/2"
5. Tolerance on wall excavation 1"



1. Expansion Anchor
2. Grout
3. Fast setting cement plug
4. Bearing plate
5 a,b,c Hex nut
6. Coupler
7. Threaded extension
8 a,b Washer plates
9 Grout tubes
10. Panel attachment bracket

NOTE: Items 5b and 8b are for erection and are optional.

Figure 29. Expansion anchor tie detail

de Neef that may have potential application is a seal that expands upon contact with water.

p. Slumps for the infill concrete must be 4 in. minimum. When trunks are used to deposit the concrete, a 5-in. slump is preferable. A more "flowable" concrete obtained with the addition of superplasticizer should solve the slump problem and save time. The diameter of the trunk should be limited to the width of the void between the monolith face and interior face of the panel. The use of a concrete pump with a hose extending to the bottom of the void should be considered in lieu of the bucket, hopper, and trunk combination used for the demonstration.

q. Additional vibrators, trunks, and other equipment should be available on site in case the original equipment is damaged or possibly lost in the infill. High-intensity lighting should be directed into the void to assist in concrete placement and consolidation efforts. In particular, the tip of the trunk or hose must be watched closely to prevent its becoming submerged in the concrete pour.

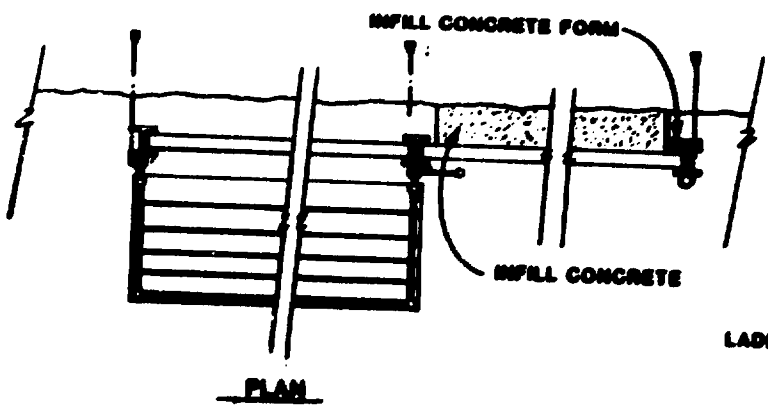
r. Angles or other structural shapes should be embedded in the infill concrete at the top of the pour for use in securing closure pour formwork and for supporting corner armor. Tack welding to rebar dowels should not be permitted.

s. A procedure in which aggregate is preplaced and then injected with grout has been suggested as another option for the infill material.

t. Work platforms (fixed or floating) or scaffolding should be developed that are mobile and easily retracted during lock openings. Some of the features to incorporate in the scaffolding may include power-adjusted platform levels, templates or guides for drilling, a reference system to determine erection tolerances and other measurements relative to the original lock surface, and a means for guiding the panels during erection. Figure 30 shows one possible concept.

u. Other alignment methods, such as rails mounted vertically at monolith joints, should be considered in guiding panels into their final position.

v. The mooring hook installed during the demonstration was precast into the panel to interlock with dowels extending from the monolith and vertical reinforcing bar placed after panel erection. The path of the mooring load is through the infill concrete and into the dowels. There are advantages to connecting the mooring hook directly to dowels or ties extending out of the monolith. There are also advantages to casting the mooring hook into a CIP closure pour rather than into the panel.



NOTES
1. COMPLETE MAJOR EXCAVATION/DEMOLITION WORK.
2. INSTALL GUIDE WHALER FRAME TO REQUIRED TOLERANCES USING GRID SYSTEM SURVEYED ALONG TOP OF MONOLITH.
3. INSTALL REQUIRED NO. OF WORK PLATFORMS TO COMPLETE HAND EXCAVATION, DRILLING, AND TIE INSTALLATION. USE TEMPLATES REFERENCED OFF GUIDE WHALER FOR GREATER ACCURACY.
4. RAISE PLATFORMS AS WORK PROCEEDS UPWARD.
5. AFTER COMPLETING SURFACE PREP, ERECT PANELS BY SLIDING INTO GUIDE WHALER. AFTER ALL PANELS ARE ERECTED, INSTALL INFILL CONCRETE FORMS OFF WHALER AND PLACE INFILL CONCRETE.
6. REMOVE INFILL CONCRETE FORMS, WHALER BOLTS AND SET GUIDE WHALER FRAME FOR NEXT MONOLITH. REPEAT ERECTION PROCEDURE.
7. DURING LOCK OPERATIONS, REMOVE ALL PLATFORMS AND RETRACT JIB CRANE AS NECESSARY.

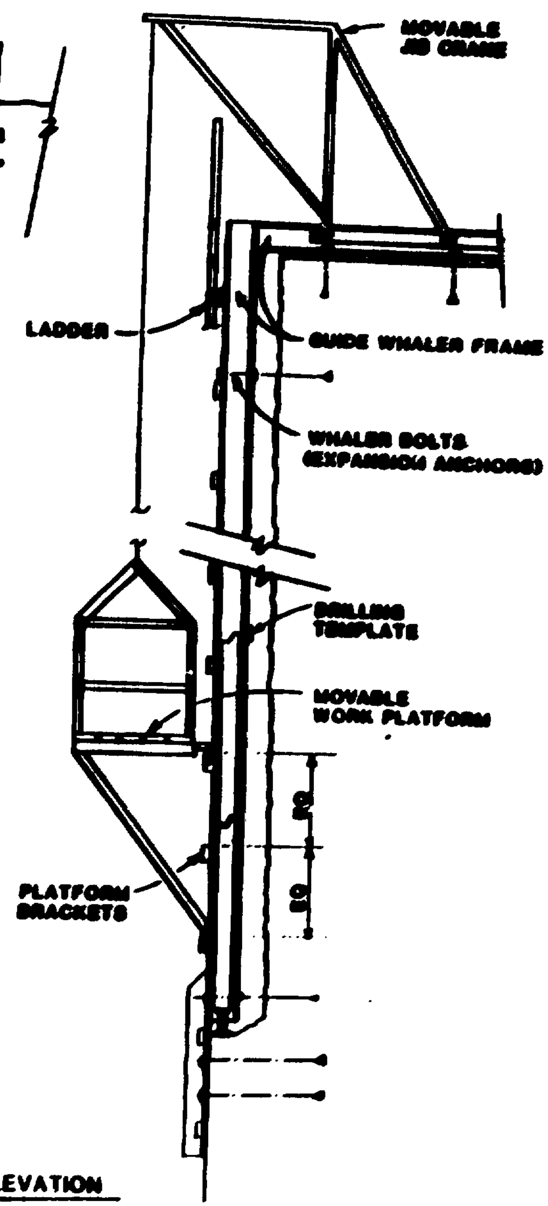


Figure 30. Erection concept

Concept Implementation

106. During Phases I and II of this research effort, many of the details of the precast panel repair procedure were developed and their functionality demonstrated. However, a number of items were addressed in concept only and require additional development and design prior to their incorporation in an actual full-scale lock repair. Several items were addressed in the previous section that would be enhancements to future installation, but these require additional investigation as well. A number of items that require more development are summarized below:

a. Detailed design of connections between ladders and floating mooring bits and the precast panels is needed. Also needed are design and detailing of a mooring bit with a direct load path into the lock wall.

b. Additional development of connections for the bottom panel is needed where these occur below low pool elevation. Detailed design of connections and support mechanisms must be completed for the preferred alternative.

c. A mechanical connection with expansion anchors appears feasible; however, cost and time estimates should be conducted to identify potential benefits. If a mechanical connection is preferred, design and detailing of the components must be completed.

d. Additional details for the joints have been suggested, including a better means of sealing the joint and possibly grouting the joints after placing infill concrete. Details that incorporate these features need to be developed and reviewed to determine their potential benefit in a full-scale installation.

e. As an outgrowth of the current phases of work, a next phase may be to perform an actual installation in a portion of a lock and to monitor the performance of the system prior to proceeding with a full-scale repair. This installation would enable incorporating additional features that could not be accommodated in the Phase II installation, demonstrate the construction in an actual lock, and enable incorporating the refinements identified in the Phase II work. In particular, the measures suggested for crack reduction in the precast panels could be verified. The result would be a more precise understanding of the schedule and cost impacts of the precast repair procedure.

PART VIII: QUALITY CONTROL PLAN

107. The success of rehabilitation to navigation lock walls with the stay-in-place concrete forming system is dependent upon good quality control procedures, both in the production and erection of panels. During precasting, thorough quality control monitoring must be performed to provide durable concrete that results in panels that have minimum cracking. In addition, overall tolerances of panel sizes and locations of embedments must be accurate to enable erection of panels to the required erection tolerances. A quality control plan has been developed and included in Appendix E which demonstrates the level of quality control measures that this rehabilitation method would require for a full-scale navigation lock repair. This plan has been developed from the perspective of a general contractor and in a format that would satisfy Corps of Engineers' standard submittal requirements for a quality control plan.

REFERENCES

ABAM Engineers Inc. 1987. "Design of a Precast Concrete Stay-in-Place Forming System for Lock Wall Rehabilitation," Technical Report REMR-CS-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

American Concrete Institute Committee 224. 1980. "Control of Cracking in Concrete Structures," Concrete International, Vol. 2, No. 10, pp. 35-76, American Concrete Institute, Detroit, MI.

American National Standards Institute. 1979 (Sept). "Structural Welding Code -- Reinforcing Steel," Standard D1.4.79, American Welding Society, Miami, FL.

Hurd, M.K. 1979. "Formwork for Concrete," SP-4 (4th Edition), American Concrete Institute, Detroit, MI.

** Revisions to specifications
29 May 1987

APPENDIX A: CONSTRUCTION SPECIFICATIONS
PHASE II DEMONSTRATION PROJECT

SECTION 1
GENERAL PROVISIONS

1.1 GENERAL

1.1.1 Description of Work

a. This work consists of demonstrating the feasibility of repairing deterioriated navigation lock wall surfaces through the use of precast, stay-in-place concrete form panels in conjunction with cast-in-place concrete bonding layers. This work will be performed on dry land at the Corps of Engineers, Waterways Experiment Station, on two existing one-half scale lock wall mock-up sections.

b. The work includes providing all materials, labor, inspections, tests, and supervision required for a complete installation as shown on the drawings and described in these specifications.

1.1.2 Definitions

a. Corps: Shall mean the Corps of Engineers who is responsible for commissioning the work. The Corps shall have the final determination regarding interpretation of contract drawings and specifications.

b. Engineer: Shall mean ABAM Engineers Inc. who is responsible for design of the precast concrete stay-in-place forming system and who shall perform reviews of Contractor's submittals, independent inspections, and surveillance of the work, and whose personnel will be available to provide direction of the work and interpretation of the design requirements.

c. Contractor: Shall mean Premier Waterproofing, Inc. who is responsible for performing all work as described in the specifications and on the drawings.

1.1.3 Prosecution of the Work

a. The stay-in-place precast form demonstration project will be carried out at the Corps' Waterways Experiment Station in Vicksburg, MS. Contractor shall be required to abide by Corps' rules and regulations in regards to the use of and access to Corps' facilities. Such regulations shall include requirements for environmental protection, health and safety, security and labor relations.

b. Corps' and Engineer's personnel will be performing inspections and tests in conjunction with Contractor's work. Full cooperation shall be given to Corps' and Engineer's personnel to install instrumentation and to monitor and inspect the work.

c. Direction of the work will be given by the Engineer. In case of conflict, Contractor shall notify Engineer for resolution.

1.1.4 Quality Control

a. Contractor shall perform all work in accordance with referenced specifications and standards.

b. Contractor shall maintain records of tests and inspections as required to demonstrate compliance with referenced standards. Such records shall be made available to the Engineer or to the Corps upon request.

1.1.5 Submittals

a. Contractor shall submit copies of all required drawings, test results, inspections, and documentation as required by these specifications to the Engineer. Contractor shall allow 7 days for review of submittals by Engineer.

b. Submittals will be reviewed by the Engineer for compliance with the contract requirements and returned either reviewed without comment, disapproved, or reviewed with comment. For those submittals disapproved or reviewed with comments, Contractor shall make the required changes and resubmit such submittals for rereview.

c. Contractor shall not proceed with work contingent upon Engineer's review until satisfactory review of necessary submittals has been completed, unless written direction to proceed is received from the Engineer.

d. Contractor shall supply samples of materials used in the work to Corps' or Engineer's personnel as requested. Such samples will be considered incidental to the work and will be used by the Corps or Engineer to verify material properties or performance.

1.1.6 Housekeeping and Cleanup

a. Contractor shall maintain work area in a neat and orderly fashion. Work area shall be cleaned daily at the close of work.

b. Refuse, shipping and packaging materials, wasted material and products, and discarded samples shall be disposed of as required by the Corps.

1.1.7 Project Photographs

The Contractor shall submit five copies of a photographic report consisting of approximately 30 photographs showing the different stages of construction. Photographs shall be taken by a competent photographer and shall be black and white, standard commercial quality, 8 x 10 in. in size and on single-weight glossy paper. The negatives of all photographs shall also be submitted.

The photographs shall be enclosed in standard three-ring binders in back-to-back double-faced plastic sleeves. Each print shall have an information band along the front bottom edge with a description of the photograph's content, reference negative number, and date photograph was taken.

As a minimum, pictures of the following items or activities shall be included in the report:

- Formwork and formwork details
- Reinforcement installed in the forms
- Steel hardware with views of hardware positioned in the forms
- Precast panel casting operation
- Panel handling and transportation
- View of the existing monolith with surface prep completed
- Tie and dowel hole drilling
- Tie and dowel installation
- Tie and dowel testing
- Panel installation, including completed tie connection, installation of seals and grout layer.
- Placement of the infill concrete
- Details of auxiliary formwork and reinforcement for the closure cap
- General view of the completed installation

SECTION 2
PRECAST CONCRETE

2.1 GENERAL

2.1.1 Work Included

The work includes all materials and workmanship required for fabrication, delivery, handling, and erection of precast concrete leave-in-place form panels.

2.1.2 Related Work

Related work includes fabrication of lock hardware and appurtenances and production and placing of cast-in-place concrete work.

2.1.3 Refcrences

a. American Concrete Institute. 1983. "Building Code Requirements for Reinforced Concrete (ACI 318-83)," ACI Standards 1963, Detroit, MI.

b. American National Standards Institute. 1979 (Sept). "Structural Welding Code -- Reinforcing Steel," Standard D1.4-79, American Welding Society, Miami, FL.

c. Gustafson, David P. et al. 1984. "Specifications for Structural Concrete for Buildings," ACI-301-84, American Concrete Institute, Detroit, MI.

d. Prestressed Concrete Institute. 1985. Manual for Quality Control for Plants and Production of Precast and Prestressed Concrete Products, 3rd edition, Chicago, IL.

e. ______________________. 1985. PCI Design Handbook: Precast and Prestressed Cocnrete, Chicago, IL.

2.1.4 Submittals

a. Contractor shall submit shop and erection drawings for all precast elements. Drawings shall indicate fabrication details, reinforcing, connection details, support items, dimensions, and temporary attachments and work.

b. Contractor shall submit details showing proposed methods of lifting, handling, storing, and erecting precast elements.

c. Weights of precast elements shall be computed and listed on shop drawings.

d. Contractor shall submit results of tests on materials as specified in Paragraphs 2.2.1 and 2.3.3.

e. Concrete mixture proportions and qualifying data shall be provided.

f. Catalog cuts of other miscellaneous products to be incorporated into the work such as nonshrink grout, joint seals, tie and dowel bonding agents, etc., shall be provided.

2.1.5 Quality Control

a. All work shall be performed in accordance with PCI Design Handbook - Precast and Prestressed Concrete, and ACI 301 Structural Concrete for Buildings.

b. Precast concrete work shall be performed by either experienced fabricators qualified in accordance with PCI MNL-116, Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products, or shall be performed by an on-site developed precasting facility meeting the requirements of PCI MNL-116. **

2.1.6 Delivery, Storage, and Handling

a. Delivery, storage, and handling of precast concrete elements shall be performed in such a manner as not to adversely affect their appearance or use. Panels shall not be lifted from the forms until panel strength has reach 0.7 f'_c.

b. Design of lifting embedments and handling devices shall be the responsibility of the Contractor. Contractor shall provide details of proposed lifting methods, attachments, and devices for engineer's review. Handling embeds shall not be installed in the exposed exterior face of the panels.

c. Panels shall be lifted only from suitably designed lifting hardware embedded into the panel or with the use of slings properly placed and rigged to prevent damage to the panels.

d. Panels shall be adequately supported at all times with suitable cribbing and bracing during shipping and storage to prevent inadvertent damage from incidental loads or movements. Panels greater than 15 ft in length shall be stored in a vertical position. **

2.2 PRODUCTS

2.2.1 Materials

a. Concrete: Precast concrete materials shall conform to the following requirements:

- Cement: Cement shall conform to the requirements of ASTM C 150.

- Aggregate: Aggregate shall conform to the requirements of ASTM C 33.

- Air-entraining admixture: Material shall conform to ASTM C 260.

- Water-reducing admixture: Material shall conform to ASTM C 494.

- Pozzolan: Pozzolan shall conform to ASTM C 618.

Precast concrete mixture shall be designed to satisfy the following requirements. Prior to commencing operations, the Contractor shall furnish the proportions of all ingredients that will be used in the manufacture of precast concrete panel elements.

Concrete mixture proportions shall be selected to satisfy the following requirements. The proportions may be based on past field experience or on trial mixtures in accordance with ACI 318, paragraphs 4.2 and 4.3. Contractor shall provide data demonstrating that the proposed mixture satisfies the following requirements:

- Minimum 28-day compressive strength: 6,500 psi
- Maximum coarse aggregate size: 3/4 in. nominal
- Minimum entrained air: 5 to 7 percent
- Maximum water cement ratio: 0.40
- Minimum cement content: 540 lb/cy (6-sack mixture)
- ~~High range water reducer (maximum): 5 oz/100 lb cement~~ **
- Slump: 3-1/2 in. ±1/2 in. **

b. Reinforcing: Mild steel reinforcing shall be new billet steel bar conforming to the requirements of ASTM A 615, Grade 60.

c. Ties: Weldable grade reinforcing steel conforming to the requirements of ASTM A 706, Grade 60, shall be used for form ties.

d. Prestressing strand: Prestressing strand, if used, shall conform to the requirements of ASTM A 416, Grade 270.

e. Welded wire reinforcement: Welded smooth wire fabric shall conform to the requirements of ASTM A 185.

~~f. Nonshrink grout: Grout for horizontal construction joints shall be a prepackaged, cementitious based, natural aggregate, nonshrink grout. Mixing water shall be added in accordancewith the manufacturer's recommendations to obtain a plastic consistency which will level off and redistribute under the pressure of the upper precast panel.~~ **

2.2.2 Accessories

a. Hardware and accessories shall be incorporated into the work as shown on the drawings. Hardware and accessories shall be fabricated in accordance with Section 4.

b. Epoxy grout shall be Concresive 1441 as manufactured by Adhesive Engineering Co., Carlstadt, NJ, or equal. Epoxy grout shall be mixed and applied in accordance with epoxy manufacturer's recommendations. **

c. Form ties shall be capable of withstanding the full anticipated load of concrete infill placement with a safety factor of at least 3.0 on failure of the tie. Ties shall be anchored to monolith concrete with epoxy grout or polyester resin cartridge anchors.

d. Bearing pads and horizontal joint seals shall be preformed neoprene material of the size, dimensions, and characteristics shown on the drawings. Vertical joint seals shall be an asphalt- or neoprene-rubber-impregnated, open-cell foam. **

2.2.3 Fabrication

a. Precast panels shall be fabricated to the dimensions shown on the drawings. Dimensional tolerances shall not exceed those specified in Section 2.2.4.

b. All reinforcing, inserts, hardware, and appurtenances shall be located as required and securely anchored to prevent movement during concrete placement.

c. Contractor shall moist-cure precast panels until the concrete reaches a minimum strength of 0.7 f'_c. Precast concrete panels may be steam cured. Control of concrete temperature during the steam cycle shall be maintained per the guidelines of PCI MNL-116. ~~Membrane curing compound shall be applied to the outside surface of the panel after completion of the moist-curing cycle.~~ **

d. Panels shall not be erected until concrete strength has reached 6500 psi.

2.2.4 Tolerances

a. Dimensional Tolerances for Precast Panel Fabrication

- Length: ±1/2 in.
- Width: ±1/4 in.
- Thickness: ±1/2 in. except ±1/16 in. at alignment angle contact surfaces. **

- o Edge squareness: ±1/8 in.

- o Planeness (measured with respect to a straight line drawn between any two opposite edges).

  - Outside surface: ±1/4 in.
  - Inside surface: 1/2 in.

- o Location of embedments: ±1/8 in. **

b. Location Tolerance for Precast Panel Erection

- o Plumbness or vertical alignment over full height of monolith section: ±1/2 in. **

- o Variation in horizontal alignment per three monolith widths: ±1/2 in. **

- o Precast element joint to joint alignment.

  - Horizontal joints: ±3/16 in. **
  - Vertical joints: ±3/16 in. **

2.2.5 Finishes

Precast panels shall have a smooth dense finish on the outside, exposed surface such as is typical of steel form or high density overlaid plywood forms. The inside panel surface shall be clean, free of laitance, and shall be intentionally roughened to an approximate amplitude of 1/4 in. Surfaces that contact alignment hardware shall be trowel finished. The surface shall be cleaned by high-pressure water spray immediately prior to erection. **

2.3 EXECUTION

2.3.1 Preparation

a. Contractor shall inspect and survey all existing work prior to fabricating and installing panels. Dimensional discrepancies shall be immediately brought to the attention of the Engineer.

b. Contractor shall prepare a written procedure for erection indicating lifting, temporary bracing, support and alignment methods. Sequence of operations and inspection hold points shall be identified.

2.3.2 Erection

a. Precast panels shall be erected as shown on the drawings. Tolerances shall be as specified in Section 2.2.4.

b. Panel form ties shall be securely fastened. Temporary supports and braces shall be used as necessary to maintain alignment.

c. ~~Nonshrink grout joint sealant;~~ Bearing pads, and neoprene seals shall be installed and applied as required on the drawings. Care shall be taken to prevent seals from being displaced during panel installation. **

d. Form tie holes shall be drilled into the monolith with suitable concrete drilling equipment. Ties shall be installed and set with epoxy grout or polyester cartridge anchors. Form tie grout shall be allowed to set for a minimum of 24 hours prior to the erection of the precast panels. Form ties shall be embedded and grouted to develop a minimum ultimate tensile load of 33 kips when tested in accordance with Section 2.3.3.f. <u>Reinforcing dowels shall be installed to obtain a minimum ultimate tensile load of 26.4 kips when tested in accordance with Section 2.3.3.f.</u> **

2.3.3 <u>Inspections and Tests</u>

a. Contractor shall be responsible for inspection of panel fabrication and erection activities to ensure that the work conforms in all respects to the drawings and specifications. A record of inspections and inspection results shall be maintained for Engineer's review.

b. Contractor shall inspect precast panel form prior to casting to ensure dimensional configuration and location of all embedded items.

c. Contractor shall inspect panels after installation to ensure that they conform to location tolerance and that they are securely tied and braced for infill concrete placement loads.

d. Contractor shall sample and test concrete used in panel fabrication as follows:

- o A minimum of two sets of three concrete specimens shall be cast, cured, and tested for each batch of concrete to determine the concrete compressive strength at 7 and 28 days. Contractor may make additional specimens to monitor strength gain during concrete curing.

- o Determine slump of concrete mixture at time of placement.

- o Determine air content of the concrete at time and point of placement.

e. Contractor shall provide to the Corps or the Engineer, for independent testing and analysis, such additional cast specimens of concrete as may be requested.

f. Contractor shall install a minimum of two additional form ties and two additional dowels at a convenient location in the monolith as directed by the Engineer. Contractor shall conduct tensile testing of the installed ties and dowels to determine their minimum ultimate load. The minimum ultimate load of the tie or dowel shall be that load at which it ruptures, slips excessively, or exhibits greater than 1/4 in. of total deflection between the face of the monolith and the connection to the form. The average of the two tension tests shall be used to establish the ultimate load of the ties and dowels.

g. All load tests shall be performed with calibrated jacks and pressure gages. Elongations shall be measured using dial gages. The load tests for the No. 7 test ties shall be conducted using epoxy grout cure times and temperatures representative of actual production ties. The cure time is defined as the time between the tie installation and application of the infill concrete pressure. The load for the No. 7 form ties shall be applied in four equal increments with elongations measured at each increment. The final increment shall be the required ultimate tensile loads. This load shall be maintained for 1 hour with periodic recording of elongation measurements. Tests of the No. 6 dowels shall be identical, except that the 1-hour sustained load will not be required. **

2.3.4 Cleanup

a. Contractor shall immediately remove spills or runs of epoxy, grout, or other materials used in the construction from the outside surface of precast panels.

b. Contractor shall maintain work areas clean and free of rubble, discarded product containers, packaging and shipping materials and other refuse.

SECTION 3
CAST-IN-PLACE CONCRETE

3.1 GENERAL

3.1.1 Work Included

The work includes all materials and workmanship required for production, delivery, placing, and curing of cast-in-place concrete.

3.1.2 Related Work

Related work includes fabrication of embedded lock hardware and appurtenances, and fabrication and erection of precast concrete leave-in-place form elements.

3.1.3 References

a. American Concrete Institute. 1983. "Building Code Requirements for Reinforced Concrete (ACI 318-83)," ACI Standards 1963, Detroit, MI.

b. Gustafson, David P. et al. 1984. "Specifications for Structural Concrete for Buildings," ACI-301-84, American Concrete Institute, Detroit, MI.

3.1.4 Submittals

a. Contractor shall submit concrete mixture proportions and test results as specified in Paragraph 3.2.1.a, below.

b. Contractor shall submit batch monitoring test results for infill concrete placements as required by Paragraph 3.3.3.b, below.

3.1.5 Quality Control

a. All work shall be performed in accordance with ACI 301 and 318 as applicable.

b. Contractor shall maintain records of tests and inspections as required herein, and make copies of such records available to Engineer on request.

3.2 PRODUCTS

3.2.1 Materials

a. Concrete: Cast-in-place concrete materials shall conform to the following requirements:

- o Cement: Cement shall conform to the requirements of ASTM C 150.

- o Aggregate: Aggregate shall conform to the requirements of ASTM C 33.

- o Air-entraining admixture: Material shall conform to ASTM C 260.

- o Water-reducing admixture: Material shall conform to ASTM C 494, Type E.

- o Water-reducing admixture, high range: Material shall conform to ASTM C 494, Type F. **

- o Pozzolan: Pozzolan shall conform to ASTM C 618.

Prior to commencing operations, the Contractor shall furnish the proportions of all ingredients that will be used in the manufacture of cast-in-place concrete. The mixture proportions shall be accompanied by test results from an independent commercial testing laboratory, attesting that the proportions selected will produce concrete of the required quality. Cast-in-place concrete mixture shall be designed to satisfy the following requirements.

- o Minimum 28-day compressive strength: 3000 psi

- o Maximum coarse aggregate size: 1-1/4 in. nominal **

- o Minimum entrained air: 3% to 5%

- o Maximum water cement ratio: 0.5

- o Minimum cement plus fly ash content: 450 lb/cy (5-sack mixture)

- ~~o High-range water reducer: Type F~~ **
- o Slump: 4-1/2 in. ±1/2 in. **

b. Reinforcing: Mild steel reinforcing shall be new billet steel bar conforming to the requirements of ASTM A 615, Grade 60.

3.2.2 Accessories

a. Hardware and accessories shall be incorporated into the work as shown on the drawings. Hardware and accessories shall be fabricated in accordance with Section 4.

b. Joint seals and joint filler materials shall be as shown on the drawings.

3.3 EXECUTION

3.3.1 Preparation

a. Contractor shall prepare a written procedure for placing concrete, identifying sequence, maximum allowable lift height and placing rate, and a checklist of inspections to be made. Contractor's proposed methods of concrete placement, consolidation, and curing shall be submitted to the Engineer for review.

b. The Contractor shall inspect all existing work prior to placing cast-in-place concrete to verify that such work is complete and ready to receive concrete.

c. The Contractor shall notify Engineer at least 24 hours in advance of any concrete placement.

d. All embedded items and reinforcement shall be securely tied to prevent movement during concrete placement and consolidation activities.

e. Formwork for cast-in-place concrete shall be in accordance with ACI 301.

3.3.2 Concrete Mixing, Placing, and Curing

Production, conveying, placing, consolidation, and curing of concrete shall be performed in accordance with ACI 301 and the following requirements:

a. Truck mixers may be used with written approval of the Engineer. When admixtures are dispensed into the truck at the site, truck capacities and batch sizes shall be selected that enable thorough and complete mixing of all constituent materials.

b. All exposed concrete surfaces shall be cured by application of absorptive mats or fabric kept wet continuously for a minimum of seven days after concrete placement. Membrane curing shall not be used.

c. The Contractor shall measure precast panel movements and deflections before and after placing concrete. The measurements shall be taken at all four panel corners and at the top, bottom, and midheight along a vertical line passing through the middle of the panel. These measurements shall be made for Panels P-1, P-2, and P-7. The Contractor shall submit his proposed measuring procedures to the Engineer for review.

3.3.3 Inspections and Tests

a. The Contractor shall be responsible for inspection and testing of cast-in-place concrete activities to ensure that the work conforms in all respects to the drawings and specifications. Records of inspections and tests shall be maintained for Engineer's review.

b. The Contractor shall provide the following necessary quality control and testing services for each batch of concrete placed:

- o Two sets of three concrete specimens shall be cast, cured, and tested to determine the concrete compressive strength at 7 and 28 days.
- o Determine slump of concrete mixture at time of placement.
- o Determine air content of concrete mixture at time and point of placement.

3.3.4 Cleanup

Contractor shall dispose of wasted concrete in accordance with Corps' requirements. Mixer trucks, pumps, tools, and placing equipment shall be cleaned in designated areas only, and wash water and spoil shall be contained as required.

SECTION 4
HARDWARE AND APPURTENANCES

4.1 GENERAL

4.1.1 Work Included

a. The work shall consist of furnishing all labor, materials, and equipment for fabrication and furnishing of hardware and appurtenances for the navigation lock repair mock-up demonstration, as shown on the drawings and as described in the specifications.

b. Hardware and appurtenances include:

- o Horizontal armor.
- o Vertical armor.
- o Line hook.
- o Top curb armor.
- o Panel joint assemblies.
- o Panel alignment assemblies.
- o Form ties.

4.1.2 Reference Standards

a. American Institute of Steel Construction. 1986. Manual of Steel Construction, 8th edition, Chicago, IL.

b. American Welding Society Structural Welding Committee. 1985 (Feb). "Structural Welding Code -- Steel," AWD1.1-85, American Welding Society, Miami, FL.

c. Steel Structures Painting Council. 1985. "Commercial Blast Cleaning," SSPC-SP-6, Vol 2, Steel Structures Painting Council Painting Manual - Systems and Specification, 4th edition, Pittsburg, PA.

4.1.3 Quality Control

a. Fabricator Qualifications: The fabricator shall be experienced in the fabrication and working of metals, including cutting, bending, forming, welding, and finishing. Fabrication of metal hardware and appurtenances shall be performed in accordance with the AISC Code.

b. Welder Qualifications: Fabricators supplying welded components shall employ only welders, operators, and tackers qualified as outlined in AWS D1.1. Welding practices shall conform to AWS D1.1.

4.1.4 Submittals

a. Contractor shall submit complete shop drawings indicating all shop and erection details, including materials of construction, finishes, methods of fastening, and location of cuts, copes, connections, holes, fasteners, and welds.

b. Contractor shall submit certificates of welder's qualifications prior to start of work of this section.

c. Contractor shall submit mill certificates for structural steel, indicating specification compliance for chemical properties, tensile strength, yield point, and elongation.

d. Contractor shall submit catalog cuts and certificates of compliance for concrete anchors, fasteners, headed studs, and other commercial products incorporated into the work.

4.2 PRODUCTS

4.2.1 Steel

a. Structural steel shapes, plates, and bars shall conform to ASTM A 36, unless noted otherwise.

b. Steel pipe shall conform to ASTM A 53, Type E or S, Grade B, unless noted otherwise.

4.2.2 Bolting Materials and Fasteners

a. Bolting material shall be either ASTM A 307 or A 449 as shown on the drawings. Bolts shall be furnished with matching nuts and washers.

b. Headed studs shall conform to ASTM A 108.

c. Deformed bar anchors shall conform to ASTM A 496.

4.2.3 Other Materials

All other materials not specifically described but required for a complete and proper installation shall be as selected by the contractor subject to approval by the Engineer.

4.3 EXECUTION

4.3.1 Fabrication

a. All structural and miscellaneous steel for hardware and appurtenances shall be fabricated in accordance with the reviewed shop drawings and shall conform to the requirements of the AISC "Manual of Steel Construction."

b. Welding of steel hardware and appurtenances shall conform to AWS D1.1, "Structural Welding Code." Type, size, and spacing of welds shall be as indicated on the reviewed shop drawings. Welding shall be accomplished in a manner which will minimize distortion of the finished parts. Weld splatter and oxides on finished surfaces shall be removed. Unless otherwise noted, headed studs and deformed bar anchors shall be welded using automatically timed stud welding equipment. The Contractor shall perform tests, as recommended by the welding equipment manufacturer, to verify proper operation and settings of the welding equipment.

4.3.2 Surface Preparation and Protective Coatings

a. After fabrication, all steel surfaces shall be blast cleaned in accordance with SSPC-SP-6, "Commercial Blast Cleaning."

b. Iron and steel surfaces to be embedded in concrete in the completed work shall be uncoated.

c. All exposed surfaces of hardware and appurtenances shall be given a shop coat of zinc-rich, rush-inhibitive primer. The dry film thickness of the primer shall be 2 mils minimum. The steel surface shall be prepared, and the primer applied in accordance with the coating manufacturer's recommendations.

d. Steel surfaces to be uncoated shall be free of loose rust, mill scale, oil, and grease.

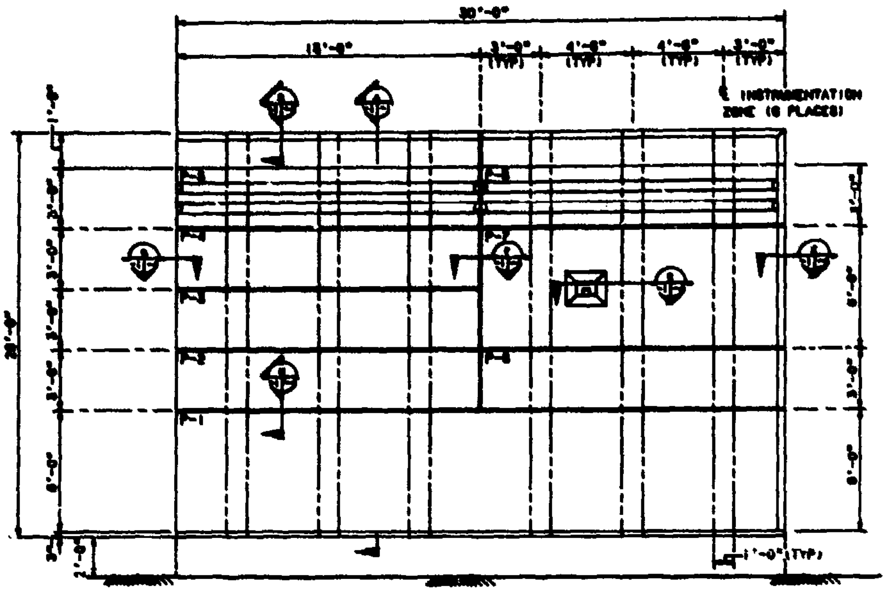
4.3.3 Inspection and Testing

a. The Contractor shall be required to perform such inspections and tests to ensure that all work is performed in full compliance with the contract documents.

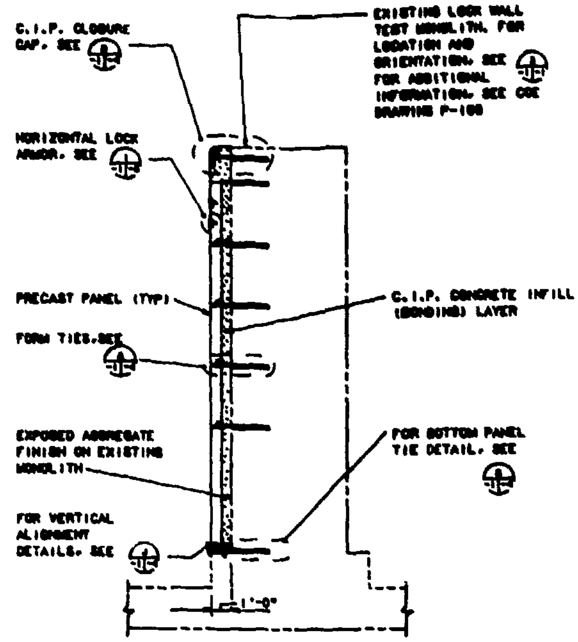
b. Inspection and testing of welding shall be in accordance with AWS D1.1, Section 6.

c. Material and workmanship will be subject to inspection by the Engineer. Testing and inspection by the Engineer will in no way relieve the Contractor of responsibility to furnish materials and construction in full compliance with the contract documents and to provide a quality control program.

APPENDIX B: DESIGN DRAWINGS
PHASE II DEMONSTRATION PROJECT



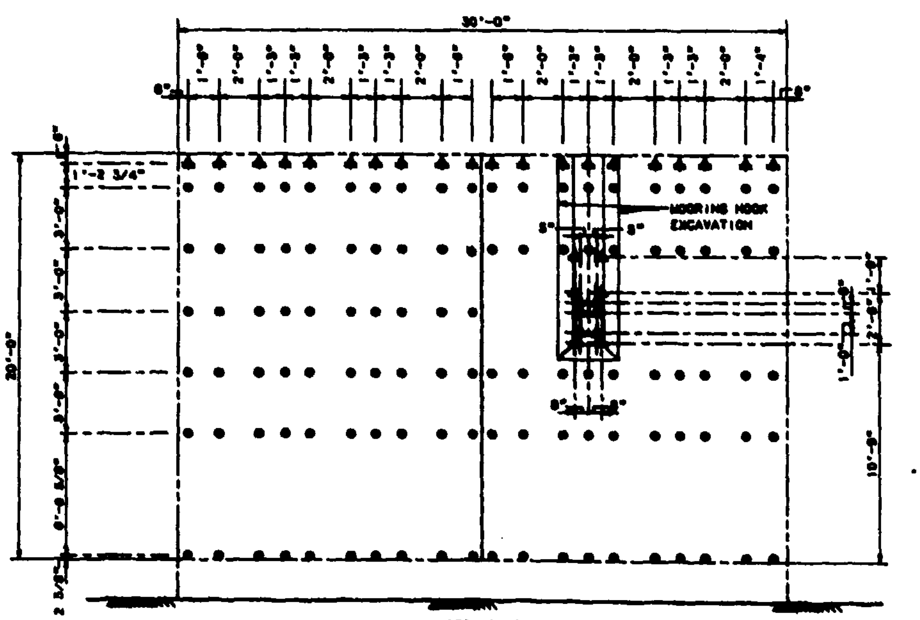
ELEVATION - LOCK SURFACE REHABILITATION MOCK-UP
SCALE: 1/4"=1'-0"



SECTION - LOCK SURFACE REHABILITATION MOCK-UP
SCALE: 1/4" = 1'-0"

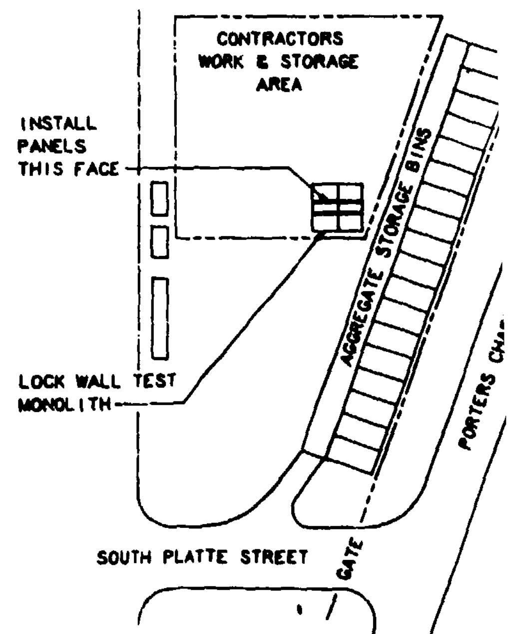
LEGEND:

- ● FORM TIE, SEE
- ♣ #6 BAR DOWELS, SEE &



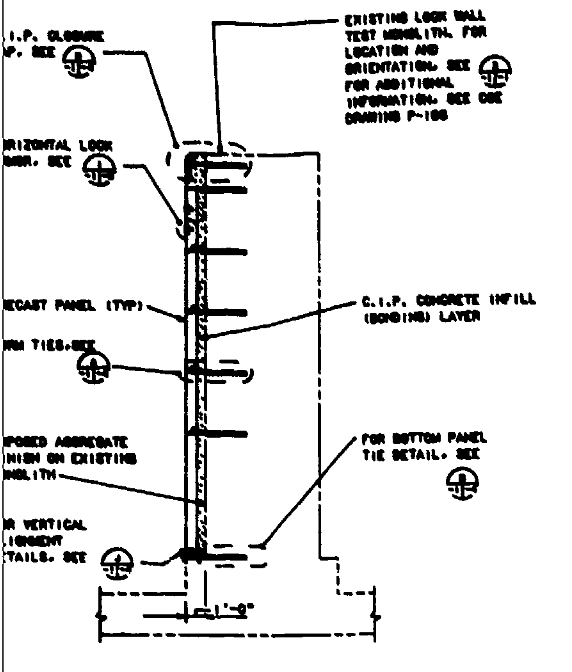
NOTE: TEST FORM TIES AND DOWELS ARE NOT SHOWN. SEE NOTE 9.

ELEVATION - FORM TIE, DOWEL & CONCRETE EXCAVATION LOCATIONS
SCALE: 1/4"=1'-0"



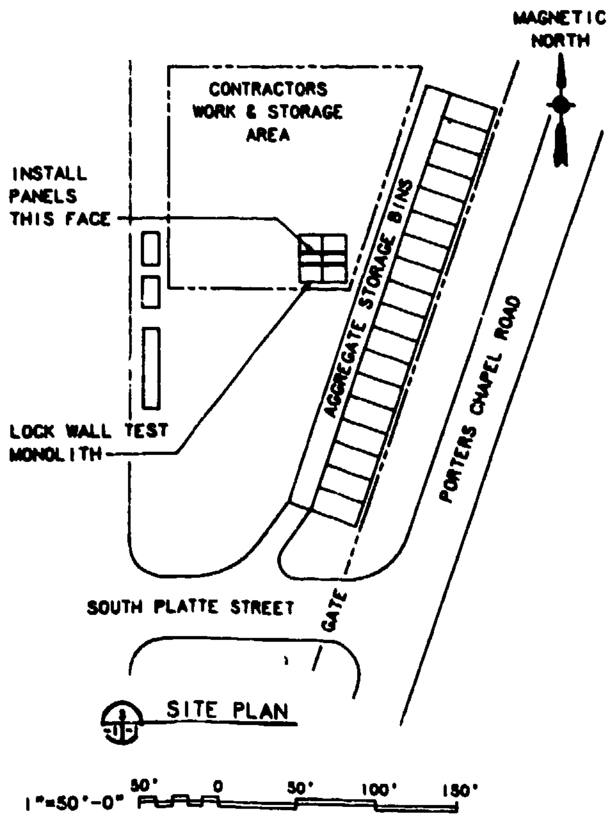
SITE PLAN

1"=50'-0" 50' 0 50' 100' 150'



SECTION - LOCK SURFACE REHABILITATION MOCK-UP

SCALE: 1/4" = 1'-0"



SITE PLAN

1"=50'-0" 50' 0 50' 100' 150'

NOTES

1. THIS WORK WILL DEMONSTRATE THE FEASIBILITY OF REPAIRING DETERIORATING NAVIGATIONAL LOCK WALL SURFACES USING PRECAST CONCRETE PANELS AS STAY-IN-PLACE FORMS. THIS WORK INCLUDES, BUT IS NOT LIMITED TO, CASTING PRECAST CONCRETE PANELS, FABRICATING MISCELLANEOUS STEEL HARDWARE ASSEMBLIES FOR INCORPORATION INTO THE WORK, SURFACE PREPARATION AND MISCELLANEOUS CONCRETE REMOVAL FROM THE MOCK-UP TEST MONOLITH, PANEL ERECTION, AND PLACEMENT OF THE CIP INFILL CONCRETE BONDING LAYER BETWEEN THE MONOLITH AND PRECAST PANELS. A COMPLETE DESCRIPTION OF THE WORK AND REQUIREMENTS ARE CONTAINED IN THE SPECIFICATIONS.

2. THE TEST MONOLITH IS BEING PROVIDED BY THE CORPS OF ENGINEERS (COE) AND IS LOCATED AT THE WATERWAYS EXPERIMENT STATION (WES) AS SHOWN IN THE SITE PLAN. ALL WORK PERFORMED ON COE'S PREMISES SHALL BE IN ACCORDANCE WITH COE RULES AND REGULATIONS. THE CONTRACTOR'S ON-SITE WORK AND LAYDOWN AREAS ARE SHOWN ON THE SITE PLAN. THE CONTRACTOR SHALL ARRANGE FOR ANY ADDITIONAL OFF-SITE FACILITIES IF REQUIRED.

3. THE CONTRACTOR SHALL SUBMIT A PRELIMINARY WORK SCHEDULE 2-WEEKS PRIOR TO COMMENCING WORK. SUBSEQUENT TO REVIEW BY COE, THE SCHEDULE WILL BE FINALIZED TO REFLECT TIME REQUIRED FOR COE TO INSTALL ANY INSTRUMENTATION OR TO COORDINATE ANY TESTING.

4. WORK SEQUENCE:

A. SURFACE PREP, DRILL HOLES, INSTALL DOWELS/TIES
B. ERECT PANEL P-1, PLACE CIP INFILL CONCRETE FOR 10-FT WIDTH COINCIDENT W/ PANELS P-2 TO P-6
C. ERECT PANEL P-2, PLACE CIP INFILL CONCRETE
D. ERECT PANEL P-3, PLACE CIP INFILL CONCRETE
E. ERECT PANEL P-4, PLACE CIP INFILL CONCRETE
F. ERECT PANEL P-5, PLACE CIP INFILL CONCRETE
G. ERECT PANELS P-6 TO P-8, PLACE INFILL CONCRETE FULL 20-FT HEIGHT OF WALL
H. COMPLETE CONCRETE CAP CONSTRUCTION
I. REMOVE AUXILIARY FORMING AND TIES, PATCH TIE HOLES

5. THE PRECAST PANELS AND FORM TIES HAVE BEEN DESIGNED FOR A MAXIMUM PRESSURE OF 1.20 KSF. PLACEMENT RATES FOR THE CIP INFILL CONCRETE SHALL BE CONTROLLED SO AS NOT TO EXCEED THE DESIGN PRESSURE.

6. MATERIALS

PRECAST CONCRETE:	f'c = 4000 PSI, W/C RATIO = 0.40
CIP CONCRETE:	f'c = 3000 PSI, W/C RATIO = 0.50
REINFORCING STEEL:	ASTM A 615, GRADE 60
FORM TIES (REINF):	ASTM A 706, GRADE 60
WELDED WIRE FABRIC:	ASTM A 185
HEADED WELD STUDS:	ASTM A 108
DEFORMED BAR ANCHORS:	ASTM A 496 F_y = 70 KSI
STEEL FOR HARDWARE:	ASTM A 36 UNLESS OTHERWISE NOTED
OTHER MISC MATERIALS:	AS NOTED IN THE DRAWINGS

STEEL FABRICATION: AISC MANUAL OF STEEL CONSTRUCTION

WELDING: AWS D1.1-88 STRUCTURAL WELDING CODE. USE AUTOMATICALLY TIMED STUD WELDING EQUIPMENT FOR WELD STUDS AND DEFORMED BAR ANCHORS UNLESS OTHERWISE NOTED.

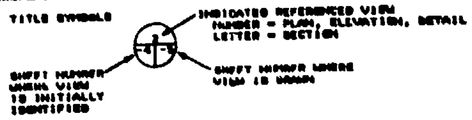
CONCRETE: ACI 301 STRUCTURAL CONCRETE FOR BUILDINGS
ACI 318 BUILDING CODE REQUIREMENTS FOR REINFORCED CONCRETE
PCI MNL-116 MANUAL FOR QUALITY CONTROL FOR PLANTS AND PRODUCTION OF PRE-CAST PRESTRESSED CONCRETE PRODUCTS

8. NO DRILLING, CHIPPING, OR CUTTING OF CONCRETE IS PERMITTED WITHIN THE INSTRUMENTATION ZONES IDENTIFIED ON THE DRAWINGS WITHOUT SPECIFIC WRITTEN APPROVAL OF THE COE. DEMOLITION/EXCAVATION OF CONCRETE FOR THE LINE WORK RECESS SHALL BE ACCOMPLISHED WITHOUT DISTURBING CONCRETE AT THE ADJACENT INSTRUMENTATION ZONES. DEMOLITION TOOLS SHALL BE SIZED TO ENABLE CONTROLLED BREAKAGE AND REMOVAL OF CONCRETE.

9. TENSILE TESTING OF SAMPLE FORM TIES AND REBAR DOWELS, AS NOTED IN THE SPECIFICATIONS, SHALL BE CONDUCTED TO ESTABLISH THE REQUIRED EMBEDMENT DEPTH. THE EMBEDMENT DEPTH SHALL BE SUFFICIENT TO DEVELOP A MINIMUM FORCE OF 20 KIPS. HOLES FOR FORM TIES AND REBAR DOWELS SHALL BE DRILLED WITH ROTARY-PERCUSSIVE EQUIPMENT. HOLES SHALL BE THOROUGHLY CLEANED PRIOR TO INSTALLING BONDING MATERIAL AND TIES/DOWELS. THE CONTRACTOR MAY ELECT TO INCLINE DOWEL AND TIE HOLES UP TO 10-DEGREES MAXIMUM TO ASSIST IN RETAINING BONDING MATERIAL.

10. CONTRACTOR SHALL PERFORM AS-BUILT MEASUREMENTS OF EXISTING LOCK-WALL TEST MONOLITH AND MAKE THE NECESSARY ADJUSTMENTS TO THE NEW WORK TO SUIT EXISTING WORK AND ADVISE ENGINEER OF MAJOR DISCREPANCIES.

11. TITLE SYMBOLS



SYM	DESCRIPTION	DATE	APPROVED
A	FOR CONSTRUCTION		

REVISIONS

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R.MONN 11 JULY 88

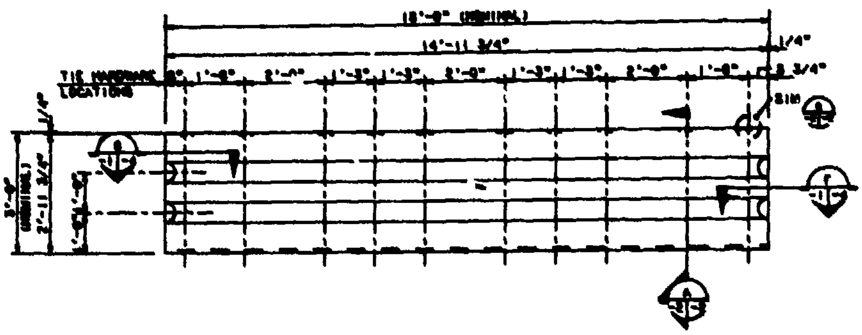
GENERAL ARRANGEMENT

U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS

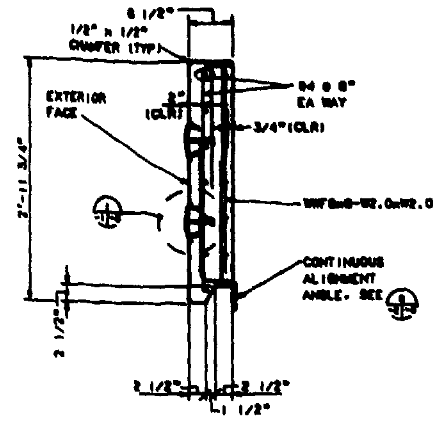
A86029-1 A

SCALE: AS NOTED

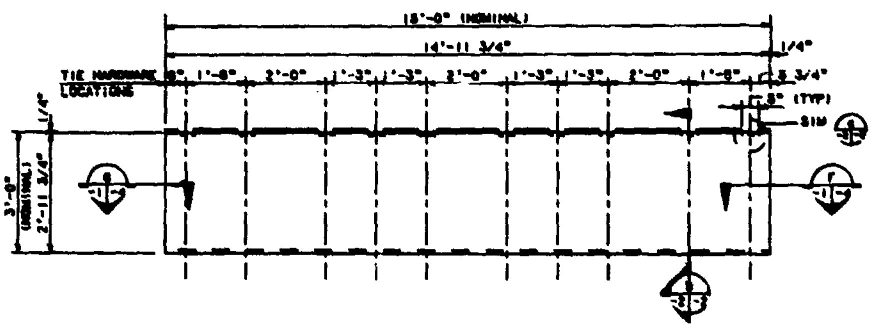
SHEET 1 OF 5



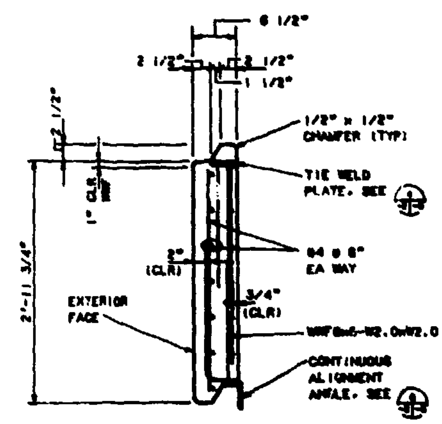
ELEVATION - PRECAST PANEL 'P-5'
SCALE: 1/2"=1'-0"



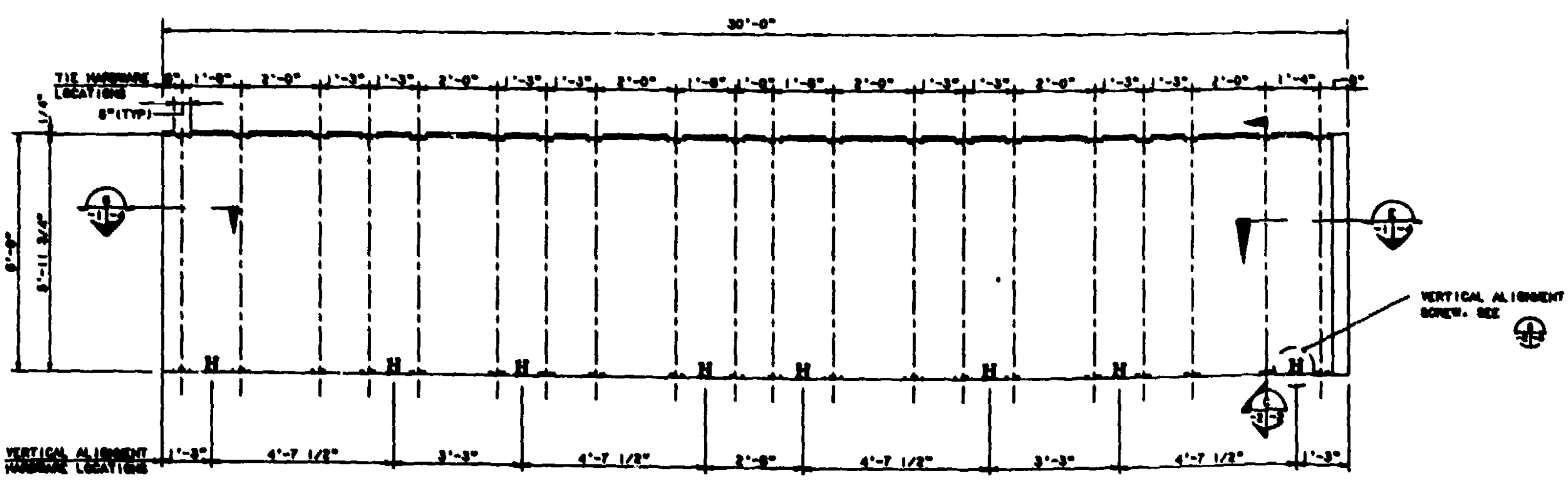
SECTION - PRECAST PANELS 'P-5' & 'P-8'
SCALE: 1"=1'-0"



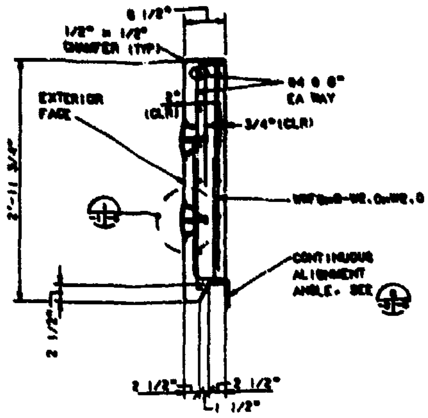
ELEVATION - PRECAST PANELS 'P-2', 'P-3', 'P-4'
SCALE: 1/2"=1'-0"



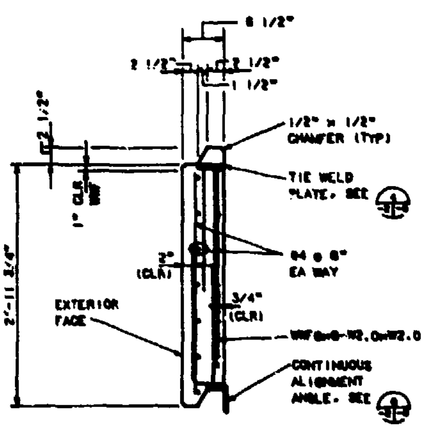
SECTION - TYP PRECAST PANEL
SCALE: 1"=1'-0" ('P-2', 'P-3', 'P-4' & 'P-6')



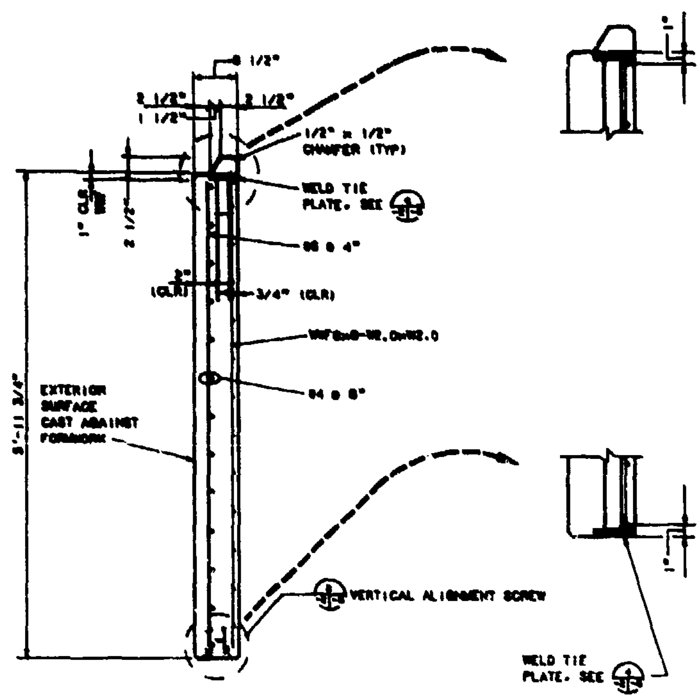
ELEVATION - PRECAST PANEL 'P-1'
SCALE: 1/2"=1'-0"



SECTION - PRECAST PANELS 'P-5' & 'P-8'
SCALE: 1"=1'-0"



SECTION - TYP PRECAST PANEL
SCALE: 1"=1'-0" ('P-2', 'P-3', 'P-4' & 'P-6')



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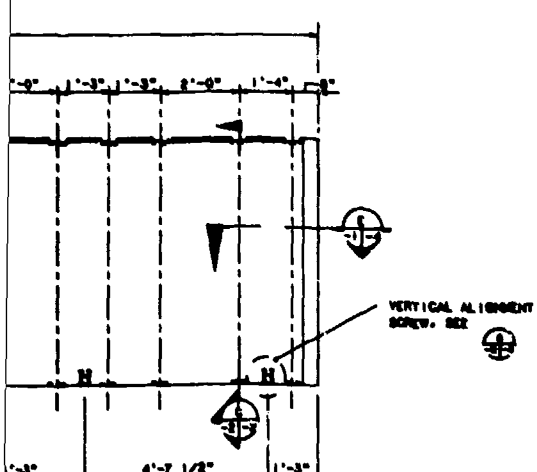
SCALE: 1"=1'-0"



SYM	DESCRIPTION	DATE	APPROVED
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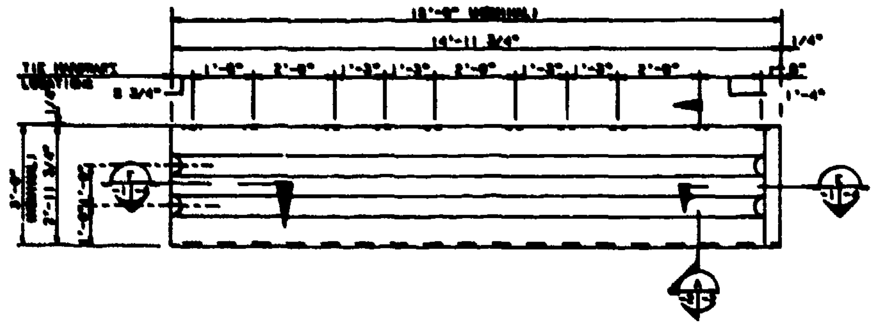
PRECAST PANELS
SHEET 1

SCALE: AS NOTED

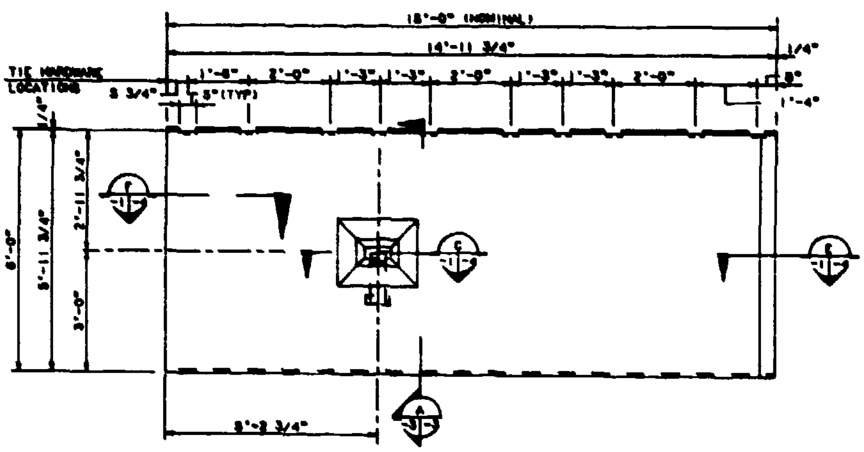
U. S. ARMY ENGINEER
WATERWAYS
EXPERIMENT STATION
CORPS OF ENGINEERS

A86029-2 | 0

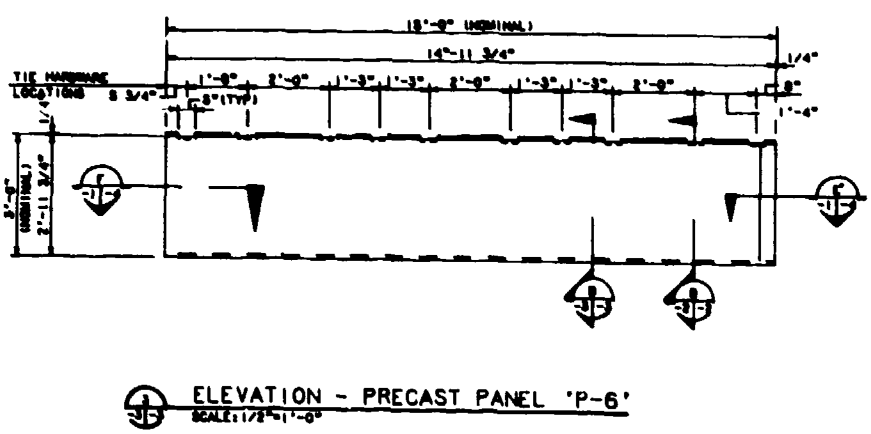
SHEET 2 OF 5



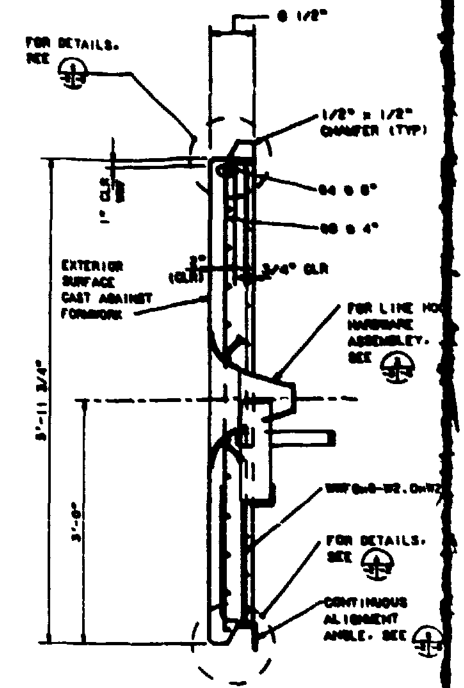
ELEVATION - PRECAST PANEL 'P-8'
SCALE: 1/2"=1'-0"



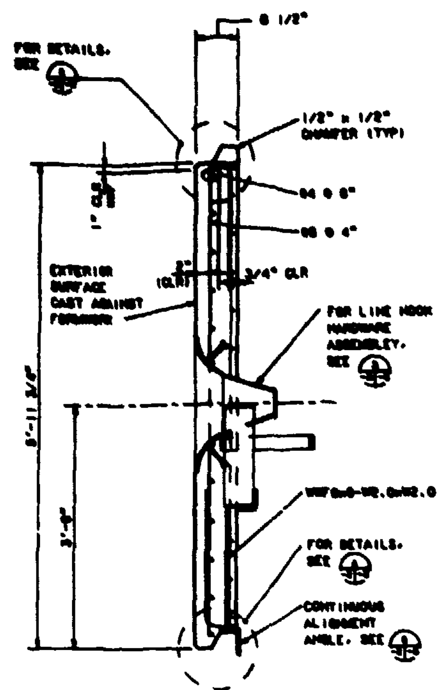
ELEVATION - PRECAST PANEL 'P-7'
SCALE: 1/2"=1'-0"



ELEVATION - PRECAST PANEL 'P-6'
SCALE: 1/2"=1'-0"



SECTION - PRECAST PANEL 'P
SCALE: 1"=1'-0"



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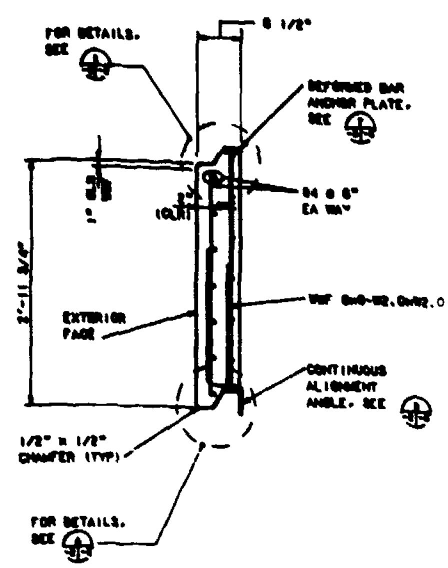

SECTION - PRECAST PANEL 'P-6'
SCALE: 1"=1'-0"

SYM	DESCRIPTION	DATE	APPROVED
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PRECAST PANELS
SHEET 2

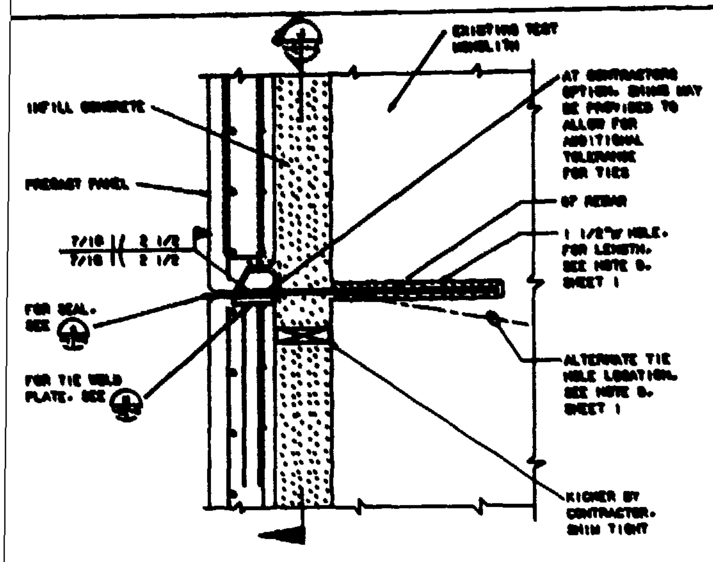
U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS

A86029-3

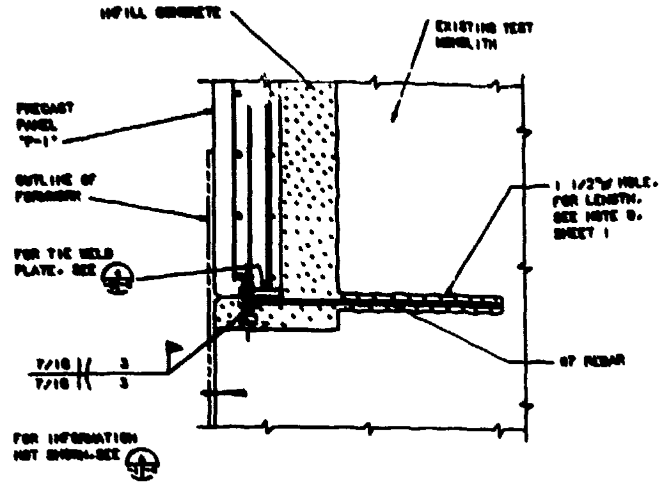
11 JULY 86

SCALE: AS NOTED

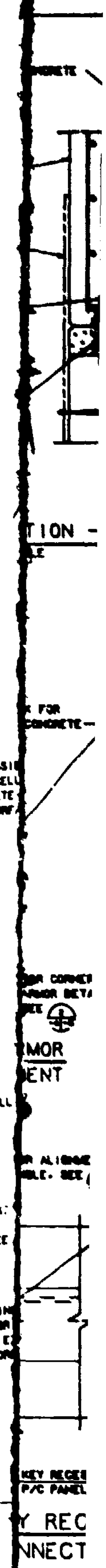
SHEET 3 OF 5

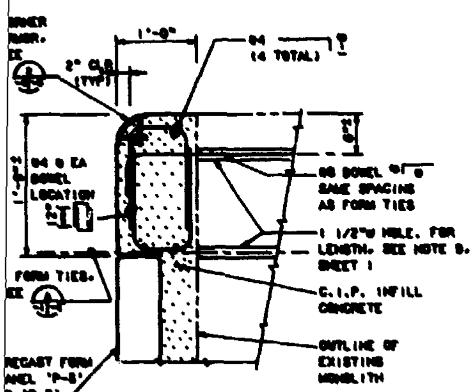


SECTION - WELDED FORM TIE
NO SCALE

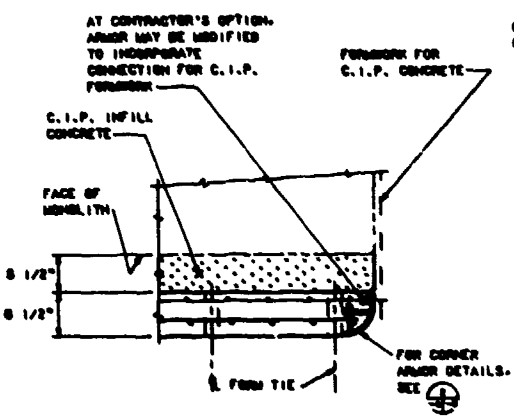


SECTION - FORM TIE AT PANEL BOTTOM
NO SCALE

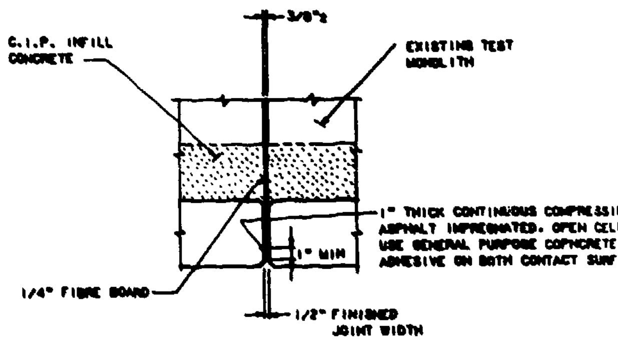




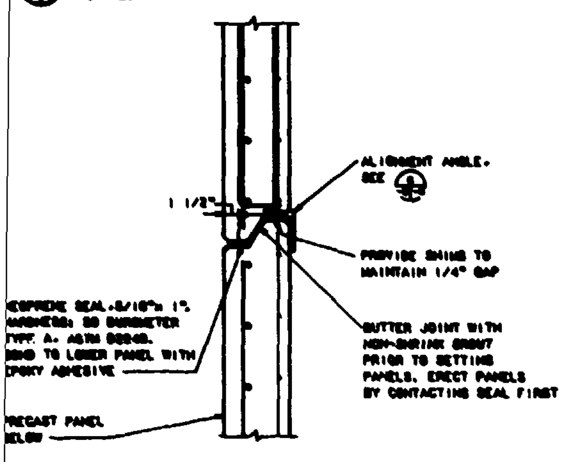
SECTION - C.I.P.CLOSURE CAP
SCALE: 1"=1'-0"



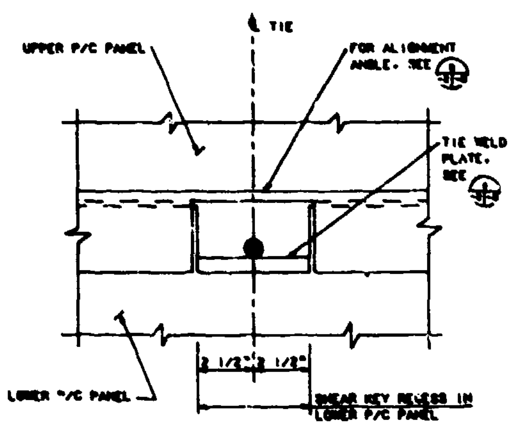
SECTION - VERTICAL ARMOR EMBEDMENT
SCALE: 1"=1'-0"



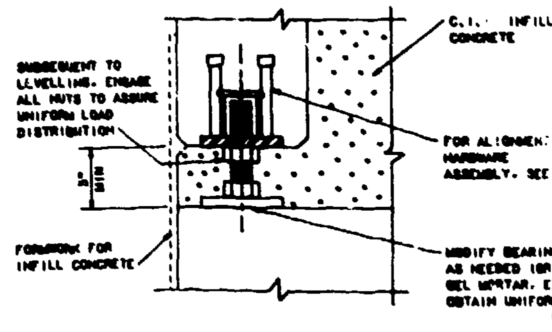
SECTION - VERTICAL EXPANSION JOINT
NO SCALE



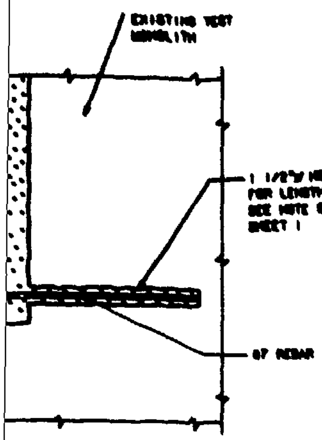
SECTION - HORIZONTAL PRECAST PANEL JOINT
NO SCALE



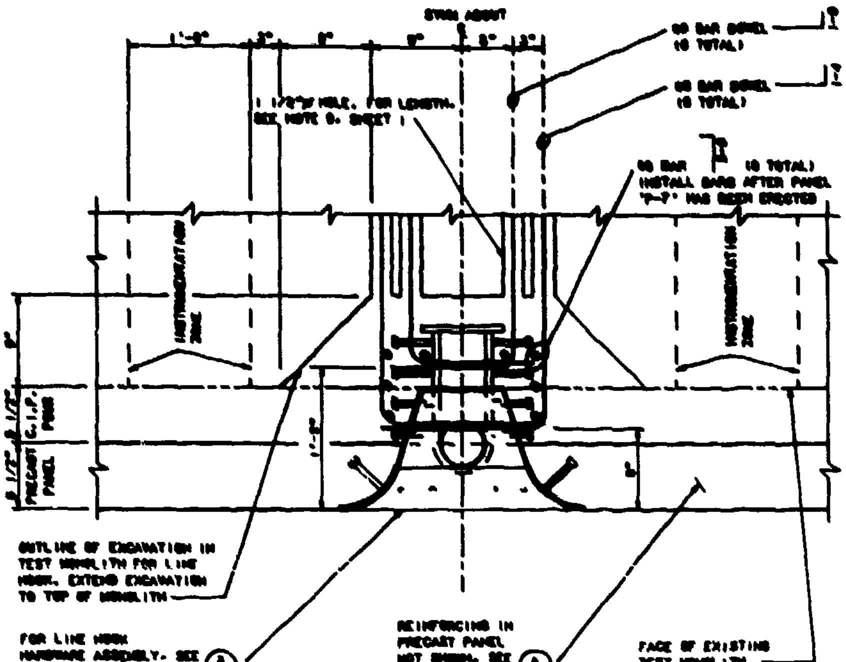
SECTION - SHEAR KEY RECESS @ TIE CONNECTION
NO SCALE



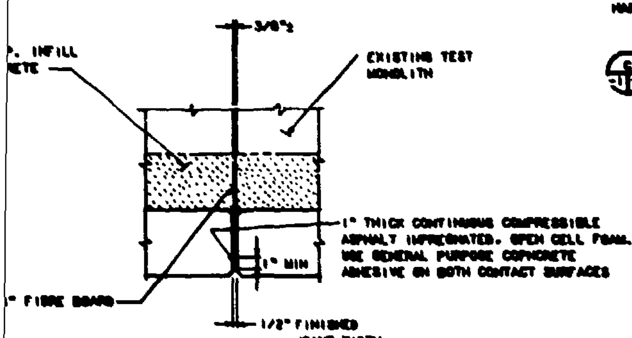
SECTION - VERTICAL ALIGNMENT SCREW
NO SCALE



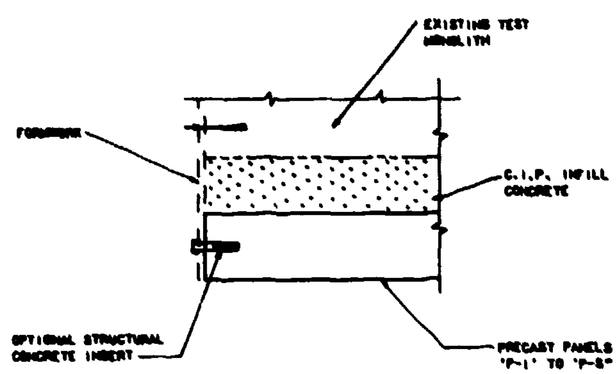
TIE AT PANEL BOTTOM



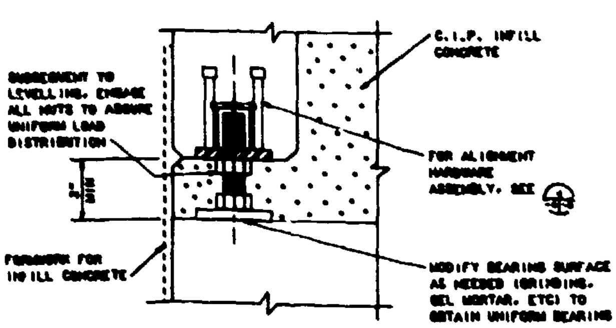
SECTION - SPECIAL EXCAVATION AT LINE HOOK
SCALE: 1-1/2"=1'-0"



SECTION - VERTICAL EXPANSION JOINT
NO SCALE



SECTION - PLAIN END JOINT
NO SCALE



SECTION - VERTICAL ALIGNMENT SCREW
NO SCALE

SYM	DESCRIPTION	DATE	APPROVED
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R.MOHN | 11 JULY 88

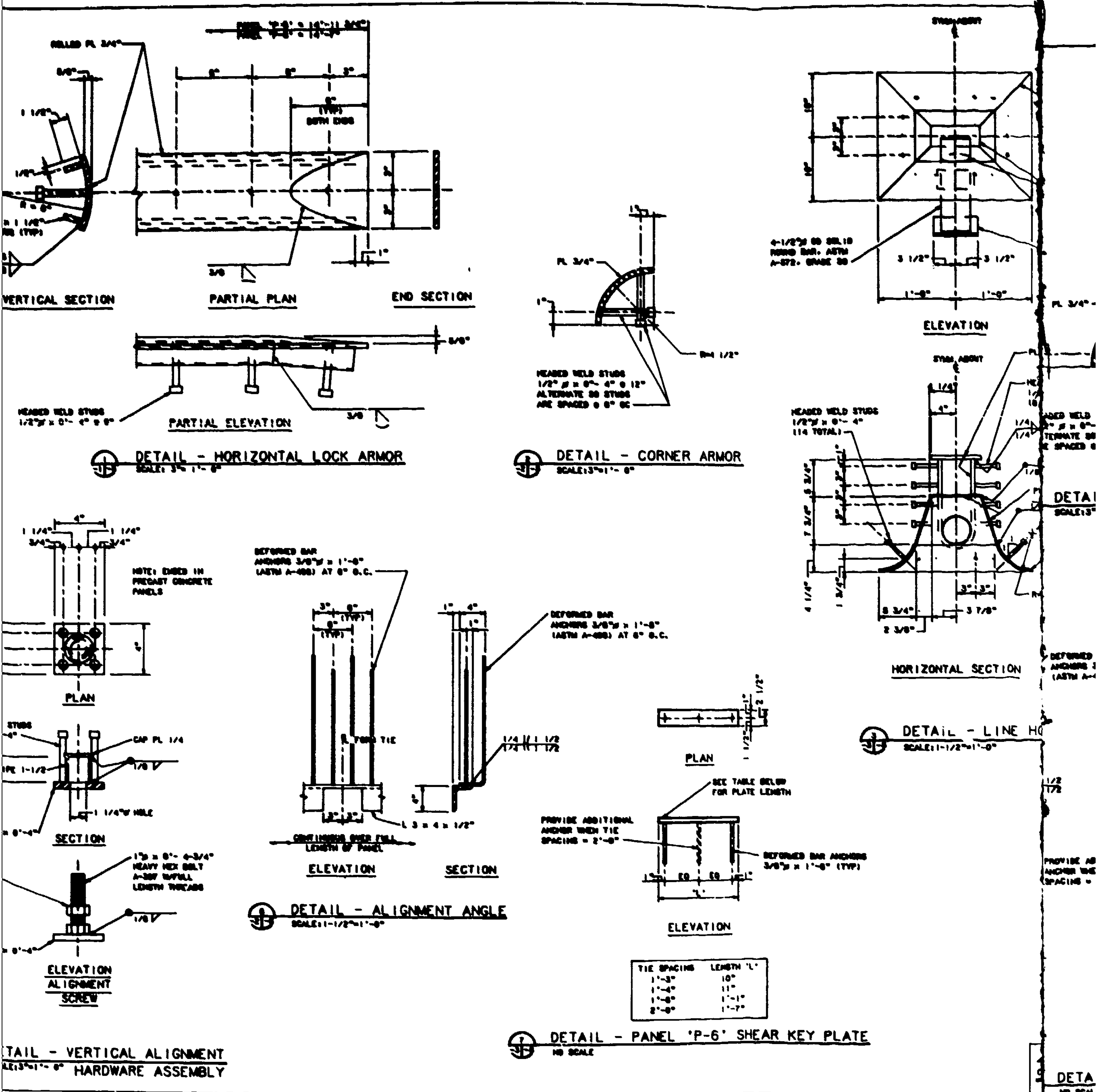
CONCRETE SECTIONS AND DETAILS

SCALE: AS NOTED

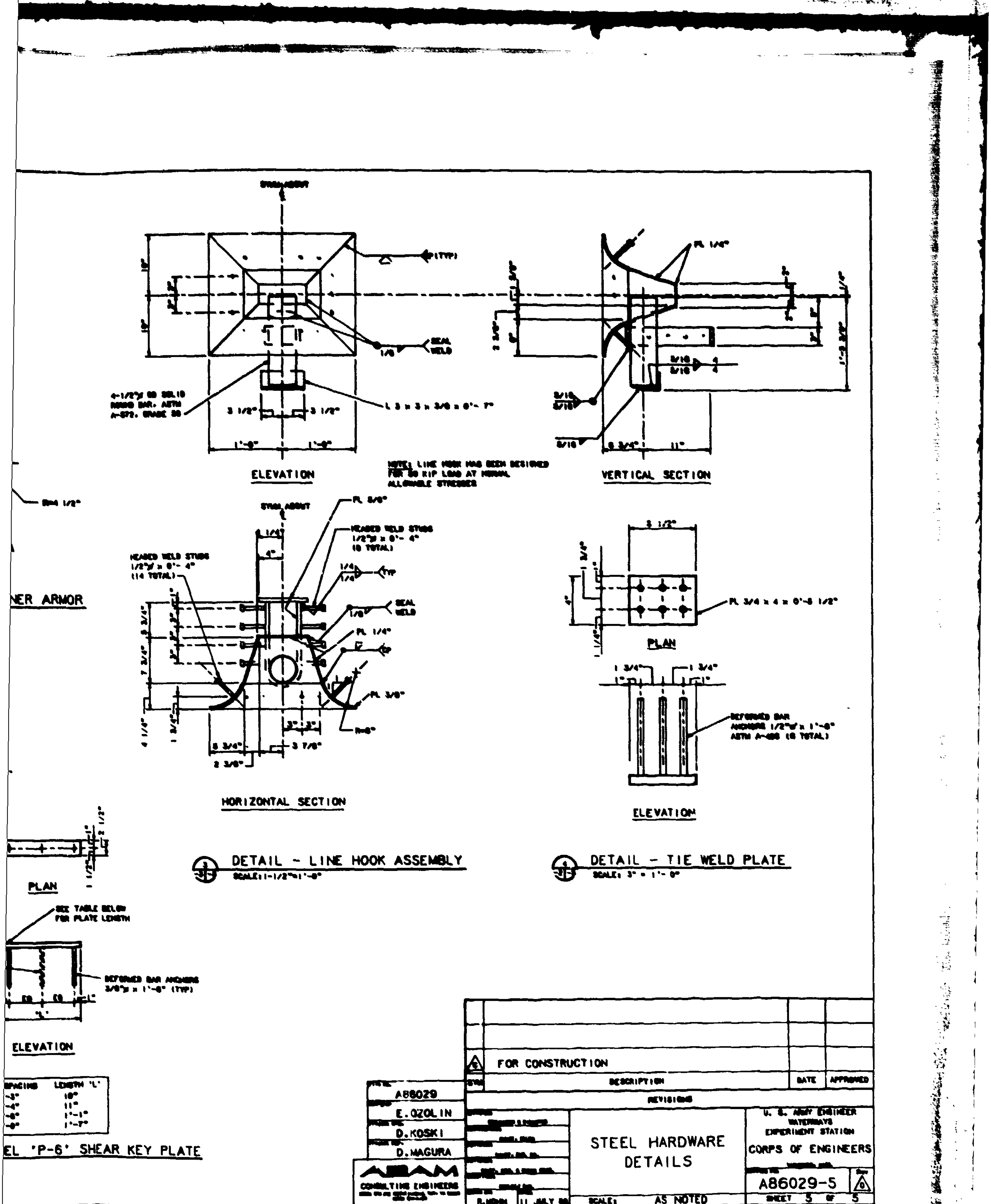
U. S. ARMY ENGINEER WATERWAYS EXPERIMENT STATION
CORPS OF ENGINEERS

A86029-4 | A

SHEET 4 OF 5



TIE SPACING	LENGTH 'L'
1'-3"	10"
1'-4"	11"
1'-6"	1'-1"
2'-0"	1'-7"


ELEVATION
VERTICAL SECTION
HORIZONTAL SECTION
PLAN
ELEVATION
DETAIL - LINE HOOK ASSEMBLY
DETAIL - TIE WELD PLATE
NER ARMOR
PLAN
ELEVATION
EL 'P-6' SHEAR KEY PLATE
FOR CONSTRUCTION
DESCRIPTION
DATE
APPROVED
REVISIONS
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D.KOSKI
D.MAGURA
CONSULTING ENGINEERS
STEEL HARDWARE
DETAILS
U. S. ARMY ENGINEER
WATERWAYS
EXPERIMENT STATION
CORPS OF ENGINEERS
A86029-5
SCALE: AS NOTED
SHEET 5 OF 5

APPENDIX C: CONSTRUCTION GUIDE

NAVIGATIONAL LOCK REHABILITATION USING PRECAST STAY-IN-PLACE FORMS

This construction guide outlines the major steps a contractor should consider in planning and successfully implementing repairs to navigational lock surfaces using precast concrete stay-in-place forms. The outline is based on the developmental design completed during the Phase I study and experience gained during the construction of the mock-up installation during Phase II. Although the outline addresses work activities separately, most activities will be ongoing concurrently within the same monolith or on adjacent monoliths. The work outline addresses rehabilitation of lock-wall surfaces only and this plan must be appended for other repair activities. Further, the plan has been developed for a generic lock repair and unique conditions at a particular lock must be considered.

I. CONTRACTOR'S PLANNING AND ENGINEERING

a. A visit to the lock site should be made to verify information contained in the contract documents; ascertain work conditions; access to site, and space; and obtain as-built measurements, etc. At this time, observations should be made of the behavior of the lock after a lockage to determine the amount of water leaking from joints and through gates.

b. Special Corps of Engineers construction and administrative requirements, such as coordination of inspections, submittals, critical path schedule, and progress meeting and reports should be identified. Most of these items will be identified in the contract documents.

c. Schedule and space constraints relative to lock closure should be identified, a detailed construction schedule developed, and a work plan established that is acceptable to the Corps of Engineers. Such a schedule may include alternating lock openings with completion of refacing in partial lifts. Alternating lock openings may impact the choice of staging or scaffolding used in the work. The work plan and schedule will identify concurrent work activities and provide a means of coordinating all phases of the work. The schedule must show consideration for seasonal construction constraints, such as the need for cold- or hot-weather concreting measures and curing procedures.

d. Shop, handling, storage, transportation, and erection drawings should be prepared. A transmittal and delivery schedule or similar vehicle should be developed to facilitate attaining project milestone dates.

e. The required material and procedure submittals should be prepared. Concrete mixture proportions and trial batches should be initiated if mixtures based on past field experience are not available. Material and procedures to embed form ties into the monolith should be selected, and trial pullout tests should be performed to determine the required embedment lengths.

f. The required construction bonds, insurance, and permits should be obtained.

g. Material suppliers, subcontractors, and necessary equipment must be selected.

h. A quality control program must be developed and approved by the Corps. This plan includes, but is not limited to, the selection of a testing agency, a schedule of material testing, procedures for review and submittal of mill and compliance certificates, development of a means of verifying tolerances and of identifying hold points at various points in the construction.

i. The construction force composition (i.e., carpenters, ironworkers, cement finishers, equipment operators, etc.) should be selected with consideration of "assembly-line" construction techniques. Any arrangements required by local trade unions must be established.

j. Upon successful review of drawings and submittals, material purchases, fabrication of steel hardware and reinforcing bars, equipment rentals, etc., should be initiated.

k. An in-depth risk analysis should be requested from the Contractor relative to the safety features and the critical path construction activities to be used.

II. GUIDELINES FOR PRECAST MANUFACTURING

a. A precast panel production facility should be mobilized (if one is not already available) that has adequate space for batch and steam plants, reinforcing bar preassembly, and materials and panel storage. The panel storage should be arranged so that lifting and transportation equipment have accessibility to any given panel. Provisions must be made to maintain production during periods of inclement weather by providing covered areas for reinforcing bar assembly and form beds, and providing graveled or paved surfaces for the frequently traveled routes.

b. The required lifting devices, spreaders, and bunking and cribbing materials should be manufactured or procured. Fabricated lifting items should be load tested to validate safe working loads.

c. Reusable forms that will produce panels to the required tolerances and enable easy form stripping should be developed. The tolerances for specific installations are contained in the project specifications but will generally include the following: panel length ±1/2 in., panel width ±1/4 in., panel thickness at other than erection contact surfaces ±1/2 in., and planeness ±1/4 in. outside surface and 1/2 in. interior face. The forms should be adequately stiff to maintain these tolerances over numerous reuses and be adaptable for incorporating lock hardware.

d. Rebar cages should be preassembled and stored until the forms become available, at which time they should be moved into forms and accurately positioned with the use of chairs or other means to prevent movement during concrete placement.

e. Lock hardware and other embedments should be positioned and secured accurately into the formwork. All items should be located to a tolerance of ±1/8 in. All QC/QA inspections should be performed to verify that the work is ready for concrete placement.

f. Concrete should be batched and placed per project and standard Corps' specifications. The concrete must be thoroughly vibrated to obtain a dense, smooth form finish for the exterior face and thoroughly consolidated around embedments.

g. The interior face that will be exposed to the infill concrete should be intentionally roughened to an amplitude of approximately 1/4 in. Bearing or contact surfaces should be troweled to obtain panel-to-panel alignment within the required tolerances.

h. Panels should be moist cured until the compressive strength reaches 0.7 (f'_c). At this strength level, the panels can be picked from the forms. Concrete cylinder tests should be performed as necessary to verify strength in order to optimize form turnaround times. Once the required strength has been attained, the panels should be moved to the storage area and bunked. Bunking procedures that are insensitive to settlement of the support points must be used. Any miscellaneous finishing or minor repairs should be completed as required.

i. Panels must be shipped to the erection site as the schedule requires. Prior to loading panels on the transporter, the strength must be checked to verify that it exceeds the required strength f'_c. Panels must be bunked and stored on the transporter so that they are not cracked or otherwise damaged during shipment.

k. An in-depth risk analysis should be requested from the Contractor relative to the safety features and the critical path construction activities to be used.

III. GUIDELINES FOR MONOLITH PREPARATION

a. Scaffolding or work platforms that provide good access to the lock face for layout, demolition, drilling, and installation of dowels and ties must be used. Scaffolding or work platforms should be readily movable or collapsible. Movable coffer dams or other measures should be developed if work below low pool elevation must be accomplished in the dry. The condition of the scaffolding or work platforms should be monitored to verify that they are safe.

b. Grid lines or a reference system should be established from which measurements can be made after deteriorated lock surface has been removed. The reference system should be capable of achieving the required tolerances for the completed installation. These tolerances are as follows: ±1/2 in. over the height of a given monolith, ±1/2-in. variation in horizontal alignment over a length of three monoliths, and ±3/16 in. across the joints between adjacent panels. Templates or alignment tools can be developed that can be used with the reference system to determine locations along the length and height of the lock and to enable verification of tolerances.

c. The locations of special lock appurtenances that require a greater depth of concrete removal must be identified.

d. The perimeter of the concrete must be saw-cut or removed using controlled demolition in order to control overbreakage.

e. Deteriorated concrete surfaces should be removed by drilling and blasting, mechanical, or other means. Once major portions of deteriorated concrete have been removed, there may be a need for hand removal of concrete.

f. Concrete debris should be cleaned up as the work progresses. At locations of inlets, gates, and valves, debris must not be allowed to fall into the lock chamber.

g. Using the reference system and/or special templates, tie and dowel holes should be located and drilled to the required tolerances. Current details allow a ±1/4-in. vertical tolerance and a ±1/2-in. horizontal tolerance on tie location. Holes must be blown clean with oil-free compressed air prior to the installation of ties and dowels.

h. Ties and dowels should be installed with the reference system and/or template. Because of the horizontal position of the bars, seals that will prevent leakage of epoxy grout must be used. Other measures that will maintain the position of the bars until the epoxy grout has sufficiently set must be used. The required pullout tests should be performed and the as-built location of ties checked to determine whether any adjustments are required prior to panel installation.

i. The erection equipment should be load tested before the panel erection work is started.

IV. GUIDELINES FOR PANEL INSTALLATION

a. Upon arrival at the installation site, the precast form panels should be carefully inspected for any damage that may have occurred during shipment. After the panels have been picked off the transporter, the interior or bonding face must be cleaned by high-pressure water wash.

b. Sacrificial support frames should be installed if required, along with vertical alignment hardware for the bottom panels.

c. After the reinforcing embedding grout has sufficiently cured, the bottom panel should be erected and carefully aligned to the required tolerances. After the tolerances are verified (paragraph III.b), the form ties should be welded to the panel. All welding must be performed with welds qualified according to AWS procedures and qualified welders.

d. Seals, shims, and nonshrink grout (optional) must be installed before the upper panel is set. After the upper panel is installed to the required tolerances, the form ties should be welded to the panel. Kickers, wedges, or portable jacks may be needed to ensure that panel connections and ties are snug. Panel erection should proceed in a similar manner to the top of the monolith section.

V. GUIDELINES FOR CAST-IN-PLACE CONCRETE WORK

a. Formwork along the base of the bottom panel and along vertical joints at panel edges must be installed.

b. Special lock hardware, such as floating mooring bits and ladders, should be installed where required.

c. Any reinforcing required in the infill concrete layer, such as at the mooring hooks, should be installed.

d. Prior to concrete placement, all inspections relative to panel alignment and tie connections should be completed. Welded connections should be inspected by an AWS-certified inspector.

e. Concrete for the infill layer can be placed in partial lifts or placed in one lift level with the uppermost erected panel. Partial lifts may be required in conjunction with lock openings and will necessitate coordination with erection work. Trunks, chutes, or pump hoses should be used to prevent segregation. Concrete lift heights should be controlled to maintain the allowable form pressure. Internal vibrators should be used to consolidate concrete but in a manner that does not result in excessive form pressures.

f. Moist curing for exposed concrete surfaces should be provided until a minimum strength $f_c = 0.7\ (f'_c)$ has been attained. Likewise, forms should be kept in place until concrete reaches $0.7\ (f'_c)$. Special measures may be required to protect the concrete during the entire curing period, depending upon seasonal weather conditions.

g. Forms should be removed and concrete surfaces finished as needed. Any minor surface defects should be repaired.

h. The cast-in-place closure cap should be formed and the corner armor and reinforcing installed, and the steel armor pieces must be properly aligned and adequately secured. After the closure cap concrete is placed, the exposed surfaces should be moist cured. The concrete must be protected during the full curing period as required by seasonal weather conditions.

i. Forms should be removed and concrete surfaces finished as needed. Any minor surface defects should be repaired.

APPENDIX D: SUBMITTALS

PART I: SUBMITTALS REGISTER

File: COE PHASE II SUBMIT
Report: RECORDS & DOCUMENTS

ITEM	SPEC OR DRWG REF	SUBMITTAL	APPROVAL	REMARKS	STATUS
PROJECT PHOTOGRAPHS	1.1.7	YES	NO	5 SETS OF APPRX 30 PHOTO'S	SUBMITTED
SHOP & ERECTION DRWGS PRECAST PANELS	2.1.4.a	YES	YES		RNC NO RESUB
MISC DETAILS-PRCCAST PANELS	2.1.4.b 2.1.6.b	YES	YES	COVERS METHODS OF LIFTING, HANDLING, STORING, ERECTING, ETC	RNC NO RESUB
CONCRETE MIX DESIGN FOR PRECAST PANELS	2.1.4.e	YES	YES		RNC RESUB
CEMENT - PRECAST CONCRETE	2.1.4.d 2.2.1.a	YES	NO	MILL CERTIFICATES	SUBMITTED
AGGREGATE FOR PRECAST CONCRETE	2.1.4.d 2.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE AND GRADATION ANALYSIS	SUBMITTED
AIR-ENTRAINING ADMIXTURE - PRECAST CONCRETE	2.1.4.d 2.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE, CATALOG CUTS	SUBMITTED
WATER-REDUCING ADMIXTURE - PRECAST CONCRETE	2.1.4.d 2.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE, CATALOG CUTS	SUBMITTED
POZZOLAN FOR PRECAST CONCRETE	2.1.4.d 2.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE, CATALOG CUTS	N/A
REINFORCING STEEL - PRECAST CONCRETE	2.1.4.d 2.2.1.b	YES	NO	MILL CERTIFICATES	SUBMITTED
REINFORCING STEEL - FORM TIES	2.1.4.d 2.2.1.c	YES	NO	MILL CERTIFICATES	SUBMITTED
WELDED WIRE REINFORCING - PRECAST PANELS	2.1.4.d 2.2.1.e	YES	NO	MILL CERTIFICATES	SUBMITTED
NONSHRINK GROUT	2.1.4.d 2.2.1.f	YES	NO	CATALOG CUTS	SUBMITTED
FORM TIE ANCHORING GROUT	2.2.2.b 2.2.2.c	YES	NO	CATALOG CUTS CONCRESIVE 1441	SUBMITTED
FORM PANEL BEARING PADS	2.2.2.d	YES	NO	CERTIFICATE OF COMPLIANCE	SUBMITTED
VERTICAL JOINT SEALS	2.2.2.d	YES	NO	CATALOG CUTS	RNC
ERECTION PROCEDURE	2.3.1.b	NO	NO	WRITTEN PROCEDURE	RNC
PANEL FABRICATION AND ERECTION	2.3.3.a	NO	NO	CONTRACTOR'S RECORD OF INSPECTIONS AND INSPECTION RESULTS	SUBMITTED
CONCRETE BATCH SAMPLING TESTS P/C	2.1.4.d 2.3.3.b	YES	NO	CONCRETE TEST RESULTS & BATCH TICKETS	SUBMITTED
FORM TIE TESTS	2.1.4.d 2.3.3.f	YES	NO	JACK CALIBRATION DATA AND TEST RESULTS	SUBMITTED
CONCRETE MIX DESIGN - CIP CONCRETE	3.1.4.a	YES	YES		RNC NO RESUB
CEMENT - CIP CONCRETE	3.1.4.a 3.2.1.a	YES	NO	MILL CERTIFICATES	SUBMITTED
AGGREGATE - CIP CONCRETE	3.1.4.a 3.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE AND GRADATION ANAYLSIS	SUBMITTED
AIR-ENTRAINING ADMIXTURE - CIP CONCRETE	3.1.4.a 3.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE, CATALOG CUTS	SUBMITTED
WATER-REDUCING ADMIXTURE - CIP CONCRETE	3.1.4.a 3.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE, CATALOG CUTS	SUBMITTED
POZZOLAN - CIP CONCRETE	3.1.4.a 3.2.1.a	YES	NO	CERTIFICATION OF COMPLIANCE, CATALOG CUTS	
REINFORCING STEEL - CIP CONCRETE	3.1.4.a 3.2.1.b	YES	NO	MILL CERTIFICATES	SUBMITTED
CONCRETE PLACING PROCEDURE - CIP CONCRETE	3.3.1.a	YES	YES	WRITTEN PROCEDURE	RNC
PRECAST PANEL MOVEMENTS & DEFLECTIONS	3.3.2.c	YES	YES	WRITTEN PROCEDURE	RNC
INSPECTION REPORTS - CIP CONCRETE	3.3.3.a	NO	NO	RECORDS OF INSPECTIONS & TESTS	
CONCRETE BATCH SAMPLING TESTS (CIP)	3.1.4.b 3.3.d	YES	NO	CONCRETE TEST RESULTS & BATCH TICKETS	SUBMITTED
SHOP DRAWINGS - STEEL HARDWARE	4.1.4.a	YES	YES		RNC NO RESUB
WELDER QUALIFICATIONS - STEEL HARDWARE	4.1.3.a 4.1.4.b	YES	NO	CERTIFICATES OF WELDER'S QUALIFICATIONS	SUBMITTED
TIE WELDING	4.1.3.b	YES	NO	WRITTEN WELDING PROCEDURE, WELDER CERTIFICATION	RNC
STRUCTURAL STEEL - STEEL HARDWARE	4.1.4.b	YES	NO	MILL CERTIFICATES	SUBMITTED
BOLTING MAT'L & FASTENERS - STEEL HARDWARE	4.1.4.d	YES	NO	MILL CERTIFICATES & CATALOG CUTS	SUBMITTED
STEEL FABRICATION INSPECTION RECORDS	4.3.3.a	NO	NO	CONTRACTOR'S RECORDS OF INSPECTIONS & INSPECTION RESULTS	SUBMITTED
WORK SCHEDULE	DWG 1, NOTE 3	YES	YES		SUBMITTED

KEY RNC REVIEWED WITH NO COMMENTS
RWC REVIEWED WITH COMMENTS
DISAP DISAPPROVED
SUBMITTED - FILE COPY ONLY NO REVIEW PERFORM

PART II: PRECAST CONCRETE MIX AND INSPECTION REPORTS

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 698-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/31/86
01/21/87
02/07/87

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

RECEIVED
JAN 26 1987

Date Cast: 12/24/86

Test Number: 19295
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon   Ticket No.:
Truck No.:   Mix I.D.: C8HR-S-AEA
CTC Rep.: B. Crume
Location of Pour: Piece #8✓

PHYSICAL PROPERTIES

Slump: 3.75   Air (%): 5.9   Wt./Cu. Ft.: 144.4
Concrete Temp. °F: 65   Air Temp. °F: 45
Time Batched: Time Tested:

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	6950	
02	28	6.00	8170	
03	28	5.98	8300	8235

Remarks: 1 hour contractor delay onsite.

Arthur P Reed
COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 698-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/30/86
01/20/87
02/06/87

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

RECE
23 1987

Date Cast: 12/23/86

Test Number: 19294
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8HR-S-AEA
CTC Rep.: B. Crume
Location of Pour: Piece #5

PHYSICAL PROPERTIES

Slump: 1.5
Air (%): 3.6
Wt./Cu. Ft.: 149.2
Concrete Temp. °F: 62
Air Temp. °F: 54
Time Batched: 12:05
Time Tested: 12:25

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	5.99	6730	
02	28	6.00	9550	
03	28	6.01	9840	9695

Remarks: 1-3/4 hour delay onsite.

Arthur P Kerst
COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 698-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/29/86
01/19/87
02/05/87

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

REC'
JAN 28 1987

Date Cast: 12/22/86

Test Number: 19292
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8HR-S-AEA
CTC Rep.: B. Crume
Location of Pour: Piece #1

PHYSICAL PROPERTIES

Slump: 2.5
Air (%): 6.2
Wt./Cu. Ft.: 146.8
Concrete Temp. °F: 61
Air Temp. °F: 51
Time Batched: 3:00
Time Tested: 3:20

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	6990	
02	28	5.99	8980	

Remarks:

COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 698-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/29/86
01/19/87
02/05/87

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

Date Cast: 12/22/86

Test Number: 19291
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8HR-S-AEA
CTC Rep.: B. Crume
Location of Pour: Piece #1

PHYSICAL PROPERTIES

Slump: 4.0 Air (%): 6.2 Wt./Cu. Ft.: 148.6
Concrete Temp. °F: 61 Air Temp. °F: 52
Time Batched: 3:00 Time Tested: 3:15

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	7000	
02	28	6.00	9160	

Remarks: 3 hour contractor delay onsite.

COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 698-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/26/86
01/16/87
02/02/87

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

REC'D
21 1987

Date Cast: 12/19/86

Test Number: 19290
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8 HRS-AEA
CTC Rep.: B. Crume
Location of Pour: Piece #7

PHYSICAL PROPERTIES

Slump: 5.25 Air (%): 5.2 Wt./Cu. Ft.: 147.1
Concrete Temp. °F: 64 Air Temp. °F: 46
Time Batched: 11:30 Time Tested: 11:45

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	7060	
02	28	6.00	9340	
03	28	5.99	9230	9285

Remarks:

COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 698-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/25/86
01/15/87
02/01/87

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

RECEIVED
JAN 21 1987
Premier Waterproofing Co.

Date Cast: 12/18/86

Test Number: 19289
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8 HRS AEA
CTC Rep.: B. Crume
Location of Pour: Piece #4

PHYSICAL PROPERTIES

Slump: 2.25 Air (%): 3.2 Wt./Cu. Ft.: 149.8
Concrete Temp. °F: 61 Air Temp. °F: 43
Time Batched: 11:05 Time Tested: 11:15

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	6950	
02	28	6.00	8590	
03	28	6.01	8320	8455

Remarks:

COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 598-1050

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles K. Miller

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/24/86
01/14/87
01/31/87

RECEIV
JAN 20 1987
Premier Waterproofing Co.

Report To: Premier Waterproofing Co.

Date Cast: 12/17/86

Test Number: 19287
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8 HRS AGA
CTC Rep.: B. Crume
Location of Pour: Piece ~~#2~~ #3

PHYSICAL PROPERTIES

Slump: 3.25 Air (%): 4.8 Wt./Cu. Ft.: 152.0
Concrete Temp. °F: 51 Air Temp. °F: 41
Time Sampled: 11:35 Time Tested: 11:45

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	7000	
02	28	5.99	9260	
03	28	6.00	9130	9195

Remarks:

Arthur P Reed
COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 598-1050

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/23/86
01/13/87
01/30/87

RECEI
JAN 30 1987

Report To: Premier Waterproofing Co.

Premier Waterproofing Co.
2310 South Inca
Denver, CO 80223

Attn: Charles R. Miller

Date Cast: 12/16/86

Test Number: 19251
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon
Ticket No.:
Truck No.:
Mix I.D.: C8 HRS AEA
CTC Rep.: B. Crume
Location of Pour: Panel ~~#1~~ #2

PHYSICAL PROPERTIES

Slump: 4.25
Air (%): 5.9
Wt./Cu. Ft.: 147.5
Concrete Temp. °F: 53
Air Temp. °F: 50
Time Batched: 1:00
Time Tested: 1:15

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	5.99	7040	
02	28	6.01	9130	
03	28	6.00	9230	9180

Remarks:

Anthony P Reed
COLORADO TEST CENTER, INC.

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COLORADO TEST CENTER, INC.

155 South Navajo
Denver, Colorado 80223
(303) 595-1050

Premier Waterproofing Co.
2311 South Inca
Denver, CO 80233

Attn: Charles R. Miller

CONCRETE TEST RESULTS

P.O. No.:
Job No.: CS-125

Report Dates: 12/22/86
01/12/87
01/29/87

Report To: Premier Waterproofing Co.

RECEIV
JAN 15 1987

Date Cast: 12/15/86

Test Number: 19275
Job Name: ABAM
Job Address: Stresscon in Colorado Springs
Contractor: Premier Waterproofing
Supplier: Stresscon   Ticket No.:
Truck No.:   Mix I.D.: C8 HRS AGA
CTC Rep.: M. Fitzgerald
Location of Pour: Panel W6

PHYSICAL PROPERTIES

Slump: 3.0   Air (%): 5.6   Wt./Cu. Ft.: 147.7
Concrete Temp. °F: 63   Air Temp. °F: 43
Time Sampled: 12:55   Time Tested: 1:15

COMPRESSIVE STRENGTH: Specified 28 Day Strength (psi) 6500

Cylinder ID	Age (days)	Size	Strength (psi)	Average Strength
01	7	6.00	7060	
02	28	5.99	9010	
03	28	6.00	9340	9175

Remarks:

Arthur P Reed
COLORADO TEST CENTER, INC.

POST OFFICE BOX NO. [illegible]
COLORADO SPRINGS, COLO. [illegible]
TELEPHONE: [illegible]

PROPOSED MIX DESIGNS FOR STAY-IN-PLACE FORMS, VICKSBURG, MS

Mix Design (1) For A One Cubic Yard

Cement	752# (8 sk)
Concrete Sand	1060# (SSD)
3/4" River Gravel	1800#
Pozzolith 300R	37 ounces (5 ounces/CWT)
Pozzolith 400N	105 ounces (14 ounces/CWT)
Air Entraining Agent	11 ounces
Total Water	34 to 36 gal. (.37 to .39 w/c)
Slump	4" to 6"
Percent Air	5 to 6

Mix Design (2) For A One Cubic Yard

Cement	752# (8sk)
Concrete Sand	1060# (SSD)
3/4" River Gravel	1800#
Pozzolith 300R	37 ounces (5 ounces/CWT)
Pozzolith 400N	120 ounces (16 ounces/CWT)
Air Entraining Agent	12 ounces
Total Water	33 to 35 gal. (.37 to .39 w/c)
Slump	5"
Percent Air	5.7

Mix Design (3) For A One Cubic Yard

Cement	752#
Concrete Sand	1060# (SSD)
3/4" River Gravel	1800#
Pozzolith 300R	37 ounces (5 ounces/CWT)
Pozzolith 400N	135 ounces (18 ounces/CWT)
Air Entraining Agent	13 ounces
Total Water	34 to 36 gal. (.38 to .40 w/c)
Slump	6"
Percent Air	6.6

Strength tests will be conducted at 14, 21, and 28 days. Test reports will be forwarded upon completion of testing.

PART III: PREDELIVERY INSPECTION REPORT

GENERAL and SPECIALTY CONTRACTORS

Premier WATERPROOFING COMPANY

2811 SOUTH INCA ■ 934-3467 ■ DENVER, COLORADO 80223

RECEIVED JAN 5 1987

JOB MEMO

TO: Elmer Ozolin, ABAM Engineers, Inc.

FROM: Charles R. Miller, Premier Waterproofing Company

SUBJECT: Field Inspection - Precast Stay-In-Place Form Panels

DATE: December 30, 1986

On December 30, 1986, 10:00 am the undersigned inspected all eight completed precast panels at Stresscon Corporation facility in Colorado Springs.

All panels looked good, some air pockets were noted on the concrete lip where concrete abuts the steel alignment angle. I instructed Joe Miller not to patch these, as we will apply grout in the field.

It was noted that we may have to grind off a small piece of concrete lip where corner armour metal work (panel above) meets the lip of the panel below. Will make a full description if this is a problem during erection.

Also noted was the fact that the raked finish was carried full panel height which may make the joint too tight, if amplitude is full ¼". Again, we will grind this excess off in the field. Recommend that rake finish stop 2½" below top of panel lip or at the weld plates.

No cracking was noted.

Measurements were taken, and are recorded on sheet two.

Panels are ready to ship and are acceptable for installation.

[signature] 12/30/86

cc: D. Schultheis

FIELD MEASUREMENTS - PRECAST PANELS

12-30-86

Panel No.	Nom. Width	Height O.A.	Height Other	Length Top	Length Btm.
P-1	6½"	6'-2½"	5'-11 5/8"	30'-0"	-
P-2	6½"	2'-11 11/16"	2'-11 5/8"	14'-11 3/4"	14'-11 3/4"
P-3	6½"	2'-11 11/16"	2'-11 11/16"	14'-11 11/16"	14'-11 11/16"
P-4	6½"	2'-11 11/16"	2'-11 11/16"	14'-11 3/4"	14'-11 3/4"
P-5	6½"	2'-11 5/8"	2'-9 1/4"	14'-11 5/8"	14'-11 5/8"
P-6	6½"	2'-11 3/4"	2'-11 11/16"	14'-11 3/4"	14'-11 3/4"
P-7	6½"	5'-11 11/16"	5'-11 5/8"	14'-11 3/4"	14'-11 5/8"
P-8	6½"	2'-11 5/8"	2'-9 1/4"	14'-11 3/4"	14'-11 11/16"

PART IV: AS-BUILT DATA

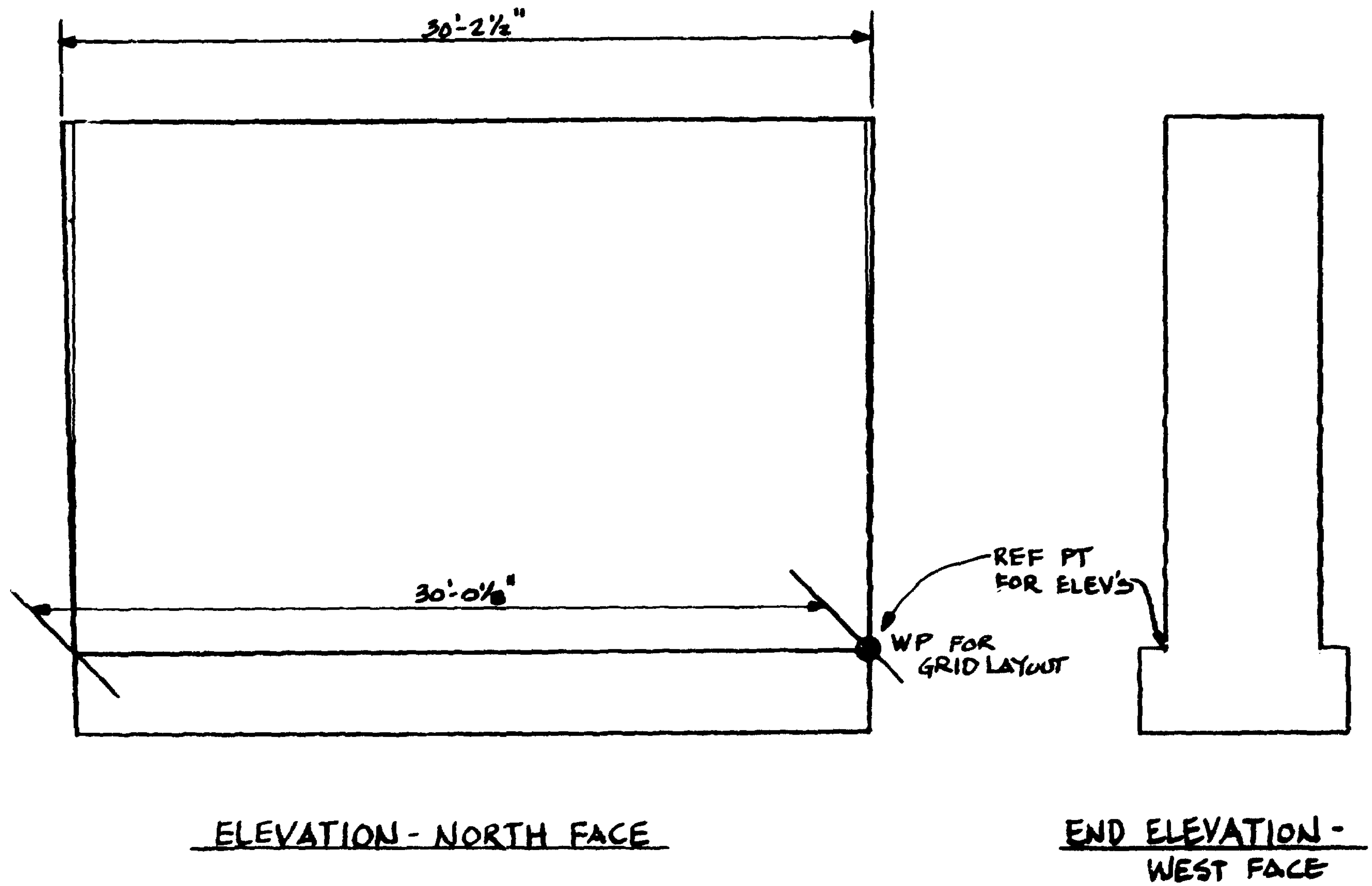


Figure D4.1. Monolith as-built data

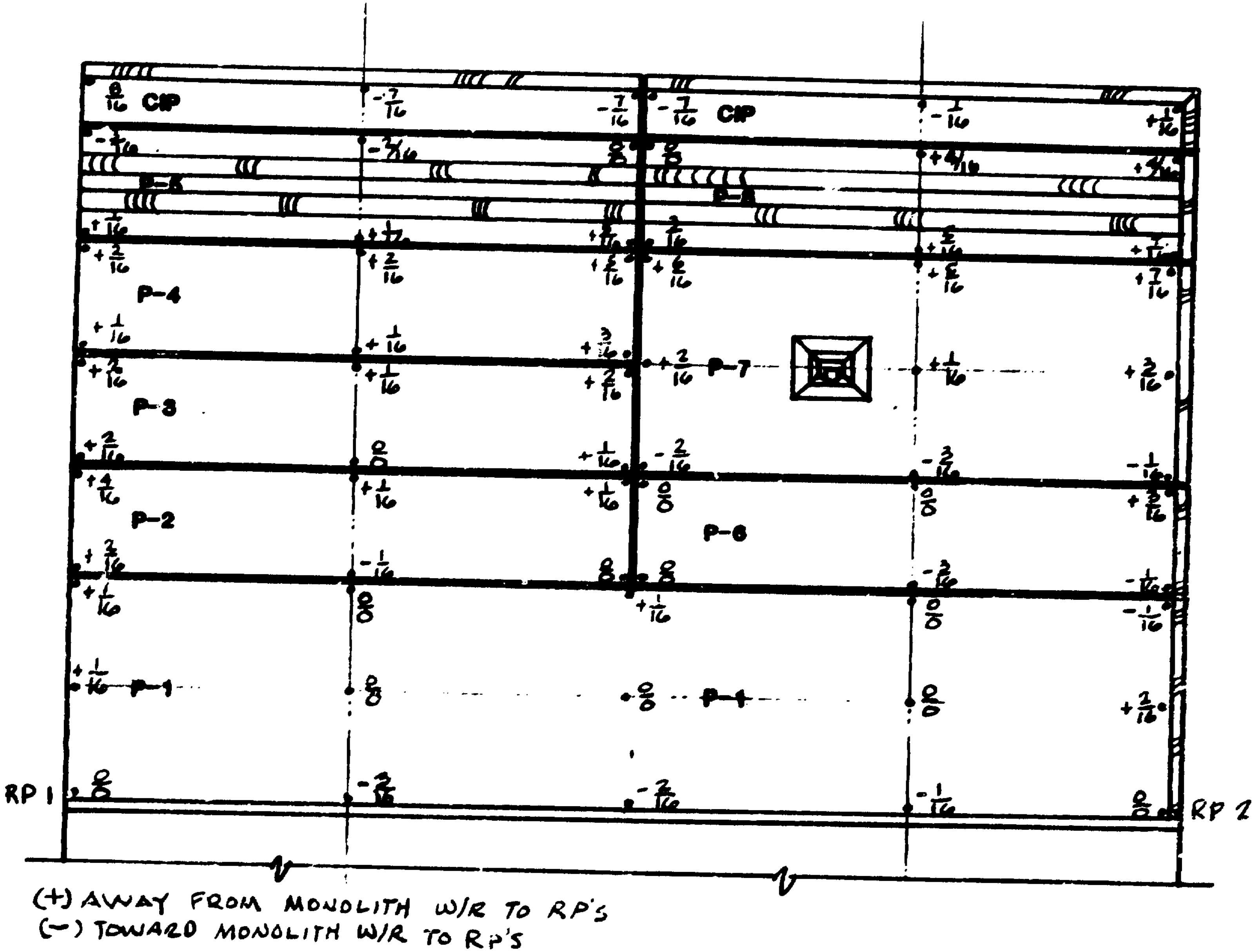


Figure D4.2. As-built offset measurements

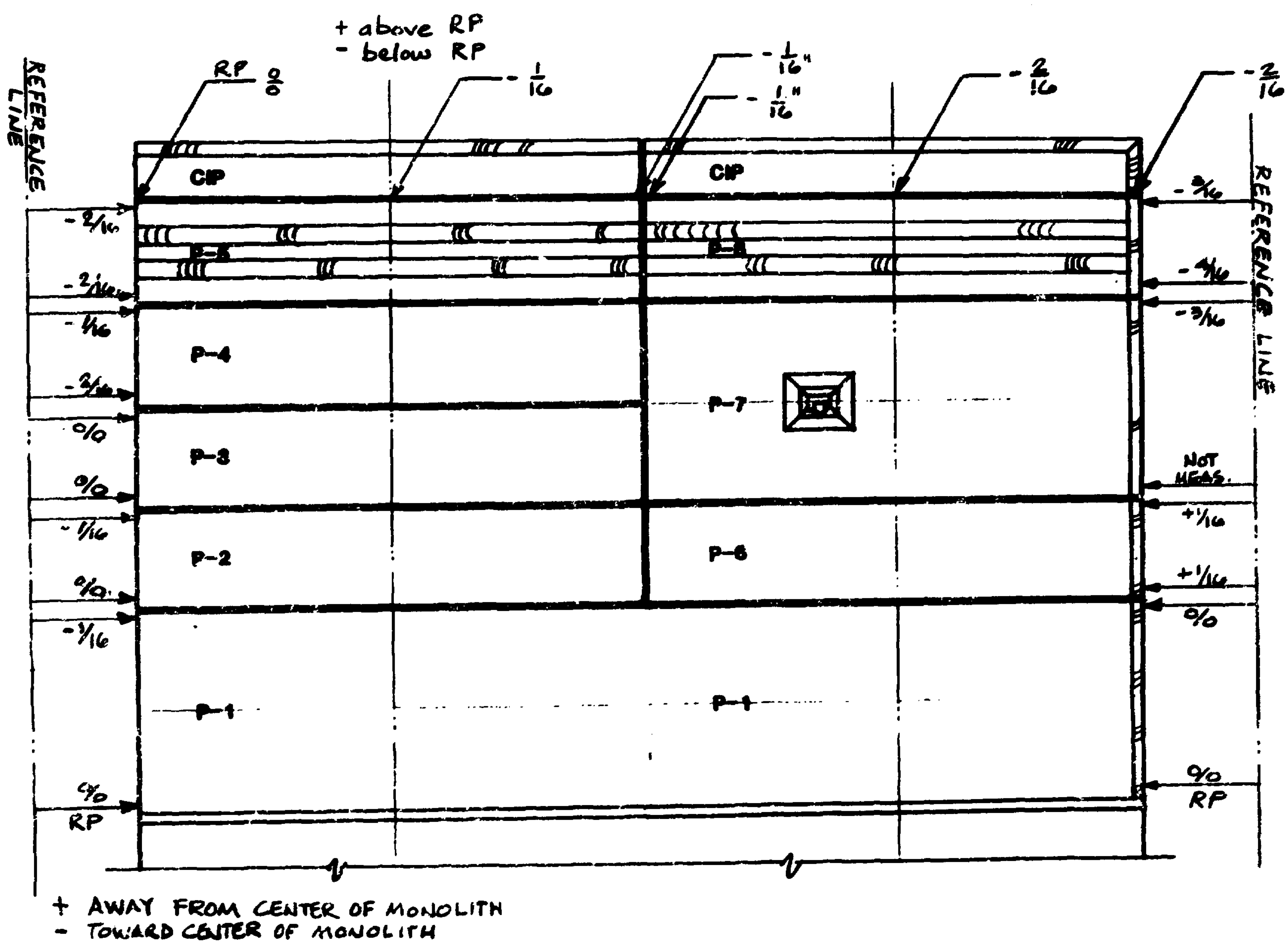


Figure D4.3. As-built data - end offsets and elevations

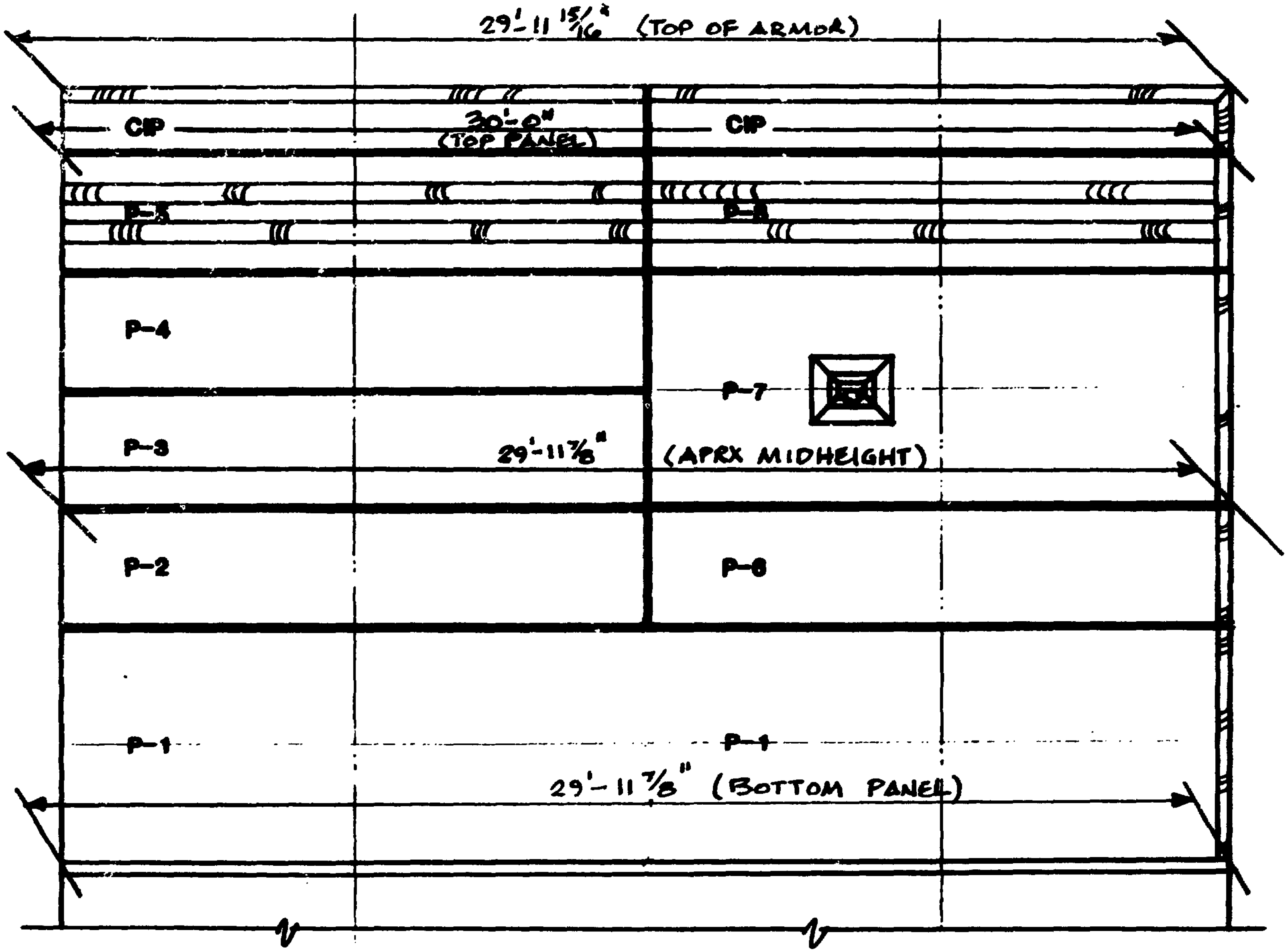
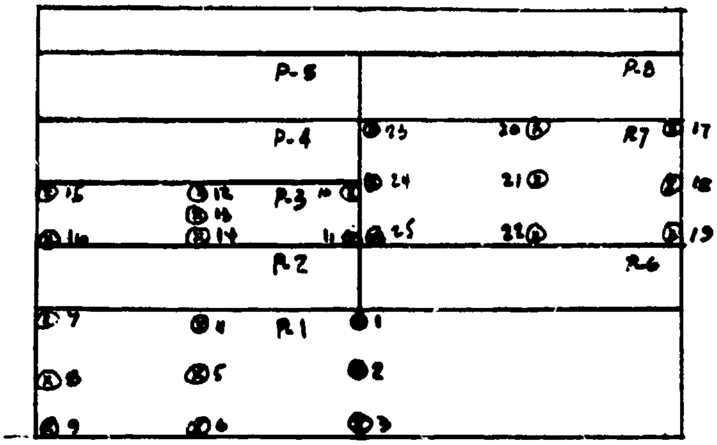


Figure D4.4. As-built data finished width



Ⓧ Location of Measurement

NOTE (-1) indicates panel movement inward

Panel	Date	Location	Before CIP Concrete	After CIP Concrete	Difference
P-1	20 Jan 87	1	23 9/16"	23 3/8"	3/16"
		2	23 5/8"	23 5/8"	—
		3	23 13/16"	23 3/4"	1/16"
		4	23 11/16"	23 5/8"	1/16"
		5	23 13/16"	23 3/4"	1/16"
		6	24"	23 15/16"	1/16"
		7	23 11/16"	23 9/16"	2/16"
		8	23 13/16"	23 9/16"	4/16"
		9	24"	24"	—
P-2	22 Jan 87	10	23 9/16"	23 5/8"	- 1/16"
		11	23 11/16"	23 11/16"	—
		12	23 13/16"	23 15/16	- 1/8"
		13	23 7/8"	23 7/8	-
		14	23 3/4"	23 15/16	- 3/16"
		15	24^{00}	23 15/16	+ 1/16
		16	23 15/16	24^{00}	- 1/16
		17	22 7/8	22 5/8	1/8"
P-7	27 Jan 87	18	23 1/8"	22 7/8	1/4"
	28 Jan 87	19	23^{00}	23 1/8	- 1/8
		20	22 13/16	22 11/16	1/8"
		21	23 1/8	23^{00}	1/8"
		22	23 1/4	23 1/4	—
		23	22 13/16	22 11/16	1/8"
		24	23 1/16	22 15/16	1/8"
		25	23 5/16	23 3/16	1/8"

Figure D4.5. Panel deflections

PART V: TIE AND DOWEL PULLOUT TESTS

Pullout tests were performed on form ties and dowels as required by Specification Section 2.2.3.f. Figure D5.1 identifies locations of the No. 7 ties and No. 6 dowels that were installed solely for the purpose of pullout testing. The reinforcing bar for testing was installed on 8 January 1987 using the same materials and general work procedures as the production bars. All tests were conducted on 13 January 1987.

Equipment for performing the tests was supplied by the Waterways Experiment Station Structures Laboratory. The equipment included two parallel mounted 10-ton flat jacks, a center hole jack, a 10,000-psi pressure gage, a 10,000-psi hand hydraulic unit, and a dial gage. The parallel flat jack configuration was used to test the No. 7 ties, whereas the center hole jack was used for the No. 6 dowels. The two jack configurations were calibrated prior to their use and the calibration data are attached. The reinforcing bar to be tested had threads provided on the projecting end for attachment to the testing equipment.

Ties and dowels were installed with the same epoxy (Concresive 1441) and general work procedures as the production ties and dowels. All were embedded 15 in. into the monolith wall except for Specimen 7-3. At this location, reinforcing steel was encountered while the hole was being drilled and the embedment was 13-1/2 in. rather than 15 in.

The test procedure for the No. 7 ties included the application of the load in four equal increments up to the required loading of 33 kips. Extension of the tie was recorded at each increment. The 33-kip load was then sustained for a minimum of 1 hour with extensions periodically measured. Following the 1-hour sustained load, additional load increments were applied which took the load beyond the theortical bar yield point.

All three No. 7 ties were successfully tested without failure. Results of the testing are summarized in pages D27 and D28. Elongations beyond the theoretical yield point remained linear. No visible distress was noted at the surface of the epoxy.

The No. 6 dowels were tested in a similar manner but without the requirement for sustaining the load for a 1-hour period. Although not specifically noted in the specification, the dowels were tested up to the yield load of 26.4 kips. Results of the No. 6 dowel tests are summarized on page D30. Testing was discontinued when the yield load was reached, at which time extension readings increased without increasing load. Two dowels yielded at the theoretical load. The third dowel, No. 6-2, required a 28.8-kip load to reach the yield point. Despite the yielding, no visible changes to the bars were observed, nor was any visible distress observed on the surface of the epoxy.

Based on the above tests, the materials and work procedures used to install ties and dowels result in capacities that meet the requirements and intent of the project specifications.

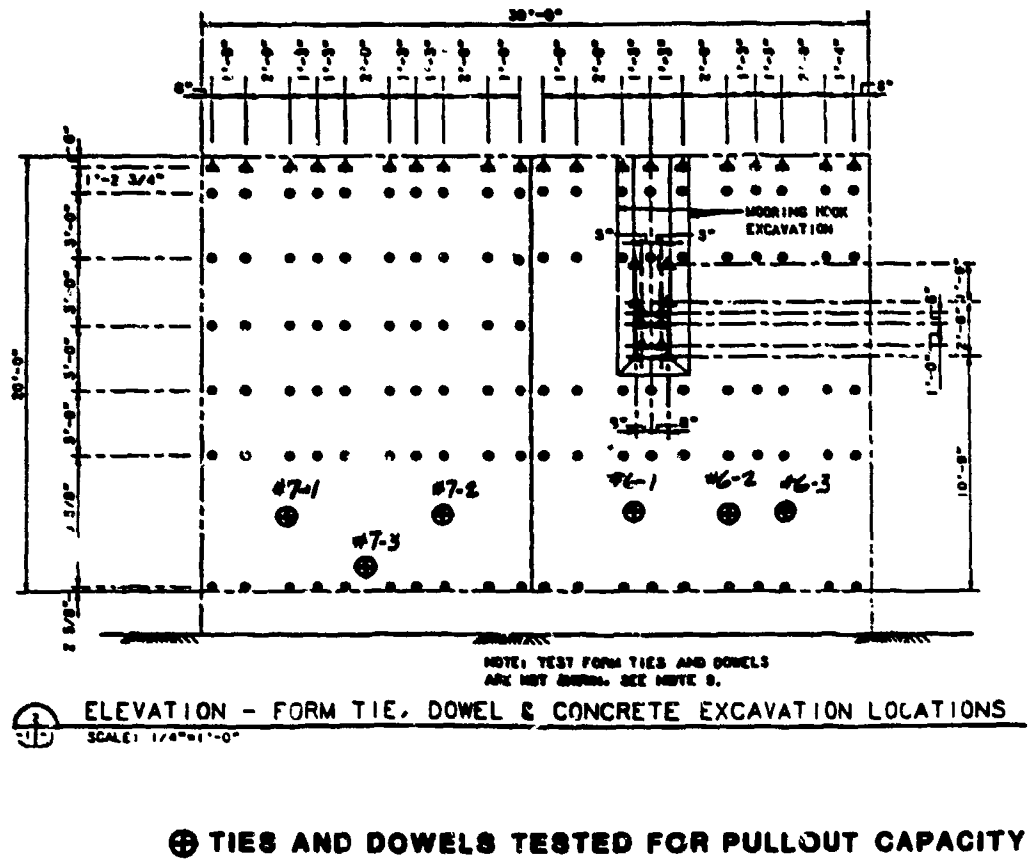
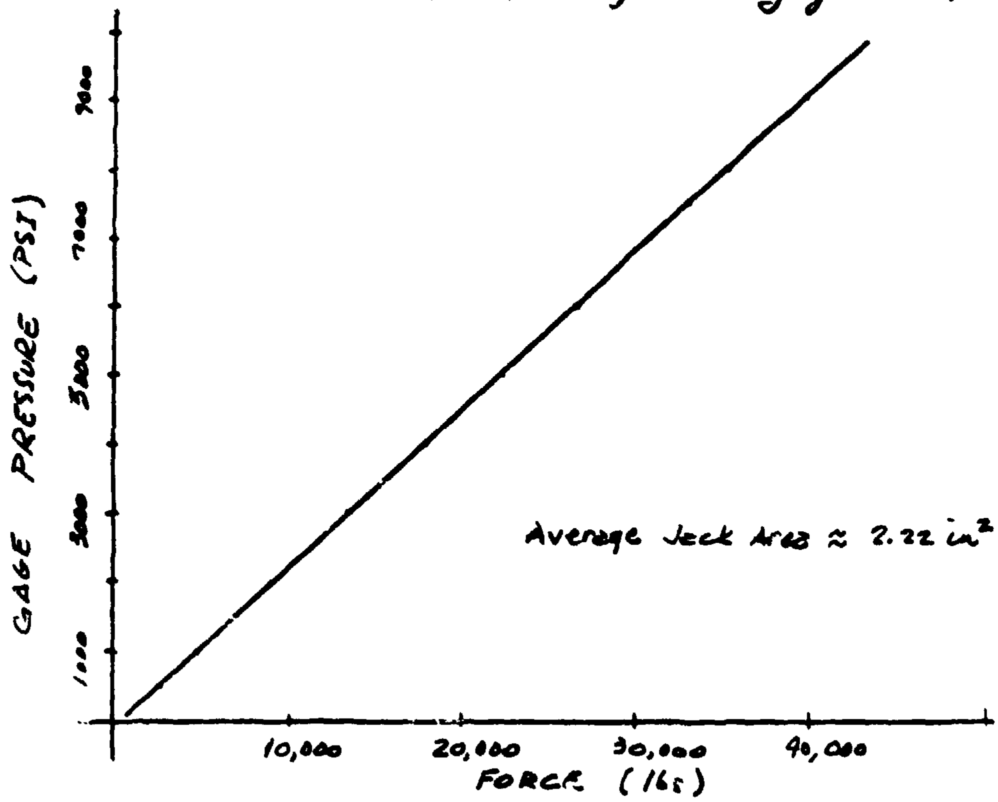


Figure D5.1. Test tie and dowel locations

Tests Performed by: E. Ozolin ABAM
D. Nilson COE
12 Jan 87

CALIBRATION TEST DATA

Jack Configuration - 2- 10 Ton Enerpac Flat Jacks
1- Enerpac 10,000 psi Hand hydraulic Unit.
1. 10,000 psi hydraulic gage "Soiltest"



TEST DATA

	FORCE (lbs)			
PRESSURE (PSI)	TRIAL 1	TRIAL 2	TRIAL 3 (*)	AVE
500	2,500	2,500		2,500
1000	4,700	4,600	4,600	4,630
1500	7,000	6,900		6,950
2000	9,100	9,100	9100	9,100
3000	13,600	13,600	13,600	13,600
4000	18,000	18,000	18,000	18,000
5000	22,400	22,400	22,300	22,370
6000	26,800	26,800	26,700	26,770
7000	31,200	31,000	31,000	31,070
7500	33,300	33,330	33,200	33,270
8000	35,500	35500		35,500
9000	40,000	40,000		40,000

(*) Performed after replacing fitting on hydraulic line

#7 BAR (TIE) PULLOUT TEST RESULTS

Required Tie Capacity - 33,000 lbs

Load Increments = $\frac{33000}{4}$ = 8250 lbs

Rebar Yield Force = 0.60 × 60,000 = 36,000 lbs

Rebar #7-1

FORCE	PRESSURE	GROSS EXTENSION	NET EXTENSION
0	0	0.486"	
			0.040"
8250 lbs	1800 psi	0.526"	
			0.015"
16500 lbs	3660 psi	0.541"	
			0.013"
24750 lbs	5540 psi	0.554"	
			0.018"
33000 lbs	7440 psi	0.572"	
			0.002"
33000 lbs	7440 psi	0.574"	
			0.002"
35500 lbs	8000 psi	0.576"	Σ = 0.090" to yield pt
			0.019"
40000 lbs	9000 psi	0.595"	

Rebar #7-2

FORCE	PRESSURE	GROSS EXTENSION	NET EXTENSION
0	0	0.271"	
			0.021"
8250 lbs	1800 psi	0.292"	
			0.010"
16500 lbs	3660 psi	0.302"	
			0.010"
24750 lbs	5540 psi	0.312"	
			0.011"
33000 lbs	7440 psi	0.323"	
			0.002"
33000 lbs	7440 psi	0.325"	
			0.003"
35500 lbs	8000 psi	0.328"	Σ = 0.057" to yield pt.
			0.016"
40,000 lbs	9000 psi	0.344"	

E. OZOLIN 13 JAN 87

REBAR #7-3 (Depth of Embedment - 13½")

FORCE	PRESSURE	GROSS EXTENSION	NET EXTENSION
0	0	0.328"	
8250 lbs	1800 psi	0.360"	0.032"
16500 lbs	3600 psi	0.386"	0.026"
24750 lbs	5540 psi	0.410"	0.024"
33000 lbs	7440 psi	0.437"	0.027"
① 33000 lbs	7440 psi	0.440"	0.003"
35500 lbs	8000 psi	0.446"	0.006"
40000 lbs	9000 psi	0.480"	0.034"

$\Sigma = 0.118"$ to yield pt.

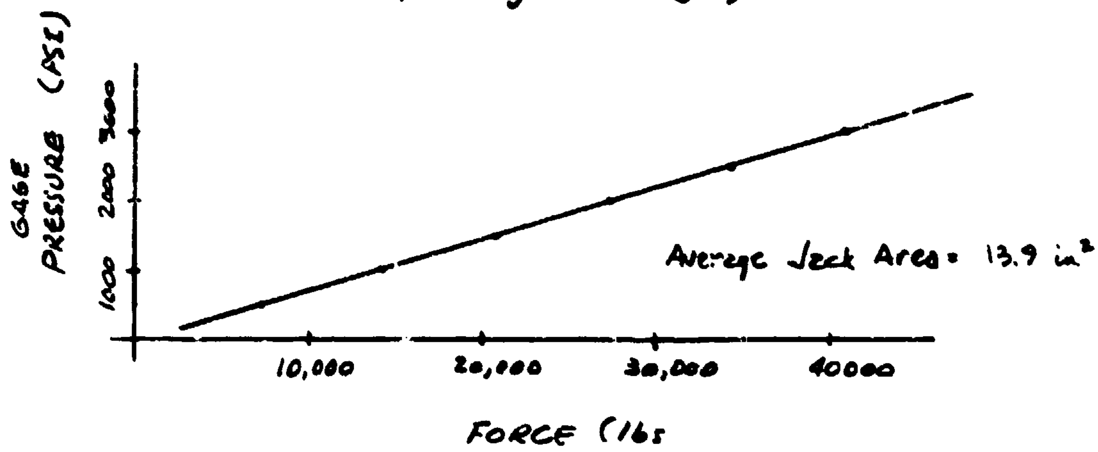
① LOAD SUSTAINED FOR 40 minutes ONLY

CALIBRATION TEST DATA

Tests Performed By:
E. Czolin ABAM
D. Wilson CoE
12 Jan 87

Jack Configuration:

1- Enerpac Center Hole Jack
1- Enerpac 10,000 psi hand hydraulic unit
1- 10,000 psi hydraulic gage "Soiltest"



CALIBRATION DATA

PRESSURE (PSI)	FORCE (lbs) TRIAL 1	TRIAL 2	AVE
500 psi	7400 lbs	7200 lbs	7300 lbs
1000 psi	14,100 lbs	13,900 lbs	14,000 lbs
1500 psi	20,700 lbs	20,700 lbs	20,700 lbs
2000 psi	27,400 lbs	27,600 lbs	27,500 lbs
2500 psi	34,200 lbs	34,500 lbs	34,350 lbs
3000 psi	40,800 lbs	41,100 lbs	40,950 lbs.

By E. Qualin 12/20/87

#6 BAR (DOWEL) PULLOUT TEST RESULTS

Required Tie Capacity 26.4 k

Load Increments = 26400/4 = 6600 lbs

DOWEL #6-1

FORCE	PRESSURE	GROSS EXTENSION	NET EXTENSION
		0.426"	
6,600 lb	450 psi	0.398"	0.028 in
13,200 lb	940 psi	0.363"	0.035 in
19,800 lb	1360 psi	0.312"	0.051 in
26,400 lb	1920 psi	Bar Yielded	

DOWEL #6-2

		0.392"	
6,600 lb	450 psi	0.365"	0.027"
13,200 lb	940 psi	0.347"	0.018"
19,800 lb	1360 psi	0.329"	0.018"
20,700 lb	1500 psi	0.323"	0.011"
22,060 lb	1600 psi	0.318"	0.005"
23,420 lb	1700 psi	0.312"	0.006"
24,780 lb	1800 psi	0.305"	0.007"
26,140 lb	1900 psi	0.300"	0.005"
27,500 lb	2000 psi	0.292"	0.008"
28,870 lb	2100 psi	0.280"	0.012"
		Yielded	

DOWEL #6-3

		0.370"	
6,600 lb	450 psi	0.200"	0.170"
13,200 lb	940 psi	0.169"	0.031"
19,800 lb	1360 psi	0.147"	0.022"
20,700 lb	1500 psi	0.138"	0.009"
22,060 lb	1600 psi	0.132"	0.007"
23,420 lb	1700 psi	0.125"	0.007"
24,780 lb	1800 psi	0.118"	0.007"
26,140 lb	1900 psi	0.108"	0.010"
	2000 psi	Thread on Rebar broke	

PART VI: WELD PROCEDURE AND WELDER QUALIFICATION TESTS

WELDING PROCEDURE FORM

Specification Number 01

Description Upper Tie Connection

PROCEDURE SPECIFICATION

Material Specification	ASTM A36 Plate - ASTM A706, Grade 60 Rebar
Welding Process	SMAW
Manual or Machine	Manual
Position of Welding	Horizontal
Filler Metal Specification	A5.5
Filler Metal Classification	E90XX
Weld Metal Grade	F4
Shielding Gas	N/A
Single or Multiple Pass	Multiple
Single or Multiple Arc	Single
Welding Current	170 - 200
Polarity	Positive
Root Treatment	None
Preheat and Interpass Temperature	N/A

WELDING PROCEDURE

PASS NO.	ELECT. SIZE	WELDING CURRENT AMPERES	WELDING CURRENT VOLTAGE	JOINT DETAIL
1	5/32	170-200	18-24	
2	5/32	170-200	18-24	
3	5/32	170-200	18-24	

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the Limitation of Variables given in 6.2.1.

Procedure No. 01

Revision No. 01

Manufacturer or Contractor Preimier Waterproofing

Authorized by Charles Miller

Date 12/4/86 Rev'd. 1/21/87

WELDING PROCEDURE FORM

Specification Number 02

Description Bottom Tie Connection

PROCEDURE SPECIFICATION

Material Specification ASTM A36 Plate - ASTM A706, Grade 60 Rebar
Welding Process SMAW
Manual or Machine Manual
Position of Welding Overhead
Filler Metal Specification A5.5
Filler Metal Classification E90XX
Weld Metal Grade F4
Shielding Gas N/A
Single or Multiple Pass Multiple
Single or Multiple Arc Single
Welding Current 150
Polarity Positive
Root Treatment N/A
Preheat and Interpass Temperature N/A

WELDING PROCEDURE

PASS NO.	ELECT. SIZE	WELDING CURRENT		JOINT DETAIL
		AMPERES	VOLTAGE	
1	1/8	150	18-24	
2	1/8	150	18-24	
3	1/8	150	18-24	
4	1/8	150	18-24	
5	1/8	150	18-24	
6	1/8	150	18-24	

This procedure may vary due to fabrication sequence, fit-up, pass size, etc. within the Limitation of Variables given in 6.2.1.

Procedure No. 02
Revision No. 00

Manufacturer or Contractor Preimier Waterproofing
Authorized by Charles Miller
Date 1/19/87

COLORADO TEST CENTER, INC.
155 SOUTH NAVAJO STREET
DENVER, COLORADO 80223
(303) 698-1060

January 16, 1987
706002

REPORT: Tensile Testing of Rebar to Plate Weld for Procedure Qualification

CLIENT: Premier Waterproofing Inc.
2311 S. Inca
Denver, CO 80223

Attn: Chuck Miller

DATE OF TEST: January 13, 1987

PROJECT: Colorado Test Center, Inc. (CTC) was requested by the client to perform a tensile test on a welded rebar specimen provided by the client. The primary objective of the test was to qualify the welding procedure used on the particular size and type of rebar and plate.

The test specimen was supplied for testing by the client and was identified as the following:

Reinforcing Steel Bar:	#7, grade 60, ASTM A706, 18 inches in length
Plate:	1/2" X 3" X 6", grade A36
Weld:	7/16 double flare bevel groove weld grade E90XX

TEST PROCEDURE: The 1/2 inch plate was welded by CTC to a larger 7/8 inch plate and then placed in the testing bay of a Tinius Olsen Universal Testing Machine. The testing machine is in current calibration and traceable to the National Bureau of Standards. The plate end was affixed to the top cross-head of the machine while the rebar end was gripped in the lower crosshead's jaws. A tensile load was gradually applied (1000 lbs/sec) until ultimate failure occurred.

TEST RESULTS: An ultimate load of 54,650 lbs. was obtained at which point the specimen failed in the rebar at the heat affected zone of the weld. The ultimate strength of the weldment

$$54,650 \text{ lbs}/0.60 \text{ inches}^2 = 91.1 \text{ ksi}$$

exceeds the specified ultimate strength of the parent material (90 ksi per ASTM A617).

80 ksi for ASTM A706 weldable grade bars
EWD

Two Macroetch samples were made of the rebar and weld cross sections. Fusion zone, heat affected zone and weld size were examined and found acceptable.

If you have any questions regarding this report please feel free to call.

Very truly yours,

COLORADO TEST CENTER, INC.

John Dinsmoor,
Test Engineer

JD:kb

EFABCO INC.

VISUAL EXAMINATION

WELDERS NAME WILLIAM L. ALLEN SS# 587-03-9693

1. **PRE-WELD Inspection:**

Material Identification Condition:		
Material Stamping	A-36 Plate - A706 Rebar	—
Storage of Welding Consumables		ok
Surface Condition		✓
Mishandling		No
Joint Preparation:		
Correct Bevel Angle		ok
Proper Cleaning		ok
Proper Root Face		ok
Dimensions		ok
Special Set-Ups:		
Jigging and Bracing		N/A
Pre-Stressing or Pre-Chambering		N/A
Joint Fit-Up and Tacking:		
Root Spacing		ok
Placement of Tacks		ok
Tacks Properly Ground		ok
Correct Type Joint per Drawing		ok

2. **INSPECTION DURING WELDING:**

Preheat		N/A
Filler Material (Type and Size)		532 E9018
Electrical Charateristics (Polarity, Amps)	DC POS 170-200	18-24 Volts
Root Pass		ok
Interpass Temperature		N/A
Cleaning between Passes		yes
Root Preparation to weld Second Side		N/A
Appearance of Passes (Compare to workmanship sample)		good

Inspection During Welding (Cont'd):

Purge Back Side (Gas & Flow Rate)	N/A
Variations from Approved WPS	None

3. INSPECTION AFTER WELDING:

Size of Filler Welds	7/16
Convexity and Concavity	1/16
Finish of Weld Surface	OK
Undercutting	None
Overlap	None
Cracking	None
Surface Porosity & Slag	None
Lack of Fusion	None
Incomplete Penetration	None
Weld Re-enforcement (Cap)	OK
Excessive Grinding	No
Excessive Center Pinching or other Marking	No
Evidence of Mishandling	No
Need of Other NDT	No

4. REPAIRS:

Marking	
Inspection of Preparation for Repair	
Inspection after Repair	
Postheat Treatment	
Hydrostatic Testing	

W. East 1-8-87

NDE Technician DATE

PART VII: CAST-IN-PLACE CONCRETE MIX AND INSPECTION REPORTS

19 December 1986

CONCRETE MIX DESIGN

MIX # 35415AWB 3000 psi

CONTRACTOR : PREMIER WATERPROOFING COMPANY
PROJECT : CORPS OF ENGINEERS STAY-IN-PLACE FORMS
SOURCE OF CONCRETE : MILLER READY-MIX CO.INC.

IDENTIFICATION OF MATERIALS

CEMENT, BRAND, TYPE	LONESTAR, C-150 [I]
MINERAL ADMIXTURE	TRINITY MATERIALS, C-618 CLASS F
FINE AGGREGATE	RUNYON 27 PIT
COARSE AGGREGATE	RUNYON 27 PIT #57
ADMIXTURE, BRAND, TYPE	GRACE WRDA-79, A
	GRACE DARASET, E
	GRACE DARACEM, F
AIR ENTRAINING AGENT	GRACE DAREX

WEIGHTS PER CUBIC YARD (SATURATED, SURFACE-DRY)

			YIELD, CF	
CEMENT, LB.	408		2.08	
MINERAL ADMIXTURE, LB.	72		0.51	
FINE AGGREGATE, LB.	1300		7.92	
COARSE AGGREGATE, LB.	1920		12.11	
WATER, LB. (GAL.)	217	(26.0)	3.47	
AIR ENTRAINMENT, PERCENT	3 to 5		1.09	
			=======	
			27.18	TOTAL
ADMIX 1, OZ	24.0			
ADMIX 2, OZ	96.0			
ADMIX 3, OZ	43.2			
AIR ENTRAINING AGENT, OZ	6.7			
WATER/CEMENT RATIO, LBS/LB	0.45			
SLUMP, INCHES	3.00	(2.00 to 4.00)		
CONCRETE UNIT WEIGHT, PCF	144.1			

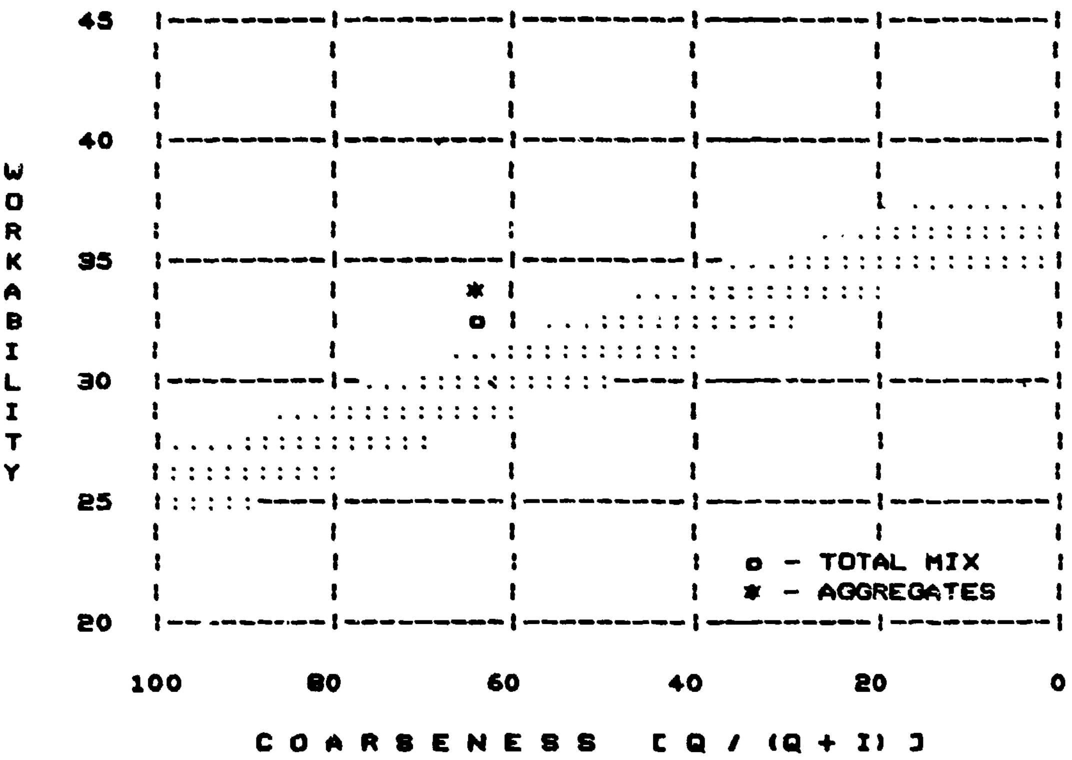
PREPARED BY :

C. R. Barry

[MIX 6 35415AWB 3000 psi] -- PAGE 2

MIX ANALYSIS

MIX VOLUME, CUBIC FEET	27.2
COARSENESS (Q / (Q + I))	64.3
WORKABILITY	34.2
W - ADJUST	32.0
PERCENT MORTAR	51.5
TOTAL FINENESS MODULUS	5.25



MIX CHARACTERISTICS

	STONE	SAND
SPECIFIC GRAVITY	2.54	2.65
% PASSING 3/8" SIEVE	30.0	100.0
% PASSING NO. 8 SIEVE	1.0	85.0
FINENESS MODULUS	6.97	2.62

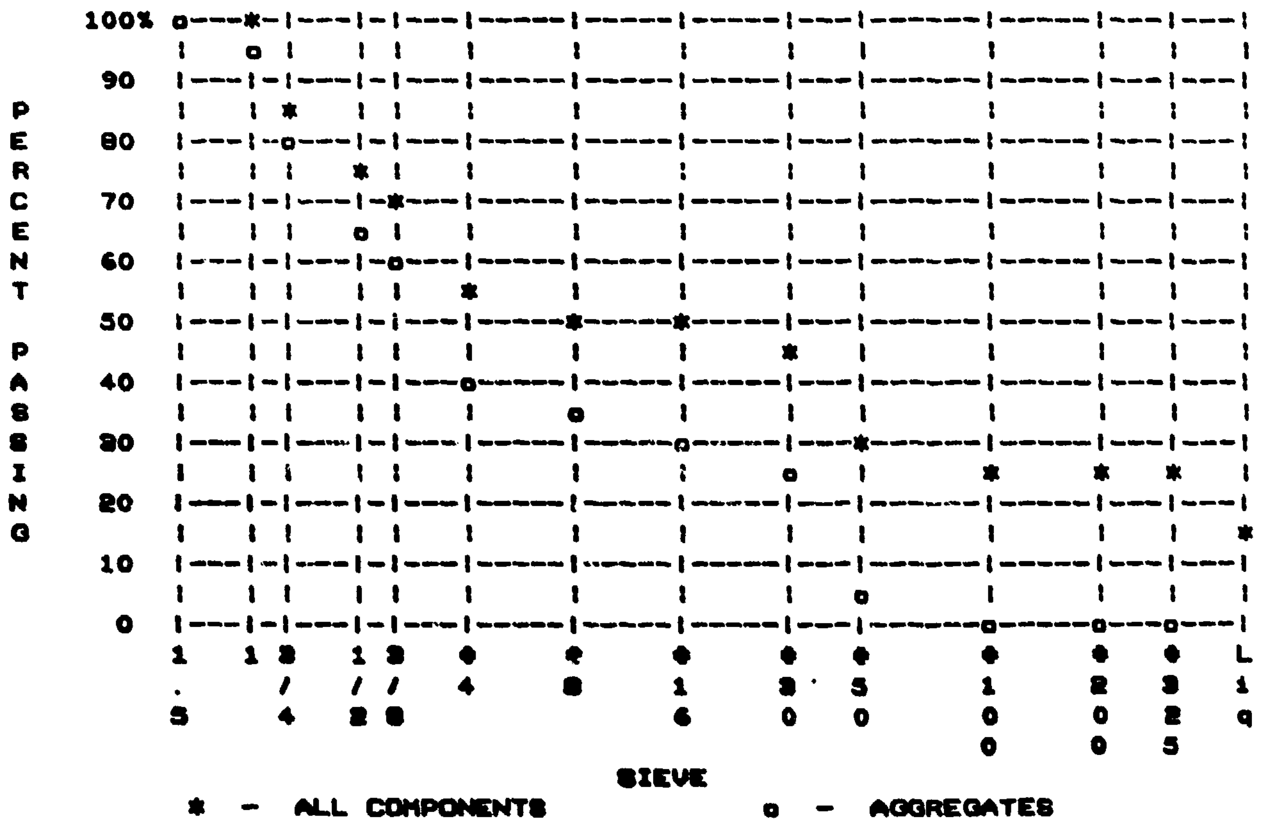
MINERAL ADMIXTURE SPECIFIC GRAVITY -- 2.26

EXPOSURE CONDITIONS -- NO SEVERE EXPOSURE

FULL GRADATION ANALYSIS

SIEVE	STONE	SAND	PASTE	TOTAL	AGGR
1-1/2"	100.0			100.0	100.0
1 "	94.5			97.5	96.7
3/4"	70.0			86.6	81.9
1/2"	46.0			75.9	67.4
3/8"	30.0	100.0		68.8	57.7
# 4	2.0	95.0		54.9	38.8
# 8	1.0	85.0		51.5	34.2
# 16	0.0	79.0		49.3	31.2
# 30		64.5		45.1	25.5
# 50		12.0		29.8	4.7
#100		2.5		27.0	1.0
#200		0.0	100.0	26.3	0.0
#325			96.1	25.3	0.0
Liquid			63.8	16.8	

GRADATION CHART



WARREN COUNTY
ENGINEERING SERVICES, INC

TESTING LABORATORY
2 OPENWOOD PLAZA
1104 OPENWOOD STREET
VICKSBURG, MS 39180
(601) 636-7842

RECEIVED
FEB 23 1987

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co. (Purchase Order # 1183) (Contract # 86-7)

DATE January 20, 1987

LAB. NO.

Date Made Jan. 20, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mel Carlson
Reported to Contractor
Quantity Poured 2 yds.
Concrete Temperature 41°
Air Temperature 38°
Entrained Air 5%

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour
PW - 1	65,500	2300	3000	7	3½	WES - Stay-in-place lock wall
PW - 2	63,000	2230		7		
PW - 3	112,000	3960		28		
PW - 4	115,000	4070		28		

Remarks:

WARREN COUNTY ENGINEERING SERVICES, INC.

cc: Miller Ready Mix

By [signature]

WARREN COUNTY
ENGINEERING SERVICES, INC
TESTING LABORATORY
2 OPENWOOD PLAZA
1104 OPENWOOD STREET
VICKSBURG, MS 39180
(601) 636-7642

RECEIV
FEB 23 1987

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co.

DATE January 21, 1987

LAB. NO.

Date Made Jan. 21, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mel Carlson
Reported to Contractor
Quantity Poured 1 yd.
Concrete Temperature 40°
Air Temperature 40°
Entrained Air 3½%

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour
PW - 5	75,500	2670	3000	7	3	WES - Stay-in-place lock wall
PW - 6	74,500	2646		7		
PW - 7	122,000	4320		28		
PW - 8	124,000	4390		28		

Remarks:

WARREN COUNTY ENGINEERING SERVICES, INC.

cc: Miller Ready Mix

By [signature]

WARREN COUNTY
ENGINEERING SERVICES, INC

TESTING LABORATORY
2 OPENWOOD PLAZA
1104 OPENWOOD STREET
VICKSBURG, MS 39180
(601) 636-7842

RECD
FEB 23 1987

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co. DATE January 22, 1987

LAB. NO.

Date Made Jan. 22, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mel Carlson
Reported to Contractor
Quantity Poured 1 yd
Concrete Temperature 45°
Air Temperature 40°
Entrained Air 4%

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour
PW - 9			3000		4½	Stay-in-place Wall
PW - 10						
PW - 11	99,000	3500		28		
PW - 12	102,000	3610		28		

Remarks:

WARREN COUNTY ENGINEERING SERVICES, INC.

CC: Miller Ready Mix

By [signature]

WARREN COUNTY
ENGINEERING SERVICES, INC

TESTING LABORATORY
2 OPENWOOD PLAZA
1104 OPENWOOD STREET
VICKSBURG, MS 39180
(601) 636-7642

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co. **DATE** January 22, 1987

LAB. NO.

Date Made Jan. 22, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mel Carlson
Reported to Contractor
Quantity Poured 1 yd
Concrete Temperature 45°
Air Temperature 40°
Entrained Air 4%

P.O 1183

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour:
PW - 9	63,500	2650	3000	7	4½	Stay-in-place Wall
PW - 10	62,000	2250		7		
PW - 11	99,000	3500		28		
PW - 12	102,000	3610		28		

Remarks:

cc: Miller Ready Mix

WARREN COUNTY ENGINEERING SERVICES, INC.

By ________ [signature]

WARREN COUNTY ENGINEERING SERVICES, INC

TESTING LABORATORY
2 OPENWOOD PLAZA
1104 OPENWOOD STREET
VICKSBURG, MS 39180
(601) 636-7642

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co. **DATE** January 23, 1987

LAB. NO.

Date Made Jan. 23, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mal Carlson
Reported to Contractor
Quantity Poured 2 yds.
Concrete Temperature 50°
Air Temperature 55°
Entrained Air 4%

P.O 1183

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour:
PW - 13	76,000	2690	3000	7	3	Stay-in-place Wall
PW - 14	77,500	2740		7		
PW - 15	112,500	3980		28		
PW - 16	113,500	4010		28		

Remarks:

cc: Miller Ready Mix

WARREN COUNTY ENGINEERING SERVICES, INC.

By [signature]

WARREN COUNTY
ENGINEERING SERVICES, INC

TESTING LABORATORY
[illegible] PLAZA
[illegible] STREET
VICKSBURG, MS 39180
(601) [illegible]

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co. **DATE** January 27, 1987

LAB. NO.

Date Made Jan. 27, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mel Carlson
Reported to Contractor
Quantity Poured 5½ yds.
Concrete Temperature 58°
Air Temperature 57°
Entrained Air 4%

P.O. 1183

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour:
PW - 17	74,500	2640	3000	7	4	Stay-in-place Lock Wall
PW - 18	75,500	2670		7		
PW - 19	107,000	3780		28		
PW - 20	105,000	3710		28		

Remarks:

WARREN COUNTY ENGINEERING SERVICES, INC.

cc: Miller Ready Mix

By [signature]

WARREN COUNTY
ENGINEERING SERVICES, INC

TESTING LABORATORY
2 GREENWOOD PLAZA
1104 GREENWOOD STREET
VICKSBURG, MS 39180
(601) 638-7842

REC'D
MAR 2 1987
[illegible]

CONCRETE CYLINDER TESTS

PROJECT: Premier Waterproofing Co. **DATE** January 28, 1987

LAB. NO.

Date Made Jan. 28, 1987
Contractor Premier Waterproofing Co.
Brand of Cement
Water, Gal. per sack of cement
Mix Design No.

Cylinders made by: Mel Carlson
Reported to Contractor
Quantity Poured 2½ yds.
Concrete Temperature 60°
Air Temperature 68°
Entrained Air 4%

PO 1123

Cylinder Number	Load Total	Pounds Per Square Inch	Required Pounds Per Square Inch (28-Day)	Age When Tested Days	Slump Inches	Location of pour
PW - 21	75,000	2650	3000	7	6	Locking Wall
PW - 22	77,500	2740		7		
PW - 23	105,000	3710		28		
PW - 24	97,500	3450		28		

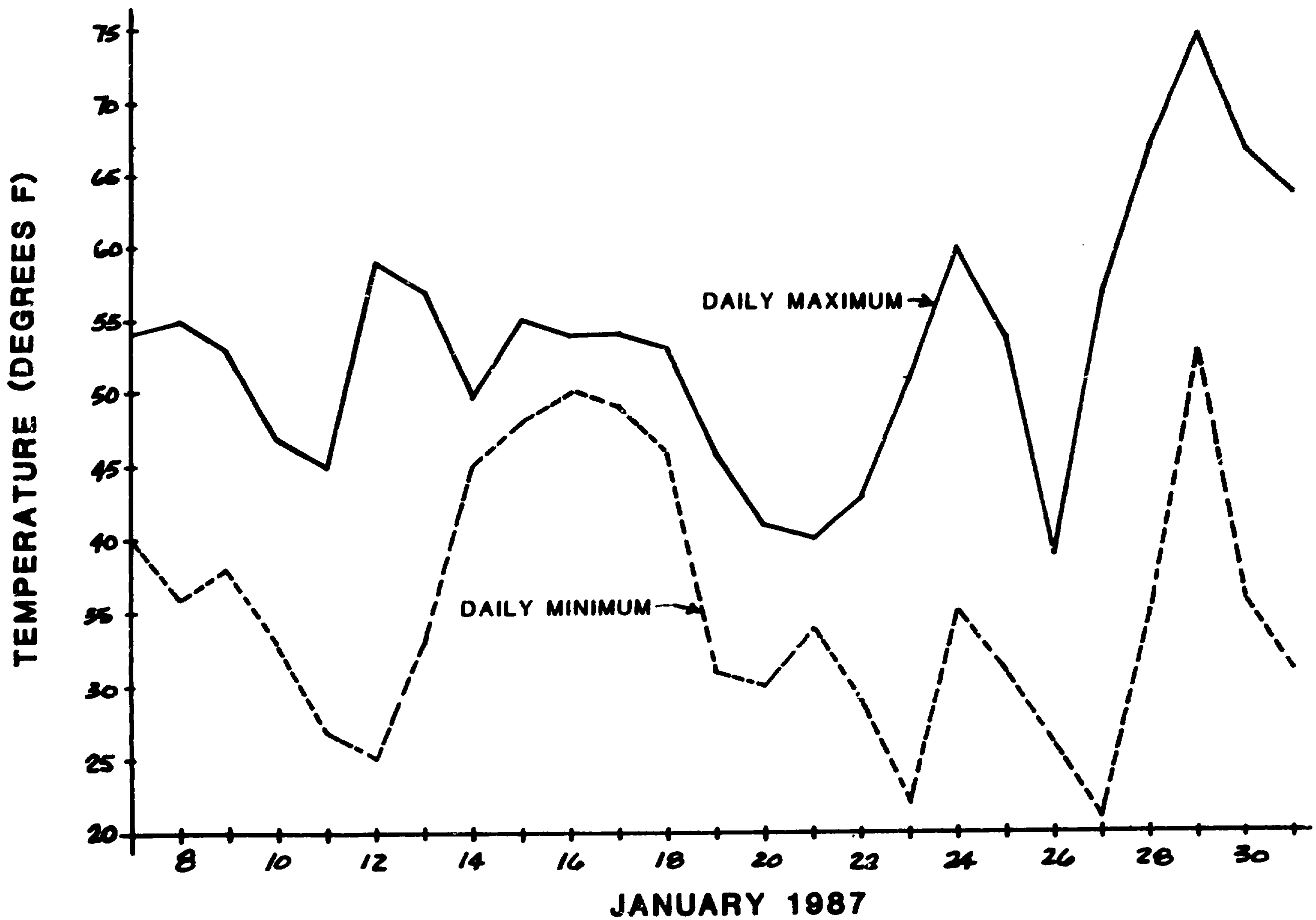
Remarks:

WARREN COUNTY ENGINEERING SERVICES, INC.

CC: Miller Ready Mix

By PCJ

PART VIII: TEMPERATURES DURING CONSTRUCTION PERIOD



TEMPERATURES DURING CONSTRUCTION

APPENDIX E: QUALITY CONTROL PLAN

The Quality Control Plan was prepared from the perspective of a contractor about to use a precast forming system to perform repairs to a navigational lock. This plan should satisfy the Corps of Engineers standard specification requirements (Section 01400) of a quality control plan submittal by the contractor. Standard Corps of Engineers forms and procedures have been incorporated whenever possible. This document can be used as a benchmark to compare to actual submittals from contractors or, with modifications to the wording, it can be appended to the contract documents for any given project. Information contained in brackets represents choices to be included in the text or commentary.

QUALITY CONTROL PLAN

Project Name ______________________________

Project Number ______________________________

Submitted by

Contractor ______________________________

Contracting Agency ______________________________

Contracting Officer ______________________________

Contractor's Representative ______________________________

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

I. IMPLEMENTATION

A. INTRODUCTION

The work covered by this contract includes the use of precast concrete stay-in-place form panels in conjunction with cast-in-place infill concrete to repair deteriorating navigational lock wall surfaces The repair will encompass _____ lin ft of lock wall surface with typical monolith dimensions of _____ ft wide by _____ ft high. The completed installation will include a total of _____ precast panels and _____ cu yd of cast-in-place concrete. All panels will be cast at a[n] _______ [on-site, remote] precasting yard and stored until they are required for erection. The form panels are erected in a horizontal orientation and attached to the lock walls using _________ [welded, mechanical] ties. Some panels contain embedded lock hardware. Additional lock hardware will be incorporated at joints between the panels and embedded into the infill concrete. The overall success of this repair depends on the Contractor's ability to install panels and construct closure pours to the tolerances specified in the contract documents while minimizing lock closure time.

B. OBJECTIVES

As a condition of the contract, a quality control (QC) plan will be implemented by _________ [contractor] to verify that all facets of the lock wall repair work are completed in accordance with the contract requirements. This document presents an outline of such a QC plan, including a comprehensive list of all required tests and inspections, identification of QC personnel, establishment of authority, and communications. Appropriate forms have been developed to document inspections for the project record and these have been incorporated in the appendix.

C. RESPONSIBILITIES AND AUTHORITY

Responsibility for the quality of the completed work rests with the contractor's project manager (PM). A QC staff, as shown in the organization chart (Figure E1), will perform the detailed QC functions described herein and report to the project manager (PM). The PM will assure that production superintendents are knowledgeable relative to the requirements of the QC program and cognizant of the authority vested in the QC staff.

A QC manager (QCM) will be responsible for the activities of the QC staff, as identified in Figure E2. The QCM will maintain daily communications with the PM regarding the status of QC matters. The QCM will be notified of any nonconforming work by the QC inspectors and will determine the need for suspending work to prevent recurrence. The QCM has the authority to issue stop work notices to the production superintendent. After stopping work, the QCM, PM, project engineer (PE), production superintendent, and Corps of Engineers resident engineer (COE RE) will meet to resolve the nonconformance. In the resolution of quality versus production schedule conflicts, quality concerns shall govern. All instances of nonconforming work shall be documented by a nonconformance report, as outlined in Section III.

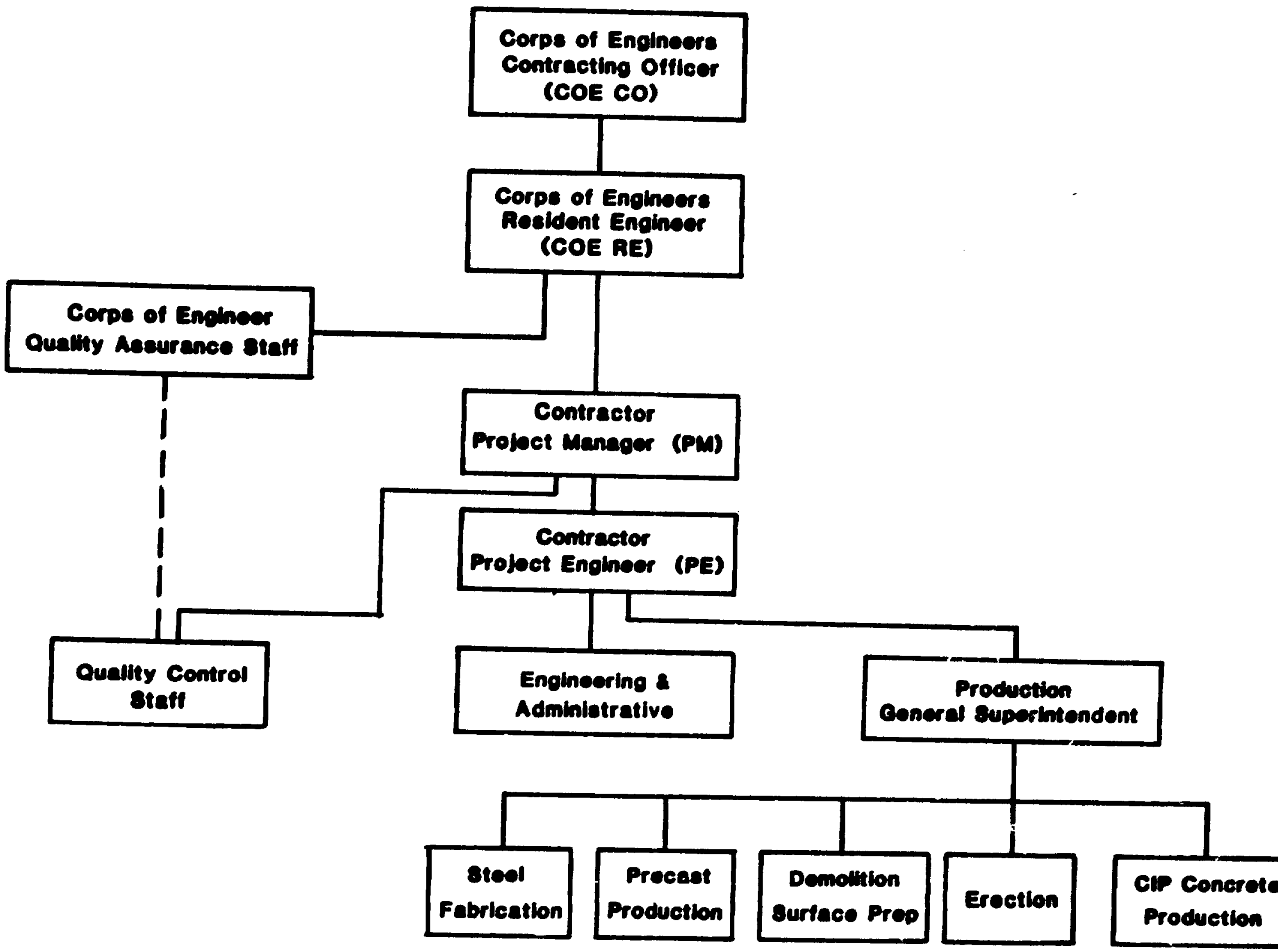


Figure E1. Organizational chart

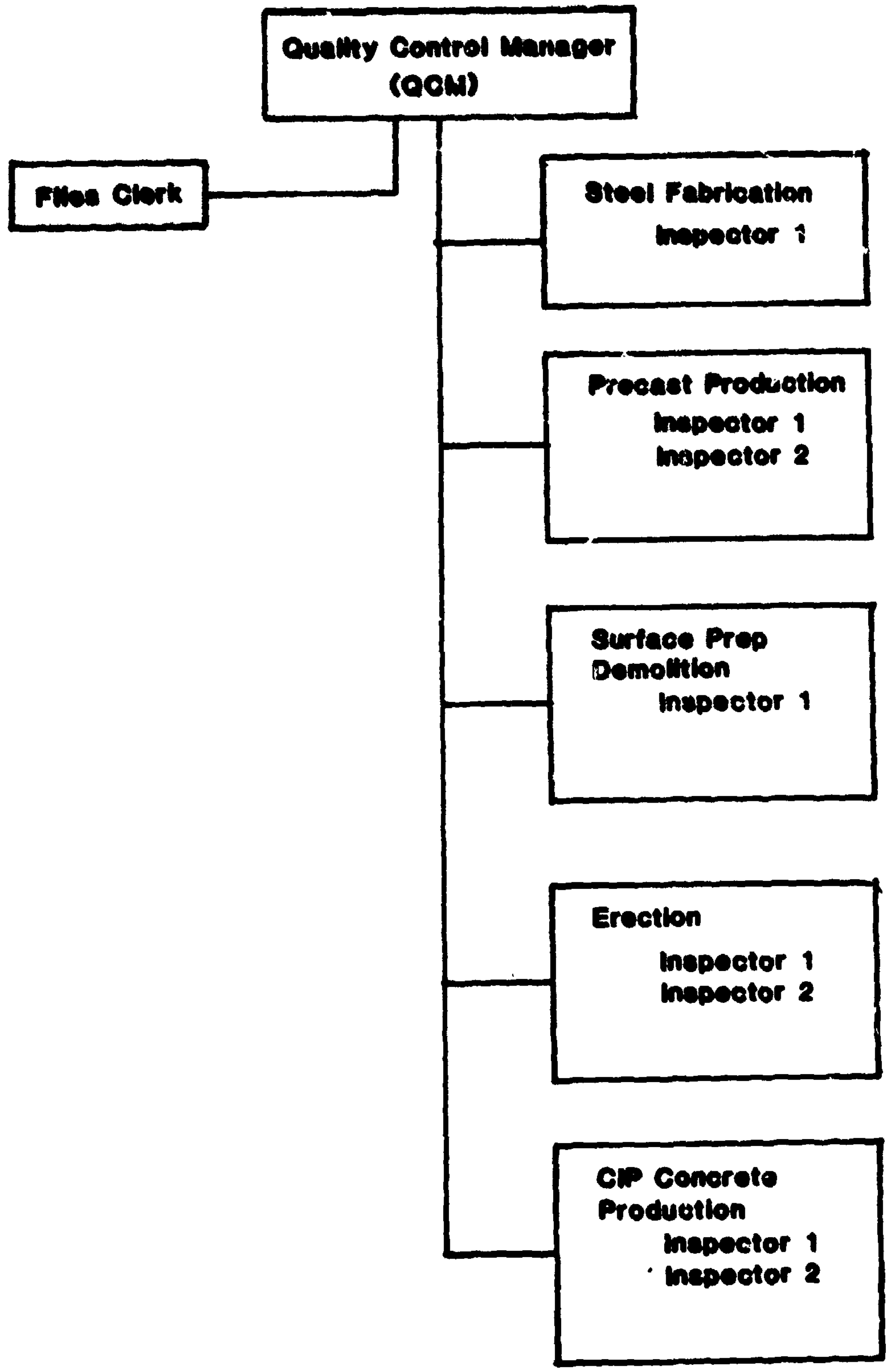


Figure E2. QC staff organization

The general superintendent will notify the QCM when a unit of work is complete and ready for final inspection. The QCM will verify that all contract requirements have been satisfied by performing field inspections and measurements and verifying the documentation in the files. If all requirements are satisfactorily completed, the QCM will advise the PM that the unit of work is ready for submitting for acceptance. Upon the PM's concurrence, the Corps of Engineers contracting officer (COE CO) will be notified in writing that the specific work is ready for acceptance. No work will be accepted with an unresolved nonconformance report.

D. COMMUNICATIONS

Communications will follow the lines shown in the organization chart in Figure E1. Two levels of communications are required to ensure that work is performed to the required quality. The first level represents formal transmittals between the contractor and the COE, which includes serially numbered transmittals over the PM's signature. These include factors such as recurrence of QC problems, schedule variations, design conflicts, and other contractual issues. The second type of communications occurs at the "worker's level," which includes actions, resolutions, exchanges of data, etc., that are within the limits of the contract documents. Typical correspondence includes daily inspection reports, checklists, internal memoranda, and discussions.

Regular meetings will be held at one-week intervals to review the performance of the QC program and other related QC concerns. Attendance by the COE RE, PM, PE, and QCM shall be mandatory. The presence of individual QC staff members may be requested by the COE RE, PM, or QCM. Special meetings may be called by the COE CO at any time. Minutes of all meetings shall be prepared by the PM and distributed to all in attendance within five working days of the meeting.

QC staff members have the authority to directly discuss QC matters with individual trade superintendents in an effort to avert nonconforming work. These discussions are not contractual obligations that intend to create change orders to the contract with cost and schedule impacts. These discussions are to maintain communications to clarify what is done within the limits of the contract documents. If a resolution cannot be reached at this level, the QCM will be notified. The QC staff members also have the authority to discuss quality matters directly with members of the COE RE's quality assurance (QA) staff.

E. DOCUMENT CONTROL AND RECORDS

All correspondence will be addressed by the PM to the COE CO and serially numbered, commencing with No. 1, with no numbers missing or duplicated. All correspondence, including attachments, will be provided in quintuplicate (five copies). All sequential transmittal numbers will be assigned by the PM, who will also maintain an outgoing correspondence log. Copies of all outgoing correspondence will be contained in master files maintained by the PM's staff and will be arranged sequentially by receipient and by subject. The PM will forward copies of correspondence pertaining to quality matters to the QCM for the QC files.

All incoming correspondence will be date stamped and ~orded in incoming correspondence logs. The PE will read all corresp ence and determine the distribution list for reading and subject file ignment. The PE will also designate responsibility for responding t~ ~tion items. The PE and all staff on the distribution list will i. al the correspondence to acknowledge that it has been read. Corres dence will be maintained in both sequential and subject files similar to the outgoing correspondence files.

A filing system also will be maintained by the QCM. This filing system shall contain all correspondence pertaining to QC matters, records, and documentation. Separate files will be maintained for each standard form used by the QC staff. In addition, the QC files will contain copies of all approved submittals, incoming and outgoing correspondence pertaining to QC data, and informal memoranda. The QC files will be open at all times to the COE CO's QA staff and will be turned over to the COE CO at the closure of the job.

II. CONTRACTOR SUBMITTALS

Submittals required to provide evidence of compliance with contract documents have been compiled on ENG Form 4288. [All required Form 4288s would be inserted following this page.] Specific submittals requiring review and approval by the COE CO have been noted on the form. No work, including materials procurement, will commence until approval has been received from the COE CO. Those submittals not specifically requiring approval by the COE CO will be reviewed by the contractor for compliance with the contract documents. Each submittal will be stamped on the first sheet and signed to indicate completion of review and approval. The PM, PE, and QCM have the authority to approve contractor submittals, depending upon the type of submittal.

Submittals for shop drawings, work procedures, choice of materials, samples, certificates of compliance, etc., will be prepared under the supervision of the PE. Submittals pertaining to material conformance to specified standards such as material certificates, gradation analysis, and other test results will be reviewed and approved by the QCM.

All submittals will be forwarded to the COE CO with a serially numbered transmittal document, ENG Form 4025. All information required to identify the transmittal will be provided.

All comments by the COE CO will be incorporated into the submittals. Submittals identified as Action Code C or E will be revised and resubmitted. No work will be started until an Action Code A or B is returned by the COE CO.

III. GENERIC QUALITY CONTROL REPORTS

The QC staff below the QCM will be assigned to cover specific construction activities as described in Sections IV through IX. QC activities and documentation specific to a particular work activity are described in these sections. Standard forms for the docuumentation are contained in the appendix. This section describes quality control documentation that will be generally used by all QC staff inspectors.

Every inspector will submit a daily inspection report to the QCM. Information to be included in the report is described on Form QC-0 and includes such items as work progress, weather conditions, number of workers, equipment, conflicts in drawings and specifications, delays, and safety. The four phases of inspections and tests are as follows:

Preparatory inspections include all activities that are to be performed prior to beginning each feature of any on-site construction work. Preparatory inspections include the following: (a) a review of submittal status, (b) a check to determine that provisions have been made for the required field control testing, (c) an examination of the work area to ascertain that all preliminary work has been completed, (d) verification of all field dimensions and advisement of discrepancies or other conflict in the drawings or specifications, (e) a physical examination of materials and equipment to assure that they conform to approved shop drawings or submittal data and that all materials and/or equipment are on hand, and (f) verification of instructions from the government or other resolutions from QC meetings.

Initial inspections will be performed as soon as work begins on a representative portion of the particular feature of work and will include examination of the quality of workmanship as well as a review of control testing procedures and results for compliance with contract requirements. As part of these inspections, the number of personnel in trades and hours worked and any instructions received from the government will be noted.

Follow-up inspections will be performed continuously as any particular feature of work progresses, to assure compliance with contract requirements including control testing, until completion of that feature of the work. The inspections will also include notation of delays to the work, defects, rejection of work, proposed remedial actions, corrective actions taken, and any instructions from the government.

Safety inspections will be performed daily to assure compliance with OSHA and EM 385-1-1. Daily QC reports are used to document the safety deficiencies and corrective actions taken. QC staff is used to perform these inspections.

Form QC-1, a certificate of compliance, will be used to document that materials or workmanship meet specified requirements. For example, the form may be used when mill certificates, test results, etc., are not readily available.

If an occasion arises in which the work is not corrected before it is completed, the QC inspector will prepare a nonconformance report (Form QC-2), which will be acknowledged by the PM. The nonconformance report will be transmitted to the COE CO by the PM within 24 hours of issuance by the QC inspector.

Remedial measures to correct the nonconforming condition will be developed by the PE. The remedial measures may be to reject the work entirely and start over. The proposed corrective measures will be submitted to the COE CO for approval prior to the commencement of repairs. Once approved, the repairs will be carried out in the presence of a QC inspector, who will verify that the materials and procedures are per the approved submittal. The inspector will sign off on the nonconformance report and submit it to the QCM for closure. No work will be submitted for acceptance with open nonconformance reports.

Other typical documents that the QC staff will maintain include the following standard COE forms:

Transmittal of Shop Drawings, etc. (NPD 300)
Screen Analysis of Concrete Aggregates (NPD 88)
Gradation Curves (ENG 2087)
Report of Concrete Mixture Design Methods (NPD 359)
Transit Mix Concrete Control Record (NPS 302)
Data Sheet Compressive and Flexural Strengths of Concrete (NPD 355)
Statistical Evaluation of Concrete Compression Tests (NPS 57)

IV. STEEL FABRICATION

A. BACKGROUND REFERENCES AND QUALIFICATIONS

This section defines the QC inspections and tests required in the production of lock hardware and miscellaneous steel embedments for panel erection. The inspections will be performed by a person experienced with general fabrication shop procedures and workmanship, including surface preparation and painting. In addition, the inspector shall be AWS-certified.

All work will be performed per the following documents. The inspector will be thoroughly familiar with their requirements.

Project Specifications, Section 05500
AISC Steel Construction Manual
AISC Code of Standard Practice
AWS D1.1, Structural Welding Code, Steel
AWS D1.4, Structural Welding Code, Reinforcing Steel

B. RESPONSIBILITIES OF THE QC INSPECTORS

Specific responsibilities of the QC inspector will include the following items:

1. Verifying that shop drawings have been approved and released for construction.

2. Reviewing and becoming familiar with all other submittals related to steel fabrication, such as work procedures and catalog cuts, and verifying their action code.

3. Obtaining weld procedure specifications and verifying that these have been qualified. Obtaining applicable test results if necessary.

4. Obtaining welder qualification records.

5. Obtaining and reviewing steel mill certificates for the steel to be incorporated into the work.

6. Verifying stockpiling of materials and selection of correct materials for use in the work.

7. Checking dimensional fit-up to verify that it is within AISC tolerances.

8. Verifying proper calibration and setup of weld equipment.

9. Inspecting welds.

10. Verifying surface preparation and painting procedures. Verifying that the required surfaces have been painted.

11. Obtaining periodic samples of steel as requested by the COE CO's QA staff and delivering them to the COE for testing.

C. REPORTS AND QC DOCUMENTATION

Reports will be prepared to document fabrication and quality control procedures. Daily inspection reports (Form QC-0) will be prepared to record work progress. Checklist QC-3 will be prepared for specific pieces or groups of like pieces fabricated simultaneously. When Checklist QC-3 has been approved by the QCM, the fabricated elements are ready for incorporating into the subsequent work (precast panels, cast-in-place concrete). Nonconformance reports (Form QC-2) will be prepared as needed.

V. PRECAST PANEL PRODUCTION

A. BACKGROUND REFERENCES AND QUALIFICATIONS

This section defines the QC inspections and tests required in the production of precast concrete panels. The inspections will be performed by persons experienced with general concrete production practices including preparation of formwork, reinforcing bar installation, concrete sampling, placing, finishing, and testing.

All work will be performed per the following documents. The inspectors will be thoroughly familiar with their requirements.

Project Specifications, Sections 03100, 03200, 03300, and 03400.

ACI 301, Structural Concrete for Buildings.

ACI 318, Building Code Requirements for Reinforced Concrete.

PCI MNL-116, Manual for Quality Control for Plants and Production of Precast Prestressed Concrete Products.

B. RESPONSIBILITIES OF THE QC INSPECTORS

Specific responsibilities of the QC inspectors will include the following items:

1. Verifing that shop drawings have been approved and released for construction.

2. Becoming familiar with all other submittals, such as work procedures, concrete mixtures, and materials, and ascertaining their action code.

3. Obtaining and reviewing for compliance mill certificates for the cement and reinforcing steel to be incorporated into the work. Verifying that the aggregate gradation and condition remain consistent throughout the course of the project. Requesting additional testing if required.

4. Verifying that reinforcing bars have been stored in an acceptable manner.

5. Checking formwork preparation, including cleaning and oiling and dimensional fit-up. (Tolerances are listed on Form QC-4.)

6. Checking QC files to assure that steel fabrications have been approved for incorporating into the precast panels (QC-3).

7. Verifying accuracy of blockout placement and the location of hardware and other embedments. Checking to make sure all blockouts and embedments are securely fastened to the formwork.

8. Checking reinforcing bars and welded wire fabric for grade, size, bending accuracy, location, cover, ties, and splice locations. Providing samples for COE testing as requested by the COE CO's QA staff.

9. Verifying locations of miscellaneous inserts required for follow-on construction and locations, lengths, and fixing of lifting devices.

10. Prior to commencing concrete placements, verifying QC inspector's sign-off on Form QC-4.

11. Performing tests and obtaining samples at the frequencies outlined in Table E1.

12. Observing concrete placing procedures, compaction, and finishing. Performing checks to verify panel thicknesses.

13. Verifying that approved curing practices are followed. Ascertaining that temperature recordings during curing are monitored.

14. Determining strengths of concrete at time of lifting panels out of the formwork.

15. Inspecting panels for surface irregularities or defects. Enforcing the use of approved methods for repairs.

16. Checking arrangement of bunking and other storage requirements.

17. Performing final inspections to verify that panels are within dimensional tolerances. Noting any panel cracking and determining whether cracking is within approved criteria.

18. Verifying that panel loadout for transportation to the erection site is per the submitted and approved procedure.

19. Maintaining a running statistical evaluation of concrete compression test results. Making sure that the required average strength (f'_{cr}) is consistent with the standard deviation or coefficient of variability and the limiting probability for low test results. [Limiting probability will be stated in the specifications; however, a 1 in 100 limiting probabiliy would be appropriate for the precast panels.]

C. REPORTS AND QC DOCUMENTATION

Reports will be prepared to document precasting and quality control procedures. Daily inspection reports (Form QC-0) will be prepared to record work progress. Checklist QC-4 will be prepared for specific panels or groups of panels constructed at the same time. When Checklist QC-4 has been approved by the QCM, the formwork is ready for concrete placement. Checklist QC-5 will be prepared to document the concrete placement activities and to acknowledge that concrete strengths have been achieved. Checklist QC-6 will document visual inspections of the finished panel, including required repairs, while QC-7 will be a record of the as-built measurements. All four checklists must be approved by the QCM before he allows a panel to be shipped. Checklist QC-5 has line items to acknowledge completion of QC-6 and QC-7; therefore, QC-5 will be used to determine when a panel or groups of panels are available for delivery. The QCM will forward copies of Checklist QC-5 to the PM, informing him of the availability of specific panels for erection. Nonconformance reports (Form QC-2) will be prepared as needed.

TABLE E1
CONCRETE TESTING

Material	Test	Minimum Sampling and Testing Frequency
Portland cement and pozzolan	Chemical and physical tests	Manufacturer's certificate of compliance with a test report for each delivery or lot. Submit a 10-lb sample for every other certification.
Admixtures	Certification of compatability and samples	Upon request by contracting officer, 1-qt samples are to be submitted during progress of work. Certification including test results for each lot are to be submitted.
Water	Sample and test	A sample and/or water quality test if requested by the contracting officer.
Coarse aggregate (for each grading size)[1]	Gradation	One test every 500 cu yd of concrete.
	Deleterious substance	One test initially and thereafter when appearance makes the material suspect.
	Abrasion	One every 5000 tons of aggregate.
	Moisture, specific gravity, and absorption[2]	One initially and every 250 cu yd thereafter. One moisture to be conducted prior to any batching and more frequently if hauling and storage do not provide a consistent moisture content.

TABLE E1
CONCRETE TESTING (continued)

Material	Test	Minimum Sampling and Testing Frequency
Fine aggregate[1]	Gradation and fineness modules	One every 250 cu yd of concrete.
	Deleterious substances	Same as coarse aggregate.
	Moisture, specific gravity, and absorption[2]	Same as coarse aggregate.
Concrete	Slump	Conduct test for each day's production with an additional test for each increment of 50-cu-yd production on a given day. Conduct tests more frequently if batching appears inconsistent. Conduct with strength tests.
	Entrained air	Conduct with slump test.
	Ambient and concrete temperatures	Conduct with slump tests.
	Unit weight, yield, and water/cement ratio	Conduct with strength tests. Check unit weight and adjust aggregate weights to ensure proper yield.
	Compressive strength and evaluation of results per ACI 214 (includes unit weight of each cylinder)	Take two sets of three cylinders at time of performing slump tests. Test two cylinders prior to lifting panels out of forms, and two cylinders at 7 days and two at 28 days. A plot and statistical evaluation shall be maintained in accordance with ACI 214 for compressive strength results. The required average strength shall be the design strength f'_c plus

TABLE E1
CONCRETE TESTING (continued)

Material	Test	Minimum Sampling and Testing Frequency
		the required overdesign factor (ASTM C 94, Table 3). The limiting probability of tests falling below the required strength shall be as required by the specifications. Cylinders to verify strength at picking shall be field-cured.
Batching and mixing equipment tests	Contract compliance	Contractor compliance with ASTM C 94, "Standard Specifications for Ready Mix Concrete," with documentation, reports, and certification of compliance.
Curing compound	Certification and submittal	A 1-gallon sample to be submitted initially with certification and test results, for each lot and type of curing compound.
Vibrators	Frequency and amplitude	Check frequency and amplitude initially and any time vibration is questionable.

[1] A petrographic report for aggregate is required with the sample for source approval. If the total amount of all types of concrete is less than 200 cu yd, service records from three separate structures in similar environments that used the aggregates may substitute for the petrographic report.

[2] Aggregate moisture tests are to be conducted in conjunction with concrete strength tests for water/cement calculations.

VI. LOCK WALL DEMOLITION, SURFACE PREPARATION, AND TIE INSTALLATION

A. BACKGROUND REFERENCES AND QUALIFICATIONS

This section defines the QC inspections and tests required to verify that surface excavation and preparation are completed in accordance with the contract documents. The inspectors will have general heavy (civil works) construction experience, including drilling, blasting, excavation, layout, and surface preparation work. Underwater construction may be required, and a certified diver/inspector will be retained to witness such work on an as-needed basis.

All work will be performed per the following documents. The inspectors will be thoroughly familiar with their requirements.

Project Specifications, Section 02071

Corps of Engineers Technical Letter ETL-1110-2-275, Concrete Removal Methods

B. RESPONSIBILITIES OF THE QC INSPECTORS

Specific responsibilities of the QC inspectors will include the following items:

1. Reviewing submittals related to work procedures and verifying their action codes. Checking to see that such procedures are being implemented as documented.

2. Checking the establishment of a reference system for use in dimensional control during construction.

3. Verifying that the extent of the area to be excavated has been correctly identified.

4. Verifying that excavation of deteriorated surface has been carried to sound concrete.

5. Checking for overbreakage along the perimeter of excavation and determining whether remedial measures are required.

6. Checking tie hole locations, depths, and diameter.

7. Verifying that tie holes have been cleaned out subsequent to drilling.

8. Witnessing and documenting test tie installation, testing procedures, and results. (Workmanship and materials for production ties will be identical to those of the test installation procedure.)

9. Verifying procedures used during production tie installation.

10. Performing random load tests on production ties. Using calibrated equipment to test 5 ties out of 100.

C. REPORTS AND QC DOCUMENTATION

Reports will be prepared to document excavation progress and quality control procedures. Daily inspection reports (Form QC-0) will be prepared to record work progress. Checklist QC-8 will be prepared for individual monolith segments. Approval by the QCM indicates that the monolith is ready for erection of precast panels. Nonconformance reports (Form QC-2) will be prepared as needed.

VII. PANEL ERECTION

A. BACKGROUND REFERENCES AND QUALIFICATIONS

This section defines the QC inspections and tests required to ensure that precast panels are erected and attached to the lock wall as required by the contract documents. The inspectors covering this work will be experienced in all phases of precast concrete erection. In addition, where tie welding is required, the inspectors will be AWS-certified. The use of a diving inspector may be required for the bottom panel, which will be partially submerged, and a certified diver/inspector will be retained to inspect such work on an as-needed basis.

All work will be performed per the following documents. The inspectors will be thoroughly familiar with their requirements.

Project Specifications, Section 03400
AWS D1.4, Structural Welding Code, Reinforcing Steel

B. RESPONSIBILITIES OF THE QC INSPECTORS

Specific responsibilities of the QC inspectors will include the following items:

1. Reviewing submittals related to work procedures (erection and rigging diagrams) and asertaining their action code disposition. Verifying that such procedures are being successfully implemented and followed throughout the work.

2. Verifying that the required panels are available for erection (Checklist QC-5) and that all surface preparation work is complete (Checklist QC-8).

3. Checking the condition of the panels upon their arrival at the erection site and comparing them to their condition at loadout (Form QC-6). Recording any damage caused by shipment and determining the need for remedial measures.

4. Verifying that rigging and lifting equipment are properly maintained throughout the course of the construction. Spot checking that all connections between panels and rigging are adequately secured. Noting any unusual wear or signs of distress and notifying the erection superintendent immediately.

5. Verifying that surface cleaning of both panels and monolith is completed prior to the erection of the panels on the monolith wall.

6. Verifying that required tolerances have been achieved after a panel has been positioned and temporarily secured. (Tolerances are shown on Checklist QC-9.)

7. Allowing work to proceed on the remainder of the form tie connections only if the panel has been positioned to the required tolerances.

8. Visually inspecting each tie connection to verify that it has been completed as required.

9. Verifying that the required items are provided at joints between adjacent panels (shims, seals, etc.)

10. Verifying that the minimum required number of tie connections has been completed if work is suspended for a lock opening.

C. REPORTS AND QC DOCUMENTATION

Each inspector will complete daily inspection reports (Form QC-0) to record work progress, weather conditions, number of workers, equipment, etc. Checklist QC-9 will be prepared for individual monolith segments. Approval by the QCM will indicate that the monolith is ready for installation of formwork and placement of cast-in-place concrete. Nonconformance reports (Form QC-2) will be prepared as needed.

VIII. CAST-IN-PLACE CONCRETE

A. BACKGROUND REFERENCES AND QUALIFICATIONS

This section defines the QC inspections and tests required to ensure that cast-in-place concrete for the infill behind the panels and for closure cap pours meets the requirements of the contract documents. The inspections will be performed by persons experienced with general concrete production practices, including preparation of formwork, reinforcing bar installation, concrete sampling, placing, finishing, and testing.

All work will be performed per the following documents. The inspectors will be thoroughly familiar with their requirements.

Project Specifications, Sections 03100, 03200, and 03300
ACI 301, Structural Concrete for Buildings
ACI 318, Building Code Requirements for Reinforced Concrete

B. RESPONSIBILITIES OF THE QC INSPECTORS

Specific responsibilities of the QC inspectors will include the following items:

1. Reviewing submittals for materials, work procedures, shop drawings, etc., and verifying the status of the assigned action codes. Making sure that documented procedures are being successfully implemented and followed throughout the work.

2. Obtaining and reviewing for compliance mill certificates for the cement and reinforcing steel to be incorporated into the cast-in-place concrete. Verifying that the aggregate gradation and condition remain consistent throughout the course of the project. Requesting additional testing if required.

3. Verifying that panel erection work has been satisfactorily completed (Form QC-9).

4. Checking that the required embedments have been approved (QC-3) and verifying whether their installation is within specified tolerances.

5. Inspecting reinforcing steel location, bar sizes, grades, splice location, etc. Providing samples for COE testing as requested by the COE CO QA staff.

6. Inspecting the formwork to ascertain that finished surfaces will be constructed to the specified tolerances. Checking to see that forms have been adequately cleaned and oiled.

7. Performing the concrete tests and obtaining the required samples as outlined on Table E1 in Section IV during concrete production.

8. Observing concrete placing procedures, compaction, and finishing.

9. Verifying that approved curing measures are followed.

10. Maintaining a running statistical evaluation of concrete compression test results. Making sure that the required average strength (f'_{cr}) is consistent with the standard deviation or coefficient of variability and the limiting probability for low test results. [Limiting probability will be stated in the specifications; however, a 1 in 10 limiting probability would be appropriate for cast-in-place concrete.]

C. REPORTS AND QC DOCUMENTATION

Each inspector will complete daily inspection reports (Form QC-0) to record work progress, weather conditions, number of workers, equipment, etc. Checklist QC-10 will be prepared by monolith segment to document the status of the work. Checklist QC-11 will be prepared to document the concrete placement activities and to acknowledge that concrete strengths have been achieved. Nonconformance reports (Form QC-2) will be prepared as needed.

IX. FINAL INSPECTION

A. BACKGROUND REFERENCES AND QUALIFICATIONS

This section defines the QC inspections required to ascertain that all work associated with an individual monolith section has been completed and that the work is ready for submitting to the contracting officer for acceptance. The inspections will be performed by persons with general construction inspection experience including surveys for verifying as-built dimensions. Some underwater inspection that can be coordinated with a diver/inspector will be necessary.

All work will be performed per the following documents. The inspectors will be thoroughly familiar with their requirements.

Project Specifications, Sections 03100, 03200, and 03300

B. RESPONSIBILITIES OF THE QC INSPECTORS

Specific responsibilities of the QC inspectors will include the following items:

1. Inspecting all concrete surfaces after removal of the formwork to determine if any surface defects that require remedial measures are present. Documenting locations of surface defects. Verifying that repair procedures have been documented and approved prior to their implementation. Observing any repairs to confirm that the approved procedure was followed.

2. Verifing that all miscellaneous surface stoning, grinding, sacking, etc., have been satisfactorily completed.

3. Reviewing documentation for all work required to complete the repairs for the monolith section under consideration. Making sure that the QC file for each monolith section contains copies of all forms used to verify completion of the work.

4. Obtaining measurements to verify whether the final installation is within the specified tolerances.

C. REPORTS AND QC DOCUMENTATION

Each inspector will complete daily inspection reports (Form QC-0) to record work progress, weather conditions, number of workers, equipment, etc. Checklist QC-12 will be prepared by monolith segment and, when completed, will be used to notify the COE CO that the referenced monolith section has been completed in its entirety and is ready for acceptance.

X. APPEARANCE STANDARDS

To assist in interpreting the contract requirements with respect to overall appearance, standards of comparison will be established for precast panels and for the completed installation.

After the first group of panels is completed, one panel will be mutually selected by the COE CO and the contractor's PM to best represent the minimum standard for surface texture, finish, and coloration. This panel will be retained at the precast plant until all panels have been approved for erection. If possible, minimum acceptable surface defects will be identified on this panel and used to determine the need for defect repairs.

The first monolith section completed will likewise be finished to the minimum required appearance criteria (surface texture, finish, and coloration) as mutually agreed upon by the COE CO and the PM. If possible, minimum acceptable surface defects will be identified. All remaining monolith sections will be compared to the baseline monolith to determine acceptable appearance.

XI. REFERENCE INFORMATION

Contract Design Drawings

Number	Title

Contract Shop Drawings

Number	Title

Corps of Engineers Resident Engineer's Manual

Corps of Engineers Quality Assurance Manual

XII. STANDARD QUALITY CONTROL FORMS

Form	Title
QC-0	Daily Construction Quality Control Report
QC-1	Certificate of Compliance
QC-2	Nonconformance Report
QC-3	Steel Fabrication Checklist
QC-4	Precasting Inspection Checklist
QC-5	Concrete Placement Checklist
QC-6	Handling, Storage, Finishing, and Shipment
QC-7	As-Built Measurements
QC-8	Demolition and Surface Preparation Checklist
QC-9	Panel Erection Checklist
QC-10	CIP Preplacement Inspection Checklist
QC-11	CIP Concrete Placement Checklist
QC-12	Final Inspection Checklist
ENG 4025	Transmittal of Shop Drawings,, Equipment Data, Material Samples, or Manufacturer's Certificates of Compliance
ENG 4288	Submittal Register
NPD 300	Transmittal of Materials Samples
NPD 88	Screen Analysis of Concrete Aggregates
ENG 2087	Gradation Curves
NPD 359	Report of Concrete Mixture Design Methods CRD-C3 and 10
NPS 302	Transit Mix Concrete Control Record
NPD 355	Data Sheet - Compressive and Flexural Strengths of Concrete
NPS 57	Statistical Evaluation of Concrete Compression Tests

(Sample of Typical Contractor Quality Control Report)

CONTRACTOR'S NAME
(Address)

DAILY CONSTRUCTION QUALITY CONTROL REPORT

Date: ______________ Report No. ______

Contract No.: ____________________

Description and Location of Work: ____

WEATHER: (Clear) (P. Cloudy) (Cloudy); Temperature: _______ Min. _______ Max;
(Snow) (Rainfall) _____________ Inches.

Contractor/Subcontractor Activity:

	Work in Progress	Contractor/ Subcontractor	Craft	Time Worked
a.				
b.				
c.				
d.				
e.				
f.				
g.				
h.				

Equipment Data: (Indicate items of construction equipment, other than hand tools, at the job site and whether or not used.)

	Equipment	Contractor/ Subcontractor	Craft	Time Used
a.				
b.				
c.				
d.				
e.				
f.				

Form QC-0

1. Preparatory Inspections

2. Initial Inspections

3. Follow-Up Inspections

4. Safety Inspections

CONTRACTOR'S VERIFICATION: The above report is complete and correct and all material and equipment used and work performed during this reporting period are in compliance with the contract plans and specifications except as noted above.

CONTRACTOR QUALITY CONTROL INSPECTOR

(1)
To: ______________________________ Date: ______________

____

____

CERTIFICATE OF COMPLIANCE

CORPS OF ENGINEERS
NAVIGATIONAL LOCK REPAIRS
USING
PRECAST CONCRETE STAY-IN-PLACE FORMS

(2) Reference Project: ______________________________

Contract Number: ______________________________

(3) Material: ______________________________

(4) In accordance to the requirements of the Contract Specifications and drawings, we hereby certify that the materials furnished per the attached documents to be in compliance with the requirements of Specification Section ______________ , Paragraph __________ , or Drawing ____________ , and the following referenced standard(s):

(5) ______________________________

(6) Tests were performed by: ______________________________ and are on file with the Manufacturer. Copies can be made available on request.

Test Results Attached

Testing Not Applicable

(7) I certify that the above statements are true and correct, and the materials delivered comply with the Contract Requirements.

______________________________ Date: ______________

____

____
(Mfr, Authorized Mfg's Representative, Contractor)

Form QC-1

INSTRUCTIONS FOR "CERTIFICATE OF COMPLIANCE" FORM

(1) Name and address of the Purchaser of the materials being certified

(2) Project Title, Contract Number

(3) A brief description of the materials being certified.

(4) The applicable specification number and paragraph number or drawing number of the materials being certified.

(5) The applicable referenced standard(s) of the materials being certified such as ASTM, AASHTO, etc.

(6) Check the appropriate box for test requirements; fill-in complete name and address of the Testing Agency if the first box is checked.

(7) Certification of Materials; signature and complete address of Manufacturer, Manufacturer's representative, or contractor.

Documentation relative to the material being certified such as catalogue cuts should be attached.

Contract Name ______________

Contract Number ______________

NON-CONFORMANCE REPORT

NCR No. ____

Date ________ Location ____________

Reference Drawing or Specification Section: ______________________

____

Description of Non-Conformance :

Initiated by ______________ (QC Inspector) Acknowledged by ______________ (Project Manager)

Proposed Corrective Action

Submitted by ______________ (Project Engineer) Approved by ______________ (Project Manager) ________ (Date)

Contracting Officer's Disposition: Approved __ Rejected __

______________ (Contracting Officer) ________ (Date)

Repairs Completed per Approved Procedure Yes __ No __

______________ (QC Inspector) ________ (Date)

NCR Closed By: ______________ (QC Manager) ________ (Date)

Form QC-2

Contract Name ____________
Contract Number ____________

STEEL FABRICATION CHECKLIST

Steel Fabrication Item ____________
No. of Pieces in Fabrication Lot ______

Reference Design Drawing No. ________
Reference Shop Drawing No. ________

Approved & Released for Construction Yes __ No __

Steel Material Used in Fabrication		Approved Mill Certificate on File
ASTM A-36	____	Yes __ No __
ASTM A-572, Grade 50	____	Yes __ No __
ASTM A-108	____	Yes __ No __
ASTM A-496	____	Yes __ No __
____________	____	Yes __ No __
____________	____	Yes __ No __

Dimensional Fit-up Within Tolerances Yes __ No __

Welders Performing Work	Qualified
____________	Yes __ No __
____________	Yes __ No __
____________	Yes __ No __

Weld Inspection Method ____________ Welds Acceptable Yes __ No __

Surface Preparation Adequate Yes __ No __

Painting:

1. Prime Coat Material ______ Dry Film Thickness ____
2. Main Coat Material ______ Dry Film Thickness ____
3. Main Coat Material ______ Dry Film Thickness ____

Required Surfaces Painted Yes __ No __

NOTES: ____
____
____
____

All work has been satisfactorily completed per the contract requirements and the above referenced steel fabrications are recommended for acceptance:

Inspector	Date	QC Manager	Date
____________	______	____________	______

Form QC-3

Contract Name ____________
Contract Number ____________

PRECASTING INSPECTION CHECKLIST

Precast Panel Mark Number ________
Other Panels in Fabrication Lot ____________

Reference Design Drawing No. ________
Reference Shop Drawing No. ________

Approved & Released for Construction Yes __ No __

Reinforcing Steel Used in Fabrication		Approved Mill Certificate on File	
ASTM A-615, Grade 60	____	Yes __	No __
ASTM A-185	____	Yes __	No __
____________	____	Yes __	No __
____________	____	Yes __	No __

Fabricated Steel Hardware Incorporated into the Panel

Type	Mark No.	No. of Pieces	QC-3 Approved	
____________	______	________	Yes __	No __
____________	______	________	Yes __	No __
____________	______	________	Yes __	No __
____________	______	________	Yes __	No __

Formwork Preparation: Cleaning: Adequate __ Inadequate __
Oiling: Adequate __ Inadequate __

Formwork Fit-up Within Tolerances Yes __ No __
(Required Tolerances: Length ± 1/2", Width ± 1/4", Thickness ± 1/2"
Edge Squareness + 1/8", Panel Planeness:
Outside Face ± 1/4", Inside Face ± 1/2",
Location of Embedments ± 1/8")

Reinforcing Steel:	OK	Inadequate		OK	Inadequate
Bar Grades	__	__	Bending Accuracy	__	__
Storage/Cleanliness	__	__	Bar Size, No., Location	__	__
Splice Locations	__	__	Ties	__	__
Lifting Devices					
Location	__	__	Length	__	__
Fixing	__	__			

NOTES: ____
____
____

All work has been satisfactorily completed per the contract requirements and the referenced panel is approved for concrete placement:

____________ Inspector ______ Date ____________ QC Manager ______ Date

Form QC-4

Contract Name ______________
Contract Number ______________

CONCRETE PLACEMENT CHECKLIST

Precast Panel Mark Number ________
Other Panels in Fabrication Lot ______________

			Comments
Placement			
Concrete Batching	OK __	Inadequate __	______________
Delivery Time	______		______________
Delivery Date	______		______________
Batch Number	______		______________
Batch Data on File	Yes __	No __	______________
No. of Cylinders Cast	____		______________
Slump, Temp., Air Tests	OK __	Inadequate __	______________
Discharge into Forms	OK __	Inadequate __	______________
Placing and Vibration	OK __	Inadequate __	______________
Screeding & Finishing	OK __	Inadequate __	______________
Curing			
Method	______________		______________
Elapsed Time	______		______________
Preset Time	______		______________
Temp. Increase Rate	______		______________
Temp. Decrease Rate	______		______________
Max. Stable Temp.	______		______________
Max. Stable Temp. Duration	______		______________
Strength/Appearance			
Strength Achieved	OK __	Inadequate __	______________
Ave 28-day fc'	______ psi		
Concrete Test Report NPD 355	OK __	Inadequate __	______________
Handling, Storage, Finishing, Shipment (QC-6)	OK __	Inadequate __	______________
As-Built Measurements (QC-7)	OK __	Inadequate __	______________

NOTES: ____

All work has been satisfactorily completed per the contract requirements and the referenced panel is approved for erection:

______________	______	______________	______
Inspector	Date	QC Manager	Date

Form QC-5

Contract Name ______________
Contract Number ______________

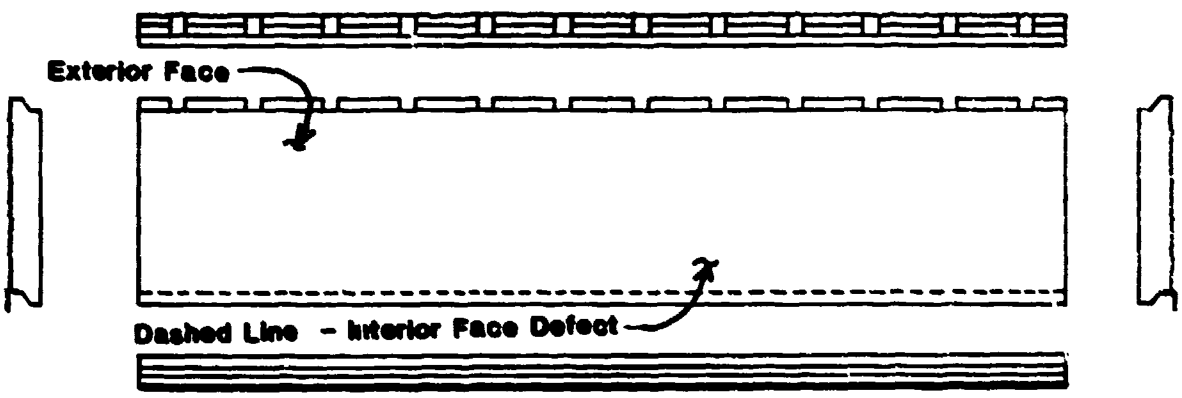
HANDLING, STORAGE, FINISHING, & SHIPMENT

Precast Panel Mark Number ________

Panel Storage: per the submitted and approved procedure: Yes __ No __

Panel Visual Inspections:

Surface Defects	Yes __	No __	(If yes, locate below)
Cracks	Yes __	No __	" " " "
Irregular Edges	Yes __	No __	
Finish, Ext Face	OK __	Inadequate __	
Finish, Int Face	OK __	Inadequate __	
Color	OK __	Inadequate __	
Finishing	OK __	Inadequate __	



Repairs:

Locations Identified and Circled on Diagrams Yes __ No __
Methods and Materials for Repairs Approved Yes __ No __
Repairs Completed Satisfactorily Yes __ No __
Repair Date ________

NOTES: ____
____
____

All work has been satisfactorily completed per the contract requirements and the referenced panel is approved for erection:

______________ Inspector ______ Date ______________ QC Manager ______ Date

Shipment:

Panels loaded for shipment per approved procedure Yes __ No __
Shipping Date ________ ______________ QC Inspector

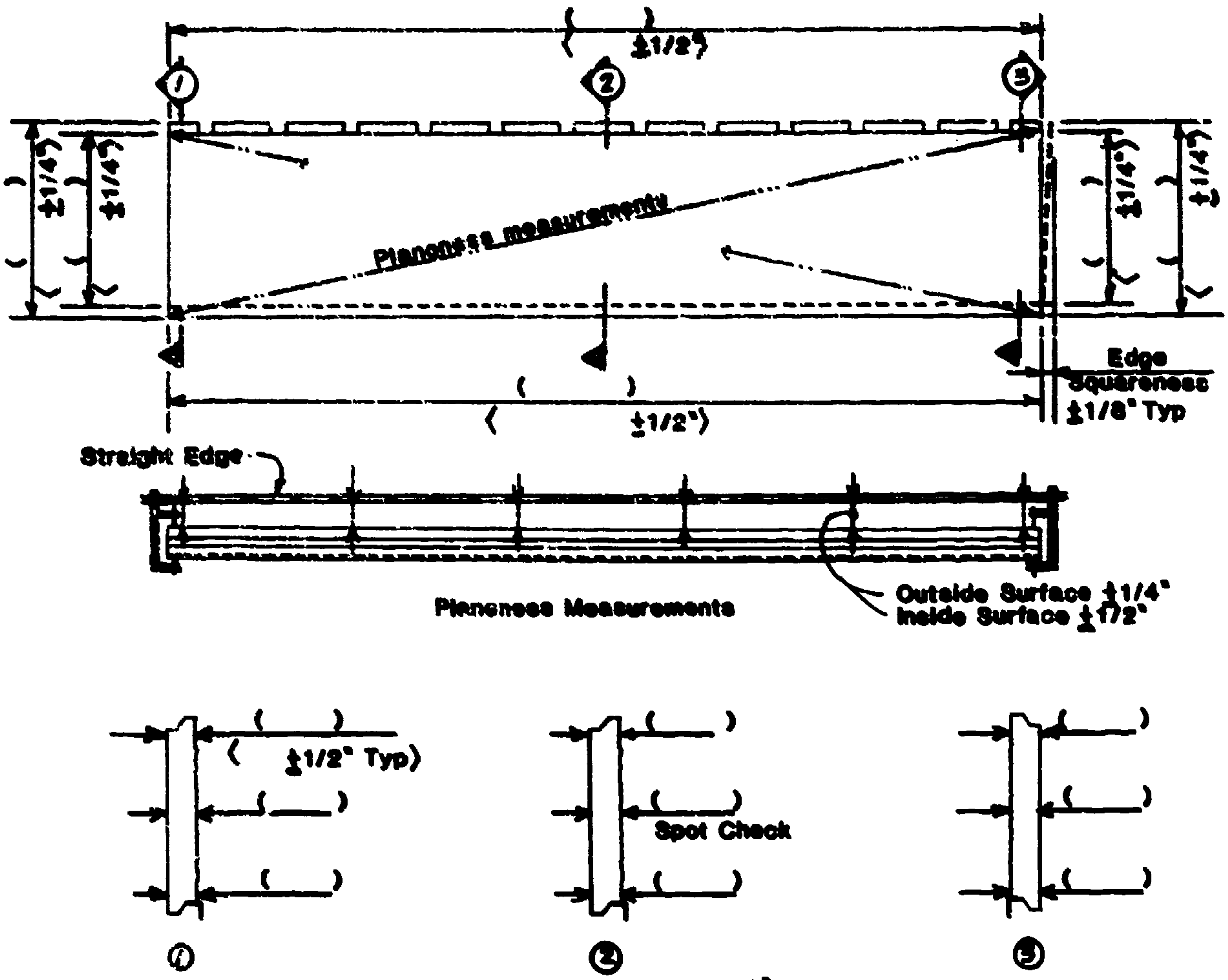
Form QC-6

Contract Name ____________________
Contract Number ____________________

AS-BUILT MEASUREMENTS

Precast Panel Mark Number __________
Date of Panel Measurements __________

(Measured Dimensions)
(Required Dimensions)



NOTES: Show Embedment Locations - Tolerance ±1/8"
____
____

Unless otherwise noted, all dimensions have been verified and found to be within the specified tolerances prescribed by the contract specifications.

Inspector	Date	QC Manager	Date

Form QC-7

Contract Name ____________
Contract Number ____________

DEMOLITION AND SURFACE PREPARATION CHECKLIST

Monolith Segment Number ________
Corresponding Precast Panels ________

Reference Design Drawing No. ________
Reference Shop Drawing No. ________ Approved and Released for Construction Yes __ No __

Demolition:

- Reference Datum Established Yes __ No __
- Limits of Excavation Correctly Established Yes __ No __
- Work According to Submitted Procedures Yes __ No __
- Excavation/Demolition Procedure ____________
- Depth of Excavation to Sound Substrate Yes __ No __
- Zones of Overbreakage Requiring Repairs Yes __ No __
- Clean-up Practices OK __ Inadequate __

Tie Installation

- Location of Tie Holes within Tolerances Yes __ No __
- Size of Tie Holes: Depth OK __ Inadequate __
  - Diameter OK __ Inadequate __
- Installation Procedures OK __ Inadequate __
- Location of Ties Within Tolerances Yes __ No __
- Tie Load Tests
  - Performed By ____________
  - Date ____________
  - Equipment Used ____________
  - Calibration Data on File Yes __ No __
  - Recalibration Data ____________

Tie No.	Load	Pass	Fail	Comments

Tie Installation Time and Date ________ (Last Tie to be Installed)
Date Ties Available for Loading ________ (Minimum Cure Period)

NOTES: ____________

All work has been verified and found to meet the requirements of the contract documents. This monolith segment is ready for precast panel installation.

Inspector	Date	QC Manager	Date

Form QC-8

Contract Name ____________
Contract Number ____________

PANEL ERECTION CHECKLIST

Monolith Segment Number ________
Corresponding Precast Panels ________ Approved for Erection (QC-5 Verified) Yes __ No __

Reference Design Drawing No. ________
Reference Shop Drawing No. ________ Approved and Released for Construction Yes __ No __

Post-Delivery Panel Inspections: Damage to Panels

Panel No	Description	Repairs Required
____	____________	Yes __ No __
____	____________	Yes __ No __
____	____________	Yes __ No __
____	____________	Yes __ No __
____	____________	Yes __ No __
____	____________	Yes __ No __
____	____________	Yes __ No __

Panel Erection:

- Monolith surface clean OK __ Inadequate __
- Panel interior face clean OK __ Inadequate __
- Rigging and Lifting Equipment OK __ Inadequate __
- Erected to Tolerance (Vertical ± 1/2", Horizontal ± 1/2", Joint-to Joint ±3/16)

Panel No.	Meets Tolerance	Description
____	Yes __ No __	____________
____	Yes __ No __	____________
____	Yes __ No __	____________
____	Yes __ No __	____________
____	Yes __ No __	____________
____	Yes __ No __	____________
____	Yes __ No __	____________

- Panel Tie Attachment OK __ Inadequate __
- No. of Tie Connections Inspected ____
- Joint Preparation/Installation OK __ Inadequate __

NOTES: ________________________________
____
____
____

All work has been verified and found to meet the requirements of the contract documents. This monolith segment is ready for cast-in-place concrete placement.

____________	______	____________	______
Inspector	Date	QC Manager	Date

Form QC-9

Contract Name ______________
Contract Number ______________

CIP PREPLACEMENT INSPECTION CHECKLIST

Reference Monolith Designation __________
Corresponding Precast Panels __________

Reference Design Drawing No. __________
Reference Shop Drawing No. __________ Approved & Released for Construction Yes __ No __

Reinforcing Steel Used in the Work — Approved Mill Certificate on File

ASTM A-615, Grade 60	____	Yes __	No __
ASTM A-185	____	Yes __	No __
______________	____	Yes __	No __
______________	____	Yes __	No __

Fabricated Steel Hardware Incorporated into the Work

Type	Mark No.	No. of Pieces	QC-3 Approved
______________	______	________	Yes __ No __
______________	______	________	Yes __ No __
______________	______	________	Yes __ No __
______________	______	________	Yes __ No __

Formwork Preparation: Cleaning: Adequate __ Inadequate __
Oiling: Adequate __ Inadequate __

Formwork Fit-up Within Tolerances Yes __ No __
(Required Tolerances: Horizontal ± 1/2", Vertical ± 1/2", Offset between CIP concrete surface and precast surface ± 3/16", Location of Embedments ± 1/8")

Reinforcing Steel:	OK	Inadequate		OK	Inadequate
Bar Grades	__	__	Bending Accuracy	__	__
Storage/Cleanliness	__	__	Bar Size, No., Location	__	__
Splice Locations	__	__	Ties	__	__

NOTES: ____
____
____
____
____

All work has been satisfactorily completed per the contract requirements and the referenced monolith section is approved for concrete placement:

______________	______	______________	______
Inspector	Date	QC Manager	Date

Form QC-10

Contract Name ____________
Contract Number ____________

CIP CONCRETE PLACEMENT CHECKLIST

Reference Monolith Designation ____________
Corresponding Precast Panels ____________

					Comments
Placement					
Concrete Batching	OK __		Inadequate	__	____________
Delivery Time	______				____________
Delivery Date	______				____________
Batch Number	______				____________
Batch Data on File	Yes __		No __		____________
No. of Cylinders Cast	____				____________
Slump, Temp., Air Tests	OK __		Inadequate	__	____________
Discharge into Forms	OK __		Inadequate	__	____________
Placing and Vibration	OK __		Inadequate	__	____________
Screeding & Finishing	OK __		Inadequate	__	____________
Curing					
Method	____________________				____________
Elapsed Time	______				____________
Concrete Testing Results - Evaluation					
Strength Achieved	OK __		Inadequate	__	____________
Ave 28-day fc'	______ psi				
Air entrainment	OK __		Inadequate	__	____________
Water/Cement Ratio	OK __		Inadequate	__	____________

NOTES: ____
____
____
____
____

All concrete production and placement work for the referenced monolith section has been satisfactorily completed per the contract requirements.

____________	______	____________	______
Inspector	Date	QC Manager	Date

Form QC-11

Contract Name ________________
Contract Number ________________

FINAL INSPECTION CHECKLIST

Reference Monolith Designation ________________
Corresponding Precast Panels ________________

Reference Design Drawing No. ________________
Reference Shop Drawing No. ________________

Concrete Surface Inspections:
- Texture/Coloration OK __ Inadequate __
- Edges/Pour Lines OK __ Inadequate __
- Surface Defects Yes __ No __
- Defect Repairs OK __ Inadequate __ NA __

Condition of Lock Hardware OK __ Inadequate __
QC Documentation OK __ Inadequate __

As-Built Dimensional Verification:
- Lock Hardware within Tolerance OK __ Inadequate __
  (± 1/2" horizontal & vertical, ± 1/8" offset)
- Summary of Offset Measurements:

NOTES: ____
____
____
____
____

All concrete production and placement work for the referenced monolith section has been satisfactorily completed per the contract requirements.

________________	________	________________	________
Inspector	Date	QC Manager	Date

Form QC-12

SUBMITTAL REGISTER (ER 415-1-10)

TITLE AND LOCATION

CONTRACTOR

CONTRACT NUMBER

NAS ACTIVITY CODE	SUBMITTAL IDENTIFICATION (ITEM NUMBER)	SPECIFICATION PARAGRAPH NUMBER	DESCRIPTION OF SUBMITTAL	TYPE OF SUBMITTAL: SHOP DRAWING	SAMPLE	GUARANTEE	MFR'S DATA	CERTIFICATE	TEST REPORT	OTHER, AS NOTED	ACTION ELEMENT: *TECH REVIEW BY	CONTRACTOR SCHEDULED DATES: SUBMIT	APPROVAL NEEDED BY	MATERIAL NEEDED BY	CORPS ACTION DATES: SUBMITTED TO CORPS	ACTION CODE	REMARKS

*AE-Architect Engineer ED-Engineering Division CD-Construction Division AREA-Area Engineer RE-Resident Engineer

ENG FORM 4288, Apr 84 EDITION OF 1 JUL 73 is OBSOLETE Page ___ Of ___ Pages (Proponent: DAEN-ECC-O)

GPO : 1984 O - 450-677

NOTES TO SUBMITTAL REGISTER

1. If ACTION ELEMENT is blank (does not identify technical review responsibility): Identified submittal shall be approved by the Contractor and then submitted to the Contracting Officer for information.

2. If the CONTRACTING OFFICER (CO) is identified in the ACTION ELEMENT column: Identified submittal shall be first approved by the Contractor and then submitted to the Contracting Officer for approval.

3. The attached Submittal Register lists only the technical items to be submitted. Contractor shall complete the Submittal Register (see SPECIAL CLAUSES SC-8), this also includes listing for submittal, to the Contracting Officer, as specified, those submittals identified in the SPECIAL CLAUSES and in Division 1 of the TECHNICAL SPECIFICATIONS.

4. Contractor shall also, when requested by the Contracting Officer, provide additional submittals at no additional cost to the Government.

5. Blank ENG FORM 4288's and full size copies of attached 4288's will be furnished by the CO.

TRANSMITTAL OF SHOP DRAWINGS, EQUIPMENT DATA, MATERIAL SAMPLES, OR MANUFACTURER'S CERTIFICATES OF COMPLIANCE

(Read instructions on the reverse side prior to initiating this form)

DATE

☐ NEW SUBMITTAL
☐ RESUBMITTAL

Section I — REQUEST FOR APPROVAL OF THE FOLLOWING ITEMS (This section will be initiated by the contractor)

TO:	FROM:	CONTRACT NO.	TRANSMITTAL NO. / PREVIOUS TRANS. NO. (If any)

SPECIFICATION SEC. NO. (Cover only one section with each transmittal)	PROJECT TITLE AND LOCATION

ITEM NO. a.	DESCRIPTION OF ITEM SUBMITTED (Type, size, model number, etc.) b.	MFG. OR CONTR. CAT., CURVE DRAWING OR BROCHURE NO. (See instruction No. 8) c.	NO. OF COPIES d.	CONTRACT REFERENCE DOCUMENT: SPEC. PARA. NO. e.	CONTRACT REFERENCE DOCUMENT: DRAWING SHEET NO. f.	VARIATION (See instruction No. 6) g.	FOR C E USE CODE h.

REMARKS

I certify that the above submitted items have been reviewed in detail and are correct and in strict conformance with the contract drawings and specifications except as otherwise stated.

NAME AND SIGNATURE OF CONTRACTOR

Section II — APPROVAL ACTION

INCLOSURES RETURNED (List by Item No.)	NAME, TITLE AND SIGNATURE OF APPROVING AUTHORITY	DATE

ENG FORM 4025, Jul 81 (ER 415-1-10) EDITION OF 1 JAN 78 IS OBSOLETE. (Proponent: DAEN-MPC) SHEET ____ OF ____

INSTRUCTIONS

1. Section I will be initiated by the Contractor in the required number of copies.

2. Each transmittal shall be numbered consecutively in the space provided for "Transmittal No." This number, in addition to the contract number, will form a serial number for identifying each submittal. For new submittals or resubmittals mark the appropriate box; on resubmittals, insert transmittal number of last submission as well as the new submittal number.

3. The "Item No." will be the same "Item No." as indicated on ENG Form 4288 for each entry on this form.

4. Submittals requiring expeditious handling will be submitted on a separate form.

5. Separate transmittal form will be used for Shop Drawings submitted under separate sections of the specifications.

6. A check shall be placed in the "Variation" column when a submittal is not in accordance with the plans and specifications—also, a written statement to that effect shall be included in the space provided for "Remarks".

7. Form is self-transmittal; letter of transmittal is not required.

8. When a sample of material of Manufacturer's Certificate of Compliance is transmitted, indicate "Sample" or "Certificate" in column c, section I.

9. U.S. Army Corps of Engineers approving authority will assign action codes as indicated below in space provided in section I, column h, to each item submitted. In addition they will ensure enclosures are indicated and attached to the form prior to return to the contractor.

THE FOLLOWING ACTION CODES ARE GIVEN TO ITEMS SUBMITTED

A – Approved as submitted

B – Approved, except as noted on drawings.
Resubmission not required.

C – Approved, except as noted on drawings.
Refer to attached sheet resubmission required.

D – Will be returned by separate correspondence

E – Disapproved (See attached)

F – Receipt acknowledged

G – Other (Specify)

10. Approval of items does not relieve the contractor from complying with all the requirements of the contract plans and specifications.

300

TRANSMITTAL OF MATERIALS SAMPLES

PROJECT AND LOCATION		TYPE EXPLORATION ☐ Churn Drill ☐ Diamond Drill ☐ Auger ☐ Test Pit ☐
EXPLORATION NO	LOCATION OF EXPL	
SAMPLES OF	GR ELEV	
DATE FORWARDED	SUBMITTED BY (DIST. OR AGENCY)	

SAMPLE NO	FIELD CLASSIFICATION	TYPE SAMPLE	DEPTH IN FEET FROM	DEPTH IN FEET TO	TESTS REQUIRED			

NPD Form 300 (Rev.) Sept. 1958 (Translucent)	DISPOSITION OF SAMPLES AFTER TESTING ☐ Discard ☐ Return ☐ Retain at Lab for	INSTRUCTIONS: Original on vellum and one copy to NPD Testing Lab with letter authorizing work. One copy to accompany samples.	SAMPLED BY TITLE

Army-Sea. Dist., Wn.

NPD Form 88
Apr 56

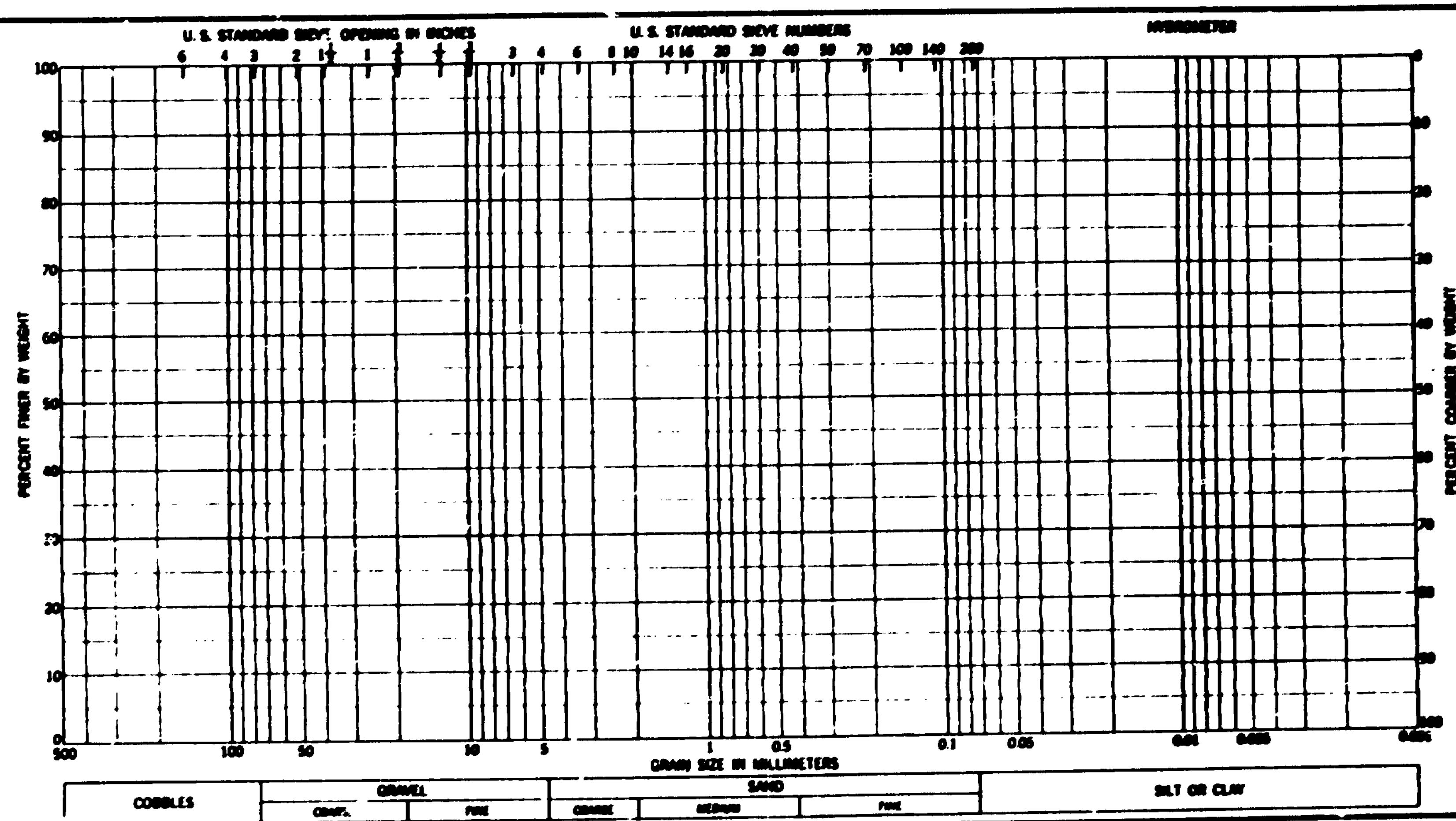
SCREEN ANALYSIS OF CONCRETE AGGREGATES

PROJECT		CONTRACT
Material	Time	Date
Wt. of Sample	Sample From	Inspector

Screen Size	Weight Retained	Percent Retained	Accum. Weight Retained	Accum. Percent Retained	Percent Passing		Remarks
					Sample	Specs.	

Total Accum. Percent Retained		Fineness Modulus
Moisture Content %	Color	Limiting F. M. (Specifications)
Clay Lumps %	Soft Fragments %	From

Remarks



Sample No	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project

Area

Boring No.

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087

MIX DATA

MATERIAL	% C.A.	SAMPLE NO.	SOLID VOLUME cu ft	WEIGHTS S.S.D. lb	BULK SP. GR. S.S.D.	% ABSORP.
Coarse Agg(A)						
" " (B)						
" " (C)						
" " (D)						
Sand						
Cement						
Pozzolan						
Water						
Air (% on-1½)						
Totals						

MIX CHARACTERISTICS

WATER-CEMENT RATIO	Gallons per bag, equivalent cement	
	By weight, " "	
	By weight, water / cement + pozzolan	
Cement factor, bags/cu yd (Eq. Sol. Vol. as P.C.)		
Pozzolan, % replacement by solid volume		
Slump, inches		
Air content (Note 1), %		
Unit weight, lbs/cu ft		
Bleeding (Note 2), %		
Sand / aggregate, % by volume		
Temperature of plastic concrete, °F		

STRENGTH TEST DATA ( )

Age, days			
Strength, p s i (average)			
Age, days			
Strength, p s i (average)			

NOTES:
1. In that portion of the concrete containing aggregate smaller than the 1½"-inch sieve.
2. Percentage of mix water separating from concrete in bleeding test.

REMARKS

SCREEN ANALYSES-% RETAINED

SIEVE SIZE	NOMINAL SIZES (A) 6" to 3"	(B) 3" to 1½"	(C) 1½" to ¾"	(D) ¾" to 4	Sand	COMBINED Coarse Aggregate	Total Aggregate
7"							
6"							
5"							
4"							
3"							
2½"							
2"							
1½"							
1"							
¾"							
½"							
⅜"							
4							
8							
16							
30							
50							
100							
PAN							
F. M.							

PROJECT

DISTRICT

FINE AGGREGATE

COARSE AGGREGATE

CEMENT

POZZOLAN

A. E. A.

OTHER ADMIXTURE

MIX NO. W/O NO.

CAST

(Date of Report) Chief, Concrete Branch

NPD RF 359 APRIL 61

REPORT OF CONCRETE MIXTURE DESIGN
METHODS CRD-C 3 AND 10
CORPS OF ENGINEERS NORTH PACIFIC DIVISION TESTING LABORATORY

TRANSIT MIX CONCRETE CONTROL RECORD

Sheet ____ of ____

CONT. NO.__________ INSP.__________ SHIFT________ TO________ DATE__________

MIX NO.	SURF. MOISTURE % & WEIGHT					LBS. WATER		W/C RATIO		TIME	SLUMP	% AIR	TEMP.		CONCRETE CYL. NO.
	SAND	3/4"	1½"	3"	6"	FREE	ADDED	DESIGN	ACTUAL				CONC.	AIR	
							(1) (2)								
							(1) (2)								
							(1) (2)								
							(1) (2)								

	CEMENT	SAND	3/4" - #4	1½" - 3/4"	WATER	A.E.A.	REMARKS
DESIGN WTS. S.S.D.							
FIELD WTS. ADJUSTED							

REMARKS:
(1) At Plant
(2) At Placement

UNIT WTS. ______________ lbs/cu.ft.

NPS FORM 302 (Rev)

COMPRESSIVE OR FLEXURAL STRENGTH SPECIMENS

Date Rec'd:

SPECIMEN NO.		DATE CAST	AGE Days	DIMENSIONS		HEIGHT H. inches (bd^2)	AREA A. sq. in.	UNIT WT. Lbs./cu. ft.	ULT. LOAD Pounds	COMP. STRENGTH psi.
LAB.	FIELD			W. pounds (b)	D. inches (d)					

REMARKS:

CAPPING MATERIAL OR METHOD
- ☐ Leadite
- ☐ Other

UNIT WEIGHT

$$P = \frac{1728W}{HA}$$

FLEXURE FORMULA

$$R = \frac{Pl}{bd} \qquad l =$$

Tested:

Computed:

Checked:

PROJECT

W/O NO.

TEST DATE

NPD Form 355 (R) JUL. 70 — DATA SHEET – COMPRESSIVE AND FLEXURAL STRENGTHS OF CONCRETE

STATISTICAL EVALUATION OF CONCRETE COMPRESSION TESTS

(PROGRAM 742-E1-03060)

SHEET ___ OF ___

PROJECT	CONTRACT	MIX	DESIGN CRITERIA				
			AGE	F'C	T	MSA	W/C

MIX DATE			CYLINDER	W/C	SLUMP	%AIR	TEMP. F		COMPRESSIVE STRENGTH (PSI)							PLACEMENT/REMARKS (LEFT JUSTIFY)
YR	MO	DA					AIR	CO	1	!	7	28	28/90	90	365	

MPS FORM 67
MAY 78