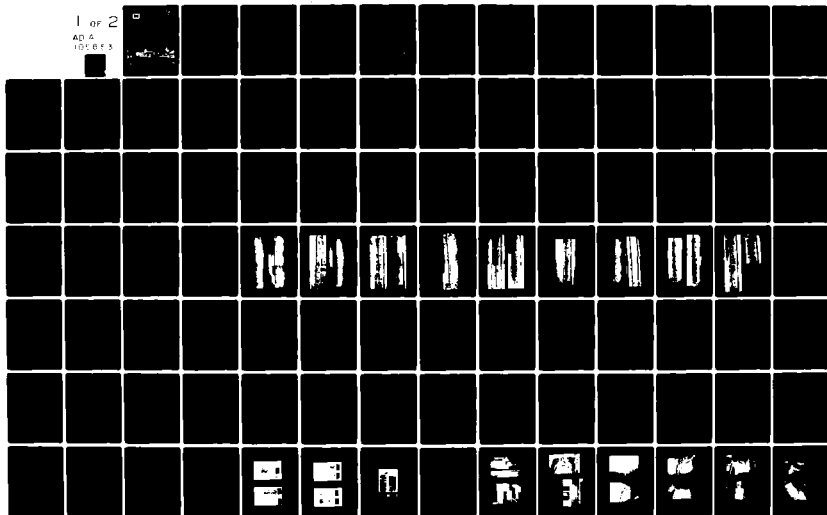


AD-A105 653 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/G 13/2
CONDITION SURVEY, REPAIR AND REHABILITATION, LOCK AND DAM NUMBE--ETC(U)
AUG 81 R L STOWE, H T THORNTON
UNCLASSIFIED WES/MP/SL-81-21 NL

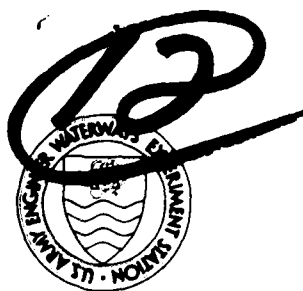
1 of 2

AD-A
105 653





LEVEL II



MISCELLANEOUS PAPER SL-81-21

**CONDITION SURVEY
REPAIR AND REHABILITATION
LOCK AND DAM NO. 24, MISSISSIPPI RIVER**

by

Richard L. Stowe, Henry T. Thornton, Jr.

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

August 1981

Final Report

Approved For Public Release; Distribution Unlimited

AD A105653



DTIC FILE COPY

Prepared for U. S. Army Engineer District, St. Louis
210 Tucker Blvd., North, St. Louis Mo. 63101

81 10 14

DTIC
ELECTE
OCT 16 1981
S D

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-81-21	2. GOVT ACCESSION NO. AR A105653	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) CONDITION SURVEY, REPAIR AND REHABILITATION, LOCK AND DAM NO. 24, MISSISSIPPI RIVER.	5. TYPE OF REPORT & PERIOD COVERED Final report.	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Richard L. Stowe Henry T. Thornton, Jr.	8. CONTRACT OR GRANT NUMBER(s) 14 WE 1/81-3-1	9. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
10. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Army Engineer Waterways Experiment Station Structures Laboratory P. O. Box 631, Vicksburg, Miss. 39180	11. CONTROLLING OFFICE NAME AND ADDRESS U. S. Army Engineer District, St. Louis 210 Tucker Blvd., North, St. Louis, Mo. 63101	12. REPORT DATE Aug 81
13. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	14. SECURITY CLASS. (of this report) Unclassified	15. NUMBER OF PAGES 137
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.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Concrete dams Concrete deterioration Laboratory tests Lock and Dam No. 24, Mississippi River Locks (Waterways)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A condition survey of the concrete was performed at Lock and Dam No. 24 on the Mississippi River. Field studies indicated that 32 percent of the concrete bridge support columns are moderately to severely deteriorated, 48 percent are slightly deteriorated, and 20 percent show no sign of damage. A small zone of concrete downstream of the trunnion shafts is severely deteriorated. Cores were recovered from areas representative of the different degrees of damaged concrete and examined and tested in the laboratory. Some of the		

(Continued)

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

48/115

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

20. ABSTRACT (Continued)

cores were extensively damaged by cycles of freezing and thawing to depths of 2 ft. Compressive strengths of the cores ranged from 2010 to 9770 psi. The minimum remaining compressive strength in the columns is estimated at 1000 psi. Techniques for removal and repair of damaged concrete are recommended. Removal of concrete by water jet is suggested.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

PREFACE

The work described herein was performed for the U. S. Army Engineer District, St. Louis (SLD), by personnel of the U. S. Army Engineer Waterways Experiment Station (WES). The work was authorized by DA Form 2544 No. ED 80-75 dated 3 September 1980, No. ED 80-75 R1 dated 25 September 1980, and ED 80-75 R2 dated 18 November 1980.

The testing program was accomplished under the direction of Mr. Bryant Mather, Chief of the Structures Laboratory (SL), WES, and Mr. John M. Scanlon, Jr., Chief of the Concrete Technology Division (CTD), SL. Mr. H. T. Thornton, CTD, was Project Leader and was assisted in performing the laboratory work by Messrs. R. L. Stowe, F. S. Stewart, and G. S. Wong and Mrs. Joyce C. Alvin, all of CTD. The core drilling was conducted by personnel of the Geotechnical Laboratory (GL), WES, under the direction of Mr. Mark A. Vispi. SLD personnel furnished the photographs in Appendix D. This report was largely written by Messrs. Stowe and Thornton; Messrs. Wong and J. E. McDonald, CTD, contributed portions.

Directors of WES during the conduct of the investigation and the publication of this report were COL N. P. Conover, CE, and COL T. C. Creel, CE. Technical Director was Mr. F. R. Brown.

Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By _____	
Distribution/ _____	
Availability Codes	
Dist	Avail and/or Special
A	

DTIC
ELECTE
OCT 16 1981
S D

CONTENTS

	<u>Page</u>
PREFACE	1
CONVERSION FACTORS, INCH-POUND TO METRIC (SI)	
UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	4
Location and General Description	4
Background	4
Objectives	5
Scope	5
PART II: PRELIMINARY ENGINEERING STUDY	7
Review of Reports and Drawings	7
Inspection of Dam	7
PART III: DRILLING AND EXCAVATION	10
Drilling	10
Excavation Around Trunnion Shaft	11
PART IV: TEST SPECIMENS AND TEST PROCEDURES	13
Cores Received	13
Selection of Test Specimens	13
Physical Property Test Procedures and Petrographic Examination	14
PART V: RESULTS AND DISCUSSION	15
Petrographic Examination	15
Extent of Damaged Concrete	16
Physical Property Tests	18
PART VI: SUMMARY AND RECOMMENDATIONS	25
Trunnion Shaft Area	25
Remaining Strength of Concrete	25
Columns Adequate to Support Bridge	26
Extent and Cause of Damaged Concrete	27
Structural Cracking	28
Removal and Repair of Damaged Concrete	29
REFERENCES	33
TABLES 1-3	
PLATES 1-46	
APPENDIX A: TYPICAL PHOTOGRAPHS SHOWING DAMAGED CONCRETE	A1
APPENDIX B: FIELD CORE LOGS	B1
APPENDIX C: REPORT OF PETROGRAPHIC EXAMINATION OF CONCRETE CORES	C1
APPENDIX D: PHOTOGRAPHS SHOWING BURST PIPE	D1

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

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

<u>Multiply</u>	<u>By</u>	<u>To Obtain</u>
Fahrenheit degrees	5/9	Celsius degrees or Kelvins*
feet	0.3048	metres
feet per second	0.3048	metres per second
inches	0.0254	metres
miles (U. S. statute)	1.609344	kilometres
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.45359237	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
square feet	0.09290304	square metres

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

CONDITION SURVEY
REPAIR AND REHABILITATION
LOCK AND DAM NO. 24, MISSISSIPPI RIVER

PART I: INTRODUCTION

Location and General Description

1. Lock and Dam No. 24, Mississippi River, is situated at Clarksville, Missouri, 93.5 miles* upstream from St. Louis, and 273.5 miles above the mouth of the Ohio River. It is close to the Missouri shore at the base of a high, steep hill. The project consists of a main lock and upper gate bay of an auxiliary lock; a dam containing a movable section of 15 tainter gates; and a fixed submersible stone-covered earth dike reaching to the Sny Island Drainage and Levee District.

2. The regulating portion of the dam consists of fifteen 80-ft-wide tainter gates. Dam piers are pile supported. The submersible dike extending from the storage yard to the Illinois shore is constructed with a core of steel pile cells covered with stone and slush concrete.

Background

3. In 1973, ultrasonic pulse velocity measurements were made through selected piers of Locks and Dams No. 24 and 25. The results of these tests were reported to the St. Louis District (SLD) by letter dated 29 October 1973, subject, "Results of Soniscope Survey of Lock and Dam No. 24 and 25, Mississippi River." In 1976,¹ the presence of alkali-silica reaction in concrete from an intermediate wall of Lock and Dam No. 24 was established by the examination of 6-in. and 4-in.-diameter cores. The concrete cores were from an area of undeteriorated concrete. In October 1978, five NX (2-1/8-in. diameter) concrete cores were received from the U. S. Army Engineer District, St. Louis, for examination.

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

These cores were taken from the downstream portions of three piers in the dam of Lock and Dam No. 24. The cores were in fragments with the longest intact piece of core being about 2-1/2 in. Results of the examination of these cores were reported in December 1978.²

4. In September 1979 members of the Structures Laboratory, Waterways Experiment Station (SL, WES), performed a more extensive ultrasonic pulse velocity investigation of the concrete portion of the dam structure at Lock and Dam No. 24. This investigation included selected concrete columns that support the service bridge as well as piers No. 2 through 15. The objectives of this investigation were to determine, by nondestructive means, the extent and severity of cracking near the trunnion shafts on the downstream portions of the piers and to determine the extent of cracking in the columns. The results of this investigation were reported in WES Miscellaneous Paper SL-80-2.³

Objectives

5. The objectives of the investigation reported herein were to:
 - a. Determine the effect of water intrusion (if any) on the reinforcing steel and tainter gate anchorage steel in the area around the trunnion shaft. Pier No. 9 was selected to be examined.
 - b. Determine the remaining compressive strength of the concrete in the piers and the service bridge support columns.
 - c. Determine the extent, severity, and cause of the concrete deterioration in the piers and support columns.
 - d. Determine the location, extent, and cause of any structural cracks.
 - e. Suggest repair materials and repair methods.

Scope

6. The investigation included:
 - a. Preliminary engineering study.
 - (1) Visual inspection of dam.
 - (2) Collection and review of all available records and data.

- b. Drilling and excavation of concrete.
- c. Laboratory testing and analysis of concrete core.

PART II: PRELIMINARY ENGINEERING STUDY

Review of Reports and Drawings

7. All available reports, records, and drawings pertinent to this study were collected and reviewed. The items available for review included construction drawings and photographs, postconstruction concrete reports, Periodic Inspection Reports including instrumentation data and analysis, concrete core test and examination reports, a report of field ultrasonic velocity measurements, and boring logs. Specific references to these reports and drawings are made in appropriate parts of this report.

Inspection of Dam

8. Personnel from the WES, SLD, and Lock and Dam No. 24 inspected the dam to observe the extent of damaged concrete on exposed surfaces, locate any structural cracks, obtain information from maintenance, repair, and operational records, and to talk with lock personnel. Persons inspecting the dam are given in Table 1. Photographs showing typical damaged concrete are presented in Appendix A, pages A2 through A5.

9. The piers and the service bridge support columns of the dam were examined to ascertain the physical condition of the exposed concrete surfaces. As a result of the examination, the exposed concrete was classified into five categories based upon crack width and frequency and the amount of exudation present. The "Concrete Condition" terms were established by the authors. The crack width ranges are given in the "Guide for Making a Condition Survey of Concrete in Service;" see Reference 4. The different concrete conditions are tabulated below:

<u>Concrete Condition</u>	<u>Description</u>
"OK"	No signs of deterioration
Very light	Local cracks (infrequent), closed hairline, one per 3- by 3-ft area, slight exudation

<u>Concrete Condition</u>	<u>Description</u>
Light	Local cracks (infrequent), fine (0.1 mm, 0.04 in.), one per 3- by 3-ft area, slight exudation
Moderate	Zone cracking, medium (1 to 2 mm, 0.04 to 0.08 in.), one crack every 3 to 4 in., heavy exudation covering 50 percent of zone
Severe	Zone cracking, medium to wide (wide 2 mm, 0.08 in.), one crack every 2 to 3 in. apart, heavy exudation covering 75 percent of zone.

10. Zones of damage were sketched (to scale) for the upstream and the downstream surfaces of the bridge columns. If a small zone of damage exists, then the whole bridge column was classified based upon the condition of the small zone. Some damaged zones extended over a few square feet while others over tens of square feet. No sketches were made for the zones of damaged concrete just downstream of the trunnion shafts in the piers. The exterior and interior extent of concrete damage in the piers and bridge columns is presented and discussed in Part V of this report.

11. A number of structural cracks were observed in the bridge columns on piers No. 9 and No. 16. The extent and width of structural cracks were mapped. For purposes of this report structural cracks are defined as those cracks caused by external applied loads. The extent of the structural cracks is presented in Part VI of this report.

12. Mr. Dan Buckley, Lockmaster at Lock and Dam No. 24, was on the inspection team. He explained to the team the difficulty encountered, on a number of occasions, in passing thick ice over a couple of the tainter gates. The ice would build up behind the gates. When it broke loose and was passing the gate, he observed a trunnion shaft oscillating due to the vibrations caused by ice hitting the piers and the gates. He also related that the townspeople, adjacent to the lock, complained of inordinate vibrations on occasions when thick ice was being passed; windows rattling and vibration felt through the floors of houses.

13. In addition to the ice problem, Mr. Buckley told us that the tainter gates are now not lowered to their design depth. When they are lowered to their maximum depth, inordinate vibrations result due to the applied water loads.

PART III: DRILLING AND EXCAVATION

Drilling

14. Information gathered during the inspection of the dam indicated that 32 percent of the service bridge support columns (total of 64) are moderately to severely deteriorated; 48 percent of the columns are very light to lightly deteriorated; and 20 percent have no signs of deterioration. Columns representative of the different concrete conditions were drilled. Six of the severely and three of the moderately deteriorated columns had short horizontal borings placed in them. Four columns showing no evidence of deterioration had borings placed in each of them. Borings in the columns were drilled through to the opposite side.

15. Three of the piers were drilled to obtain information on the quality of the concrete with depth. Vertical borings were located in those piers where nondestructive testing (Reference 3) indicated poor concrete and where survey data indicated the greatest amount of settlement and downstream movement of the piers.⁵ The measured settlement and downstream movement are relatively small, 0.03 ft and 0.06 ft, respectively. In general, the piers indicating the greatest movement also indicate the greatest settlement. Short horizontal borings were also placed in the piers. Borings in the piers were drilled in the vicinity of the trunnion shafts. See Plate 1 for general boring locations; specific boring locations are given on plates presented in Part V of this report.

16. Boring designations appearing on Plate 1 are explained as follows; S WES P04.1 and S WES C02.2N are used as examples: S, sponsor (St. Louis District); WES, drilling agency (Waterways Experiment Station); P&C, for pier and column; first two numbers for pier numbers; third number is column number 1 through 4; and last letter represents north, east, south, or west face of a column. See Plate 1 for order of column numbers.

17. A total of 4 vertical borings and 21 horizontal borings were drilled. A total of 161 ft of core was recovered. Core recovery was

99 percent. See Table 2 for detailed boring information. The following information is presented for each boring; the direction of the boring, the location, the elevation of the top of boring, the elevation bottom of boring, depth of horizontal borings, and the date when the boring was started. Core logs are presented in Appendix B.

18. A WES drill crew conducted the drilling at Lock and Dam No. 24. Drilling equipment consisted of an Acker Toredon Mark II and a Sprage and Henwood skid-mounted rotary drill rig. A Diamond Core Drill Manufacturers Association standard 4-in. by 5-1/2-in. double tube swivel tube core barrel and 5-7/8- by 6-1/8-in. thin wall barrel were used with diamond bits to obtain the concrete core. Access to the dam was by a marine floating plant supplied by the SLD; once on the dam, the crane on top of structure was used to position and move drill equipment. The crane was operated by a WES operator. Continuous samples were obtained in all borings. A Concord portable electric drill rig was used in drilling horizontal borings in the columns.

19. All borings were backfilled with concrete using packaged dry combined materials. To each 50 lb of materials was added 10 lb of portland cement. To each 60 lb of materials, enough water was added to make a stiff mixture. Prior to adding the required water to the materials, 1 ml of air-entraining admixture was mixed in the water. After a 24-hr period, the crown area of the backfilled horizontal borings in the columns were sealed. A slightly expanding cement grout (aluminum powder was added to cement) was pumped into and along the crown area of the borings. The sealing operation was necessary due to the shrinkage of the concrete away from the crown area of the horizontally drilled hole. It was directed that all borings in the columns be backfilled and sealed before the crane was allowed to pass over those columns that were drilled.

Excavation Around Trunnion Shaft

20. Concrete from around the trunnion shaft in pier No. 9 was excavated to expose a small portion of the tainter gate anchorage steel. This work was done to reveal the physical condition of the anchorage

steel. With evidence of cracked concrete and impounding water in the area of the trunnion shaft, there was concern that rusting of the anchorage steel had reduced the steel's cross section. See Plate 2 for a cross section of the zone examined. Photographs No. 8 through 13, Appendix A, show the excavated zone.

21. The concrete was removed from around the anchorage steel using a hand held air-hammer. The first foot of concrete was removed without great difficulty as compared to the remaining 1-1/2 ft. The concrete was hard and tough to remove. Occasional cracks were encountered that were lightly stained; the staining resulted from infiltrating rain water.

22. A plastic cork, as described on the original plans, was found bonded to the anchorage steel. It was intact and had to be torn away from the steel except near the top of the pier. The area crossed hatched in Plate 2 indicates the zone of rusting that was detected. The rusting reduced the steel cross section about 1/64 in. on the trunnion collar; original thickness of collar is 2 in. The damage to the steel is considered insignificant. See photographs No. 11, 12, and 13 (Appendix A) for rusted zone.

23. An asphaltic bonding material was applied to the anchorage steel prior to backfilling the excavated hole. The hole was cleaned of loose material, air blown, and backfilled with air-entrained concrete. The concrete was vibrated in 1-ft lifts, finished, and cured.

PART IV: TEST SPECIMENS AND TEST PROCEDURES

Cores Received

24. Concrete core from 25 borings was received at the WES. Shipment of the core was handled by the WES drill crew. Cores were shipped in sawdust lined core boxes. Upon receipt of the core, it was inspected for damage; there was no damage due to handling and shipping. The core that was not selected for testing remains at the WES; it will be discarded or shipped to the SLD after completion of the investigation.

Selection of Test Specimens

25. A detailed visual examination of all the core was made to assist in the selection of representative test specimens. The examination was further used to verify the depth of damaged concrete in the core. Test specimens were selected from the top, middle, and bottom portions of all the vertical cores and on those horizontal drilled cores where core was intact and could be tested. Many test specimens contained portions of damaged concrete; i.e., horizontal and inclined cracks and weathered concrete. Some specimens were pieced back together for compressive strength testing; e.g., on some cores where an inclined or horizontal crack caused separation of the core, pieces were placed back together and tested. Nominal 6-in.-diameter by 12-in.-long specimens were used for the various physical property tests. Test specimen locations on the cores are given on appropriate drawings and sketches in Part V of this report.

26. After examining the core in detail, a comparison between the condition of the core and the condition of the in-place surface concrete was made. The core and in-place surface concrete compared quite well; i.e., where severe deteriorated core exists, severe deteriorated in-place surface concrete existed. This comparison enables one to say that other columns with the same classification ("OK", moderate, and severe) would likely contain internal concrete similar to the columns that were cored.

This information will be helpful if the damaged concrete is replaced.

27. Portions of concrete from five cores were selected for detailed petrographic examination. A general description of the 6-in.-diameter concrete cores is as follows:

<u>Field Identification No.</u>	<u>Description</u>
S WES-C16.2 N-80	Horizontal core into badly deteriorated concrete, from column
S WES-C16.3 E-80	Horizontal core into moderately deteriorated concrete, from column
S WES-C13.2 N	Horizontal core into good concrete, from column
S WES-P04.1	Vertical core into good concrete, from pier
S WES-P09.1	Vertical core into good concrete, from pier

Physical Property Test Procedures
and Petrographic Examination

28. The physical property tests were conducted in accordance with the appropriate test methods tabulated below:

<u>Property</u>	<u>Test Method</u>
Unit Weight (As Received), γ_m	CRD-C 107-69 ⁶
Water Content, w	CRD-C 113-80 (ASTM C 566-78)
Pulse Velocity, V_p	CRD-C 51-72 (ASTM C 597-687)
Compressive Strength, q_u	CRD-C 27-78 (ASTM C 42-77)
Elastic Modulus, E	CRD-C 19-75 (ASTM C 469-65)
Poisson's Ratio, ν	CRD-C 19-75 (ASTM C 469-65)

29. Applicable portions of CRD-C 57-78 (ASTM C 856-77) were used in conducting a petrographic examination on representative concrete core; see Appendix B for specific works accomplished.

PART V: RESULTS AND DISCUSSION

Petrographic Examination

30. The results of the petrographic examination of the concrete cores are presented in detail in Appendix C. A brief summary is presented in the following paragraphs.

31. The concrete is not air entrained. The concrete contains gravel and sand of mixed composition; maximum size aggregate is about 1-1/2 in. Coarse aggregate consists of sandstone, quartz, chert, carbonate rock particles, igneous rock particles, and some particles of ironstone. Chalcedony in the chert particles was identified as the common reactive material in the concrete. This finding is similar to the observations made in previous reports. (1,2)

32. The major deterioration consists of parallel to subparallel cracking occurring parallel to the formed core surfaces. This type of cracking is characteristic of freezing and thawing action. The concrete tends to be saturated with white alkali-silica gel. The alkali-silica reaction contributed to the concrete cracking. The gel is present as coatings (exudation) on cracks and exterior core surfaces. The calcium hydroxide has carbonated to calcite on exposed surfaces.

33. The black coating observed on a cracked core surface at about 12.5 ft of core S WES-P04.1 is a pliable tar-like substance; it appears to be a bond-breaker material that was applied to the surface examined or that flowed from somewhere else to its present location.

34. It is not possible to determine how much of the damage in the cores was due to freezing and thawing and alkali-silica reaction. An additional mechanism could have caused some of the observed cracking or initiated cracking which allowed freezing and thawing and alkali-silica reaction to begin.

Extent of Damaged Concrete

35. The extent of concrete damage was ascertained from the field investigation and the detailed examination of the core. The photographs of cores presented in Plates 3 through 11 are typical examples of three different concrete conditions, the "OK" (no deterioration), moderate, and severe deterioration. Cross section and orthographic projection drawings were made to show the extent of damaged concrete in the downstream portions of the piers and in the bridge columns; see Plates 12 through 31.

36. There is a distinct difference in the physical condition of the cores representing the "OK" (no deterioration) and the moderately and severely deteriorated concrete; view Plates 3 through 13. The "OK" cores represent sound concrete with an occasional natural break. The term natural break is used to describe a break in the concrete when the mechanism that caused the break is unknown. The cores representing the moderately and severely deteriorated concrete show clear evidence of damage by frost action, i.e., subparallel cracks to the formed surfaces (end of cores). Note that the majority of the damaged concrete is near the formed surfaces; there is little or no damage towards the middle of the core. For all practical purposes the core representing the moderate and severe class concrete can be grouped together when considering their physical condition. Cores from both classifications contain about the same amount of damaged concrete. Core S WES C09.2N is of poor quality; however, it looks worse as a core than the concrete it represents in-place. The broken condition of the core is due to frost action, alkali-silica reaction, and core barrel blockage. The concrete was cracked in place as evidenced by its weathered nature, but broken somewhat during drilling and upon removal from the core barrel.

Piers

37. Cross sections for the three piers (No. 4, No. 9, and No. 15) in which vertical and horizontal borings were drilled are presented in Plates 12, 13, and 14. A small zone of severely deteriorated concrete exists below and downstream of the trunnion shaft for the full 10-ft

width of the pier. The zone extends from station 99.75 ft to a maximum depth at station 98.5 ft in pier No. 4. In pier No. 9 the zone is 0.9 ft deep and in pier No. 15 the zone is 0.4 ft deep. The depth of the zone could be deeper in the piers not drilled. Major cracks in the core recovered from the piers are presented on these three cross sections. The cracks help to explain some of the "no readings, NR," in the downstream portions of the piers.³ Plate 13b shows the location of the ultrasonic velocity measurements taken on pier No. 9 and the cracks observed in borings S WES P09.1 and P09.3. The uppermost crack in P09.1 could account for the "no reading" at stations No. 6 and 7. This plate also indicates that other "no readings" are accounted for by the anchor-
age steel; the interface between the concrete, plastic cork, and the steel would attenuate the transmitted pulse. The in-place velocities obtained by Thornton³ compare well with the velocities recorded on the laboratory test specimens.

38. The physical properties from the pieces of core tested are presented on Plates 12 through 14. Stress-strain curves for selected core from the piers are presented in Plates 15 through 18. Circled numbers adjacent to the borings indicate the location (elevation) from which a test specimen was taken. Like circled numbers, on-line with the various physical properties, represent those numbers adjacent to the cores. The physical properties obtained on the core recovered from the three piers indicate good quality concrete throughout the downstream portion of the piers. The lowest strength is 5840 psi on the uppermost piece of concrete from S WES P15.1. There is no reason to suspect that interior concrete in the other piers has less quality than the concrete tested during this investigation. The concrete in the piers is sound although a few natural breaks are present. These breaks could be sealed by injecting a bonding agent into the breaks.

Columns

39. The extent of damaged concrete in the bridge columns is presented in Plates 19 through 35. Physical property test results for core taken from the columns is included on appropriate plates. The surface extent and depth of damaged concrete can be readily seen on Plates 19

through 35. For those columns where borings were made, the actual depth of damaged concrete is shown. Some of the backsides of the columns (opposite side of columns from the side the drill entered) contained damaged concrete; it is shown where it occurs. The average depth of damaged concrete on the outside in the moderately and severely deteriorated columns is 1 ft. For the moderately and severely deteriorated columns that were not drilled, the 1-ft depth of damaged concrete is believed to exist and is shown. The average depth of damaged concrete on the backside for both the moderate and severe classiflicated columns is 0.25 ft. The middle of the columns do not show freeze-thaw damage. The following tabulation summarizes the depth of damaged concrete in the columns. The greatest amount of damaged concrete was recovered from the downstream and the upstream faces of the columns.

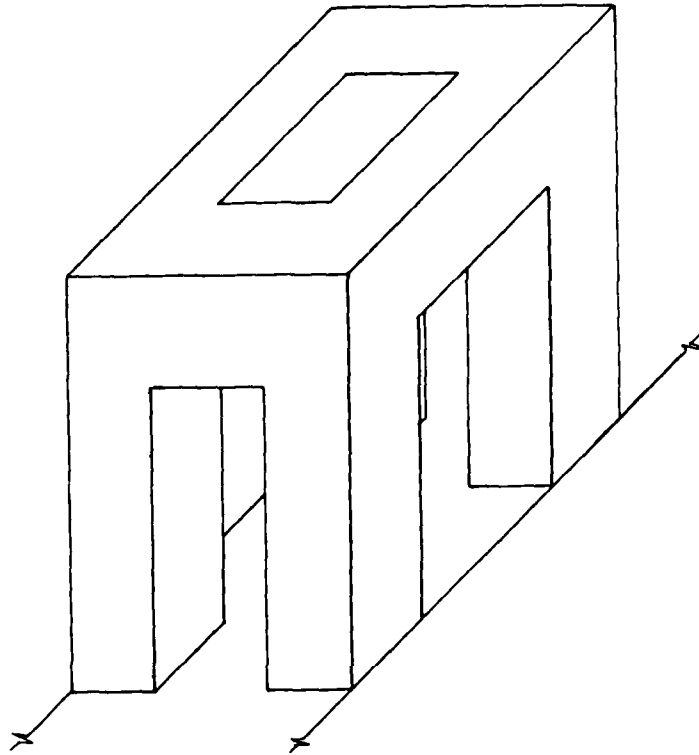
<u>Core Location</u>	<u>Depth of Damage</u>	
	<u>Moderate Deterioration</u>	<u>Severe Deterioration</u>
Outside	1 ft (0.7 ft - 1.7 ft)	1 ft (0.6 ft - 2.0 ft)
Middle	Slight	None
Backside	0.2 ft	0.3 ft

The plan cross sectional area of a column is 10.5 ft^2 . Considering the average depth of damage for the full width of a column, the damaged concrete occupies 3.75 ft^2 , there remains within a column 6.75 ft^2 of undamaged concrete.

Physical Property Tests

40. A summary of the physical properties for the "OK", moderate, and severely deteriorated concrete is presented in Figures 1 through 3. Stress-strain curves for selected core taken from the columns are presented in Plates 36 through 43. Some of the compression test specimens were selected to include the damaged concrete; some of the outside and the backside specimens contain damaged concrete. In several cases core that was separated by the action of freezing and thawing was put back together and tested in compression. See photographs in Plates 44 through

"OK"(NO DETERIORATION), COLUMNS



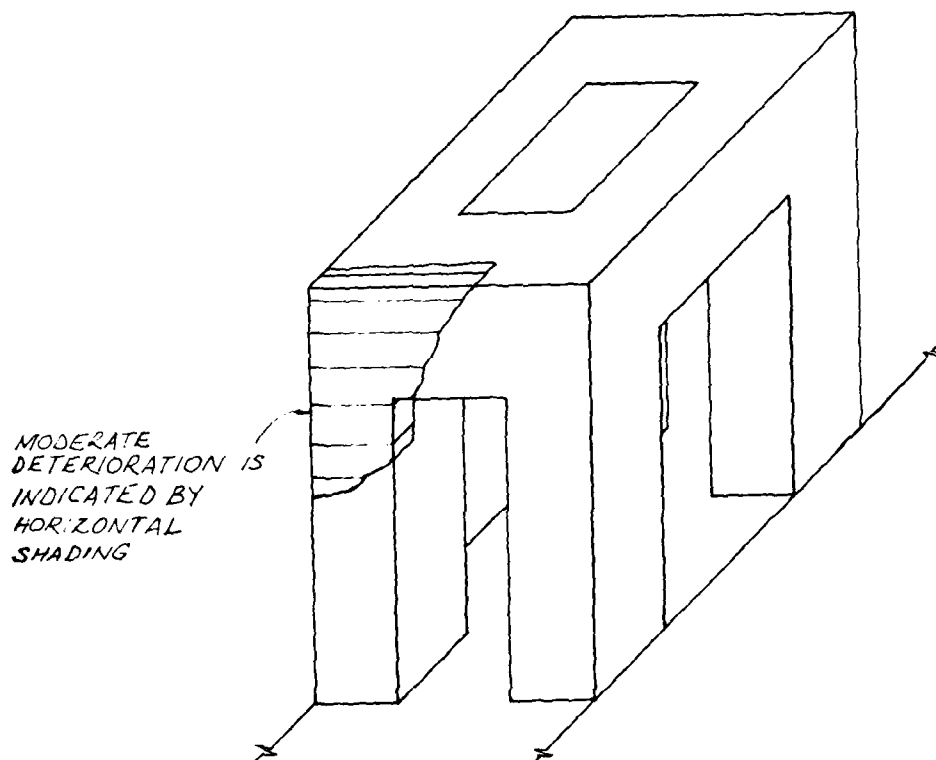
AVERAGE PROPERTIES WITH RANGES

<u>TEST</u>	<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>
γ , lb/ft ³	157.5	152.5 (152.2-152.8)	158.0
w , pct	4.8	4.4	4.4
V_p , Fps	15,333	15,665 (15,134-16,196)	15,073
q_u , psi	9,770	9,080 (8,870-9,770)	10,310
E , $\times 10^6$ psi	5.04	5.55	5.34
ν ,	0.25	0.19	0.18

	<u>Lowest</u>	<u>Average</u>	<u>Highest</u>
Original concrete strength, Class B	4,710 psi	5,930 psi	7,040 psi

Figure 1. Average physical properties with ranges for the OK class concrete

MODERATE DETERIORATION, COLUMNS



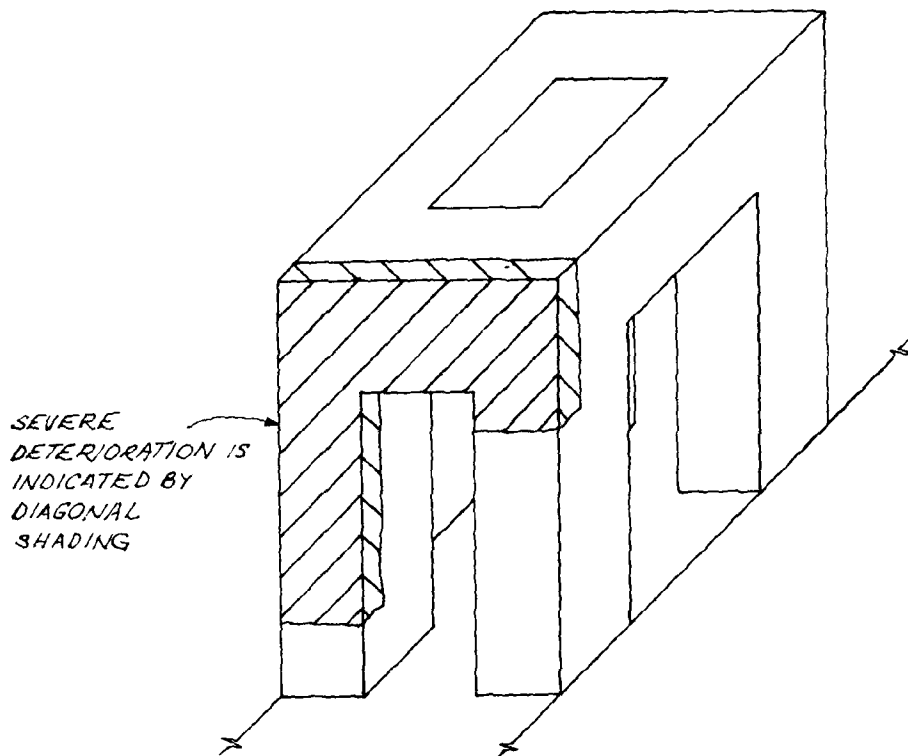
AVERAGE PROPERTIES WITH RANGES

TEST	OUTSIDE	MIDDLE	BACKSIDE
γ , lb/ft ³	156.3 (154.7-160.8)	151.0 (150.2-152.0)	
w , pct	5.3 (5.0-5.7)	5.2 (4.9-5.6)	
V_p , fps	11,995 (10,757-14,178)	13,140 (12,125-13,555)	
q_u , psi	6,630 (6,490-6,720)	7,650 (7,350-8,250)	
E , $\times 10^6$ psi	1.55 (1.42-1.72)	3.95 (2.42-3.52)	
α	0.16 (0.14-0.17)	0.15 (0.14-0.18)	

	<u>Lowest</u>	<u>Average</u>	<u>Highest</u>
Original concrete strength, Class B	4,710 psi	5,930 psi	7,040 psi

Figure 2. Average physical properties with ranges for the moderate class concrete

SEVERE DETERIORATION, COLUMNS



AVERAGE PROPERTIES WITH RANGES

TEST	OUTSIDE	MIDDLE	BACKSIDE
γ_c, ft^3	152.5 (148.7-160.3)	150.0 (146.5-154.3)	150.7 (147.8-154.6)
w, pcf	5.6 (4.9 - 6.2)	5.4 (4.4 - 6.4)	5.4 (5.1 - 5.7)
$v_p, \text{ft/s}$	4,381 (2,774-8,924)	11,961 (11,111-14,303)	9,730 (9,090-10,707)
μ, psi	2,760 (2,070-5,450)	4,700 (3,080-6,050)	3,770 (2,010-5,750)
$E, \times 10^6 \text{ psi}$	0.21 (0.18-0.25)	0.85 (0.38-1.50)	0.28 (0.20-0.36)

	<u>Lowest</u>	<u>Average</u>	<u>Highest</u>
Original concrete strength, Class B	4,700 psi	5,930 psi	7,040 psi

Figure 3. Average physical properties with ranges for the severe class concrete

46. This procedure was used to determine the lowest remaining concrete strength in the columns. The physical properties will be discussed under the "OK", moderate, and severe classes of concrete. Strengths of cylinders that were cast during construction show the following strengths:

<u>Lowest</u>	<u>Average</u>	<u>Highest</u>
4710 psi	5930 psi	7040 psi

41. "OK". The densities of the outside, middle, and backside core are reasonable for sound concrete; the range is from 152.2 to 158.0 lb/ft³; the average outside, middle, and backside densities are 157.5, 152.5, and 158.0 lb/ft³, respectively. There is a 5- to 6-lb/ft³ difference between the density of the near surface and middle core; the difference is attributed to, in part, the presence of reinforcing bars contained within the near surface cores. The water content of the near surface cores is about the same as the middle core. The moderate and severely deteriorated cores have a water content about 1 percent higher than the "OK" class cores. This higher water content is attributed to the presence of the damaged concrete; the cracked concrete with its increased surface area contains additional water.

42. The velocities are indicative of good quality concrete. The range in velocity is 15,073 to 16,196 ft/sec. The compressive strengths for the near surface and middle concrete are higher than the highest cylinder break obtained during construction. The range in strength is 8,870 to 10,310 psi. The modulus was figured as a secant value to 40 percent of the compressive strength. The modulus ranges from 5.04×10^6 psi to 5.55×10^6 psi. The Poisson's ratio is reasonable for good quality concrete; it ranges from 0.18 to 0.25.

43. Moderate. The outside and middle concrete show about the same difference in the average density, i.e., 5 lb/ft³, as does the "OK" class concrete. The outside core has a greater range in density (154.7-160.8 lb/ft³) than the middle core (150.8-152.6); again the higher density of the outside core is due to the inclusion of reinforcing bar in the outside specimens. The average outside and middle densities are

156.8 lb/ft³ and 151.7 lb/ft³, respectively. The average water contents are 5.3 and 5.2 percent for the outside and middle cores.

44. The difference between the average velocities of the outside and middle core is indicative of the damaged outside concrete. The outside velocity averages 11,995 ft/sec (range is 10,757-14,178 ft/sec) while the middle average is 13,140 ft/sec (range is 12,725-13,555 ft/sec). Note the smaller range of the middle cores, indicating more consistency of the concrete. The average strength of the outside and middle cores is above the average of the cylinder strengths cast during construction. The average outside and middle strengths are 6630 psi and 7650 psi. The average modulus of the outside concrete is about one-half the average modulus of the middle cores. The modulus of the moderately deteriorated concrete is considerably below the modulus of the "OK" classified concrete. The reason for the difference is probably due to the fact that the moderately deteriorated concrete contains cracks and voids that closed up under the compressive load applied to the core, resulting in larger axial deformations and hence lower modulus values. The Poisson's ratio for the outside and middle core is 0.16.

45. Severe. The average density values for the three sections of core are considered the same, 152.5, 150.0, and 150.7 lb/ft³ for the outside, middle, and backside, respectively. The range over the full length of the cores is 146.5-160.3 lb/ft³. The lowest density (146.5 lb/ft³) was obtained for the severe class of concrete and is attributed, in part, to the damage caused by freezing-thawing and alkali-silica reaction. The greatest water content was measured on a piece of core from the severe class of concrete, i.e., 6.4 percent. The average water content for the severe class concrete is slightly above the average water content of the moderate class concrete.

46. There is no appreciable difference between the water contents in cores taken from the top of the columns to near the base of the piers. It was thought that the water contents, with depth, might be different, and if so, help to explain why some of the concrete was more heavily damaged.

47. The velocities measured on this class concrete were the lowest measured on all the cores tested. A velocity of 2,774 ft/sec was obtained on an outside core. The average outside, middle, and backside velocities are 4,381, 11,961, and 9,730 ft/sec, respectively. These relatively low values are indicative of poor quality concrete; the low velocities were anticipated considering the damaged condition of the severe class concrete. The middle cores have velocities ranging from 11,111 to 14,303 ft/sec. Again the middle cores are of better quality than the near surface core.

48. The lowest strengths were obtained from the severe class concrete; 2,070 psi for an outside core and 2,010 psi from a backside core. The lowest strength middle core is 3,080 psi; the lowest strength middle core in the other classes of concrete is 7040 psi. The average modulus values for outside and backside core are 0.21×10^6 psi and 0.28×10^6 psi. Again, large deformations of the core due to cracks and voids in the damaged concrete account for the very low modulus values. The stress-strain curves for the cores containing portions of damaged concrete show the typical stress-strain relation for cores containing open cracks; see Plates 37, 38, 40, and 42. Note the concave upwards portion of the curves which represents closure of the cracks and the voids within the specimen. Poisson's ratios are not available because lateral deformation was not measured on the severe class concrete. There was no easy way of mechanically or electrically monitoring lateral movement of the core due to its broken nature.

PART VI: SUMMARY AND RECOMMENDATIONS

Trunnion Shaft Area

49. A few fine (<1 mm, 0.04 in.) and wide (>2 mm, 0.08 in.) cracks in the concrete exist near and intersect with the trunnion shaft on all piers. Rain water has permeated the concrete along these cracks as evidenced by the presence of stains on surfaces of concrete excavated from around portions of the tainter gate anchorage steel on pier No. 9. An insignificant amount of rusting has occurred on the top 2-ft portion of the trunnion shaft collar on pier No. 9. Because all the piers have cracks in the concrete around the trunnion shafts, it is reasonable to assume that a portion of the collars on all piers is lightly rusted. The H beams of the anchorage are protected by plastic cork and are not rusted in pier No. 9. In conclusion, there is no significant damage due to rusting of the anchorage steel.

Remaining Strength of Concrete

50. The remaining compressive strength of the concrete in the piers is considered to be at least equal to the lowest compressive strength obtained on the core from the piers; that strength is 5840 psi. Except for a small zone of damaged concrete downstream of the trunnion shafts on all the piers, the interior pier concrete is sound and will serve its original intended purpose. A few natural breaks occur in the piers, but these breaks should not affect the structural integrity of the piers.

51. The remaining concrete compressive strength in the columns with the greater amount of damaged concrete is probably between 1000 and 2,000 psi; the exterior 1 ft having the 1,000-psi strength and the interior section having the 2,000-psi strength. The lowest exterior and interior core strengths were 2,010 psi and 3,080 psi, respectively. These strengths have been reduced by 1000 psi to account for a reduction

in strength. The reason for reducing the strength has to do with the difference in strength between horizontal and vertically aligned core that is cracked.

52. All cores from the columns were drilled horizontally and the cracks (closely spaced) caused by frost damage are subparallel to the core axis. Laboratory tests, from an unreported study by the principle author, of jointed concrete specimens indicate that when the joints are perpendicular to the axis of applied load, as were the cracks in the horizontally drilled core, the strength is higher than when the joints are parallel to the applied load. With closely spaced joints parallel to the applied load, eccentric loading results as individual jointed members of the specimen flex. The eccentric loads cause reduced strengths. It is not known how much the actual core strengths should be reduced; however, a 1,000-psi reduction is considered conservative.

53. Columns containing the moderately and severely deteriorated concrete that were not drilled could contain low strength concrete equal to the reduced 1,000- to 2,000-psi strengths.

Columns Adequate to Support Bridge

54. This investigation shows that the columns are not weak enough to crumble under static compressive loads. The study shows that compressive strength between 1,000 and 2,000 psi exists which is about one-half the acceptable value of the lowest original strength of 4,710 psi. Some of the concrete in the columns is now not serving its originally intended purpose. The static analysis that a SLD technical staff member conducted on 1 May 1980, "Dam 24 Service Bridge Pier," shows that 240-psi strength is required from the concrete. Based upon these computations and our strength test results, there is no problem at the present time. The concrete strength will decrease with time if the deterioration of the concrete is allowed to continue. We can not assure the adequacy of the columns due to structural movement or dynamic stresses caused by inordinate vibrations from ice loading or other conditions at the dam. It is

suggested that a dynamic stability analysis of the piers and columns be made to see if they are adequate against some critical loading conditions with the present low strength concrete.

Extent and Cause of Damaged Concrete

55. A small zone of severely deteriorated concrete exists below and downstream of the trunnion shaft for the full width of the pier; i.e., the upper part of the downstream vertical face of the piers. This condition exists on all piers. Depth of the zone is about 1.0 ft.

56. The top portions of the columns contain the greatest amount of damaged concrete; the concrete towards the bottom of the columns is sound. Trapped water on the top of the columns probably infiltrated the concrete and the freezing and thawing action caused damage near the top of the columns. With time the damaged zone has extended downwards. The downstream and upstream faces of the columns contain more damaged concrete than any other column surfaces. These column faces have more exposure to the sun and are subject to more cycles of freezing and thawing. The average depth of damage for the moderately and severely deteriorated columns is 1 ft on the upstream and downstream faces.

57. The lack of entrained air in this concrete caused the concrete to be susceptible to frost damage. The repeated freezing and thawing of the concrete while critically saturated has caused delamination of the concrete, especially near surfaces. The opening of the concrete by frost action has accelerated the alkali-silica reaction. This deleterious chemical reaction has caused additional disaggregation of the frost-damaged concrete. The interior concrete shows slight indications of alkali-silica reaction, but has not caused any significant damage to the interior concrete.

58. Another mechanism could have initiated cracking in selected piers in order for action to begin. For instance, vibration of the dam could have caused microcracking to occur at specific locations along the dam, i.e., on piers No. 5, No. 9, and No. 16. Frost action then could have started at these specific locations. The columns on these three

piers contain much more damaged concrete than do the other columns on any other piers. With all columns exposed to the same environment, and assuming that all the concrete in the columns was of the same quality, some unknown mechanism probably contributed to the damaged concrete that exists in piers No. 5, No. 9, and No. 16.

Structural Cracking

59. District personnel visited the dam and found a burst pipe on pier No. 16. They believe that the structural cracks in the columns on piers No. 9 and No. 16 were caused by bursting pipes and freezing water associated and adjacent to the pipe. Some WES personnel agree that the bursting pipe could cause the concrete to split as was found. However, it should not be overlooked that some of the structural cracks observed at the dam could have been caused in part or in whole by some loading condition other than freezing water. See Appendix D for photographs of the damage concrete due to the burst pipe.

60. The broken section of column No. 3 on pier No. 16 was removed and a 1-1/2-in. diameter pipe, a section of electrical conduit (ref drawing ML 24 56/1), was found to be split as if it had burst. The top of the conduit was once flush with the top of the columns and capped, however, it is now rusted off; see Photograph 5 in Appendix D. Evidently, rain water collecting on the top of the columns had drained into the conduit, frozen, burst the pipe, and cracked portions of the column. The columns on pier No. 9 were examined and it is believed that a similar situation to the one that caused the cracks on pier No. 16 developed on pier No. 9.

61. Original drawings show that 1-1/2-in. diameter electrical conduits are present in all downstream columns. Additionally, the downstream column on the Missouri side of each pier contains a 1-1/2-in. diameter drum-heater conduit which makes a 90-deg bend below the column and continues to a cast-iron junction box located above the trunnion shaft. A single 1/2-in. diameter conduit was provided for drainage of this entire line. According to lock personnel, the junction box and

drain line are silt laden. Also, short conduit elbows, plugged at both ends, were installed in the upstream and downstream cross walls which span between tops of the columns. The electrical conduits, the drum-heater conduits, drain conduits, and conduit elbows are potential sources of water which could be responsible for some of the deterioration of columns and the zone below and downstream of the trunnion shaft. Since these conduits are no longer in use, and if they are not proposed to be used in the future, it is recommended that they be cleaned out, grouted, and capped.

Removal and Repair of Damaged Concrete

62. The basic phenomena which initiated cracking in the concrete columns and piers were not identified in this study; therefore, it is impossible to suggest a repair procedure with any assurance that the same phenomena will not cause similar problems in the repair. It is most important that the basic cause of the cracking be ascertained before final selection of any repair procedure aimed at eliminating future cracking. Lacking this information, any repairs at present must be considered as only remedial work to improve the current condition of the columns and piers.

63. The surface cracks on the piers should be adequately sealed to keep water from infiltrating the concrete, especially in the area of the trunnion shaft. If the water is kept out, rusting of anchorage steel, frost action, and alkali-silica reaction will be greatly reduced.

64. There appear to be two basic approaches for repair of the concrete pier columns. The first approach should be considered an interim repair aimed at reducing the current rate of deterioration. The second approach would involve major rehabilitation of the pier columns.

65. The orientation and extent of cracking in the columns is such that the ingress of moisture (rain, snow, ice, etc.) from the top surfaces of the columns and cross members contributes to freezing and thawing and alkali-silica reaction within the concrete. Potential procedures to minimize this ingress of moisture would include (1) sloping the tops

of the columns and cross members to insure drainage towards the interior opening between the columns, (2) drilling holes along the lift joint between the columns and column facing to allow drainage to the outside of the columns, and (3) sealing the top surfaces of the columns and cross members. In this case the latter approach appears to offer ease of construction and the greatest potential for success. A number of materials are available to seal these horizontal surfaces; however, based on previous experience a heavy duty membrane of rubberized asphalt integrally bonded to polypropylene mesh is suggested. The use of such a membrane should be restricted to horizontal surfaces with the possible exception of those vertical surfaces within 3 to 6 in. of the tops of the columns. Such an overlap would allow installation of a mechanical band around the columns to further secure the membrane. Specifications for this membrane are included in Table 3. This approach should reduce the rate of deterioration while additional work is being done to determine the basic cause of deterioration or until major rehabilitation of the pier columns is initiated.

66. Major rehabilitation would involve removal of unsound concrete from those areas previously described as moderately or severely deteriorated and replacement with new concrete; i.e., the upper part of the downstream face of the piers and certain pier columns. It is anticipated that the location and extent of reinforcing steel and the strength of the existing concrete will be such that concrete removal may be difficult. The concrete removal operation should be closely monitored to insure that the amount of concrete removed is kept to the minimum necessary for replacement with new concrete. In general this minimum depth would be that necessary to completely expose the outer layer of reinforcing.

67. It is recommended that the surface removal of distressed/deteriorated concrete from the piers and the bridge columns be done using high-pressure water jets. The reasoning behind the selection of the water jet over conventional removal methods is amount of reinforcing steel in the concrete. The water jet leaves the steel reinforcing clean and undamaged for reuse, thus eliminating the need for replacement steel. In addition to reinforcing the concrete, the steel will act as a dowel

between the existing and replacement concrete allowing loads to be transferred between them. Other advantages of the water jet are:

- a. Minimal damage to the concrete that remains is produced.
- b. Irregular shaped volumes can be removed.
- c. No dust and little noise are produced.

The main concern with the water jet is its variable productivity rate. Under certain conditions, such as cutting concrete containing large abrasive-resistant aggregate, this rate can be very low. To avoid contracting a jet with undesirable productivity rate, it is recommended that a short-term (say, 3 days) pilot test program be used to determine the productivity and acceptability of the jet. The following contractors are among the most promising for doing a satisfactory removal job:

Flow Industries
Kent, Washington
(206) 872-8500

McCartney Mfg Co., Inc.
Baxter Springs, Kansas
(316) 856-2151

iIT Research Institute
Chicago, Illinois
(312) 567-4400

Daedalean Associates, Inc.
Woodbine, Maryland
(301) 442-2620

68. In those cases where 50 percent or more of the concrete column area is expected to require removal, consideration should be given to providing temporary support for the column loads and completely removing and replacing the existing columns. Either sawing or explosives is suggested for concrete removal in these instances.

69. Replacement concrete should be proportioned in accordance with current standard practice. Particular attention should be given to freezing and thawing resistance and the potential for alkali-silica reaction.

70. Some recent rehabilitation projects have encountered cracking in the replacement concrete. In general these problems were associated with concrete overlays which were rather thin relative to the remaining

concrete monoliths. Such problems appear to be the result of the tremendous restraint provided by the existing concrete making thermal considerations during construction even more important than in new construction. While the concrete sections involved in this work are relatively small, the potential for thermal cracking still exists. Attention should be given to minimize temperature differentials between existing and replacement concrete during placing and curing of the replacement concrete. Also, differentials in temperature between the replacement concrete and ambient at the time of form removal and immediately following should be within 25 F or less.

71. Depending upon when this repair is scheduled, a vacuum polymer impregnation technique currently under development may have potential application. This technique consists of wrapping the structure in polyethylene and creating a vacuum through the use of a vacuum pump. A resin is then injected and flows, through the cracks in the structure, towards the source of the vacuum. The vacuum evacuates water and fine contaminants from the fissures prior to impregnation with the resin. With the aid of the vacuum, resin penetrates throughout the crack system and dust or loose particles acts as a filler in the resin. Repair is accomplished without removal of damaged concrete. Fine aggregate may be mixed with the resin to repair large cracks, voids, or badly deteriorated surfaces. The technique is currently being investigated by application to damaged 6-in. by 12-in. cylinders and 3-1/2- by 4-1/2- by 16-in. beams. Damage is being produced for laboratory testing by compressive and splitting tensile testing, exposure to high temperature (1000⁰ F), accelerated freezing and thawing, and accelerated alkali-silica reaction. If laboratory testing continues to show favorable results, this technique may warrant field testing on one or more of the damaged piers or columns.

REFERENCES

1. U. S. Army Engineer Waterways Experiment Station Petrographic Report, dated 23 January 1976, subject, "Tests and Examination of Concrete Cores from Lock and Dam 24 and Lock and Dam 25," Vicksburg, Miss.
2. U. S. Army Engineer Waterways Experiment Station Petrographic Report, dated 4 December 1978, subject, "Project Examination of Fragmented Concrete Cores from Lock and Dam 24, U. S. Army Engineer District, St. Louis," Vicksburg, Miss.
3. Thornton, Henry T., Jr. and Glass, Dale, "Ultrasonic Velocity Measurements in Concrete, Lock and Dam No. 24, Mississippi River," WES Miscellaneous Paper SL-80-2, Apr 1980, Vicksburg, Miss.
4. ACI Committee 201, "Guide for Making a Condition Survey of Concrete in Service," ACI Journal, Proceedings, Vol 65, No. 11, Nov 1968, pp 905-918.
5. U. S. Army Engineer District, St. Louis, "Periodic Inspection Report No. 3, Lock and Dam No. 24, Mississippi River," Sep 1977.
6. U. S. Army Engineer Waterways Experiment Station, CE, "Handbook for Concrete and Cement," with quarterly supplements, Vicksburg, Miss., Aug 1949.

Table 1

Inspection Team, Lock and Dam No. 24

<u>Name</u>	<u>Organization</u>
Riley Pope	SLD-ED
Mel Stegall	SLD-ED
Don Buckley	Lockmaster
Carl Pace	WESSC
Henry Thornton	WESSC
Richard Stowe	WESSC

Table 2

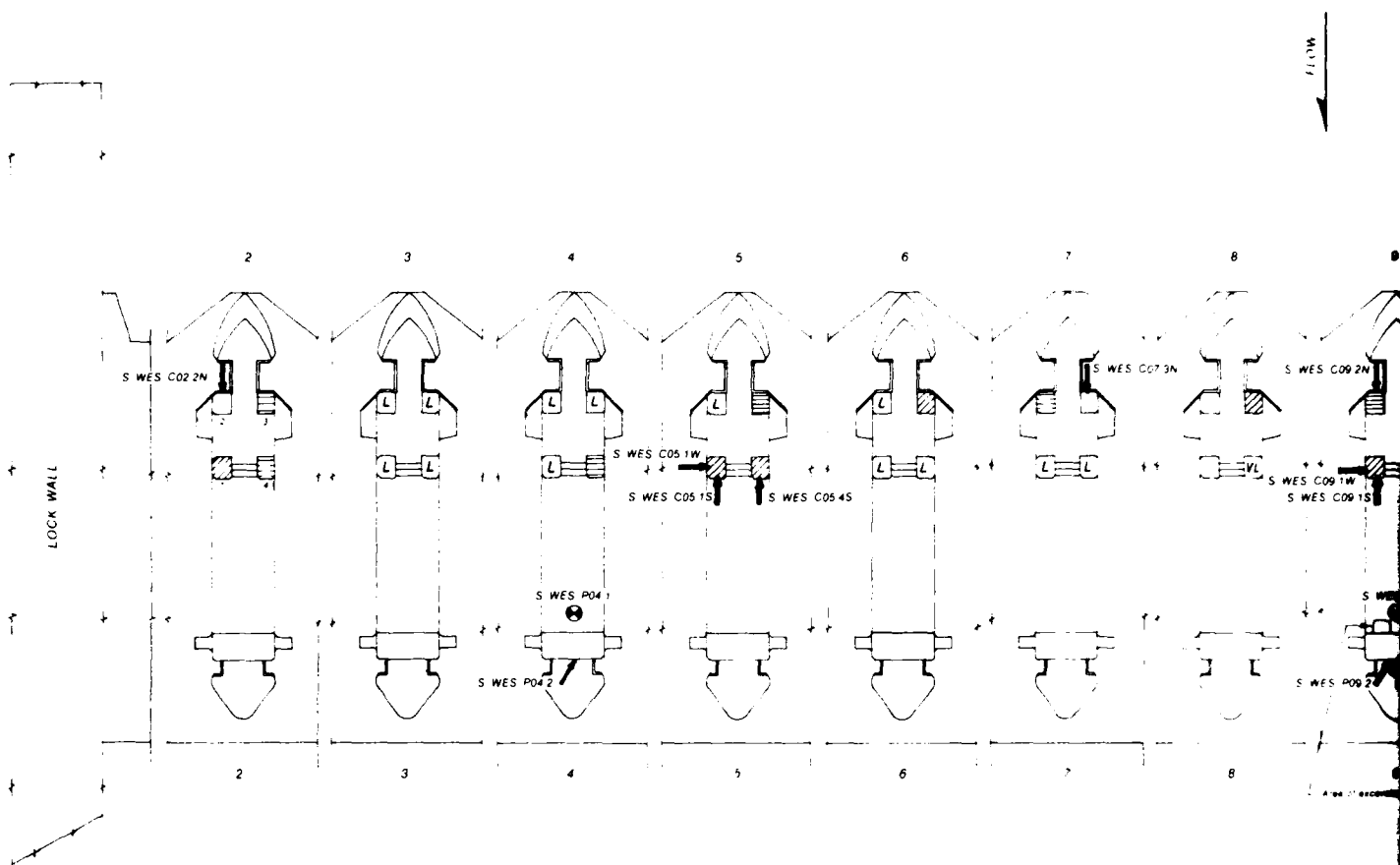
Directions, Locations, Elevations, Horizontal Boring Depths, and Starting Dates

Boring No. S WES	Direction of Boring	Location	El Top of Boring ft	El Bottom of Boring ft	Depth of Horizontal Boring, ft	Start Date
P04.1-80	Vertical	Pier, D/S portion	454.0	440.3		30 Oct 1980
P04.2-80	Inclined 90°	Pier, D/S portion	448.0	448.0	6.4	28 Nov 1980
P09.1-80	Vertical	Pier, D/S portion	454.0	439.8		28 Oct 1980
P09.3-80	Vertical	Pier, D/S portion	444.0	431.2		24 Nov 1980
P09.2-80	Inclined 90°	Pier, D/S portion	448.0	448.0	5.9	06 Nov 1980
P15.1-80	Vertical	Pier, D/S portion	454.0	412.9		21 Oct 1980
P15.2-80	Inclined 90°	Pier, D/S portion	448.1	448.1	6.55	07 Nov 1980
C02.2N-80	Inclined 90°	Column	468.6	468.6	3.5	21 Nov 1980
C07.3N-80	Inclined 90°	Column	464.7	464.7	3.5	13 Nov 1980
C13.2N-80	Inclined 90°	Column	462.0	462.0	3.5	11 Nov 1980
C13.3N-80	Inclined 90°	Column	460.0	460.0	3.55	21 Nov 1980
C09.2N-80	Inclined 90°	Column	469.2	469.2	3.6	12 Nov 1980
C09.3N-80	Inclined 90°	Column	467.3	467.3	3.5	19 Nov 1980
C16.3N-80	Inclined 90°	Column	475.4	475.4	3.5	10 Nov 1980
C16.3E-80	Inclined 90°	Column	469.0	469.0	3.0	20 Nov 1980
C05.1W-80	Inclined 90°	Column	466.5	466.5	3.1	18 Nov 1980
C05.1S-80	Inclined 90°	Column	465.5	465.5	3.5	17 Nov 1980
C05.4S-80	Inclined 90°	Column	466.5	466.5	3.5	18 Nov 1980
C09.1W-80	Inclined 90°	Column	466.0	466.0	3.05	14 Nov 1980
C09.1S-80	Inclined 90°	Column	468.0	468.0	3.50	14 Nov 1980
C09.4S-80	Inclined 90°	Column	465.7	465.7	3.5	19 Nov 1980
C16.1S-80	Inclined 90°	Column	475.45	475.45	3.6	08 Nov 1980
C16.1W-80	Inclined 90°	Column	466.9	466.9	3.1	13 Nov 1980
C16.2N-80	Inclined 90°	Column	467.45	467.45	3.5	10 Nov 1980
H5.1-80	Inclined 90°	Column	471.6	471.6	0.72	01 Dec 1980

Table 3
Description of Asphaltic Membrane

TYPE AND CONSTRUCTION		SPECIFICATIONS		APPLICATIONS	
		PROPERTY	AVERAGE TEST VALUE	TEST METHOD	WATERPROOFING
STANDARD GRADE		PERMEANCE SI (Ng m ² Sec Pa) Polyethylene Rubberized Bitumen	5.72 1.43	ASTM E 96 METHOD B	Above & Below Ground foundations tanking, plazas and terraces, non-exposed roofing and reservoirs
Polyethylene Sheet	0.1mm				
Bitumen-Rubber Compound	1.5mm	WATER ABSORPTION % by weight in 72 hours	0.22%	ASTM D 1228	
Total	1.6mm				
Interwound Release Paper		PLIABILITY 180° bend over 25mm mandrel at -32°C	Unaffected	ASTM D 146	
	0.2mm				
		CYCLING over crack at -26°C	Unaffected	100 cycles over 0-6.4mm distance	
		25mm joint at -26°C	Unaffected	1000 cycles over 19.0-31.8mm distance	
		TENSILE STRENGTH Polyethylene	280 kg sq. cm 27 580 kPa	ASTM D 412 (Die C) modified	
		ELONGATION % of original distance at ultimate failure Rubberized Bitumen	300%	ASTM D 412 (Die C) modified	
		PUNCTURE RESISTANCE Stretched by Blunt Object	25kg	ASTM E 154	
		PEEL ADHESION Membrane is peeled at 90° angle	1.86kg/cm width	7 days dry at 21°C 7 days dry at 49°C 7 days wet at 21°C	
HEAVY DUTY		Specifications as for STANDARD GRADE except for the following			Vehicular traffic structures, parking decks, bridge decks and highways
Polypropylene Mesh	0.3mm	PUNCTURE RESISTANCE Stretched by blunt Object	118kg	ASTM E 154	
Bitumen-Rubber Compound	1.5mm				
Total	1.8mm				
Interwound Release Paper	0.2mm				
BITUTHENE CRM*		Specifications as for STANDARD GRADE except			New Roofing Re-Roofing Remedial Roofing
Polyethylene Sheet	0.2mm	PLIABILITY 180° bend over 6.4mm mandrel at -37	Unaffected	ASTM D 146	
Bitumen-Rubber Compound	1.5mm				
Total	1.7mm	CYCLING over crack at -32°C	Unaffected	200 cycles over 0-6.4mm	
Interwound Release Paper		6.4mm joint at -32°C	Unaffected	3 000 cycles over 3.2-9.5mm distance	
	0.2mm	PUNCTURE RESISTANCE Stretched by blunt object	120kg	ASTM E 154	

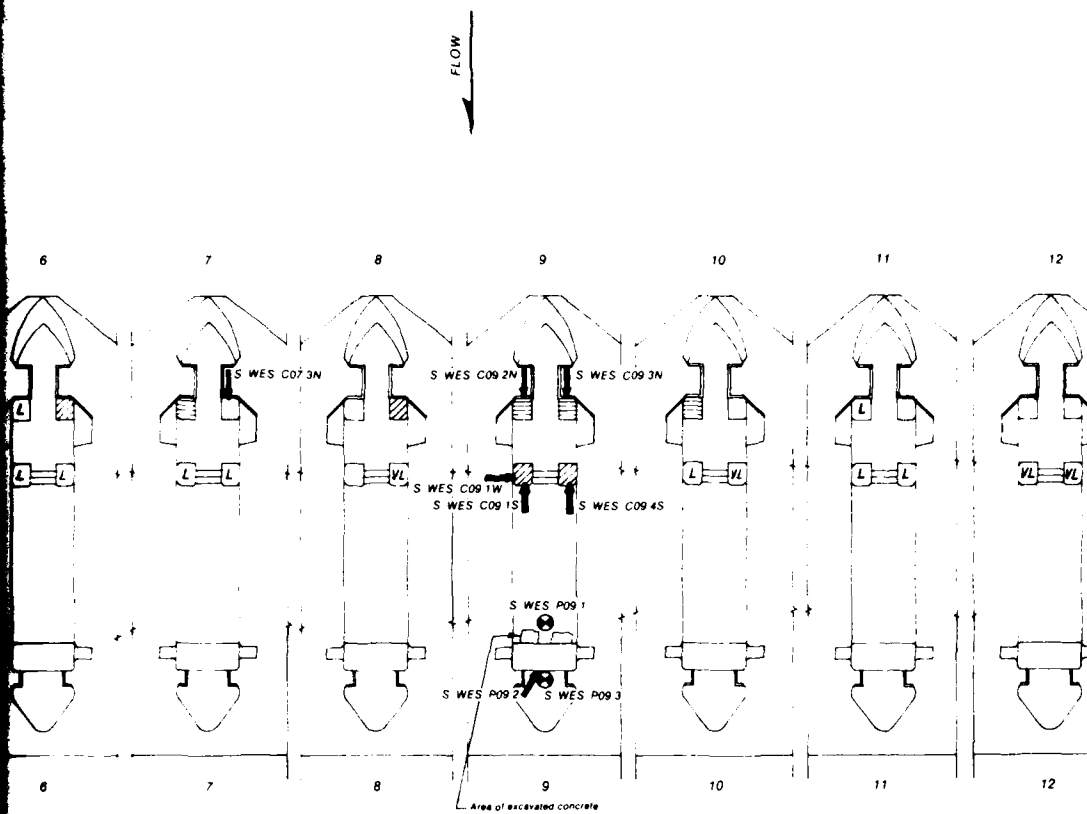
CRM = Compliant roofing membrane



PLAN VIEW

SYMBOL	CONCRETE CONDITION	DESCRIPTION	No. of COLUMNS	PERCENT TOTAL
	OK	No signs of deterioration	12	20
	Very light deterioration	Local hairline, one per 9 m ² area, slight exudation	12	20
	Light deterioration	Local cracks, fine, one per 9 m ² area, slight exudation	17	28
	Moderate deterioration	Zone cracking, medium, one crack per 3 to 4-in. heavy exudation covering 50% of zone	10	17
	Severe deterioration	Zone cracking, medium to wide, one crack per 2 to 3-in. heavy exudation covering 75% of zone	9	15
	Fine: 1 mm (0.04 in.)			
	Medium: 1 to 2 mm (0.04 to 0.08 in.)			
	Wide: 2 mm (0.08 in.)			
	Vertical boring: 6 x 8 1/2-in. (15.7-in. core)			
	Horizontal boring: in per 6 x 8 1/2-in. (15.7-in. core)			
	Vertical and horizontal borings denote horizontal borings in columns: 6 x 8 1/2-in. (15.7-in. core)			

NOTE: A small area of severely deteriorated concrete exists downstream of the trunnion shaft; the zone is not shown on this plate; see Photo No. 1, Appendix A, for typical damage zone.



PLAN VIEW DAM

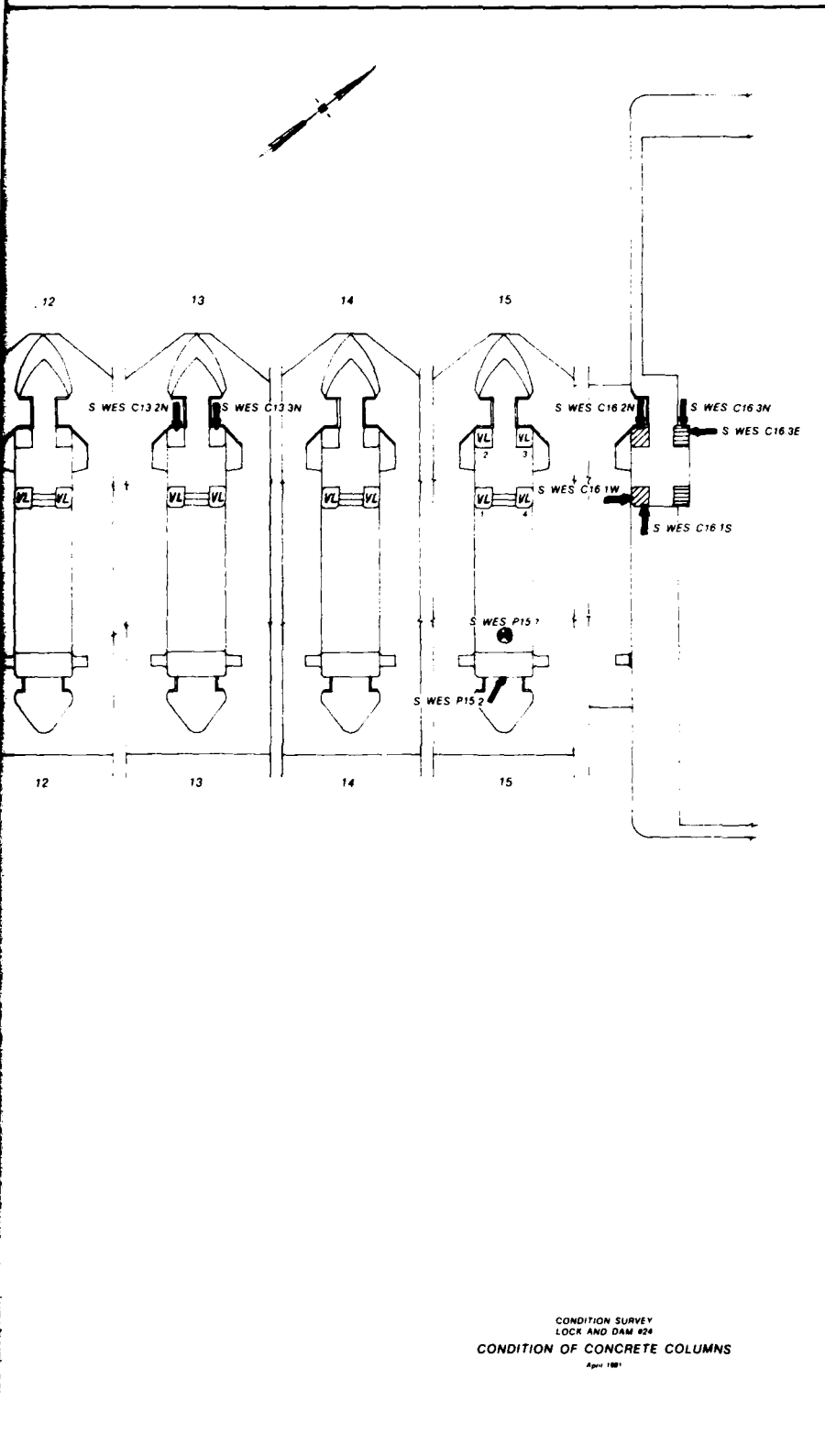
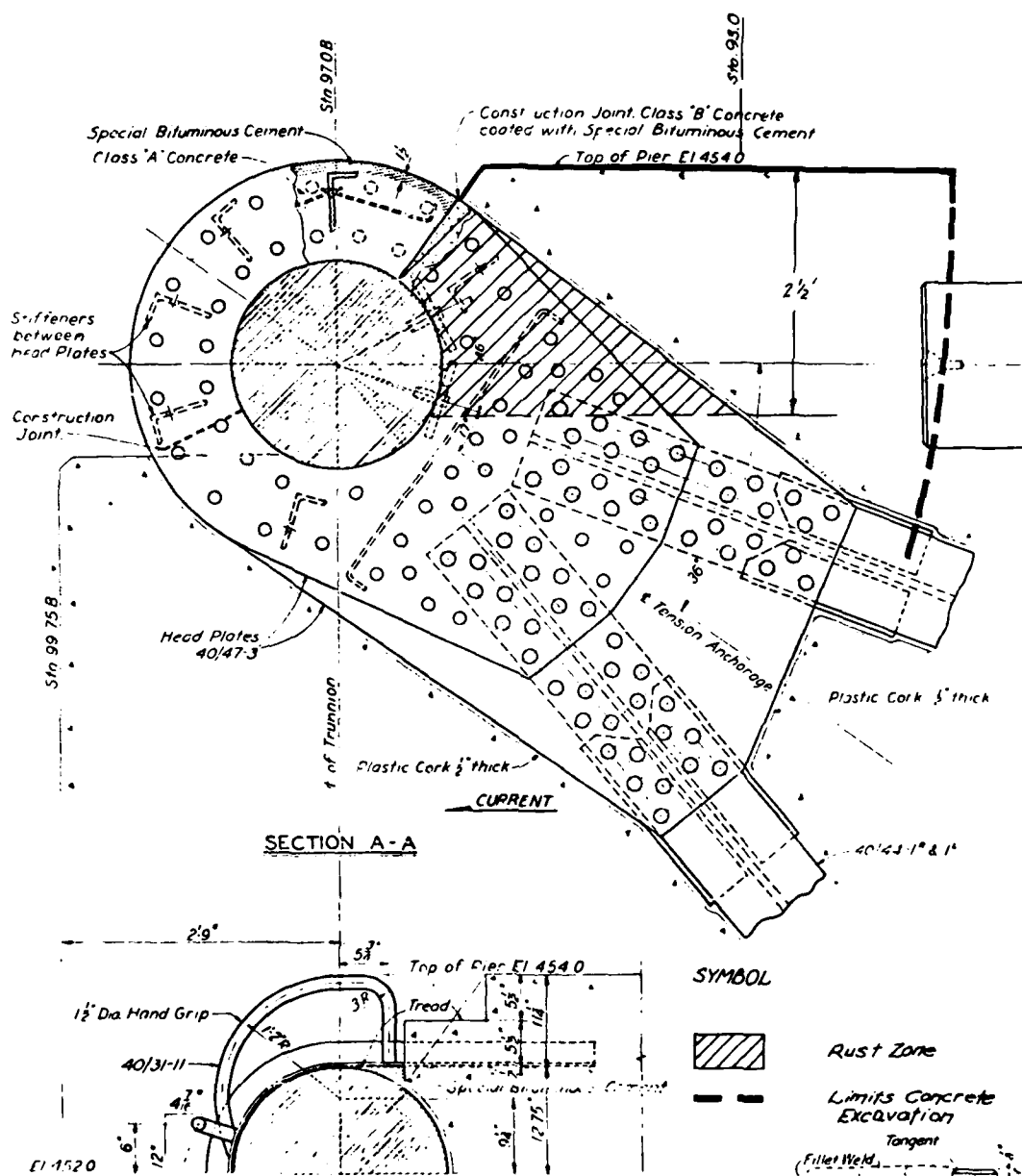
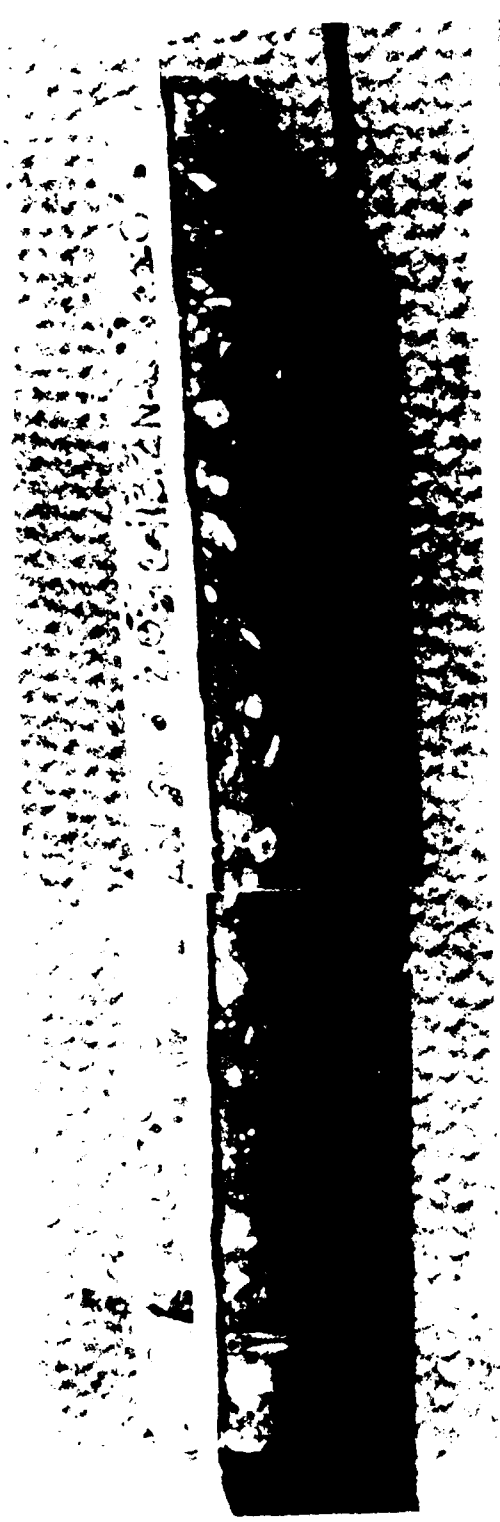


PLATE 1

3



Detail showing rusted zone on anchorage collar and approximate extent of excavated concrete. Reference M-124 40/45.1



C 13.25

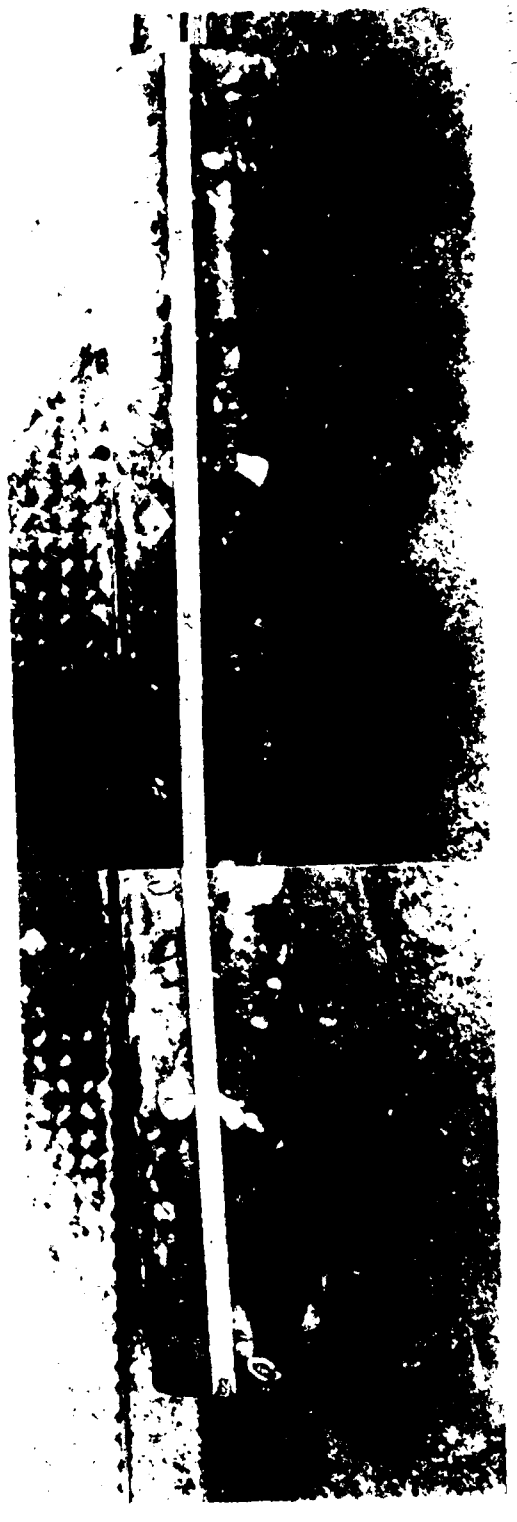
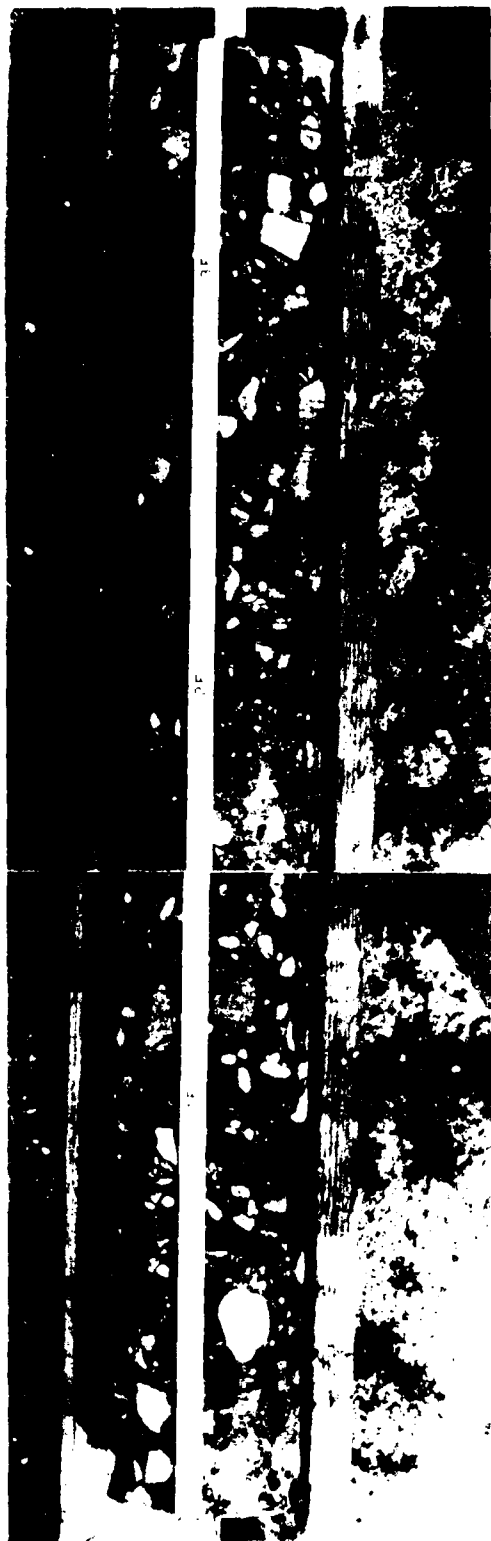
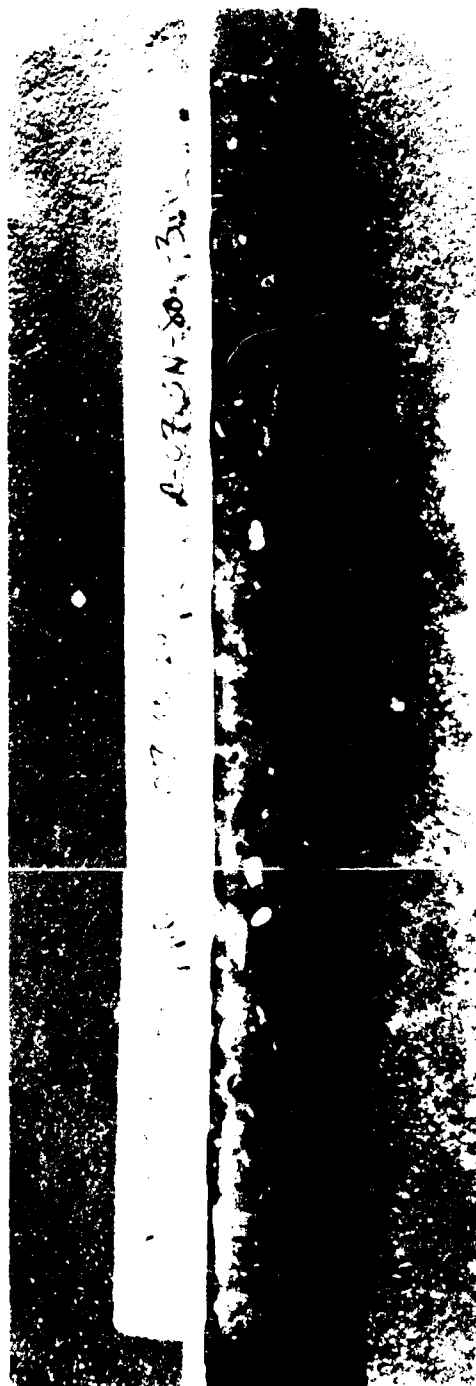


PLATE 3



C. 13. 38





C. 100.25



C. 100.25

NO. 101 RATT



C 09.3N

MODERATE



C 16.2N



C 16.1S

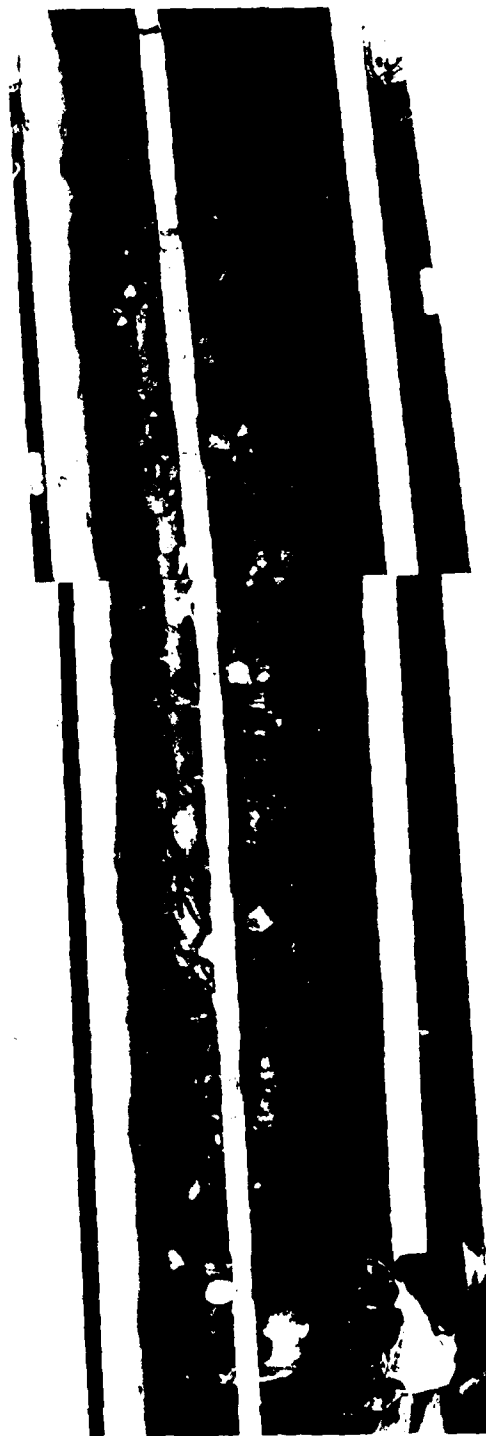
SEVERE



SEVEN

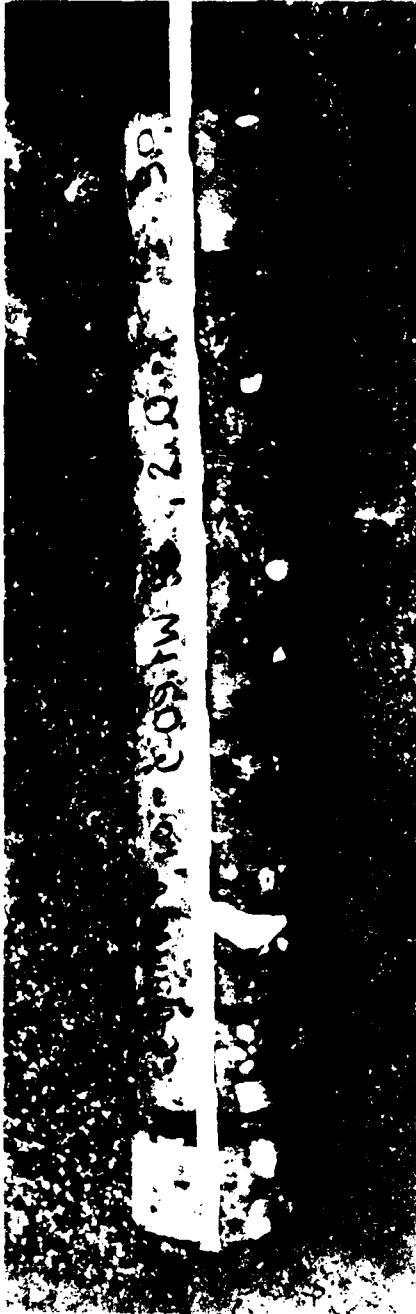


C 5.18



C 05.28

SECRET



C 09.1K



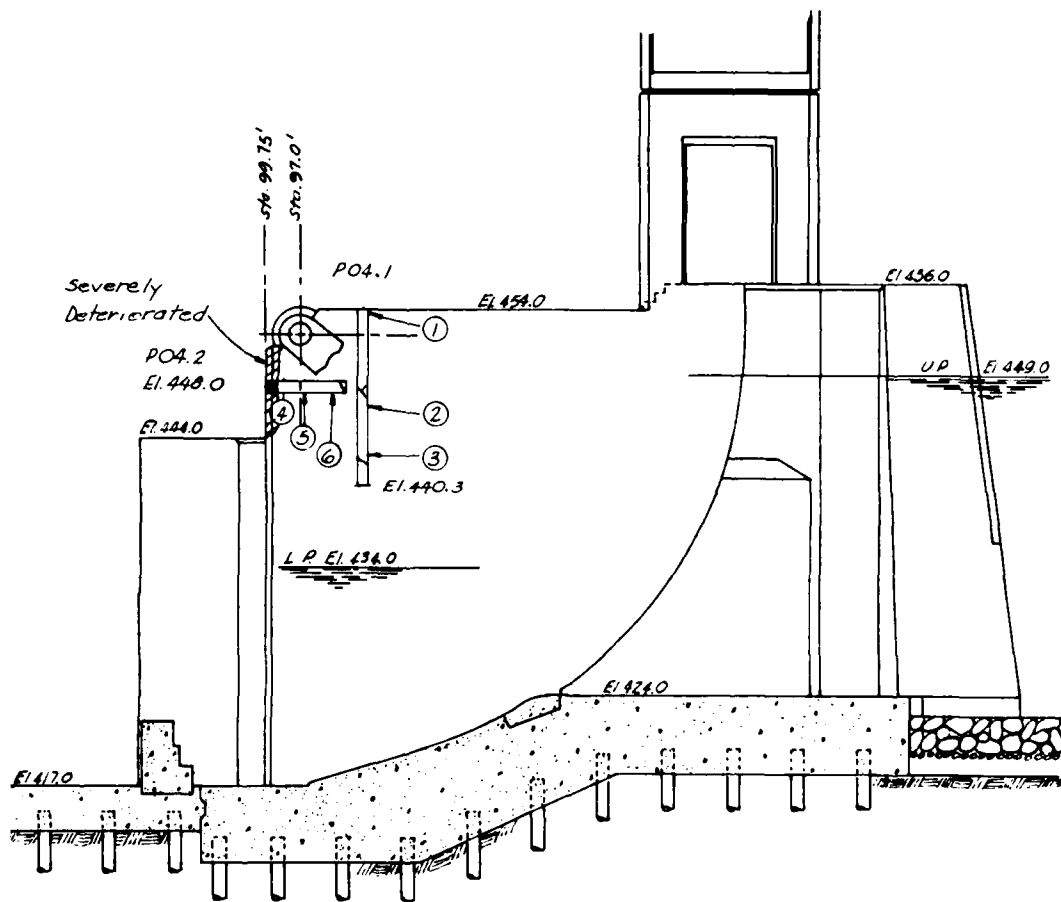
SEVERE

C 09.1S



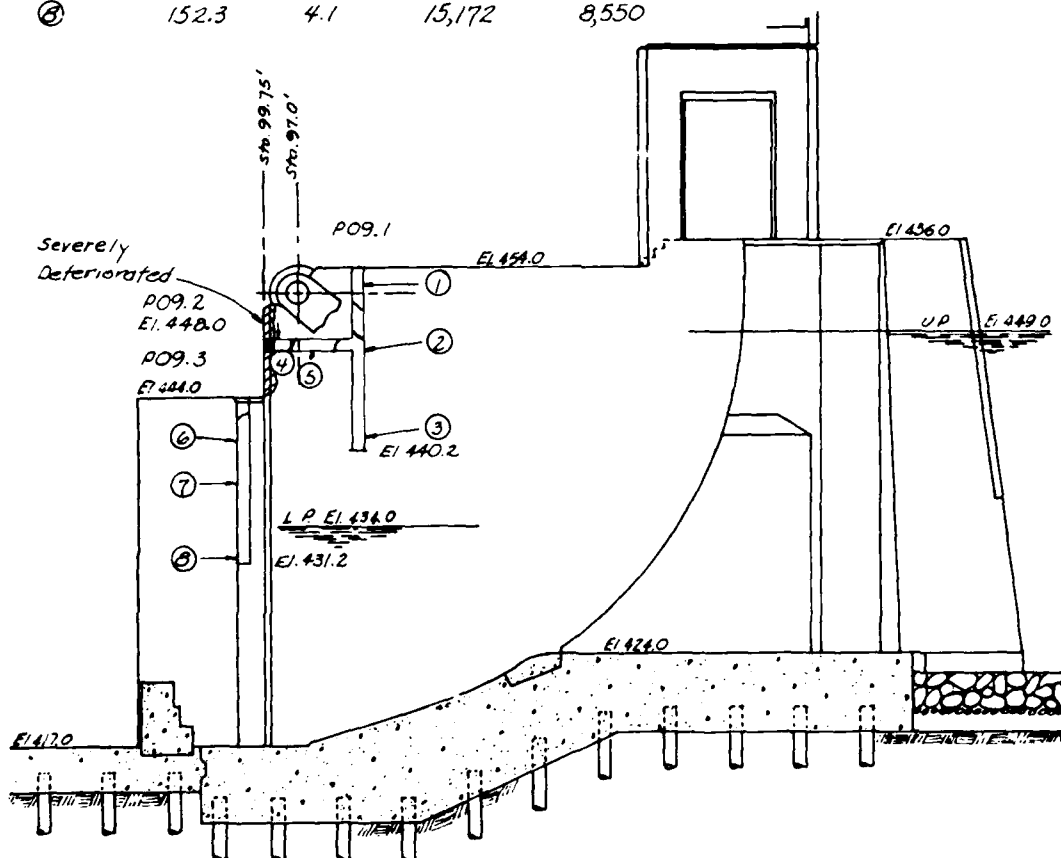
P 09.2
PIER

	γ $\frac{\text{lb}}{\text{ft}^3}$	w pcf	V_p $\frac{\text{ft}}{\text{ps}}$	q_u psi	E $\times 10^6 \text{ psi}$	ν
①	155.4	5.0	15,651	8,050		
②	153.5	4.7	15,873	10,410		
③	152.3	4.6	14,166	10,020	5.53	0.17
④	154.0	4.6	14,416	7,180	1.99	0.12
⑤	151.4	3.9	16,527	7,800		
⑥	152.4	4.6	16,639	6,970	6.03	0.18



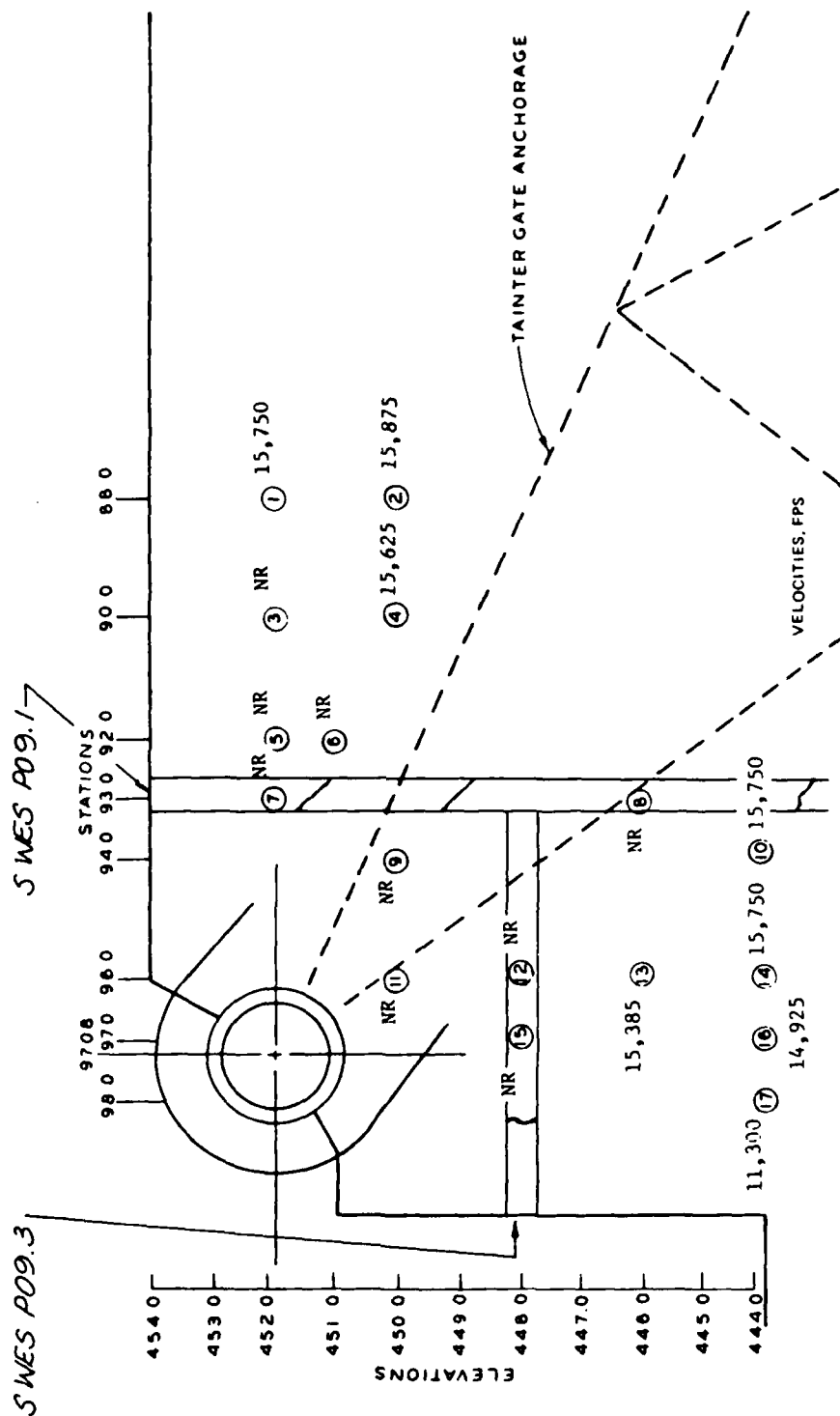
CROSS SECTION PIER #4

	γ <u>lb/ft³</u>	w <u>pcf</u>	V_p <u>fps</u>	q_u <u>psi</u>	E <u>$\times 10^6$ psi</u>	ν
①	152.3	4.5	13,715	6,830	2.98	0.13
②	152.3	4.7	15,037	7,910		
③	151.6	5.0	15,064	9,130	5.20	0.18
④	152.1	5.6	13,515	7,970	2.89	0.21
⑤	148.6	4.0	15,625	8,300	4.95	0.18
⑥	151.0	4.5	14,987	7,960		
⑦	154.3	5.2	15,024	9,010	5.34	0.18
⑧	152.3	4.1	15,172	8,550		

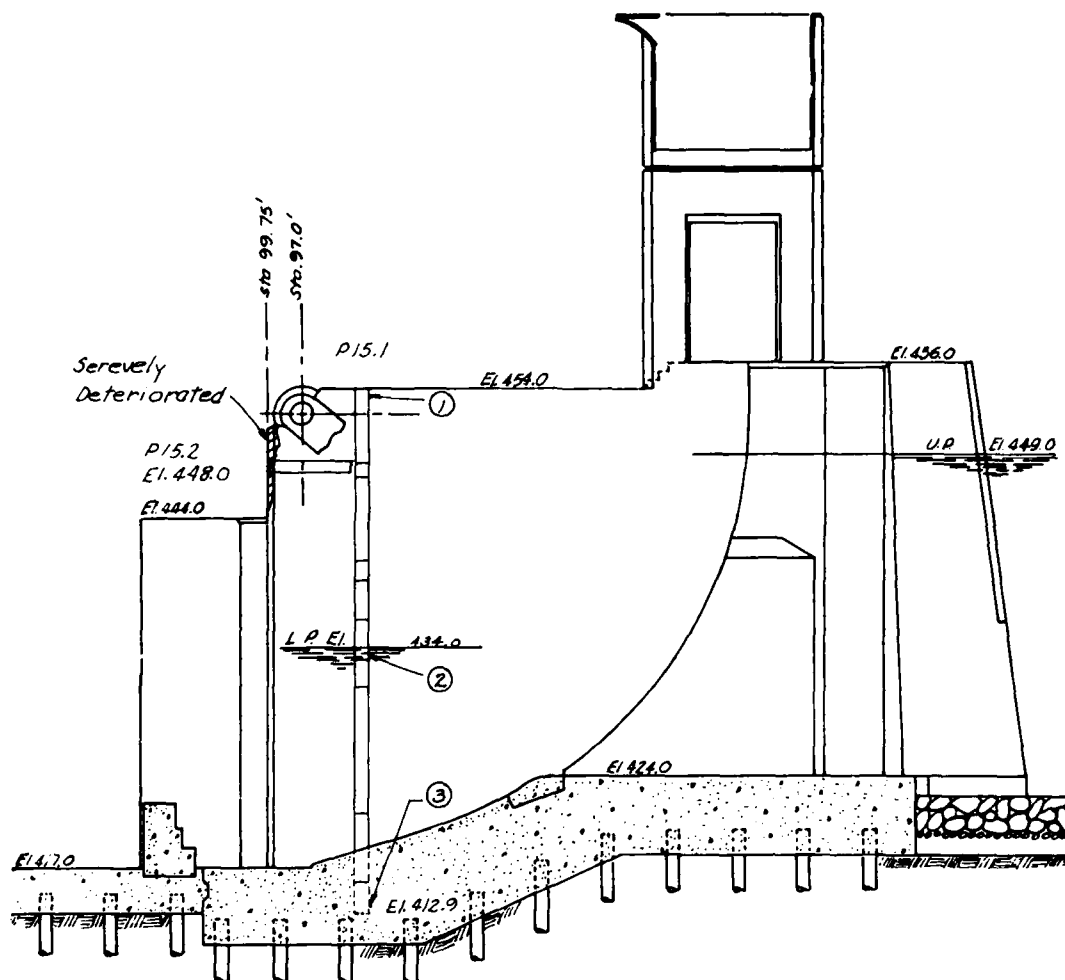


CROSS SECTION PIER #9

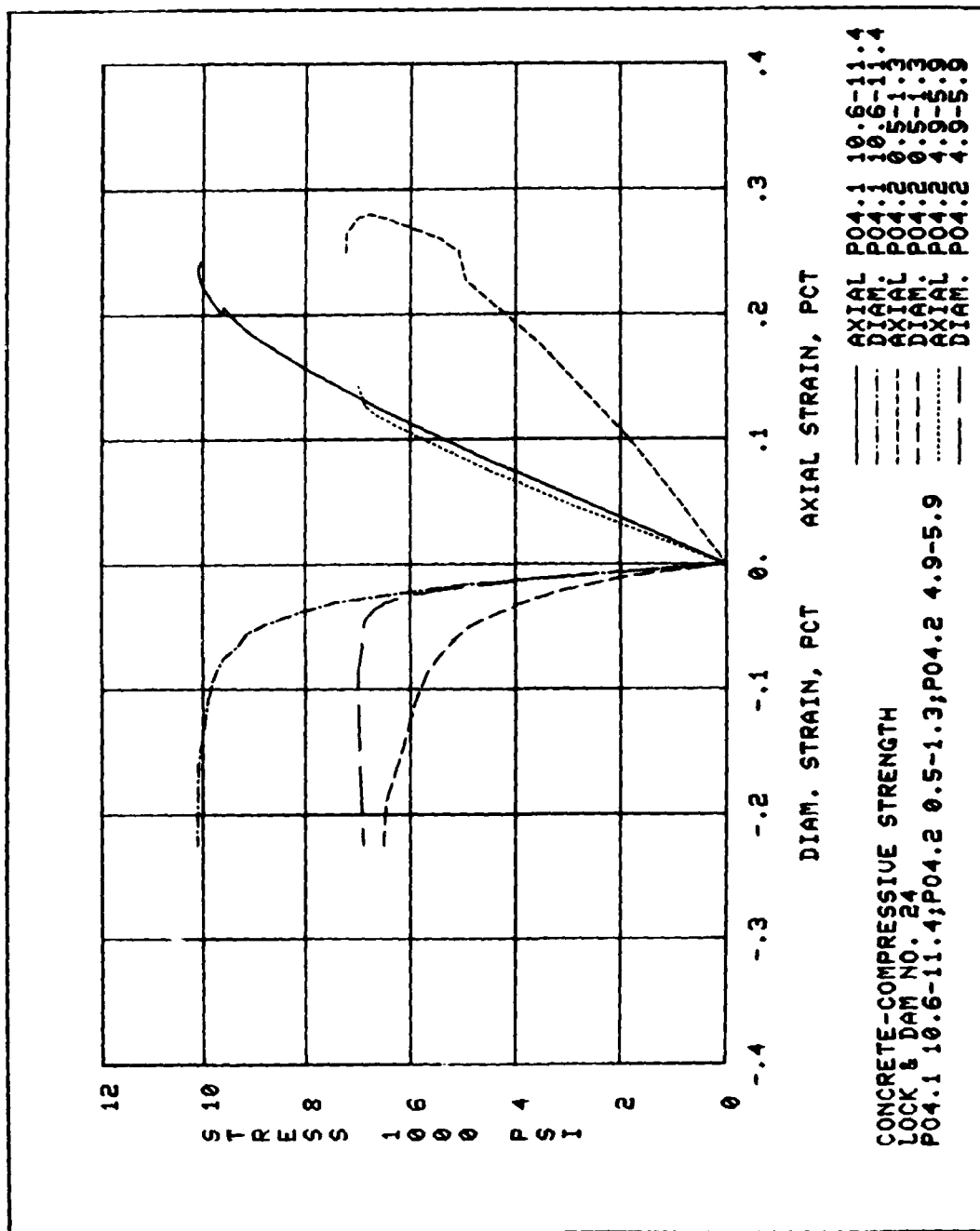
PIER NO. 9



	γ lb/ft ³	w pcf	V_p fps	q_u psi	E $\times 10^6$ psi	ν
①	151.0	6.0	14,404	5,840	2.80	0.14
②	151.6	4.2	15,126	8,380	5.84	0.22
③	151.0	4.3	15,625	7,000		



CROSS SECTION PIER #15



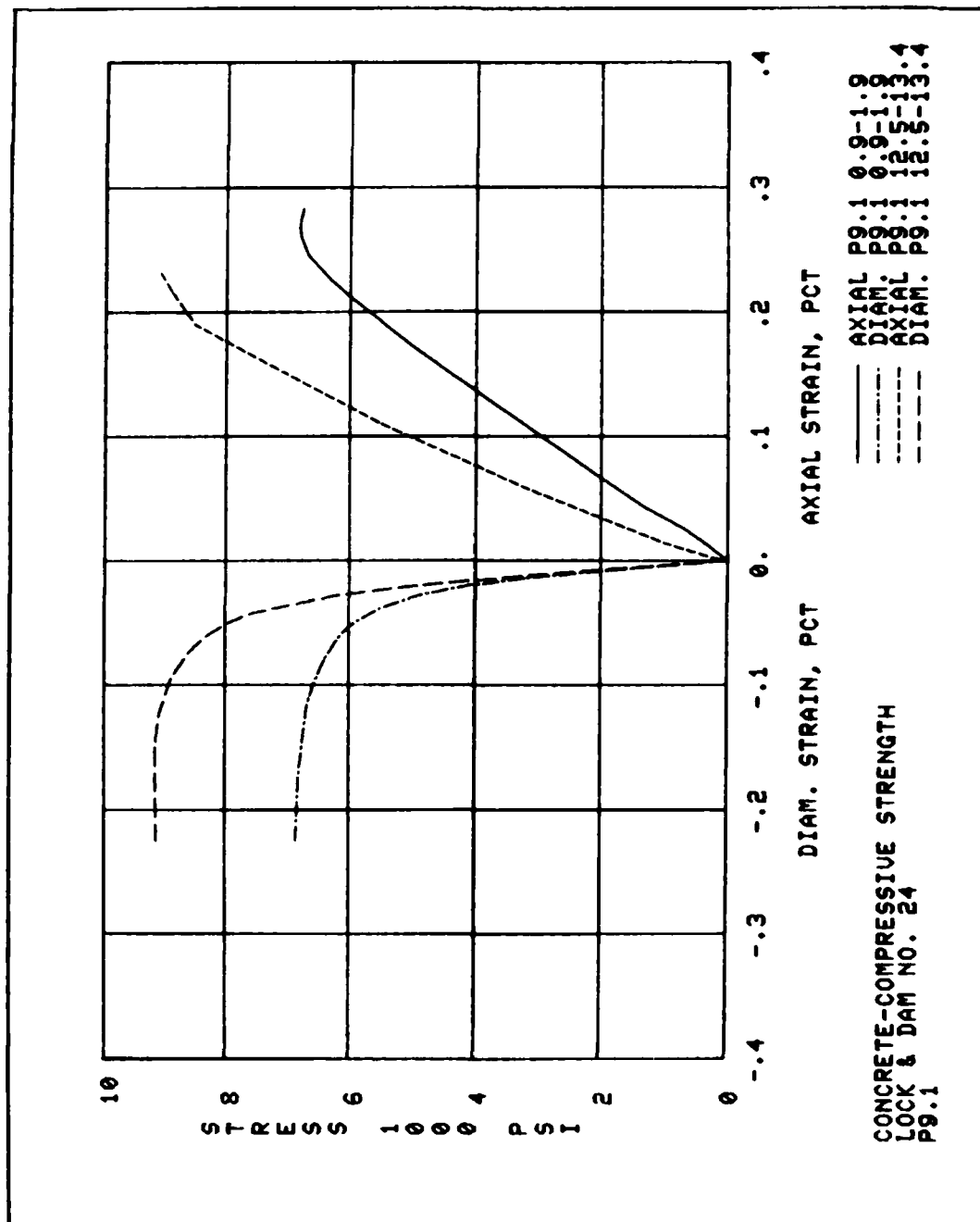
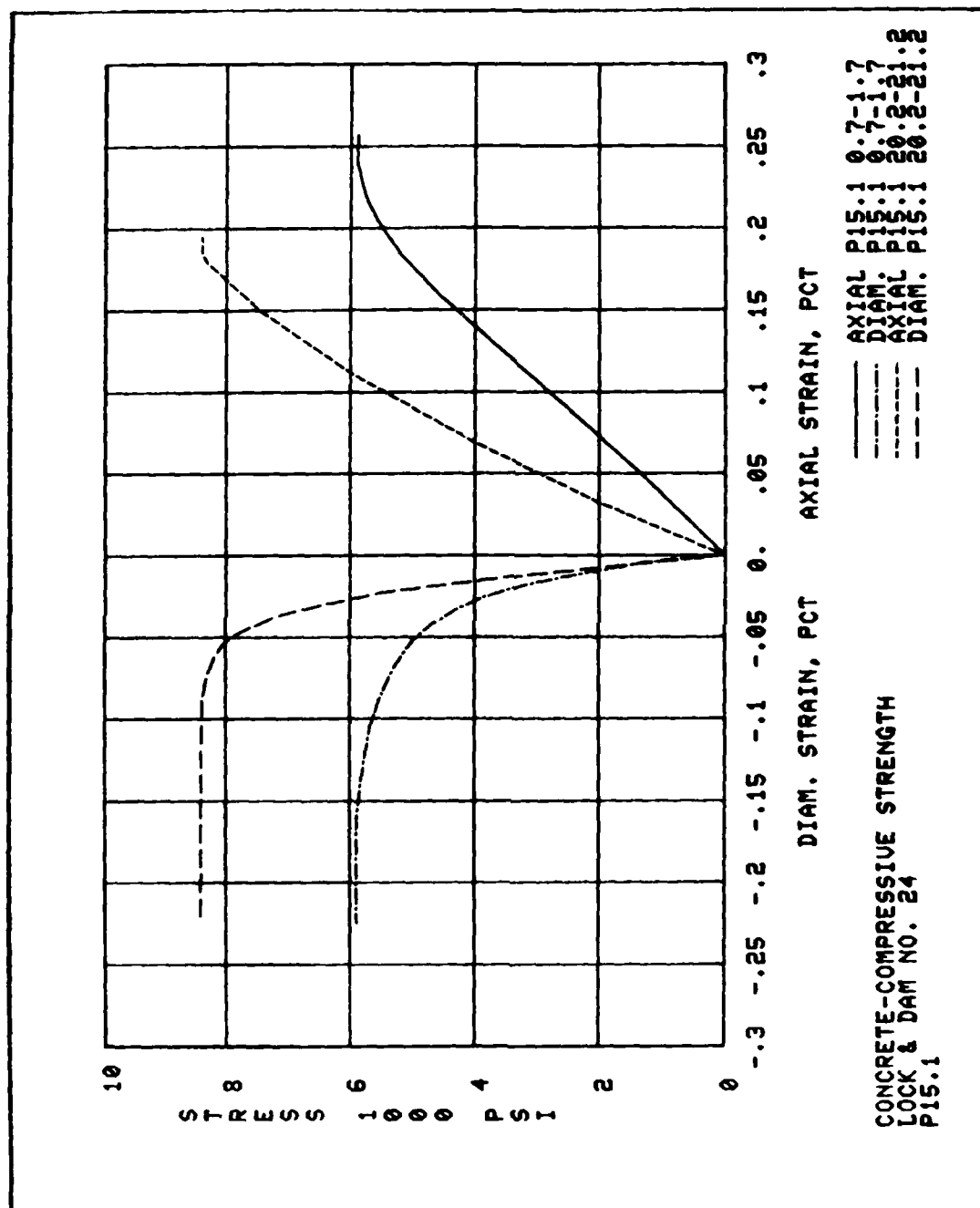
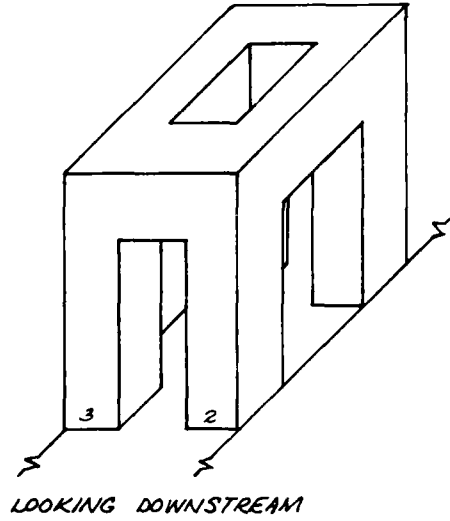
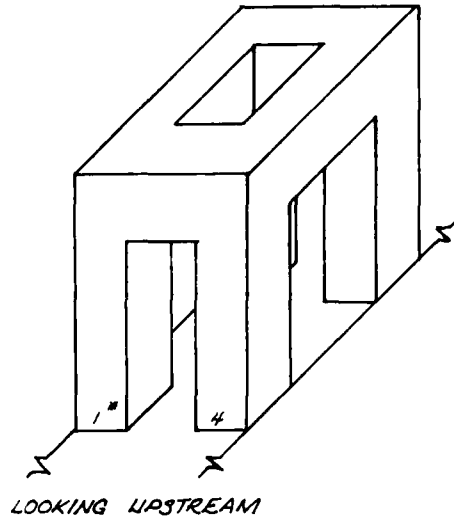


PLATE 16

PLATE 18



COLUMNS PIER #1



<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
<u>CONCRETE</u>	<u>NO.</u>	

<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

No damaged concrete, no core take
 * Column numbers

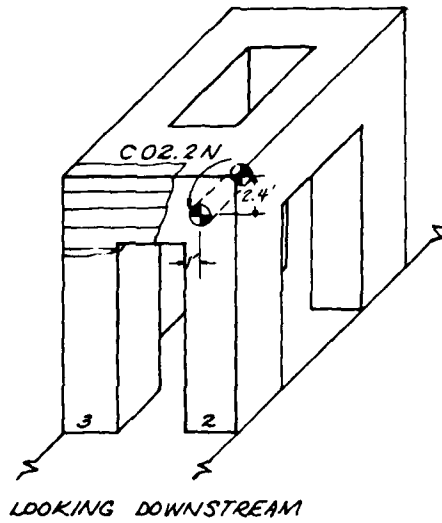
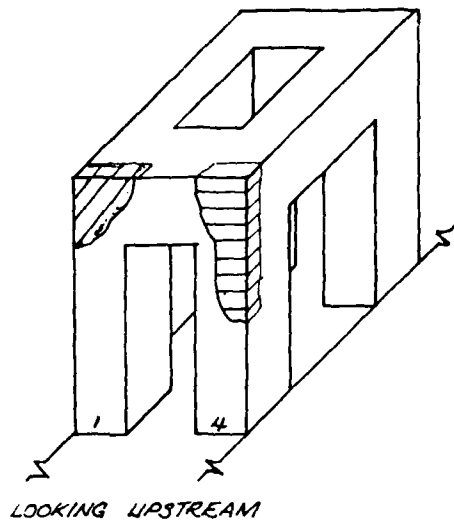
 OK

 MODERATE

 SEVERE

SCALE 1/8" = 1'

COLUMNS PIER #2



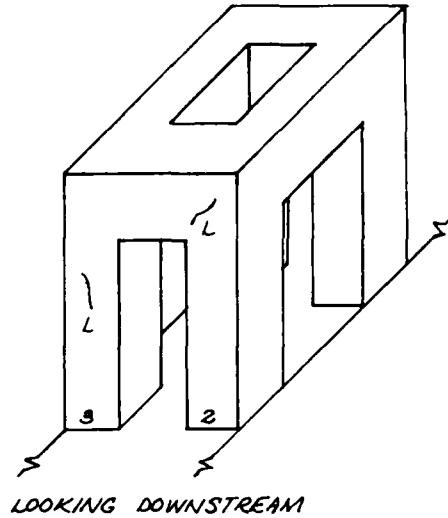
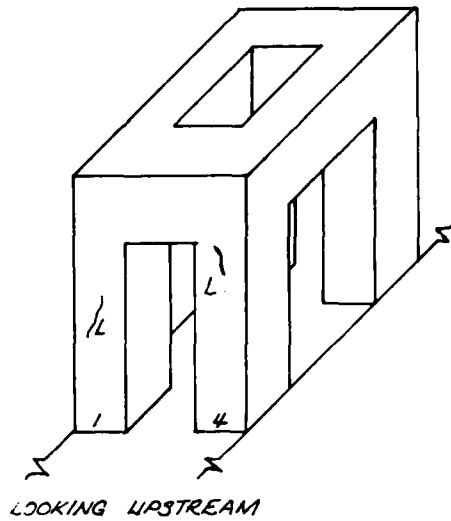
CLASS CONCRETE	CORE NO.	TEST
OK	C 02.2N	γ , lb/ft ³ W, pct Vp, fps q _u , psi

PHYSICAL PROPERTIES		
OUTSIDE	MIDDLE	BACKSIDE
	152.9	
	4.4	
	16,196	
	8,870	



SCALE 1/8" = 1'

COLUMNS PIER #3



<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
<u>CONCRETE</u>	<u>NO.</u>	

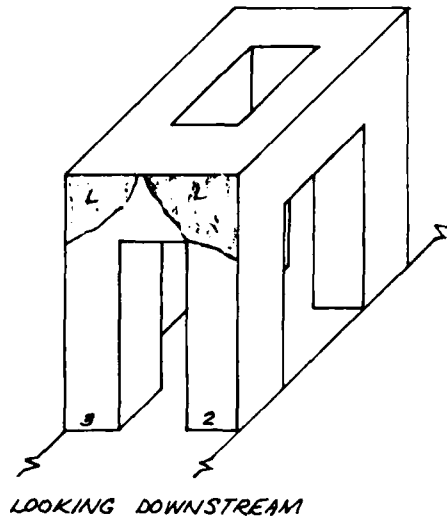
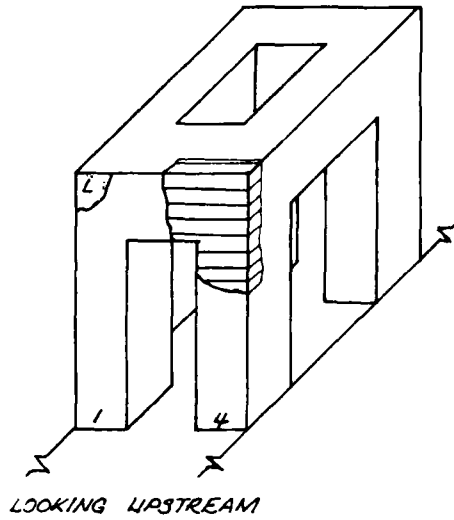
<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

Lt damage over columns, no core taken.

 LIGHT	 MODERATE	 SEVERE
---	--	--

SCALE 1/8" = 1'

COLUMNS PIER #4



CLASS	CORE	TEST
CONCRETE	NO.	

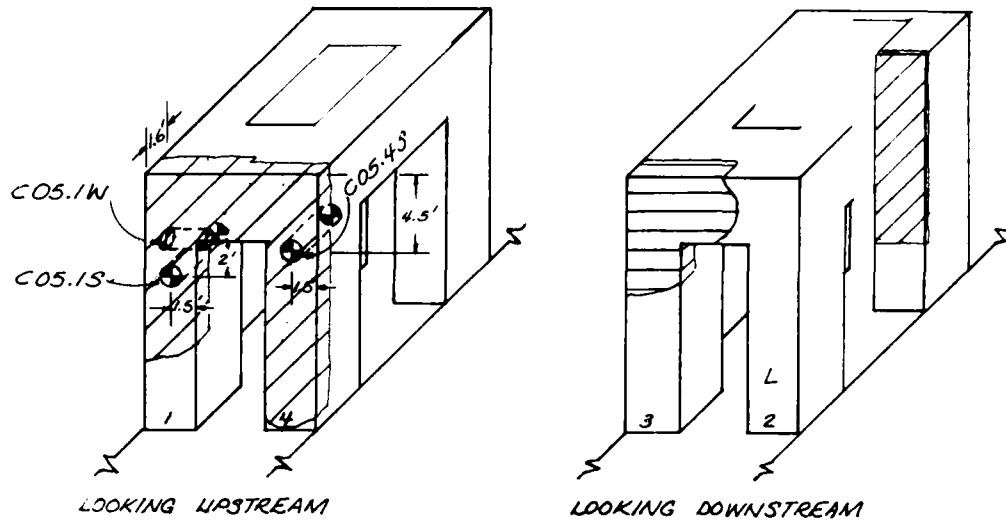
PHYSICAL PROPERTIES		
OUTSIDE	MIDDLE	BACKSIDE

No core taken.

 LIGHT	 MODERATE	 SEVERE
---	--	--

SCALE 1/8" = 1'

COLUMNS PIER #5

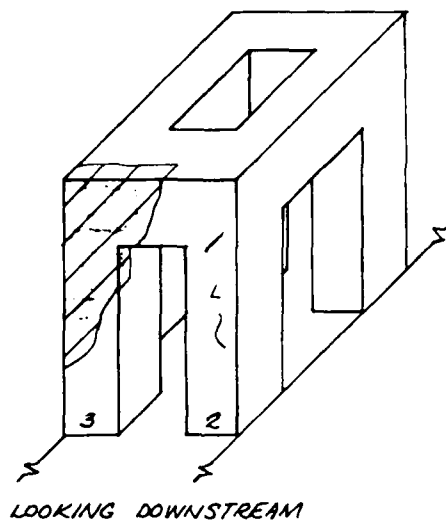
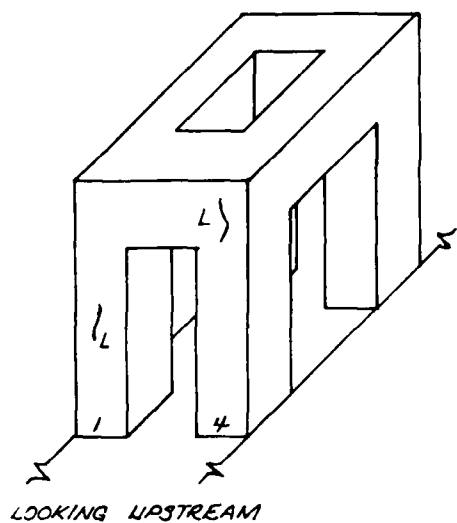


CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES		
			OUTSIDE	MIDDLE	BACKSIDE
SEV	COS.1S	γ , lb/cu ft	148.7	150.0	154.6
		w, pct	5.6	5.1	5.0
		v _p , fps	4,602	14,303	9,093
		q _u , psi	3,860	5,380	5,750
		E, x10 ⁶ psi	0.24	0.88	
SEV	COS.4S	γ , lb/cu ft			147.8
		w, pct			5.4
		v _p , fps			10,707
		q _u , psi			3,570
		E, x10 ⁶ psi			0.36
SEV	COS.1W	No tests			

L LIGHT
 MODERATE
 SEVERE

SCALE 1/8" = 1'

COLUMNS PIER #6



CLASS	CORE	TEST
CONCRETE	NO.	

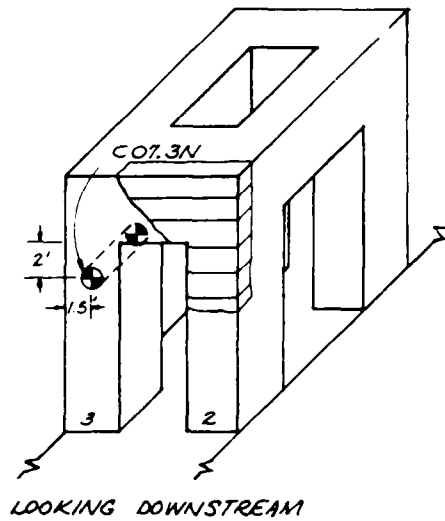
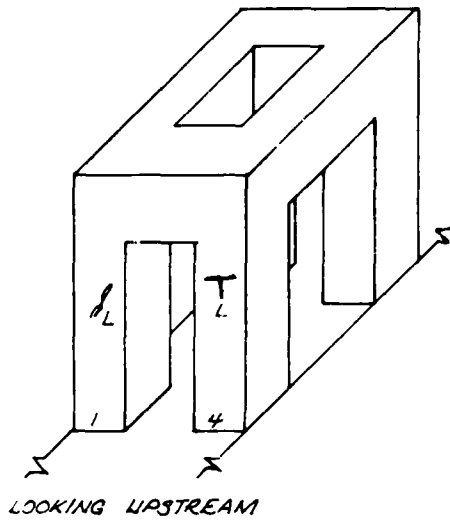
PHYSICAL PROPERTIES		
OUTSIDE	MIDDLE	BACKSIDE

Lf. damage over columns 1, 2 & 4. No core taken.

L LIGHT	MODERATE	SEVERE
--	--	---

SCALE 1/8" = 1'

COLUMNS PIER #7



<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
<u>CONCRETE</u>	<u>NO.</u>	
OK	C07.3N	No tests

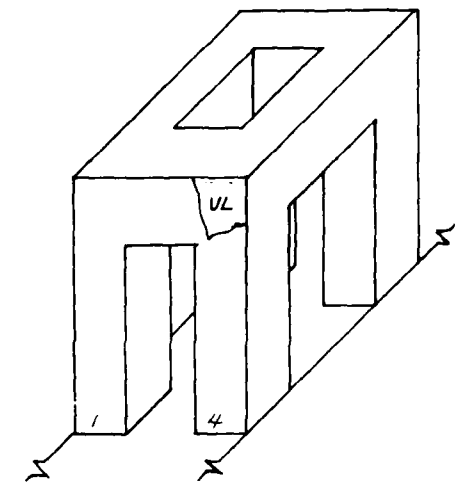
<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

Lt. damage over columns 1 & 4

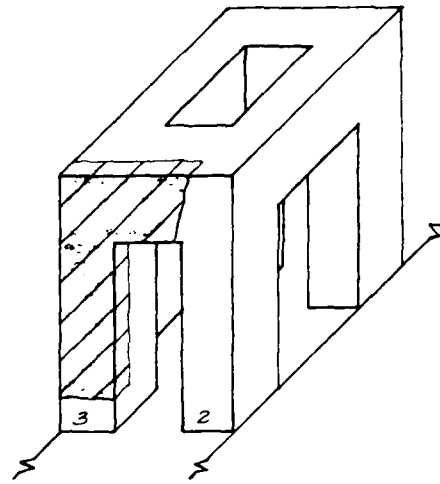


SCALE 1/8" = 1'

COLUMNS PIER #8



LOOKING UPSTREAM



LOOKING DOWNSTREAM

<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
CONCRETE	NO.	

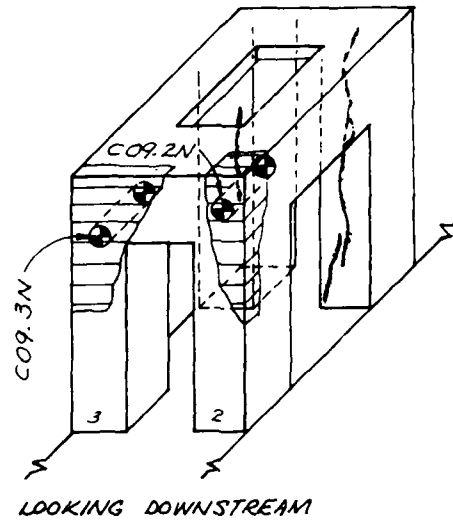
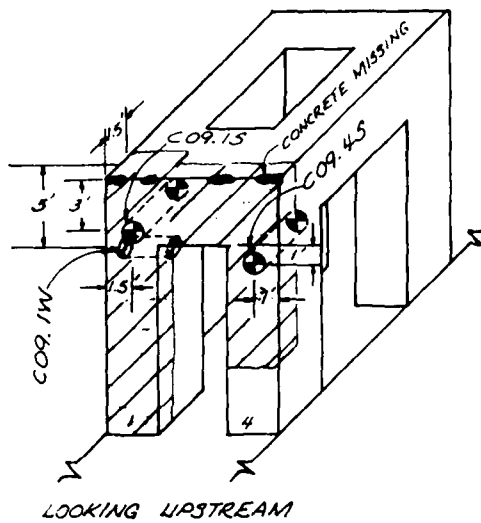
<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

Very light damage over column 4

VL	VERY LIGHT		MODERATE	\\	SEVERE
--	------------	---	----------	--	--------

SCALE 1/8" = 1'

COLUMNS PIER #9



			<u>PHYSICAL PROPERTIES</u>		
<u>CLASS</u> <u>CONCRETE</u>	<u>CORE</u> <u>NO.</u>	<u>TEST</u>	<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>
SEV	CO9.1S	$\gamma, lb/ft^3$	149.1	149.5	
		w, pct	6.0	6.4	
		V_p, f_{ps}	5,781	11,721	
		q_u, psi	2,880	3,080	
		$E, \times 10^6 psi$	0.18	0.63	
MOD	CO9.3N	$\gamma, lb/ft^3$	160.8	150.8	
		w, pct	5.7	4.8	
		V_p, f_{ps}	11,050	12,725	
		q_u, psi	6,680	7,040	
		$E, \times 10^6 psi$	1.72	2.42	
		ν	0.17	0.14	
SEV	CO9.4S	$\gamma, lb/ft^3$	150.1	146.5	
		w, pct	6.2	5.5	
		V_p, f_{ps}	8,924	10,709	
		q_u, psi	2,070	4,280	
		$E, \times 10^6 psi$	0.25	0.38	



STRUCTURAL
CRACK



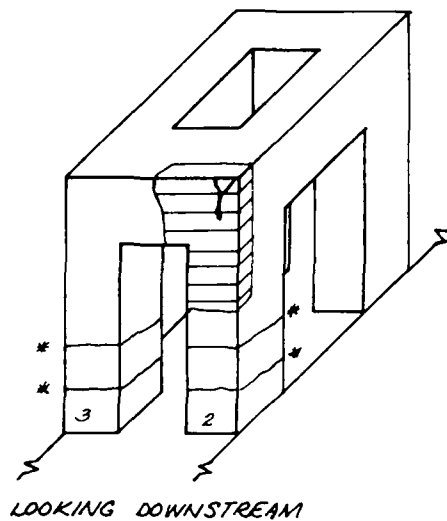
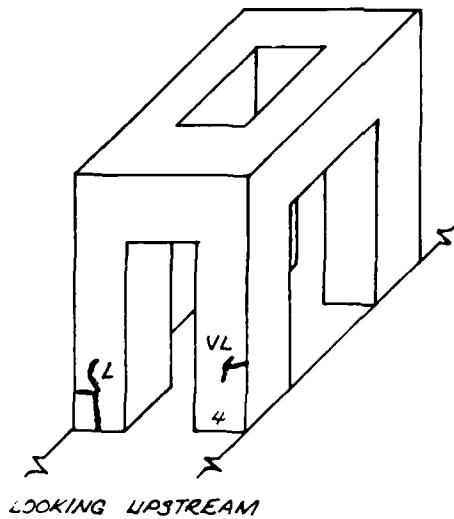
MODERATE



SEVERE

SCALE 1/8" = 1'

COLUMNS PIER #10



CLASS	CORE	TEST
CONCRETE	NO.	

PHYSICAL PROPERTIES		
OUTSIDE	MIDDLE	BACKSIDE

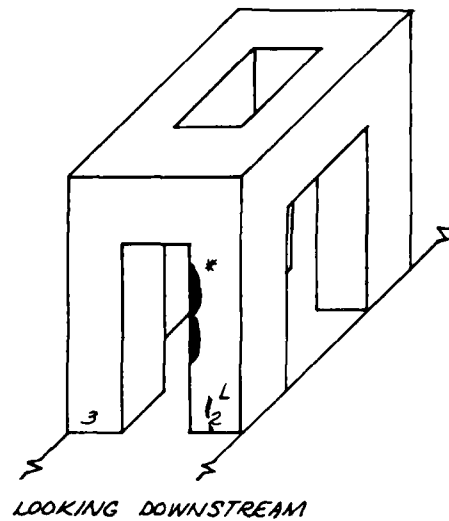
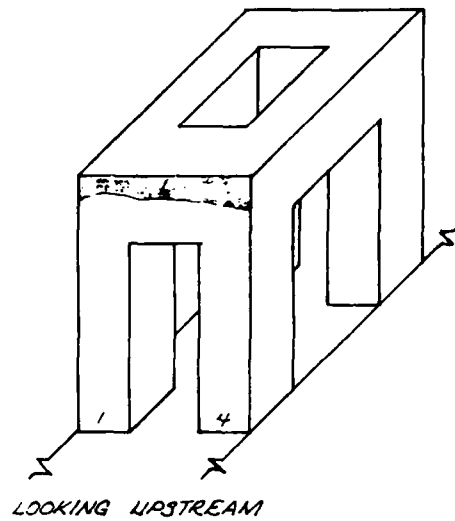
No core taken
Very light column 4; light column 1.

* CRACKS CAUSED BY BARGE IMPACT, EPOXY FILLED.

VL	VERY LIGHT		MODERATE	///	SEVERE
L	LIGHT				

SCALE 1/8" = 1'

COLUMNS PIER #11



<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
<u>CONCRETE</u>	<u>NO.</u>	

<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

No core taken.

* Slight honeycombing, no exudation.



LIGHT



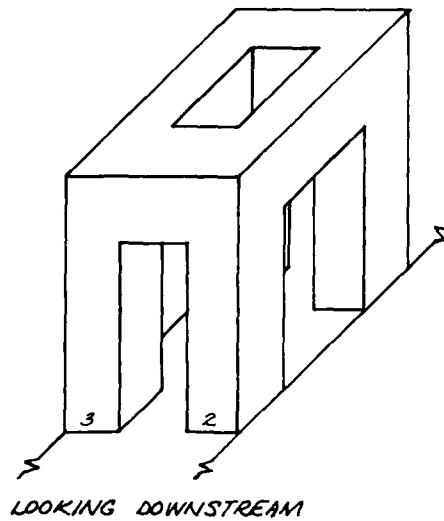
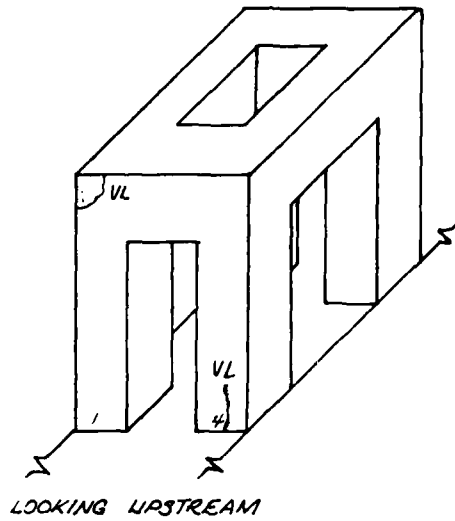
MODERATE



SEVERE

SCALE 1/8" = 1'

COLUMNS PIER #12



<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
CONCRETE	NO.	

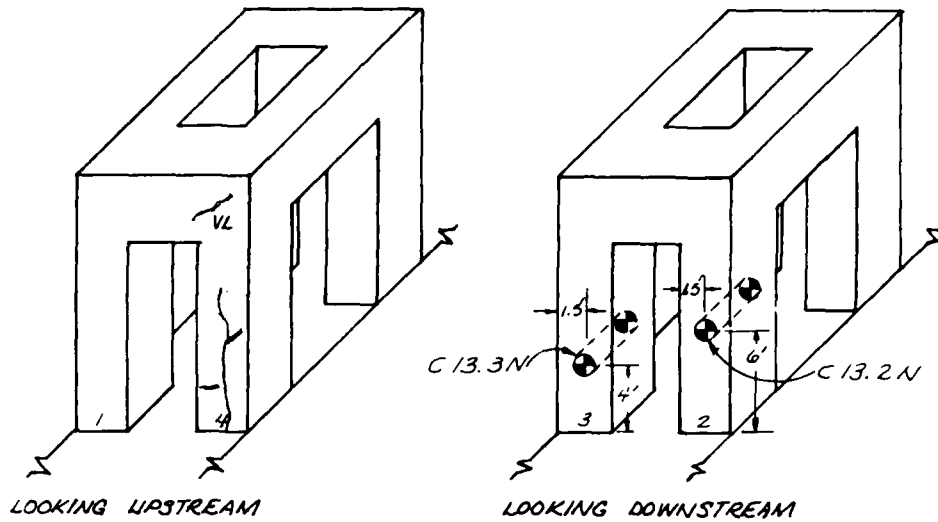
<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

No core taken
 Lt damage columns 1 & 4.

VL	VERY LIGHT		MODERATE		SEVERE
---	------------	--	----------	---	--------

SCALE 1/8" = 1'

COLUMNS PIER #13



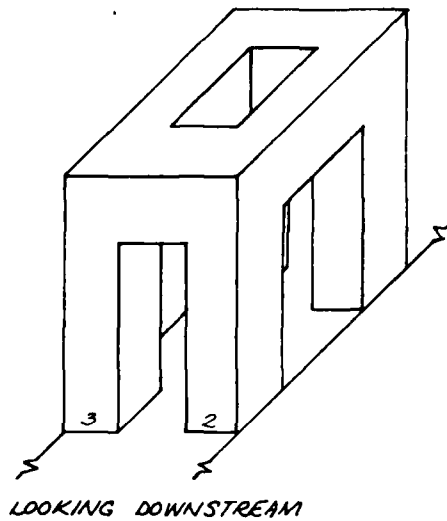
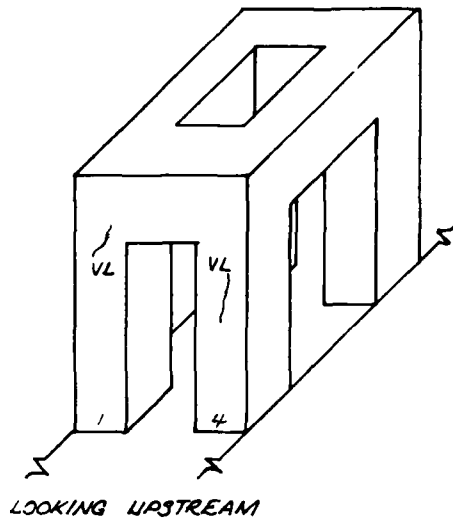
<u>CLASS</u> <u>CONCRETE</u>	<u>CORE</u> <u>NO.</u>	<u>TEST</u>
OK	C13.3N	γ , lb/ft ³
		w, pct
		Vp, fps
		QU, psi
		E, $\times 10^6$ psi
		ν

<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>
157.5	152.2	158.4
4.8	4.4	4.4
15,333	15,134	15,073
9,770	9,280	10,310
5.04	5.55	5.34
0.25	0.19	0.18

VL VERY LIGHT
 MODERATE
 SEVERE

SCALE 1/8" = 1'

COLUMNS PIER #14



CLASS	CORE	TEST
CONCRETE	NO.	

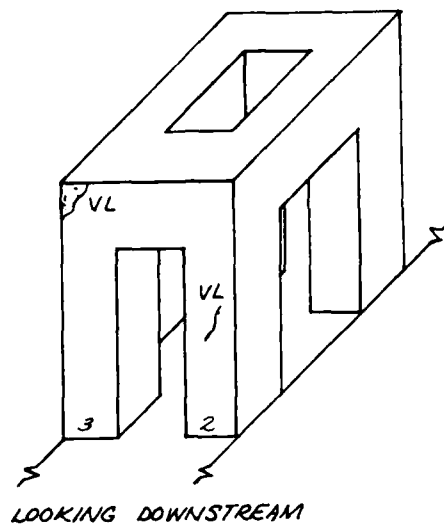
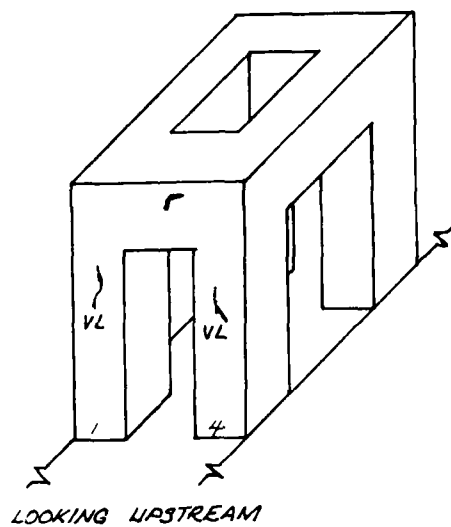
PHYSICAL PROPERTIES		
OUTSIDE	MIDDLE	BACKSIDE

No core taken.
Very light Columns 1 & 4.

VL	VERY LIGHT		MODERATE	///	SEVERE
--	------------	---	----------	---	--------

SCALE 1/8" = 1'

COLUMNS PIER #15



<u>CLASS</u>	<u>CORE</u>	<u>TEST</u>
CONCRETE	NO.	

<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>

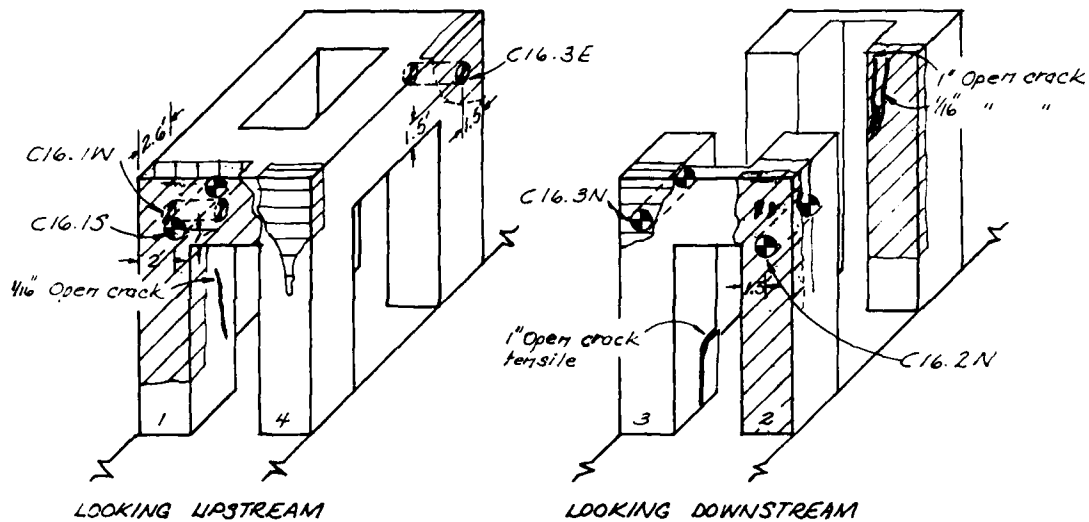
No core taken.

All columns very light damage to concrete.

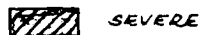
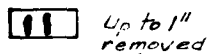
VL	VERY LIGHT	≡	MODERATE	▨	SEVERE
--	------------	---	----------	---	--------

SCALE 1/8" = 1'

COLUMNS PIER #16

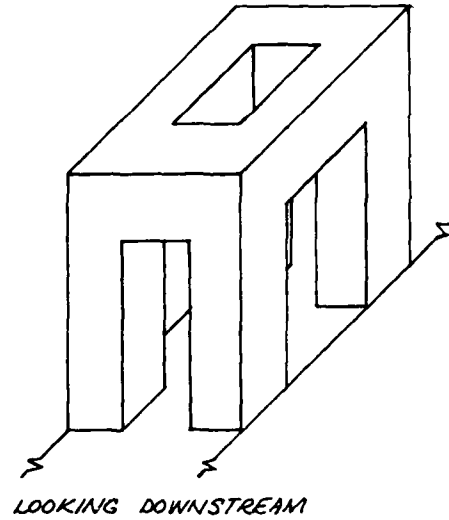
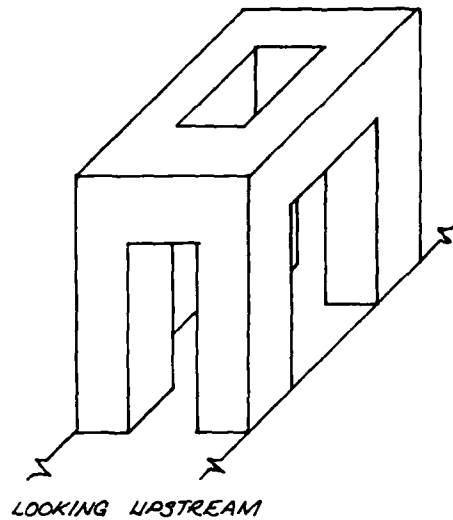


CLASS CONCRETE	CORE NO.	TEST	PHYSICAL PROPERTIES		
			OUTSIDE	MIDDLE	BACKSIDE
SEV	C16.1S	γ , lb/ft ³	154.0	154.3	149.6
		w, pct	5.3	4.4	5.7
		V_p , fps	2,774	11,111	9,385
		q_u , psi	2,240	6,050	2,010
		E , $\times 10^6$ psi	0.18	1.50	0.20
		ν		0.18	
SEV	C16.1W	γ , lb/ft ³	160.3		
		w, pct	4.9		
		q_u , psi	5,450		
SEV	C16.2N	No tests due to breaks and repairs.			
MOD	C16.3E	γ , lb/ft ³		154.7	
		w, pct		5.1	
		V_p , fps		14,178	
		q_u , psi		6,720	



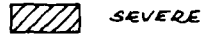
SCALE 1/8" = 1'

COLUMNS PIER #16 (CONT.)



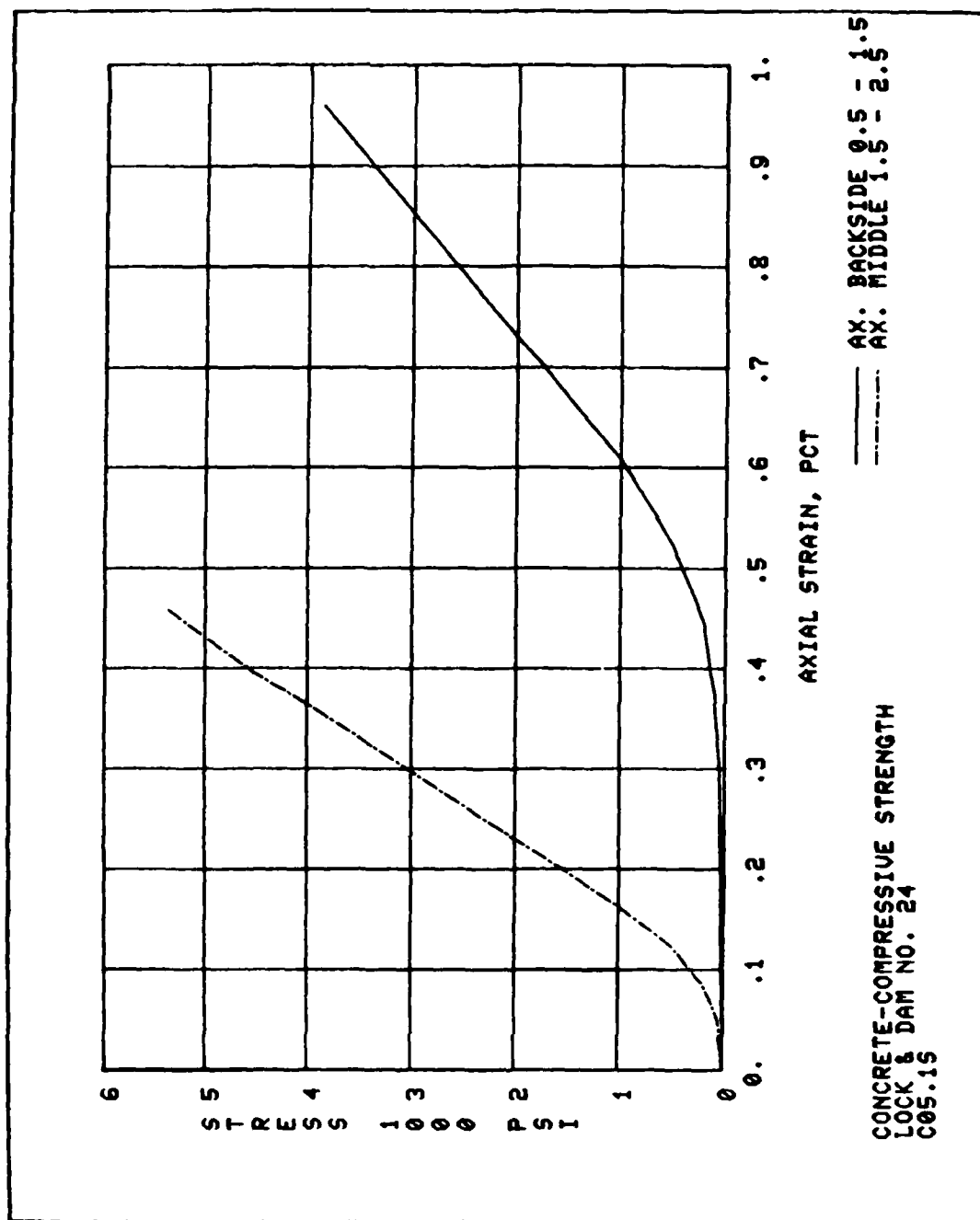
<u>CLASS</u> <u>CONCRETE</u>	<u>CORE</u> <u>NO.</u>	<u>TEST</u>
MOD	C16.3N	$\gamma, lb/ft^3$ w, pct v_p, fps q_u, psi $E, \times 10^6 psi$ ν

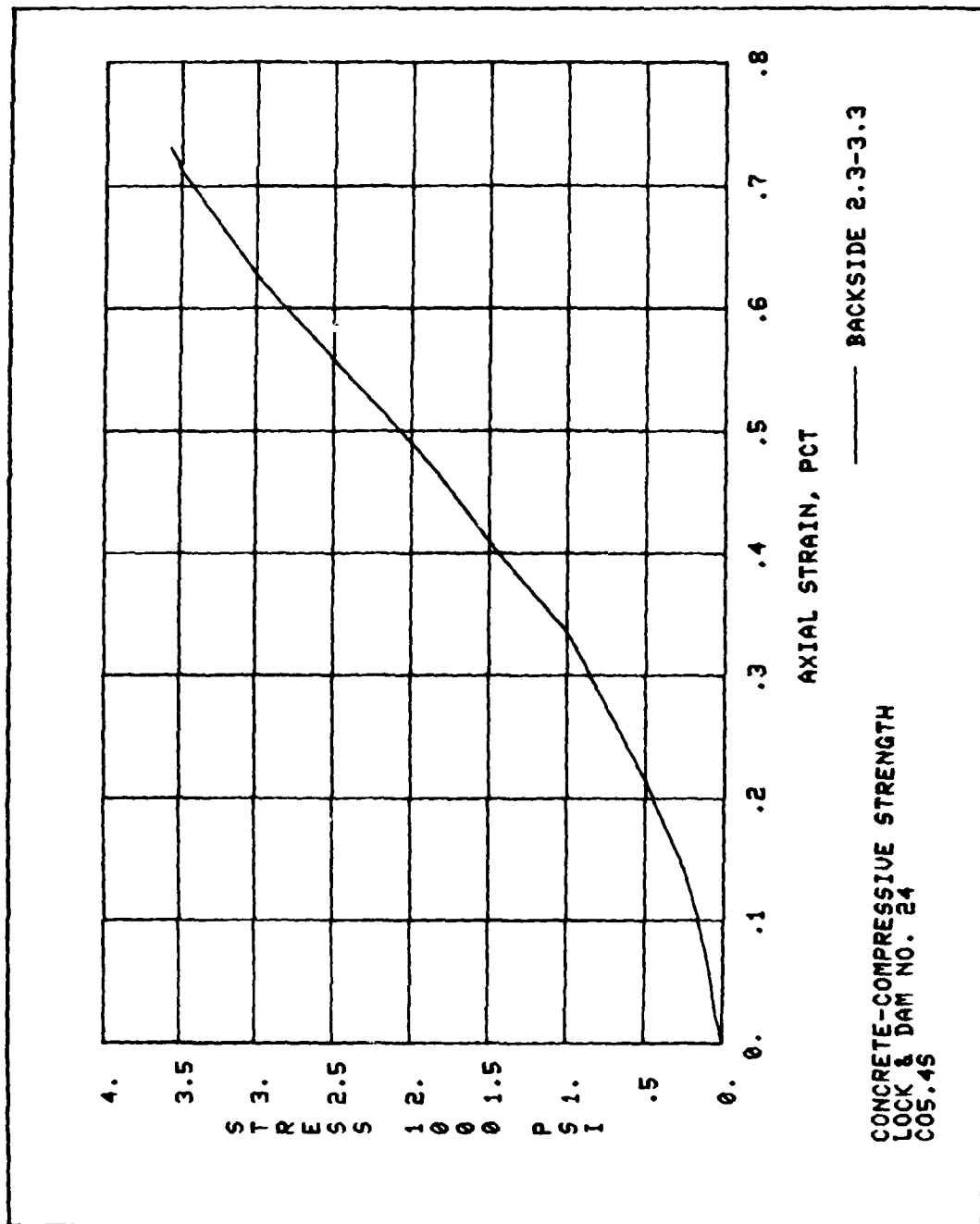
<u>PHYSICAL PROPERTIES</u>		
<u>OUTSIDE</u>	<u>MIDDLE</u>	<u>BACKSIDE</u>
154.8	152.6	
5.0	5.6	
10,757	13,555	
6,490	8,250	
1.42	3.52	
0.14	0.18	

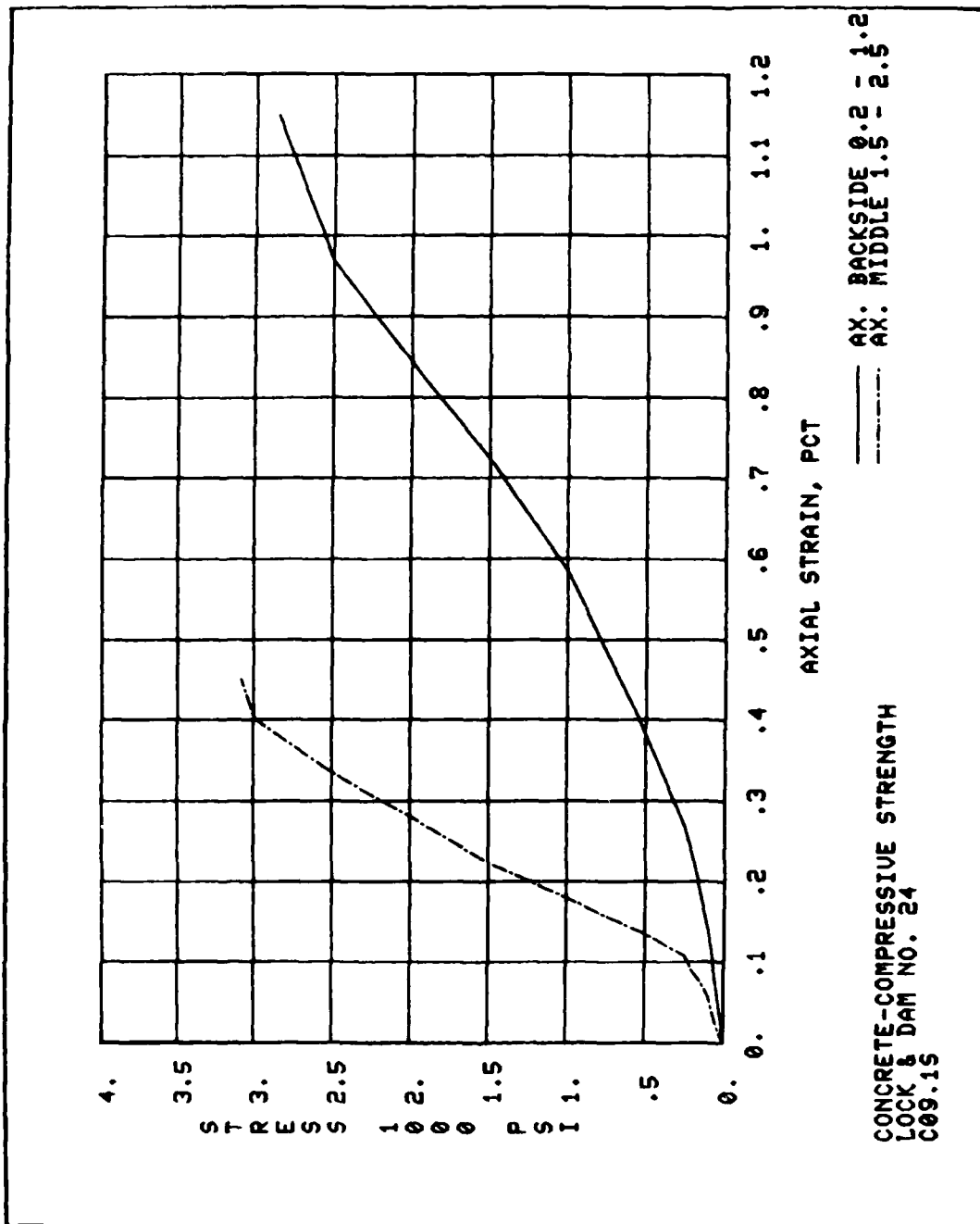


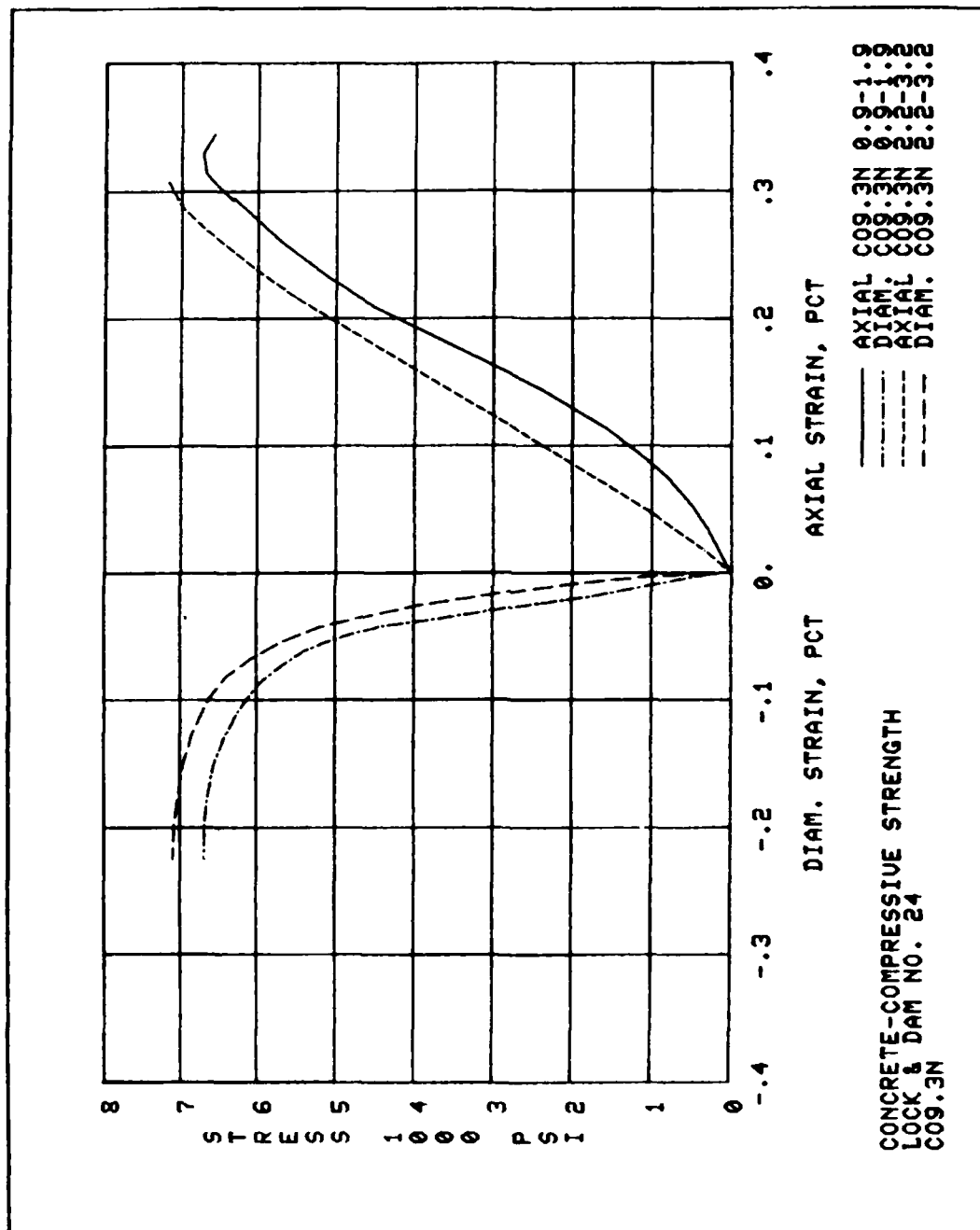
SCALE 1/8" = 1'

PLATE 36









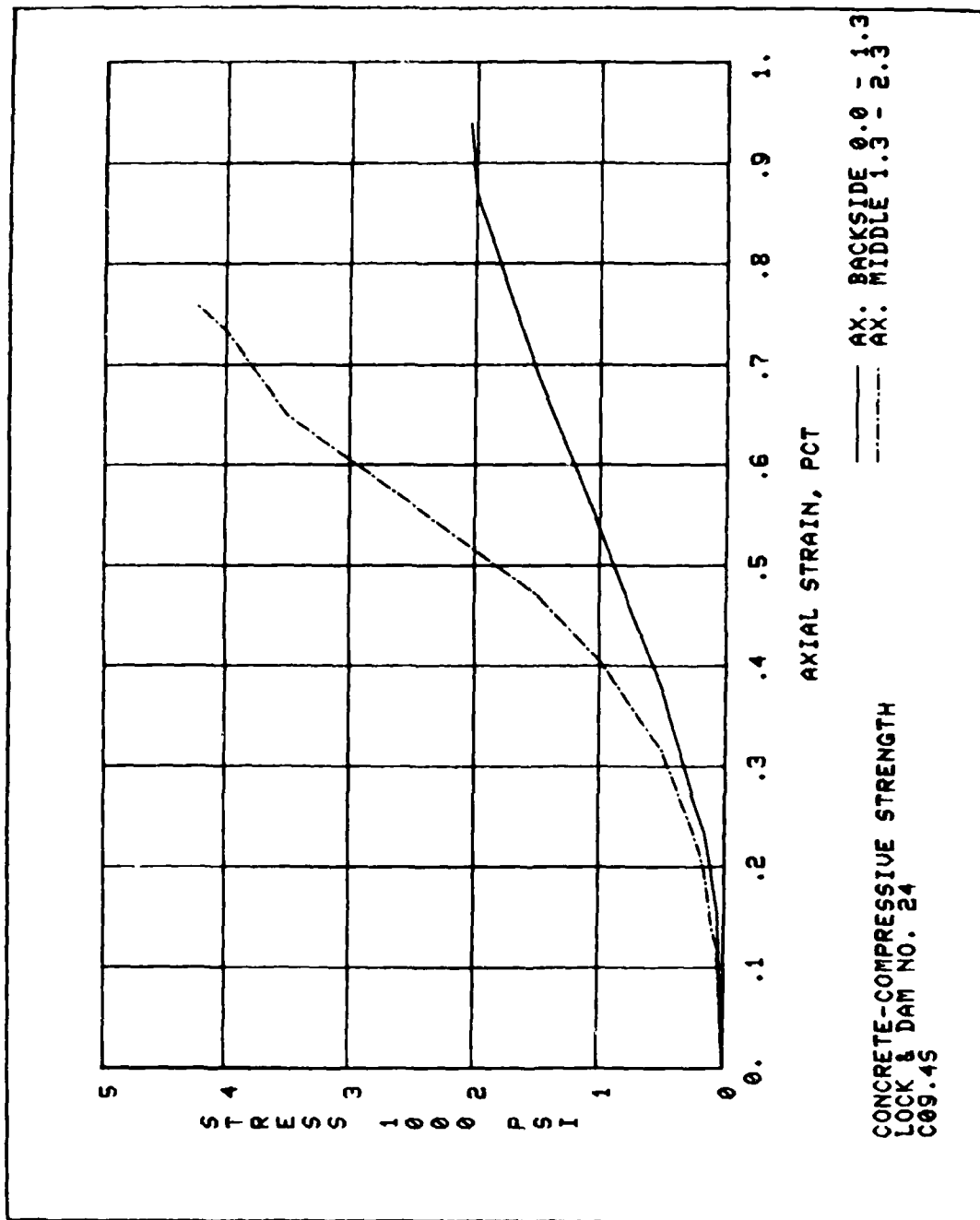
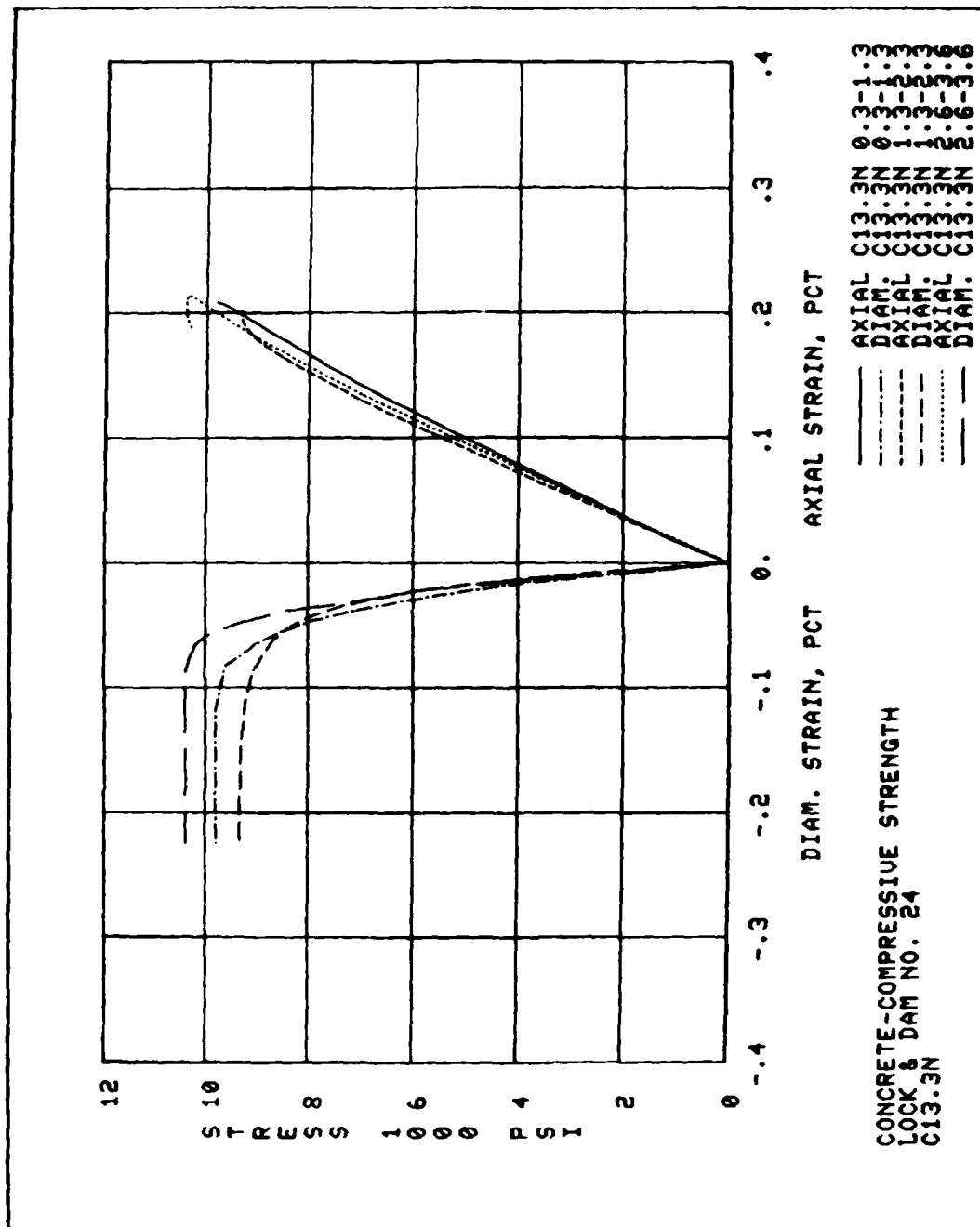
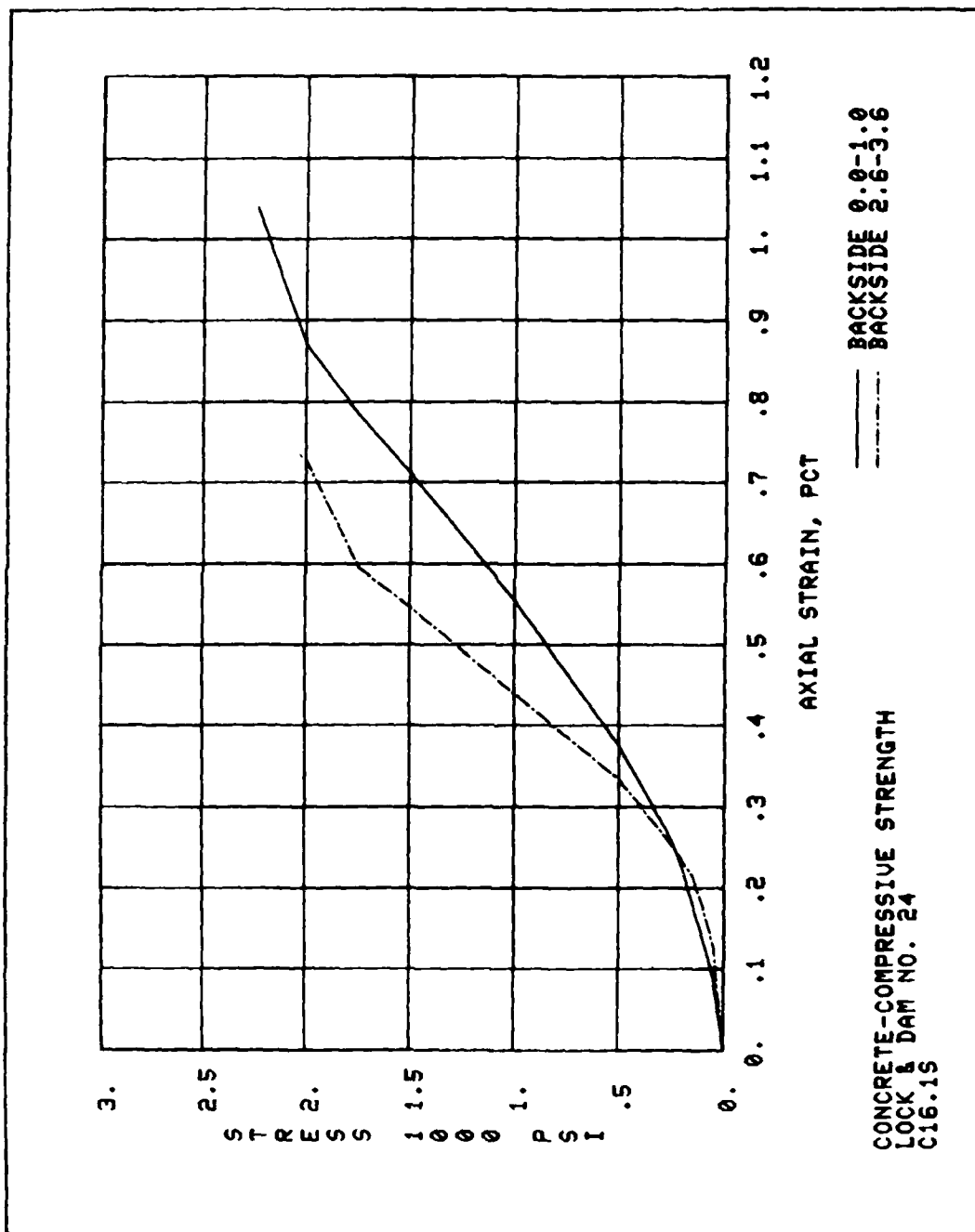
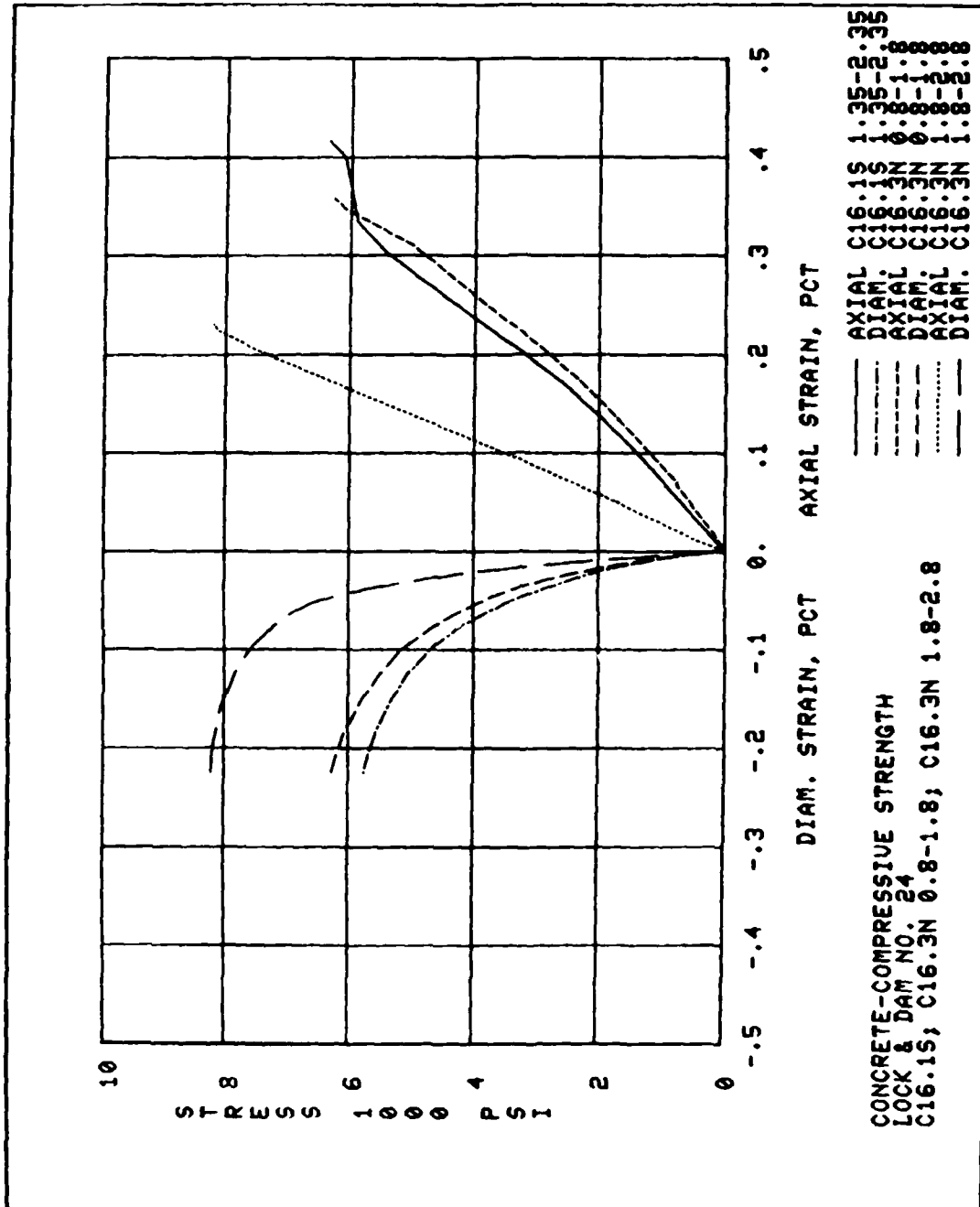


PLATE 40

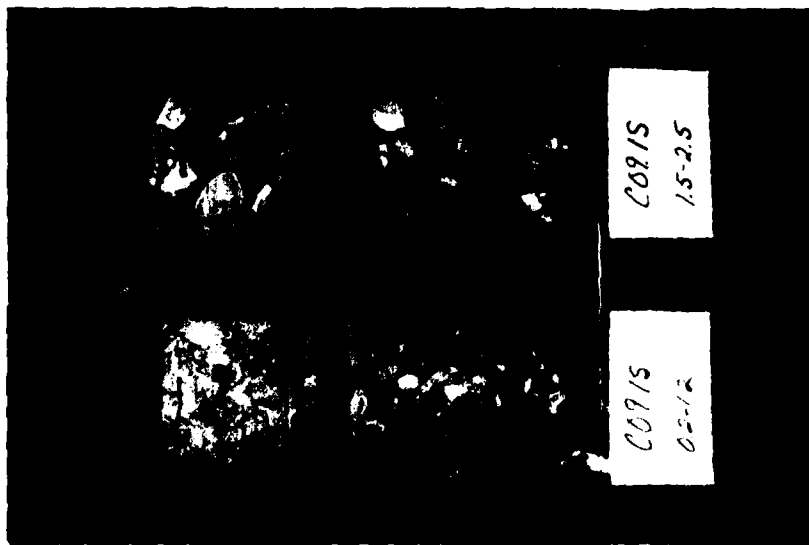








Photographs showing damaged and undamaged concrete cores selected for compressive strength testing; SEES C05.1S and SEES C05.4S



Photographs of damaged concrete cores selected for compressive strength testing;
SWES C09.1S and SWES C09.4S



Photograph of SWES C16.1S showing damaged concrete core
representing the outside and backside of column No. 1
on pier 16

APPENDIX A: TYPICAL PHOTOGRAPHS
SHOWING DAMAGED CONCRETE

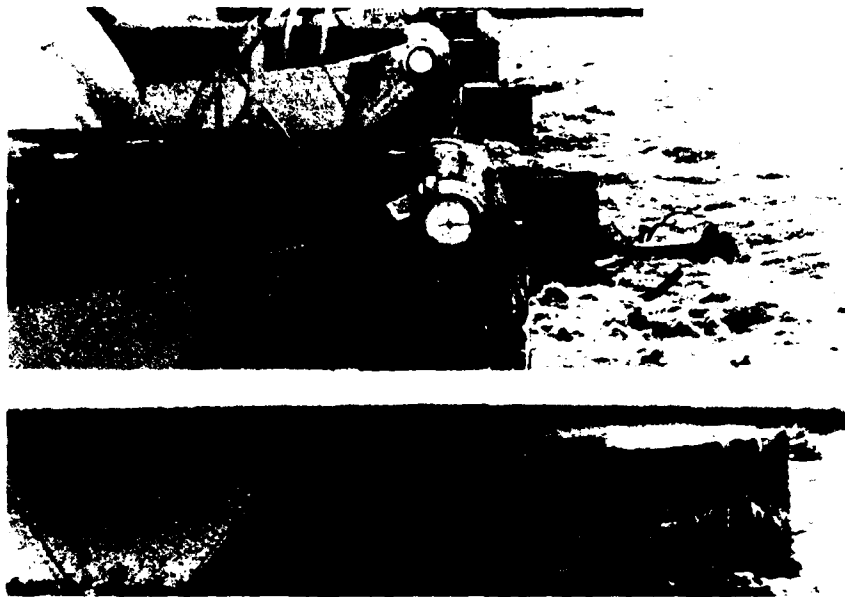


Photo 1. Looking across dam from pier No. 1. Typical cracking pattern with exudation downstream of trunnion pin, pier No. 2



Photo 2. Looking upstream from pier No. 1. Moderately deteriorated concrete on service bridge support column, pier No. 2



Photo 3. Looking at downstream faces of service bridge support columns, pier No. 9. Typical crack pattern and exudation of severe deterioration



Photo 4. Looking downstream on left dam abutment pier No. 16



Photo 5. Looking downstream, left dam abutment pier No. 16. Structural crack high on downstream column. Crack ± 1 -in. wide



Photo 6. Looking downstream, left dam abutment pier No. 16. Structural crack low on upstream column diagonal to column shown in Photo 5



Photo 7. Close up of crack shown in Photo 6. Note large aggregates as well as concrete matrix is fractured

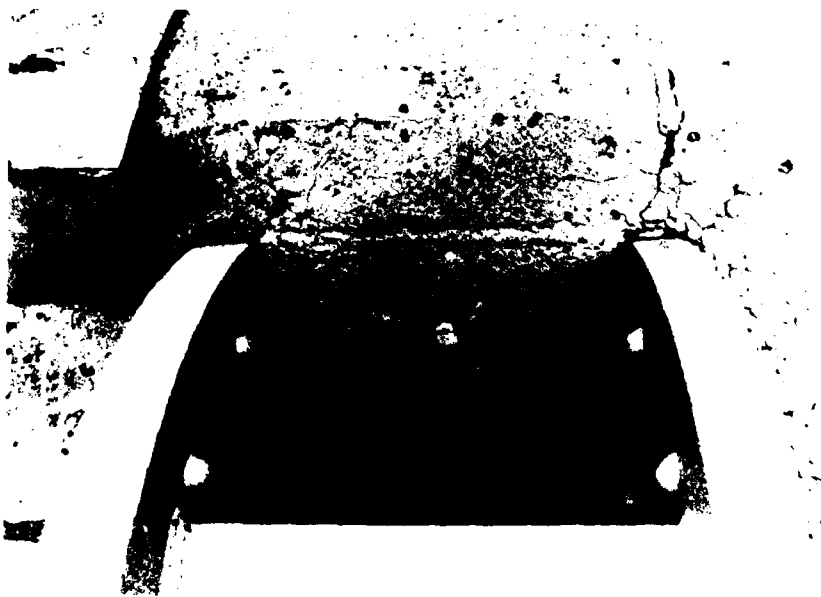


Photo 8. Looking upstream at trunnion shaft area. Typical crack pattern where anchorage collars extend from concrete



Photo 9. Looking upstream at trunnion shaft area. Note wetted area of concrete next to anchorage collar



Photo 10. Looking downstream at trunnion shaft area. Portions of anchorage steel and reinforcing steel exposed by excavating the surrounding concrete



Photo 11. Close up of trunnion shaft anchorage collar,
note minor rusted collar steel



Photo 12. Excavation carried deeper. Note minor rusting
on anchorage collar steel and cross member steel plate

ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG--ETC F/6 13/2
CONDITION SURVEY, REPAIR AND REHABILITATION, LOCK AND DAM NUMBE--ETC(U)
AUG 81 R L STOWE, H T THORNTON
WES/MP/SL-81-21 NL

NIL

AD Δ
10 = 6.63

END
DATE
FILMED
11-8
PTIC

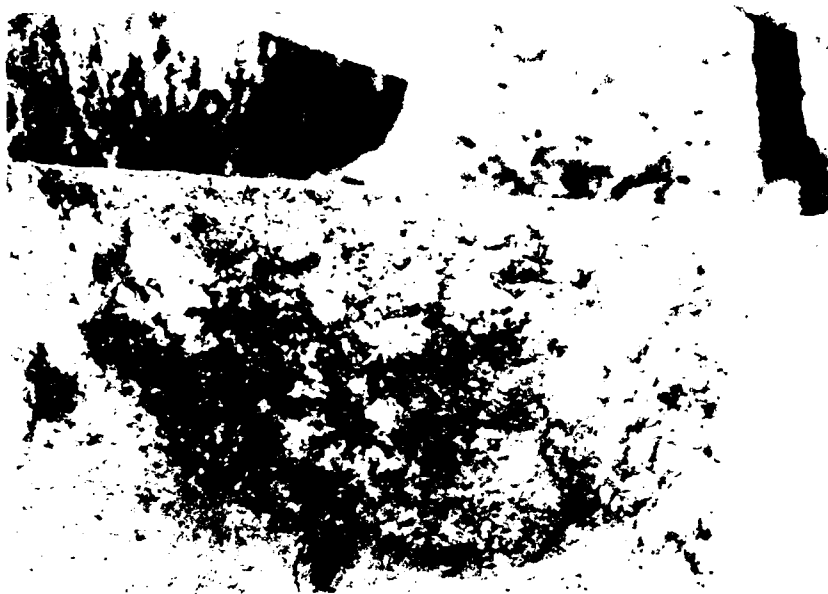


Photo 13. Looking upstream at cross member steel plate in foreground and anchorage collar in the background partially uncovered

APPENDIX B: FIELD CORE LOGS

Hole No. SAES-C16.75-80

DRILLING LOG		INSTALLATION	
PROJECT <u>St. Louis, Mo</u>		LOG AND DATA No. <u>24</u>	
LOG No. <u>24</u>		10. SIZE AND TYPE OF BIT <u>6" SEC BELOW</u>	
LOCATION (Continuation of Station)		11. DEPTH FOR ELEVATION SHOWN (Top or Bottom)	
<u>SEE BELOW</u>		<u>NISL</u>	
1. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL	
<u>CH-16-S</u>		<u>ELECTRIC RIG - CONG DRILL</u>	
2. HOLE NO. (As shown on drawing title)		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	
<u>SAES-C16.75-80</u>			
3. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES	
<u>H. McNamee</u>		<u>ONE</u>	
4. DIRECTION OF HOLE		15. ELEVATION GROUND WATER	
☐ VERTICAL ☒ INCLINED <u>90°</u> DEG FROM VERT.			
5. THICKNESS OF OVERBURDEN		16. DATE HOLE	
		<u>20 NOVEMBER 80</u> ☒ STARTED ☐ COMPLETED	
6. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE	
<u>30'</u>		<u>469.0</u>	
7. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING	
		<u>100%</u>	
		19. SIGNATURE OF INSPECTOR	
		<u>[Signature]</u>	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Describe in detail)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water level, depth of penetration, etc., if significant)
4690	10	CRACKS - CLOSED NB				Run No. 1 20 Nov 80 RL — Run 30 Begad 1000 Rec 30 End 1113 Loss — Time 75min Gals — Drl time 20min Hyd press — Water pressure — RE: 3000 Drl Action Suppl — Water ret — Bore — Remarks —
4690	10	Δ	CONCRETE	100%	Box 1	
4690	20	Δ				
4690	30	Δ	Run No. 1 ROD = 88 3/4"	3.0		
CONCRETE PHYSICAL PROPERTIES SAME - CONCRETE IS IN FAIR CONDITION. UPPER FOOT IS WEATHERED WITH HAIRLINE CRACKS AND MODERATE REACTION PRODUCT —						

DIAMOND Bit No

81PC120
81PC169

LEGEND

Δ - CONCRETE
 □ - HAIRLINE CRACK
 NB. - NATURAL BREAK
 MB. - MACHINE BREAK

LOCATION

PIER No. 16
 1.5'
 COLUMN 4
 COLUMN 3
 VIEW LOOKING WEST

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
1. PROJECT		ST. LOUIS, MO		LOCE + Dam #24		2 OF 2 SHEETS	
2. LOCATION (Coordinates or Station)				11. DATE FOR ELEVATION BROWN (YEN = MSL)			
3. DRILLING AGENCY				12. MANUFACTURER'S DESIGNATION OF DRILL			
4. HOLE NO. (As shown on drawing title and site number)				13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN		DISTURBED UNDISTURBED	
5. NAME OF DRILLER				14. TOTAL NUMBER CORE BOXES			
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED DEG. FROM VERT.				15. ELEVATION GROUND WATER			
7. THICKNESS OF OVERBURDEN				16. DATE HOLE		STARTED COMPLETED	
8. DEPTH DRILLED INTO ROCK				17. ELEVATION TOP OF HOLE			
9. TOTAL DEPTH OF HOLE				18. TOTAL CORE RECOVERY FOR BORING		1	
				19. SIGNATURE OF INSPECTOR			
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	SCORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)	
4490	100	Δ	RUN #5 RRD-100%			Run #5	Run 1.65
		Δ				Run 4.00	Reo 1.65
		Δ				End 5.20	Loss
		Δ				Time 6.00	Gain
4430	110	Δ				Dr time 8.00	
		Δ				Hyd press 300	
		Δ				Water press	
		Δ				SP 75	
		Δ				Dr Action Smooth	
		Δ				Water ret	
		Δ				Remarks	
4420	120	Δ	NB 1/4" - NEARLY - BLACK DISCOLORATION ON THE SURFACE OF BREAK - OILY APPEARANCE AND SMELL	100%	Box 3		
		Δ				Run #6	Run 1.65
		Δ				Run 3.1	Reo 3.1
		Δ				End 7.30	Loss
		Δ				Time 11.45	Gain
		Δ				Time 2.00	Gain
		Δ				Dr time 2.00	
		Δ				Hyd press 300	
		Δ				Water press	
		Δ				SP 75	
		Δ				Dr Action Smooth	
		Δ				Water ret	
		Δ				Remarks	
4410	130	Δ	RUN #6 RRD-100%			Run #7	Run 0.2
		Δ				Run 12.50	Reo 0.2
		Δ				End 2.08	Loss
		Δ				Time 7.00	Gain
		Δ				Dr time 7.00	
		Δ				Hyd press 300	
		Δ				Water press	
		Δ				SP 75	
		Δ				Dr Action Smooth	
		Δ				Water ret	
		Δ				Remarks	
4400	140	Δ	CONCRETE - Brownish Grey in color, NATURAL AGGREGATE - SIZE SAND TO COARSE GRAVEL (2") WITH THE MAJORITY OF THE AGGREGATE RUNNING FROM 1/4" TO 3/4". SHAPE, ANGULAR TO ROUNDED WITH MAJORITY BEING ROUNDED IN SHAPE. ORIGIN - GLACIAL OR RIVER, TYPE, IGN. SED. + META. WITH HIGH PER CENTAGE OF CHESTS, GRANITES. CONDITIONS - V. LITTLE TO NO REACTION PRODUCT AND OCCURRING AT SHALLOW DEPTHS. GENERAL CONDITION APPEARS GOOD - NATURAL FRACTURING OF CONCRETE AT 115' AND 6.4'. CONCRETE DISCOLORED AT 115'. MATERIAL HAS AN OIL RESIDUE ON SURFACE OF BREAK.				
LEGEND							
Δ - CONCRETE							
MB - MACHINE BREAK							
NB - NATURAL BREAK							

Note No. SWES-P04-1-80

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
ST. LOUIS, MO.		LOCK & DAM #34		SHEET 1 OF 2 SHEETS			
1. PROJECT Locks Dam #24				2. SIZE AND TYPE OF BIT 6" 744 - 5" 1-2" 744			
3. LOCATION (Coordinates or Station) Pier No. 4 - 4:30' from U/S side of upper				11. DATE FOR ELEVATION SHOWN (TYP. or ME.) 11/5/80			
4. DRILLING AGENCY CEWES				12. MANUFACTURER'S DESIGNATION OF DRILL Hiker			
5. HOLE NO. (As shown on drawing 100) and file number SWES-P04-1-B0				13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED UNDISTURBED			
6. NAME OF DRILLER A. McNAHARA				14. TOTAL NUMBER CORE BORES Three			
7. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED ☐ HOR. FROM VERT.				15. ELEVATION GROUND WATER			
8. THICKNESS OF OVERBURDEN				16. DATE HOLE STARTED 30 October 80 COMPLETED 4 November 80			
9. DEPTH DRILLED INTO ROCK 13.7'				17. ELEVATION TOP OF HOLE 454.0'			
10. TOTAL DEPTH OF HOLE				18. TOTAL CORE RECOVERY FOR BORING 94.3%			
				19. SIGNATURE OF INSPECTOR Joseph B. Dumbare			

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)
454.0	0.0	Δ				Run #1 30 Oct - 31 Oct WL - 195' Began 2:00 - 5:10 Rec. 195' End 7:30 to 9:00 Loss - Time 120 min Gain - Drl time 270 min Hyd press 200 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
453.0	1.0	Δ	1/2" Ra-9-AE CONCRETE L.1	100%		Remarks Straining Bbl - changed B.15
452.0	2.0	Δ	Run #1 RQD = 100%		Box 1	Run #2 WL - Rec. 195' Began 9:10 Rec. 195' End 10:40 Loss - Time 30 min Gain - Drl time 30 min Hyd press 250 Water press - RFM 702 Drl Action Smooth Water ret Brown
451.0	3.0	Δ	CONCRETE L.1	100%		Run #3 WL - Run 1/2 Began 10:50 Rec. 0.0 End 1:05 Loss 1/2 Time 35 min Gain - Drl time 35 min Hyd press 200 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
450.0	4.0	Δ	Run #2 RQD = 100%		Box 1	Run #4 WL - Run 36' Began 11:55 Rec. 48 End 3:45 Loss - Time 250 min Gain 1/2 Drl time 250 min Hyd press 300 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
449.0	5.0	Δ	CONCRETE L.1	0.0%		Run #3 WL - Run 1/2 Began 10:50 Rec. 0.0 End 1:05 Loss 1/2 Time 35 min Gain - Drl time 35 min Hyd press 200 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
448.0	6.0	Δ	Run #3		Box 2	Run #4 WL - Run 36' Began 11:55 Rec. 48 End 3:45 Loss - Time 250 min Gain 1/2 Drl time 250 min Hyd press 300 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
447.0	7.0	Δ	2:45° } Natural fracturing 45° } NB	133%		Run #4 WL - Run 36' Began 11:55 Rec. 48 End 3:45 Loss - Time 250 min Gain 1/2 Drl time 250 min Hyd press 300 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
446.0	8.0	Δ	CONCRETE L.1			Run #4 WL - Run 36' Began 11:55 Rec. 48 End 3:45 Loss - Time 250 min Gain 1/2 Drl time 250 min Hyd press 300 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
445.0	9.0	Δ	Run #4 RQD = 85.4%		Box 1	Run #4 WL - Run 36' Began 11:55 Rec. 48 End 3:45 Loss - Time 250 min Gain 1/2 Drl time 250 min Hyd press 300 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown
444.0	10.0	Δ	CONCRETE	100%	Box 3	Run #4 WL - Run 36' Began 11:55 Rec. 48 End 3:45 Loss - Time 250 min Gain 1/2 Drl time 250 min Hyd press 300 PSI Water press - RFM 702 Drl Action Smooth Water ret Brown

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT

WELL NO.

Hole No. SWES-P02-1-80

DRILLING LOG		DIVISION St Louis, Mo.		INSTALLATION Lock & Dam #24		SHEET 1 of 2 SHEETS	
1. PROJECT Lock & Dam #24				10. SIZE AND TYPE OF BIT See Page Two			
2. LOCATION (Contingency or Station) See Page Two				11. DEPTH FOR ELEVATION SHOWN (TBM or BBL)			
3. DRILLING AGENCY CFWES				12. MANUFACTURER'S DESIGNATION OF DRILL HCKR			
4. HOLE NO. (As shown on drawing title and file number) SWES-P02-1-80				13. TOTAL NO. OF OVER- BURDEN SAMPLES TAKEN		DISTURBED ☐ UNDISTURBED ☐	
5. NAME OF DRILLER A. McNAMARA				14. TOTAL NUMBER CORE BOXES Four		15. ELEVATION GROUND WATER	
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.				16. DATE HOLE 28 October 80		COMPLETED 30 October 80	
7. THICKNESS OF OVERBURDEN 14.2'				17. ELEVATION TOP OF HOLE 454.0		18. TOTAL CORE RECOVERY FOR BORING 97.2%	
8. DEPTH DRILLED INTO ROCK				19. SIGNATURE OF INSPECTOR [Signature]			
9. TOTAL DEPTH OF HOLE							

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
454.0	0.0	Δ		100%	Box 1	Run #1 28 Oct. 80 WL — Run 0.9' Began 1.30 Rec 0.9' End 3.48 Loss — Time 138 min Gain — Drl time 138 min Hyd press 750 to 700 PSI Water press — RPM 742 Drl Action Smooth Water ret Began Remarks - CHANGED BITS - STARTING BBL
453.0	1.0	Δ	CONCRETE ✓	88.1%	Box 1	Run #2 29 October 80 WL — Run 2.1' Began 4.06-5.20 Rec 1.85' End 8.00-9.10 Loss 0.25' Time 144 min Gain — Drl time 144 min Hyd press 3002 Water press — RPM 702 Drl Action Smooth Water ret Began STARTING Bbl. Remarks
452.0	2.0	Δ	NO & NO SURFACE PARTIALLY STAINED Run #2 RRD-100%			
451.0	3.0	Δ	CONCRETE ✓		Box 1	
450.0	4.0	Δ	Run #3 RRD-100%			
449.0	5.0	Δ	CONCRETE ✓	162%	Box 2	Run #3 1.65' WL — Run 3.05' Began 9.30 Rec — End 11.00 Loss 1.65' Time 90 min Gain — Drl time 90 min Hyd press 3002 Water press — RPM 752 Drl Action Smooth Water ret Began Remarks Continued with STARTING Bbl to Make Bore For 5' Bbl - from DECK
448.0	6.0	Δ	Run #4 RRD-100%	7.2		
447.0	7.0	Δ	CONCRETE ✓	100%	Box 3	Run #4 WL — Run 3.45' Began 11.15 Rec 4.95' End 2.50 min Loss — Time 215 min Gain 1.90' Drl time 215 min Hyd press 300-500 Water press — RPM 752 Drl Action Smooth Water ret Began Remarks
446.0	8.0	Δ				
445.0	9.0	Δ				
444.0	10.0	Δ				

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.
(TRANSLOGENT)

PROJECT

HOLE NO.

Hole No. SWES-P04 2-60

DRILLING LOG		Division	INSTALLATION	SHEET
1. PROJECT <u>Lock and Dam No. 24</u>		<u>St. Louis Mo.</u>	<u>Locks Dam No. 24</u>	OF 1 SHEETS
2. LOCATION (Coordinates or Station) <u>See below</u>			10. SIZE AND TYPE OF BIT <u>M.S.G.</u>	
3. DRILLING AGENCY <u>BEWES</u>			11. DAY USE FOR ELEVATION MEASUREMENT <u>Below</u>	
4. HOLE NO. (As shown on drawing, hole, and file number) <u>SWES-P04 2-60</u>			12. MANUFACTURER'S DESIGNATION OF DRILL <u>Elsevier - Core Drill</u>	
5. NAME OF DRILLER <u>A. McNamara</u>			13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN <u>Disturbed</u> <u>Undisturbed</u>	
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED <u>9.0</u> DEG. FROM VERT.			14. TOTAL NUMBER CORE BOXES <u>THD</u>	
7. THICKNESS OF OVERBURDEN <u>1.64</u>			15. ELEVATION GROUND WATER	
8. DEPTH DRILLED INTO ROCK <u>1.64</u>			16. DATE HOLE STARTED <u>28 Nov 60</u>	COMPLETED <u>28 Nov 60</u>
9. TOTAL DEPTH OF HOLE			17. ELEVATION TOP OF HOLE <u>448.0</u>	
			18. TOTAL CORE RECOVERY FOR FORMING <u>100%</u>	
			19. MEASURE OF PRODUCTION	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water flow, depth of penetration, etc., if significant)
4480	0					Run No. 1 28 Nov 60
			Concrch.	100%	Box 1	WL — Run 1.35 Began 1.30 Rec 1.35 End 1.30 Loss — Time 6 min Gain — Drl time 6 min Hyd press — Water press MID RPM 3005 Drl Action Spout Water ret Brown Remarks
4480	10					Run No. 2
			Concrch.	100%	Box 1	WL — Run 2.2 Began 1.35 Rec 2.2 End 3.15 Loss — Time 10 min Gain — Drl time 10 min Hyd press — Water press MID RPM 3005 Drl Action Spout Water ret Brown Remarks
4480	20					Run No. 3
			Concrch. Fair condition — UPPER PORTION IS VERY POOR. NUMEROUS BREAKS & CRACKS, ALTHOUGH WITH MODERATE AMOUNTS OF REACTION PRODUCT.	100%	Box 2	WL — Run 2.85 Began 3.30 Rec 2.85 End 5.40 Loss — Time 13 min Gain — Drl time 13 min Hyd press — Water press MID RPM 3005 Drl Action Spout Water ret Brown Remarks
4480	30					Run No. 3 RQD = 85.9%
			Physical properties same as other w.t.s. borings			
4480	40					
4480	50					
4480	60					

DIAMOND BITS
79PN0437
79PB687

LEGEND
 [A] - Concrch.
 [B] - Natural cracks
 MB - Machine break
 NB - Natural break

LOCATION

 View Looking N/S
 Center of pier NO. 4

SWES-P04 2-60

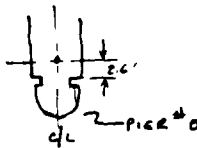
ENC FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
MAR 71 (TRANSLUCENT)

Note No. 5455-209-2-80

DRILLING LOG		DIVISION St. Louis, Mo.		INSTALLATION Lock & Dam No. 24		SHEET 1 OF 3 SHEETS	
1. PROJECT Lock & Dam No. 24				10. SIZE AND TYPE OF BIT 6.75" - See Page 129			
2. LOCATION (Continent or Station) See Page 129				11. DAY OF YEAR FOR ELEVATION DETERMINED MSL			
3. DRILLING AGENCY C.E.W.E.S.				12. MANUFACTURER'S DESIGNATION OF DRILL KEEER			
4. HOLE NO. (As shown on drawing 100%) SACS-P083-R0				13. TOTAL NO. OF OVER- BURDEN SAMPLES TAKEN Disturbed Undisturbed			
5. NAME OF DRILLER McNairner				14. TOTAL NUMBER CORE BOXES THREE			
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED See from vert.				15. ELEVATION GROUND WATER			
7. THICKNESS OF CONCRETE 13.1 ft				16. DATE HOLE STARTED 24 November 1970 COMPLETED			
8. DEPTH DRILLED INTO ROCK (Recovered) 12.9 ft				17. ELEVATION TOP OF HOLE 444.0 ft			
9. TOTAL DEPTH OF HOLE 13.1 ft				18. TOTAL CORE RECOVERY FOR BORING 100%			
19. SIGNATURE OF INSPECTOR James B. Vink							

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	RECOVER e	BOX OR SAMPLE NO. f	REMARKS g (Drilling time, water used, grade of mudlogging, etc., if significant)
444.0	0.0	Δ	CONCRETE	100%	Box 1	Run No. 1 24 Nov. 80 HL — Run 2.50 Began 11:45 Rec 2.50 End 2.30 Loss — Time 245 min Gain — Drl time 245 min Hyd press 750 PSI Water press 1450 RPM 750 Drl Action Smooth Water ret Brown Remarks
443.0	1.0	Δ				Run No. 2 25 Nov. 80 HL — Run 1.5 Began 7.45 Rec 1.5 End 11.15 Loss — Time 210 min Gain — Drl time 210 min Hyd press 750 PSI Water press 700 to 100 RPM 750 Drl Action Smooth Water ret Brown Remarks
442.0	2.0	Δ				Run No. 3 25 Nov. 80 HL — Run 0.6 Began 11:45 Rec 0.6 End 1.75 Loss 0.6 Time 100 min Gain — Drl time 100 min Hyd press 200 PSI Water press 1450 RPM 750 Drl Action Smooth Water ret Brown Remarks
441.0	3.0	Δ	CONCRETE	100%	Box 1	Run No. 4 HL — Run 2.8 Began 1.30 Rec 2.8 End 1.45 Loss — Time 145 min Gain 0.8 Drl time 145 min Hyd press 600 PSI Water press 1450 RPM 750 Drl Action Smooth Water ret Brown Remarks
440.0	4.0	Δ	CONCRETE	100%	Box 2	
439.0	5.0	Δ	CONCRETE	100%	Box 2	
438.0	6.0	Δ	CONCRETE	100%	Box 2	
437.0	7.0	Δ	CONCRETE	100%	Box 2	
436.0	8.0	Δ	CONCRETE	100%	Box 2	
435.0	9.0	Δ	CONCRETE	100%	Box 3	
434.0	10.0	Δ	CONCRETE	100%	Box 3	

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

DRILLING LOG		DIVISION		INSTALLATION		SHEET 2 OF 3 SHEETS	
1. PROJECT				10. SIZE AND TYPE OF BIT			
2. LOCATION (Coordinates or Station)				11. DAYUM FOR ELEVATION KNOWN (FTN = MSL)			
3. DRILLING AGENCY				12. MANUFACTURER'S DESIGNATION OF DRILL			
4. HOLE NO. (As shown on drawing No. and its number)				13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN		14. TOTAL NUMBER CORE BOXES	
5. NAME OF DRILLER				15. ELEVATION GROUND WATER		16. DATE HOLE	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.				17. ELEVATION TOP OF HOLE		18. TOTAL CORE RECOVERY FOR BORING	
7. THICKNESS OF OVERBURDEN				19. SIGNATURE OF INSPECTOR			
8. DEPTH DRILLED INTO ROCK							
9. TOTAL DEPTH OF HOLE							
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)	
444.0	10.0	Δ	Run #5 RQD=100%		Box 3	Run #5 Began 3:15 hu. 2.7 End 5:20 Rec 2.7 Time 1:05 min Gain - Drl time 1:05 min Hyd press 500-700 Water press - RPM 50 to 75 Drl Action Smooth Water ret Brown Remarks -	
443.0	11.0	Δ			Box 4		
442.0	12.0	Δ	CONCRETE	89.5%			
441.0	13.0	Δ	NA CONCRETE HAS ODD APPEARANCE - BREAKS HAS "INNER PUG" - POSSIBLY TWO PUGS		13.3	Run #6 30 October 60 KL - Run 3.6' Began 7:30 Rec 3.4' End 11:30 Loss 0.4 Time 2:40 min Gain - Drl time 2:40 min Hyd press 500-700 Water press - RPM 50-75 Drl Action Smooth Water ret Brown Remarks Left last 0.4' in hole	
440.0	14.0	Δ	Run #6 RQD=88.0%				
CONCRETE - BROWNISH GRAY IV COLOR, NATURAL AGGREGATE - 3/8" SAND TO COARSE GRAVEL (2") WITH MAJORITY OF AGGREGATE RUNNING FROM 1/2" TO 3/4" SHAPE - ANGULAR TO ROUND - 5-20% ANNUAL WITH MOST BEING ROUND - ORIGIN - GLACIAL OR RIVER - TYPE - IGNEOUS - SEDIMENTARY - METAMORPHIC, HIGH PERCENTAGE OF CRYSTALS AND GRANITES - CONDITION - V. LITTLE TO NO REACTION PRODUCT VISIBLE, GENERAL CONDITION APPEARS TO BE GOOD. ODD BREAK AT 13.4'							
BITS		LOCATION		LEGEND			
801B/2				[B] - CONCRETE NA - NATURAL BREAK MB - MAINLINE BREAK			

Note No. SAES 2095-50

DRILLING LOG		DIVISION	INSTALLATION		SHEET 7 OF 8 SHEETS	
1. PROJECT		10. SIZE AND TYPE OF BIT				
2. LOCATION (Continent or Station)		11. DATE FOR ELEVATION SHOWN (YR - MO - DAY)				
3. DRILLING AGENCY		12. MANUFACTURER'S DESIGNATION OF DRILL				
4. HOLE NO. (As shown on drawing title and file number)		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN				
5. NAME OF DRILLER		14. TOTAL NUMBER CORE BOXES				
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.		15. ELEVATION GROUND WATER				
7. THICKNESS OF OVERBURDEN		16. DATE HOLE ☐ STARTED ☐ COMPLETED				
8. DEPTH DRILLED INTO ROCK		17. ELEVATION TOP OF HOLE				
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING				
		19. SIGNATURE OF INSPECTOR				
ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	1. CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant) g
			CONCRETE: GRAYISH BROWN IN COLOR WITH NATURAL AGGREGATE. THE AGGREGATE RANGES IN SIZE FROM 1/8" TO 2" MAX WITH 80% RUNNING FROM 1/4" TO 1". THE SHAPE OF AGGREGATE IS ANGULAR TO ROUNDED WITH 90% BEING ROUNDED OR SEMI-ROUND. THE CONCRETE IS IN GOOD CONDITION, IN THAT IT LACKS HAIRLINE BREAKS, CRACKS, AND SIGNIFICANT ~~2~~ AMOUNTS OF REACTION PRODUCT. ALL BREAKS IN CORE ARE THE RESULT OF MACHINE ACTION (BREAKS AT 10.5' & 12' ~~2~~ ARE NATURAL BREAKS). DRILL TIMES FOR EACH RUN INDICATE A VERY "TOUGH," HARD CONCRETE.			

Hole No. 545-89-3 E

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
1. PROJECT				2. HOLE NO. <u>24</u>		3. SHEET <u>2</u> OF <u>3</u> SHEETS	
4. LOCATION (Continuation of Station)				10. SIZE AND TYPE OF BIT		11. DAY USE FOR ELEVATION KNOWN (YES = YES)	
5. DRILLING AGENCY				12. MANUFACTURER'S DESIGNATION OF DRILL			
6. HOLE NO. (As shown on drawing sheet) and file number				13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN		14. DISTURBED UNDISTURBED	
7. NAME OF DRILLER				15. TOTAL NUMBER CORE BOXES			
8. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.				16. ELEVATION GROUND WATER			
9. THICKNESS OF OVERBURDEN				17. DATE HOLE STARTED COMPLETED			
10. DEPTH DRILLED INTO ROCK				18. ELEVATION TOP OF HOLE			
11. TOTAL DEPTH OF HOLE				19. TOTAL CORE RECOVERY FOR BORING			
				20. SIGNATURE OF INSPECTOR			
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	1. CORE RECOVERY	2. BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)	
4340	100	Δ	Run No. 7 RQD = 100%			Run No. 5 26 Nov 60 WL — Run 0.55 Began 7:40 Rec 0.55 End 9:30 Loss — Time 11 min Gain — Drl time 11 min Hyl press 400 PSI Water press 110 PSI RPM 800 Drl Action Smooth Water ret Remarks	
4330	110	Δ	Concrete	100%	Bx 3		
		Δ	Run No. 8 RQD = 100%				
4320	120	Δ	Run No. 9 RQD = 100%		Bx 3	Run No. 6 WL — Run 1.11 Began 9:35 Rec 1.11 End 11:55 Loss — Time 150 min Gain — Drl time 150 min Hyl press 400 PSI Water press 110 PSI RPM 800 Drl Action Smooth Water ret Remarks	
4310	130	Δ	Run No. 9			Run No. 10 WL — Run 1.45 Began 12:45 Rec 1.45 End 1:45 Loss — Time 10 min Gain — Drl time 10 min Hyl press 400 PSI Water press 110 PSI RPM 800 Drl Action Smooth Water ret Remarks	
		Δ	Run No. 10			Run No. 7 WL — Run 1.45 Began 12:45 Rec 1.45 End 1:45 Loss — Time 10 min Gain — Drl time 10 min Hyl press 400 PSI Water press 110 PSI RPM 800 Drl Action Smooth Water ret Remarks	
		Δ	Run No. 8			Run No. 8 27 Nov 60 WL — Run 1.2 Began 8:30 Rec 1.2 End 11:30 Loss — Time 180 min Gain — Drl time 180 min Hyl press 400 PSI Water press 110 PSI RPM 800 Drl Action Smooth Water ret Remarks	

LEGEND

Δ CONCRETE

M.B. MACHINE BREAK

N.B. NATURAL BREAK

LOCATION

DIAMOND BITS

- 80 PSI 1162

- RS 80 PSI 1164

- 80 PSI 1153

PLAN VIEW

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
MAR 71

PROJECT

HOLE NO.

Hole No. SWES-P151-80

DRILLING LOG		Division	INSTALLATION	SHEET		
1. PROJECT <u>Lock 1 Dam #24</u>		<u>St. Louis, Mo</u>	<u>Lock 1 Dam #24</u>	<u>1</u> OF <u>5</u> SHEETS		
2. LOCATION (Coordinate or Station) <u>Lock 1 Dam #24</u>		10. SIZE AND TYPE OF BIT <u>6.75" - SEE PAGE</u>				
3. DRILLING ASPECT <u>CE 104</u>		11. DAY OF ELEVATION (Elevation in MSL) <u>MSL</u>				
4. HOLE NO. (As shown on drawing title) <u>SWES-P151-80</u>		12. MANUFACTURER'S DESIGNATION OF DRILL				
5. NAME OF DRILLER <u>A. McNamee</u>		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN				
6. DIRECTION OF HOLE ☒ VERTICAL ☐ INCLINED _____ DEG FROM VERT		14. TOTAL NUMBER CORE BOXES <u>11</u>				
7. THICKNESS OF OVERBURDEN <u>0</u>		15. ELEVATION GROUND WATER <u>?</u>				
8. DEPTH DRILLED INTO ROCK <u>41.1</u>		16. DATE HOLE STARTED <u>21 October 1980</u> COMPLETED <u>27 October 1980</u>				
9. TOTAL DEPTH OF HOLE <u>41.1 Concrete</u>		17. ELEVATION TOP OF HOLE <u>454.0'</u>				
		18. TOTAL CORE RECOVERY FOR BORING <u>1</u>				
		19. SIGNATURE OF INSPECTOR <u>See Number 4</u>				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)
454.0	00	Δ				Began 8:00 Run 1.75'
		Δ	1/4" Rock		Box 1	End 10:15 Loss -
		Δ	CONCRETE	100%		Time 135min Gain -
453.0	10	Δ	Run #1 RQD-100%			Drl time 135min
		Δ				Hyd press 200-400 PSI
		Δ				Water press -
		Δ				RPM 75-150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
452.0	20	Δ	CONCRETE	100%	Box 1	Run #2
		Δ				WL Run 1.75'
		Δ				Began 10:30 Rec 1.75'
		Δ				End 11:30 Loss -
		Δ				Time 60min Gain -
		Δ				Drl time 60min
		Δ				Hyd press 400
		Δ				Water press -
		Δ				RPM 50
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
450.0	40	Δ	CONCRETE - GRAY BROWN IN COLOR, NATURAL RUB-GLASS AGG. S&S. IOW. MTH - ANGULAR		Box 1	Run #3
		Δ	NO TO BOUNDED WITH HARDNESS 4.75			WL Run 4.65'
		Δ	BEING BOUNDED AND SIZE DISTRIBUTION IS FROM SAND AND FINE GRAVEL, TO A VERY COARSE GRAVEL, 100%			Began 1:30 Rec 4.65'
		Δ	SUBT REACTION PRODUCT ALONG WITH EVIDENT RING IN GRAVEL ARE VISIBLE, AS WELL AS A PURGUS			End 4:40 Loss -
		Δ	NO HARDNESS CORE			Time 170min Gain -
		Δ	APPEARANCE TO THE CONCRETE BRKES ARE THROUGH THE SOFT AGG. AND BECOMING DROWN IN THE HARDER MATERIAL.			Drl time 160min
449.0	50	Δ	Run #3 RQD-100%			Hyd press 200-300
		Δ				Water press -
		Δ				RPM 70-150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
448.0	60	Δ			Box 2	Run #4
		Δ				22 October 80
		Δ				WL Run 7.75'
		Δ				Began 5:00 Rec 7.75'
		Δ				End 7:30 Loss 0.25
		Δ				Time 140min Gain -
		Δ				Drl time 140min
		Δ				Hyd press 200-300
		Δ				Water press -
		Δ				RPM 150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
447.0	70	Δ			Box 2	Run #4
		Δ				22 October 80
		Δ				WL Run 7.75'
		Δ				Began 5:00 Rec 7.75'
		Δ				End 7:30 Loss 0.25
		Δ				Time 140min Gain -
		Δ				Drl time 140min
		Δ				Hyd press 200-300
		Δ				Water press -
		Δ				RPM 150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
446.0	80	Δ			Box 3	Run #4
		Δ				22 October 80
		Δ				WL Run 7.75'
		Δ				Began 5:00 Rec 7.75'
		Δ				End 7:30 Loss 0.25
		Δ				Time 140min Gain -
		Δ				Drl time 140min
		Δ				Hyd press 200-300
		Δ				Water press -
		Δ				RPM 150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
445.0	90	Δ			Box 3	Run #4
		Δ				22 October 80
		Δ				WL Run 7.75'
		Δ				Began 5:00 Rec 7.75'
		Δ				End 7:30 Loss 0.25
		Δ				Time 140min Gain -
		Δ				Drl time 140min
		Δ				Hyd press 200-300
		Δ				Water press -
		Δ				RPM 150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks
444.0	100	Δ			Box 3	Run #4
		Δ				22 October 80
		Δ				WL Run 7.75'
		Δ				Began 5:00 Rec 7.75'
		Δ				End 7:30 Loss 0.25
		Δ				Time 140min Gain -
		Δ				Drl time 140min
		Δ				Hyd press 200-300
		Δ				Water press -
		Δ				RPM 150
		Δ				Drl Action Smooth
		Δ				Water ret
		Δ				Brown
		Δ				Remarks

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

Hole No. SWES-PO9-2-80

DRILLING LOG		Division	INSTALLATION	SHEET		
PROJECT		ST LOUIS, MO.	LOCK AND DAM # 24	OF 1 SHEETS		
1. PROJECT LOCK # DAM No 24		10. SIZE AND TYPE OF BIT 6" - B.T. No. 792671				
2. LOCATION (Coordinate or Figure) PIER NO. 9 - 4 UP FROM VERTICAL FACE OF CEWES UNDER TUNNEL PIN.		11. DAY ON FOR ELEVATION SHOWN (75% = MEAN) MSL				
3. DRILLING AGENCY / DISTORTION OF PIER NO. 9 CEWES UNDER TUNNEL PIN.		12. MANUFACTURER'S DESIGNATION OF DRILL SPARKLE AND HENWOOD				
4. HOLE NO. (as shown on drawing 100% and 50% reduced) SWES-PO9-2-80		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED _____ UNDISTURBED _____				
5. NAME OF DRILLER A. McNAMARA		14. TOTAL NUMBER CORE BOXES Two				
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT		15. ELEVATION GROUND WATER _____				
7. THICKNESS OF OVERBURDEN		16. DATE HOLE STARTED 6 November 80 COMPLETED 6 November 80				
8. DEPTH DRILLED INTO ROCK 5.9'		17. ELEVATION TOP OF HOLE 448.0 - CENTER OF BORING				
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR BORING 100%				
		19. SIGNATURE OF INSPECTOR Joseph B. Brunkner				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	BOX OR RECOVERY NO.	REMARKS (Drilling logs, water level, depth of overburden, etc., if significant)	
4480	00	HAIRLINE CRACKS - CLOSED			Run #1 6 November 80 FL - RCD 240 Began 843 Rec 190 End 10.50 Loss 0.5 Time 127 min Gain - Drl time 112 min Hyd press 60 to 70 PSI Water press Low RPM 502 Drl Action 3400 N Water ret Bottom Remarks STARTING BLI.	
4480	10	HAIRLINE CRACKS - CLOSED		79.2%	Box 1	
4480	20	UPPER SURFACE OF CONCRETE IS PITTED AND MUCH WEATHERED - WEATHERED CONDITION OCCURS TO 0.3 FT WHERE CONDITION IMPROVES - MODERATE REACTION PRODUCT IN WEATHERED AREA				Run #2 FL - Run 240' Began 1115 Rec 290' End 130 - Loss 0.20' Time 135 min Gain 0.50' Drl time 135 min Hyd press 60 to 80 PSI Water press Low RPM 745 Drl Action Smooth Water ret Bottom Remarks
4480	30	CONCRETE - GOOD CONDITION		115%	Box 1	
4480	40					Run #3 FL - Run 0.90' Began 205 Rec 1.10' End 330 Loss 0.0' Time 93 min Gain 0.10' Drl time 23 min Hyd press 70 PSI Water press Low RPM 755 Drl Action Smooth Water ret Bottom Remarks
4480	50	CONCRETE		122.3%	Box 2	
4480	60	INTERSECTED SWES-PO9-1-80				
LEGEND - CONCRETE --- - HAIRLINE CRACKS MB - MACHINE BREAK NB - NATURAL BREAK CONCRETE IS SAME AS ENCOUNTERED IN OTHER W.E.S BORINGS - ADHERENT; TYPE, SIZE, AND SHAPE IS SAME						

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
MAR 71 (TRANSLUCENT)

PROJECT

NOLE NO.

Hole No. 9W65-P151-80

DRILLING LOG		DIVISION		INSTALLATION		SHEET 3 OF 5 SHEETS	
1. PROJECT		2. LOCATION (Coordinates or Address)		3. SIZE AND TYPE OF BIT		4. DAY OF YEAR ELEVATION SHOWN (TBM = 1000)	
5. DRILLING AGENCY		6. NAME OF DRILLER		7. MANUFACTURER'S DESIGNATION OF DRILL		8. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	
9. HOLE NO. (As shown on drawing title and site number)		10. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT		11. TOTAL NUMBER CORE BOXES		12. ELEVATION GROUND WATER	
13. THICKNESS OF OVERBURDEN		14. DEPTH DRILLED INTO ROCK		15. DATE HOLE STARTED		16. DATE HOLE COMPLETED	
17. TOTAL DEPTH OF HOLE		18. SIGNATURE OF INSPECTOR		19. ELEVATION TOP OF HOLE		20. TOTAL CORE RECOVERY FOR BORING	
21. ELEVATION		22. DEPTH		23. LEGEND		24. CLASSIFICATION OF MATERIALS (Designation)	
25. CORE RECOVERY		26. BOX OR SAMPLE NO.		27. REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)			

434.0	20.0	Δ	Run # 8	100%	Box 6	23 Oct - 24 Oct 1980 Run # 8 Began 2:15-5:00 Rec 4.25 End 7:50-Rec Loss - Time 355 min Gain - Drl time 340 min Hyd press 1250-300 Water press - Rpt 702 Drl Action Smooth Water ret Began Remarks Run # 10 Began 1:10 Rec 2.75 End 3:30 Loss - Time 140 min Gain - Drl time 140 min Hyd press 150 Water press - Rpt 502 Drl Action Smooth Water ret Began Remarks Run # 11 25 Oct 80 Began 3:57-5:05 Rec 5.6 End 7:42-11:00 Loss - Time 278 min Gain - Drl time 278 min Hyd press 200 Water press - Rpt 702 Drl Action Smooth Water ret Began Remarks Run # 12 Began 11:45 Rec 4.1 End 3:20: Loss - Time 215 min Gain - Drl time 215 min Hyd press 200 Water press - Rpt 702 Action Smooth Water ret Began Remarks
433.0	21.0	Δ	CONCRETE	100%	Box 7	
432.0	22.0	Δ				
431.6	23.0	Δ				
430.0	24.0	Δ	Run # 9 RQD=100%	100%	Box 8	
429.0	25.0	Δ	CONCRETE	100%	Box 8	
428.0	26.0	Δ				
427.0	27.0	Δ				
426.0	28.0	Δ	Run # 10 RQD=100%	100%	Box 8	
425.0	29.0	Δ	CONCRETE	100%	Box 8	
424.0	30.0	Δ				

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

(TRANSLUCENT)

DRILLING LOG			DIVISION		INSTALLATION		SHEET 2 OF 5 SHEETS	
1. PROJECT			2. LOCATION (Coordinates or Township)		3. DRILLING AGENCY		4. HOLE NO. (As shown on drilling site and on maps)	
5. NAME OF DRILLER			6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.		7. THICKNESS OF OVERBURDEN		8. DEPTH DRILLED INTO ROCK	
9. TOTAL DEPTH OF HOLE			10. SIZE AND TYPE OF BIT		11. MANUFACTURER'S DESIGNATION OF DRILL		12. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	
13. ELEVATION GROUND WATER			14. DATE HOLE STARTED		15. ELEVATION TOP OF HOLE		16. TOTAL CORE RECOVERY FOR BORING	
17. SIGNATURE OF INSPECTOR			18. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN		19. TOTAL NUMBER CORE BOXES		20. SIGNATURE OF INSPECTOR	
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)		
444.0	10.0	Δ	CONCRETE		Box 3	Run #5 WL - Run 1.30 Began 10:30 Rec 1.55 End 1:39 Loss - Time 109 min Gain 25 Drl time 18 min Hyd press 250-300 Water press - RPM 150 Drl Action Smooth Water ret Brown Remarks		
443.0	11.0	Δ	Run #5 R&D 100%		Box 3			
442.0	12.0	Δ	CONCRETE	100%	Box 3	Run #6 WL - Run 3.3 Began 2:30 Rec 3.3 End 5:30 Loss - Time 180 min Gain - Drl time 170 min Hyd press 200-400 Water press - RPM 70 Drl Action Smooth Water ret Brown Remarks		
441.0	13.0	Δ	CONCRETE	100%	Box 3			
440.0	14.0	Δ	Run #6 R&D 100%		Box 3			
439.0	15.0	Δ	CONCRETE	100%	Box 3			
438.0	16.0	Δ	Run #7 R&D 80%		Box 4	Run #7 23 September 80 WL - Run Began 8:30 Rec End 11:30 Loss Time 180 min Gain Drl time 15 min Hyd press 200 Water press - RPM 70 Drl Action Smooth Water ret Brown - changed bits Remarks		
437.0	17.0	Δ	CONCRETE	100%	Box 4			
436.0	18.0	Δ	CONCRETE	100%	Box 4			
435.0	19.0	Δ	CONCRETE	100%	Box 5	Run #8 WL - Run 4.5 Began 12:35 Rec 4.5 End 2:30 Loss Time 135 min Gain - Drl time 135 min Hyd press 250 Water press - RPM 70 Drl Action Smooth Water ret Brown		
434.0	20.0	Δ	R&D 100%		Box 5			

ENG FORM 18-36
MAR 71PREVIOUS EDITIONS ARE OBSOLETE
(TRANSLUCENT)

PROJECT

DATE

HOLE NO.

Hole No. SWES-PIS-2-80

DRILLING LOG		DIVISION <u>St Louis Mo</u>	INSTALLATION <u>Lock + Dam No 24</u>	SHEET <u>1</u> of <u>1</u> SHEETS
1. PROJECT <u>Lock + Dam No. 24</u>		10. SIZE AND TYPE OF BIT <u>6 1/2" - 5/8" - 11/16"</u>		
2. LOCATION (Continent or Section) <u>SEE BELOW</u>		11. DATE FOR ELEVATION SHOWN (Time or Date) <u>MSL</u>		
3. DRILLING AGENCY <u>C.F. N.E.S.</u>		12. MANUFACTURER'S DESIGNATION OF DRILL <u>SPEAKE AND HENWOOD</u>		
4. HOLE NO. (As shown on drawing title) and file number <u>SWES-PIS-2-80</u>		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN DISTURBED _____ UNDISTURBED _____		
5. NAME OF DRILLER <u>A. McNamara</u>		14. TOTAL NUMBER CORE BOXES <u>TWO</u>		
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED <u>90°</u> DEG. FROM VERT.		15. ELEVATION GROUND WATER STARTED _____ COMPLETED _____		
7. THICKNESS OF OVERBURDEN <u>6.55'</u>		16. DATE HOLE STARTED <u>7 Nov. 80</u> COMPLETED _____		
8. DEPTH DRILLED INTO ROCK <u>6.55'</u>		17. ELEVATION TOP OF HOLE <u>448.1'</u>		
9. TOTAL DEPTH OF HOLE <u>6.55'</u>		18. TOTAL CORE RECOVERY FOR BORING <u>100%</u>		
		19. SIGNATURE OF INSPECTOR <u>James B. Dunt</u>		

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)
448.1	0.0		WEATHERED			Run No 1 - 7 Nov 80 NL _____ Run 1.50' Began 8:10 Rec 1.50' End 10:30 Loss _____ Time 140 min Gain _____ Drl time 135 min Hyl press 75 Water press low RPM 75 Drl Action Smooth Water ret BROWN
448.1	1.0		Run No. 1 - RAD.	100%	Box	Remarks Disturbed Hydraulic Pump
448.1	2.0		CONCRETE.		1	Run No 2 - 2 Dec 80 NL _____ Run 2.70' Began 9:30 Rec 2.70' End 1:30 Loss _____ Time 240 min Gain _____ Drl time 230 min Hyl press 70-100 Water press MID RPM 75 Drl Action Smooth Water ret BROWN
448.1	3.0			100%		Remarks - CHANGED B.T.
448.1	4.0		Run No 2 - RAD - 100%	4.15		Run No 3 - 3 Dec 80 NL _____ Run 2.40' Began 1:30 Rec 2.40' End 9:50 Loss _____ Time 35 min Gain _____ Drl time 30 min Hyl press 70-100 Water press MID RPM 75 Drl Action Smooth Water ret BROWN
448.1	5.0		CONCRETE: GOOD CONDITION, PHYSICAL PROPERTIES SAME AS PREVIOUS BORINGS - VERY LITTLE TO NO R-P AND HAIRLINE CRACKS	100%		Remarks
448.1	6.0		Run No 3 RAD - 100%	6.55		

DIAMOND BITS 79 HWT 33 79 PB 607

LEGEND

X CONCRETE

/ HAIRLINE BREAK

M.B. MACHINE BREAK

N.B. NATURAL BREAK

LOCATION

Pier No. 15
VIEW LOOKING UP
TENNISON PIER

SWES-PIS-2-80

Recorder line

Hole No. SUEI-515750

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
1. PROJECT				LOCK + DAM #24		2 of 5 SHEETS	
2. LOCATION (Coordinates or Station)				10. SIZE AND TYPE OF BIT			
3. DRILLING AGENCY				11. DATUM FOR ELEVATION SHOWN (TYP. or MSL)			
4. HOLE NO. (As shown on drawing title) and site number				12. MANUFACTURER'S DESIGNATION OF DRILL			
5. NAME OF DRILLER				13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN		DISTURBED UNDISTURBED	
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED DEG. FROM VERT.				14. TOTAL NUMBER CORE BOXES			
7. THICKNESS OF OVERBURDEN				15. ELEVATION GROUND WATER			
8. DEPTH DRILLED INTO ROCK				16. DATE HOLE STARTED COMPLETED			
9. TOTAL DEPTH OF HOLE				17. ELEVATION TOP OF HOLE			
				18. TOTAL CORE RECOVERY FOR BORING		%	
				19. SIGNATURE OF INSPECTOR			

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)
4240	30°	Δ				
			RUN #11 RQD=100%		36.75	
4230	31°	Δ				
4210	32°	Δ				
4200	33°	Δ	NO CONCRETE LOT	100%	Box 9	
4190	34°	Δ				
4180	35°	Δ	RUN #12 RQD=100% 2" MACHINE BREAK		34.8	
			CONCRETE LOT			
4174	34°	Δ	3/4" REBAR RUN #13			
					Box 10	
4160	37°	Δ				
			CONCRETE LOT			
4150	38°	Δ			37.95	
4140	39°	Δ			Box 11	
4130	40°	Δ	RUN #14			

Run #13
 WL Began 4.05 Run 0.9
 End 5.45 Loss 0.1
 Time 63 min Gain 0.8
 Drl time 6 min
 Hyd press 7002
 Water press —
 RPM 785
 Drl Action Smooth
 Water ret —
 Remarks —

Run #14
 27 October 80
 WL — Run #14
 Began 10.40 Run 42
 End 3.25 Loss —
 Time 75 min Gain 0.8
 Drl time 70 min
 Hyd press 7002
 Water press —
 RPM 502
 Drl Action Smooth
 Water ret —
 Remarks —

BNG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE.
 MAR 71 (TRANSLUCENT)

PROJECT

HOLE NO.

Hole No. SWES-COS-1W-50

DRILLING LOG		DIVISION	INSTALLATION	SHEET		
PROJECT		ST. LOUIS, MO.	LOCK-DAM No 24	1 OF 1 SHEETS		
1. LOCATION (Compass or Station)		10. SIZE AND TYPE OF BIT				
2. DRILLING AGENCY		11. DAY FOR ELEVATION FROM (F.M. or M.S.L.)				
3. HOLE NO. (As shown on drawing title)		12. MANUFACTURER'S DESIGNATION OF DRILL				
4. NAME OF DRILLER		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN				
5. DIRECTION OF HOLE		14. TOTAL NUMBER CORE BORES				
6. THICKNESS OF OVERBURDEN		15. ELEVATION GROUND WATER				
7. DEPTH DRILLED INTO ROCK		16. DATE HOLE				
8. TOTAL DEPTH OF HOLE		17. ELEVATION TOP OF HOLE				
		18. TOTAL CORE RECOVERY FOR BORING				
		19. SIGNATURE OF INSPECTOR				
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	SCORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)
466.500	0.0		~ BROKEN UP			Run No 1 18 Nov 80
466.510	1.0		REBAR - 1/2"			WL - 0.40
466.520	2.0		CONCRETE	100%	Box 1	Began 2.20 P. 0.40
466.530	3.0		REBAR - 1/2"			End 2.35 Lcp -
			Run No 2 RRD = 100%			Time 13min Gull -
						Drl time 15min
						Hyd press -
						Water press MOD
						RPM 300
						Drl Action Smooth
						Water ret
						Brown
						Remarks
						Run No 2
						Run 2.7'
						Began 2.45
						Rec 2.7'
						End 3.50
						Loss -
						Time 65min
						Drl time 65min
						Hyd press -
						Water press MOD
						RPM - 300
						Drl Action Smooth
						Water ret
						Brown
						Remarks
						CONCRETE: PHYSICAL PROPERTIES SAME.
						CONDITION OF CONCRETE IS FAIR.
						ENDS ARE WEATHERED WITH TOP
						PORTION BROKEN UP AT REBAR.
						LITTLE TO NO REACTION PRODUCT
						IS VISIBLE -

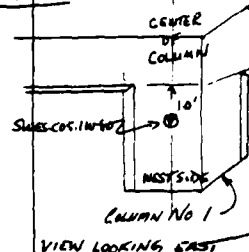
DIAMOND BIT No

81PC178
81PC173

LEGEND

- CONCRETE
- HAIRLINE CRACK
- MB - MACHINE BREAK
- NB - NATURAL BREAK
- BROKEN UP - PIECES TOO SMALL TO LOG

LOCATION



ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
MAR 71 (TRANSLUCENT)

PROJECT HOLE NO

Hole No. SWS-CO2-2N-50

DRILLING LOG		Division ST. LOUIS, Mo.		INSTALLATION LOCK & DAM No 24		SHEET 1 OF 1 SHEETS	
1. PROJECT LOCK & DAM No 24		10. SIZE AND TYPE OF BIT 3 1/2" Delta 626 1/2"		11. DAY/TON FOR ELEVATION BROWN (FEET - INCHES) MSL		12. MANUFACTURER'S DESIGNATION OF DRILL ELECTRIC - CORE DRILL	
2. LOCATION (Continuation of Section) SEE BELOW		13. TOTAL NO. OF OVER- BURDEN SAMPLES TAKEN		14. TOTAL NUMBER CORE BOXES ONE		15. ELEVATION GROUND WATER	
3. DRILLING AGENCY C.E.W.E.S.		16. DATE HOLE 21 Nov 60		17. ELEVATION TOP OF HOLE 468.6 FT. GROUND		18. TOTAL CORE RECOVERY FOR BORING 100%	
4. HOLE NO. (As shown on drawing sheet) and site number SWS-CO2-2N-50		19. SIGNATURE OF INSPECTOR <i>James B. Winkler</i>		20. SIGNATURE OF DRILLER <i>James B. Winkler</i>			
5. NAME OF DRILLER H. McNAMARA		16. DATE HOLE 21 Nov 60		17. ELEVATION TOP OF HOLE 468.6 FT. GROUND		18. TOTAL CORE RECOVERY FOR BORING 100%	
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.		19. SIGNATURE OF INSPECTOR <i>James B. Winkler</i>		20. SIGNATURE OF DRILLER <i>James B. Winkler</i>			
7. THICKNESS OF OVERBURDEN		16. DATE HOLE 21 Nov 60		17. ELEVATION TOP OF HOLE 468.6 FT. GROUND		18. TOTAL CORE RECOVERY FOR BORING 100%	
8. DEPTH DRILLED INTO ROCK 3.5'		19. SIGNATURE OF INSPECTOR <i>James B. Winkler</i>		20. SIGNATURE OF DRILLER <i>James B. Winkler</i>			
9. TOTAL DEPTH OF HOLE		16. DATE HOLE 21 Nov 60		17. ELEVATION TOP OF HOLE 468.6 FT. GROUND		18. TOTAL CORE RECOVERY FOR BORING 100%	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	BOX OR RECORD NO. e	BOX OR RECORD NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
468.6 00		Δ				Run No 1 21 Nov 60
		Δ	1 1/2" SH REBAR			AL — RC: 3.5'
468.6 10		Δ	1 1/2" SH REBAR			Began 10 05 RC 3.5
		Δ	1 1/2" SH REBAR			End 11 20 LOSS —
		Δ	1 1/2" SH REBAR			Time 75 min GAIN —
468.6 20		Δ	1 1/2" SH REBAR			Drill time 10 min
		Δ	1 1/2" SH REBAR			Hyd press —
		Δ	1 1/2" SH REBAR			Water press 160
		Δ	1 1/2" SH REBAR			RFN 5005
		Δ	1 1/2" SH REBAR			Drill Action Smooth
		Δ	1 1/2" SH REBAR			Water ret
		Δ	1 1/2" SH REBAR			(Beckman)
		Δ	1 1/2" SH REBAR			Remarks
468.6 30		Δ	CONCRETE			
		Δ	Run No 1 R&D 100%			
		Δ	Run No 1 R&D 100%			

CONCRETE: VERY GOOD CONDITION, NO HAIRLINE
CRACKS, VERY LITTLE TO NO REACTION PRODUCT,
AND PHYSICAL PROPERTIES SAME AS OTHER
W.E.S. BORINGS

DIAMOND BITS

79PN429

LEGEND

10. CONCRETE

11. HAIRLINE CRACK

MB. MACHINE BREAK

NB. NATURAL BREAK

LOCATION

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
MAR 71 (TRANSLUCENT)

Hole No. SWES-COS 45-80

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
1. PROJECT		2. LOCATION		3. DATE AND TYPE OF BIT		4. DATE FOR ELEVATION	
LOCK + DAM NO. 24		SEE BELOW		M3L		11/15/80	
5. DRILLING AGENCY		6. HOLE NO. (As shown on drawing sheet) and site number		7. NAME OF DRILLER		8. DIRECTION OF HOLE	
CEWES		SWES-COS 45-80		McNamara		90° DES. FROM VERT.	
9. THICKNESS OF OVERBURDEN		10. DEPTH DRILLED INTO ROCK		11. TOTAL DEPTH OF HOLE		12. DATE HOLE	
3.5		3.5		446.5' - CENTER		11/15/80	
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN		14. TOTAL NUMBER CORE BOXES		15. ELEVATION GROUND WATER		16. ELEVATION TOP OF HOLE	
0		ONE				446.5' - CENTER	
17. TOTAL CORE RECOVERY FOR BORING		18. SIGNATURE OF INSPECTOR		19. SIGNATURE OF DRILLER		20. SIGNATURE OF WITNESS	
100%		[Signature]		[Signature]		[Signature]	
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	1. CORE RECOVERY	2. BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)	
466.5	0.0		MATERIAL IN RUN NO. 1 IS LOOSE GRAVEL & RUBBLE - CORES ARE VISIBLE FROM BORING	100%	Box 1	Run No. 1 18 Nov 80 WL --- Run 0.8' Began 11:05 Rec 0.8' End 11:15 Loss --- Time 10 min Gals --- Drl time 10 min Hyd press --- Water press MED RPM 300 Drl Action Smooth Water ret Brown Remarks Blocked off - Run	
466.5	1.0		CONCRETE	100%	Box 1	Run No. 2 WL --- Run 2.7 Began 11:30 Rec 2.7 End 1:30 Loss --- Time 12 min Gals --- Drl time 12 min Hyd press --- Water press MED RPM 300 Drl Action Smooth Water ret Brown Remarks	
466.5	2.0						
466.5	3.0						
Run No. 2 RRD = 96.3% 3.50 CONCRETE: PHYSICAL PROPERTIES THE SAME - CONDITION IS VERY POOR FROM 0.0 TO 0.8'. MATERIAL IS RUBBLE - CONDITION IMPROVING WITH DEPTH - MODERATE REACTION PRODUCT.							
DIAMOND BIT NO		LEGEND		LOCATION			
81 PC 175		CONCRETE MINOR CRACK MA MACHINE BREAK NB. NATURAL BREAK		PIER NO. 5 CONSTRUCTION JOINT 45' SWES-COS 45-80 CENTER OF COLUMN VIEW LOOKING UP			

BMC FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

DIVISION			INSTALLATION		SHEET	
DRILLING LOG			LOCK + Dam No 24		OF 1 SHEETS	
1. PROJECT			10. SIZE AND TYPE OF BIT		11. DATUM FOR ELEVATION (FROM) =	
2. LOCATION (Coordinate or Station)			6" NEW - See Below		MSL	
3. DRILLING AGENCY			12. MANUFACTURER'S DESIGNATION OF DRILL		ELECTRIC - CORE DRILL	
4. NAME OF DRILLER			13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN		DISTURBED UNDISTURBED	
5. HOLE NO. (As shown on drawing title and file number)			14. TOTAL NUMBER CORE BORES		ONE	
6. DATE OF DRILLING			15. ELEVATION GROUND WATER			
7. DIRECTION OF HOLE			16. DATE HOLE		STARTED COMPLETED	
8. THICKNESS OF OVERBURDEN			17. ELEVATION TOP OF HOLE		465.5	
9. DEPTH DRILLED INTO ROCK			18. TOTAL CORE RECOVERY FOR BORING		100%	
10. TOTAL DEPTH OF HOLE			19. SIGNATURE OF INSPECTOR		J. B. Smith	
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)
465.5	00		Run No 1 RQD = 0%			Run No 1 17 Nov 50
465.5	10		Run No 2 RQD = 100%	100%	Box 1	Run 3.15 Began 12.25 End 1.15 Time 50 min Dri time 30 min Hyd pres. - Water press 41D RPM 300 Dri Action Smooth Water ret Brown Remarks Blocked off
465.5	20		Concrete			Run No 2
465.5	30		1/2 Run Restress 1" x 1"			Run 3.15 Began 12.25 End 1.15 Time 50 min Dri time 30 min Hyd pres. - Water press 41D RPM 300 Dri Action Smooth Water ret Brown Remarks
Concrete Physical Properties SAME - size and shape of Agg, color, etc. Condition of concrete is poor. Numerous hairline cracks and moderate amount of reaction product in cracked portions of core all visible						
Diamond Bit No			LEGEND		LOCATION	
81PC135			A. CONCRETE		VIEW LOOKING W/S	
81PC132			--- HAIRLINE CRACK		PIER NO 5	
			MB MACHINE BREAK		20' CENTER OF COLUMN	
			NB NATURAL BREAK		SWNS-COS-15-80	
					COLUMN NO. 1	

Hole No. SWES-C07.3N-80

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
PROJECT		ST. LOUIS		LOCK 3 DAM No 24		1 OF 1 SHEETS	
1. PROJECT		2. LOCATION (If Supplemental to Station)		10. SIZE AND TYPE OF BIT		11. DATE FOR ELEVATION THOUGHT	
Lock + Dam No 24		SEE BELOW		SEE BELOW - 6"		4647	
3. DRILLING AGENCY		4. HOLE NO. (As shown on drawing title and file number)		12. MANUFACTURER'S DESIGNATION OF DRILL		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	
C.S.W.S.		SWES-C07.3N-80		ELECTRIC - C-07.3N-80		DISTURBED UNDISTURBED	
5. NAME OF DRILLER		6. DIRECTION OF HOLE		14. TOTAL NUMBER CORE BOXES		15. ELEVATION GROUND WATER	
A. McNamara		VERTICAL INCLINED 90 DEG. FROM VERT.		ONE			
7. THICKNESS OF OVERBURDEN		8. DEPTH DRILLED INTO ROCK		16. DATE HOLE		17. ELEVATION TOP OF HOLE	
3.5		3.5		15 November 80		4647	
9. TOTAL DEPTH OF HOLE		18. TOTAL CORE RECOVERY FOR SPRING		19. SIGNATURE OF INSPECTOR		20. REMARKS	
4647		100%		Joseph B. Dill		Run No 1 15 Nov 80 WL - Run 3.5 Began 11:30 Re 3.5 End 3:30 Loc - Time 240 min Gals - Drl time 125 min Hyd press - Water press MED RPM 3000 Drl Action Smooth Water ret Brown Remarks Drill Binding UP at Dred Dred	
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)	
4647.80	0.0	Δ	1" x 1" STEEL				
4647.10	0.7	Δ	1/2" REBAR				
4647.20	0.8	Δ	1/2" REBAR	100%	Box 1		
4647.30	0.9	Δ	CONCRETE:				
			HAIRLINE CRACK (1/16" TO 1/8" MAX WIDTH)				
			1" x 1" REBAR				
			1/2" REBAR				
			Run No 1 RCD=100%		35		
CONCRETE: Physical Properties Same. Condition Appears Good. LARGE CRACK AT 2.5' TO 3.5' WAS FOUND ON CORE. VERY LITTLE REACTION PRODUCT WAS VISIBLE.							
DIAMOND BIT No 81PC 72 81PC 175				LEGEND [A] - CONCRETE MB - MACHINE BIT NB - NATURAL BIT			
				LOCATION PIEL No. 7 VIEW LOOKING D/S SWES-C07.3N-80 Center of column Column # 3			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

Hole No. SWES-HS1-60

DRILLING LOG		DIVISION <u>St. Louis, Mo</u>		INSTALLATION <u>Lake & Dam No 24</u>		SHEET <u>1</u> OF <u>1</u> SHEETS	
1. PROJECT <u>Lock & Dam No. 24</u>				10. SIZE AND TYPE OF BIT <u>6 x 1 1/2"</u>			
2. LOCATION (To nearest or known) <u>SEE BELOW</u>				11. STATUS FOR ELEVATION FROM ITEM 10 <u>MSL</u>			
3. DRILLING AGENCY <u>CEWES</u>				12. MANUFACTURER'S DESIGNATION OF DRILL <u>ELECTRIC - CORE DRILL</u>			
4. HOLE NO. (As shown on opening note) and the number <u>SWES-HS1-60</u>				13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN <u>UNDISTURBED</u>			
5. NAME OF DRILLER <u>H. Mc Namara</u>				14. TOTAL NUMBER CORE BOXES <u>ONE</u>			
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED <u>90°</u> DEG. FROM VERT.				15. ELEVATION GROUND WATER			
7. THICKNESS OF OVERBURDEN <u>0.2'</u>				16. DATE HOLE <u>1 Dec 50</u> STARTED <u>1 Dec 50</u> COMPLETED			
8. DEPTH DRILLED INTO ROCK				17. ELEVATION TOP OF HOLE <u>271.6 - Center</u>			
9. TOTAL DEPTH OF HOLE				18. TOTAL CORE RECOVERY FOR BORING <u>100%</u>			
				19. SIGNATURE OF INSPECTOR <u>Jan 15 1951</u>			

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	3 CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)
4733.80	0.0	• 8.0	Concrete - Good Condition -			
		• 6.0	Rebar - 1/2" - Run No 1			ROD = 100%
4733.10	1.0		LOCATION - Pier No 5			
						AL — . Fur. 0.72 Began 10:30 Rec 0.72 End 10:45 Loss — Time 15 min Gain — Dri time 10 min Hyd press — Water press Hand RPM 3000 Dri Action Signal Water ret Brown Remarks
			1.7' 23" SWES-HS1-60 CENTERLINE VIEW LOOKING U/S LEGEND LB - CONCRETE MB - MACHINE BREAK NB - NATURAL BREAK DIAMOND BITS 79PB689			

BIG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
PROJECT		ST. LOUIS MO		Locks Dam No. 24		1 OF 1 SHEETS	
LOCATION (Continent or Station)		SEE BELOW		MSL			
DRILLING AGENCY		C.F.W.E.S.		MANUFACTURER'S DESIGNATION OF DRILL		ELECTRIC - CORE DRILL	
HOLE NO. (As shown on drawing title)		SWES-C09-1W-80		TOTAL NO. OF OVERBURDEN SAMPLES TAKEN		DISTURBED UNDISTURBED	
NAME OF DRILLER		A. McNamara		TOTAL NUMBER CORE BOXES		ONE	
DIRECTION OF HOLE		90° DEG. FROM VERT.		DATE HOLE		STARTED 14 NOVEMBER 1980 COMPLETED 14 NOVEMBER 1980	
THICKNESS OF OVERBURDEN		3.05'		ELEVATION TOP OF HOLE		4660	
DEPTH DRILLED INTO ROCK		3.05'		TOTAL CORE RECOVERY FOR BORING		100%	
TOTAL DEPTH OF HOLE		3.05'		SIGNATURE OF INSPECTOR		J. B. Numb	
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Designation)	SCORE	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)	
4660	00	Δ	Run No. 1 RQD = 0.0%			WL 14 NOV 80 Run 8.15 Began 3:45 Rec 0.15 End 4:00 Loss - Time 15 min Gain - Drl time 15 min Hyd press - Water press MED RPM 300 ± Drl Action Smooth Water ret Brown Remarks Blacked off on REBAR	
4660	10	Δ	Concrete				
4660	20	Δ	Concrete				
4660	30	Δ	Run No. 2 RQD = 88.8%			AL Run 2.7 Began 4:05 Rec 2.7 End 5:10 Loss - Time 65 min Gain - Drl time 65 min Hyd press - Water press MED RPM 300 ± Drl Action Smooth Water ret Brown Remarks	
CONCRETE PHYSICAL PROPERTIES THE SAME AS OTHER W.E.S. BORINGS - COAR, AGG. ETC. CONDITION OF CONCRETE APPEARS GOOD NO HAIRLINE CRACKS, SLIGHT REACTION PRODUCT, ALONG WITH V. HIGH RQD - BREAK AT 2.5 WAS DONE IN HANDLING.							
DIAMOND Bit No		LEGEND		LOCATION			
BIP 172		[A] CONCRETE		ON CONSTRUCTION JOINT COLUMN No. 1			
BIP 175		[---] HAIRLINE CRACK		50'			
		MB - MACHINE BREAK		ON CENTER OF COLUMN			
		NB - NATURAL BREAK		PIER No. 9			

Hole No. SWES-C09.2N-80

DRILLING LOG		DIVISION		INSTALLATION		SHEET	
PROJECT LOCK & DAM No 24		ST. LOUIS, MO		LOCK & DAM No 24		OF 1 SHEETS	
LOCATION (Coordinate or Station) See Below				10. SIZE AND TYPE OF BIT 6" x 6" - No. 7944M32			
DRILLING AGENCY CEWES				11. DAYTON FOR ELEVATION SHOWN FROM - MSL MSL			
HOLE NO. (As shown on drawing title) SWES-C09.2N-80				12. MANUFACTURER'S DESIGNATION OF DRILL ACKS			
NAME OF DRILLER A. McNamara				13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN UNOBTAINED			
DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT				14. TOTAL NUMBER CORE BOXES ONE			
THICKNESS OF OVERBURDEN 3.6'				15. ELEVATION GROUND WATER			
DEPTH DRILLED INTO ROCK 3.6'				16. DATE HOLE 12 November 80			
TOTAL DEPTH OF HOLE				17. ELEVATION TOP OF HOLE 469.2 ft			
				18. TOTAL CORE RECOVERY FOR BORING 100%			
				19. SIGNATURE OF INSPECTOR Joseph B. Smith			

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS
469.2	00	MB	1" REBAR Run #1 RRD=0.0%	100%		Run #1 12 November 80 Began 12.15 Reo 0.5 End 1.20 Loss Time 65 min Gain Drl time 60 min Hyd press 100 PSI Water press 160 RPM 800 Drl Action Smooth Water rot Remarks Backed off on Core
469.2	10	MB	1/4 REBAR - PITTED & OXIDIZED SLIGHT CRACK 45° to 90° are broken NB 45° at 90° to 1/4 break 100% Rubble, pieces from 1/2 to 1/4 NB 1/2" in size, broken in place		Box 1	Run #2 Began 1.35 Reo 2.25 End 3.40 Loss Time 120 min Gain Drl time 120 min Hyd press 100 PSI Water press 160 RPM 800 Drl Action Smooth Water rot Remarks Backed off
469.2	20	MB	1/4 REBAR Run #2 RRD=0.0%			Run #2 Began 3.45 Reo 3.25 End 5.20 Loss Time 80 min Gain Drl time 75 min Hyd press 100 PSI Water press 160 RPM 800 Drl Action Smooth Water rot Remarks Backed off
469.2	30	MB	1/4 REBAR Run #3 RRD=100%	100%	Box 1 36	Run #3 Began 4.00 Reo 4.85 End 5.20 Loss Time 80 min Gain Drl time 75 min Hyd press 100 PSI Water press 160 RPM 800 Drl Action Smooth Water rot Remarks Backed off
NOTE: Lost some water through crack on west edge of pier at approximately 110' - Cause of Corrosion on 1/4" REBAR.						

LEGEND

[A.] - CONCRETE

[MB] - BROKEN UP - TOO SMALL TO BEG + NO ORIENTATION OF PIECES.

MB - MACHINE BREAK

NB - NATURAL BREAK

LOCATION

CONCRETE - VERY POOR CONDITION

INTENSE WEATHERING WITH REACTION PRODUCT FOUND ON ENTIRE SURFACE OF DRILLED CORE - CORE CAME AWAY AS RUBBLE FOR MATERIAL AS SHOWN ABOVE - STEEL WAS OXIDIZED AND PITTED SEE ABOVE FOR LOCATION

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT _____ HOLE NO. _____

DRILLING LOG		SYMBOL		INSTALLATION		SHEET	
PROJECT		St Louis, Mo		Lock + Dam No 24		OF 1 SHEETS	
1. LOCATION (Continuation of Section)		SEE BELOW		10. SIZE AND TYPE OF BIT		11. DATE FOR ELEVATION MEASUREMENT	
2. DRILLING AGENCY		C.E.W.E.S.		12. MANUFACTURER'S DESIGNATION OF DRILL		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	
3. HOLE NO. (As shown on drawing only) and file number		SND-CC-9 45-46		14. TOTAL NUMBER CORE BOXES		15. ELEVATION GROUND WATER	
4. NAME OF DRILLER		H. McVannhed		16. DATE HOLE		17. ELEVATION TOP OF HOLE	
5. DIRECTION OF HOLE		90°		18. DATE HOLE		19. TOTAL CORE RECOVERY FOR BORING	
6. THICKNESS OF OVERBURDEN		3.3		19. SIGNATURE OF INSPECTOR		20. SIGNATURE OF INSPECTOR	
7. TOTAL DEPTH OF HOLE		3.3		20. SIGNATURE OF INSPECTOR		21. SIGNATURE OF INSPECTOR	
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Including time, water flow, depth of overburden, etc., if significant)	
4657.00	0.0	MB	Run No. 2 R.D. 0.0%			Run 1 19 Nov 80	
4657.10	1.0	Δ	CONCRETE	100%	Box 1	FL — 0.25 Began 2:50 — 0.25 End 3:05 — 0.25 Time 15 min Drill time 15 min Water press — Drill Action Smooth Water ret — Brown Remarks —	
4657.20	2.0	Δ	CONCRETE	100%	Box 1	Run 2 FL — Run 3:25 Began 3:40 — Run 3:25 End 4:05 — Run 3:25 Time 30 min Drill time 30 min Water press — Drill Action Smooth Water ret — Brown Remarks —	
4657.30	3.0	Δ	CONCRETE	100%	Box 1	Run 3 FL — Run 3:25 Began 3:40 — Run 3:25 End 4:05 — Run 3:25 Time 30 min Drill time 30 min Water press — Drill Action Smooth Water ret — Brown Remarks —	
CONCRETE PHYSICAL PROPERTIES SAME FAIR CONDITION - LITTLE TO NO REACTION PRODUCT WITH NO OXIDATION ON STEEL'S SURFACE. ENDS ARE SLIGHTLY WEATHERED.							
DIAMOND BITS		LEGEND		LOCATION			
81RCHB		10. CONCRETE		Center of column			
81RCHB		11. MACHINE BREAK		View looking U/S			
		MB - MACHINE BREAK		SND-CC-9 45-46			
		NB - NATURAL BREAK		Column No. 2			

 ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
 MAR 71 (TRANSLUCENT)

DRILLING LOG		DIVISION		INSTALLATION		HOLE NO.	
ST. LOUIS, MO		LOCK & DAM No. 24		SHEET 1 OF 1 SHEETS		Hole No. SNES-C09-3N-0	
PROJECT		LOCK & DAM No. 24		10. SIZE AND TYPE OF BIT		11. RETURN FOR ELEVATION (ROUGH TYPE - RMC)	
LOCATION (Coordinate or Station)		SEE BELOW		M.S.L.		12. MANUFACTURER'S DESIGNATION OF DRILL	
DRILLING AGENCY		CENES		ELSCOR - CORE DRILL		13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN	
HOLE NO. (As shown on drawing title) and file number		SNES-C09-3N-00		14. TOTAL NUMBER CORE BOXES		15. ELEVATION GROUND WATER	
NAME OF DRILLER		A. McNAMARA		16. DATE HOLE		17. ELEVATION TOP OF HOLE	
DIRECTION OF HOLE		VERTICAL ☐ INCLINED ☒ 90°		18. TOTAL CORE RECOVERY FOR BORING		19. SIGNATURE OF INSPECTOR	
THICKNESS OF OVERBURDEN		3.5		100%		20. SIGNATURE OF INSPECTOR	
DEPTH DRILLED INTO ROCK		3.5		100%		20. SIGNATURE OF INSPECTOR	
TOTAL DEPTH OF HOLE		3.5		100%		20. SIGNATURE OF INSPECTOR	
ELEVATION		DEPTH		LEGEND		CLASSIFICATION OF MATERIALS (Description)	
467.3		00		1/4" HOLE		Run No. 1	
467.3		10		STEEL 1" x 1"		Run No. 1 19 Nov. 80	
467.3		20		CONCRETE		Run No. 1 19 Nov. 80	
467.3		30		CONCRETE		Run No. 2	
467.3		40		CONCRETE		Run No. 2	
467.3		50		CONCRETE		Run No. 2	
467.3		60		CONCRETE		Run No. 2	
467.3		70		CONCRETE		Run No. 2	
467.3		80		CONCRETE		Run No. 2	
467.3		90		CONCRETE		Run No. 2	
467.3		100		CONCRETE		Run No. 2	
467.3		110		CONCRETE		Run No. 2	
467.3		120		CONCRETE		Run No. 2	
467.3		130		CONCRETE		Run No. 2	
467.3		140		CONCRETE		Run No. 2	
467.3		150		CONCRETE		Run No. 2	
467.3		160		CONCRETE		Run No. 2	
467.3		170		CONCRETE		Run No. 2	
467.3		180		CONCRETE		Run No. 2	
467.3		190		CONCRETE		Run No. 2	
467.3		200		CONCRETE		Run No. 2	
467.3		210		CONCRETE		Run No. 2	
467.3		220		CONCRETE		Run No. 2	
467.3		230		CONCRETE		Run No. 2	
467.3		240		CONCRETE		Run No. 2	
467.3		250		CONCRETE		Run No. 2	
467.3		260		CONCRETE		Run No. 2	
467.3		270		CONCRETE		Run No. 2	
467.3		280		CONCRETE		Run No. 2	
467.3		290		CONCRETE		Run No. 2	
467.3		300		CONCRETE		Run No. 2	
467.3		310		CONCRETE		Run No. 2	
467.3		320		CONCRETE		Run No. 2	
467.3		330		CONCRETE		Run No. 2	
467.3		340		CONCRETE		Run No. 2	
467.3		350		CONCRETE		Run No. 2	
467.3		360		CONCRETE		Run No. 2	
467.3		370		CONCRETE		Run No. 2	
467.3		380		CONCRETE		Run No. 2	
467.3		390		CONCRETE		Run No. 2	
467.3		400		CONCRETE		Run No. 2	
467.3		410		CONCRETE		Run No. 2	
467.3		420		CONCRETE		Run No. 2	
467.3		430		CONCRETE		Run No. 2	
467.3		440		CONCRETE		Run No. 2	
467.3		450		CONCRETE		Run No. 2	
467.3		460		CONCRETE		Run No. 2	
467.3		470		CONCRETE		Run No. 2	
467.3		480		CONCRETE		Run No. 2	
467.3		490		CONCRETE		Run No. 2	
467.3		500		CONCRETE		Run No. 2	
467.3		510		CONCRETE		Run No. 2	
467.3		520		CONCRETE		Run No. 2	
467.3		530		CONCRETE		Run No. 2	
467.3		540		CONCRETE		Run No. 2	
467.3		550		CONCRETE		Run No. 2	
467.3		560		CONCRETE		Run No. 2	
467.3		570		CONCRETE		Run No. 2	
467.3		580		CONCRETE		Run No. 2	
467.3		590		CONCRETE		Run No. 2	
467.3		600		CONCRETE		Run No. 2	
467.3		610		CONCRETE		Run No. 2	
467.3		620		CONCRETE		Run No. 2	
467.3		630		CONCRETE		Run No. 2	
467.3		640		CONCRETE		Run No. 2	
467.3		650		CONCRETE		Run No. 2	
467.3		660		CONCRETE		Run No. 2	
467.3		670		CONCRETE		Run No. 2	
467.3		680		CONCRETE		Run No. 2	
467.3		690		CONCRETE		Run No. 2	
467.3		700		CONCRETE		Run No. 2	
467.3		710		CONCRETE		Run No. 2	
467.3		720		CONCRETE		Run No. 2	
467.3		730		CONCRETE		Run No. 2	
467.3		740		CONCRETE		Run No. 2	
467.3		750		CONCRETE		Run No. 2	
467.3		760		CONCRETE		Run No. 2	
467.3		770		CONCRETE		Run No. 2	
467.3		780		CONCRETE		Run No. 2	
467.3		790		CONCRETE		Run No. 2	
467.3		800		CONCRETE		Run No. 2	
467.3		810		CONCRETE		Run No. 2	
467.3		820		CONCRETE		Run No. 2	
467.3		830		CONCRETE		Run No. 2	
467.3		840		CONCRETE		Run No. 2	
467.3		850		CONCRETE		Run No. 2	
467.3		860		CONCRETE		Run No. 2	
467.3		870		CONCRETE		Run No. 2	
467.3		880		CONCRETE		Run No. 2	
467.3		890		CONCRETE		Run No. 2	
467.3		900		CONCRETE		Run No. 2	
467.3		910		CONCRETE		Run No. 2	
467.3		920		CONCRETE		Run No. 2	
467.3		930		CONCRETE		Run No. 2	
467.3		940		CONCRETE		Run No. 2	
467.3		950		CONCRETE		Run No. 2	
467.3		960		CONCRETE		Run No. 2	
467.3		970		CONCRETE		Run No. 2	
467.3		980		CONCRETE		Run No. 2	
467.3		990		CONCRETE		Run No. 2	
467.3		1000		CONCRETE		Run No. 2	
467.3		1010		CONCRETE		Run No. 2	
467.3		1020		CONCRETE		Run No. 2	
467.3		1030		CONCRETE		Run No. 2	
467.3		1040		CONCRETE		Run No. 2	
467.3		1050		CONCRETE		Run No. 2	
467.3		1060		CONCRETE		Run No. 2	
467.3		1070		CONCRETE		Run No. 2	
467.3		1080		CONCRETE		Run No. 2	
467.3		1090		CONCRETE		Run No. 2	
467.3		1100		CONCRETE		Run No. 2	
467.3		1110		CONCRETE		Run No. 2	
467.3		1120		CONCRETE		Run No. 2	
467.3		1130		CONCRETE		Run No. 2	
467.3		1140		CONCRETE		Run No. 2	
467.3		1150		CONCRETE		Run No. 2	
467.3		1160		CONCRETE		Run No. 2	
467.3		1170		CONCRETE		Run No. 2	
467.3		1180		CONCRETE		Run No. 2	
467.3		1190		CONCRETE		Run No. 2	
467.3		1200		CONCRETE		Run No. 2	
467.3		1210		CONCRETE		Run No. 2	
467.3		1220		CONCRETE		Run No. 2	
467.3		1230		CONCRETE		Run No. 2	
467.3		1240		CONCRETE		Run No. 2	
467.3		1250		CONCRETE		Run No. 2	
467.3		1260		CONCRETE		Run No. 2	
467.3		1270		CONCRETE		Run No. 2	
467.3		1280		CONCRETE		Run No. 2	
467.3		1290		CONCRETE		Run No. 2	
467.3		1300		CONCRETE		Run No. 2	
467.3		1310		CONCRETE		Run No. 2	
467.3		1320		CONCRETE		Run No. 2	
467.3		1330		CONCRETE		Run No. 2	
467.3		1340		CONCRETE		Run No. 2	
467.3		1350		CONCRETE		Run No. 2	
467.3		1360		CONCRETE		Run No. 2	
467.3		1370		CONCRETE		Run No. 2	
467.3		1380		CONCRETE		Run No. 2	
467.3		1390		CONCRETE		Run No. 2	
467.3		1400		CONCRETE		Run No. 2	
467.3		1410		CONCRETE		Run No. 2	
467.3		1420		CONCRETE		Run No. 2	
467.3		1430		CONCRETE		Run No. 2	
467.3		1440		CONCRETE		Run No. 2	
467.3		1450		CONCRETE		Run No. 2	
467.3		1460		CONCRETE		Run No. 2	
467.3		1470		CONCRETE		Run No. 2	
467.3		1480		CONCRETE		Run No. 2	
467.3		1490		CONCRETE		Run No. 2	
467.3		1500		CONCRETE		Run No. 2	
467.3		1510		CONCRETE		Run No. 2	
467.3		1520		CONCRETE		Run No. 2	
467.3		1530		CONCRETE		Run No. 2	
467.3		1540		CONCRETE		Run No. 2	
467.3		1550		CONCRETE		Run No. 2	
467.3		1560		CONCRETE		Run No. 2	
467.3		1570		CONCRETE		Run No. 2	
467.3		1580		CONCRETE		Run No. 2	
467.3		1590		CONCRETE		Run No. 2	
467.3		1600		CONCRETE		Run No. 2	
467.3		1610		CONCRETE		Run No. 2	
467.3		1620		CONCRETE		Run No. 2	
467.3		1630		CONCRETE		Run No. 2	
467.3		1640		CONCRETE		Run No. 2	
467.3		1650		CONCRETE		Run No. 2	
467.3		1660		CONCRETE		Run No. 2	
467.3		1670		CONCRETE		Run No. 2	
467.3		1680		CONCRETE		Run No. 2	
467.3		1690		CONCRETE		Run No. 2	
467.3		1700		CONCRETE		Run No. 2	
467.3		1710		CONCRETE		Run No. 2	
467.3		1720		CONCRETE		Run No. 2	
467.3		1730		CONCRETE		Run No. 2	
467.3		1740		CONCRETE		Run No. 2	
467.3		1750		CONCRETE		Run No. 2	
467.3		1760		CONCRETE		Run No. 2	
467.3		1770		CONCRETE		Run No. 2	
467.3		1780		CONCRETE		Run No. 2	
467.3		1790		CONCRETE		Run No. 2	
467.3		1800		CONCRETE		Run No. 2	
467.3		1810		CONCRETE		Run No. 2	
467.3		1820		CONCRETE		Run No. 2	
467.3		1830		CONCRETE		Run No. 2	
467.3		1840		CONCRETE		Run No. 2	
467.3		1850		CONCRETE		Run No. 2	
467.3		1860		CONCRETE		Run No. 2	
467.3		1870		CONCRETE		Run No. 2	
467.3		1880		CONCRETE		Run No. 2	
467.3		1890		CONCRETE		Run No. 2	
467.3		1900		CONCRETE		Run No. 2	
467.3		1910		CONCRETE		Run No. 2	
467.3		1920		CONCRETE		Run No. 2	

Hole No. S.W.E.S.-C09-24-50

DRILLING LOG		DIVISION	INSTALLATION	SHEET 1 OF 1 SHEETS		
1. PROJECT			10. SIZE AND TYPE OF BIT			
2. LOCATION (Continent or Island)			11. DAYS FOR ELEVATION BROWN (TIME IN MIN)			
3. DRILLING AGENCY			12. MANUFACTURER'S DESIGNATION OF DRILL			
4. HOLE NO. (As shown on drawing 1100) and No. of samples			13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN			
5. NAME OF DRILLER			14. TOTAL NUMBER CORE BOXES			
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED _____ DEG. FROM VERT.			15. ELEVATION GROUND WATER			
7. THICKNESS OF OVERBURDEN			16. DATE HOLE STARTED COMPLETED			
8. DEPTH DRILLED INTO ROCK			17. ELEVATION TOP OF HOLE			
9. TOTAL DEPTH OF HOLE			18. TOTAL CORE RECOVERY FOR BORING			
			19. SIGNATURE OF INSPECTOR			
ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Described)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water used, depth of penetration, etc., if significant)
4692	00		CLOSED OPEN - CRACKS			
4692	10		HAIRLINE - CLOSED			
4692	20		AS VIEWED INSIDE BORING			

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT)

PROJECT

HOLE NO.

Hole No. 9463-C13-3A-80

DRILLING LOG PROJECT: <u>Lock and Dam No. 24</u> LOCATION: <u>SEE BELOW</u> DRILLING AGENCY: <u>C.F.W.E.S.</u> HOLE NO. (As shown on drawing sheet and file number): <u>SWES-C13.3N-50</u> NAME OF DRILLER: <u>M. McNamee</u> DIRECTION OF HOLE: ☐ VERTICAL ☒ INCLINED <u>90°</u> DEG. FROM VERT. THICKNESS OF OVERBURDEN: <u>3.55</u> DEPTH DRILLED INTO ROCK: <u>3.55</u> TOTAL DEPTH OF HOLE: <u>3.55</u>		INSTALLATION LOCK AND DAM No. 24 SIZE AND TYPE OF BIT: <u>6 3/4" - SEE BELOW</u> DATE FOR ELEVATION DETERMINATION: <u>M.S.L.</u> MANUFACTURER'S DESIGNATION OF DRILL: <u>ELCIRK - CORE DRILL</u> TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: <u>UNOBTAINED</u> TOTAL NUMBER CORE BOXES: <u>ONE</u> ELEVATION GROUND WATER: <u>21 NOVEMBER 1960</u> DATE HOLE STARTED: <u>21 NOVEMBER 1960</u> DATE HOLE COMPLETED: <u>21 NOVEMBER 1960</u> ELEVATION TOP OF HOLE: <u>166.0' CENTER ROAD</u> TOTAL CORE RECOVERY FOR BORING: <u>100%</u> SIGNATURE OF DRILLER: <u>Joseph B. Smith</u>	
--	--	--	--

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE RECOVERY %	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc., if significant)
166.0	00	1/2" Rebar	STEEL			Run No. 1 21 Nov 60 HL Run 3.55 Began 3-5.0 Reo 3.55 End 7-45-10.45 Loss - Time 12 min. Calc - Drl time 120 min. Hyd press - Water press 1000 RPM 300 Drl Action Smooth Water set Brown Remarks Drilling Left Binding UP 3 INTERMITTING -
1600	10	Δ	CONCRETE SAME	100%	Box 1	
1600	20	Δ				
1600	30	Δ				
1600	30	Δ				
1600	30	Δ	1/2" Rebar			
1600	30	Δ	STEEL			
			Run No. 1 RQD = 100%	355		
CONCRETE - PHYSICAL PROPERTIES SAME AS OTHER WES. BORINGS. CONDITION OF CONCRETE IS GOOD - VERY LITTLE TO NO REACTION AND NO SIGNS OF WEATHERING. SLIGHT OXIDATION OF STEEL AT 0.35 FT						

DIAMOND BIT **LEGEND** **LOCATION**

79PN429

79PN430

13- CONCRETE

14- MACHINE CORNER

11B - MACHINE BREAK

11B - NATURAL BREAK

Pier No. 13

Column No. 3

40'

CENTER OF COLUMN

VIEW LOOKING 45°

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE (TRANSLUCENT) PROJECT HOLE NO.

Hole No. SWES-C13.240

DRILLING LOG		DIVISION <u>St Louis, Mo</u>		INSTALLATION <u>LOCK # Dam #24</u>		SHEET <u>1</u> OF <u>1</u> SHEETS	
1. PROJECT <u>LOCK # Dam #24</u>		10. SIZE AND TYPE OF BIT <u>6" SEE BELOW</u>		11. DATUM FOR ELEVATION MEASUREMENT <u>MSL</u>		12. MANUFACTURER'S DESIGNATION OF DRILL <u>ALCO</u>	
2. LOCATION (Coordinates or Section) <u>SEE BELOW</u>		13. TOTAL NO. OF OVER- BURDEN SAMPLES TAKEN		14. TOTAL NUMBER CORE BOXES <u>ONE</u>		15. ELEVATION GROUND WATER	
3. DRILLING AGENCY <u>CEWES</u>		16. DATE HOLE <u>11 November 1912</u>		17. ELEVATION TOP OF HOLE <u>462.0</u>		18. TOTAL CORE RECOVERY FOR BORING <u>100%</u>	
4. HOLE NO. (As shown on drawing and No. and No. number) <u>SWES-C13.2400</u>		19. SIGNATURE OF INSPECTOR <u>James B. Smith</u>					
5. NAME OF DRILLER <u>H. McNamee</u>		19. DATE HOLE <u>11 November 1912</u>					
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED <u>90°</u> DEG. FROM VERT.		17. ELEVATION TOP OF HOLE <u>462.0</u>		18. TOTAL CORE RECOVERY FOR BORING <u>100%</u>			
7. THICKNESS OF OVERBURDEN		19. SIGNATURE OF INSPECTOR <u>James B. Smith</u>					
8. DEPTH DRILLED INTO ROCK <u>3.5</u>							
9. TOTAL DEPTH OF HOLE							

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant)
4620	00	8.5'	1" Rod Run #1	100%		Run #1 11 November 1912 Began 12:19 Run 0:25 End 1:20 Rec 0:35 Time 71 min Gain — Drl time 71 min Hyd press 100 PSI Water press 100 PSI RPM 70.5 Drl Action Smooth Water ret Bored Remarks Tide up Impregnated Box on end of R.R.
4620	10	Δ	1" of Rod - 1" x 2" Steel			
4620	20	Δ	1/4" Rod	100%	Box 1	Run #2 11/3/12 November 1912 Began 2:30 - 5:15 Rec 3:15 End 7:30 - 10:30 Loss — Time 3:40 min Gain — Drl time 3:40 min Hyd press 100 PSI Water press 100 PSI RPM 80.5 Drl Action Smooth Water ret Bored Remarks
4620	30	Δ	1/4" Rod			
			Run #2 R.R.D. 100%	5.5'		
CONCRETE - GREY BROWN IN COLOR, NATURAL AGGREGATE (SIZE AND SHAPE AS INDICATED IN OTHER W.E.S. BORINGS), STEEL APPEARS UN- OXIDIZED AND CONDITION OF CONCRETE FROM THIS COLUMN IS VERY GOOD. LITTLE TO NO R.P. AND WITH NO OTHER SIGNS OF WEATHERING, VISIBLE.						

DIAMOND BITS

790690

790432

LEGEND

Δ - CONCRETE

MB - MACHINE BREAK

NB - NATURAL BREAK

R.P. - REACTION PRODUCT

LOCATION

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO. (TRANSLUCENT)

Hole No. SAKS-C16.1W-80

DRILLING LOG		DIVISION St. Louis, Mo.	INSTALLATION Lock & Dam No. 24	SHEET Of 1 SHEETS
PROJECT Lock & Dam # 24		NO. SIZE AND TYPE OF BIT 6" - SEE BELOW		
LOCATION (Continent or Station) See Below		DATE FOR ELEVATION ABOVE (FMS - MSL) MSL		
DILLING AGENCY C.E.W.S.		MANUFACTURE'S DESIGNATION OF DRILL ELECTRIC-CORE DRILL		
HOLE NO. (As shown on drawing title and file number) SAKS-C16.1W-80		TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN ☒ DISTURBED ☐ UNDISTURBED		
NAME OF DRILLER J. McNamara		TOTAL NUMBER CORE BOXES ONE		
DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.		ELEVATION GROUND WATER _____		
THICKNESS OF OVERBURDEN		DATE HOLE ☒ STARTED ☐ COMPLETED 13 November 1960 13 November 1960		
DEPTH DRILLED INTO ROCK 3.1'		ELEVATION TOP OF HOLE 466.9 FT		
TOTAL DEPTH OF HOLE		TOTAL CORE RECOVERY PER BORING 100%		
		SIGNATURE OF INSPECTOR Joseph B. [Signature]		

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	REMARKS (Drilling time, water loss, depth of overburden, etc., if significant) e
4669	0	Run #1	Run #1 RQD=00%	Run #1 13 November 1960 WL - Run 0.35 Began 1.45 RQD 0.35 End 2.00 Loss - Time 15 min. Gals - Drl time 15 min Hyd press - Water press ASD RPM 500 Drl Action Smooth Water rpt Brown Remarks CHANGED BITS - REAR
4669	10	Run #2	Run #2 RQD=100%	Run #2 WL - Run 2.25' Began 2.45 RQD 2.75' End 4.40 Loss - Time 60 min. Gals - Drl time 60 min Hyd press - Water press ASD RPM 300 Drl Action Smooth Water rpt Brown Remarks BROKEN UP ELECTRIC MOTOR REPLACED MOTOR WITH SPARE
4669	20	CONCRETE	CONCRETE	
4669	30	CONCRETE	CONCRETE	

CONCRETE: PHYSICAL PROPERTIES
SAME AS OTHER BORINGS -
AGG. COND. ETC. CONDITION
OF CONCRETE APPEARS TO
BE GOOD. VERY LITTLE
TO NO. REACTION PRODUCT
AND STEEL SURFACES APPEARS
UNOXIDIZED.

DIAMOND BITS

81R176

81R17A

LEGEND

CONCRETE

BROKEN UP. TO SMALL TO LOG

MA - MACHINE BREAK

NB - NATURAL BREAK

LOCATION

Pier No. 6

UNABLE TO GET HIGHER
DUE TO SUPERSTRUCTURE
OF BRIDGE-CHANNING

DRILLING LOG		DIVISION	INSTALLATION	SHEET	
PROJECT		ST. LOUIS, MO	LOCK 1 DAM #24	OF 1 SHEETS	
1. LOCATION (Coordinate or Station)		LOCK 1 DAM #24			
2. DRILLING AGENCY		A. McNameel			
3. NAME OF DRILLER		A. McNameel			
4. HOLE NO. (As shown on drawing info)		SNES-C16.15-80			
5. DIRECTION OF HOLE		90 DEG. FROM VERT.			
6. THICKNESS OF OVERBURDEN		3.6'			
7. DEPTH DRILLED INTO ROCK		3.6'			
8. TOTAL DEPTH OF HOLE		3.6'			
9. SIZE AND TYPE OF BIT		MSL			
10. DAYTON ELEVATION (FROM - MSL)		MSL			
11. MANUFACTURER'S DESIGNATION OF DRILL		HCC			
12. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN		0			
13. TOTAL NUMBER CORE BOXES		ONE			
14. ELEVATION GROUND WATER		10 November 80			
15. DATE HOLE		10 November 80			
16. ELEVATION TOP OF HOLE		438.45 - Center Boring			
17. TOTAL CORE RECOVERY FOR BORING		100.0%			
18. SIGNATURE OF INSPECTOR		G. B. Bunker			
19. SIGNATURE OF DRILLER		A. McNameel			

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of penetration, etc. if different)
475.45	0.0		0.0 - 1.3' & 2.5 - 3.6'			Run #1 8 November 80
			HAIRLINE CRACKS DUE TO FRETZ DAMAGE - FREEZE THAW			AL Run 19
						Began 800
						End 810
						Time 160 min
						Drill time 160 min
						Hyd. press 50 to 80 PSI
						Water press Low to Med
						RPM 50 to 70
						Drill Action Smooth
						Water ret
						Bunker
						Remarks
						CHINNEY BITS
						Run #2 10 November 80
						AL Run 17
						Began 800
						End 1130
						Time 190 min
						Drill time 190 min
						Hyd. press 80 PSI
						Water press Low to Med
						RPM 70
						Drill Action Smooth
						Water ret
						Bunker
						Remarks

CONCRETE: PHYSICAL PROPERTIES ARE SAME AS ENCOUNTERED IN OTHER BORINGS (AGGREGATE, COLOR OF CONCRETE, ETC.)

CONDITION OF CONCRETE IS POOR.

INTENSE WEATHERING WAS FOUND IN THE CONCRETE. NUMEROUS HAIRLINE CRACKS WITH REACTION PRODUCT AND REACTION RIMS ON THE AGGREGATE WERE VISIBLE. STEEL SURFACES WERE NOT OXIDIZED WHERE VISIBLE. - BOTH STEEL AND COPPER REBAR WAS ENCOUNTERED

LEGEND

□ CONCRETE

— HAIRLINE CRACKS

MB MACHINE BREAK

NB NATURAL BREAK

DIAMOND BITS

81PC177

81PC170

LOCATION

SNES-C16.15-80

PIECE #16

COLUMN NO. 1

VIEW LOOKING UP

Hole No. SWES CIL 3N 80

DRILLING LOG		Division	INSTALLATION	SHEET
PROJECT		<u>St. Louis, Mo</u>	<u>LOCK & DAM #24</u>	OF 1 SHEETS
1. LOCATION (Continuation of Form)		10. SIZE AND TYPE OF BIT <u>"16-79 PNC 432"</u>		
2. DRILLING AGENCY		11. DATE FOR ELEVATION INFORMATION <u>1960</u>		
3. HOLE NO. (As shown on drawing sheet and No. number)		12. MANUFACTURER'S DESIGNATION OF DRILL <u>M5 L</u>		
4. NAME OF DRILLER		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN		
5. DIRECTION OF HOLE		14. TOTAL NUMBER CORE BOXES <u>ONE</u>		
6. THICKNESS OF OVERBURDEN		15. ELEVATION GROUND WATER		
7. DEPTH DRILLED INTO ROCK		16. DATE HOLE		
8. TOTAL DEPTH OF HOLE		17. ELEVATION TOP OF HOLE		
9. ELEVATION		18. TOTAL CORE RECOVERY FOR BORING		
10. DEPTH		19. SIGNATURE OF INSPECTOR		
11. LEGEND		20. REMARKS		
12. CLASSIFICATION OF MATERIALS		21. CORE RECOVERY		
13. BOX OR SAMPLE NO.		22. REMARKS		

1. PROJECT LOCK & DAM #24
 2. DRILLING AGENCY SEE BELOW
 3. HOLE NO. SWES CIL 3N 80
 4. NAME OF DRILLER A. McNamara
 5. DIRECTION OF HOLE ☒ VERTICAL ☒ INCLINED 90° DES. FROM VERT
 6. THICKNESS OF OVERBURDEN 35'
 7. DEPTH DRILLED INTO ROCK 35'
 8. TOTAL DEPTH OF HOLE 35'
 9. ELEVATION 475.48
 10. DEPTH 10'
 11. LEGEND CONCRETE
 12. CLASSIFICATION OF MATERIALS CONCRETE
 13. BOX OR SAMPLE NO. 1
 14. TOTAL NUMBER CORE BOXES ONE
 15. ELEVATION GROUND WATER
 16. DATE HOLE 10 November 60
 17. ELEVATION TOP OF HOLE 475.48
 18. TOTAL CORE RECOVERY FOR BORING 100%
 19. SIGNATURE OF INSPECTOR [Signature]
 20. REMARKS Run #1
M. Run 350
Began 3:30-5:30 Reg 350
End 7:45-11:15 Log
Time 330 min. Calc
Drill time 30 min
Hyd. press 80 to 100 PSI
Water press MED
RPM 702
Drill Action Smooth
Water ret
Brown
Remarks
Run #2 RQD: 77.1%
CONCRETE: PHYSICAL PROPERTIES SAME
AS OTHER BORINGS (COLOR, AGGREGATE, ETC)
CONDITION OF CONCRETE IS FAIR.
ONLY THE FIRST FOOT IS INTENSELY
WEATHERED AND REMAINING CONCRETE
APPEARS TO BE IN GOOD CONDITION.
NUMEROUS HAIRLINE CRACKS, BREAKS, AND MOD.
REACTION PRODUCT IS VISIBLE IN THE
FIRST FOOT, STEEL LOOKS TO BE IN
GOOD CONDITION, THERE IS NO OXIDATION
FOUND ON STEEL'S SURFACE (BAR @ 0.35')
DIAMOND BIT
79PNC432
 LOCATION PER #16
 COLUMN #3
 VIEW LOOKING D/S

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE
MAR 71 (TRANSLUCENT)

DRILLING LOG		INSTALLATION		SHEET	
PROJECT: <u>LOCK 1 Dam #24</u>		DATE: <u>10/10/60</u>		OF 1 SHEETS	
1. LOCATION: <u>LOCK 1 Dam #24</u>		2. HOLE NO. (As shown on drawing sheet and the number): <u>SWES-CK-2N-Rc</u>		3. HOLE AND TYPE OF BIT: <u>6"-55" Drill</u>	
4. DRILLING METHOD: <u>CEWES</u>		5. DRILLING AGENCY: <u>MSL</u>		6. DATE OF ELEVATION GROUND WATER: <u>MSL</u>	
7. NAME OF DRILLER: <u>A. McVay</u>		8. MANUFACTURER'S DESIGNATION OF DRILL: <u>ALGER</u>		9. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: <u>UNDISTURBED</u>	
10. DIRECTION OF HOLE: <u>90°</u> DEG. FROM VERT.		11. TOTAL NUMBER CORE BOXES: <u>ONE</u>		12. ELEVATION GROUND WATER: <u>467.45'</u>	
13. THICKNESS OF OVERBURDEN: <u>3.5</u>		14. DATE HOLE: <u>10/10/60</u>		15. COMPLETED: <u>10/10/60</u>	
16. DEPTH DRILLED INTO ROCK: <u>3.5</u>		17. ELEVATION TOP OF HOLE: <u>467.45'</u>		18. TOTAL CORE RECOVERY FOR BORING: <u>100%</u>	
19. TOTAL DEPTH OF HOLE: <u>3.5</u>		20. SIGNATURE OF INSPECTOR: <u>John B. Taylor</u>		21. SIGNATURE OF DRILLER: <u>A. McVay</u>	

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling data, sample logs, depth of penetration, etc., if significant)
467.45	0.0	NO	HAIRLINE CRACKS			Run #1 10/10/60
467.45	1.0	NO	STEEL REBAR		Box 1	Run 12/5 Began 12/5 End 1/3 Time 30min Drl time 50min Hyd press 600 Water press 100 to 140 RPM 700 Drl Action Smooth Water ret Bowl Remarks SPECIAL HARD ON CORE BIT
467.45	2.0	NO	CONCRETE		Box 1	Run #2 13/10/60
467.45	3.0	NO	HAIRLINE CRACKS		3.5	Run 2.6 Began 8:30 End 10:00 Time 1:30min Drl time 1:30min Hyd press 750 Water press 100 RPM 750 Drl Action Smooth Water ret Bowl Remarks
CONCRETE: WEATHERED AT ENDS WITH NUMEROUS HAIRLINE CRACKS, MODERATE REACTION PRODUCT, AND NATURAL BETAS - CENTER OF CORE APPEARS IN CONDITION BUT STILL NOTICABLE IS SLIGHT AMOUNT OF REACTION PRODUCT. STEEL WARE EXPOSED DOES NOT APPEAR OXIDIZED OR CORRODED. - ENDS ARE IN POOR CONDITION WHILE CENTER IS IN FAIR CONDITION.						

DIAMOND BIT

81 PC 17H

81 PC 17C

LEGEND

□ CONCRETE

MB - MACHINE BREAK

NB - NATURAL BREAK

— HAIRLINE CRACK

LOCATION

APPENDIX C: REPORT OF PETROGRAPHIC
EXAMINATION OF CONCRETE CORES

Corps of Engineers, USAE Waterways Experiment Station	Concrete Report	Structures Laboratory P. O. Box 631 Vicksburg, Mississippi
Project	Investigation of Concrete Deterioration, Lock and Dam 24	Date 13 March 1981 GSW

Samples

1. Portions of concrete from five cores from Lock and Dam No. 24 were selected for detailed petrographic examination. A general description of the 6-in.-diameter concrete cores is as follows:

<u>Field Identification No.</u>	<u>Description</u>
S WES-C16.2 N-80	Horizontal core into badly deteriorated concrete
S WES-C16.3 E-80	Horizontal core into moderately deteriorated concrete
S WES-C13.2 N	Horizontal core into good concrete
S WES-P04.1	Vertical core into good concrete
S WES-P09.1	Vertical core into good concrete

Test procedures

2. The concrete cores that were examined represented different visual physical conditions of the concrete. Some portions of the concrete examined were deep interior concrete while other concrete represented the near surface material.
3. The appearance and condition of this concrete was compared to that of the concrete previously examined from the same structure in 1976⁽¹⁾ and 1978.⁽²⁾ The current samples are more representative of the general condition of the concrete deterioration and the extent of the damage.
4. Twenty-five cores were examined megascopically to determine the overall homogeneity of the concrete. Portions of the concrete cores described earlier were selected for further examination.
5. Several pieces of core were sawed longitudinally. One of each pair of sawed surfaces was ground smooth and examined with a stereomicroscope.
6. The core surfaces were examined for signs of deleterious chemical reaction and/or physical degradation. Fresh fracture surfaces were also examined. A stereomicroscope was used as needed to aid in the examination.

WES FORM No. 1115
Rev Feb 1970

7. Reaction products from interior concrete surfaces and exudation from core surfaces were examined as oil immersion mounts using a polarizing microscope.

8. A black substance coating a break in core S WES-P04.1 at about 12.5-ft depth was also examined. Acetone was used to remove the coating from the break surface before the concrete was examined.

Results

9. Concrete from core S WES-C16.2 N-80 represented severely deteriorated concrete. This concrete was highly fractured and tended to disaggregate easily during drilling and handling. The concrete from boring S WES-C16.3 E-80 represented moderately deteriorated concrete. This concrete contained a major longitudinal crack in the center of the core in which a white exudation is collecting on the exposed surface of the concrete. All other concrete cores represented intact concrete from both the interior and near surface concrete of the structure.

10. The concrete in all the cores examined contained gravel and sand of mixed composition. The maximum size coarse aggregate was about 1-1/2 in. The aggregate consisted of sandstone, quartz, chert, carbonate rock particles, dark fine-grained igneous rock particles, coarse-grained igneous rock particles, and some particles of ironstone. Chalcedony in chert particles was identified as the most common reactive aggregate material in this group of concrete cores. This finding is similar to the observations made in the two earlier reports.^(1,2)

11. Some of the concrete contained pale yellowish brown (10 YR 6/2)⁽³⁾ paste while the remainder of the concrete contained medium light gray (N6)⁽³⁾ paste. There was no apparent physical difference between the different colored pastes. White alkali silica gel was present in both colors of paste.

12. The general deterioration consisted of parallel to subparallel cracking occurring parallel to the formed surface of the cores. These partings tended to be closely spaced near the outer surface of the concrete and were absent in the interior concrete. The photographs in Figure C1 are a set of pictures of core S WES-C16.2 N-80 drilled through a column on pier No. 16. Deterioration was present at both ends of this core while the central portion of it remained relatively intact.

13. Examination of ground surfaces indicated that this concrete was not air entrained. The concrete contained a few entrapped air voids but generally the concrete was dense and intact.

14. The maximum depth of deterioration was to a depth of 1.5 ft as found in core S WES-C16.2 N-80. Most of the deterioration was confined to the exterior 0.6 ft of concrete.

15. This concrete also tended to be saturated with white alkali-silica gel. This gel was present coating the cracks and as surface exudation. Some calcium hydroxide was also carried to surfaces in solution and deposited as white deposits. The alkali-silica gel ranged from a thick white to a clear material totally encasing the reactive aggregate and penetrating into the adjacent paste.

16. The black material coating the broken surface of core S WES-P04.1 at about 12.5 ft was a pliable black tar-like substance. The concrete beneath the coating was undisturbed. The coating appeared to have been put on the concrete as some sort of a bond breaker.

Conclusions

17. The lack of entrained air in this concrete caused the concrete to be susceptible to frost damage. The repeated freezing and thawing of the concrete while critically saturated has caused delamination of the concrete, especially near surfaces.

18. The opening of the concrete by frost action has accelerated the alkali-silica reaction. This deleterious chemical reaction has caused additional disaggregation of the frost-damaged concrete. The interior concrete shows slight indications of alkali-silica reaction, but has not caused any significant damage to the interior concrete.

References Cited

1. U. S. Army Engineer Waterways Experiment Station petrographic report dated 30 January 1976 to the U. S. Army Engineer District, St. Louis, subject: "Test and Examination of Concrete Cores from Lock and Dam 24 and Lock and Dam 25."
2. U. S. Army Engineer Waterways Experiment Station petrographic report dated December 1978 to the U. S. Army Engineer District, St. Louis, subject: "Examination of Concrete Cores from Lock and Dam 24."
3. The Rock Color Chart Committee, E. N. Goddard, Chm, "Rock Color Chart," 1975, The Geological Society of America, Boulder, Colo.



(a)



(b)

Figure C1. Opposite ends of core S WES-C16.2 N-80 drilled through a concrete column. The cracking is parallel to the formed surface and tends to go around the aggregate particles as well as through them

APPENDIX D: PHOTOGRAPHS SHOWING BURST PIPE



Photo 1. Fractured concrete wedge before removal. Column 3 on pier No. 16.



Photo 2. Concrete wedge removed exposing burst pipe, reinforcing steel, and wetted concrete.



Photo 3. Close-up of area shown in Photo 2. Notice burst pipe and wetter concrete. Most all large aggregate show clean tensile failure surfaces.



4
The above described concrete is not a
type of concrete that is used in the
construction of the bridge.



Fig. 10. Floor surface atop of bridge support column. X-ray diffraction plates removed during next to complete. X-ray diffraction plates removed during next to complete. X-ray diffraction plates removed during next to complete. X-ray diffraction plates removed during next to complete.

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.

Stowe, Richard L.

Condition survey repair and rehabilitation Lock and Dam No. 24, Mississippi River / by Richard L. Stowe, Henry T. Thornton, Jr. (Structures Laboratory, U.S. Army Engineer Waterways Experiment Station). -- Vicksburg, Miss. : The Station ; Springfield, Va. : available from NTIS, 1981.

90 p. in various pagings, 46 p. of plates : ill. ; 27 cm. -- (Miscellaneous paper / U.S. Army Engineer Waterways Experiment Station ; SL-81-21)

Cover title.

"August 1981."

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

Final report.

Bibliography: p. 33.

1. Concrete dams. 2. Concrete research. 3. Locks (Hydraulic engineering). 4. Mississippi River.
I. Thornton, Henry T., Jr. II. United States. Army.

Stowe, Richard L.

Condition survey repair and rehabilitation : ... 1981.
(Card 2)

Corps of Engineers. St. Louis District. III. U.S. Army Engineer Waterways Experiment Station. Structures Laboratory. IV. Title V. Series: Miscellaneous paper (U.S. Army Engineer Waterways Experiment Station) ; SL-81-21.
TA7.W34m no.SL-81-21