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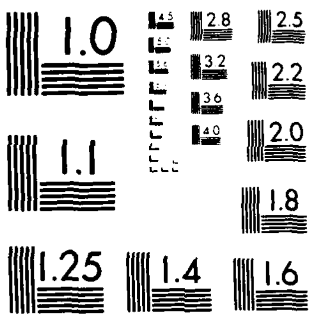

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CONCRETE QUALITY ASSURANCE USING ACCELERATED STRENGTH TESTING

by

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P. O. Box 631, Vicksburg, Miss. 39180

March 1984

Final Report

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

This report provides additional information and guidance to division laboratories and field offices within the Corps of Engineers on the use of accelerated strength testing for predicting potential compressive strengths of concrete and assuring the quality of concrete production. Emphasis is placed on the use of ACI Standard 214 for interpreting accelerated strength test results.

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20. ABSTRACT (Continued).

One hundred and eighty-one pairs of accelerated and 90-day compressive strength test results, representing one concrete mixture used at the Richard B. Russell Dam, Savannah District were collected. In addition, 519 pairs of test results, representing four concrete mixtures used at Lock and Dam No. 1, Red River Waterway, New Orleans District, were also collected. The Richard B. Russell Dam test results were analyzed using a regression equation developed by the U. S. Army Corps of Engineers South Atlantic Division Laboratory (SADL). The Lock and Dam No. 1 test results were analyzed using a regression equation developed by the U. S. Army Corps of Engineers Waterways Experiment Station (WES) Structures Laboratory.

Approximately one-half of the Richard B. Russell Dam test results represented concrete produced during a time period when three fly ash sources were being used. Only those test results representing concrete which contained fly ash from the originally proposed source are analyzed in this report. In general, the SADL regression equation, $Y_{90} = 7.64a + 159$ psi, did not accurately predict average 90-day concrete strengths. Therefore, a new regression equation, $Y_{90} = 4.53 + 1374$ psi, was developed from 30 pairs of field test results. This regression equation accurately predicted the 90-day average strengths and produced more suitable required average accelerated strengths, F_{cr_a}, for controlling concrete production.

The WES regression equation, $Y_{90} = 2.39a + 3063$ psi, accurately predicted average 90-day strengths for three of the four Lock and Dam No. 1 concrete mixtures. The equation was probably less sensitive to changes in accelerated strength than desirable because the test results used to develop the equation did not include 90-day strength values less than the specified strength of 3000 psi. The F_{cr_a}'s computed from the regression equation were suitable for controlling concrete production for all of the mixtures.

The report concludes that accelerated strength testing can apparently predict concrete potential compressive strengths and assure proper quality control of concrete production if a valid regression equation is developed. The regression equation may be developed from laboratory or field test data. The regression analysis should use a minimum of 30 sets of test data which have a broad strength range. If project materials change during the course of construction, a new linear regression analysis must be performed using compressive strength data representing concrete made from the new materials. Additional investigative studies involving compressive strength test data for future projects are recommended to determine if additional guidance on the use of accelerated strength testing is needed.

PREFACE

Personnel of the Structures Laboratory (SL) of the U. S. Army Engineer Waterways Experiment Station (WES) conducted the study reported herein under the sponsorship of the Headquarters, U. S. Army Corps of Engineers (HQUSACE), as a part of Civil Works Investigation Studies Work Unit 31138, "New Technologies for Testing and Evaluating Concrete." Mr. Fred Anderson of the Structures Branch, Engineering Division, HQUSACE, was the Technical Monitor.

The study was under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John Scanlon, Chief, Concrete Technology Division (CTD), SL; and under the direct supervision of Mr. Kenneth L. Saucier, Chief, Concrete and Grout Group, CTD. This report was prepared by Mr. Steven A. Ragan.

COL Tilford C. Creel, CE, was Commander and Director of WES during this study and preparation and publication of this report. Mr. F. R. Brown was Technical Director.

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CONTENTS

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
inches	25.4	millimetres
pounds (force) per square inch	0.00689476	megapascals
pounds (mass) per cubic yard	0.59327642	kilograms per cubic metre

CONCRETE QUALITY ASSURANCE USING ACCELERATED STRENGTH TESTING

PART I: INTRODUCTION

Background

1. The U. S. Army Corps of Engineers uses a construction inspection system to ensure that finished work is of satisfactory quality. In major Civil Works concrete construction projects the resident engineer has the responsibility for ensuring that the quality of concrete in various parts of the structure is satisfactory based on engineering considerations and instructions received from the Engineering Division of the district office. The Contracting Officer may or may not be responsible for selecting concrete mixture proportions, but the Contracting Officer is always responsible for ensuring that the strength requirements, either as set forth in the specifications or in the designer's instructions to the field, are met. This responsibility includes molding, curing, and determining the compressive strength of concrete test cylinders. Guidance in EM 1110-2-2000* recommends using ACI Standard 214** to evaluate the compressive strength test results for within-test coefficient of variation and overall standard deviation. These statistical functions are used to measure the testing variability and field control of concrete production so that the average compressive strength may be maintained high enough to ensure an assigned probability of satisfactory concrete quality.

2. Traditionally, the specified compressive strength of concrete, f'_c , has been based on a test age of 28 days. This age was established during early studies on portland cement concrete as that age at which most of the strength gain has taken place. The 28-day test age is also the specified compressive strength test age recommended by the ACI Building Code, Standard 318. However, a substantial amount of the concrete produced for the Corps of Engineers is used to build structures in which the in-service loadings are not

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* Department of the Army, Corps of Engineers, Office of the Chief of Engineers. 1982. "Engineering and Design, Standard Practice for Concrete," Engineer Manual No. 1110-2-2000, Washington, D. C.

** American Concrete Institute (ACI) Standards referenced herein are from: Part 1: Materials and General Properties of Concrete, ACI Manual of Concrete Practice, 1982, Detroit, Mich.

likely to occur for 90 days, 180 days, or even 1 year. Much of the concrete contains pozzolan and relatively small amounts of cement resulting in a slower strength development than that of concrete containing only portland cement. Therefore, a specified compressive strength test age of 90 days is often selected for this type of concrete construction.

3. A major disadvantage in applying the statistical functions given in ACI 214 to strength data obtained at 28- or 90-days age is that a large volume of concrete may be placed in the interim between cylinder fabrication and testing. Therefore, concrete that is unsatisfactory may be buried in the structure before test results become available. Similarly, economical adjustments to concrete mixture proportions that result in unnecessarily high compressive strengths may be delayed. Therefore, early assessment of concrete strength is desirable.

4. In 1971, the American Society for Testing and Materials (ASTM)* standardized three procedures for accelerated curing and testing of concrete compression test specimens (ASTM C 684; CRD-C 97)** which enabled meaningful test results to be obtained in 1 or 2 days. Division laboratories within the Corps of Engineers subsequently conducted a cooperative laboratory testing program using the warmwater procedure (ASTM Procedure A).† The purpose of the study was to evaluate this test procedure for use in routine quality control of concrete and prediction of potential strength of concrete in a structure. Results of the cooperative investigaton revealed that accelerated strength testing is a reliable method for controlling the production of concrete whether it contains a pozzolan or not. Instructions were incorporated into EM 1110-2-2000 directing Corps of Engineers' division laboratories and field offices to use accelerated strength data for controlling the production of concrete to be used in major civil works concrete structures.

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* ASTM Standards referenced herein are from: "Concrete and Mineral Aggregates; Manual of Concrete Testing," 1982 Annual Book of ASTM Standards, Philadelphia, Pa.

** U. S. Army Engineer Waterways Experiment Station, CE. 1949 (Aug). "Handbook for Concrete and Cement" (with quarterly supplements), Vicksburg, Miss.

† Joseph F. Lamond. 1979. "Accelerated Strength Testing by the Warm Water Method," Journal, American Concrete Institute, Proceedings, Vol 76, No. 4, pp 499-512.

Purpose

5. This report provides Corps of Engineers division laboratories and field offices with additional information and guidance on the use of accelerated strength testing of concrete. Such testing can be used to estimate potential compressive strength of concrete and to control the quality of concrete production. Emphasis is placed on the use of ACI 214.1R for interpreting accelerated strength test results.

Scope

6. The results of testing 181 pairs of accelerated and 90-day compressive strength specimens representing one of the concrete mixtures used at Richard B. Russell Dam, Savannah District, and 519 pairs representing four mixtures used at Lock and Dam No. 1, Red River Waterway, New Orleans District, were collected and used to provide the basis of information for this report. A test is defined as the average strength of all specimens of the same age fabricated from a single batch of concrete. All accelerated strength tests were conducted according to ASTM C 684 (CRD-C 97),* Procedure A.

7. The concrete mixture represented by the Richard B. Russell test data contained Type II portland cement, Class F fly ash, and had a 6-in.** nominal maximum size crushed coarse aggregate and a manufactured fine sand. All of the concrete sampled contained the same type and brand of portland cement; however, the fly ash used in the concrete mixture was obtained from three different sources. The coarse and fine aggregates were crushed and manufactured at an on-site quarry.

8. The four concrete mixtures represented by Lock and Dam No. 1 test data contained Type II portland cement, Class F fly ash, and had 3-, 1-1/2-, and 3/4-in. nominal maximum size coarse aggregate. The mixture contained the same type and brand of portland cement, and the fly ash was obtained from a single source. The coarse aggregate was obtained from an off-site quarry, and the fine aggregate was obtained from an off-site pit.

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* U. S. Army Engineer Waterways Experiment Station, CE, op. cit.

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

9. A computer program CONEVAL* was written to evaluate compressive test results at all test ages using the statistical functions described in ACI 214. In addition, the program uses accelerated strength test results to estimate potential compressive strengths and evaluate concrete quality control as described in ACI 214.1R. The program also has plot capabilities that permit the user to generate control charts similar to those shown in ACI 214 for assessing concrete quality control.

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* Roy L. Campbell, Jr. 1983. "Computer-Aided Analysis of Concrete Strength Test Results," Instruction Report SL-83-1, Oct 1983, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART II: DEVELOPMENT OF DIVISION LABORATORY REGRESSION ANALYSIS

Richard B. Russell Dam

10. Test data were obtained and regression analyses performed at the U. S. Army Corps of Engineers South Atlantic Division Laboratory (SADL) and the U. S. Army Engineer Waterways Experiment Station (WES) Structures Laboratory. However, this work was done prior to the publication of the guidance given in ACI 214.1R.

11. The SADL developed a linear regression equation of $Y_{90} = 7.64a + 159$ psi , where Y_{90} = the predicted 90-day compressive strength and a = the average accelerated strength of companion test specimens. In the regression analysis, SADL used 19 sets of test data, obtained during the proportioning of the concrete mixtures for the Richard B. Russell Dam. The accelerated strength test results ranged from 176 to 406 psi and the 90-day test results ranged from 1521 to 3178 psi. Table 1 shows the SADL accelerated and 90-day test results. Guidance given in ACI 214.1R advises that a minimum of 30 sets of test data covering a wide strength range are needed to establish an adequate correlation; and that for a single strength requirement the strength range should include the specified strength and should equal at least 75 percent of the specified strength. The specified strength (2000 psi) is included within the strength range of the SADL test data and the range of test results (1660 psi) exceeds 75 percent of the specified strength. The correlation coefficient of the test data is 0.936. According to the American Concrete Institute a correlation coefficient of less than 0.80 should be regarded with suspicion. Figure 1 shows the correlation curve for the test data.

Red River Waterway, Lock and Dam No. 1

12. The WES Structures Laboratory proportioned the concrete mixtures used at Red River Waterway, Lock and Dam No. 1, and used the accelerated and 90-day strength test results to develop a linear regression equation of $Y_{90} = 2.39a + 3063$ psi. WES used 13 sets of test data representing all concrete mixtures containing portland cement and fly ash to perform the regression analysis. The correlation coefficient of the test data is 0.963. The accelerated strength test results range from 365 to 1580 psi and the 90-day

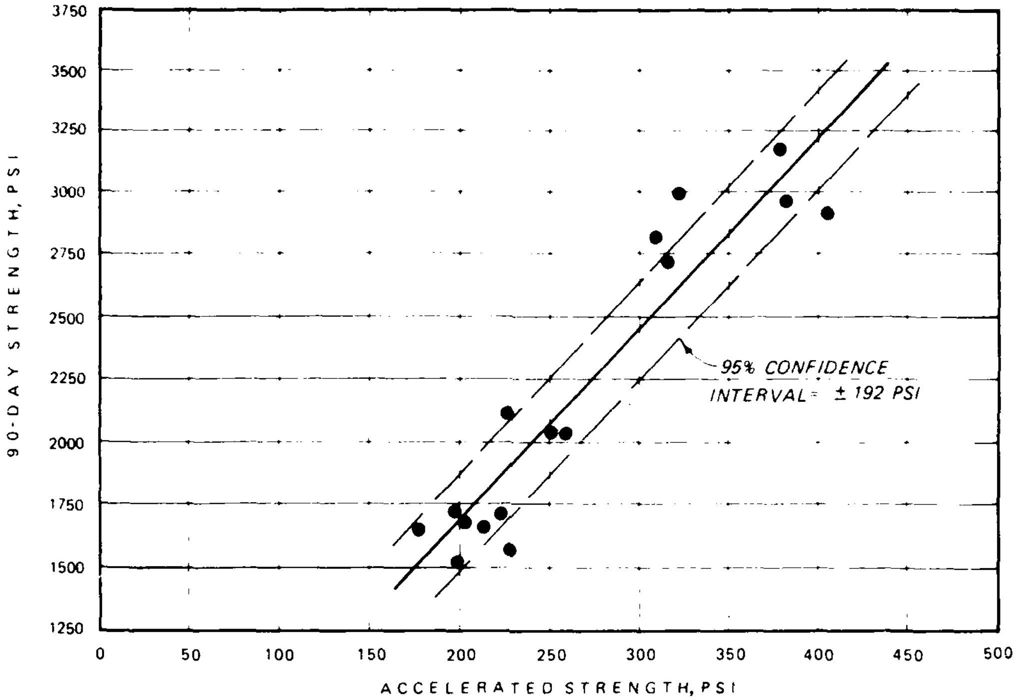

Figure 1. SADL correlation between accelerated and 90-day strength test results

test results range from 3760 to 6620 psi. Table 2 shows the WES accelerated and 90-day strength test results. ACI 214.1R suggests that a broader strength range which includes both specified strengths (3000 and 4000 psi) is needed to develop a more realistic regression equation having a larger slope coefficient and smaller intercept. Figure 2 shows the correlation curve for the test data.

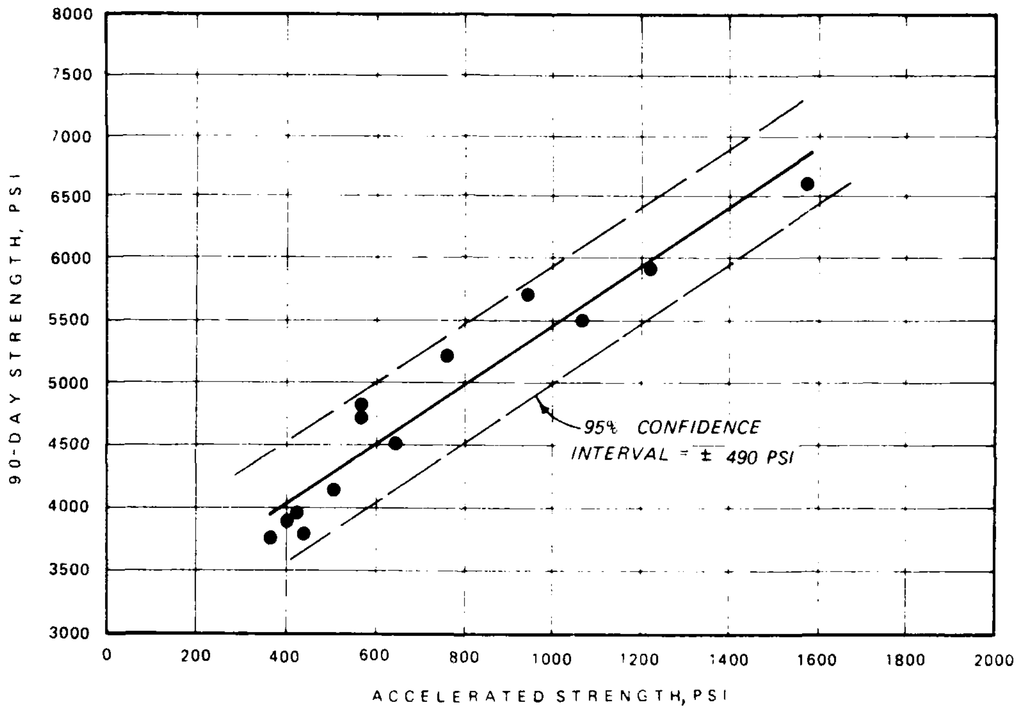

Figure 2. WES correlation between accelerated and 90-day strength test results

PART III: CONCRETE MIXTURES AND TEST DATA

Field Mixtures Analyzed

13. Test data were compiled from concrete samples representing the following mixtures:

Mixture No.	Water-Cement Ratio by Mass	Nominal Maximum Size Aggregate mm	in.	Cementitious Content lb/yd^3	Slump (ASTM C 143) in.	Air Content Pressure Method (ASTM C 231) percent
				Richard B. Russell Dam		
12	0.67	150	6	246*	2	5.5**
				Red River Waterway Lock and Dam No. 1		
3F 0.75	0.57	19.0	3/4	385†	3	6.0
3F 1.5	0.58	37.5	1-1/2	357†	2-1/2	5.0
3F 3	0.57	7.5	3	305†	1-1/2	5.0**
4F 1.5	0.45	37.5	1-1/2	461†	2	5.0

* Fly ash, 35 percent by solid volume of cementitious content.
** In that portion of the concrete wet-sieved over a 1-1/2-in. sieve as recommended in ASTM C 172.
† Fly ash, 25 percent by solid volume of cementitious content.

The proportions of the mixtures are given in Table 3.

Field Test Data

Richard B. Russell Dam

14. A total of 181 pairs of accelerated and 90-day compressive strength tests of samples representing one concrete mixture were collected and test results are presented in Appendix A. The samples tested represent concrete placed in the structure over a 16-month period. The results are compiled in groups of at least 30, since EM 1110-2-2000 suggests that adjustments to mixture proportions be made after every set of 30 tests when there is an indicated change in standard deviation. The mixture was proportioned to obtain a specified strength of 2000 psi at 90 days age. Adjustments to the water-cement ratio of the mixture were made approximately 12 and 14 months after the beginning of concreting operations, from 0.67 to 0.65 and 0.75, respectively.

Red River Waterway
Lock and Dam No. 1

15. A total of 519 pairs of accelerated and 90-day age test results representing concrete samples from four mixtures were compiled:

118 sets from mixture No. 3F 0.75
140 sets from mixture No. 3F 1.50
184 sets from mixture No. 3F 3.00
77 sets from mixture No. 4F 1.50

Test results are given in Appendix B. Mixtures 1, 2, and 3 were proportioned to obtain a specified strength of 3000 psi at 90 days age, and mixture 4 was proportioned to meet a specified strength of 4000 psi at 90 days age. The samples tested represented concrete placed in the lock and dam over a 29-month period. No major adjustments were made in any of the mixtures during this period.

PART IV: DISCUSSION OF TEST RESULTS

Prediction of Potential Compressive Strengths

16. Correlation between accelerated early strength of test specimens and strength at some later age achieved by conventional curing methods depends upon the materials comprising the concrete and the specific accelerated curing procedure used. Since a test result primarily has value as an indicator of a possibility that the desired load-bearing capability has or can be obtained in the structure by use of a particular concrete mixture, there is no fundamental reason why the accelerated early strength cannot be used to evaluate concrete quality in the way conventional 28-day strengths are currently used. The practice of using strength results obtained from standard-cured cylinders at 28-days age is long established and widespread, but it is recognized that predictions of later age strengths from accelerated early strengths are desirable.

Richard B. Russell Dam

17. Table 4 summarizes the average 90-day strengths (estimated and actual) for the six groups of test data analyzed. Standard deviations of each test group are also shown in Table 4. The SADL regression equation, $Y_{90} = 7.64a + 159$ psi, was used to make the strength predictions. The concrete proportioned prior to period 4 contained fly ash obtained from three different sources. Therefore, the SADL regression equation may not accurately represent the relationship between 1- and 90-day compressive strength data from June 1979 through November 1979 (periods 1-3). The compressive strength data summarized in periods 4-6 represent samples taken from concrete containing fly ash from the originally proposed source. However, the SADL regression equation does not accurately predict the 90-day average strengths for periods 5 and 6. Therefore, a new linear regression equation was developed from the compressive strength data obtained in period 4. The data are presented in Table A4 and represent concrete containing fly ash from the originally proposed source. The strength range of the test data includes the f'_c and equals at least 75 percent of f'_c as recommended in ACI 214.1R. The regression equation developed from the strength data shown in Table A4 is $Y_{90} = 4.53a + 1374$ psi, and the correlation coefficient is 0.843. Figure 3 shows the correlation curve for the test data.

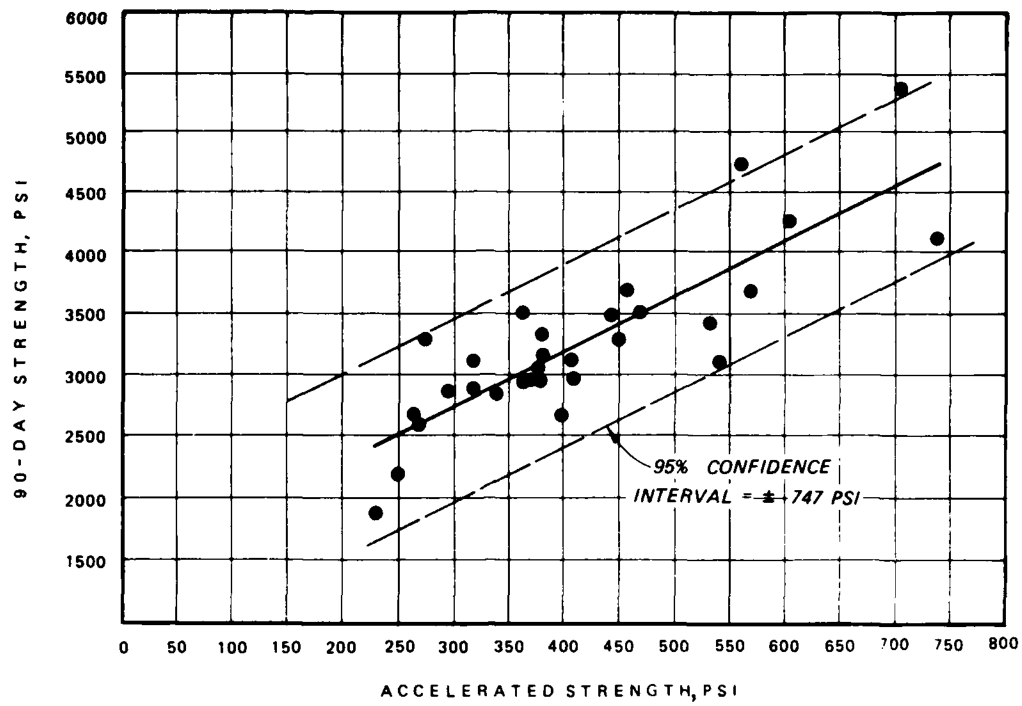

Figure 3. Correlation between accelerated and 90-day strength test results, Richard B. Russell Dam, period 4

18. Table 5 summarizes the average 90-day strengths and average predicted 90-day strengths obtained during periods 4-6 using the field regression equation previously mentioned. The close accuracy of the strength predictions indicates that a regression equation can be developed from field data and successfully used to predict later age compressive strengths.

Red River Waterway
Lock and Dam No. 1

19. Table 6 summarizes the average estimated and actual 90-day strengths for 15 groups of test data representing four concrete mixtures. The WES regression equation, $Y_{90} = 2.39a + 3063$, was used to estimate the 90-day strengths. The overall standard deviations of the accelerated and 90-day test results within each period are also shown in Table 6. For mixtures No. 3 F 0.75, 3 F 1.5, and 3 F 3, the accuracy of the strength predictions appears very good as indicated by the Δ_{A-P}'s . The accuracy of the predictions is slightly less for mixture No. 4 F 1.5. The larger Δ_{A-P}'s for mixture No. 4 F 1.5 may be due in part to the WES regression equation. As

previously stated, no 90-day test results less than 3000 psi were available for use in the regression analysis. As a result, the regression line is probably less sensitive to changes in accelerated strength than it should be. Field control of concrete production may also affect the accuracy of strength predictions. In general, the larger the standard deviation of a group of field test data, the greater the variability of the predicted later age strengths.

Field Control of Concrete Production

20. Although accelerated strength test results may be used to predict the potential compressive strength of concrete at some later age, the most important use is for control of concrete production so that rapid adjustments of batching and mixing can be made. The accelerated test data collected at the two project sites were not used to specifically control concrete production and make mixture proportion adjustments. However, an analysis of the data was performed for guidance on future projects.

21. ACI 214 can be used in interpreting compressive strength test results of both standard-cured and accelerated-cured specimens. A required average strength, f_{cr}, must be computed for each sample of data, so that a specific percentage of future tests will be greater than the specified strength, f'_c. The value of the required average strength may be either the later age strength, f_{cr}, or the actual accelerated strength, f'_{c_a}, depending upon the corresponding value of f'_c. The formula used to compute f_{cr} is $f_{cr} = f'_c + t\sigma$, where t is a constant depending on the proportion of tests that may fall below f'_c, and σ is the value of the standard deviation. Values of t are given in Table 4.1 of ACI 214. The value of f'_{c_a} is computed by first calculating the accelerated strength, a, corresponding to the later age f'_c using the regression equation. The required average accelerated strength may then be calculated using the formula $f'_{c_a} = a + t\sigma$, where σ is the value of the standard deviation of the accelerated strengths, and t is the constant previously described.

22. If fewer than 30 sets of data are used in establishing the laboratory regression curve, a more sophisticated statistical treatment is needed to determine the required average accelerated strength. The laboratory test results should be corrected to the upper 95 percent confidence interval for

the regression of accelerated strength on later age strength. The resulting average accelerated strength, f_{cr_a}, is more conservative than the f'_{c_a} computed from the previously mentioned formula. The appendix of ACI 214.1R shows how to calculate f_{cr_a} using the formula $f_{cr_a} = f'_{c_a} + t'\sigma_{y \cdot x}$, where $\sigma_{y \cdot x}$ is the standard deviation of y values for a given x value, also called the standard error of estimate, and t' is a constant multiplier for $\sigma_{y \cdot x}$ that depends on the number of pairs of data, n, used in calculating the linear regression line. Values for t' are given in Table 2 of ACI 214.1R. The value of f'_{c_a} or f_{cr_a} is computed for the user in the CONEVAL computer program. Since both the SADL and WES regression lines were based on less than 30 sets of test data, all required average strengths shown in Tables 7 and 9 were determined by correcting the laboratory test results to the upper 95 percent confidence interval for the regression of accelerated strength on 90-day strength.

23. Statistical information given in Table 4.3 of ACI 214 may be used as additional guidance for controlling structural concrete production. Values given in column 3 of the table are strength levels below which averages of different numbers of tests should not normally fall. These values are based on the premise that the concrete is proportioned to produce an average strength equal to the required average strength of the accelerated or later age tests. The probability of these values being exceeded when the concrete is properly controlled is approximately 2 percent. Failure to meet the tabulated limits in a larger proportion of cases than 2 percent may indicate that the current average accelerated or later age strength is less than f_{cr} or that the standard deviation of the accelerated or later age strength tests has increased. This failure could be caused by lower strength or poorer control than expected, or both. When low test results occur, sampling or testing errors should not be overlooked as a possible cause. In any case, corrective action is suggested.

Richard B. Russell Dam

24. Tables 7 and 8 give a chronological account of the 6-in. nominal maximum size aggregate concrete control during periods 4, 5, and 6. The test data obtained during periods 1, 2, and 3 are not summarized in these tables because the concrete proportioned during these periods contained fly ash from more than one source. A single regression equation used to analyze test data

from these periods might produce inaccurate values of f_{cr_a}. The regression equation developed from SADL test data, $Y_{90} = 7.64a + 159$ psi, was used to determine the values of f_{cr_a} in Table 7. The regression equation developed from field test data, $Y_{90} = 4.53a + 1374$ psi, was used to determine required average accelerated strengths in Table 8. Since 30 sets of test data were used to develop the field regression equation, the test results were not corrected to the upper 95 percent confidence interval for the regression of accelerated strength on 90-day strength.

25. The concrete mixture was proportioned to ensure that not more than two 90-day test results in ten would be less than the 2000-psi f'_c. Based on the SADL proportioning results, beginning in March of 1979 the concrete was batched with 246 pounds of portland cement and fly ash per cubic yard. Tables 7 and 8 show that the average 90-day strength of period 4 exceeded the 90-day f_{cr}. Table 7 shows that the average accelerated strength of period 4 was less than the f_{cr_a}. Table 8, however, shows that the average accelerated strength for the period exceeded the required average accelerated strength. The test results in Table A4 indicate that only 3 percent of the 90-day strengths, one in thirty, were less than the f'_c. The required average accelerated strength given in Table 8 is therefore more suitable for controlling concrete production than the f_{cr_a} shown in Table 7.

26. In March of 1980, the mass of cementitious materials was reduced to 226 pounds per cubic yard and the water-cementitious materials ratio was reduced from 0.67 to 0.65. Tables 7 and 8 show that the average 90-day strength during period 5 was greater than the 90-day f_{cr}. However, Table 7 indicates that the average accelerated strength during the period was less than the f_{cr_a}. Table 8, conversely, shows that the average accelerated strength during period 5 was greater than the required average accelerated strength. Table A5 shows that in period 5 only 17 percent of the 90-day compressive strengths were less than f'_c. The value of the required average accelerated strength shown in Table 8, therefore, appears more accurate for controlling concrete production.

27. In early May of 1980, the water-cementitious materials ratio was increased to 0.75 while the mass of cementitious materials was maintained constant. The average 90-day compressive strength for period 6 was less than

the 90-day f_{cr} . Table 7 shows that the average accelerated strength for period 6 was also less than the f_{cr_a} . Table 8, however, indicates the average accelerated strength for the period was slightly greater than the required average accelerated strength. Table A6 shows that 20 percent of the 90-day strengths in period 6, or exactly two in ten, were less than the f'_c The required average accelerated strength given in Table 8, therefore, again seems more suitable for concrete control than the f_{cr_a} given in Table 7.

Red River Waterway
Lock and Dam No. 1

28. Table 9 summarizes the concrete control for the four mixtures studied. Each mixture was proportioned to ensure that not more than one 90-day test result in ten would be less than the specified strengths of 3000 and 4000 psi. The average 90-day strength of each test period exceeded the respective 90-day f_{cr} . The average accelerated strength of each period also exceeded the respective f_{cr_a} . One might expect, therefore, that no test period would contain more than one 90-day test result in ten less than the 90-day f'_c . The test data shown in Tables B1 through B15 indicate that this conclusion is true.

PART V: CONCLUSIONS AND RECOMMENDATIONS

29. Accelerated strength testing appears to have potential value as a means for predicting concrete potential compressive strengths if a valid regression equation is developed. The regression analysis should use a minimum of 30 sets of test data which have a broad strength range.

30. If the laboratory regression line is reasonably correct or if a valid regression line can be developed from the field data, accelerated strength testing can be used effectively to control the quality of concrete production. The statistical procedures given in ACI 21 .1R and ACI 214 may be used with the laboratory regression to evaluate accelerated strength test data and determine if mixture adjustments are needed. If the laboratory regression equation is based on less than 30 sets of test data, the required average accelerated strength should be computed by correcting the test data to the upper 95 percent confidence interval of the regression curve.

31. The laboratory regression equation should be verified early in the construction phase of a structure using at least 30 sets of field data covering a wide strength range. If project materials different than those used by the laboratory are employed, a new linear regression analysis must be performed using compressive strength data representing concrete made from the new materials.

32. The CONEVAL computer program should be used by project and district personnel to reduce and analyze accelerated and later age strength test results. The program is accessible through the Honeywell computer at WES.

33. Additional investigative work involving the analysis of compressive strength test data from future projects is suggested to determine if additional guidance on the use of accelerated strength testing is needed.

Table 1

SADL Compressive Strength

Test Results

Accelerated Strength psi	90-Day Strength psi
309	2819
316	2719
323	2991
227	2115
250	2045
227	2097
202	1681
176	1646
197	1716
406	2915
383	2968
379	3178
257	2037
260	2037
257	2037
198	1521
223	1710
227	1570
213	1655
Avg 265	Avg 2182

Table 2

WES Structures Laboratory Compressive

Strength Test Results

Accelerated Strength psi	90-Day Strength psi
570	4790
760	5220
945	5700
365	3760
405	3890
440	3800
570	4740
425	3960
510	4140
645	4520
1065	5500
1220	5920
1580	6620
Avg 731	Avg 4812

Table 3

Mixture Proportions

Mixture No.	Property	Portland Cement	Fly Ash	Fine Aggregate	Coarse Aggregate	Water	Air	Water-Reducing Admixture	Total
				Richard B. Russell Dam					
Tot 12	Solid volume, ft^3	0.880	0.473	5.035	16.857	2.837	0.918		27.000
	Bulk density, saturated surface-dry, lb/yd^3	173.0	73.0	864.0	2935.0	177.0		0.8	4222.0
			Red River Waterway, Lock and Dam No. 1						
1	Solid volume, ft^3	1.586	0.528	8.295	11.456	3.515	1.620		27.000
	Bulk density, saturated surface-dry, lb/yd^3	311.7	73.1	1361.3	1923.0	218.1		1.2	3888.4
2	Solid volume, ft^3	1.471	0.490	7.741	12.630	3.318	1.350		27.000
	Bulk density, saturated surface-dry, lb/yd^3	289.1	67.9	1270.4	2120.1	207.0		1.1	3955.6
3	Solid volume, ft^3	1.256	0.418	6.872	14.603	2.784	1.067		27.000
	Bulk density, saturated surface-dry, lb/yd^3	246.9	57.9	1127.8	2456.6	172.8		1.0	4063.0
4	Solid volume, ft^3	1.898	0.632	7.325	12.473	3.322	1.350		27.000
	Bulk density, saturated surface-dry, lb/yd^3	373.1	87.6	1202.1	2093.7	205.9		1.4	3963.8

Table 4

Richard B. Russell Dam

Average and Predicted 90-Day Compressive Strengths

Mixture No.	Period No.	No. Tests in Period	End of Test Period	Avg Accelerated Strength for Period, psi	Avg 90-Day Strength for Period, psi	Avg Predicted 90-Day Strength for Period, psi	Δ_{A-P} psi	Standard Deviation for Period psi: A	Standard Deviation for Period psi: 90-Day
Tot 12	1	30	Jun 79	447	4020	3574	446	111	729
Tot 12	2	30	Aug 79	531	3871	4216	-345	90	567
Tot 12	3	31	Nov 79	434	3732	3475	257	107	707
Tot 12	4	30	Feb 80	408	3258	3276	-18	130	698
Tot 12	5	30	May 80	201	2434	1695	739	50	403
Tot 12	6	30	Oct 80	191	2291	1618	673	62	418

Table 5

Richard B. Russell Dam

Average and Predicted 90-Day Compressive Strengths

Field Regression Equation

Mixture No.	Period No.	No. Tests in Period	End of Test Period	Avg Accelerated Strength for Period, psi	Avg 90-Day Strength for Period, psi	Avg Predicted 90-Day Strength for Period, psi	Δ_{A-P} psi	Standard Deviation for Period psi A	Standard Deviation for Period psi 90-Day
Tot 12	4	30	Feb 80	408	3258	3222	36	130	698
Tot 12	5	30	May 80	201	2434	2285	149	50	403
Tot 12	6	30	Oct 80	191	2291	2239	52	62	418

Table 6

Red River Waterway, Lock and Dam No. 1, Average and Predicted 90-Day Compressive Strengths

Mixture No.	Period No.	No. Tests in Period	End of Test Period	Avg Accelerated Strength for Period, psi	Avg 90-Day Strength for Period, psi	Avg Predicted 90-Day Strength for Period, psi	Δ_{A-P} psi	Standard Deviation for Period psi A	Standard Deviation for Period psi 90-Day
3 F 0.75	1	30	Jan 81	512	4296	4287	9	54	337
3 F 0.75	2	30	Mar 81	470	4225	4186	39	65	447
3 F 0.75	3	58	Feb 82	436	4209	4105	104	101	726
3 F 1.5	1	30	Jul 81	414	4218	4052	166	79	628
3 F 1.5	2	30	Sep 81	471	4038	4189	-151	184	710
3 F 1.5	3	30	Oct 81	633	4458	4576	-118	205	534
3 F 1.5	4	50	Dec 81	559	4580	4399	181	136	550
3 F 3	1	30	Mar 81	413	3957	4050	-93	61	574
3 F 3	2	30	May 81	382	3950	3976	-26	49	362
3 F 3	3	30	Jun 81	427	4091	4084	7	80	565
3 F 3	4	30	Jul 81	412	4063	4048	15	66	569
3 F 3	5	30	Aug 81	460	3996	4162	-166	176	710
3 F 3	6	34	Feb 82	453	4194	4146	48	131	663
4 F 1.5	1	30	Jun 81	831	5657	5049	608	172	857
4 F 1.5	2	47	Sep 81	766	5214	4894	320	130	514

Table 7

Richard B. Russell Dam

Required Average Compressive Strengths

SADL Regression Equation

Mixture No.	Period No.	End of Test Period	Avg Accelerated Strength for Period, psi	f_{cr_a} psi	Avg 90-Day Strength for Period, psi	f_{cr} psi	Standard Deviation for Period, psi: a	Standard Deviation for Period, psi: 90-Day
Tot 12	4	Feb 80	408	431	3258	2586	130	698
Tot 12	5	May 80	201	364	2434	2339	50	403
Tot 12	6	Oct 80	191	374	2291	2351	62	418

Note: Underlined strength values are those which fail to meet the required average strength.

Table 8

Richard B. Russell Dam

Required Average Compressive Strengths

Field Regression Equation

Mixture No.	Period No.	End of Test Period	Avg Accelerated Strength for Period, psi	f_{cr_a} psi	Avg 90-Day Strength for Period, psi	f_{cr} psi	Standard Deviation for Period, psi: a	Standard Deviation for Period, psi: 90-Day
Tot 12	4	Feb 80	408	247	3258	2586	130	698
Tot 12	5	May 80	201	180	2434	2339	50	403
Tot 12	6	Oct 80	191	190	2291	2351	62	418

Note: Underlined strength values are those which fail to meet the required average strength.

Table 9

Red River Waterway, Lock and Dam No. 1,

Required Average Compressive Strengths

Mixture No.	Period No.	End of Test Period	Avg Accelerated Strength for Period, psi	f_{cr_a} psi	Avg 90-Day Strength for Period, psi	f_{cr} psi	Standard Deviation for Period, psi: a	Standard Deviation for Period, psi: 90-Day
3 F 0.75	1	Jan 81	512	174	4296	3431	54	337
3 F 0.75	2	Mar 81	470	188	4225	3572	65	447
3 F 0.75	3	Feb 82	436	234	4209	3929	101	726
3 F 1.5	1	Jul 81	414	206	4218	3804	79	628
3 F 1.5	2	Sep 81	471	341	4038	3909	184	710
3 F 1.5	3	Oct 81	633	368	4458	3683	205	534
3 F 1.5	4	Dec 81	559	279	4580	3704	136	550
3 F 3	1	Mar 81	413	183	3957	3735	61	574
3 F 3	2	May 81	382	168	3950	3463	49	362
3 F 3	3	Jun 81	427	208	4091	3723	80	565
3 F 3	4	Jul 81	412	190	4063	3728	[illegible]	569
3 F 3	5	Aug 81	460	330	3996	3908	176	710
3 F 3	6	Feb 82	453	273	4194	3849	131	663
4 F 1.5	1	Jun 81	831	744	5657	5097	172	857
4 F 1.5	2	Sep 81	766	690	5214	4658	130	514

APPENDIX A

RICHARD B. RUSSELL DAM

COMPRESSIVE STRENGTH TEST RESULTS

Table A1

Richard B. Russell Dam

Compressive Strength Test Results

Mixture No. 12, Period No. 1

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	267	1786
2	265	3316
3	327	3908
4	305	3891
5	336	3714
6	380	3767
7	358	3926
8	351	3183
9	622	4943
10	635	4015
11	375	4342
12	591	5447
13	430	4041
14	531	4501
15	488	4351
16	470	4200
17	588	4704
18	536	3873
19	511	3776
20	420	3856
21	422	3873
22	533	5111
23	377	4156
24	345	2865
25	373	3555
26	460	4085
27	416	3431
28	550	4722
29	402	4050
30	658	5226
Overall Standard Deviation, psi	111	729
Overall Coefficient of Variation, percent	24.8	18.1

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Table A2

Richard B. Russell Dam

Compressive Strength Test Results

Mixture No. 12, Period No. 2

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	761	5305
2	568	3935
3	474	4173
4	511	4236
5	550	4174
6	552	4156
7	518	3891
8	542	4032
9	573	4775
10	442	3095
11	476	3404
12	594	4209
13	489	3838
14	358	2936
15	329	2706
16	543	3670
17	635	4289
18	577	3378
19	607	3511
20	480	3590
21	495	3988
22	437	3590
23	679	4545
24	608	4306
25	393	3484
26	547	3590
27	598	4129
28	550	4501
29	504	3015
30	540	3678
Overall Standard Deviation, psi	90	567
Overall Coefficient of Variation, percent	16.9	14.6

Table A3

Richard B. Russell Dam

Compressive Strength Test Results

Mixture No. 12, Period No. 3

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	456	4076
2	531	4156
3	380	3271
4	388	3847
5	382	3802
6	347	5040
7	345	2971
8	414	3396
9	378	2768
10	570	4076
11	363	2741
12	375	2901
13	649	4466
14	366	2971
15	524	4536
16	543	3829
17	711	5376
18	301	2865
19	482	4421
20	386	3643
21	428	4350
22	322	2936
23	305	3148
24	540	4112
25	564	4678
26	464	3970
27	378	3803
28	391	3537
29	273	2741
30	352	3369
31	559	3891
Overall Standard Deviation, psi	107	707
Overall Coefficient of Variation, percent	24.7	18.9

Table A4

Richard B. Russell Dam

Compressive Strength Test Results

Mixture No. 12, Period No. 4

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	381	3139
2	451	3281
3	562	4740
4	605	4262
5	709	5376
6	407	3113
7	534	3434
8	363	2936
9	541	3113
10	377	3077
11	740	4140
12	571	3687
13	274	3290
14	230	1875
15	267	2617
16	409	2971
17	250	2193
18	338	2847
19	363	3502
20	458	3688
21	317	2874
22	398	2680
23	264	2671
24	373	2962
25	380	3333
26	469	3520
27	318	3113
28	379	2963
29	444	3484
30	296	2864
Overall Standard Deviation, psi	130	698
Overall Coefficient of Variation, percent	31.9	21.4

Table A5

Richard B. Russell Dam

Compressive Strength Test Results

Mixture No. 12, Period No. 5

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	265	2776
2	197	2511
3	186	2122
4	345	3183
5	202	2299
6	175	2166
7	194	2414
8	158	1689
9	195	2573
10	134	1875
11	177	2246
12	221	2546
13	134	1892
14	175	1892
15	161	2220
16	218	2829
17	186	2263
18	269	2732
19	149	1963
20	246	2891
21	172	2732
22	174	2170
23	262	3112
24	239	2449
25	303	3218
26	193	2785
27	212	2661
28	172	2086
29	146	2245
30	168	2502
Overall Standard Deviation, psi	50	403
Overall Coefficient of Variation, percent	24.8	16.6

Table A6

Richard B. Russell Dam

Compressive Strength Test Results

Mixture No. 12, Period No. 6

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	143	2175
2	140	2025
3	154	2343
4	143	2149
5	168	2326
6	124	1468
7	175	2131
8	118	1512
9	90	1884
10	187	2741
11	219	2484
12	170	2175
13	250	3095
14	230	2759
15	228	2246
16	160	1733
17	318	2989
18	233	2326
19	313	2414
20	216	2096
21	149	1812
22	250	[illegible]
23	181	2114
24	134	2131
25	141	2361
26	159	1972
27	301	2688
28	134	3210
29	299	2608
30	207	2369
Overall Standard Deviation, psi	62	418
Overall Coefficient of Variation, percent	33.0	18.2

APPENDIX B

RED RIVER WATERWAY LOCK AND DAM NO. 1

COMPRESSIVE STRENGTH TEST RESULTS

Table B1

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 0.75, Group No. 1

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	610	5035
2	650	4595
3	385	3630
4	515	4400
5	485	4150
6	535	4410
7	565	4435
8	475	4150
9	525	4680
10	530	4785
11	495	4435
12	565	4420
13	480	4505
14	560	4810
15	500	4155
16	505	4390
17	515	4340
18	500	4525
19	515	4385
20	605	4695
21	465	4065
22	425	3870
23	485	4020
24	450	3955
25	540	4420
26	470	3965
27	490	3925
28	470	3835
29	520	3925
30	525	3905
Overall Standard Deviation, psi	54	337
Overall Coefficient of Variation, percent	10.5	7.8

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Table B2

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 0.75, Group No. 2

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	375	3135
2	400	3800
3	365	3540
4	390	3370
5	455	3955
6	485	3850
7	485	3940
8	445	3920
9	425	3850
0	465	4010
11	475	4400
12	600	4370
13	450	4380
14	610	5020
15	535	4665
16	540	4515
17	480	4055
18	565	4635
19	510	4300
20	535	4600
21	480	4655
22	465	4415
23	475	4575
24	470	4010
25	475	4030
26	525	4435
27	435	4370
28	445	5945
29	415	4790
30	335	4205
Overall Standard Deviation, psi	65	447
Overall Coefficient of Variation, percent	13.8	10.6

Table B3

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 0.75, Group No. 3

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	395	4520
2	460	4845
3	320	4045
4	405	4400
5	410	4080
6	390	4310
7	360	4080
8	425	4470
9	370	4115
10	450	4220
11	520	4260
12	415	3870
13	400	3780
14	400	3975
15	390	3960
16	460	4045
17	420	4045
18	380	3855
19	315	4225
20	305	3745
21	485	4310
22	310	3000
23	495	4540
24	160	1715
25	440	4130
26	355	3745
27	425	4590
28	475	4645
29	525	4950
30	445	4330
31	370	3800
32	390	3000
33	315	3210
34	400	3815
35	505	4630
36	535	4353
37	420	3645
38	510	4512
39	345	3026
40	510	4459
41	420	3786

(Continued)

Table B3 (Concluded)

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
42	425	4016
43	510	4194
44	330	4034
45	375	4253
46	505	4105
47	420	3845
48	669	4848
49	563	4406
50	641	5981
51	531	4831
52	535	4831
53	363	5167
54	804	5432
55	496	5149
56	516	5684
57	495	5681
58	260	3680
Overall Standard Deviation, psi	101	726
Overall Coefficient of Variation, percent	23.1	17.2

Table B4

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 1.5, Period No. 1

Sequence No.	Accelerated Strength, psi	[illegible] Strength, psi
1	445	[illegible]
2	445	[illegible]
3	430	[illegible]
4	540	[illegible]
5	425	[illegible]
6	365	[illegible]
7	350	[illegible]
8	300	[illegible]
9	275	[illegible]
10	450	[illegible]
11	335	[illegible]
12	280	[illegible]
13	330	[illegible]
14	345	[illegible]
15	315	[illegible]
16	440	[illegible]
17	420	[illegible]
18	420	[illegible]
19	490	[illegible]
20	505	[illegible]
21	490	[illegible]
22	440	[illegible]
23	520	[illegible]
24	435	[illegible]
25	500	[illegible]
26	490	5015
27	440	3835
28	360	4060
29	405	3770
30	420	3785
Overall Standard Deviation, psi	79	628
Overall Coefficient of Variation, percent	19.0	14.9

Table B5

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 1.5, Period No. 2

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	375	3769
2	355	3264
3	400	4406
4	410	3804
5	355	3213
6	405	4512
7	335	3565
8	310	3362
9	370	3680
0	405	3786
11	370	3482
12	550	4193
13	650	4751
14	525	4370
15	475	4141
16	425	3715
17	1350	6935
18	530	3946
19	340	3129
20	450	3822
21	465	3567
22	545	4760
23	520	4830
24	480	4158
25	490	4140
26	485	4141
27	370	3574
28	415	3928
29	440	4105
30	540	4087
Overall Standard Deviation, psi	184	710
Overall Coefficient of Variation, percent	39.1	17.6

Table B6

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 1.5, Period No. 3

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	565	4406
2	520	4105
3	710	5114
4	620	4954
5	650	4477
6	510	4211
7	395	3468
8	470	4034
9	480	4034
10	425	3663
11	520	4707
12	580	4609
13	810	5255
14	685	5060
15	650	5184
16	609	4459
17	598	3716
18	556	4016
19	672	4556
20	941	5414
21	711	4990
22	797	5131
23	573	4485
24	1529	5184
25	623	3999
26	609	4070
27	573	3945
28	580	4175
29	506	4052
30	517	4264
Overall Standard Deviation, psi	205	534
Overall Coefficient of Variation, percent	32.3	12.0

Table B7

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 1.5, Period No. 4

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	757	5308
2	715	4299
3	664	4865
4	931	5467
5	733	5052
6	694	4901
7	683	5363
8	1048	6022
9	606	4264
10	616	3946
11	528	4158
12	584	4600
13	542	4476
14	740	5095
15	566	4414
16	676	4706
17	584	4520
18	524	4450
19	514	3840
20	511	4494
21	570	4848
22	542	4547
23	407	4070
24	535	4618
25	510	4565
26	446	4123
27	513	3999
28	563	4105
29	669	5167
30	521	4512
31	531	5255
32	566	4441
33	418	4269
34	591	5096
35	538	4671
36	570	5432
37	552	4477
38	552	5414
39	357	3963
40	407	3220
41	485	4560

(Continued)

Table B7 (Concluded)

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
42	386	3936
43	407	4892
44	499	4485
45	486	5361
46	474	4219
47	507	4857
48	340	3874
49	429	3857
50	358	3946
Overall Standard Deviation, psi	136	550
Overall Coefficient of Variation, percent	24.3	12.0

Table B8

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 3, Period No. 1

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	410	3280
2	320	2985
3	350	3390
4	345	3395
5	380	3365
6	415	3445
7	390	3365
8	370	3675
9	415	3835
10	570	4465
11	355	3685
12	400	3835
13	380	3720
14	470	3585
15	350	3450
16	420	4895
17	535	5495
18	425	4805
19	485	4560
20	400	4025
21	385	4010
22	360	3765
23	435	4450
24	445	4555
25	355	3855
26	395	4135
27	380	4115
28	470	4490
29	540	4435
30	430	3635
Overall Standard Deviation, psi	61	574
Overall Coefficient of Variation, percent	14.8	14.5

Table B9

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 3, Period No. 2

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	370	3870
2	380	3855
3	500	4750
4	485	3800
5	350	4155
6	430	3100
7	335	3565
8	430	4505
9	355	4080
10	350	3905
11	350	3870
12	350	3835
13	355	3710
14	425	4130
15	360	3655
16	405	4240
17	425	4450
18	420	4490
19	400	4330
20	390	4115
21	460	4415
22	300	3585
23	350	3885
24	395	3770
25	380	3890
26	325	3575
27	360	3750
28	315	3585
29	385	4095
30	315	3540
Overall Standard Deviation, psi	49	362
Overall Coefficient of Variation, percent	12.8	9.1

Table B10

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 3, Period No. 3

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	330	3375
2	380	3115
3	395	3890
4	435	4010
5	665	4845
6	370	3535
7	325	3285
8	335	3190
9	370	3710
10	410	3940
11	365	3870
12	330	3455
13	435	4860
14	505	4860
15	355	3195
16	420	4010
17	430	3835
18	590	4365
19	510	4490
20	570	5035
21	400	4485
22	420	4080
23	400	3835
24	445	4330
25	370	4240
26	450	4820
27	510	4630
28	430	4505
29	400	4345
30	450	4595
Overall Standard Deviation, psi	80	565
Overall Coefficient of Variation, percent	18.7	13.8

Table B11

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 3, Period No. 4

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	540	5125
2	420	4595
3	590	4610
4	560	5215
5	475	4630
6	480	4750
7	375	5210
8	385	3905
9	350	3545
10	420	4485
11	415	3905
12	420	3815
13	365	3835
14	390	3850
15	420	4645
16	365	4100
17	410	4185
18	340	3570
19	300	3165
20	350	3500
21	385	3550
22	440	3875
23	470	4193
24	405	3413
25	415	4034
26	370	3379
27	385	3910
28	345	3560
29	410	3822
30	350	3500
Overall Standard Deviation, psi	66	569
Overall Coefficient of Variation, percent	16.0	14.0

Table B12

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 3, Period No. 5

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	460	4185
2	390	4123
3	400	4379
4	330	3291
5	400	4017
6	305	3238
7	310	3380
8	470	4158
9	345	3291
10	400	3928
11	360	3325
12	380	3698
13	325	3318
14	410	3701
15	325	3185
16	425	3778
17	540	4379
18	455	3742
19	495	4388
20	430	3990
21	570	4476
22	540	4671
23	390	3442
24	450	3822
25	1225	6617
26	355	3521
27	675	4707
28	420	3592
29	505	4370
30	720	5167
Overall Standard Deviation, psi	176	710
Overall Coefficient of Variation, percent	38.2	17.8

Table B13

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 3 F 3, Period No. 6

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	390	3645
2	355	3114
3	385	3500
4	545	4415
5	540	4866
6	365	3539
7	310	3539
8	360	3340
9	415	3839
10	435	4353
11	300	3415
12	905	5503
13	420	3503
14	1340	5396
15	818	5485
16	422	3104
17	481	4352
18	513	4176
19	623	4742
20	481	4830
21	516	4742
22	566	4406
23	422	4353
24	358	4565
25	382	4123
26	425	5149
27	446	4662
28	359	4998
29	453	4193
30	396	4025
31	389	3482
32	503	4804
33	329	3698
34	354	3972
Overall Standard Deviation, psi	131	663
Overall Coefficient of Variation, percent	28.9	15.8

Table B14

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. [illegible]

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	610	[illegible]
2	730	[illegible]
3	810	5865
4	1020	[illegible]
5	685	5070
6	700	[illegible]
7	735	[illegible]
8	820	[illegible]
9	655	[illegible]
10	660	[illegible]
11	510	[illegible]
12	755	[illegible]
13	900	[illegible]
14	925	[illegible]
15	705	[illegible]
16	890	[illegible]
17	1125	[illegible]
18	1030	[illegible]
19	700	[illegible]
20	450	[illegible]
21	905	[illegible]
22	770	[illegible]
23	1080	[illegible]
24	855	[illegible]
25	1065	[illegible]
26	895	[illegible]
27	990	[illegible]
28	1090	[illegible]
29	960	[illegible]
30	845	[illegible]
Overall Standard Deviation, psi	172	[illegible]
Overall Coefficient of Variation, percent	20.7	[illegible]

Table B15

Red River Waterway Lock and Dam No. 1

Compressive Strength Test Results

Mixture No. 4 F 1.5, Period No. 2

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
1	870	5090
2	880	5315
3	900	5335
4	845	5120
5	770	4954
6	935	6317
7	900	5627
8	675	4423
9	770	4936
10	465	4017
11	700	5140
12	670	4627
13	680	5237
14	555	4335
15	640	5432
16	745	5644
17	720	5476
18	605	5061
19	595	4689
20	695	4813
21	710	4778
22	735	5166
23	835	5715
24	1005	5591
25	765	5007
26	630	4450
27	880	5202
28	835	6016
29	1035	6263
30	635	4689
31	535	5043
32	935	6246
33	855	5166
34	930	5627
35	810	5237
36	715	4972
37	845	5450
38	710	4583
39	940	6122
40	705	5149
41	765	5131

(Continued)

Table B15 (Concluded)

Sequence No.	Accelerated Strength, psi	90-Day Strength, psi
42	880	5609
43	590	5167
44	710	5503
45	915	5750
46	685	4724
47	815	5096
Overall Standard Deviation, psi	130	514
Overall Coefficient of Variation, percent	17.0	9.9

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