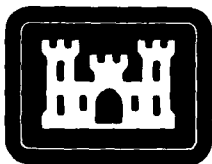


MICROCOPY RESOLUTION TEST CHART
NBS 1963-A

M. P. SL-82-5

DETERMINATION OF PROPERTIES OF CONCRETE USED IN THERMAL STUDIES FOR

AD A 117285



2

MISCELLANEOUS PAPER SL-82-5

DETERMINATION OF PROPERTIES OF CONCRETE USED IN THERMAL STUDIES FOR LOCK AND DAM NO. 2, RED RIVER WATERWAY

by

Terence C. Holland, Tony C. Liu, Anthony A. Bombich

Structures Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

June 1982
Final Report

Approved For Public Release; Distribution Unlimited

DTIC
ELECTE
S JUL 21 1982 D
A



DTIC FILE

Prepared for U. S. Army Engineer District, St. Louis
St. Louis, Mo. 63101
and U. S. Army Engineer District, New Orleans
New Orleans, La. 70160

82 07 21 040

**Destroy this report when no longer needed. Do not return
it to the originator.**

**The findings in this report are not to be construed as an official
Department of the Army position unless so designated
by other authorized documents.**

**The contents of this report are not to be used for
advertising, publication, or promotional purposes.
Citation of trade names does not constitute an
official endorsement or approval of the use of
such commercial products.**

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper SL-82-5	2. GOVT ACCESSION NO. AD-A117285	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DETERMINATION OF PROPERTIES OF CONCRETE USED IN THERMAL STUDIES FOR LOCK AND DAM NO. 2, RED RIVER WATERWAY	5. TYPE OF REPORT & PERIOD COVERED Final Report	
	6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s) Terence C. Holland Tony C. Liu Anthony A. Bombich	8. CONTRACT OR GRANT NUMBER(s)	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Structures Laboratory P. O. Box 631, Vicksburg, Miss. 39180	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS	
11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, St. Louis St. Louis, Mo. 63101 and U. S. Army Engineer District, New Orleans New Orleans, La. 70160	12. REPORT DATE June 1982	
	13. NUMBER OF PAGES 62	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report) Unclassified	
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES Available from National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22151. This is CTIAC Report No. 55.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Concrete properties Red River Waterway Strain capacity (concrete) Thermal properties (concrete)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Two concrete mixtures, one containing and one not containing fly ash, were tested to determine pertinent physical properties for use in a finite element method (FEM) analysis of concrete thermal conditions during the construction of Lock and Dam No. 2 on the Red River Waterway. The overall objective of this testing and analysis was to develop construction procedures aimed at eliminating thermally induced concrete cracking during construction of the structure. (Continued)		

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued).

cent → The concrete mixtures tested were selected to be representative of those which will be used in the project. Aggregates and cements were from suppliers who could be expected to participate in the actual construction. The testing program included determination of ultimate strain capacity, compressive strength, splitting tensile strength, modulus of elasticity, Poisson's ratio, thermal diffusivity, specific heat, adiabatic temperature rise, and coefficient of linear thermal expansion.

The strain capacity data presented are somewhat unique in that the two concrete mixtures evaluated more closely resembled structural concretes than typical mass concretes.

A limited investigation of the effect of the size of the concrete specimens on their strain capacity was also conducted. Strain capacities were seen to decrease with specimen size for specimens in the range from 18 by 18 by 96 in. to 6 by 6 by 36 in. This decrease may have been the result of one or more of the following: (a) differences in instrumentation used to measure strains; (b) differences in setting and curing temperatures as well as thermally induced strains for the larger beams; and (c) a greater probability of flaws in the larger cross sections of the larger beams.

This report presents and summarizes all data obtained during physical testing of the two concrete mixtures. The FEM thermal analysis will be reported separately.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

The investigation described in this report was conducted for the U. S. Army Engineer District, St. Louis, and the U. S. Army Engineer District, New Orleans, by the Concrete Technology Division (CTD) of the Structures Laboratory (SL), U. S. Army Engineer Waterways Experiment Station (WES). Authorization for the investigation was given in DA Forms 2544 dated 2 May 1979 and 15 February 1980.

The investigation was performed under the general supervision of Mr. Bryant Mather, Chief, SL, and Mr. John Scanlon, Chief, CTD; and under the direct supervision of Dr. Tony C. Liu, who served as principal investigator. MAJ Terence C. Holland monitored production of strain capacity specimens and reduced all strain capacity data. Mr. Anthony A. Bombich performed the thermal properties analyses. Mr. Frank Stewart and Mr. Frank Dorsey prepared the concrete mixtures and the strain capacity specimens, respectively. This report was prepared by MAJ Holland.

Funds for the publication of this report were provided from those made available for operation of the Concrete Technology Information Analysis Center (CTIAC). This is CTIAC Report No. 55.

The Commanders and Directors of the WES during this investigation and the preparation and publication of this report were COL Nelson P. Conover, CE, and COL Tilford C. Creel, CE. Technical Director was Mr. Fred R. Brown.



A

CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, INCH-POUND TO METRIC (SI)	
UNITS OF MEASUREMENT.	3
PART I: INTRODUCTION	4
Background.	4
Purpose and Scope	4
PART II: TESTING PROGRAM AND DATA OBTAINED	6
Materials	6
Concrete Mixtures	7
Ultimate Strain Capacity Tests.	7
Elastic Properties.	11
Thermal Properties.	11
PART III: DISCUSSION	14
FIGURES 1-9	
TABLES 1-21	
APPENDIX A: PETROGRAPHIC REPORT	
APPENDIX B: COMPUTER PROGRAM LISTING	

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

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

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
Btu (International Table) per pound (mass) × degree Fahrenheit	4186.8	joules per kilo- gram Kelvin
Btu (International Table) × foot per hour × square foot × degree Fahrenheit	1.730735	watts per metre Kelvin
calories (International Table) per gram	4186.80	joules per kilo- gram
cubic feet	0.02831685	cubic metres
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
inches	25.4	millimetres
miles (U. S. statute)	1.609347	kilometres
pounds (force)	4.448222	newtons
pounds (force) per square inch	6894.757	pascals
pounds (force) per square inch per minute	114.91262	pascals per second
pounds (force) per square inch per week	0.114001	pascals per second
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds (mass) per cubic yard	0.59328	kilograms per cubic metre
square feet per hour	0.0000258064	square metres per second

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

DETERMINATION OF CONCRETE PROPERTIES USED IN THERMAL STUDIES
FOR LOCK AND DAM NO. 2, RED RIVER WATERWAY

PART I: INTRODUCTION

Background

1. Control of thermally induced cracking is an important aspect of mass concrete construction. Unless adequate temperature control measures are implemented, cracks that may have serious consequences during the service life of the structure may develop during construction. However, the cost of temperature control measures may be quite high; therefore, it is unwise to require more control than is actually necessary.

2. To determine the degree of temperature control necessary requires a knowledge of the properties of the concrete to be used as well as a prediction of the temperatures and stresses which may be expected to develop during construction. Both temperature changes created internally (heat of hydration) and externally (weather variations) must be considered. Once temperature predictions have been developed, the strain induced in the concrete may be calculated. Then, the induced strain may be compared to the strain capacity of the concrete to determine if and where cracking may be expected. Based on the outcome of these comparisons, appropriate measures for controlling concrete placement temperature, heat generation, or rate of heat loss may be developed and recommended. Additionally, critical stages during the construction process may be identified and appropriate measures recommended.

Purpose and Scope

3. The purpose of this study was to determine the pertinent properties of two concretes similar to those anticipated to be used during construction of Lock and Dam 2 on the Red River Waterway. Concrete properties investigated were ultimate strain capacity, compressive strength,

splitting tensile strength, modulus of elasticity, Poisson's ratio, thermal diffusivity, specific heat, adiabatic temperature rise, and coefficient of linear thermal expansion. The data developed during this study will be used in a finite element method (FEM) analysis of the thermal considerations associated with the construction of the structure. The FEM study will be reported separately.

4. The determination of strain capacity and elastic properties was conducted in two rounds of testing. With the exception of a slight increase in the number of strain capacity specimens in the second round, the scope of testing was identical for both rounds.

PART II: TESTING PROGRAM AND DATA OBTAINED

Materials

5. The coarse and fine aggregates used (NO-57 G-3 and NO-57 S-3, respectively) were natural materials from a source in the vicinity of the project. Data on the aggregates are presented in Table 1, and a petrographic report is in Appendix A.

6. Because of the presence of chalcedonic chert in the sand and possible presence in the gravel (see petrographic report), Type II low alkali cements were selected for this investigation. The cements selected also met the optional heat of hydration requirement (limit of 70 cal/g* at 7 days) of CRD-C 201-79 (ASTM C 150-78a),** "Standard Specification for Portland Cement." Cements from different manufacturers were used for the two rounds of the investigation. Detailed chemical and physical properties may be found as follows:

Round 1	Cement RC-586	Table 2
Round 2	Cement RC-847	Table 3

7. The pozzolanic material used was a laboratory stock fly ash (AD-590) which is from a source in Georgia. Data on the fly ash are presented in Table 4. This material complied with the applicable portions of CRD-C 255-79 (ASTM C 618-78), "Standard Specification for Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Portland Cement Concrete," for a Class F mineral admixture.

8. The air-entraining agent used was a laboratory stock neutralized vinsol resin (AEA-965).

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

** All references to CRD-C test methods are from U. S. Army Engineer Waterways Experiment Station, CE, 1949, Handbook for Concrete and Cement (with quarterly supplements), Vicksburg, Miss.

Concrete Mixtures

9. Two concrete mixtures were used during these tests. Mixture A (without pozzolan) was proportioned for a nominal average compressive strength of 3000 psi at 28 days. Mixture B (with a 25 percent by volume pozzolanic replacement) was proportioned for a nominal average compressive strength of 3000 psi at 90 days. Both mixtures contained 5 ± 1 percent entrained air and both had slumps in the range of $2\text{-}1/2 \pm 1/2$ in. With the exception of the change in cements noted above, concrete for the two rounds of tests was similar in composition and proportions. Proportions for the two mixtures are given in Tables 5 and 6. These mixtures were somewhat atypical for mass concrete construction due to their high cementitious material contents and their use of 1-1/2-in. maximum sized aggregates. The mixtures were selected on the basis that the contractor ultimately awarded the project could be expected to use the locally available aggregates.

Ultimate Strain Capacity Tests

Test method and schedule

10. Ultimate strain capacity tests were performed in accordance with CRD-C 71-80, "Standard Test Method for Ultimate Strain Capacity of Concrete." Briefly, the procedure was as follows: Concrete specimens for the tests were 12 by 12 by 66 in. and were cast in steel forms. At an average age of 3 days, the specimens were removed from the forms, wrapped in a waterproof material to retain moisture, and tested or stored pending testing as appropriate. Internal strain meters (Carlson meters) were used for both the rapid and slow loading specimens. One meter was embedded in the compression zone of the specimen and one was embedded in the tension zone. Readings for all tests were taken manually using an automatic digital readout device. Rapid loading was accomplished using a 50,000-lb (force) electrohydraulic loading system. The rate of loading was set to cause a 40-psi/min increase in extreme fiber stress. For the rapid loading tests, strain readings were taken at 500-lb (force)

increments. Slow loading was accomplished using hydraulic rams in conjunction with pressure gages. Rams and gages were calibrated in a testing machine to develop a loading equation for each ram. This equation was then used to determine necessary gage pressure to develop the required loads for the desired slow loading rate of 25 psi/week increase in extreme fiber stress. After initial loading, hydraulic pressures were checked daily to maintain the proper loads. For the slow load specimens strain readings were taken on a daily basis.

11. The overall test program is shown in Table 7. Limited testing (rapid only) was accomplished using specimens 1 and 90 days old while complete testing (rapid, slow, and companion rapid) was accomplished using specimens 3, 7, and 28 days old. The test program was identical during both rounds except that an additional 28-day slow load and companion rapid load beam were added for both mixtures during the second round. This was done to compensate for questionable data obtained from the 28-day slow load beams during the first round of testing.

12. Specimens were identified during the testing program (and in the tables which are described below) as follows:

- a. Round 1: Mixture, beam number (as per Table 7).
Example: Beam A3: Round 1, Mixture A, 3-day slow load specimen.
- b. Round 2: 2, Mixture, beam number (as per Table 7).
Example: Beam 2B6: Round 2, Mixture B, 7-day slow load specimen. A letter following the beam number indicates a duplicate specimen. Example: Beams 2A9A and 2A9B were duplicates tested under the same conditions.

Data reduction and test results

13. Test data were reduced using a locally prepared computer program (Appendix B). Strains measured at the strain meters were extrapolated to the surface fibers of the specimens. Extrapolation was normally accomplished using the tensile and compressive strains as measured at the meters without requiring the neutral axis to lie at the middepth of the beam. The depth of the neutral axis was calculated as a check. If the calculated neutral axis was not close (± 1 in.) to the middepth of the beam or if one of the meters malfunctioned, the neutral axis was assumed to be at middepth and strains were extrapolated on that basis.

Once the extreme fiber strain was determined, a linear regression analysis was performed to relate extreme fiber strain to applied stress.

14. The modulus of rupture was determined for each specimen in accordance with CRD-C 16-79 (ASTM C 78-75), "Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)." The equation produced by the linear regression analysis was used to determine the extreme fiber strain at 90 percent of the modulus of rupture. This strain is reported as the ultimate strain capacity.

15. Data from the ultimate strain capacity tests are presented in Tables 8-14 as follows (comments concerning the data are given in the following subparagraphs):

- a. Table 8. Detailed Data, Mixture A, Round 1. The tension strain meter on beam A9 (28-day slow load) malfunctioned. The compressive strain capacity for that beam appears to be very low indicating a possible malfunction.
- b. Table 9. Detailed Data, Mixture A, Round 2. Duplicate 28-day slow load and companion rapid load beams were included in this round to compensate for the malfunction which occurred in Round 1. The compression strain meters in all of the slow load specimens in this round malfunctioned; therefore, tensile strain capacity for slow load specimens was extrapolated from meter readings using a fixed neutral axis. The break in beam 2All occurred outside the middle third of the beam, necessitating a reduction in the calculated modulus of rupture.
- c. Table 10. Detailed Data, Mixture B, Round 1. The tensile strain capacity for beam B9 (28-day slow load) appears to be quite low, and there is a large difference between the compressive and tensile strain capacities.
- d. Table 11. Detailed Data, Mixture B, Round 2. Same notes as Table 9.
- e. Table 12. Summarized Data, Mixture A, Rapid Load Tests. There appears to be good agreement between the two rounds of testing.
- f. Table 13. Summarized Data, Mixture B, Rapid Load Tests. There also appears to be good agreement between the two rounds for Mixture B.
- g. Table 14. Summarized Data, Mixtures A and B, Slow Load Tests. Agreement between the two rounds of tests appears to be acceptable. Because of the malfunctions on the compression meters for both Mixtures A and B during Round 2, strain capacities for Round 1 were calculated

using a fixed neutral axis to allow for accurate comparison. Note, however, that there is very little difference between the results obtained using the two extrapolation methods, provided that the tension and compression meters are both functioning properly.

16. The data presented in Tables 12, 13, and 14 were also plotted and are shown in Figures 1, 2, and 3, respectively.

Size effects investigation

17. A limited investigation of the effect of the size of beam tested on the ultimate strain capacity was also conducted. Beams smaller (6 by 6 by 36 in.) than those normally tested (12 by 12 by 56 in.) and beams larger (18 by 18 by 96 in.) than normal were tested under rapid loading conditions. These tests were conducted during both rounds of the test program. Concrete Mixture A was used for all size effects testing.

18. For the small beams (6 by 6 by 36 in.) strains were obtained using strain gages bonded to the concrete surface. For the large beams (18 by 18 by 96 in.) internal strain meters were used, and data reduction was accomplished in the same manner as described above for the normal sized beams. Figure 4 shows one of the large beams before and after loading.

19. Data from the tests of the small and large beams are presented in Table 15. These data show a good general consistency from Round 1 to Round 2. Average values for the small and large beams are compared to average values of normal sized beams (made with the same concrete mixture) in Table 16. The average values for ultimate tensile strain capacity for the three sizes of beams are plotted in Figure 5.

20. With the exception of the 28-day value for the small beams, the size effects data appear to be consistent. The ultimate tensile strain capacity for the small beams at 28 days was low for both rounds of tests. For the first round, the data are believed to be acceptable. For the second round, the low value is believed to be due to problems which were encountered bonding the surface gages to the concrete specimens on the day of testing the 28-day specimens.

Elastic Properties

Compressive and splitting tensile strength

21. Compressive strength testing and splitting tensile strength testing were conducted whenever a rapid load beam was tested or whenever a slow load beam was initially loaded. Compressive strength testing was done in accordance with CRD-C 14-73 (ASTM C 39-80), "Standard Method of Test for Compressive Strength of Cylindrical Concrete Cylinders." Splitting tensile strength testing was done in accordance with CRD-C 77-72 (ASTM C 496-71), "Standard Method of Test for Splitting Tensile Strength of Cylindrical Concrete Specimens."

22. Data for the compressive strength and splitting tensile strength tests are presented in Tables 17 and 18 for mixtures A and B, respectively. Compressive strength and splitting tensile strength data for the two mixtures have been plotted in Figures 6 and 7. The data for both compressive strength and splitting tensile strength show good agreement for the two rounds of testing with the values for the second round being consistently slightly lower than the first round. The difference does not appear to be significant.

Modulus of elasticity and Poisson's Ratio

23. The modulus of elasticity and Poisson's ratio were obtained from cylinders tested for compressive strength at 1, 3, 7, 28, and 90 days. Testing was in accordance with CRD-C 19-75 (ASTM C 469-65), "Standard Method of Test for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression."

24. Modulus of elasticity and Poisson's ratio data for both mixtures are presented in Table 19 and are shown in Figure 8. There appears to be satisfactory agreement between the two rounds of tests.

Thermal Properties

25. The various thermal properties listed in paragraph 3 were determined for Mixture B during this study. (The cement used during

the thermal studies was that used in the second round of ultimate strain capacity tests.) The same thermal properties had been determined earlier for Mixture A during a study in conjunction with the construction of Lock and Dam No. 1 on the Red River Waterway* and were not repeated. Data from that study are presented in this report to allow comparisons with Mixture B. A summary of all thermal properties is presented in Table 20.

26. Thermal diffusivity for Mixture B was determined in accordance with CRD-C 36-73, "Method of Test for Thermal Diffusivity of Concrete." Two 6- by 12-in. cylinders, each containing a copper-constantan thermocouple at the centroid, were used for the tests. The average thermal diffusivity of the concrete at 28 days was $0.045 \text{ ft}^2/\text{hr}$. The value determined previously for Mixture A was $0.042 \text{ ft}^2/\text{hr}$.

27. Specific heat for Mixture B was determined in accordance with CRD-C 124-73, "Method of Test for Specific Heat of Aggregates, Concrete, and Other Materials (Method of Mixtures)." Concrete from the cylinders tested for thermal diffusivity was used for the specific heat tests. The specific heat of Mixture B was determined to be $0.22 \text{ Btu/lb} \times ^\circ\text{F}$. The same value was determined earlier for Mixture A.

28. Thermal conductivity for Mixture B was calculated in accordance with CRD-C 44-63, "Method for Calculation of Thermal Conductivity of Concrete," using experimentally derived values for thermal diffusivity, specific heat, and unit weight. The thermal conductivity of Mixture B was $1.38 \text{ Btu} \times \text{ft}/\text{hr} \times \text{ft}^2 \times ^\circ\text{F}$. The value determined earlier for Mixture A was $1.32 \text{ Btu} \times \text{ft}/\text{hr} \times \text{ft}^2 \times ^\circ\text{F}$.

29. An adiabatic temperature rise test was conducted for mixture B in accordance with CRD-C 38-73, "Method of Test for Temperature Rise in Concrete." The concrete sample used was a 30- by 30-in. cylinder containing five resistance thermometers. The adiabatic temperature rise for Mixture B at 28 days was 64.66°F . The value determined earlier

* U. S. Army Engineer District, New Orleans, CE. 1977. "Red River Waterway; Design Memorandum No. 8, Lock and Dam No. 1, Sources of Construction Materials," New Orleans, Louisiana.

for Mixture A was 70.07°F. Temperature rise versus age data for both mixtures are in Table 21 and are plotted in Figure 9.

30. The coefficient of linear thermal expansion for Mixture B was not determined directly. Based on earlier studies,^{*} it appears that the inclusion of fly ash, in the proportions used for Mixture B, does not significantly affect linear thermal expansion. Therefore, the value of linear thermal expansion determined earlier for Mixture A, 7.0 millionths/°F, was judged to be also the appropriate value for Mixture B.

* J. E. McDonald. 1973. "Ultimate Strain Capacity Tests, Clarence Cannon Dam, St. Louis District," Miscellaneous Paper C-73-5, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.
J. E. McDonald, A. A. Bombich, and B. R. Sullivan. 1972. "Ultimate Strain Capacity and Temperature Rise Studies, Trumbull Pond Dam," Miscellaneous Paper C-72-20, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

PART III: DISCUSSION

31. The data obtained for elastic and thermal properties of the two concrete mixtures appear to be consistent and suitable for use in further analysis. The use of two different cements during the two rounds of the study should help to insure that values representative of the actual construction conditions were obtained.

32. A lack of test data for similar concretes makes comparison of strain capacity data obtained during the present study with data obtained during earlier work essentially impossible. However, the general performance of the two mixtures evaluated appears to be consistent with that of a wide variety of concrete mixtures evaluated during other investigations. The strain capacity data appear to be suitable for use in cracking predictions.

33. Mixture A showed tensile strain capacities during slow loading which were 1.80, 1.97, and 2.43 times those obtained during rapid loading for tests conducted at 3, 7, and 28 days, respectively. The continued increase in slow loading strain capacity at 28 days is somewhat unusual when compared to earlier tests. Beams tested under rapid loading conditions on the days when failure occurred for companion slow loaded beams showed tensile strain capacities which were 1.11, 1.06, and 1.13 times those seen in initial rapid load tests at 3, 7, and 28 days, respectively.

34. Mixture B showed tensile strain capacities during slow loading which were 2.34, 2.42, and 1.76 times those obtained during rapid loading for tests conducted at 3, 7, and 28 days, respectively. The decrease in slow loading strain capacity at 28 days is consistent with data reported for other projects. Beams tested under rapid loading conditions on the days when failure occurred for companion slow loaded beams showed tensile strain capacities which were 1.38, 1.36, and 1.10 times those seen in initial rapid load tests at 3, 7, and 28 days, respectively.

35. The two mixtures may be compared as follows:

- a. Under rapid loading conditions, Mixture A showed greater tensile strain capacities at 3 and 7 days than did Mixture B. For 28 days and beyond rapid loading, there was little difference in tensile strain capacity between the two mixtures.
- b. Under slow loading conditions, there was little difference in tensile strain capacity between the mixtures for the tests initiated at 3 and 7 days, although Mixture B showed a much greater ratio of slow to rapid loading tensile strain capacity. For slow load testing initiated at 28 days, Mixture A showed a significantly greater tensile strain capacity than Mixture B.
- c. The companion beams tested in rapid loading after a slow loaded beam failed showed very little differences between the two mixtures.

35. Based upon the limited size effect investigation carried out during the present study, measured rapid load tensile strain capacity appears to be affected by the size of the beam tested. Using the data presented in Table 16, the values below may be obtained (based upon the data in the last three rows of Table 16 in which the strains attributable to the dead loads of the various sized beams have been added to the measured strain capacities):

Beam Size, in.	Percent of 6- by 6- by 36-in. Tensile Strain Capacity			
	3 days	7 days	28 days	90 days
6 by 6 by 36	100	100	100	100
12 by 12 by 66	101	85	83	85
18 by 18 by 96	89	72	80	81

These values do show a difference in indicated strain capacity based upon beam size. The differences noted may have been caused by one or more of the following items:

- a. Some of the difference may have been due to instrumentation rather than concrete properties since the small beams (6 by 6 in.) were instrumented with surface bonded strain gages while the other two sizes of beams used internal strain meters.
- b. The larger beams would have generated a greater amount of heat due to hydration and would have lost that heat more slowly. The temperature under which concrete sets and

cures may influence its strain capacity. Additionally, particularly for the tests at earlier ages, thermal strains may have been present in the larger specimens which reduced measured strain capacities.

- c. There was a greater probability of flaws being present in the larger beams due to their larger cross sectional areas.

Regardless of the cause, the differences in strain capacity noted raise the question of which is the appropriate size specimen to use to determine tensile strain capacities for concretes to be used in massive structures. Additional work is needed in this area.

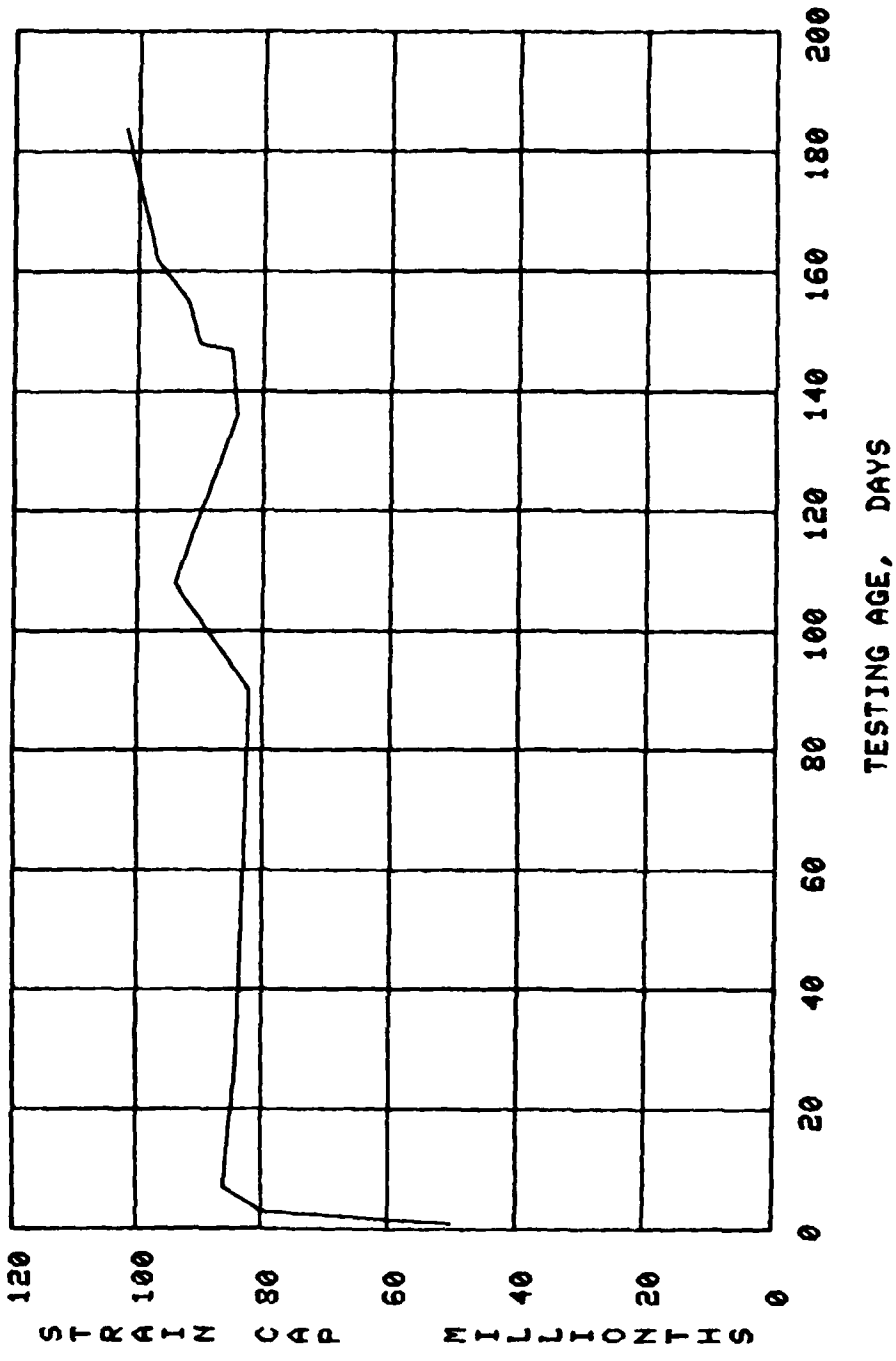


Figure 1. Tensile strain capacity, rapid loading, Mixture A

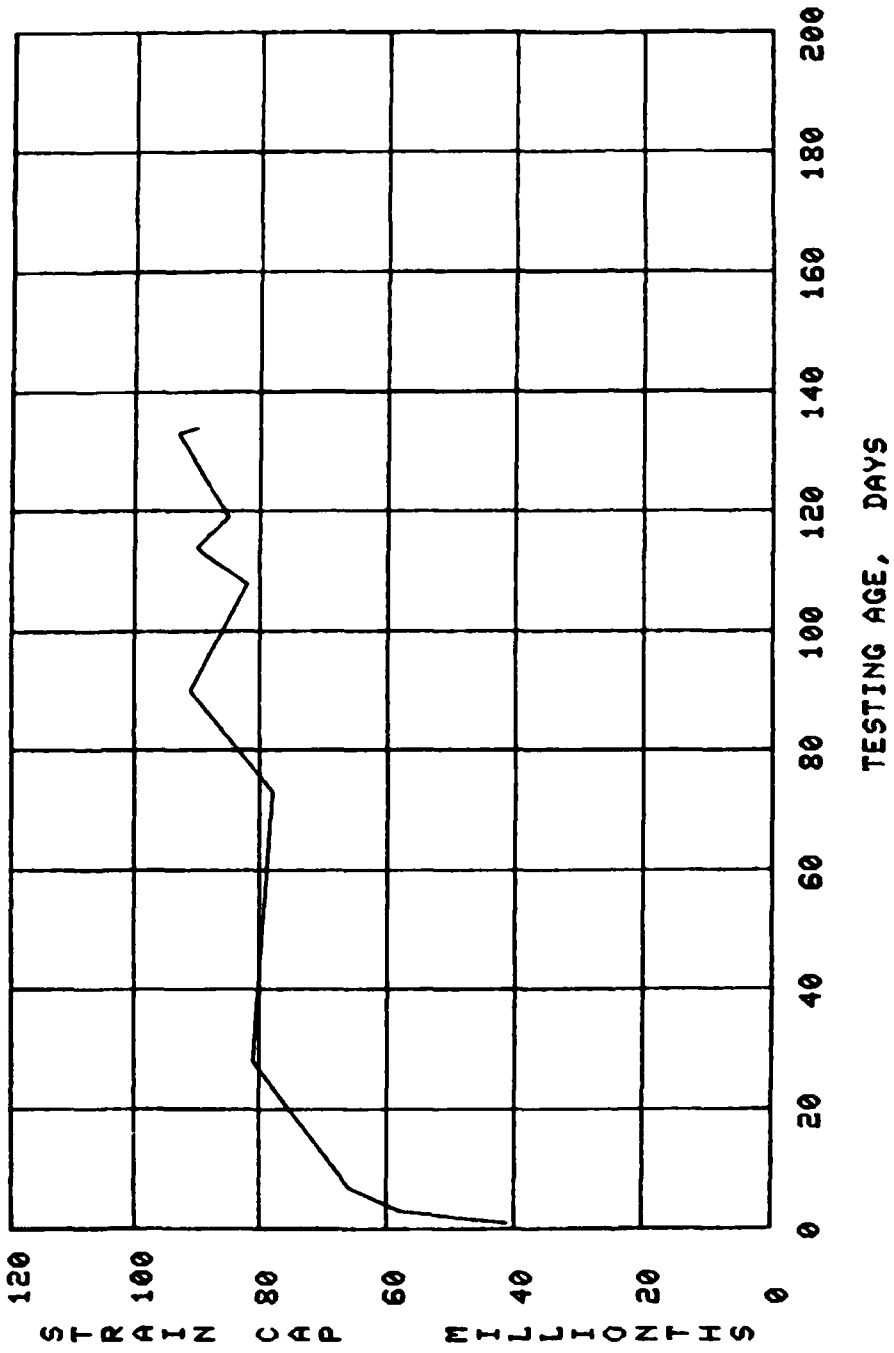


Figure 2. Tensile strain capacity, rapid loading, Mixture B

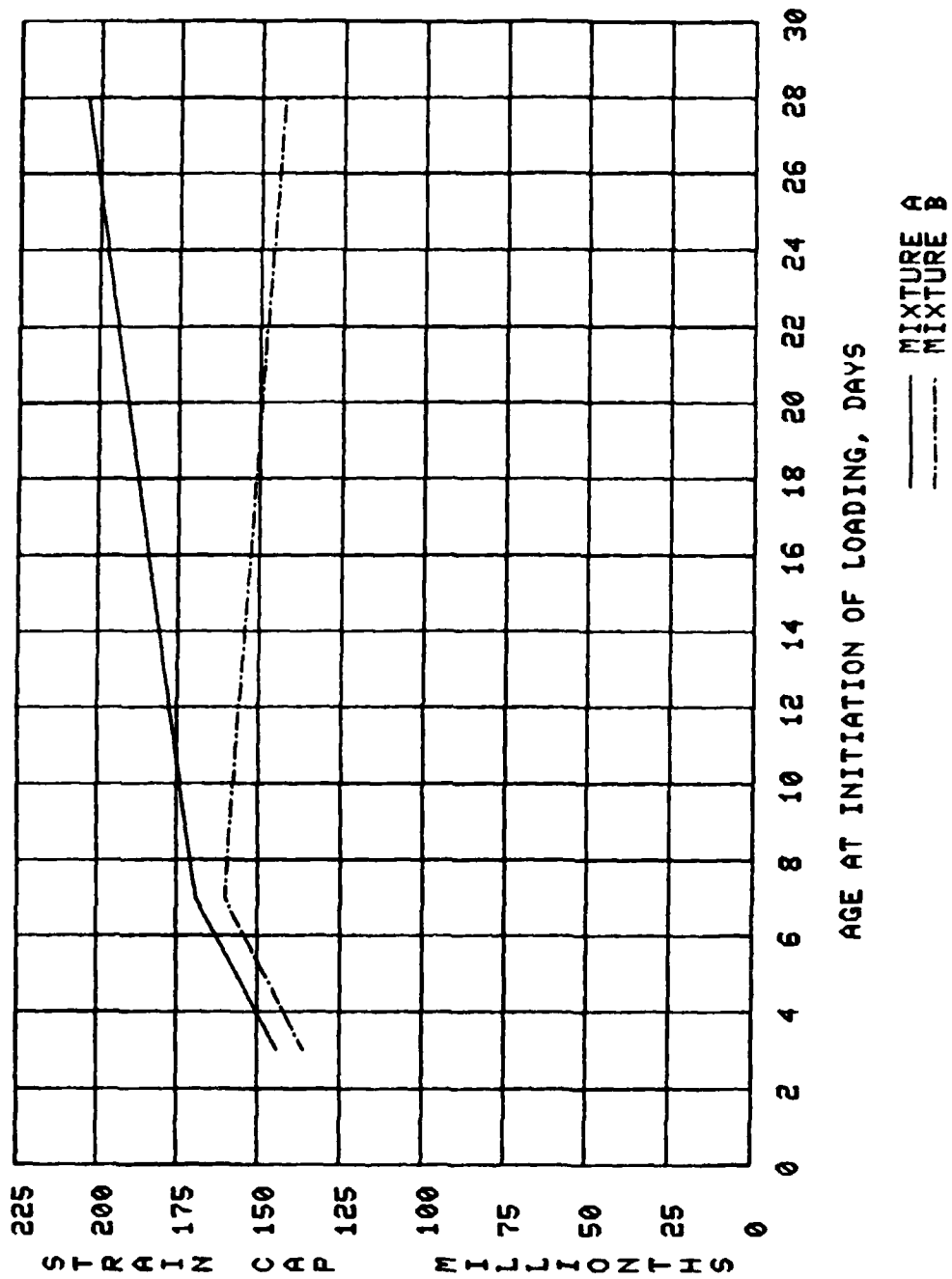
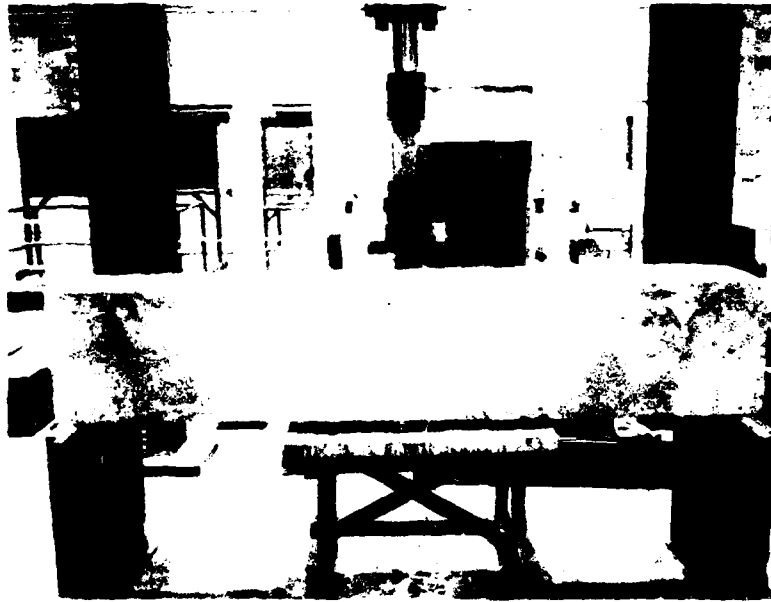


Figure 3. Tensile strain capacity, slow loading, Mixtures A and B



a. Prior to testing



b. After testing

Figure 4. Testing of 18- by 18- by 96-in. beam for ultimate strain capacity

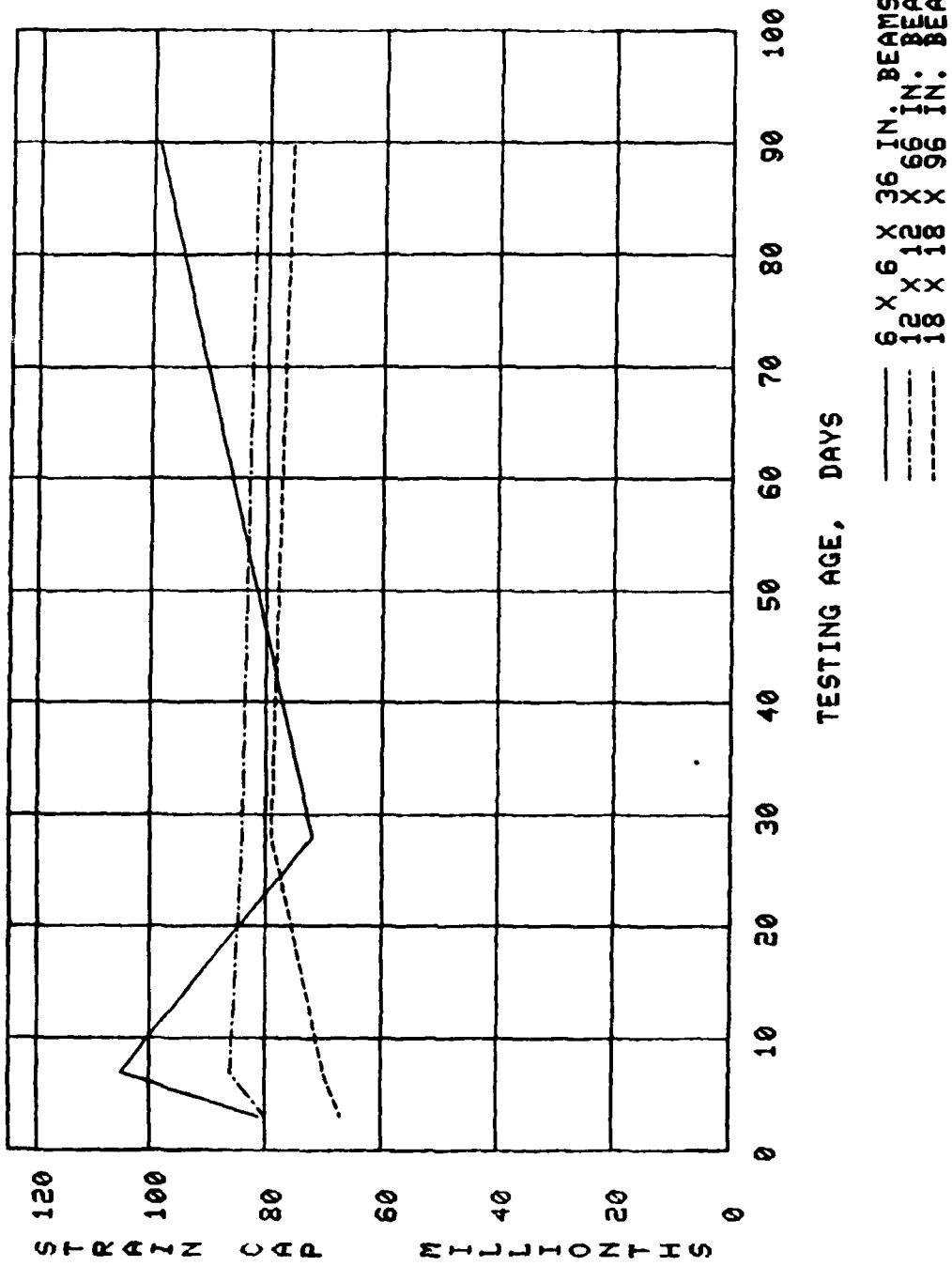


Figure 5. Tensile strain capacity, rapid loading, various sized beams, Mixture A. (Not adjusted for dead load strains)

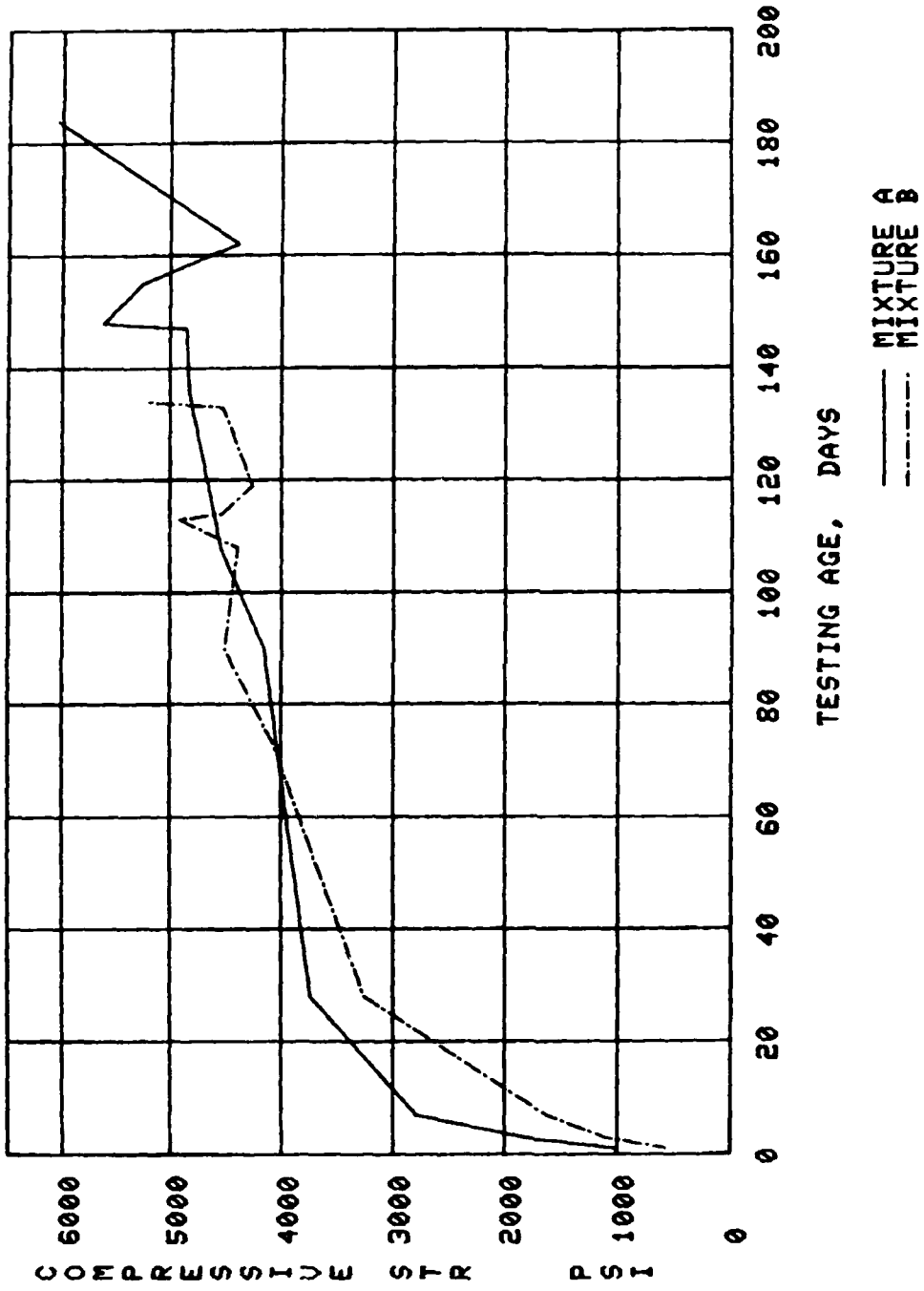


Figure 6. Compressive strength, Mixtures A and B

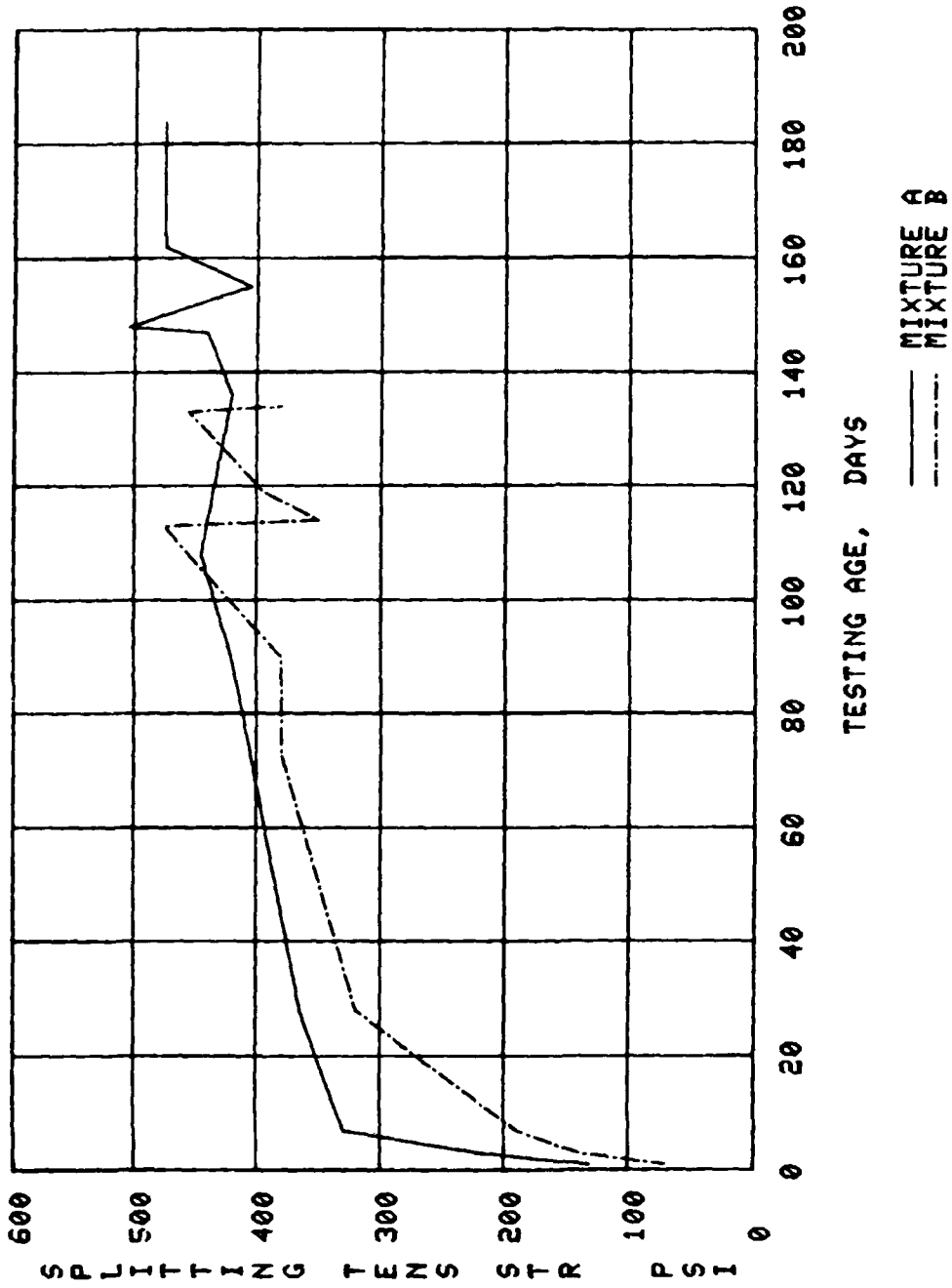


Figure 7. Splitting tensile strength, Mixtures A and B

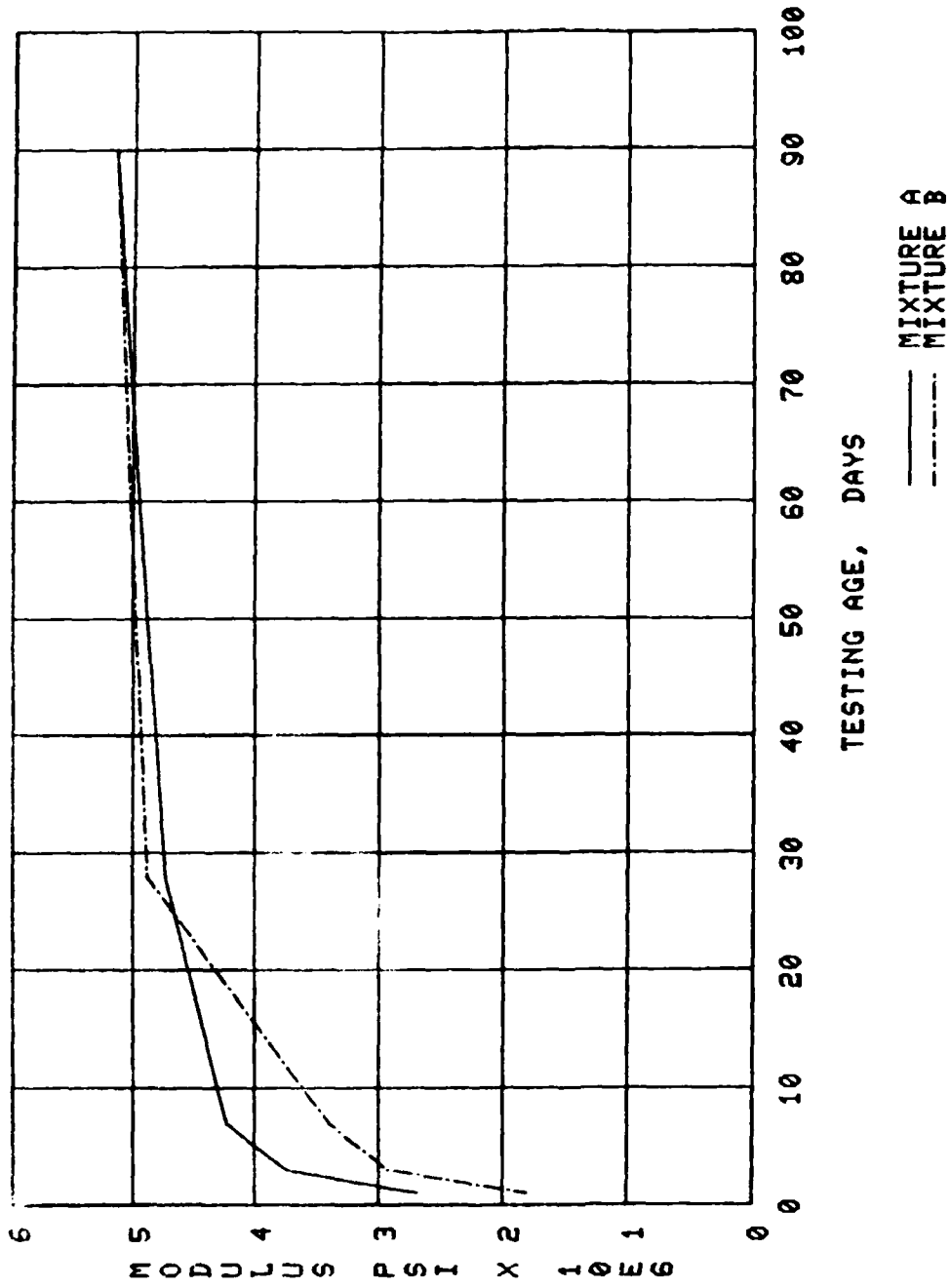


Figure 8. Modulus of elasticity, Mixtures A and B

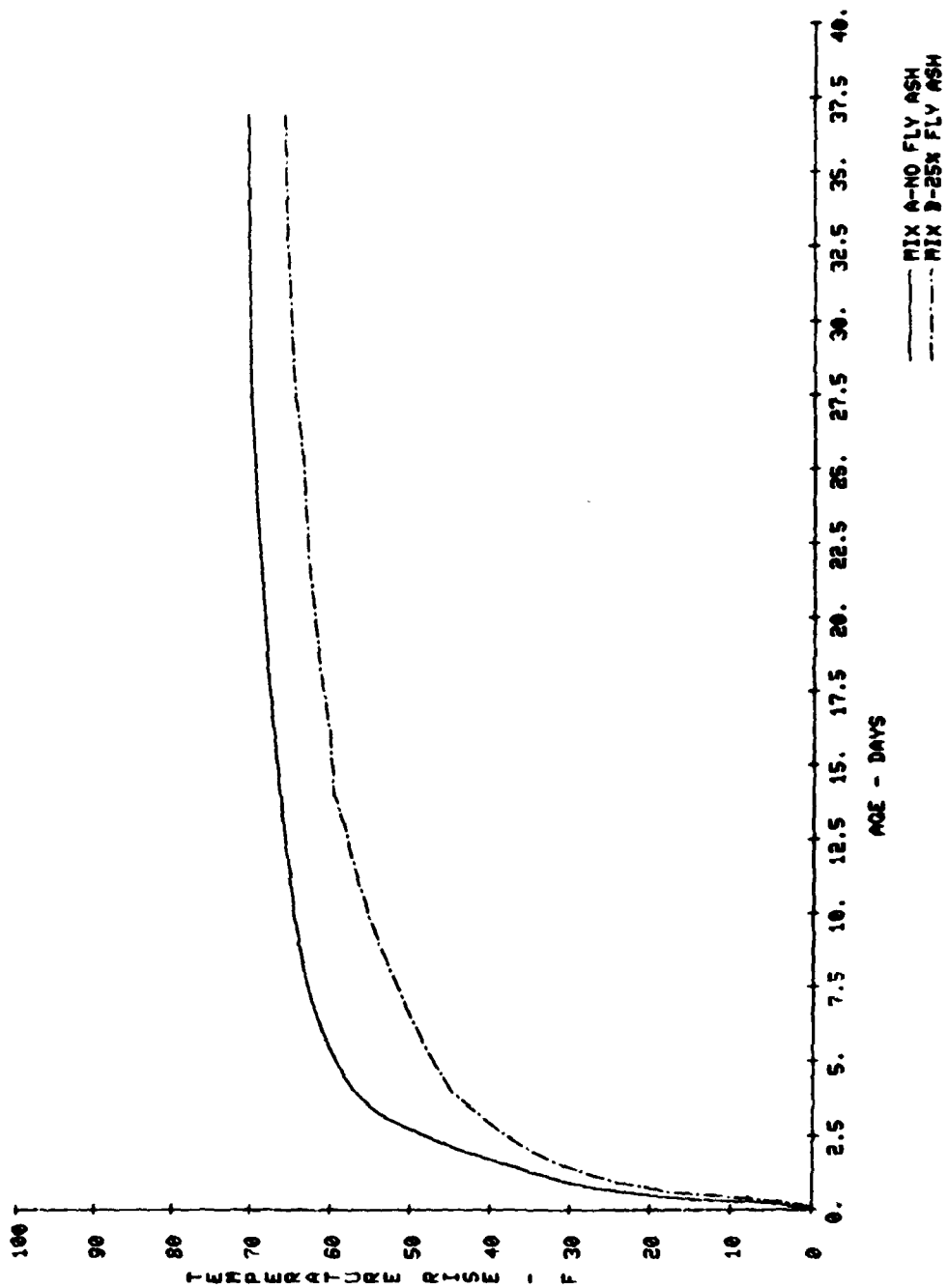


Figure 9. Adiabatic temperature rise, Mixtures A and B

Table 1
Aggregate Data

STATE	LA	INDEX NO	17	AGGREGATE DATA SHEET	TESTED BY	USAEWES			
LAT	31	LONG	92		DATE	7-20-79			
LAB SYMBOL NO	NO-57 G-3(2) S-3(2)			TYPE OF MATERIAL	Natural				
LOCATION	On NE side of Salem Creek, approx. 1.7 miles east of LA 459 and 8.2 miles NE of Jena, LA								
PRODUCER	Amyx Sand and Gravel, Jena, LA								
SAMPLED BY	B. Houston, J. Tom, D. Howell, D. Heffner								
TESTED FOR	Red River L & D No. 2								
USED AT									
PROCESSING BEFORE TESTING									
GEOLOGICAL FORMATION AND AGE	Pleistocene Terrace (Willizna) deposit								
GRADING (CRD-C 103) (CUM % PASSING)				TEST RESULTS					
SIEVE	3/4"	1 1/2"	2 1/2"	#4	FINE AGG.				
6 IN					BULK SP GR S.S.D. (CRD-C 107, 108)	3/6" 1 1/2" 2 1/2" #4" FINE AGG			
5 IN					ABSORPTION, % (CRD-C 107, 108)	2.54 2.54 2.61			
4 IN					ORGANIC IMPURITIES, FIG NO (CRD-C 121)	1.07 1.52 0.68			
3 IN					SOFT PARTICLES, % (CRD-C 130)				
2 1/2 IN					% LIGHTER THAN SP GR (CRD-C 122)				
2 IN					% FLAT AND ELONGATED (CRD-C 118, 120)				
1 1/2 IN					WT AV % LOSS, 5 CYC H ₂ SO ₄ (CRD-C 115)				
1 IN		100.0			L.A. ABRASION LOSS, % (CRD-C 117, 125) GRADING				
3/4 IN		74.0			UNIT WT, LB CU FT (CRD-C 106)				
1/2 IN		40.7	100.0		FRIABLE PARTICLES, % (CRD-C 142)				
1/4 IN		8.7	72.8		SPEC HEAT, BTU LB/DEG F (CRD-C 124)				
NO. 4		4.5	31.6		REACTIVITY WITH NSOM (CRD-C 128)	SC, BM L RE, BM L			
NO. 8		1.2	2.0	96.7					
NO. 16				90.1					
NO. 30				80.2	MORTAR-MAKING PROPERTIES (CRD-C 116)				
NO. 50				43.7	TYPE CEMENT, RATIO DAYS				
NO. 100				7.3	LINEAR THERMAL EXPANSION MILLIONTHS DEG F (CRD-C 125, 126)				
NO. 200				0.9	ROCK TYPE	PARALLEL ACROSS ON AVERAGE			
+200 #1									
F.N.#1				2.81					
10) CRD-C 105	10) CRD-C 104	MORTAR							
MORTAR-BAR EXPANSION AT 100F, % (CRD-C 123)		FINE AGGREGATE			COARSE AGGREGATE				
		2 MO	6 MO	9 MO	12 MO	3 MO	6 MO	9 MO	12 MO
LOW-ALK CEMENT * N ₂ O EQUIVALENT									
HIGH-ALK CEMENT * N ₂ O EQUIVALENT									
SOUNDNESS IN CONCRETE (CRD-C 40, 114)					FSY	HWCO	HD-CR		
FINE AGG.		COARSE AGG			DFE 100				
FINE AGG.		COARSE AGG			DFE 100				
PETROGRAPHIC DATA (CRD-C 127)									
REMARKS									

Table 2
Cement Properties, Round 1

TO J. E. McDonald Structures Laboratory Structures Branch Vicksburg, MS		REPORT OF TESTS OF PORTLAND CEMENT RC-586		FROM CORPS OF ENGINEERS ARMY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180	
TEST REPORT NO.	WES-216-79	DATE	23 May 79		
SPECIFICATION	SS-C-1960/3, Type II, LA, HH	DATE SAMPLED	14 May 79		
COMPANY	Alpha Portland	LOCATION	Birmingham, AL		
THIS CEMENT DOES <input checked="" type="checkbox"/> MEET SPECIFICATION REQUIREMENTS					
SAMPLE NO	1				
SO ₂ %	22.5				
Al ₂ O ₃ %	4.3				
Fe ₂ O ₃ %	3.5				
MgO %	2.9				
SiO ₂ %	2.0				
LOSS ON IGNITION, %	1.2				
ALKALIES-TOTAL AS Na ₂ O %	0.45				
Na ₂ O %	0.06				
K ₂ O %	0.59				
INSOLUBLE RESIDUE, %	0.35				
CaO %	62.8				
C ₂ S %	45				
C ₃ A %	6				
C ₄ S %	30				
C ₂ A + C ₃ S %	51				
C ₄ AF %	11				
C ₄ AF + 2C ₃ A %	22				
HEAT OF HYDRATION 70, CAL/G	67				
HEAT OF HYDRATION 280, CAL/G					
SURFACE AREA, SQ CM/GIA.P.	3320				
AIR CONTENT, %	8.0				
COMP. STRENGTH, 3 D, PSI	1890				
COMP. STRENGTH, 7 D, PSI	2590				
COMP. STRENGTH, D, PSI					
FALSE SET-PEN. FI %					
SAMPLE NO	1				
AUTOCLAVE EXP., %	0.08				
INITIAL SET, HR:MIN	3:15				
FINAL SET, HR:MIN	5:20				
SAMPLE NO					
AUTOCLAVE EXP., %					
INITIAL SET, HR:MIN					
FINAL SET, HR:MIN					
REMARKS 441-S707.19SC41					
THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT					
W. G. MILLER Chemist Chief, Cement & Pozzolan Test Branch					

CMAP 44
WES 117

Table 3
Cement Properties, Round 2

TO Structures Laboratory Research Group ATTN: Tony Liu Vicksburg, MS 39180		REPORT OF TESTS OF PORTLAND CEMENT RC-847		FROM: CIVIL ENGINEERS STRUCTURES Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Group P. O. Box 631 Vicksburg, MS 39180	
TEST REPORT NO.	WES-609-79	BIN NO.	5	WT REPRESENTED	
SPECIFICATION	SS-C-1960/3, Type II, LA, HH	DATE SAMPLED	19 Dec 79	DATE	14 Jan 80
COMPANY	Citadel	LOCATION	Birmingham, AL	BRAND	
THIS CEMENT MEETS	X	NEXT SPECIFICATION REQUIREMENTS			
SAMPLE NO.	1				
SiO ₂ %	22.1				
Al ₂ O ₃ %	4.7				
Fe ₂ O ₃ %	4.2				
MgO %	4.3				
SO ₃ %	1.7				
LOSS ON IGNITION %	1.0				
ALKALIES - TOTAL AS Na ₂ O %	0.48				
N ₂ O %	0.14				
H ₂ O %	0.51				
INSOLUBLE RESIDUE %	0.23				
CaO %	61.5				
C ₂ S %	41				
C ₃ A %	5				
C ₂ S %	33				
C ₃ A + C ₄ A %	46				
C ₄ AF %	13				
C ₄ AF + 2C ₃ A %	23				
HEAT OF HYDRATION, 70, CAL/G	66				
HEAT OF HYDRATION 280, CAL/G					
SURFACE AREA, SQ CM/G (BET)	3790				
AIR CONTENT %	7.3				
COMP STRENGTH, 1 D, PSI	1080				
COMP STRENGTH, 3 D, PSI	1980				
COMP STRENGTH, 7 D, PSI	2720	COMP. STRENGTH 28 D, PSI	4970		
FALSE SET - PEN. FT					
SAMPLE NO.	1				
AUTOCLAVE EXP.	0.04				
INITIAL SET, HR:MIN	2:20				
FINAL SET, HR:MIN	4:45				
SAMPLE NO.					
AUTOCLAVE EXP.					
INITIAL SET, HR:MIN					
FINAL SET, HR:MIN					
REMARKS	Job #483-SC04.10SC21				
THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U.S. GOVERNMENT					
W. G. MILLER Chemist Chief, Cement & Pozzolan Group					

Table 4
Pozzolan Properties

LABORATORY Structures Laboratory USAE Waterways Exp St ATTN: Cem & Pozz Test Br P. O. Box 631 Vicksburg, MS 39180		REPORT OF TESTS ON POZZOLAN SS-C-1960/5 AD-590		REPORT NO. WES-319F-79 SHEET 1 of 1 DATE 16 July 79 6 August 79			
CLASS (P) N	KIND OF POZZOLAN Fly Ash		SOURCE Williams Bros., Atlanta, GA				
TEST RESULTS OF THIS SAMPLE LOT <input checked="" type="checkbox"/> COMPLY <input type="checkbox"/> DO NOT COMPLY WITH SPECIFICATION WITH SEE REMARKS							
FOR USE AT							
CONTRACT NO							
DISTRICT/ST							
SAMPLED BY Structures Branch				DATE SAMPLED 2 July 79			
FIELD SAMPLE NO		BIN NO		LAB SAMPLE NO			
DATE RECEIVED 2 July 79		LAB LOT NO		CHECKED BY			
TESTED BY Cem & Pozz Testing Branch							
TESTS ON COMPOSITE OF THE 100-YON SAMPLES LISTED BELOW							
SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃ %	MO %	SO ₃ %	AVAILABLE ALKALIES %	POZZOLAN STRENGTH % CONTROL	INCREASE IN SHRINKAGE (%)	A. TO. LALE EXPANSION (%)	REQUIREMENT EXPANSION (%)
REQUIREMENTS							
MIN 70.0	MAX 5.0	MAX 4.0	MAX 1.5	MIN 5	MAX 1.0	MAX 10	MIN 5
TEST RESULTS							
88	1.3	0.7	* 0.65	* 91		0.03	
TESTS ON SAMPLES REPRESENTING 100 TONS OR LESS							
SAMPLE NO	MOISTURE CONTENT %	LOSS ON IGNITION %	Fineness % pts		WATER REQUIREMENT % of Control	SPECIAL QUALITY	SP. OR VARIATION FROM AVERAGE OF PRE. B. TING
			325 Mesh var from Sieve % avg prev Retained 10	TEMP. CORRECTED COMP. STRENGTH (%)			
REQUIREMENTS							
	MAX 1.0	MAX 10.0 (IN) 6.0 (IP)	MAX 34	MAX 5	MIN 500	MAX 105	MAX 5
TEST RESULTS							
1	0.5	2.0	21		1120	97	2.43
AVERAGE							
(1) APPLICABLE ONLY TO CLASS N				LABORATORY CEMENT USED Alpha, Birmingham, AL, WES-216-79			
(2) OPTIONAL REQUIREMENT				LABORATORY LINE USED Chemstone			
REMARKS Meets 7 day specification requirements. *28 day test report							
441-S920.19SC42				W. G. MILLER Chemist Chief, Cement & Pozzolan Test Branch			
NOTE THE INFORMATION GIVEN IN THIS REPORT SHALL NOT BE USED IN ADVERTISING OR SALES PROMOTION TO INDICATE EITHER EXPLICITLY OR IMPLICITLY ENDORSEMENT OF THIS PRODUCT BY THE U. S. GOVERNMENT							

Table 5
Mixture Proportions, Mixture A

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS (CRD-C-3)											
PROJECT NAME			SYMBOL SERIAL NO		DATE						
CONCRETE REQUIRED FOR				MIXTURE NO A							
MATERIALS											
PORTLAND CEMENT, SS-C-192 TYPE II ADDITIONS BRAND AND MILL		POZZOLON OR OTHER CEMENT TYPE SOURCE		AIR ENT ADMIXTURE TYPE NVR AMOUNT AEA-965							
FINE AGGREGATE			COARSE AGGREGATE								
TYPE Natural			TYPE Natural								
SOURCE Amyx Sand & Gravel Co., Jena, LA			SIZE 1-1/2 SOURCE Amyx Sand & Gravel Co., Jena, LA								
MATERIALS	SAMPLE SERIAL NO	SIZE RANGE	COARSE AGGR %	BULK SP GR SSI	ABSORP %						
PORTLAND CEMENT *	RC-586/RC-847			3.15							
FINE AGGREGATE	NO-57 S-3(2)	No. 4 - 200		2.61	0.7						
COARSE AGGREGATE (A)	NO-57 G-3(2)	No. 4 - 3/4 in.	30	2.54	1.5						
COARSE AGGREGATE (B)	NO-57 G-3(2)	3/4 - 1-1/2 in.	70	2.54	1.1						
COARSE AGGREGATE (C)											
COARSE AGGREGATE (D)											
MIXTURE DATA				SPECIMEN DATA							
MATERIALS	MIX BY WEIGHT	S S D WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)	CYLINDERS			BEAMS				
				SIZE	NO	AGE	PSI	SIZE	NO	AGE	PSI
PORTLAND CEMENT	1.00	450.0	2.289								
FINE AGGREGATE	2.44	1093.9	6.717								
COARSE AGGREGATE (A)	1.38	619.9	3.911								
COARSE AGGREGATE (B)	3.21	1446.6	9.127								
COARSE AGGREGATE (C)											
COARSE AGGREGATE (D)											
WATER	0.50	225.0	3.606								
AIR (5%)			1.350								
TOTAL		3835.4	27.000								
W/C RATIO	0.50		S A S VOLUME	34							
SLUMP (IN.)	2-1/4		THEO UNIT WT (LB CU FT)	142.1							
BLEEDING (%)			ACTUAL UNIT WT (LB CU FT)	142.2							
AIR CONTENT (%)	4.5		THEO CEMENT FACT (LB CU YD)	450.0							
AIR CONTENT (%)			ACTUAL CEMENT FACT (LB CU YD)	450.0							
1 Calculated on the basis of 2 Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C-9 3 In the entire batch as mixed 4 In that portion of the concrete containing aggregate smaller than the 1-1/2-in. sieve * For "other cement," pozzolan, second size of fine aggregate, as may be required											
REMARKS: Condition of mix, workability, plasticity, bleeding, etc. * RC-586, Round 1 of tests RC-847, Round 2 of tests											

Table 6
Mixture Proportions, Mixture B

REPORT OF SELECTION OF CONCRETE MIXTURE PROPORTIONS <small>CRD-C-9</small>									
PROJECT NAME			SYMBOL SERIAL NO		DATE				
CONCRETE REQUIRED FOR					MIXTURE NO B				
MATERIALS									
PORTLAND CEMENT, SS-C-192 TYPE II ADDITIONS BRAND AND MILL			POZZOLON OR OTHER CEMENT TYPE Fly Ash SOURCE AD-590		AIR ENIT. CEMENTURE TYPE NVR AMOUNT AEA-965				
FINE AGGREGATE			COARSE AGGREGATE						
TYPE Natural SOURCE Amyx Sand & Gravel Co., Jena, LA			TYPE Natural SIZE 1-1/2 SOURCE Amyx Sand & Gravel Co., Jena, LA						
MATERIALS	SAMPLE SERIAL NO	SIZE RANGE	COARSE AGGR.	BULK SPGR SSC	ABSORP.				
PORTLAND CEMENT *	RC-586/RC-847			3.15					
Fly Ash	AD-590			2.43					
FINE AGGREGATE	NO-57 S-3(2)	No. 4 - 200		2.61	0.7				
COARSE AGGREGATE (A)	NO-57 G-3(2)	No. 4 - 3/4 in.	30	2.54	1.5				
COARSE AGGREGATE (B)	NO-57 G-3(2)	3/4 - 1-1/2 in.	70	2.54	1.1				
COARSE AGGREGATE (C)									
COARSE AGGREGATE (D)									
MIXTURE DATA				SPECIMEN DATA					
MATERIALS	MIX BY WEIGHT	SS D WEIGHTS ONE CU YD BATCH (LB)	SOLID VOL ONE CU YD (CU FT)	CYLINDERS			BEAMS		
				SIZE	AGE	PSI	SIZE	AGE	PSI
PORTLAND CEMENT	100	337.5	1.717						
Fly Ash		86.7	0.572						
FINE AGGREGATE		1093.9	6.717						
COARSE AGGREGATE (A)		619.9	3.911						
COARSE AGGREGATE (B)		1446.6	9.127						
COARSE AGGREGATE (C)									
COARSE AGGREGATE (D)									
WATER		225.0	3.606						
AIR (5%)			1.350						
TOTAL		3809.6	27.000						
W. C. WT. 0.53				S. A. S. VOLUME 34					
SLUMP (IN.) 2-1/2				THEO. UNIT WT. (LB. CU FT.) 141.1					
BLEEDING (%)				ACTUAL UNIT WT. (LB. CU FT.) 147.4					
AIR CONTENT (%) 4.3				THEO. CEMENT FACT. (LB. CU YD.)					
				ACTUAL CEMENT FACT. (LB. CU YD.) 424.2					
<small>1. Calculated on the basis of 2. Expressed as the percentage of mixing water separating from the concrete when tested by CRD-C-9 3. In the moist batch as mixed 4. In that portion of the concrete containing aggregate smaller than the 1/2 in. sieve * For "other cement" pozzolan, second size of fine aggregate, as may be required REFERENCE: Condition of mix, workability, practices, bleeding, etc.</small>									
*RC-586, Round 1 of tests RC-847, Round 2 of tests									

Table 7
Testing Program,
Ultimate Strain Capacity Tests

<u>Beam</u>	<u>Age, days</u>	<u>Test</u>
1	1	Rapid
2	3	Rapid
3	3 } *	Slow
4	*	Rapid
5	7	Rapid
6	7 } *	Slow
7	*	Rapid
8	28	Rapid
9	28 } *	Slow
10	*	Rapid
11	90	Rapid

* Beams so marked were tested in rapid loading on the day the companion beam failed in slow loading.

Table 8
Detailed Data, Ultimate Strain
Capacity Tests, Mixture A, Round 1

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths	
				Compressive	Tensile
A1	1	40 psi/min	159	51	46
A2	3	40 psi/min	281	78	82
A3	3-136	25 psi/week	450	115 (112)†	131 (134)†
A4	136	40 psi/min	427	84	84
A5	7	40 psi/min	377	83	83
A6	7-155	25 psi/week	495	132 (130)†	147 (150)†
A7	155	40 psi/min	458	80	92
A8	28	40 psi/min	393	82	88
A9	28-162	25 psi/week	450	56†	NA††
A10	162	40 psi/min	395	77	97
A11	90	40 psi/min	380	83	72

* Extrapolated outside fiber strain at 90 percent of ultimate load.

** Determined at 90 percent of ultimate load.

† Value determined with neutral axis fixed at center of beam.

†† No readings; meter malfunctioned.

Table 9
Detailed Data, Ultimate Strain
Capacity Tests, Mixture A, Round 2

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths	
				Compressive	Tensile
2A1	1	40 psi/min	145	50	53
2A2	3	40 psi/min	255	71	78
2A3	3-108	25 psi/week	360	--†	154††
2A4	108	40 psi/min	442	84	94
2A5	7	40 psi/min	352	82	89
2A6	7-148	25 psi/week	473	--†	188††
2A7	148	40 psi/min	473	92	90
2A8	28	40 psi/min	350	74	80
2A9A	28-184	25 psi/week	518	--†	224††
2A10A	184	40 psi/min	475	89	102
2A9B	28-147	25 psi/week	405	--†	183††
2A10B	147	40 psi/min	427	84	85
2A11	90	40 psi/min	332‡	83	91

- * Extrapolated outside fiber strain at 90 percent of ultimate load.
 ** Determined at 90 percent of ultimate load.
 † No readings; meter malfunctioned.
 †† Value determined with neutral axis fixed at center of beam.
 ‡ Reduced modulus based upon break outside middle third of beam.

Table 10
Detailed Data, Ultimate Strain
Capacity Tests, Mixture B, Round 1

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths	
				Compressive	Tensile
B1	1	40 psi/min	81	41	39
B2	3	40 psi/min	206	52	53
B3	3-108	25 psi/week	360	123 (122)†	129 (129)†
B4	108	40 psi/min	411	80	82
B5	7	40 psi/min	246	67	70
B6	7-113	25 psi/week	360	127 (125)†	139 (141)†
B7	113	40 psi/min	458	85	89
B8	28	40 psi/min	323	80	79
B9††	28-134	25 psi/min	360	89 (93)†	67 (64)†
B10	134	40 psi/min	406	81	90
B11	90	40 psi/min	359	83	91

* Extrapolated outside fiber strain at 90 percent of ultimate load.

** Determined at 90 percent of ultimate load.

† Value determined with neutral axis fixed at center of beam.

†† Tensile strain capacity appears to be low due to possible meter malfunction.

Table 11
Detailed Data, Ultimate Strain
Capacity Tests, Mixture B, Round 2

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths	
				Compressive	Tensile
2B1	1	40 psi/min	81	36	42
2B2	3	40 psi/min	175	61	63
2B3	3-73	25 psi/week	248	--†	143††
2B4	73	40 psi/min	347	75	78
2B5	7	40 psi/min	176	51	62
2B6	7-114	25 psi/week	360	--†	178††
2B7	114	40 psi/min	412	83	90
2B8	28	40 psi/min	317	70	82
2B9A	28-133	25 psi/week	338	--†	143††
2B10A	133	40 psi/min	392	79	93
2B9B	28-119	25 psi/week	315	--†	142††
2B10B	119	40 psi/min	395	82	85
2B11	90	40 psi/min	422	84	90

* Extrapolated outside fiber strain at 90 percent of ultimate load.
 ** Determined at 90 percent of ultimate load.
 † No readings; meter malfunctioned.
 †† Value determined with neutral axis fixed at center of beam.

Table 12
Summarized Data, Ultimate Strain Capacity Tests,
Rapid Loading, Mixture A, Rounds 1 and 2

<u>Age, Days</u>	<u>Beam</u>	<u>Stress Capacity,* psi</u>	<u>Average</u>	<u>Tensile Strain Capacity,** millionths</u>	<u>Average</u>
1	A1	159	152	46	50
	2A1	145		53	
3	A2	281	268	82	80
	2A2	255		78	
7	A5	377	365	83	86
	2A5	352		89	
28	A8	393	372	88	84
	2A8	350		80	
90	A11	380	356	72	82
	2A11	332†		91	
108	2A4	442	NA	94	NA
136	A4	427	NA	84	NA
147	2A10B	427	NA	85	NA
148	2A7	473	NA	90	NA
155	A7	458	NA	92	i A
162	A10	395	NA	97	NA
184	2A10A	475	NA	102	NA

* Determined at 90 percent of ultimate load.

** Extrapolated outside fiber strain at 90 percent of ultimate load.

† Reduced modulus based upon break outside middle third of beam.

Table 11
Detailed Data, Ultimate Strain
Capacity Tests, Mixture B, Round 2

Beam No.	Testing Age, days	Loading Rate	Stress Capacity,** psi	Strain Capacity,* millionths	
				Compressive	Tensile
2B1	1	40 psi/min	81	36	42
2B2	3	40 psi/min	175	61	63
2B3	3-73	25 psi/week	248	--†	143††
2B4	73	40 psi/min	347	75	78
2B5	7	40 psi/min	176	51	62
2B6	7-114	25 psi/week	360	--†	178††
2B7	114	40 psi/min	412	83	90
2B8	28	40 psi/min	317	70	82
2B9A	28-133	25 psi/week	338	--†	143††
2B10A	133	40 psi/min	392	79	93
2B9B	28-119	25 psi/week	315	--†	142††
2B10B	119	40 psi/min	395	82	85
2B11	90	40 psi/min	422	84	90

* Extrapolated outside fiber strain at 90 percent of ultimate load.
 ** Determined at 90 percent of ultimate load.
 † No readings; meter malfunctioned.
 †† Value determined with neutral axis fixed at center of beam.

Table 13
Summarized Data, Ultimate Strain Capacity Tests,
Rapid Loading, Mixture B, Rounds 1 and 2

Age, Days	Beam	Stress Capacity,*		Tensile Strain Capacity,**	
		psi	Average	millionths	Average
1	B1	81	81	39	41
	2B1	81		42	
3	B2	206	191	53	58
	2B2	175		63	
7	B5	246	211	70	66
	2B5	176		62	
28	B8	323	320	79	81
	2B8	317		82	
73	2B4	347	NA	78	NA
90	B11	359	391	91	91
	2B11	422		90	
108	B4	411	NA	82	NA
113	B7	458	NA	89	NA
114	2B7	412	NA	90	NA
119	2B10B	395	NA	85	NA
133	2B10A	392	NA	93	NA
134	B10	406	NA	90	NA

* Determined at 90 percent of ultimate load.

** Extrapolated outside fiber strain at 90 percent of ultimate load.

Table 14
Summarized Data, Ultimate Strain Capacity Tests,
Slow Loading, Mixtures A and B, Rounds 1 and 2

<u>Age, Days</u>	<u>Beam</u>	<u>Stress Capacity,* psi</u>	<u>Average</u>	<u>Tensile Strain Capacity,** millionths</u>	<u>Average</u>
<u>Mixture A</u>					
3-136	A3	450	405	131 (134)†	144
3-108	2A3	360		154†	
7-155	A6	495	484	147 (150)†	169
7-148	2A6	473		188†	
28-162	A9	450	458	NA	204
28-184	2A9A	518		244†	
28-147	2A9B	405		183†	
<u>Mixture B</u>					
3-108	B3	360	304	129 (129)†	136
3-73	2B3	248		143†	
7-113	B6	360	360	139 (141)†	160
7-114	2B6	360		178†	
28-134	B9	360	338	67 (64)†, ††	143
28-133	2B9A	338		143 †	
28-119	2B9B	315		142 †	

* Determined at 90 percent of ultimate load.
 ** Extrapolated outside fiber strain at 90 percent of ultimate load.
 † Value determined with neutral axis fixed at center of beam.
 †† Not included in average.

Table 15
Size Effects Data, Ultimate Strain
Capacity Tests, Mixture A, Rounds 1 and 2

Test- ing Age, days	Beam No.	Beam Size, in.	Compressive Strength, psi	Stress Capacity,** psi	Strain Capacity,* millionths	
					Compressive	Tensile
<u>Round 1</u>						
3	C3	6 × 6 × 36	1720	288	70	87
3	C4	18 × 18 × 96	2200	264	NA†	66††
7	C1	6 × 6 × 36	3010	400	80	100
7	C2	18 × 18 × 96	2850	307	68	65
28	C5	6 × 6 × 36	4020	356	84	74
28	C6	18 × 18 × 96	3570	419	82	84
<u>Round 2†</u>						
3	2C7	6 × 6 × 36	1800	297	68	75
3	2C8	18 × 18 × 96	1800	258	64	67
7	2C1	6 × 6 × 36	2650	377	NA†	109
7	2C2	18 × 18 × 96	2650	294	68	74
28	2C3	6 × 6 × 36	4250	372	105	70
28	2C4	18 × 18 × 96	4250	378	69	74
90	2C5	6 × 6 × 36	4200‡‡	379	85	99
90	2C6	18 × 18 × 96	4200‡‡	351	71	76

- * Outside fiber strain at 90 percent of ultimate load, extrapolated for 18- by 18- by 96-in. beams, measured for 6- by 6- by 36-in. beams.
- ** Determined at 90 percent of ultimate load.
- † No reading; meter or gage malfunctioned.
- †† Value determined with neutral axis fixed at center of beam.
- ‡ Values shown for 6- by 6- by 36-in. beams for Round 2 are averages of two specimens tested except for 2C1 for which data were obtained for only one specimen.
- ‡‡ Compressive strength of concrete in beams 2C5 and 2C6 was below average at 28 days.

Table 16

Size Effects Comparisons, Average Values for Beams of Sizes Indicated, Mixture A

Beam Size	Age at Testing											
	3 Days			7 Days			28 Days			90 Days		
	Com-pressive Strength, psi	Stress Capacity, ** psi	Tensile Strain Capacity, * mil-lionths	Com-pressive Strength, psi	Stress Capacity, ** psi	Tensile Strain Capacity, * mil-lionths	Com-pressive Strength, psi	Stress Capacity, ** psi	Tensile Strain Capacity, * mil-lionths	Com-pressive Strength, psi	Stress Capacity, ** psi	Tensile Strain Capacity, * mil-lionths
6 x 6 x 36 in.†	1760	293	81	2830	389	105	4140	364	72	4200	379	99
12 x 12 x 66 in.†	1820	268	80	2790	365	86	3740	372	84	4150	356	82
18 x 18 x 96 in.†	2000	261	67	2750	301	70	3910	399	79	4200	351	76
6 x 6 x 36 in.††			81			105			104			99
6 x 6 x 36 in.‡			84			107			106			101
12 x 12 x 66 in.‡			85			91			88			86
18 x 18 x 96 in.‡			75			77			85			82

* Outside fiber strain at 90 percent of ultimate load, extrapolated for 18- by 18- by 96-in. and 12- by 12- by 66-in. beams, measured for 6- by 6- by 36-in. beams.

** Determined at 90 percent of ultimate load.

† Strains as measured, no adjustments.

†† 28-day data point replaced by value which is a straight line interpolation between the 7-day and 90-day values.

‡ Adjusted strains in which strains due to dead loads of the beams have been added to measured strains to obtain total strain capacity.

Table 17
Compressive Strength and Splitting Tensile
Strength Data, Mixture A, Rounds 1 and 2

Age, Days	Beam	Compressive Strength,		Splitting Tensile Strength,	
		psi	Average	psi	Average
1	A1	1000	1000	135	130
	2A1	990		120	
3	A2	1970	1820	240	220
	A3	1920		225	
	2A2	1790		205	
	2A3	1580		200	
7	A5	2880	2790	350	330
	A6	3040		335	
	2A5	2550		320	
	2A6	2680		315	
28	A8	3970	3740	420	365
	A9	3610		420	
	2A8	3130		305	
	2A9A	3870		300	
	2A9B	4130		390	
90	A11	4450	4150	420	420
	2A11	3840		420	
108	2A4	4540	NA	445	NA
136	A4	4830	NA	420	NA
147	2A10B	4850	NA	440	NA
148	2A7	5620	NA	505	NA
155	A7	5260	NA	405	NA
162	A10	4380	NA	475	NA
184	2A10A	6040	NA	475	NA

Table 18
Compressive Strength and Splitting Tensile
Strength Data, Mixture B, Rounds 1 and 2

Age, Days	Beam	Compressive Strength, psi	Average	Splitting Tensile Strength, psi	Average
1	B1	600	570	80	70
	2B1	530		55	
3	B2	1220	1110	150	140
	B3	1180		155	
	2B2	1070		130	
	2B3	970		115	
7	B5	1830	1630	220	190
	B6	1910		225	
	2B5	1250		140	
	2B6	1520		180	
28	B8	3380	3260	345	320
	B9	3570		310	
	2B8	3400		315	
	2B9A	3070		335	
	2B9B	2880		295	
73	2B4	4070	NA	380	NA
90	B11	4520	4510	380	NA
	2B11	4500		NA	
108	B4	4390	NA	455	NA
113	B7	4920	NA	475	NA
114	2B7	4530	NA	350	NA
119	2B10B	4260	NA	395	NA
133	2B10A	4520	NA	455	NA
134	B10	5220	NA	380	NA

Table 19
Modulus of Elasticity and Poisson's
Ratio Data, Mixtures A and B, Rounds 1 and 2

<u>Age,</u> <u>days</u>	<u>Beam</u>	<u>Modulus of</u> <u>Elasticity</u> <u>psi x 10⁶</u>	<u>Average</u>	<u>Poisson's</u> <u>Ratio</u>	<u>Average</u>
<u>Mixture A</u>					
1	A1	2.90	2.68	0.14	0.18
	2A1	2.45		0.21	
3	A2	4.10	3.75	0.13	0.13
	2A2	3.40		0.12	
7	A5	4.60	4.23	0.17	0.19
	2A5	3.85		0.20	
28	A8	5.00	4.73	0.18	0.16
	2A8	4.45		0.14	
90	A11	5.50	5.15	0.17	0.14
	2A11	4.80		0.10	
<u>Mixture B</u>					
1	B1	2.20	1.80	0.15	0.14
	2B1	1.40		0.13	
3	B2	3.40	2.93	0.12	0.12
	2B2	2.45		0.11	
7	B5	4.05	3.40	0.14	0.13
	2B5	2.75		0.11	
28	B8	5.20	4.88	0.13	0.15
	2B8	4.55		0.17	
90	B11	5.40	5.15	0.12	0.14
	2B11	4.90		0.16	

Table 20
Summary of Thermal
Properties, Mixtures A and B

<u>Property</u>	<u>Mixture A</u>	<u>Mixture B</u>
Thermal Diffusivity, ft ² /hr	0.042	0.045
Specific Heat, Btu/lb-°F	0.22	0.22
Thermal Conductivity, Btu-ft/hr-ft ² -°F	1.32	1.38
Adiabatic Temperature Rise (28 days), °F	70.07	64.66
Coefficient of Linear Expansion, millionths/°F	7.0×10^{-6}	7.0×10^{-6}

Table 21
Adiabatic Temperature Rise Test
Data, Mixtures A and B

MIXTURE A		MIXTURE B	
AGE (DAYS)	TEMP. RISE (DEG F)	AGE (DAYS)	TEMP. RISE (DEG F)
0.	0.	0.	0.
0.04	0.56	0.08	0.48
0.15	2.81	0.13	0.83
0.25	5.76	0.17	1.23
0.35	14.25	0.21	2.00
0.46	18.97	0.35	6.50
0.60	23.25	0.45	10.87
0.70	26.00	0.50	13.45
0.80	28.20	0.60	17.80
0.90	29.98	0.70	19.40
1.00	31.37	0.80	21.50
1.20	33.80	0.92	24.12
1.50	37.70	1.14	26.86
1.80	41.20	1.40	30.00
2.04	44.00	1.70	32.80
2.30	46.40	1.93	34.54
2.50	48.30	2.30	36.90
2.80	50.80	2.70	39.15
3.08	52.93	3.00	40.50
3.25	53.90	3.50	42.70
3.50	55.10	4.00	44.95
3.75	56.18	4.50	46.00
4.04	57.11	4.92	46.99
4.50	58.26	5.50	48.22
5.00	59.30	5.92	48.99
5.50	60.20	6.50	50.00
6.00	61.00	6.96	50.76
6.50	61.65	7.96	52.36
7.04	62.33	8.96	53.86
8.04	63.22	10.00	55.25
9.00	63.89	11.00	56.40
10.20	64.58	12.02	57.46
11.04	64.94	13.04	58.32
13.00	65.80	14.00	59.56
15.00	66.61	16.00	60.06
17.00	67.33	18.00	61.15
18.00	67.68	20.00	62.00
21.04	68.46	22.00	62.75
24.08	69.25	25.00	63.37
28.00	70.07	28.00	64.66
35.00	70.50	33.00	65.60
37.00	70.55	37.00	66.00

APPENDIX A: PETROGRAPHIC REPORT

Corps of Engineers, USAE Waterways Experiment Station	Petrographic Report	Concrete Laboratory P. O. Box 631 Vicksburg, Mississippi						
Project Tests of Aggregate for New Orleans District		Date 15 April 1977 ADB						
<u>Samples</u>								
<p>1. Pit run samples of gravel and sand were received on 28 December 1976 from the US Army Engineer District, New Orleans, for testing. The material is identified below:</p> <table border="0"> <thead> <tr> <th style="text-align: center;"><u>Concrete Laboratory Serial No.</u></th> <th style="text-align: center;"><u>Field Data, New Orleans Identification</u></th> </tr> </thead> <tbody> <tr> <td style="text-align: center;">NO-57 G-3</td> <td style="text-align: center;">No. 1-3192-17A; sample No.</td> </tr> <tr> <td style="text-align: center;">NO-57 S-3</td> <td style="text-align: center;">LAS-1-1, from Amyx Gravel Co., Jena, La.</td> </tr> </tbody> </table>			<u>Concrete Laboratory Serial No.</u>	<u>Field Data, New Orleans Identification</u>	NO-57 G-3	No. 1-3192-17A; sample No.	NO-57 S-3	LAS-1-1, from Amyx Gravel Co., Jena, La.
<u>Concrete Laboratory Serial No.</u>	<u>Field Data, New Orleans Identification</u>							
NO-57 G-3	No. 1-3192-17A; sample No.							
NO-57 S-3	LAS-1-1, from Amyx Gravel Co., Jena, La.							
<p>2. Since the total amount of gravel was insufficient for all tests, some physical tests were made on the same material that was used for the petrographic examination.</p>								
<p>3. Each sample was from a source that had been tested before. The District identification number served to identify that source in the appropriate volume of Technical Memorandum No. 6-370.¹ There were no previous petrographic data for these materials.</p>								
<p>4. The as-received grading of this sample did not conform to a Guide Specification grading, hence the composition was calculated by sieve sizes only. The total composition may be calculated once a satisfactory grading is established, or by using an assumed grading.</p>								
<u>Test procedure</u>								
<p>5. <u>Gravel</u>. A representative portion of each sieve size that made up 5 percent or more of the total sample was separated into lithologic types, using a stereoscopic microscope as needed. Particles were examined while dry and usually again while wet; occasional particles were broken and examined as powder immersion mounts with a polarizing microscope to assist in classification. The largest material was always examined regardless of the amount in the sieve fraction, as it is easier to establish the lithologic types using large material.</p>								
<p>6. <u>Sand</u>. Representative portions of the sizes larger than 600 μm (No. 30 sieve) were immersed in water, and classified while using a stereoscopic microscope to examine the particles. Representative portions of the sizes smaller than 600 μm that amounted to 5 percent or more of the total sample were examined as powder immersion mounts with a polarizing microscope.</p>								
<p>1. "Test Data - Concrete Aggregates in Continental United States," with periodic supplements, US Army Engineer Waterways Experiment Station, Vicksburg, Miss., Sep 1953.</p>								

7. All powder immersion mounts, whether of gravel or sand, were made using an oil of 1.544 refractive index, which permitted determination of chalcedonic chert by searching for chert particles with indices below 1.544, the upper index of chalcedonic chert.

8. Since the sizes smaller than 150 μm (No. 100 sieve) usually amounted to less than 5 percent of the total sand sample, their composition was usually assumed to be the same as the next larger size or was estimated by examination of a powder immersion mount.

Results

9. Gravel (NO-57 G-3). The sample was a brown chert gravel consisting largely of tabular to blocky particles with rounded edges. More of the particles were pyramidal or irregular in shape as size decreased.

a. Dense chert. The chert was dense, structureless rock.

b. Fractured chert. Similar to the dense chert except that the particles contain fractures; it is assumed that normal handling and or mixing procedures would cause these particles to separate along the fractures. Such separation can be significant if there is a substantial amount of fractured chert because the development of new surface area could affect the workability and water demand of concrete mixtures.

c. Vuggy chert. Similar to the dense chert, but with the particles characterized by surface reentrants so that the total surface area is greater than it would be for a particle of similar size without reentrants.

d. Porous chert. The porous chert particles are frequently pale colored grading to white and are more ellipsoidal in shape than the other varieties of chert. Such aggregate particles may be expected to form unsightly popouts on concrete surfaces when they are embedded close enough to a concrete surface and are frozen in a saturated condition. Some particles are porous throughout, while other particles contain some areas of porous rock. The areas of porous rock occur as scattered patches, as particle rims, or as particle interiors.

e. Quartz. The quartz particles tend to be light colored. The shape is tabular with rounded edges in the larger sizes and becomes ellipsoidal with decreasing particle size. Quartz increases with decreasing particle size (Table 1).

f. Miscellaneous. This category is composed of tan to red fine-grained sandstone and or quartzite particles, igneous rock particles, and pink to white feldspar particles. The sandy and the igneous rock particles are usually tabular or ellipsoidal in shape while the feldspars are blocky with sharp edges. The feldspar is usually found in the smaller particle sizes. Some of each of these types is weathered rock.

10. Sand (NO-57 S-3). The sand is dark yellowish orange (10 YR 6/6).² Its composition by size fractions is shown in Table 2. It is a typical natural sand with quartz increasing and chert decreasing as the particle size decreases. A description of the sand constituents follows:

a. Quartz. The particles are mostly light colored and translucent in the largest size. As size decreases the particles become predominantly clear transparent quartz. The shape is blocky with rounded edges or ellipsoidal.

b. Chert. These are usually dense chert particles with blocky shapes and rounded edges. Some of the chert is chalcedonic.

c. Feldspar. This material was separated from the miscellaneous category since it amounts to from 6 to 14 percent of the different sizes (Table 2). It is like the feldspar particles in the gravel. Most of the particles are orthoclase but some microcline and plagioclase particles were seen.

d. Miscellaneous. This material amounts to 10 percent of the 150- μ m (No. 100) size and less than 5 percent of the other sizes (Table 2). It is a mixture of sandstone, quartzite, igneous rocks, various heavy minerals, and opaque rock particles.

Discussion

11. Chalcedonic chert is present in the sand and is assumed to be present in the gravel since both samples are from the same source. Thus, the possibility of deleterious alkali-silica reaction exists if either or both of these materials is used as concrete aggregate, and appropriate control measures should be specified. The control measures possible include use of low-alkali cement or the addition to a medium-alkali cement of an adequate amount of a suitable pozzolan. If this second course is chosen, tests of the aggregate, job cement, and job pozzolan should be made according to CRD-C 123.

2. The Rock-Color Chart Committee, National Research Council, Rock-Color Chart, Washington, DC, 1963.

Table 1
Composition of Pit Run Gravel NO-57 G-3
from Amyx Gravel Co., Jena, La.

Constituents	Composition of Sizes Indicated Below, Percent*				
	25 mm (1 in.)	19 mm (3/4 in.)	12.5 mm (1/2 in.)	9.5 mm (3/8 in.)	4.75 mm (No. 4)
Chert					
dense	81	87	82	} 78	} 64
fractured	--	2	1		
wuggy	2	2	--		
porous	15	9	7	7	4
Quartz	2	--	6	13	32
Miscellaneous**	--	--	4	2	--
Total	100	100	100	100	100

Table 2
Composition of Pit Run Sand NO-57 S-3
from Amyx Gravel Co., Jena, La.

Constituents	Composition of Sizes Indicated Below, Percent*				
	2.36 mm (No. 8)	1.18 mm (No. 16)	600 μm (No. 30)	300 μm (No. 50)	150 μm (No. 100)
Quartz	44	62	87	84	69
Chert	38	22	6	6	13
Feldspar	14	14	6	6	8
Miscellaneous**	4	2	1	4	10
Total	100	100	100	100	100

* Based on examination of 300 or more particles when possible. The 25-, 19-, and 9.5-mm sizes consisted of 46, 134, and 280 particles, respectively.

** Sandstone or quartzite, igneous rocks, and feldspar. Some of each type is weathered. The sand also includes mica, and unidentified heavy minerals and opaque particles. Feldspar was counted separately in the sand.

APPENDIX B: COMPUTER PROGRAM LISTING

```

01000C
01010C **** PROGRAM STRAIN CALCULATIONS
01020C
01030C      TERENCE C. HOLLAND
01040C      WATERWAYS EXPERIMENT STATION
01050C      JANUARY, 1981
01060C
01070C **** THIS PROGRAM IS INTENDED FOR USE WITH TEST
01080C      METHOD CRD-C 71, "STANDARD TEST METHOD FOR
01090C      ULTIMATE TENSILE STRAIN CAPACITY OF
01100C      CONCRETE." THE PROGRAM REDUCES DATA OBTAINED
01110C      FROM CARLSON INTERNAL STRAIN METERS FOR
01120C      EITHER THE SLOW OR RAPID LOADING CASES. AN
01130C      OPTIONAL REGRESSION ANALYSIS IS ALSO AVAIL-
01140C      ABLE TO ALLOW STRAIN CAPACITY DETERMINATION AT
01150C      90 PERCENT OF THE MODULUS OF RUPTURE. ADDITIONAL
01160C      DETAILS ARE AVAILABLE FROM THE AUTHOR.
01170C
01180C **** ESSENTIAL VARIABLES ARE DEFINED WHEN FIRST USED
01190C
01200      CHARACTER IDENT*60, LABEL*25, FN*8, AFN*16,
01210&      SYFLAG*5, AXFLAG*5, LOFLAG*5, DAFLAG*5
01220      DIMENSION R0(2), TR(2), TC(2), CAL(2),
01230&      VOLTS(200), CALSTR(200), RESIS(2,200),
01240&      RATIO(2,200), TEMP0(2,2), RATO(2,2), TEMP(2,200),
01250&      DELTMP(2), DELRAT(2), STRIND(2,200), STRACT(2,200),
01260&      LABEL(200), EXTSTR(2,200), START(2), NUM(2),
01270&      SUMX(2), SUMX2(2), SUMXY(2), SUMY(2),
01280&      SUMY2(2), B(2), R(2), STRAN9(2), BUFF(380), MN(2)
01290      REAL LOAD(200), NUAXIS(200), M(2), LEN
01300      INTEGER DATE(200,3), DATE1, DATE2, DATE3,
01310&      LO(2), HI(2), ERFLAG
01320C
01330C **** SET USER CONTROLLED OPTIONS
01340C
01350C      AXFLAG CONTROLS NEUTRAL AXIS
01360C          AXFLAG="CALCU", CALCULATES
01370C          AXFLAG="FIXED", USES MID DEPTH
01380C      SYFLAG CONTROLS SYSTEM SELECTION
01390C          SYFLAG="TIMES", TIMESHARE (INTERACTIVE)
01400C          * SINGLE BEAM
01410C          * SELECT DATA PRINT
01420C          * SELECT REGRESSION
01430C          SYFLAG="BATCH", BATCH VIA CARDIN (NOT INTERACTIVE)
01440C          * SINGLE OR MULTIPLE BEAMS
01450C          * PRINTS ALL DATA
01460C          * NO REGRESSION
01470C
01480      AXFLAG = "FIXED"
01490      SYFLAG = "BATCH"

```

```

01500C
01510C **** THIS SECTION CONTROLS INPUT IN BATCH MODE
01520C
01530C     A FILE NAMED "LIST" MUST CONTAIN NAMES OF
01540C     DATA FILES, ONE DATA FILE IS REQUIRED FOR EACH BEAM.
01550C
01560C     FN = FILENAME
01570C     AFN = MODIFIED FILE NAME "R0CC45/FN;"
01580C     BUFF = BUFFER FOR ATTACH
01590C
01600     IF (SYFLAG.EQ."TIMES") GO TO 130
01610C
01620     CALL ATTACH(21, "R0CC45/LIST;", 1, 0, , BUFF)
01630 100 READ (21,110,END = 960) FN
01640 110 FORMAT (A8)
01650     ENCODE (AFN,120) FN
01660 120 FORMAT ("R0CC45/", A8, ";")
01670     CALL ATTACH(20, AFN, 1, 0, , BUFF)
01680C
01690C **** INPUT BEAM CONSTANTS AND DATA FOR BOTH METERS
01700C
01710C     LOFLAG DETERMINES TYPE OF LOADING
01720C     LOFLAG="RAPID", RAPID LOAD
01730C     LOFLAG="SLOW ", SLOW LOAD
01740C
01750 130 READ (20,140) LOFLAG
01760     IF (LOFLAG.EQ."RAPID") GO TO 150
01770     IF (LOFLAG.EQ."SLOW ") GO TO 150
01780     ERFLAG = 100
01790     GO TO 940
01800 140 FORMAT (A5)
01810 150 READ (20,160) IDENT
01820     READ (20,170) SIZE, SPAN, LEN
01830 160 FORMAT (A60)
01840     READ (20,170) MN(1), R0(1), TR(1), TC(1), CAL(1)
01850     READ (20,170) MN(2), R0(2), TR(2), TC(2), CAL(2)
01860 170 FORMAT (V)
01870C
01880C **** INPUT DATA LEVEL, INITIALIZE COUNTERS, AND
01890C     TRANSFER TO CORRECT DATA INPUT
01900C
01910C     DAFLAG DETERMINES AMOUNT OF DATA
01920C     DAFLAG="COMPL", COMPLETE DATA
01930C     DAFLAG="ABBRE", ABBREVIATED DATA (NONE PRIOR TO LOADING)
01940C
01950     READ (20,140) DAFLAG
01960     I = 1
01970     IF (DAFLAG.EQ."COMPL") GO TO 190
01980     IF (DAFLAG.EQ."ABBRE") GO TO 180
01990     ERFLAG = 200

```

01/30/81

FILE - STRAIN

10:35

```
02000      GO TO 940
02010C
02020 180 IFLAG1 = 0
02030      IFLAG2 = 0
02040      GO TO 230
02050C
02060C **** INPUT DATA FOR PHASE PRIOR TO LOADING
02070C      (COMPLETE DATA ONLY)
02080C
02090 190 READ (20,200) (DATE(I,J), J = 1, 3), RESIS(1,I),
02100&      RATIO(1,I), RESIS(2,I), RATIO(2,I), LABEL(I)
02110 200 FORMAT (I2, 2I3, F6.2, F7.2, F6.2, F7.2, A25)
02120      VOLTS(I) = 0.
02130      LOAD(I) = 0.0
02140      IF (DATE(I,1).EQ.55) GO TO 210
02150      IF (DATE(I,1).EQ.77) GO TO 220
02160      I = I + 1
02170      GO TO 190
02180C
02190 210 IFLAG1 = I - 1
02200      GO TO 190
02210C
02220 220 IFLAG2 = I - 1
02230C
02240C **** BASED ON LOADING RATE TRANSFER TO INPUT
02250C      LOADING DATA
02260C
02270 230 IF (LOFLAG.EQ."RAPID") GO TO 240
02280      IF (LOFLAG.EQ."SLOW ") GO TO 270
02290C
02300C **** INPUT DATA FOR LOADING PHASE (RAPID LOAD)
02310C
02320 240 READ (20,170) DATE1, DATE2, DATE3
02330 250 READ (20,260,END = 290) VOLTS(I), RESIS(1,I),
02340&      RATIO(1,I), RESIS(2,I), RATIO(2 I), LABEL(I)
02350 260 FORMAT (F6.4, F6.2, F7.2, F6.2, F7.2, A25)
02360      DATE(I,1) = DATE1
02370      DATE(I,2) = DATE2
02380      DATE(I,3) = DATE3
02390      I = I + 1
02400      GO TO 250
02410C
02420C **** INPUT DATA FOR LOADING PHASE (SLOW LOAD)
02430C
02440 270 READ (20,280,END = 290) (DATE(I,J), J = 1,
02450&      3), LOAD(I), RESIS(1,I), RATIO(1,I), RESIS(2,I),
02460&      RATIO(2,I), LABEL(I)
02470 280 FORMAT (I2, 2I3, F7.0, F6.2, F7.2, F6.2, F7.2, A25)
02480      I = I + 1
02490      GO TO 270
```

```
02500C
02510C **** SET COUNTER FOR NUMBER OF DATA POINTS.
02520C     TRANSFER TO CALCULATE LOADS AND STRESSES
02530C
02540 290 IFLAG3 = I - 1
02550     IF (LOFLAG.EQ."RAPID") GO TO 300
02560     IF (LOFLAG.EQ."SLOW ") GO TO 320
02570C
02580C **** CALCULATE LOADS AND STRESSES.
02590C     NOTE - CALSTR IS A FUNCTION OF BEAM SIZE.
02600C
02610C +++++ RAPID
02620C
02630 300 DO 310 J = 1, IFLAG3
02640     LOAD(J) = VOLTS(J) * 50000.
02650     CALSTR(J) = (3. * LOAD(J) * SPAN) / SIZE ** 3
02660 310 CONTINUE
02670     GO TO 340
02680C
02690C +++++ SLOW
02700C
02710 320 DO 330 J = 1, IFLAG3
02720     CALSTR(J) = (3. * LOAD(J) * SPAN) / SIZE ** 3
02730 330 CONTINUE
02740     GO TO 340
02750C
02760C **** BASED ON DATA LEVEL, SET BASE VALUES FOR
02770C     TEMP AND RATIO. SET START/STOP POINTS
02780C     FOR CALCULATIONS.
02790C
02800 340 IF (DAFLAG.EQ."COMPL") GO TO 350
02810     IF (DAFLAG.EQ."ABBRE") GO TO 370
02820C
02830C +++++ COMPLETE DATA
02840C
02850 350 N1 = IFLAG1 + 1
02860     N2 = IFLAG2 + 1
02870     DO 360 K = 1, 2
02880     TEMPO(K,1) = (RESIS(K,N1) - RO(K)) * TR(K)
02890     TEMPO(K,2) = (RESIS(K,N2) - RO(K)) * TR(K)
02900     RATO(K,1) = RATIO(K,N1)
02910     RATO(K,2) = RATIO(K,N2)
02920 360 CONTINUE
02930C
02940     JFLAG = 0
02950     ISTART = IFLAG1 + 2
02960     ISTOP = IFLAG2
02970     J2 = 1
02980     GO TO 390
02990C
```

```
03000C +---+ ABBREVIATED DATA
03010C
03020 370 DO 380 K = 1, 2
03030     TEMPO(K,2) = (RESIS(K,1) - R0(K)) * TR(K)
03040     RATO(K,2) = RATIO(K,1)
03050 380 CONTINUE
03060C
03070     ISTART = 2
03080     ISTOP = IFLAG3
03090     JFLAG = 1
03100     J2 = 2
03110     GO TO 390
03120C
03130C **** PERFORM CALCULATIONS
03140C
03150C     J COUNTS DATA POINTS
03160C     J1 COUNTS METER
03170C         J1=1, COMPRESSION METER
03180C         J1=2, TENSION METER
03190C     J2 COUNTS LOADING PHASE
03200C         J2=1, PRIOR TO LOADING PHASE
03210C         J2=2, LOADING PHASE
03220C     JFLAG CAUSES REPEAT FOR SECOND
03230C     PHASE (COMPLETE DATA ONLY)
03240C
03250 390 CONTINUE
03260     IF (AXFLAG.EQ."FIXED") GO TO 400
03270C
03280     A1 = SIZE - 3.0
03290     A2 = (SIZE - 1.5) / A1
03300     A3 = 1.5 / A1
03310C
03320 400 DO 430 J = ISTART, ISTOP
03330     DO 410 J1 = 1, 2
03340         TEMP(J1,J) = (RESIS(J1,J) - R0(J1)) * TR(J1)
03350         DELTMP(J1) = TEMP(J1,J) - TEMPO(J1,J2)
03360         DELRAT(J1) = RATIO(J1,J) - RATO(J1,J2)
03370         STRIND(J1,J) = DELRAT(J1) * CAL(J1) * 100.
03380         STRACT(J1,J) = STRIND(J1,J) + DELTMP(J1) *
03390&         TC(J1) - DELTMP(J1) * 5.5
03400 410 CONTINUE
03410C
03420     IF (J2.EQ.1) GO TO 430
03430     IF (AXFLAG.EQ."FIXED") GO TO 420
03440     SUM = ABS(STRACT(1,J)) + ABS(STRACT(2,J))
03450     EXTSTR(1,J) = STRACT(1,J) / ABS(STRACT(1,J)) *
03460&     (ABS(STRACT(1,J)) + SUM * A3)
03470     EXTSTR(2,J) = (SUM * (A2) - ABS(STRACT(1,J))) *
03480&     (STRACT(2,J) / ABS(STRACT(2,J)))
03490     NUAXIS(J) = ((A1*ABS(STRACT(2,J))) / SUM) + 1.5
```

01/30/81

FILE - STRAIN

10:35

```
03500      GO TO 430
03510C
03520 420 EXTSTR(1,J) = (SIZE / (SIZE - 3.0)) * STRACT(1,J)
03530      EXTSTR(2,J) = (SIZE / (SIZE - 3.0)) * STRACT(2,J)
03540      NUAXIS(J) = - 6.0
03550C
03560 430 CONTINUE
03570C
03580      IF (JFLAG.EQ.1) GO TO 440
03590      JFLAG = 1
03600      ISTART = IFLAG2 + 2
03610      ISTOP = IFLAG3
03620      J2 = 2
03630      GO TO 400
03640C
03650C **** DETERMINE IF DATA OUTPUT IS DESIRED
03660C      (INTERACTIVE ONLY)
03670C
03680 440 CONTINUE
03690      IF (SYFLAG.EQ."BATCH") GO TO 460
03700      PRINT 450
03710 450 FORMAT ( // , "IF COMPLETE DATA NOT DESIRED ENTER 1" )
03720      READ (05,170) J6
03730      IF (J6.EQ.1) GO TO 690
03740      GO TO 460
03750C
03760C **** OUTPUT DATA DESCRIBING METERS AND ALL RAW DATA
03770C
03780 460 CONTINUE
03790      PRINT 470, IDENT
03800 470 FORMAT ( // , A60, // )
03810      PRINT 480, MN(1)
03820      PRINT 500, R0(1), TR(1), TC(1), CAL(1)
03830      PRINT 490, MN(2)
03840      PRINT 500, R0(2), TR(2), TC(2), CAL(2)
03850 480 FORMAT ("COMP. METER NO. ", I4)
03860 490 FORMAT ("TENS. METER NO. ", I4)
03870 500 FORMAT (7X, "METER RESIS (R0) (OHMS) = ",
03880&      F6.2, / , 7X, "TEMP/RESIS (TR) (DEG F/OHM) = ",
03890&      F6.2, / , 7X, "TEMP CORRECTION (TC) (UIN/IN/DEG F) = ",
03900&      F6.2, / , 7X, "CAL CONST (CAL) (UIN/IN/0.01% RATIO) = ",
03910&      , F6.2)
03920      PRINT 510
03930 510 FORMAT ( / , "RAW DATA", // )
03940C
03950      IF (LOFLAG.EQ."SLOW ") GO TO 550
03960C
03970C +*** RAPID
03980C
03990      PRINT 520
```

01/30/81

FILE - STRAIN

10:35

```

04000 520 FORMAT (2X, "DATE", 5X, "VOLTS", 3X, "COMPRESSION",
04010& 5X, "TENSION", 12X, "REMARKS", / , 19X,
04020& "RESIS RATIO", 3X, "RESIS RATIO", // )
04030 DO 540 K = 1, IFLAG3
04040 PRINT 530, (DATE(K,J), J = 1, 3), VOLTS(K),
04050& RESIS(1,K), RATIO(1,K), RESIS(2,K), RATIO(2,K), LABEL(K)
04060 530 FORMAT (3I3, F8.4, 4F7.2, A25)
04070 540 CONTINUE
04080 GO TO 590
04090C
04100C +++++ SLOW
04110C
04120 550 PRINT 560
04130 560 FORMAT (2X, "DATE", 5X, "LOAD,", 3X, "COMPRESSION",
04140& 5X, "TENSION", 12X, "REMARKS", / , 11X,
04150& "LBS", 5X, "RESIS RATIO", 3X, "RESIS RATIO", // )
04160 DO 580 K = 1, IFLAG3
04170 PRINT 570, (DATE(K,J), J = 1, 3), LOAD(K),
04180& RESIS(1,K), RATIO(1,K), RESIS(2,K), RATIO(2,K), LABEL(K)
04190 570 FORMAT (3I3, F8.0, 4F7.2, A25)
04200 580 CONTINUE
04210C
04220C ***** IF COMPLETE DATA, OUTPUT DATA FOR PRIOR
04230C TO LOADING PHASE
04240C
04250 590 IF (DAFLAG.EQ."ABBRE") GO TO 640
04260C
04270 PRINT 600, IDENT
04280 600 FORMAT ( // , A60, // , "REDUCED DATA == PRIOR TO LOADING"
04290& , // )
04300 PRINT 610
04310 610 FORMAT (1X, "LOAD, CALC", 6X, "COMPRESSION METER",
04320& 9X, "TENSION METER", / , 2X, "LBS STRESS,",
04330& 5X, "TEMP, ACTSTN,", 12X, "TEMP, ACTSTN,",
04340& / , 11X, "PSI", 8X, "DEG F UIN/IN", 12X,
04350& " DEG F UIN/IN", // )
04360 ISTART = IFLAG1 + 2
04370 DO 630 L = ISTART, IFLAG2
04380 PRINT 620, LOAD(L), CALSTR(L), TEMP(1,L),
04390& STRACT(1,L), TEMP(2,L), STRACT(2,L)
04400 620 FORMAT (2F7.0, 4X, 2F8.1, 10X, 2F8.1)
04410 630 CONTINUE
04420 GO TO 640
04430C
04440C ***** OUTPUT DATA FOR LOADING PHASE
04450C
04460 640 CONTINUE
04470 PRINT 650, IDENT
04480 650 FORMAT ( // , A60, // , "REDUCED DATA == DURING LOADING",
04490& // )

```

```
04500 PRINT 660
04510 660 FORMAT (1X, "LOAD, CALC", 6X, "COMPRESSION METER",
04520& 9X, "TENSION METER", 7X, "NU-AX", /, 2X,
04530& "LBS STRESS, TEMP,", 2X, "ACSTN, EXSTN,"
04540& , " TEMP, ACSTN, EXSTN, ABOVE", /,
04550& 11X, "PSI", 4X, "DEG F UIN/IN UIN/IN "
04560& , " DEG F UIN/IN UIN/IN BASE, IN", // )
04570 ISTART = IFLAG2 + 2
04580 DO 680 L = ISTART, IFLAG3
04590 PRINT 670, LOAD(L), CALSTR(L), TEMP(1,L),
04600& STRACT(1,L), EXTSTR(1,L), TEMP(2,L), STRACT(2,L),
04610& EXTSTR(2,L), NUAXIS(L)
04620 670 FORMAT (2F7.0, 7F8.1)
04630 680 CONTINUE
04640C
04650C **** DETERMINE IF CURVE FIT IS DESIRED
04660C (INTERACTIVE ONLY)
04670C
04680 690 CONTINUE
04690 IF (SYFLAG.EQ."BATCH") GO TO 920
04700 PRINT 700
04710 700 FORMAT ( // , " IF CURVE FIT IS DESIRED ENTER 1")
04720 READ (05,170) J5
04730 IF (J5.NE.1) GO TO 920
04740C
04750C **** ENTER NECESSARY DATA FROM TERMINAL
04760C
04770 PRINT 710
04780 710 FORMAT (" ENTER STARTING STRESS AND NUMBER"
04790& , " OF POINTS FOR COMPRESSION FIT")
04800 READ (05,170) START(1), NUM(1)
04810 PRINT 720
04820 720 FORMAT (" ENTER STARTING STRESS AND NUMBER"
04830& , " OF POINTS FOR TENSION FIT")
04840 READ (05,170) START(2), NUM(2)
04850 PRINT 730
04860 730 FORMAT (" ENTER FAILURE STRESS")
04870 READ (05,170) FLSTR
04880C
04890C **** DETERMINE START AND STOP POINTS FOR REGRESSION
04900C
04910 DO 760 J = 1, 2
04920 DO 740 I = ISTART, IFLAG3
04930 IF (ABS(START(J) - CALSTR(I)).LE.0.50) LO(J) = I
04940 IF (ABS(START(J) - CALSTR(I)).LE.0.50) GO TO 750
04950 740 CONTINUE
04960 750 HI(J) = LO(J) + NUM(J) - 1
04970 760 CONTINUE
04980C
04990C **** COMPUTE VARIABLES FOR REGRESSION ANALYSIS
```

```

05000C
05010      DO 780 K = 1, 2
05020      SUMX(K) = 0.0
05030      SUMX2(K) = 0.0
05040      SUMXY(K) = 0.0
05050      SUMY(K) = 0.0
05060      SUMY2(K) = 0.0
05070      L1 = LO(K)
05080      L2 = HI(K)
05090      DO 770 L = L1, L2
05100      SUMX(K) = SUMX(K) + CALSTR(L)
05110      SUMX2(K) = SUMX2(K) + CALSTR(L) ** 2
05120      SUMXY(K) = SUMXY(K) + CALSTR(L) * EXTSTR(K,L)
05130      SUMY2(K) = SUMY2(K) + EXTSTR(K,L) ** 2
05140      SUMY(K) = SUMY(K) + EXTSTR(K,L)
05150 770 CONTINUE
05160C
05170      DENOM = NUM(K) * SUMX2(K) - SUMX(K) ** 2
05180      M(K) = (NUM(K) * SUMXY(K) - SUMX(K) * SUMY(K)) / DENOM
05190      B(K) = (SUMY(K) * SUMX2(K) - SUMX(K) * SUMXY(K)) / DENOM
05200      R(K) = (NUM(K) * SUMXY(K) - SUMX(K) * SUMY(K)) /
05210&      (SQRT(DENOM) * (SQRT(NUM(K) * SUMY2(K) - SUMY(K) ** 2)))
05220 780 CONTINUE
05230C
05240C **** COMPUTE 90 PERCENT VALUES
05250C
05260      FLSTR9 = 0.9 * FLSTR
05270      DO 790 I = 1, 2
05280      STRAN9(I) = M(I) * FLSTR9 + B(I)
05290 790 CONTINUE
05300C
05310C **** OUTPUT DATA
05320C
05330      PRINT 470, IDENT
05340      IF (AXFLAG.EQ."CALCU") PRINT 840
05350      IF (AXFLAG.EQ."FIXED") PRINT 850
05360      DO 800 I = 1, 2
05370      IF (I.EQ.1) PRINT 810
05380      IF (I.EQ.2) PRINT 820
05390      I1 = LO(I)
05400      I2 = HI(I)
05410      PRINT 830, CALSTR(I1), EXTSTR(I,I1), CALSTR(I2),
05420&      EXTSTR(I,I2), M(I), B(I), R(I)
05430 800 CONTINUE
05440 810 FORMAT (" FOR COMPRESSION FIT == ")
05450 820 FORMAT (" FOR TENSION FIT == ")
05460 830 FORMAT (5X, "START", F6.0, 2X, "PSI,", F8.1,
05470&      2X, "UIN/IN", /, 5X, "STOP ", F6.0, 2X,
05480&      "PSI,", F8.1, 2X"UIN/IN", /, 5X, "M = ",
05490&      F6.3, /, 5X, "B = ", F6.3, /, 5X, "R = ", F6.3, // )

```

01/30/81

FILE - STRAIN

10:35

```
05500 840 FORMAT ("FOLLOWING VALUES BASED ON CALCULATED NEUTRAL AXIS"  
05510& , / )  
05520 850 FORMAT ("FOLLOWING VALUES BASED ON FIXED NEUTRAL AXIS",  
05530& / )  
05540C  
05550 PRINT 860  
05560 860 FORMAT (" SUMMARY OF STRAIN CAPACITY TEST", )  
05570 PRINT 470, IDENT  
05580 PRINT 870, SIZE  
05590 870 FORMAT (" BEAM SIZE, IN == ", F8.2)  
05600 PRINT 880, LEN  
05610 880 FORMAT (" BEAM LENGTH, IN == ", F8.2)  
05620 PRINT 890, FLSTR  
05630 890 FORMAT (" MODULUS OF RUPTURE, PSI == ", F8.0)  
05640 PRINT 900, FLSTR9  
05650 900 FORMAT (" 90 PERCENT OF MODULUS, PSI == ", F8.0)  
05660 PRINT 910, STRAN9(1), STRAN9(2)  
05670 910 FORMAT (" EXTREME FIBER STRAIN AT 90 PERCENT"  
05680& , " OF MODULUS, UIN/IN == ", / , 5X, "COMPRESSION",  
05690& F8.1, / , 5X, "TENSION", F8.1)  
05700C  
05710 920 CONTINUE  
05720 IF (SYFLAG.EQ."TIMES") GO TO 960  
05730 CALL DETACH(20, , )  
05740 PRINT 930  
05750 930 FORMAT ("1")  
05760 GO TO 100  
05770C  
05780 940 PRINT 950, ERFLAG  
05790 950 FORMAT (" ERROR FLAG = ", I5, "PROGRAM HALTED")  
05800C  
05810 960 CALL EXIT  
05820 STOP  
05830 END
```

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Holland, Terence C.

Determination of properties of concrete used in thermal studies for Lock and Dam No. 2, Red River Waterway / by Terence C. Holland, Tony C. Liu, Anthony A. Bombich (Structures Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1982.

62 p. in various pagings ; ill. ; 27 cm. -- (Miscellaneous paper ; SL-82-5)

Cover title.

"June 1982."

"Prepared for U.S. Army Engineer District, St. Louis and U.S. Army Engineer District, New Orleans."

1. Concrete--Testing. 2. Concrete--Thermal properties. 3. Concrete dams. 4. Red River (Tex.-La.) I. Liu, Tony C. II. Bombich, Anthony A. III. United States Army. Corps of Engineers. St. Louis District. IV. United

Holland, Terence C.

Determination of properties of concrete used in : ... 1982.
(Card 2)

States. Army. Corps of Engineers. New Orleans District. V. U.S. Army Engineer Waterways Experiment Station. Structures Laboratory. VI. Title VII. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-82-5.
TA7.W34m no.SL-82-5

DATE
FILME

8-8