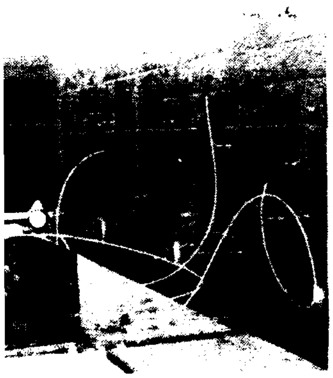
US Army Corps of Engineers

AD-A229 429



DTIC FILE COPY

(2)

REPAIR, EVALUATION, MAINTENANCE, AND REHABILITATION RESEARCH PROGRAM

TECHNICAL REPORT REMR-CS-30

IN SITU REPAIR OF DETERIORATED CONCRETE IN HYDRAULIC STRUCTURES: EPOXY INJECTION REPAIR OF A BRIDGE PIER

by

R. P. Webster, L. E. Kukacka, D. Elling

Process Sciences Division
Department of Applied Science
Brookhaven National Laboratory
Associated Universities, Inc.
Upton, New York 11973

September 1990

Final Report

Approved For Public Release; Distribution Unlimited

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

Under Civil Works Research Work Unit 32308

Monitored by Structures Laboratory
US Army Engineer Waterways Experiment Station
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

90 1[illegible] 9

The following two letters used as part of the number designating technical reports of research published under the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program identify the problem area under which the report was prepared:

	Problem Area		Problem Area
CS	Concrete and Steel Structures	EM	Electrical and Mechanical
GT	Geotechnical	EI	Environmental Impacts
HY	Hydraulics	OM	Operations Management
CO	Coastal		

COVER PHOTOS:

TOP - Wet drilling of port holes.

BOTTOM - Manifold system used to inject three ports simultaneously.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

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

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY 2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) BNL-43313	5. MONITORING ORGANIZATION REPORT NUMBER(S) Technical Report REMR-CS-30
6a. NAME OF PERFORMING ORGANIZATION Brookhaven National Laboratory 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION USAEWES Structures Laboratory
6c. ADDRESS (City, State, and ZIP Code) Upton, NY 11973	7b. ADDRESS (City, State, and ZIP Code) 3909 Halls Ferry Road Vicksburg, MS 39180-6199
8a. NAME OF FUNDING/SPONSORING ORGANIZATION US Army Corps of Engineers 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Washington, DC 20314-1000	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. / WORK UNIT ACCESSION NO. 32308

11. TITLE (Include Security Classification)
In Situ Repair of Deteriorated Concrete in Hydraulic Structures: Epoxy Injection Repair of a Bridge Pier

12. PERSONAL AUTHOR(S)
Webster, R. P., Kukacka, L. E., and Elling, D.

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
Final Report	FROM ____ TO ____	September 1990	109

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

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Bridge pier; Field test; Pressure injection; Concrete; Hydraulic structures; Cracking; In situ repair

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

Presented are the results of the fourth and final phase of a research program directed toward identifying in situ repair procedures to be utilized in the rehabilitation of cracked concrete hydraulic structures. Emphasis of the laboratory and field research performed in Phase Four was directed toward the optimization of equipment and materials to be used with pressure injection repair techniques. Once optimized, the repair procedure was demonstrated in a field test performed at Lock and Dam 13 on the Mississippi River, Fulton, IL.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL	22b. TELEPHONE (Include Area Code) / 22c. OFFICE SYMBOL

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

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

PREFACE

The study reported herein was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32308, "In Situ Repair of Deteriorated Concrete," for which Mr. James E. McDonald, Research Civil Engineer, Concrete Technology Division (CTD), Structures Laboratory (SL), US Army Engineer Waterways Experiment Station (WES), is Principal Investigator. This work unit is part of the Concrete and Steel Structures Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program. The Overview Committee of HQUSACE for the REMR Research Program consists of Mr. James E. Crews (CECW-OM) and Dr. Tony C. Liu (CECW-EG). The Technical Monitor for this study was Dr. Liu.

This study was sponsored by WES and conducted by the Brookhaven National Laboratory (BNL) under the auspices of the Department of Energy under Support Agreement No. WESSC-86-01. This report was prepared by Messrs. R. P. Webster, L. E. Kukacka, and D. Elling, Energy Efficiency and Conservation Division, BNL. The study was performed under the general supervision of Messrs. Bryant Mather, Chief, SL, and Kenneth L. Saucier, Chief, CTD, WES. Direct supervision was provided by Mr. McDonald. Program Manager for REMR is Mr. William F. McCleese (CEWES-SC-A), CTD, WES. This report was published at WES by the Visual Production Center, Information Technology Laboratory.

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

CONTENTS

	Page
PREFACE	1
CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT	3
PART I: INTRODUCTION	4
Background	4
Objectives of the Phase Four Program	7
PART II: LABORATORY TEST PROGRAM	8
Evaluation of Injection Ports	8
Techniques for Drilling Port Holes	11
Modification and Repair of the A3-10 Injection Machine	14
Freezing and Thawing Durability Tests	14
PART III: FIELD TEST PROGRAM	18
Background	18
Repair Procedure	22
Economic Evaluation	49
Safety and Environment	51
PART IV: SUMMARY AND RECOMMENDATIONS	55
REFERENCES	58
APPENDIX A: INSPECTION REPORTS FOR PIER NO. 13, LOCK AND DAM 13	A1
APPENDIX B: DRILLING LOGS FOR CORES REMOVED PRIOR TO EPOXY INJECTION..	B1
APPENDIX C: DRILLING LOGS FOR CORES REMOVED AFTER EPOXY INJECTION	C1
APPENDIX D: TECHNICAL INFORMATION AND MATERIAL SAFETY DATA SHEETS	D1

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

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

Multiply	By	To Obtain
centipoises	0.001	pascal-seconds
cubic feet per minute	0.0283168	cubic metres per minute
Fahrenheit degrees	5/9	Celsius degrees or kelvins*
feet per second	0.3048	metres per second
gallons	3.785	litres
gallons per minute	3.785	litres per minute
horsepower	745.70	watts
inches	25.4	millimetres
ounce (fluid)	29.57	millilitres
pounds	453.5924	grams
pounds (force) per square inch	0.006894757	megapascals
square feet	0.0929030	square metres
square feet per gallon	0.2642	square metres per litres

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

IN SITU REPAIR OF DETERIORATED CONCRETE IN HYDRAULIC STRUCTURES: EPOXY INJECTION REPAIR OF A BRIDGE PIER

PART I: INTRODUCTION

Background

1. Over the last 75 to 80 years, portland-cement concrete has been used extensively in the United States in hydraulic structures, such as dams, spillways, lock chambers, and bridge support columns and piers. The US Army Corps of Engineers estimates that it operates and maintains 536 dams and 260 lock chambers at 596 sites (Scanlon et al. 1983). Over 40 percent of these are more than 30 years old, and 29 percent were built before 1940. In addition, nearly half of the 260 lock chambers will reach their 50-year design lives by the turn of the century. Periodic inspections of these structures show that a large number of the older ones require significant maintenance, repair, and rehabilitation.

2. Repairs to many such structures involve removing the deteriorated concrete and replacing it with new concrete. Considerable savings in time and cost could be realized if methods and materials were identified and developed to repair such deteriorated structures without extensive removal of the deteriorated concrete. To this end, Brookhaven National Laboratory (BNL), under contract to the US Army Corps of Engineers, carried out a program entitled "In Situ Repair of Deteriorated Concrete in Hydraulic Structures." The results from Phases One, Two and Three of this program were documented in reports to the Corps of Engineers (Webster and Kukacka 1987; Webster and Kukacka 1988; Webster, Kukacka, and Elling 1989).

3. The objectives of Phase One of the BNL program were to (a) identify the most prevalent forms of deterioration in concrete hydraulic structures, and (b) identify methods and materials commonly used to repair and rehabilitate concrete structures. This information then was evaluated to determine the applicability of the various repair methods and materials for in situ repair.

4. A survey started in 1982 by the US Army Corps of Engineers (McDonald and Campbell 1985) showed that the three most common problems encountered in the Corps' civil works concrete hydraulic structures were (a) cracking, (b) seepage, and (c) spalling. These three problems accounted for 77 percent of the 10,096 deficiencies identified in a review of inspection reports. Concrete cracking was the most frequent, accounting for 38 percent of the defects. In situ repair seems ideally suited to repairing deterioration caused by cracking and spalling; the procedure may not be readily applicable to seepage damage.

5. Three techniques for repairing cracks and two techniques for repairing spalled concrete were identified as being most applicable for in situ restoration. The methods include pressure injection, polymer impregnation, and the addition of reinforcement. Together with these procedures, thin reinforced overlays and shotcrete were identified as methods for repairing spalled concrete and resurfacing a cracked structure after repair. Based upon these findings, BNL developed a laboratory testing program in Phase Two to evaluate two of the crack-repair methods: pressure injection and polymer impregnation.

6. The primary objectives of the Phase Two program were to experimentally evaluate and develop methods and materials for the in situ repair of cracked concrete hydraulic structures by pressure injection and polymer impregnation. A laboratory-scaled test program was developed to (a) evaluate the effectiveness of selected injection adhesives to repair air-dried and water-saturated cracked concrete and (b) evaluate the effectiveness of polymer impregnation for repairing highly cracked concrete.

7. In general, the results suggested that pressure injection can effectively restore the integrity of air-dried and water-saturated cracked concrete. For example, concrete slabs that had preinjection pulse velocities of 7,000 to 11,000 ft*/sec had pulse velocities of 13,500 to 15,000 ft/sec after injection. Sound, uncracked concrete normally has a pulse velocity of 14,000

---

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

to 15,000 ft/sec. The splitting tensile strength of air-dried concrete, repaired by pressure injection, varied between 410 and 845 psi, depending upon the adhesive used. Water-saturated concrete repaired by injection had splitting tensile strengths varying between 435 and 703 psi. Sound concrete had a splitting tensile strength of about 600 psi.

8. The laboratory results showed that polymer impregnation can improve the quality of the concrete surrounding the crack network. However, its effectiveness in sealing the crack network depended on the thickness of the cracks and the viscosity of the impregnant used. Pressure injection and polymer impregnation used in conjunction will effectively repair and improve the overall quality of a structure.

9. BNL developed a program in Phase Three directed towards developing and optimizing the procedures for pressure injection to be used in the field. The procedures then were evaluated in a small-scale field test on Pier No. 27 at Lock and Dam 20 on the Mississippi River, Canton, Mo.

10. The repair work done on Pier No. 27 was limited to the top 4.2 ft of the pier stem (that portion located above the archway ceiling of the walk-through). The deterioration in this area was characterized by two major cracks that extended from the top of the pier stem down to the ceiling of the archway. Also, a network of cracks was visible on the upstream and downstream faces of the pier stem.

11. Approximately 5 gal of Denepox 40 epoxy was injected into the top of the pier stem over 2 days using a portable epoxy injection machine. Postinjection pulse velocity values measured at 6 locations between opposite faces of the pier stem varied between 5,215 and 15,124 ft/sec, averaging 10,131 ft/sec. Before injection, a pulse velocity value could be obtained at only 1 of the 6 locations; that location had a preliminary value of 9,717 ft/sec and a postinjection value of 15,121 ft/sec.

12. A visual examination of 3 cores taken from Pier No. 27 after completing the injection repair work suggested that 80- to 90-percent of the crack network was filled with epoxy. Ultrasonic pulse velocity tests showed that these cores had an average pulse velocity of 11,759 ft/sec, compared to a value of 7,166 ft/sec that was measured for a highly cracked core containing no visible epoxy within its crack network. The splitting tensile strength of the repaired cores averaged 513 psi compared to 548 psi for an apparently uncracked control.

13. An evaluation of the resistance of repaired cores to deterioration due to cycles of freezing and thawing indicated a 26-percent decrease in the pulse velocity values and a 31-percent decrease in the splitting tensile strength after being subjected to 100 cycles.

Objectives of the Phase Four Program

14. While the small-scale field test at Lock and Dam 20 was generally considered to be a success, several problems suggested that several areas needed further optimization. The emphasis of the Phase Four program was directed towards solving these problems:

- a. The identification and evaluation of a better system of injection ports.
- b. Evaluation of the need to pre-drill into the crack network to facilitate the penetration of epoxy into the interior of the network.
- c. The evaluation of other materials as sealants.
- d. The repair and further modification of the portable epoxy injection equipment.

Once completed, the procedures were evaluated in a large-scale field test at Lock and Dam 13, Fulton, Il.

PART II: LABORATORY TEST PROGRAM

15. The emphasis of the work performed in the laboratory phase of the program was directed towards:

a. The identification and development of a better method for attaching the injection ports to the concrete. Excessive leakage of epoxy from around the injection ports was encountered on several occasions during the small-scale field test at Lock and Dam 20.

b. The evaluation of methods to drill down into the crack network to facilitate the penetration of epoxy into the interior of the crack network.

c. The repair and modification of the injection equipment used in the small-scale field test.

16. Laboratory work also evaluated the long-term freeze-thaw durability of concrete which had been repaired by epoxy injection.

Evaluation of Injection Ports

17. Tests were run with three sets of molded injection ports to evaluate a) the physical integrity of the ports, and b) the method used to attach the ports to a concrete surface so they could withstand the range of pressures commonly used in injection repairs.

18. Two of the ports were molded polyethylene ports obtained from Dural International, Inc., and are designed for surface mounting, Figure 1. The other injection port evaluated was Lily Corporation's Injecti-port nozzle, Figure 2, which is a one-piece, molded polyethylene port designed for either surface mounting or for insertion into a drilled port hole. A tapered collar on the injection port allows it to fit tightly into holes 1/2- to 57/100-in. in diameter.

19. Four port arrangements were pressure tested. Each of the three types of ports were mounted on the surface of a concrete slab. In addition, the Injecti-port was inserted into a 1/2-in.-diam by 1-1/2-in.-deep drilled hole, Figure 3. The concrete slab used in the test had a light brush-finished surface, which was sandblasted before attaching the ports.

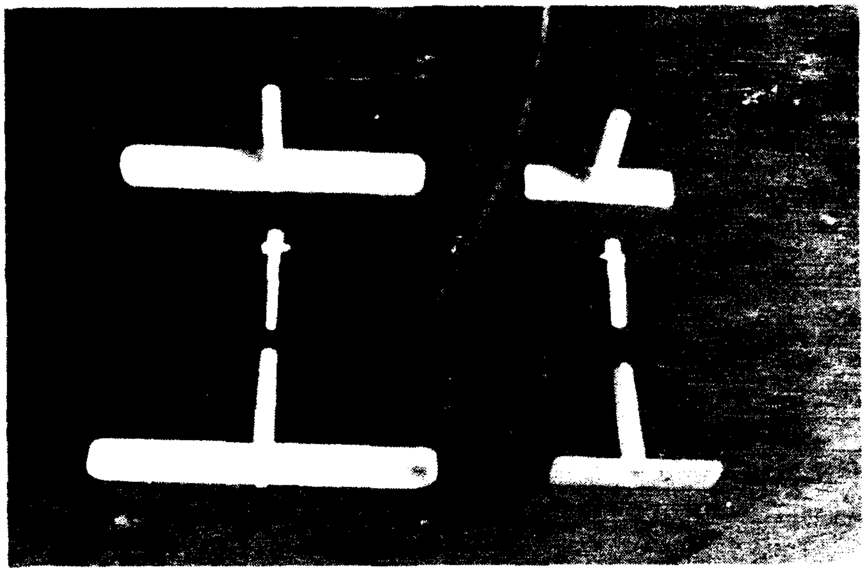


Figure 1. Molded injection ports designed for surface mounted applications (Type A, left, and Type B, right)

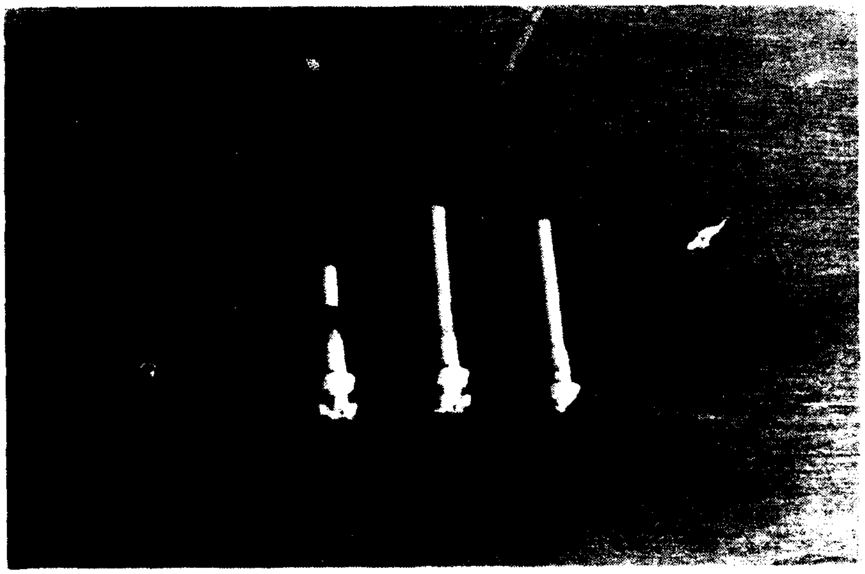


Figure 2. Lily Corporation's Injecti-Port nozzle

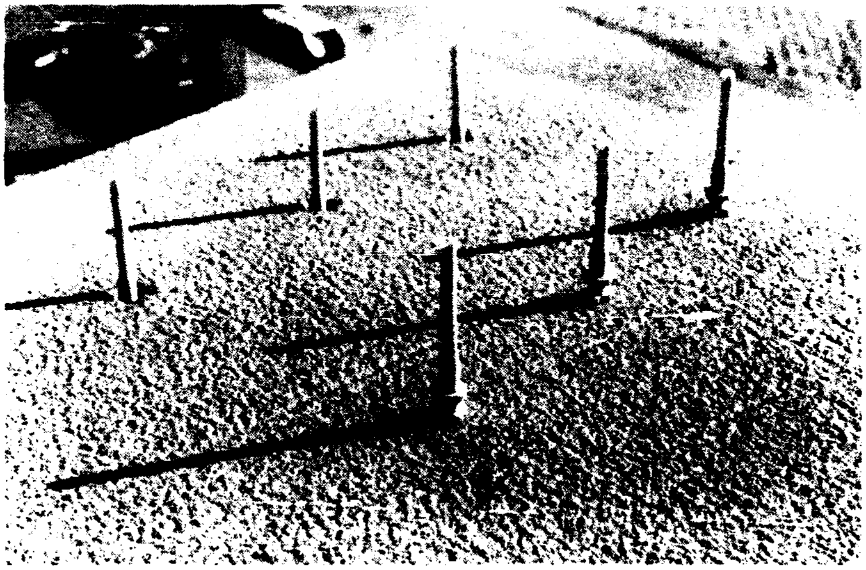


Figure 3. Injecti-port nozzles inserted into a drilled port hole and surface mounted onto the concrete test slab (before application of seal coat)

20. The surface mounted ports were attached to the slab by first pretreating the concrete with a liquid accelerator (Lily Corporation's SAF Accelerator/Filler) intended for use on cold or rough surfaces. A bead of quick-setting adhesive (Lily Corporation's Stick-It Adhesives) was applied to the base of the ports, after which they were immediately pressed against the treated concrete. Bonding was achieved in 10 to 15 sec. The bases of the ports were then sealed by covering them with a coat of DeNeef America Inc.'s Deltapox VM epoxy.

21. The ports inserted into the drilled port holes were secured by applying a bead of quick-setting adhesive to the collar of the port. The port was immediately inserted into the hole, so that the top of the collar was approximately 3/8-in. below the surface of the concrete. The port was then sealed in place using the Deltapox VM epoxy. The epoxy seal coat was allowed to fully cure before the ports were tested.

22. The injection ports were hydrostatically tested using a stainless steel vessel pressurized with a compressed air bottle, Figure 4. Each set of ports was simultaneously tested at each pressure level for 15 min, after which the pressure was increased to the next level. Once a port failed, the pressure line to that port was closed and the test was continued. The results are summarized in Table 1.

23. In general, all of the failures resulted from leaks developing around the parameter of the injection port and propagating through the interface of the epoxy seal coat and the injection port. This problem was primarily due to the inability of the epoxy to securely bond to the polyethylene. In no instance did the injection ports physically fail. The results indicate that surface-mounted ports will withstand lower injection pressures than ports mechanically mounted in a drilled port hole. The Lily Injecti-port withstood pressures of 200 to 275 psig when inserted within a drilled port hole, but only 150 psig when surface-mounted. Also, the ability of a surface-mounted port to withstand injection pressures seems to be related to the surface area of the port in contact with the concrete; ports with a larger surface area were able to withstand the least amount of pressure. The surface-mounted Lily Injecti-port withstood the greatest test pressure, 150 psig, while having the least contact surface area, 0.8 cm^2. The Type B (refer to Figure 1) surface-mounted port had the greatest contact surface area and withstood the least amount of pressure.

Techniques for Drilling Port Holes

24. After determining that injection ports mounted within a drilled port hole could withstand the 200 to 275 psig injection pressures anticipated in the field, tests were done to determine the best method for drilling the port holes. Three drilling techniques were evaluated: dry rotary drilling, dry drilling using a hollow drill stem and bit, and wet drilling using a hollow drill stem and bit.

25. The dry rotary drilling was done with a Skil 728 heavy duty electric roto-hammer and a 1/2-in.-diam masonry bit. Drilling fines were removed from the hole by the action of the drill bit and by blowing the hole out with compressed air.

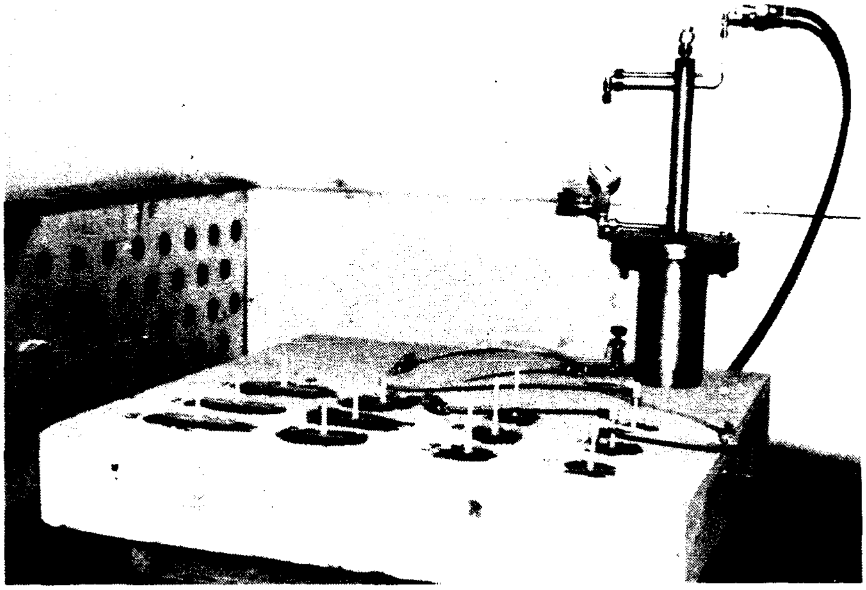


Figure 4. Hydrostatic test set-up used to test injection ports

Table 1

Results of Hydrostatic Testing of Injection Port Configurations

Type of Injection Port	Port No.	Contact Surface area, cm^2	Test Pressure, psig 50	100	150	200	250	275
Type A, surface mounted.	1	5.3	P*	SF**				
	2		P	SF				
	3		P	SF				
Type B, surface mounted.	4	9.1	SF					
	5		SF					
	6		P	SF				
Injecti-port, surface mounted.	7	0.8	P	P	P	SF		
	8		P	P	P	SF		
	9		P	P	P	SF		
Injecti-port, inserted into port hole	10	—	P	P	P	P	SF	
	11	—	P	P	P	P	P	P
	12	—	P	P	P	P	SF	

*P = passed. **SF = seal coat failure.

26. The dry drilling with a hollow drill stem and bit was done with a Chicago Pneumatic CP-9RR air-powered rock drill and a 1/2-in.-diam drill bit. The drilling fines were removed from the hole during the drilling operation by a stream of air blown through the drill stem and out the nozzle of the drill bit.

27. The wet drilling was also done using the CP-9RR air-powered rock drill. The drill was modified to close off the air vent to the drill stem and a water collar was machined into a hollow drill stem, allowing for a stream of water to pass through the drill bit which removed the drilling fines.

28. In general, the test involved using each technique to drill a series of 0.5-in.-diam by 3- to 4-in. deep port holes into a cracked concrete retaining wall. Crack widths generally varied between 0.010 and 0.025 in. Lily Injecti-ports were then inserted into the port holes so that the top of the collar was approximately 0.5 in. below the surface of the concrete. The port holes and surfaces of the cracks were sealed with Deltapox VM epoxy, water was then injected into the cracks, and injection pressures were monitored to determine the ease with which water could be injected from one port to the next.

29. The results showed that the wet drilling technique worked the best. Injection pressures were generally lower and communication with successive ports was much quicker than in the holes which were drilled dry. It is felt that the dry drilling techniques tended to compact fines into the crack interface, thereby restricting the flow of water from one port to the next and subsequently increasing the injection pressure. The wet drilling appears to dilute the drilling fines as they are made and before they can become impacted into the crack interface. The fines are then flushed out of the drill hole in a continuous stream of water.

30. Vacuum drilling was not evaluated. This method, however, normally requires larger diameter holes for efficient vacuum operation, and the clogging of bits is quite often a problem when the concrete is damp.

Modification and Repair of the A3-10 Injection Machine

31. Before the field test done in 1987 at Lock and Dam 20, a few modifications were made to the A3-10 injection machine, manufactured by Otto Engineering Inc. These modifications included adding a regulator/filter/dryer unit to the inlet air system to clean and dry incoming air from the compressor. Also, check valves were installed in the material output lines before the static mixing head, to prevent accidental back-pressuring and mixing of the A and B components of the injection epoxy. The problems encountered during the field test indicated that a few more modifications to the equipment were necessary.

32. It was felt that some of the problems encountered in operating the injection machine during the field test were caused by moisture getting into the pneumatic logic circuit that operates the machine. The one dryer unit could not remove all of the moisture present in the air around the lock and dam. Therefore, second air regulator/filter/dryer unit was added to the inlet air system, in series with the first unit.

33. A pressure gauge was added to the downstream end of the static mixing head to monitor injection pressures: monitoring is helpful in indicating the ease with which the epoxy is being pumped into the crack network, and will also indicate when the crack network has been filled with epoxy, as shown by a buildup of pressure. Monitoring pressures should help to eliminate some of the problems associated with injection-port blowouts.

34. Routine maintenance performed on the injection machine included replacement of all pump seals, cleaning of all valves and connections, and the replacement of all high-pressure resin lines within the machine.

Freezing and Thawing Durability Tests

35. Tests were done to evaluate the resistance of cracked beams that had been repaired by epoxy injection to cycles of freezing and thawing. The tests were done on 3-in. by 4-in. by 16-in. concrete flexure beams. The "cracked" beams were fabricated by casting them individually in steel flexure beam molds. After the concrete had taken its initial set (4 to 5 hr after pouring), the sides of the forms were removed and the beam was flexed by hand to produce a crack network through the midpoint of the beam, Figure 5. The beam halves were held together by a piece of 4 by 4 stainless-steel woven wire

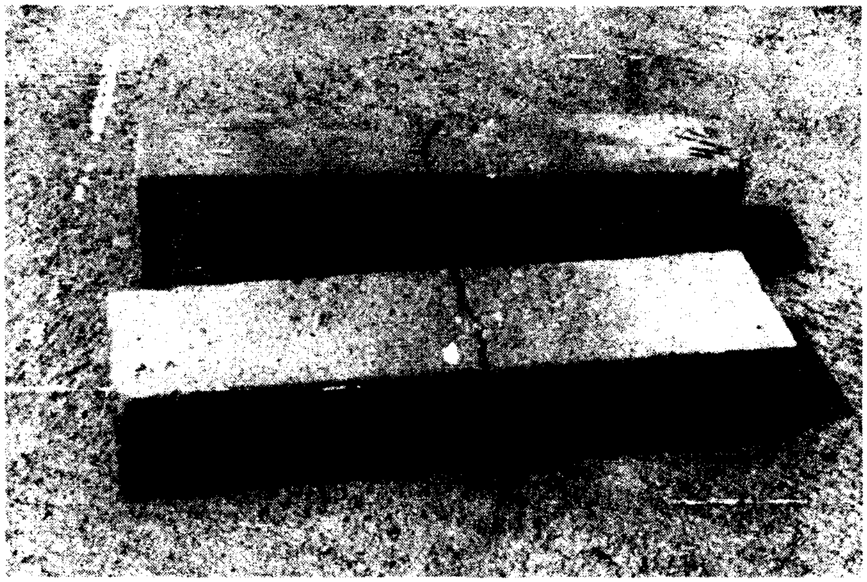


Figure 5. Cracked flexure beam used in the freezing and thawing study

cloth that had been cast into the center of the beam, running parallel to the 4-in. wide face. With this technique, cracks varying in width from hairline to 1/8-in. could be created.

36. All tests were done on air-entrained concrete beams. The concrete mixture contained: portland cement - Type I; fine aggregate - graded silica sand; coarse aggregate - 3/8-in. nominal - graded crushed siliceous gravel; w/c = 0.42 and an entrained air content of about 7 percent. Twenty-eight day tests showed that the concrete had an average compressive strength of 4675 psi.

37. The beams were repaired by attaching an injection port (a 1-in.-diam by 1/2-in. high wooden disc with a 1/8-in.-diam hole in the center) on two adjacent faces, the surface of the cracks were then sealed with Deltapox VM epoxy. Once the epoxy seal coat had fully cured, the beams were repaired by injecting Denepox 40 epoxy into the cracks with a syringe.

38. Six beams were repaired with the cracks in an air-dried condition, and six beams were repaired with the cracks in a water-saturated condition. The cracks were saturated by injecting them several times with water immediately before injecting them with epoxy.

39. The epoxy injected into the repaired beams was allowed to cure for a minimum of 72 hr. The injection ports were then removed and the seal coat was ground off each face of the beam, using a hand-held grinder. The beams were then subjected to 200 cycles of freezing and thawing in accordance with ASTM C666 - Procedure A.

40. Performance of the beams was based upon visual examinations and the results of ultrasonic pulse velocity and splitting tensile strength tests. The splitting tensile strength tests were done on 2-3/4-in.-diam cores taken from the repaired zone of the beam through the 4-in. wide face. The results of both tests are summarized in Table 2.

41. Ultrasonic pulse velocity (PV) values were taken at various times throughout the test. The results indicate that the PV values remained essentially unchanged. The values for each of the three sets of specimens tested varied within ± 2 percent of the values measured at the start of the test.

42. A visual examination of the beams throughout the test showed very little physical damage. Slight surface scaling was noted on some of the beams after approximately 125 cycles.

Table 2
Freezing and Thawing Test Results

Type of Beam	Ultrasonic Pulse Velocity, ft/sec*						Splitting Tensile Strength psi*	
	Number of Freezing and Thawing Cycles							
	0	25	50	100	150	200	0	200
Uncracked control	14,926	14,766	14,732	14,652	14,848	15,238	680	825
Cracked, dry repair	14,909	14,620	14,692	14,625	14,802	15,023	903	822
Cracked, wet repair	14,853	14,639	14,599	14,577	14,805	15,037	729	752

*Values reported are an average for six beams.

43. Results of the splitting tensile strength tests indicate that the cycles of freezing and thawing had very little, if any, effect upon the beams. Two of the three series of beams, the uncracked controls, and the beams repaired wet actually exhibited increases in strength after 200 cycles. The third series exhibited only a 9 percent decrease in strength.

44. The relative stability of the PV and splitting tensile strength test data taken before and after the 200 cycles of freezing and thawing demonstrated that the epoxy injection was effective in restoring the integrity of the cracked beams.

PART III: FIELD TEST PROGRAM

Background

45. After completing the laboratory work, a large-scale field test was performed on Pier No. 13, Lock and Dam 13, Fulton, Il., (Figure 6) during 15-31 August, 1988. Lock and Dam 13, which was placed into service in 1939, is one of 12 navigation structures operated by the Rock Island District, US Army Corps of Engineers as part of the Nine-Foot Channel Navigation Project. It is located at Upper Mississippi River (UMR) Mile 522.5, 2.2 miles upstream from the town of Fulton, Il. Pier No. 13 is located in the storage yard situated on the Iowa side of the Mississippi River.

46. Periodic inspection of Pier No. 13 indicated extensive deterioration in the lower 12-ft of the pier, i.e., between El. 590.5 and 602.55 (Figure 7). The deterioration was characterized by an extensive crack network running throughout the base of the pier, large sections of drummy concrete in the corners, and excessive amounts of efflorescence on the exterior surfaces (Figures 8-10). The inspection reports are presented in Appendix A.

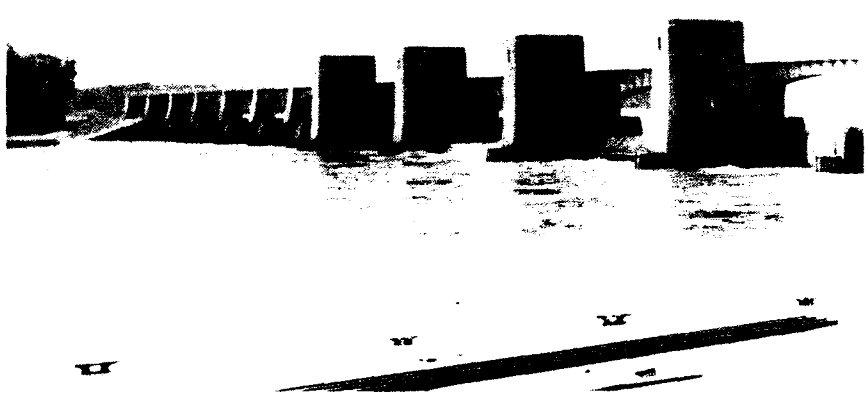


Figure 6. Lock and Dam 13. Pier No. 13 is the second bridge pier from the left.

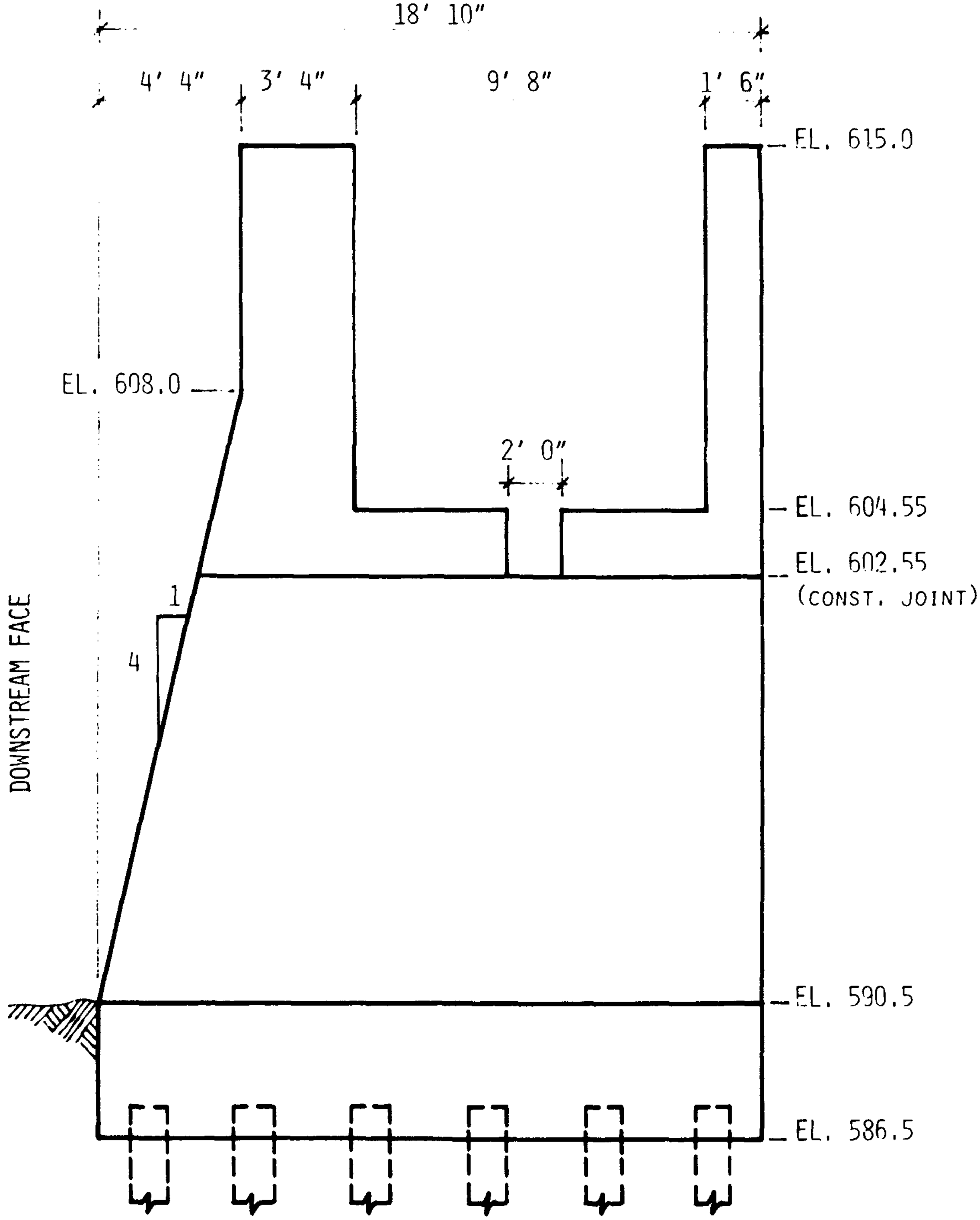


Figure 7. Elevation of (Illinois face) Pier No. 13

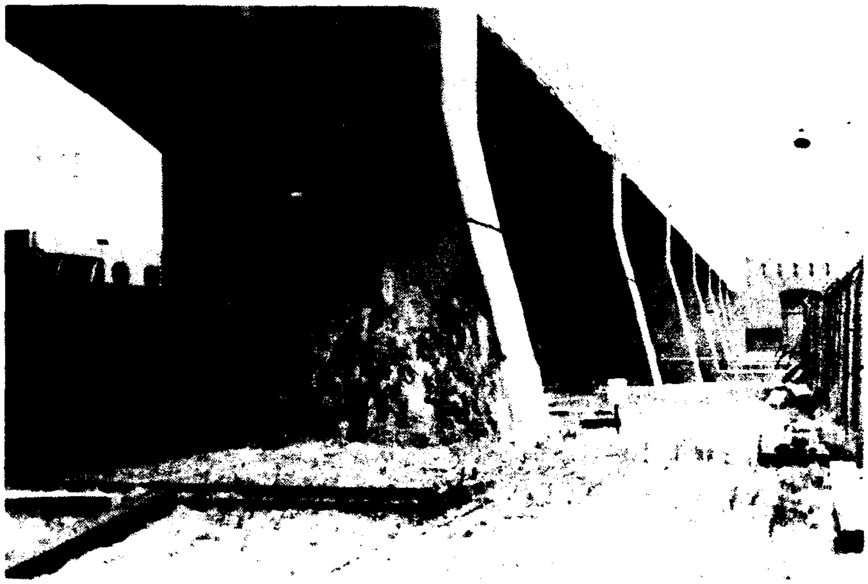


Figure 8. Iowa face of Pier No. 13

Figure 9. Illinois face of Pier No. 13

(a)
downstream edge of Iowa face

(b)
upstream edge of Illinois face

Figure 10. Closeup views of deterioration present in Pier No. 13

47. An evaluation of the pier by the Corps of Engineers Rock Island District stated that the deterioration was primarily the result of water ponding at the level of the bridge-bearing seat, El. 602.55, that subsequently saturated the non-air-entrained concrete. Cycles of freezing and thawing then led to the start of the deterioration. To try to alleviate the ponding problem, a 2-ft-wide slot was cut in the center of both curtain walls, in 1980, to improve drainage of the bridge-bearing seat. In addition, the top of the concrete seat was sealed with fiber-reinforced "Black Jack" roof cement that was sloped toward the openings.

48. An inspection in 1983 showed that the seal coat was in good condition and that there was no surface cracking or disbonding of the coating. Drainage of the pier top appeared to be adequate and no ponded water was observed in the seat. Efflorescence was still very evident on the exterior surfaces.

49. Because of its extensive deterioration and need for repairs, Pier No. 13 was selected for a large-scale field test of the epoxy-injection repair procedure.

50. BNL personnel inspected the pier in July 1988 before the start of the field test. The inspection confirmed the extensive cracking throughout the base of the pier. Crack thicknesses varied from less than 0.030-in. up to 1/4- to 1/2-in. Cores removed from the Iowa and Illinois faces (Figure 11) revealed an extensive crack network running parallel to the surface and extending 6 to 12 in. into the pier. Isolated crack planes as deep as 26 in. were noted. Drilling logs are presented in Appendix B. An inspection of the base of the pier also showed that the crack network extended approximately 12 in. below ground level.

Repair Procedure

51. The repair work on Pier No. 13 was limited primarily to that portion of the pier between El. 590.5 and 602.55, the bridge-bearing seat and the bearing seat curtain walls. To speed up the repair time, a private contractor, Big River Equipment Co. of Bettendorf, Ia., was hired by the Rock Island District, US Army Corps of Engineers, to; a) remove the roofing cement from the surface

Figure 11. Cores removed from the Iowa (4-IA and 9-IA) and Illinois (4-IL and 9-IL) faces of Pier No. 13 before repair

of the bridge-bearing seat, b) dig a 3-ft-wide by 1-1/2-ft-deep trench around the base of the pier, and c) sandblast the faces and bearing seat of the pier before the BNL crew arrived at the site. This work was done by a 3-man work crew on August 10 and 11, 1988.

52. The procedure used by BNL to repair Pier No. 13 is outlined below and subsequently discussed in detail.

- a. Erect scaffolding.
- b. Take preliminary ultrasonic pulse velocity measurements.
- c. Sandblast pier.
- d. Place injection ports and seal pier stem surfaces.
- e. Take preinjection ultrasonic pulse velocity measurements.
- f. Inject crack network.
- g. Take postinjection ultrasonic pulse velocity measurements.
- h. Take cores for mechanical analysis.

Erect scaffolding

53. Five-foot high sections of construction scaffolding were erected along the Iowa and Illinois faces of the pier to provide access to the upper half of the base of the pier (Figure 12). Access to the upstream and downstream faces was provided by planks laid between the scaffolding framework.

Figure 12. Construction scaffolding in place around pier

Preliminary ultrasonic pulse velocity data

54. Before starting any repair work, a visual survey was made of the pier. In addition, preliminary ultrasonic pulse velocity (PV) data were obtained for 30 locations on the pier.

55. The visual examination showed:

a. Bridge-bearing seat - with the exception of 2 major cracks running through the center of the seat (Figure 13), this section was in good condition.

b. Downstream face - the major portion of the cracking noted on this face was confined to areas near the corners and near the construction joint (El. 602.5). A large portion of the Iowa corner had broken away due to delamination of the concrete. Sounding of the face with a hammer indicated that the lower two-thirds of the face was probably very delaminated.

c. Upstream face - most of the cracking was confined to the areas near the corners and the upper half of the section just below the construction joint. Sounding of the face indicated large sections of delaminated concrete.

d. Illinois face - the entire face below the construction joint was highly cracked and delaminated, the worst areas being the upstream and downstream edges. The bridge-bearing seat curtain walls were also highly cracked.

e. Iowa face - the face was highly cracked around its perimeter, below the level of the construction joint. The interior portion of the face did not appear to be highly cracked; however, it sounded very delaminated. The corner shared with the downstream face, as previously noted, was partially broken away as a result of the cracking and delaminations. The upstream portion of the bearing seat curtain wall was cracked but relatively sound. The downstream half, however, was badly deteriorated and needed to be patched before the cracks could be repaired.

56. Preliminary PV data were taken between opposite points at 14 locations on the Illinois and Iowa faces of the pier, using the direct transmission method. Readings were also taken diagonally through the corners of the pier using the semi-direct transmission method. The direct transmission method was also used to obtain readings longitudinally through the bridge-bearing seat curtain walls. The general locations of the PV readings are illustrated in Figure 14, and the readings are summarized in Table 3.

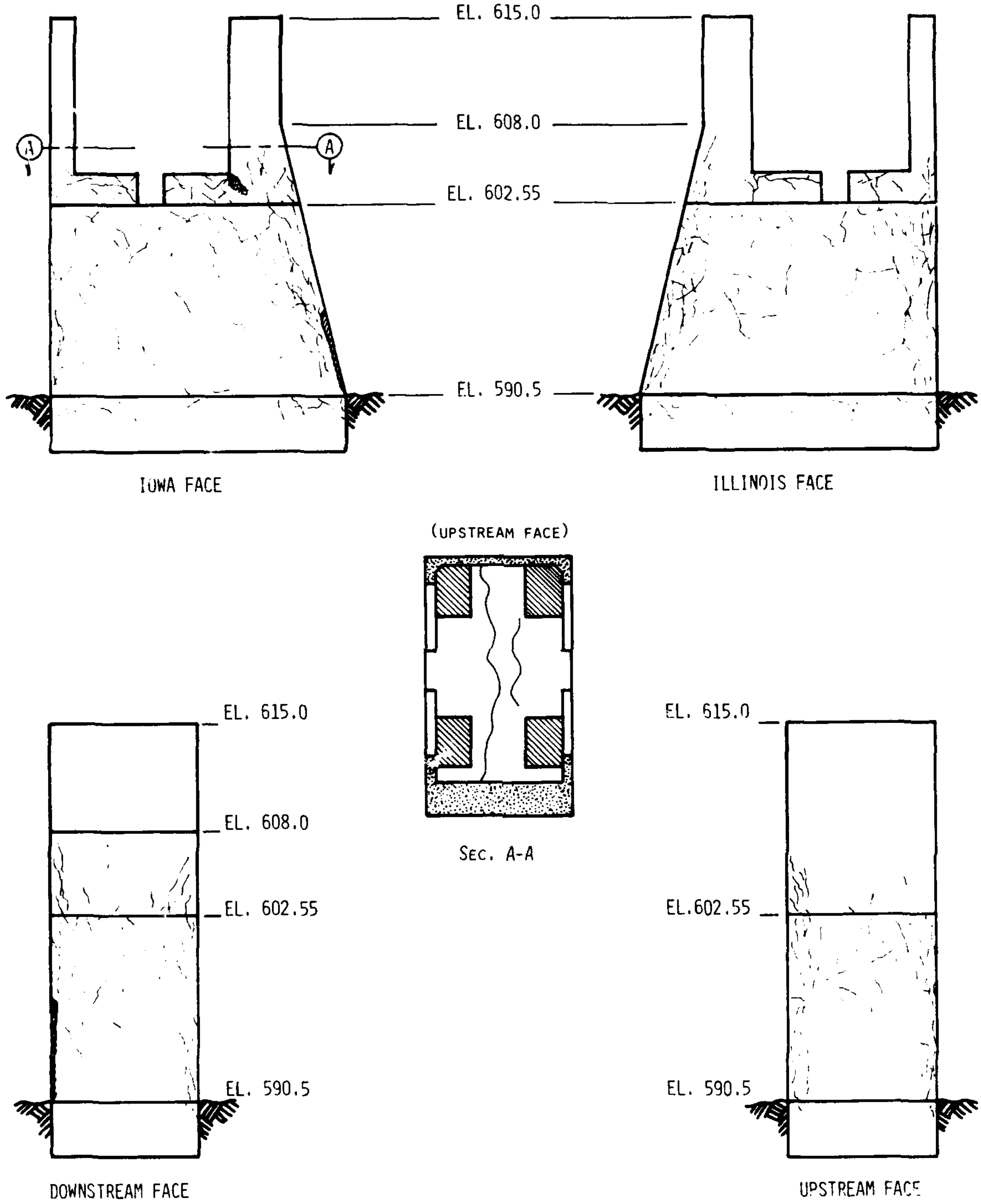


Figure 13. Drawing showing crack patterns

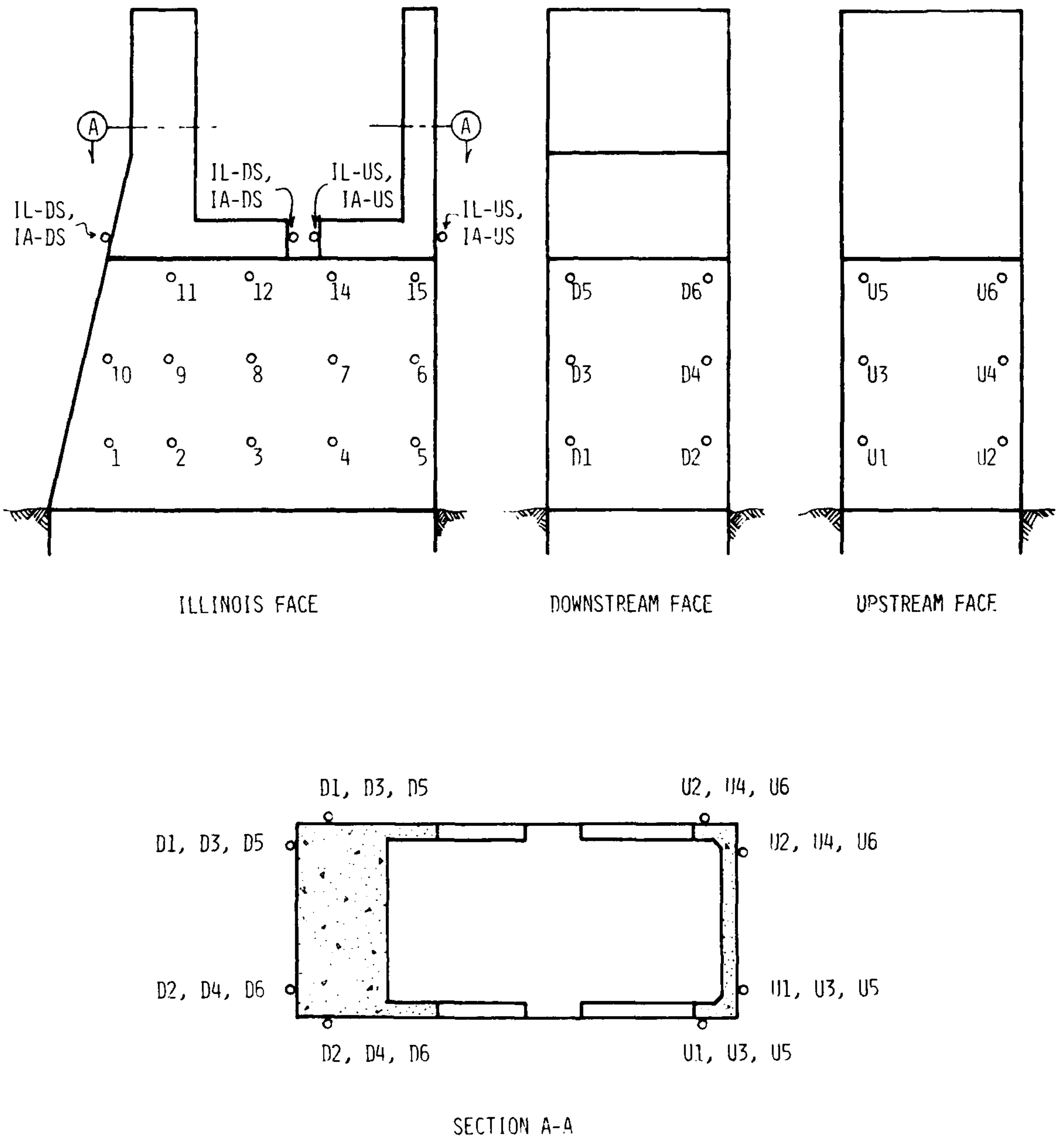


Figure 14. Locations of ultrasonic pulse velocity readings

Table 3
Ultrasonic Pulse Velocity Data for Pier No. 13, Lock and Dam 13

Location/No.	Type of Transmission	Ultrasonic Pulse Velocity, ft/sec Preliminary*	Pre-Injection**	Post-Injection
Side of pier				
1	Direct	915	1,362	9,902
2		911	1,740	1,515
3		842	3,365	5,899
4		1,393	1,194	2,073
5		1,370	864	5,418
6		2,693	1,132	2,965
7		5,404	2,883	2,671
8		1,227	1,917	1,478
9		1,144	2,708	1,480
10		1,035	1,434	8,060
11		936	1,065	2,081
12		1,088	1,784	6,274
13		1,180	1,284	4,553
14		1,145	1,402	2,664
	AVG	1,502	1,724	4,074
Pier corners				
U1	Semi-direct	3,122	2,811	10,795
U2		2,800	2,139	12,297
U3		2,393	2,071	11,883
U4		2,683	2,092	12,974
U5		2,845	2,426	12,297
U6		3,441	2,741	11,785
D1		3,072	3,269	12,633
D2		2,919	3,614	11,873
D3		2,589	2,017	12,147
D4		2,202	2,815	12,055
D5		2,125	2,766	12,434
D6		1,921	3,501	7,484
	AVG	2,676	2,689	11,721
Curtain wall				
IA-U	Direct	11,675	10,086	12,538
IA-D		916	2,365	2,220
IL-U		8,692	7,516	13,867
IL-D		3,004	3,889	10,088
	AVG	6,071	5,964	9,678

* Taken before seal coat was applied.
**Taken after seal coat was applied to pier.

57. The results of the PV tests suggested that the quality of the concrete in the base of the pier was extremely poor. The PV values measured between the Iowa and Illinois faces averaged 1,502 ft/sec, those measured through the corners averaged 2,676 ft/sec, and those measured through the curtain walls averaged 6,071 ft/sec. Concrete having a PV value of less than 7,000 ft/sec is generally considered to be of very poor quality.* It should be noted that the readings obtained during the preliminary survey were very unstable due to the highly deteriorated condition of the pier and therefore are considered to be "best guess" estimates.

Sandblasting of pier

58. After the preliminary survey, portions of the pier were sandblasted to clean areas that the contractor had not been required to sandblast (Figure 15). This work was done using a small portable unit (Sandy Jet Pressure Blaster, Model F-110) which was operated off of a 86-cfm portable air compressor. Approximately 150 lb of No. 1 blasting sand was used for this touch-up work.

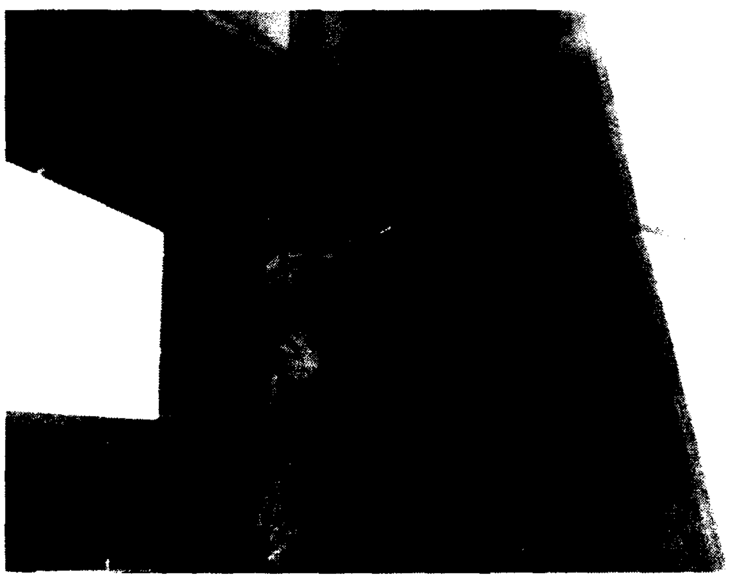


Figure 15. Sandblasting the pier

---

* Muenow, R. A. 1966. Reprint of "Nondestructive Testing of Structural Members," from the November issue of Public Works Magazine.

Installation of injection ports and sealing of the pier surface

59. The injection ports used in the repair were manufactured by the Lily Corporation, Aurora, Il., and are marketed under the name of Lily Injecti-port nozzles (see Figure 2 on page 9). The ports are a one-piece, molded polyethylene port designed for either surface mounting or for insertion into a drilled port hole. All work done on this project utilized ports inserted into a drilled port hole.

60. In general, all port holes were wet drilled, i.e., the hole was drilled using a hollow drill stem and bit which delivered a constant flow of water through the tip of the bit during drilling. The flushing removed the fines as they were formed and before they could become compacted into the crack plane.

61. Two methods were used to drill the port holes. Initial plans called for drilling the holes using an air-powered Chicago Pneumatic CP-9RR rock drill with a modified hollow drill stem for wet drilling (Figures 16 and 17). Approximately 75-1/2-in.-diam by 6-in.-deep port holes were drilled before this equipment broke down. The method used to drill the remaining port holes consisted of predrilling (dry) the holes using a Skil 728 heavy duty roto-hammer with a 3/8-in.-diam by 12-in.-long (9-in. working length) carbide bit (Figures 18 and 19) and then reaming the hole by wet drilling with a Milwaukee hammerdrill with a 1/2-in.-diam by 12-in.-long hollow stemmed bit (Figures 20 and 21). A total of 722 port holes were drilled using this technique.

62. Water was supplied to the hydro-drills through a 1/2-in.-diam garden hose connected to a 30-gal drum located approximately 23 ft above the work area on the top of the service bridge. Water was gravity-fed through the hydrodrills at an average flow rate of 0.25 gal/min. Water was supplied to the drum by a pump placed in the Mississippi River.

63. Of the two methods used to drill the port holes, the latter method, i.e., the use of two drills, produced a more uniform port hole. The pneumatic rock drill produced a very irregular and fragmented hole. As a result, the injection port did not always fit tightly into the hole, thereby creating a potential for leakage during injection. However, the two-drill technique was much more time consuming.

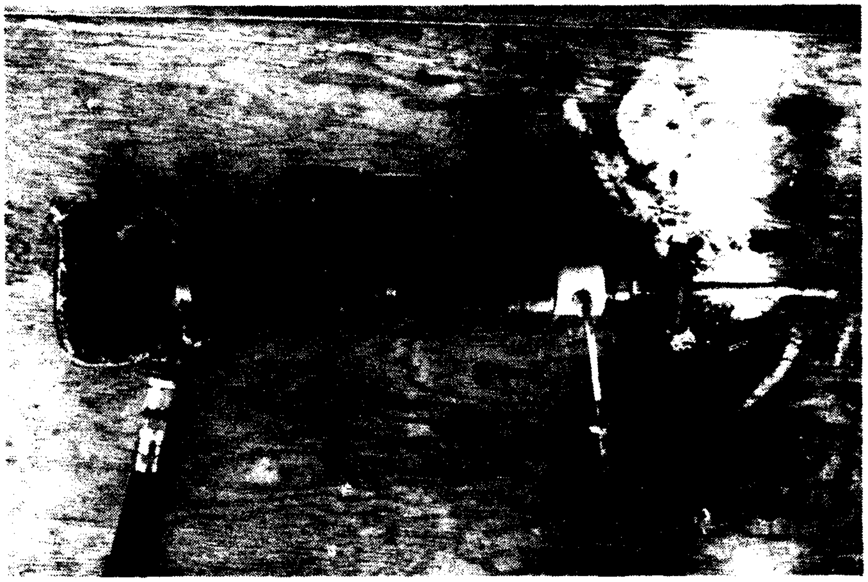


Figure 16. Modified CP-9RR pneumatic rock drill

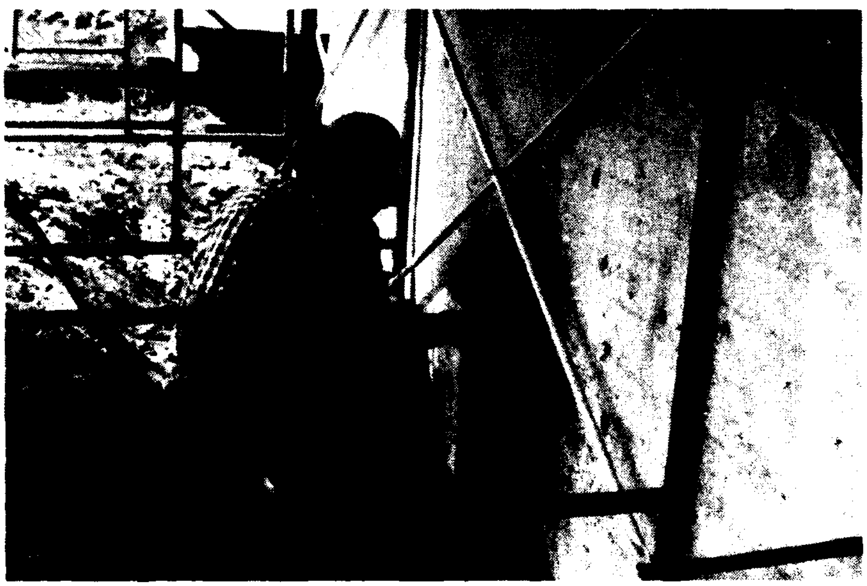


Figure 17. Drilling of port holes using the CP-9RR rock drill

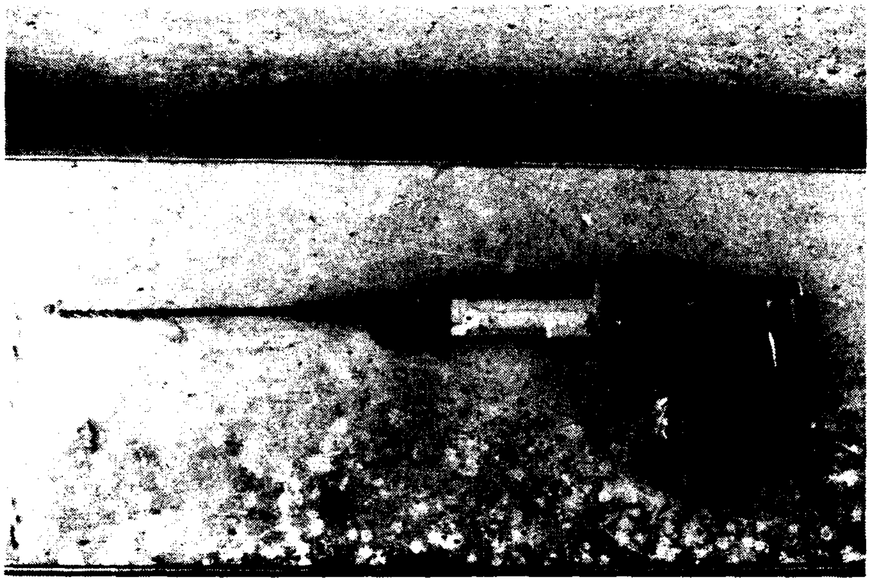


Figure 18. Skil 728 heavy duty electric roto-hammer

Figure 19. Predrilling of port holes

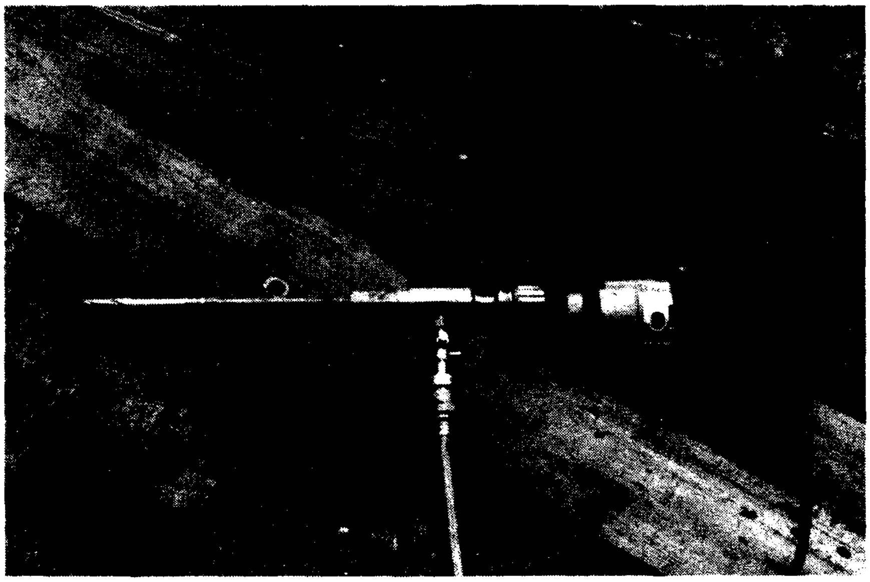


Figure 20. Milwaukee Magnum electric hammer-drill with attachment for wet drilling

Figure 21. Wet drilling of port holes

64. Port hole locations were selected to ensure adequate interconnection of ports along a particular crack. In general, the ports were laid out 9 to 12 in. o.c. along all of the major cracks visible on the surface of the pier. For sections with very few or no cracks, the ports were laid out in a 12 by 12-in. grid. In hindsight, a grid may have been a more practical approach for laying out ports over the entire pier, since many of the crack planes within 12 in. of the surface were interconnected. This approach would also have reduced, by 25-percent, the number of port holes that had to be drilled.

65. The injection ports were inserted into the port holes by placing them into a driving tool and hammering them into the hole (Figures 22 and 23). To ensure a tight-sealing collar, a bead of quick setting adhesive (Lily's Stick-it adhesive) was placed around the edge of the collar before inserting the injection port into the port hole.

66. Once all the ports were inserted into the holes, the entire surface of the pier was sealed using DeNeef America, Inc.'s Deltapox VM epoxy. Deltapox VM is a two-part epoxy, containing a thixotropic agent, designed for use in vertical and overhead applications. The epoxy seal coat was applied to the surface by hand using paint brushes (Figure 24). Approximately 11-1/2-gal of epoxy was used to seal the surface of the pier and the bridge-bearing seat, at an application rate of approximately 71 sq ft/gal. The epoxy seal coat was allowed to cure for approximately 23 hr before starting epoxy injection of the pier.

<u>Preinjection ultrasonic pulse velocity data</u>

67. After the epoxy seal coat had cured, preinjection ultrasonic PV values were measured to determine whether the seal coat had any effect upon the preliminary readings taken before the work on the pier had started. These results are summarized in Table 3 (page 28).

68. In general, the PV values measured between the Iowa and Illinois faces and those measured through the upstream corners of the pier increased slightly, while those measured through the downstream corners decreased. However, as with the preliminary PV readings, these readings were very unstable due to the highly deteriorated condition of the pier.

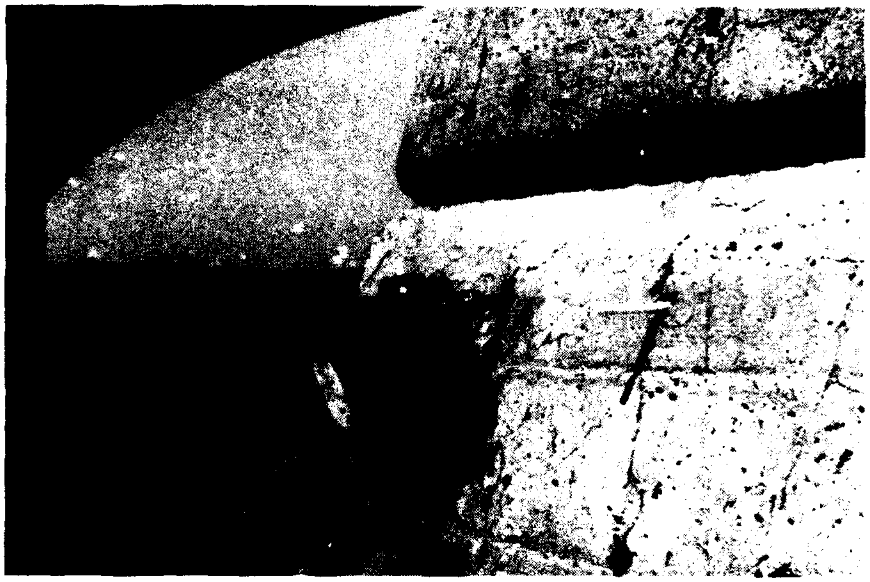


Figure 22. Insertion of injection port into drilled port hole

Figure 23. Injection port in place in drilled port hole

Figure 24. Application of epoxy seal coat

Epoxy injection of the pier

69. The resin used to repair the pier was DeNeef America, Inc.'s Denepox 40 epoxy. Denepox 40 is an ultra-low viscosity (40 cP at 77°C), two-component epoxy designed specifically for pressure injection repairs.

70. The resin was injected into the pier using Otto Engineering Inc.'s A3-10 epoxy injector (Figure 25). The A3-10 is a pneumatically operated, portable injection unit consisting of an aluminum suitcase, two stainless-steel resin tanks, and two 20-ft dispensing lines which are connected to a static mixing head immediately in front of the injection nozzle. The suitcase houses two positive displacement pumps, resin feed lines, and the pneumatic logic circuit which operates the unit. Mix ratios varying between 1:1 and 4:1 can be handled by the unit. The Denepox 40 has a mix ratio of 2.85:1. The unit operates at an inlet air pressure and flowrate of 85 psi and 2 cfm, respectively, and dispenses the mixed epoxy at injection pressures up to 275 psi. A 2-HP, 20-gal portable air compressor operated the injection machine in the field. Two regulator/filter/dryer units were installed on the unit to clean

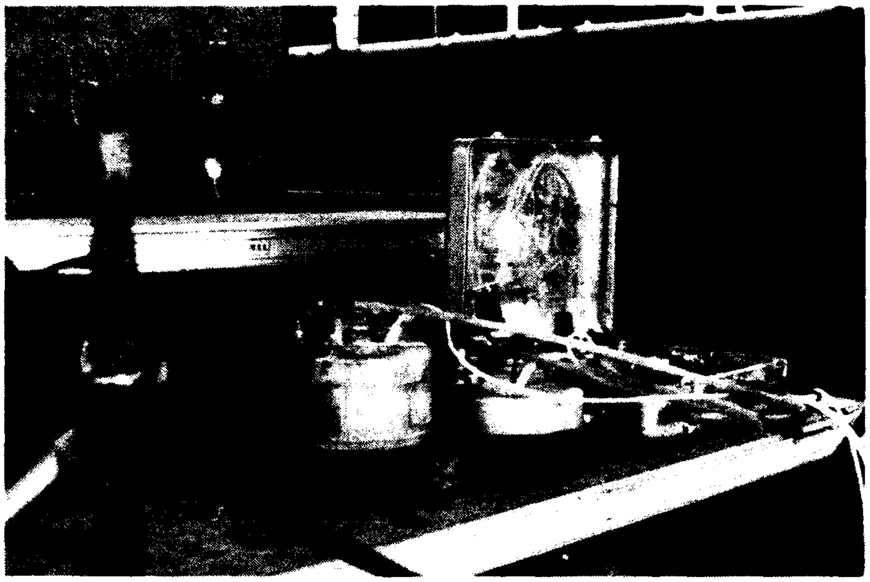


Figure 25. A3-10 epoxy injection machine

and dry incoming air from the compressor. Also, check valves were installed in the material output lines in front of the mixing head to prevent accidental back-pressuring and mixing of the A and B components of the epoxy.

71. The epoxy was injected through a manifold system that allowed for injection into 3 injection ports at once, thereby speeding up the process (Figure 26). The manifold lines were 1/4-in.-O.D., heavy duty (maximum burst pressure of 1000 psi) nylon tubing. Push-to-connect fittings (Figure 27) attached the manifold lines to the injection ports. A pressure gauge was mounted in the junction of the manifold system to monitor injection pressures.

72. The pier was injected in sections and took 4 days. The sections were injected in the following sequence:

Day 1: lower half of the Illinois face

Day 2: upper half of the Illinois face
and all of the upstream face

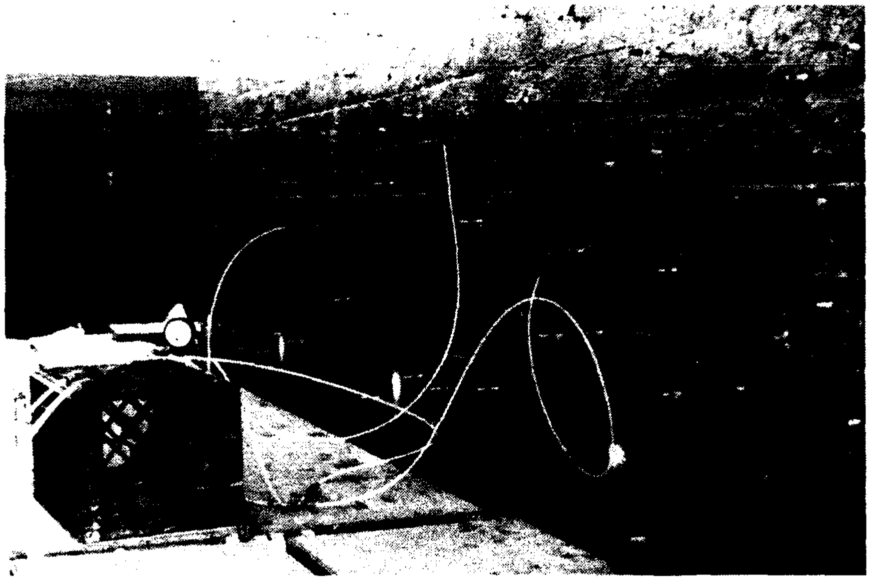


Figure 26. Manifold system used to inject three ports simultaneously

Figure 27. Close-up view of connection to injection port

Day 3: curtain wall on the Illinois face,
all of the downstream face, and
downstream third of the the Iowa face

Day 4: remainder of the Iowa face (including
the curtain wall), bridge bearing seat
surface, and reinjection of voids
detected in other sections

73. With the exception of Day 3, the weather was generally clear and sunny with daytime temperatures varying between 75° and 85°F. On Day 3 it was overcast, with periodic rain showers and temperatures in the low 60's. To continue work, tarps were hung up to protect the injection equipment and the faces of the pier being injected.

74. Injection of epoxy into the pier began in the lower corner of the downstream edge of the Illinois face. In general, the technique used to inject the pier involved first injecting all of the major cracks in the surface of the pier. Injection proceeded along the length of the crack until all connecting cracks were filled, as evidenced by the pumping of epoxy out of the injection ports. Once connection with an injection port was made, the port was sealed by closing off, i.e., crimping, the metal sleeve on the nozzle of the port with a pair of diagonal pliers. Once all interconnected cracks were injected, all remaining unsealed injection ports were injected individually.

75. Injection pressures generally varied between 50 and 150 psig, depending upon the width of the crack being injected. Pressures went as high as 275 psig, but this usually occurred only when very fine cracks were being injected. Generally, if the pressure increased much above 150 psig, it was an indication that the crack had been filled with epoxy. The manifold line to this port was then closed off, the injection port sealed, and the line moved to a new location.

76. Periodically, a 1-fl-oz gel sample of epoxy was drawn from the manifold vent line to ensure that the proper mixing ratio was being maintained and that the epoxy was curing properly. The samples were collected every 35 to 45 min, and whenever the pots were refilled. Thirty-seven gel samples were taken

during the 4 days work. The gel samples were left at the job site each night to cure at ambient conditions. In every case, each sample had cured out and was tack free to the touch within 24 hr.

77. Approximately 24 hr after a section was injected, it was sounded with a hammer to determine if there were any voids near the surface of the repaired area. If any voids were found, they were marked for reinjection. Figure 28 shows the voids found in the pier after each face had been injected a first time.

78. The largest void was found in the lower half of the Illinois face and measured approximately 15 sq ft in area. Several other voids were found in each of the other faces, but they were small, measuring 1 to 2 sq ft in area. New injection ports were installed in each of these areas and they were subsequently reinjected. Sounding of these areas after reinjection indicated no significant voids remained near the face of the pier.

79. Approximately 62 gal of epoxy were injected into Pier No. 13; Table 4 summaries the amounts of epoxy injected into each section.

Table 4

Amounts of Epoxy Injected into Pier No. 13

Section	Amount of Epoxy Injected, gal
Illinois face (including curtain wall)	21.5
Upstream face	11.8
Downstream face	11.0
Iowa face (including curtain wall)	15.0
Top of bridge bearing seat	1.0
Reinjection of hollow areas	1.5
Total	61.8

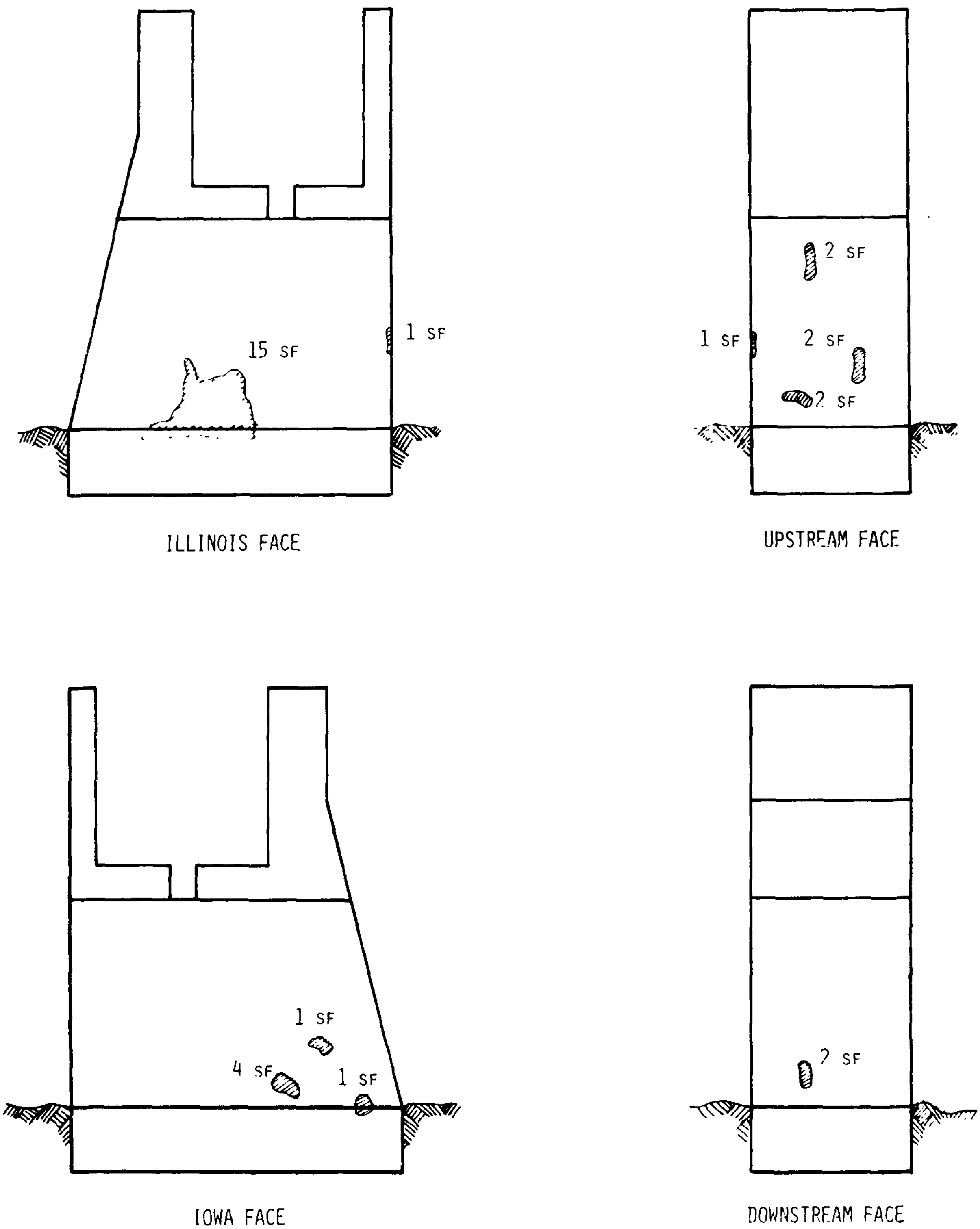


Figure 28. Void areas marked for reinjection

80. Although some problems were encountered, it is felt that the repairs went well. The major problems encountered were those associated with localized failures in the epoxy seal coat; either pin-hole leaks that occurred in the seal coat or localized rupturing of the concrete substrate beneath the seal coat. Rupturing was caused by pressure building up during the injection of epoxy.

81. When a leak or rupture occurred, the injection line to that section was immediately shut off and the area was repaired using a quick setting putty (Lily's 505 Epoxy Putty). Then, injection into that section was resumed.

Postinjection ultrasonic pulse velocity data and removal of cores

82. Approximately 18 hr after completion of the epoxy injection, post-injection PV measurements were taken to evaluate the repair (Table 3). In general, the results show some improvement in the average PV values taken between the Illinois and Iowa faces and through the bearing-seat curtain walls. The average PV value between the Illinois and Iowa faces increased from 1,502 to 4,074 ft/sec, while the average value through the curtain walls increased from 6,071 to 9,678 ft/sec. As with the previous series of readings taken in these locations, the readings were very unstable. The PV values measured through the corners of the pier showed significant improvement after the epoxy injection; increasing from an average value of 2,676 ft/sec to 11,721 ft/sec.

83. Next, personnel from the Rock Island District office removed five 4-in.-diam cores from the Illinois and Iowa faces. Four of the cores were removed from areas close to where the pre-injection cores had been taken (Figure 29). A visual examination of these cores suggested that the crack network within 6 to 10 in. of the surface appears to be filled with epoxy and epoxy was visible as deep as 15 in. from the surface (Figure 30 and 31). Drilling logs are presented in Appendix C.

84. The results of the ultrasonic pulse velocity tests and the visual examination of the postinjection cores indicates that the crack network within the top 6 to 10 in. was repaired by the epoxy injection, which appeared to have

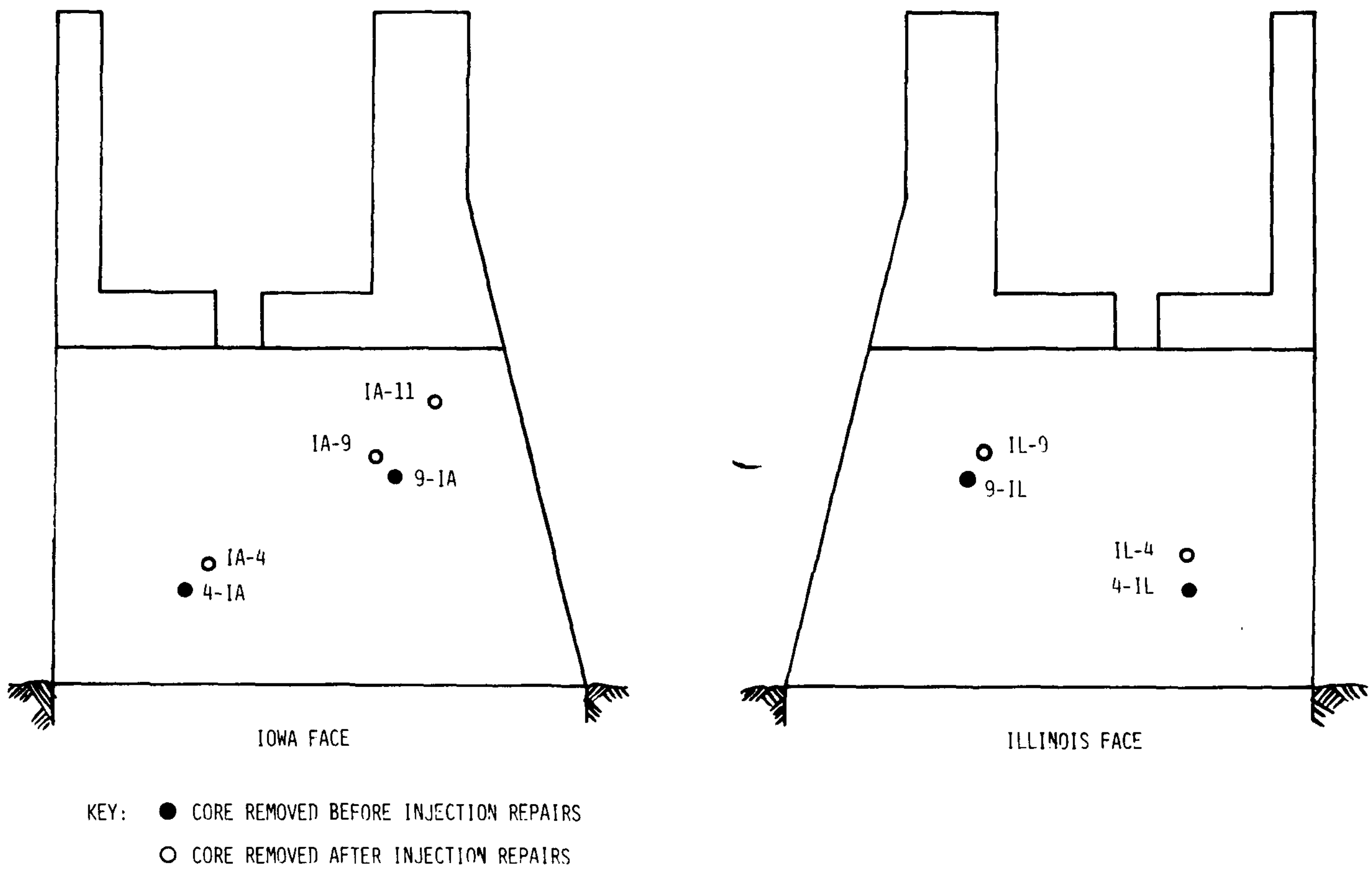


Figure 29. Location of cores taken before and after epoxy injection repair

Figure 30. Cores removed from Pier No. 13 after epoxy injection repair

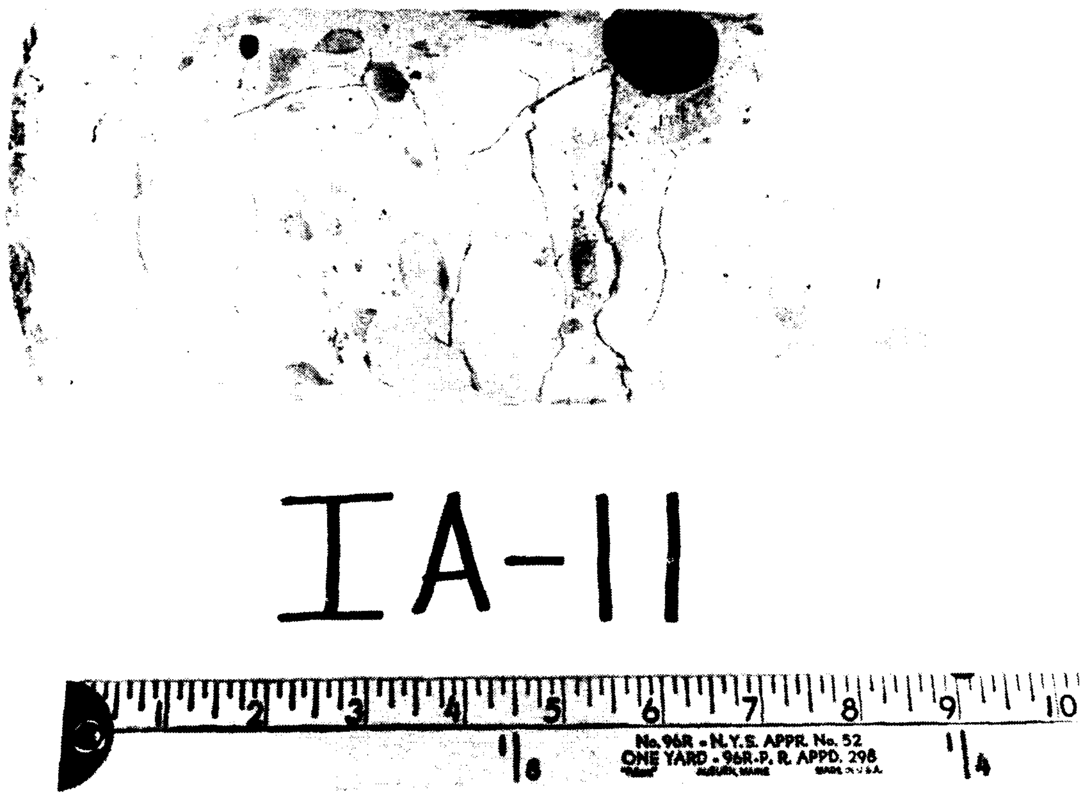


Figure 31. Closeup of core IA-11 showing epoxy-filled crack network

created a protective shell, 6 to 10 in. in thickness, around the face of the pier. It should be noted that this thickness directly corresponds to the depth to which the port holes had been drilled. Therefore unless the crack planes within the pier were intersected by the drilled port holes, they were not repaired by injection. Also, there seemed to be significant cracking within the interior of the pier that did not appear in the cores taken before injection. This analysis helps to explain why the postinjection pulse velocity readings taken between the Illinois and Iowa faces of the pier were so much lower than those readings through the corners of the pier. Those readings taken through the corners were taken through the zone which had been repaired, while those readings taken between the Illinois and Iowa faces were influenced by the unrepaired cracks within the interior of the pier.

Evaluation of concrete cores

85. Comparative testing was done on the cores removed before and after the pier was injected with epoxy to evaluate the effectiveness of the repair. Evaluation was based upon visual examination of the cores, and the results of ultrasonic pulse velocity, splitting tensile strength, and resistance to freezing and thawing tests (Table 5).

86. Four sets of specimens were tested. Set 1 contained specimens cut from sections of the unrepaired cores which contained open cracks. Set 2 contained specimens cut from sections of the repaired cores that contained epoxy-filled cracks. Set 3 was made up of specimens cut from sections of the repaired cores that contained apparently unfilled cracks. Set 4 consisted of specimens cut from sections of both the unrepaired and repaired cores that contained no visible cracks.

87. As previously stated, a visual examination of the cores removed before the repair work (cores 4IA, 9IA, 4IL, and 9IL) revealed an extensive crack network within the top 6 to 12 in. of the cores, with crack planes generally running parallel to the face of the cores. Sections cut from these cores had an average ultrasonic pulse velocity of 4,868 ft/sec and an average splitting tensile strength of 265 psi.

88. A visual examination of the cores removed after the repairs were completed (cores IA-4, IA-9, IA-11, IL-4, and IL-9) suggested that the crack network within the top 6 to 10 in. was 90-to 95-percent filled with epoxy, and that the epoxy had penetrated as deep as 15 in. from the surface in core IA-11. Thicknesses of the cracks filled with epoxy varied between 0.002 and 0.045 in. Sections cut from these cores (Set 2) had an average ultrasonic pulse velocity of 8,828 ft/sec and an average splitting tensile strength of 595 psi.

89. Tests on apparently uncracked sections from the lower portions of the cores (Set 4) had an average ultrasonic pulse velocity of 12,837 ft/sec and an average splitting tensile strength of 665 psi (control values).

90. A comparison of the results shows that significant improvements were made in the ultrasonic pulse velocity and splitting tensile strength of the concrete in the first 6 to 10 in. of the cores as a result of the epoxy

Table 5

Ultrasonic Pulse Velocity and Splitting Tensile Strength Test Results

Core Description		Initial		After 25 Cycles of Freezing and Thawing	
Specimen No.	Core No.	Ultrasonic PV Value, ft/sec	Splitting Tensile Strength, psi	Ultrasonic PV Value, ft/sec	Splitting Tensile Strength, psi
Set 1 - Unrepaired cores					
1	4IA	10,599	NT	4,167	240
2	4IA	2,731	NT	0	0
3	9IA	2,801	259	-	-
4	9IA	6,500	NT	0	0
5	4IL	2,306	195	-	-
6	4IL	2,905	NT	0	0
7	9IL	NT	342	-	-
8	9IL	6,234	NT	0	0
	AVG	4,868	265	833	48
Set 2 - Repaired cores, cracks filled with epoxy					
9	IA-4	11,139	635	-	-
10	IA-4	9,013	NT	6,316	634
11	IA-9	6,634	668	-	-
12	IA-9	7,018	NT	2,323	294
13	IA-11	9,908	580	-	-
14	IA-11	13,258	NT	7,955	423
15	IL-4	7,754	NT	4,523	683
16	IL-9	5,901	497	-	-
	AVG	8,828	595	5,279	509
Set 3 - Repaired cores, no epoxy in cracks					
17	IA-4	7,774	NT	4,134	442
18	IA-9	4,376	NT	0	0
19	IL-9	5,026	NT	3,081	NT
	AVG	5,725	-	2,405	221

(Continued)

Table 5 (Concluded)

Core Description			Initial		After 25 Cycles of Freezing and Thawing	
Specimen No.	Core No.		Ultrasonic PV Value, ft/sec	Splitting Tensile Strength, psi	Ultrasonic PV Value, ft/sec	Splitting Tensile Strength, psi
Set 4 - Apparently uncracked sections taken from both repaired and unrepaired cores						
20	4IA		14,084	674	-	-
21	4IA		14,323	NT*	4,351	438
22	9IA		10,657	NT	2,590	114
23	4IL		13,408	840	-	-
24	4IL		12,987	NT	8,993	636
25	9IL		11,662	NT	4,914	147
26	IA-4		12,379	NT	-	-
27	IL-4		13,376	707	-	-
28	IL-4		12,661	NT	3,279	413
29	IL-9		NT	439	-	-
		AVG	12,837	665	4,825	350

*NT = No test performed.

injection. The average ultrasonic pulse velocity was increased from 4,868 to 8,828 ft/sec, while the average splitting tensile strength increased from 265 to 595 psi. However, these values for repaired concrete were still lower than those for control specimens cut from the bottoms of the cores. Such differences may partly be due to the fact that not all of the cracks within the repaired zone were completely filled with epoxy. In addition, the quality of the cement paste in the upper, more deteriorated, sections of the cores may not be as good as that in the lower, uncracked sections.

91. Tests were also done to evaluate the resistance of the repaired and nonrepaired cores to cycles of freezing and thawing. Sections cut from the cores were subjected to 25 cycles of freezing and thawing, in accordance with

ASTM C666, Procedure A. Evaluation of the core sections was based upon ultrasonic PV and splitting tensile strength test data.

92. The average PV value for each set of specimens decreased after 25 cycles of freezing and thawing; varying between 3,608 and 5,279 ft/sec.

93. The core sections in Sets 1 and 3 exhibited the greatest amount of deterioration. Four of the five specimens tested in Set 1 and one of the three specimens tested in Set 3 fell apart after 25 cycles of freezing and thawing. The one intact specimen in Set 1 (specimen No. 1) showed a decrease in its PV value from 10,599 to 4,167 ft/sec, while the PV value of the specimen in Set 3 declined from 5,725 to 2,405 ft/sec.

94. The core sections in Set 2 exhibited minor deterioration in the form of surface scaling and aggregate popouts. The average PV value decreased from 8,828 to 5,279 ft/sec.

95. Set 4 exhibited varying degrees of deterioration ranging from slight surface scaling and aggregate popouts to major cracking and disintegration of the cement paste. The average PV value dropped from 12,837 to 4,825 ft/sec.

96. The splitting tensile strength tests indicated that the strength of the core sections decreased after 25 cycles of freezing and thawing. The strengths of the core sections in Sets 1, 2 and 4 decreased to 48, 509 and 350 psi, respectively. The specimens in Set 2, i.e., those containing the epoxy-filled cracks, exhibited the least reduction in strength, decreasing from 595 to 509 psi.

Economic Evaluation

97. Based upon the experience gained during the field test, an economic analysis was made to determine the projected cost of repairing Pier No. 13. This analysis can be used to project repair costs for piers in similar condition, provided the following assumptions are made.

- a. The design and dimensions of the pier are similar to Pier No. 13 at Lock and Dam 13.
- b. The repair work uses equipment and techniques similar to those used in the field test.
- c. The work is done in the central region of the United States.
- d. Quality control evaluation, such as ultrasonic pulse velocity testing and coring, is done by personnel from the Corps of Engineers.

98. Table 6 summarizes the man-power requirements to repair the pier. These figures are based upon the time taken to perform these tasks during the field test, i.e., approximately 246 man-hr. Where several piers are being repaired, this figure should decrease with the efficient use of personnel, and as workers become familiar with the repeated requirements of the job. However, the reduction in manpower requirements due to "the learning curve was not factored into the economic analysis.

Table 6
Estimated Man-Power Requirements

Task	Man-Power Requirements Type	Number	Man-hours
Move equipment to and set up at work site	Laborer Crane Operator	2 1	8 4
Clean top of pier, sandblast pier, dig trench	Laborer	3	48
Erect scaffolding	Laborer	2	6
Touch-up sandblasting	Laborer	2	4.5
Drill port holes	Laborer	2	47
Place injection ports	Laborer	3	10.5
Apply seal coat	Laborer	3	20
Inject pier	Laborer	2	77
Remove injection ports	Laborer	2	3
Cleanup work site	Laborer	2	6
Remove equipment from worksite	Laborer Crane Operator	2 1	8 4
Total	Laborer Crane Operator		238 8

99. A breakdown of the projected $33,108 repair cost is presented in Table 7. Equipment costs represent the largest percentage of the repair, 49.8 percent. The significance of this cost would be reduced on projects where more than one pier is being repaired. Materials and supplies account for 13.2 percent of the cost, and labor for 17 percent. Labor costs would become more significant as the number of piers being repaired is increased. Materials and supplies costs would also increase slightly. Some costs would increase directly with the number of piers being repaired, such as the cost of injection epoxy, seal coat epoxy, and sandblasting sand. Other costs, such as that for scaffolding, increase only slightly, as many of these items can be reused.

Safety and Environment

100. Safety procedures described in this section pertain only to the handling and storage of the epoxy compounds and cleaning solvents used on this project. The procedures are meant to serve only as a guide and are not a specification. Information contained in the manufacturers technical information and material safety data sheets and ACI 503R-80 "Use of Epoxy Compounds With Concrete,"* served as guides for establishing the safety procedures used in the field.

101. The US Army Corps of Engineers Safety and Health Requirement Manual, EM 385-1-1, April 1981 established the safety procedures for all work not relating specifically to the handling and storage of the epoxy compounds and solvents.

General information

102. The specific problems related to the safe use of epoxy compounds depends upon the formulation of the epoxy being used. In general, two areas require particular attention; handling and storage.

103. Uncured epoxy compounds are a strong irritant to the skin, two health hazards may be encountered when epoxies are improperly handled. These hazards take the form of skin irritations and skin sensitization. Skin irritations are conditions such as burns, rashes and itches. Skin sensitization is the development of an allergic reaction as a result of exposure or contact with the epoxy compound.

---

* ACI Manual of Concrete Practice, Part 5: Masonry, Precast Concrete and Special Processes, 1985. American Concrete Institute, Detroit, Mi.

Table 7

Analysis of Costs for Epoxy Injection Repair

Parameters	Cost	Cost Percentage
Equipment costs (EC)		
Air compressors (100 cfm & 2 cfm units)	$ 7,500	
Portable sandblasting unit	500	
Pressure injection equipment	7,500	
Misc. equipment and tools	1,000	
Total equipment costs	$16,500	49.8%
Materials and supplies (MS)		
Injection epoxy (Denepox 40)	$ 2,781	
Seal coat epoxy (Deltapox VM)	512	
Injection porting system	400	
Sandblasting sand	110	
Cleaning solvent	36	
Scaffolding (rental)	200	
General supplies	335	
Total cost of materials & supplies	$ 4,374	13.2%
Labor (L)*		
Laborers, 238 man-hr @ $19.63/hr	$ 4,672	
Crane operator, 8 man-hr @ 25.91/hr	208	
Supervisory labor (15% of total operating labor)	732	
Total labor costs	$ 5,612	17.0%
Total repair costs (TRC = EC + MS + L)	$26,486	
Overhead and profit (25% of TRC)	$,6,622	20.0%
Total project costs		
TRC + overhead and profit	$33,108	

*Laborer and crane operator wage rates were obtained from ENR, 26 Jan. 1989, and are an average for St. Louis, Mo., and Chicago, Il.

104. These potential hazards can be minimized by working in a well ventilated area, by using disposable equipment whenever possible, and by paying very careful attention to personal cleanliness and protection.

105. The problems associated with the storage of epoxies generally relate to flammability and explosion hazards. However, most epoxies have a relatively high flash point which greatly reduces the dangers associated with flammable or explosive materials.

106. Solvents used to clean equipment will often require more caution than the epoxy, the additional precautions needed depending upon the type of solvent. In general, solvents should not be used to clean epoxy from the skin as they may dry the skin, and also cause dermatitis. Also, the solvents will dissolve the epoxy compound and carry it into more intimate contact with the skin, thereby aggravating the problems normally associated with skin contact.

107. Many solvents have a low flash point and, therefore, represent a fire hazard. These materials should be used in a well ventilated area, equipment should be grounded and smoking and other fire initiating devices should be banned from the immediate work and storage areas.

108. Personnel working with epoxy compounds and solvents should always be thoroughly informed of the characteristics and hazards of the materials they are working with. The instructions on the label and manufacturer's literature should be reviewed and closely followed.

109. Two epoxies, DeNeef America Inc.'s Deltapox VM and Denepox 40, and one solvent, acetone, were used in the work performed on Pier No. 13. Appendix D has the technical information and material safety data sheets for each material.

Storage of Materials

110. All epoxies and solvents were stored in one of the gate houses until needed at the job site. The gate house provided a cool shaded area to which access could be limited. Since acetone and one of the epoxy compounds, the Deltapox VM-A component, were considered flammable materials, no smoking was allowed in or around the storage area.

111. Once moved to the job site, the epoxies and solvent were stored in a shaded area off to one end of the work area. Access to this area was restricted. No smoking was permitted in or near the storage area. A fire extinguisher was located near the storage area.

Handling of Materials

112. Personnel working with the epoxy compounds and solvents were instructed in the characteristics and hazards of the materials. Protective clothing was required while working with the materials, including impervious rubber gloves or disposable cotton gloves, protective jump suits (disposable), safety shoes with impervious rubber soles, and safety glasses or goggles. Full face shields were required during the epoxy injection process.

113. A separate work area was set up to mix the epoxies and clean the equipment. The ground within this work area was covered with a sheet of heavy duty polyethylene film to protect the area from spills. A garbage pail, lined with heavy duty trash bags, was placed near the work bench to collect solid waste. A waste solvent can was used to collect used solvent for subsequent disposal.

114. A pail of water and soap was kept near the work area so that personnel could immediately wash if epoxy or solvent was spilled onto the skin.

Environmental

115. In addition to the potential adverse worker health and safety effects discussed above, improper handling and disposal of epoxy materials and their associated solvents may have adverse environmental effects. Reasonable caution should guide activities involving potentially hazardous and toxic chemical substances. Manufacturer's directions and recommendations for the protection of environmental quality should be carefully followed. The MSDS, Appendix D, should be consulted for detailed handling and disposal instructions. The MSDS also provides guidance on appropriate responses in the event of spills. In cases where the effects of a chemical substance on environmental quality are unknown, chemical substances should be treated as potentially hazardous or toxic materials. The MSDS recommends that Federal, state, and local regulations be consulted prior to determining disposal requirements.

PART IV: SUMMARY AND RECOMMENDATIONS

116. A survey by the US Army Corps of Engineers (McDonald and Campbell 1985), showed that the three most common problems encountered in the Corps' civil works concrete hydraulic structures were (a) cracking, (b) seepage, and (c) spalling. These three problems accounted for 77 percent of the 10,096 deficiencies identified during a review of inspection reports. Concrete cracking was observed most often, accounting for 38 percent of the deficiencies. In situ repairs seem suited to repairing deterioration caused by cracking and spalling, although they may not be readily applicable to seepage problems.

117. Brookhaven National Laboratory, under contract to the US Army Corps of Engineers, conducted a program to experimentally evaluate and develop new methods and materials for the in situ repair of cracked concrete hydraulic structures. The major emphasis of this work was to evaluate techniques for pressure injection repair. The results of Phases One, Two and Three of this program were documented earlier (Webster and Kukacka 1987, Webster and Kukacka 1988, Webster, Kukacka and Elling, 1989): the results of Phase Four are presented in this report.

118. The emphasis in Phase Four was on the continued development and optimization of pressure injection procedures to be used in the field. Once developed, the procedures were evaluated in a large-scale field test at Lock and Dam 13, Fulton, IL.

119. The laboratory phase of the program was directed towards:

a. The identification and development of a better method for attaching injection ports to the concrete.

b. The evaluation of methods to drill down into the crack network to facilitate the penetration of epoxy into the interior of the crack network.

c. The repair and modification of the A3-10 epoxy injection machine.

d. The evaluation of the long-term freeze-thaw durability of cracked concrete beams which were repaired by epoxy injection.

120. The results of hydrostatic pressure tests showed that molded injection ports mounted within a drilled port hole can withstand pressures of 200 to 275 psig before leaks begin to develop around the perimeter of the injection ports. Surface-mounted ports withstand pressures between 50 and 150 psig, depending upon the type of port.

121. Wet drilling using a hollow drill stem and bit was the most effective method for drilling port holes. The water flowing through the drill bit removes the drilling fines as they occur and before they can become impacted into the interface of the crack plane.

122. An evaluation of the resistance of cracked concrete beams, which had been repaired by epoxy injection, to 200 cycles of freezing and thawing demonstrated that epoxy injection very effectively restores structural integrity. Ultrasonic pulse velocity (PV) values measured for each of the three sets of specimens remained essentially unchanged throughout the test, varying within ±2 percent of the values measured at the start of the test. Splitting tensile strengths also remained almost unchanged.

123. When the laboratory work was completed, a large-scale field test was performed on Pier No. 13, Lock and Dam 13, Fulton, Il., on 15-31 August, 1988. The objectives of the field test were to demonstrate the value of the procedures developed in the laboratory and to evaluate the effectiveness of the materials and equipment selected for use.

124. The repair work done on Pier No. 13 was limited to the lower 12 ft of the pier. The deterioration in this area was characterized by an extensive crack network, large sections of drumming concrete, and excessive amounts of efflorescence on the exterior faces.

125. Approximately 62 gal of Denepox 40 epoxy was injected into the pier using the following procedure:

- a. Erect scaffolding.
- b. Take preliminary ultrasonic pulse velocity measurements.
- c. Sandblast pier.
- d. Install injection ports and seal pier surfaces.
- e. Take preinjection ultrasonic pulse velocity measurements.

f. Inject crack network.

g. Take postinjection ultrasonic pulse velocity measurements.

h. Take cores for mechanical analysis.

126. Preliminary ultrasonic PV values measured between opposite points at 14 locations on the Illinois and Iowa faces of the pier had an average PV value of 1,502 ft/sec. After repair by epoxy injection, the value increased to 4,074 ft sec.

127. A visual examination of five cores removed after the repair revealed that the crack network within 6 to 10 in. of the surface appeared to be filled with epoxy, and epoxy was visible as deep as 15 in. from the surface. Cracks below this depth contained no epoxy. The epoxy seemed to have created a protective shell, 6 to 10 in. in thickness, around the perimeter of the pier. This thickness directly corresponds to the depth of the drilled port holes.

128. Ultrasonic PV tests showed that the top sections of the cores taken after the repair had an average PV value of 8,828 ft/sec compared with an average value of 4,868 ft/sec that was measured in four cores before the repair work. The splitting tensile strength of the cores increased from 265 to 595 psi as a result of epoxy injection.

129. Tests done to evaluate the resistance of various sections of the cores to 25 cycles of freezing and thawing demonstrated that those sections containing the epoxy-filled cracks exhibited the least amount of deterioration.

130. An economic analysis of the repair showed that 246 man-hr were required to complete the work, at an estimated cost of $33,108.

REFERENCES

McDonald, J. E., and Campbell, R. L. 1985. "The Condition of Corps of Engineers Civil Works Concrete Structures," Technical Report REMR-CS-2, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Scanlon, J. M., et al. 1983. "REMR Research Program Development Report, Final Report," US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Webster, R. P., and Kukacka, L. E. May 1987. "In Situ Repair of Deteriorated Concrete in Hydraulic Structures: Feasibility Study," Technical Report REMR-CS-6, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

———. January 1988. "In Situ Repair of Deteriorated Concrete in Hydraulic Structures: Laboratory Study," Technical Report REMR-CS-11, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Webster, R. P., Kukacka, L. E., and Elling, D. April 1989. "In Situ Repair of Deteriorated Concrete in Hydraulic Structures: A Field Study," Technical Report REMR-CS-21, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

APPENDIX A

Inspection Reports for Pier No. 13,
Lock and Dam 13

NCDED-T (30 May 80) 1st Ind
SUBJECT: Nine-Foot Channel Project, Mississippi River, Clinton, Iowa, Lock and Dam No. 13, Periodic Inspection Report No. 3, September 1979

DA, North Central Division, Corps of Engineers, 536 South Clark Street, Chicago, Illinois 60605

26 JUN 1980

TO: District Engineer, Rock Island

1. The inspection report is approved.

2. Two items should be added to para 6 on page 5, "Conclusions and Recommendations".

a. The District should investigate and provide a solution for the cracking, and leaching of bridge pier No. ~~14~~ 13.

b. The deteriorated riprap should be replaced during the normal maintenance.

FOR THE DIVISION ENGINEER:

1 Incl
2 cys wd

ZANE M. GOODWIN, P.E.
Chief, Engineering Division

Copy Furnished:
DAEN-CWE-BB, w/bsc & Incl

PERIODIC INSPECTION REPORT #3
SEPT. 1979

5. Inspection Results

a. Dam

(1) The dam masonry is generally in good condition with minor cracking and spalling. Most piers have typical cracking on the top surface of the upstream and downstream noses and in the access archway.

(2) Most of the tainter gate piers have cracked and spalled concrete in the trunnion box pour. Piers No. 1 thru 4 have eroded concrete near the waterline at the upstream bulkhead slots (photograph No. 8).

(3) Cracks were noted in the top of the pier stem on the downstream side of Pier No. 1 (photograph No. 5).

(4) The roller gate piers have minor typical cracking on the top surface of the upstream nose (photograph No. 10). Some of the bridge bearing grout pads are spalling outside of the masonry plates. Spalled concrete was noted on the bridge seat for Span No. 7 on Pier No. 7.

(5) Many of the gratings over the access shaft in the pier stems are in need of repair.

Pier 13.

(6) Extensive cracking and leaching was noted on Pier No. ~~14~~ 13 in the storage yard (photographs No. 16 and 17).

(7) Abutment A and Abutment B in the storage yard are in good condition. Broken concrete was noted at the downstream end of Abutment A (photograph No. 14).

(8) The storage yard retaining walls have small vertical cracks, but the alignment is straight and no signs of distress were noted.

(9) The dam gates are generally in good condition. The gates were last painted in 1975-1977. Some of the tainter gate chains have stiff links and many of the chain guard support beams are bent from operation with stiff chain links.

(10) The service bridge is in good condition with corrosion beginning. The timber deck was replanked in 1974 (photograph No. 3).

(11) The nonsubmersible earth dike between the storage yard and the submersible dike are in good condition with adequate control of vegetation. The riprap protection of this dike and the storage yard shows signs of freeze/thaw weathering with areas of appreciable fines (photographs No. 15, 18, 19 and 20).

(12) The submersible dike is in good condition with some undercutting of the slush grout at the west end. The dike was repaired in 1975 (photographs No. 21 and 22).

NCRED-G — Deteriorating Concrete, Lock and Dam No. 13, Bridge Pier No. 13

// THRU: ED — ED-G — 19 Sep 80

BURKE/srs/247

TO: OD

1. References:

a. Nine-Foot Channel Project, Mississippi River, Clinton, Iowa, Lock and Dam No. 13, Periodic Inspection Report No. 3, September 1979.

b. Paragraph 2a of 1st Ind to NCRED-D, letter of 30 May 1980, subject, Cracking and Leaking of Bridge Pier No. 13.

2. The purpose of this investigation is to determine the cause of deterioration of the Portland cement concrete in bridge pier No. 13, and to comply with reference b above.

3. On 21 August 1980, one six-inch diameter vertical concrete core was drilled into the top of bridge pier No. 13 to a depth of two feet, and one six-inch diameter horizontal concrete core was drilled into the west side of bridge pier No. 13 to a depth of two feet. Detailed locations and descriptions are shown in Inclosures 1 through 4.

4. It was originally planned to test these cores for compressive strength, modulus of elasticity, and petrographic examination. However, after examining the cores it was concluded that due to the advanced deteriorated condition, and the lack of intact concrete cores, compressive strength and modulus of elasticity would not be possible and would yield little or no beneficial information (photos attached).

A petrographic examination of the horizontal core will be accomplished by the Missouri River Division Laboratory (MRD) and will supplement this investigation at a later date.

5. A general visual examination of the cores reveals that the concrete contains one and one-half-inch maximum size natural (gravel) coarse aggregate, natural (sand) siliceous fine aggregate, and some entrapped air. The cracking observed appears to be the type associated with freeze-thaw deterioration caused by lack of entrained air in the concrete. Both cores contained calcium deposits in voids and as linings in cracks.

6. Frost action and probable alkali-silica reactions have combined to cause deterioration of the concrete. The maximum depth of concrete deterioration appears to extend beyond two feet as both cores contained visible cracks throughout their length.

NCRED-G
SUBJECT: Deteriorating Concrete, Lock and Dam No. 13, Bridge Pier No. 13

7. The non air-entrained concrete containing significant amounts of non-durable aggregates has been damaged by freeze-thaw mechanisms. The deterioration is progressive because cracks allow moisture to penetrate the concrete. This condition coupled with freezing temperatures results in further freeze-thaw damage.

8. It is recommended that adequate drainage and waterproofing be provided to insure that water is not ponded and allowed to seep into existing cracks. NCRED-D DF of 9 September 1980 contains details for remedial work.

4 Incl
as

BURKE

CF:
NCDED-G
ED-D
ED-G
Lockmaster, L&D 13

NCRED-G
// THRU: ED

Petrographic Examination Results of Concrete Core, Lock and Dam No. 13, Bridge Pier No. 13

ED-G

5 Nov 80
BURKE/dmw/247

TO: OD

1. Reference: NCRED-G, DF of 19 September 1980, Paragraph 4.

2. Transmitted for information and to supplement the referenced DF are results of the petrographic examination of the concrete core.

3. Paragraph 4 of the subject petrographic examination indicates the primary cause of concrete deterioration was caused by freeze-thaw mechanisms with alkali-silica reactivity as a secondary cause, which occurred after the concrete had become cracked.

4. This concludes the investigation of causes of concrete deterioration at Lock and Dam No. 13, pier No. 13, by this office

1 Incl
as

BURKE

CF:
NCDED-G
ED-D
ED-G
L&D 13 (Lockmaster)

DEPARTMENT OF THE ARMY
MISSOURI RIVER DIVISION, CORPS OF ENGINEERS
DIVISION LABORATORY
OMAHA, NEBRASKA 68102

MRC Lab. No. 80/208

23 OCT 1980

Subject: Petrographic Examination of Concrete Cores

Project: Lock and Dam No. 13 and 20
Intended Use: Investigation
Source of Material: Concrete Cores from Piers of Locks No. 13 and 20 Rock Island District

Submitted by: Deputy District Engineer, Rock Island District
Date Sampled: -, Date Received: 11 September 1980
Method of Test or Specification: CRD-C57

References: Rock Island District Request No. NCR IA-80-669, dated 10 Sep 80

SAMPLE IDENTIFICATION

MRD Lab. No. 80/208. Four 6-inch diameter concrete cores were taken from pier No. 13, Lock No. 13 and pier Nos. 6, 39, and 42, Lock No. 20, Rock Island District. The cores were obtained from the face of the piers horizontally and they extend into the concrete for a depth of 1.85 feet.

TEST PROGRAM

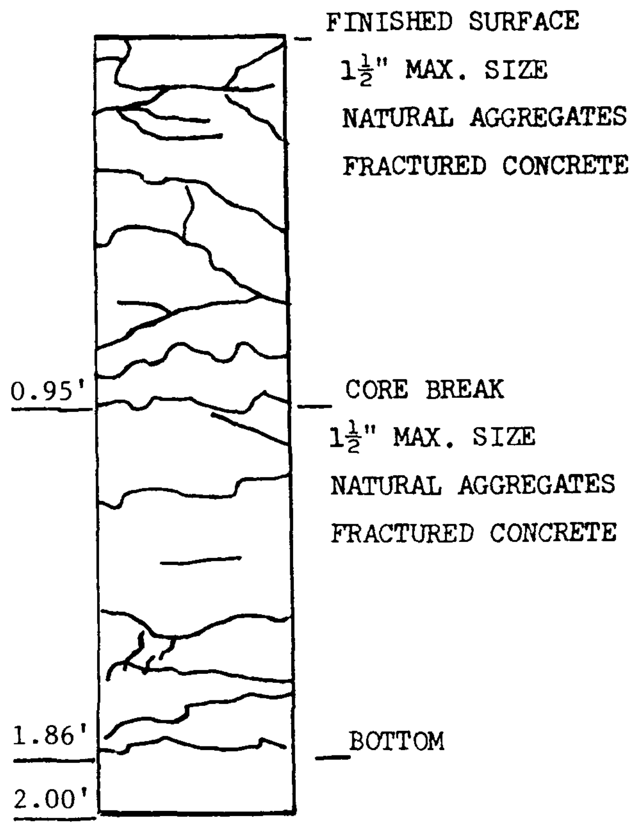
1. The concrete cores were examined under a stereoscopic microscope and the various features recorded. Some portions were more closely examined for evidence to identify the causes of deterioration.

TEST RESULTS

2. Each core from the Lock piers is described as follows:

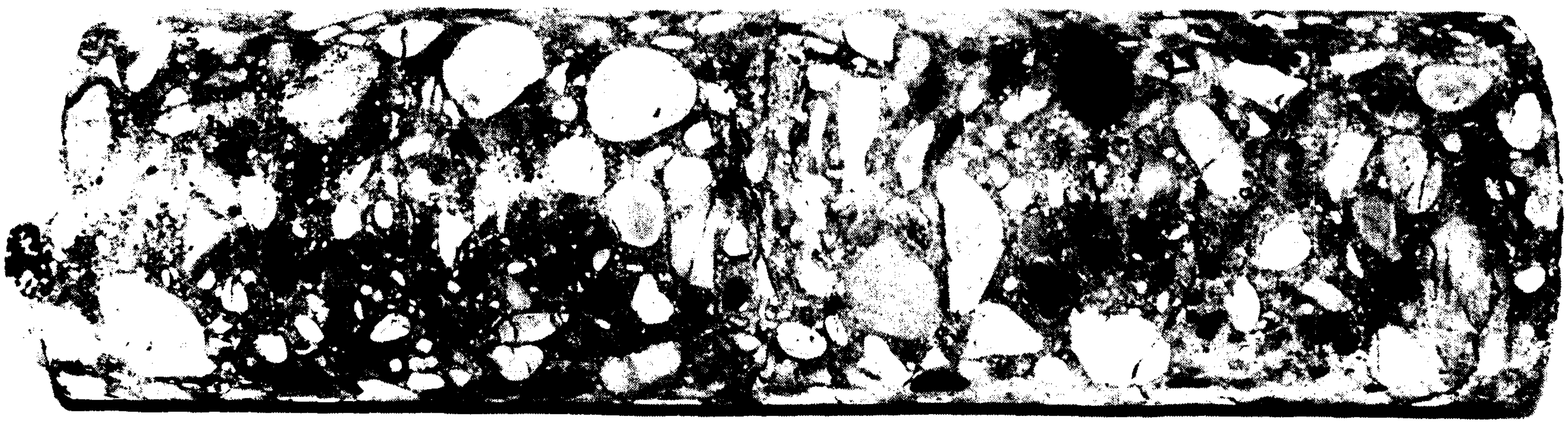
a. Lock No. 13, Pier No.13 0-1.84 ft. This core is highly fractured with multiple parallel cracks about ½ to 1-inch apart in the first one foot of core running parallel to the face of the core. Then the cracks become somewhat diagonal and about 3 to 4-inches apart. Much evidence of silica gel deposits around white and brown chert particles is noted. Many of the chert and sandstone - siltstone particles are shattered. The crack pattern is characteristic of freeze-thaw action and probably results from poor frost protection of the mortar since it is not air-entrained. Some of the porous cherts and siltstones are of low durability also. Alkali-silica reactivity is evident, but it is believed that the freeze-thaw cracking came first, then the reactivity along the cracks which were open to water. Some cracks are lined with lime deposits and much of the silica gel has become carbonated.

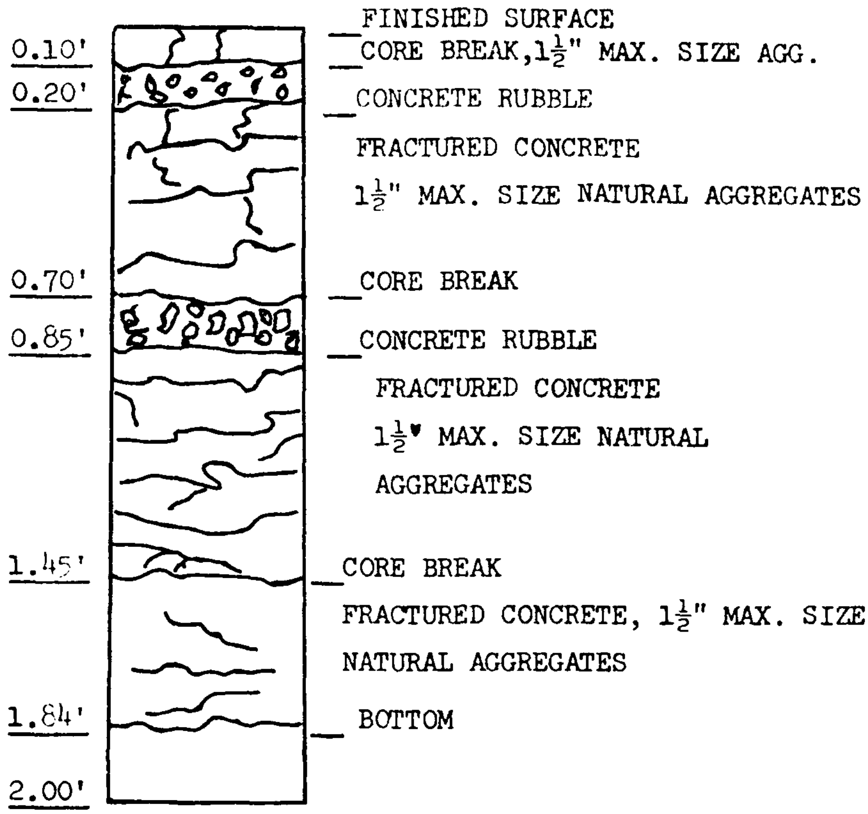
MRD FORM 115
MAY 70 EDITION OF FEB 67 IS OBSOLETE.



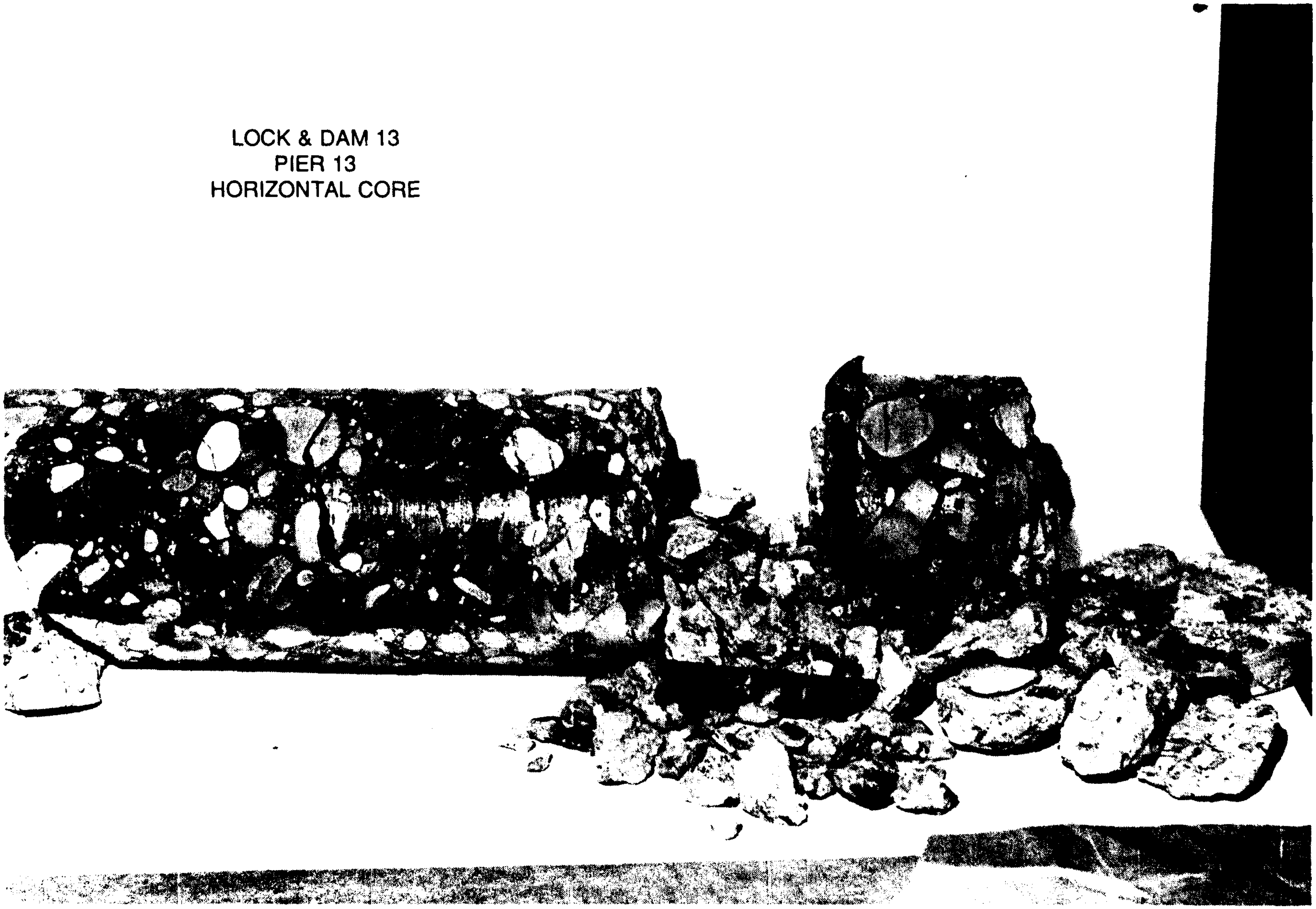
6-inch DIA. CONCRETE CORE
LOCK AND DAM 13
PIER 13
LOG OF VERTICAL CORE
21 AUGUST 1980

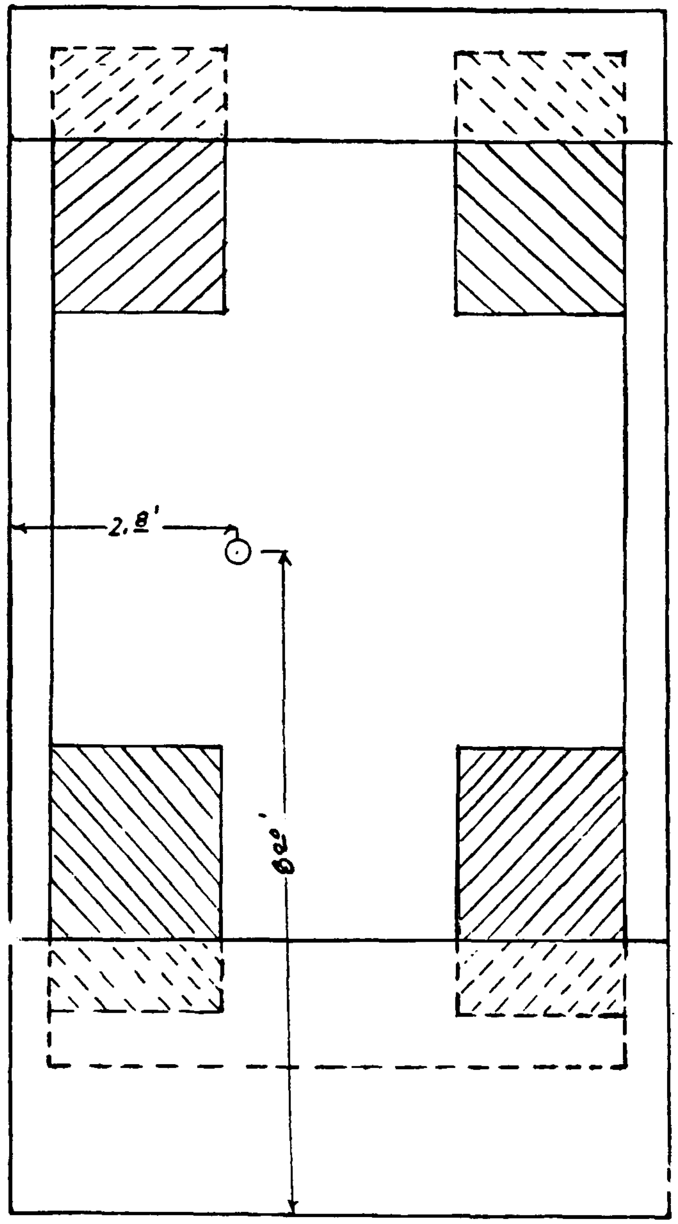
LOCK & DAM 13
PIER 13
VERTICAL CORE





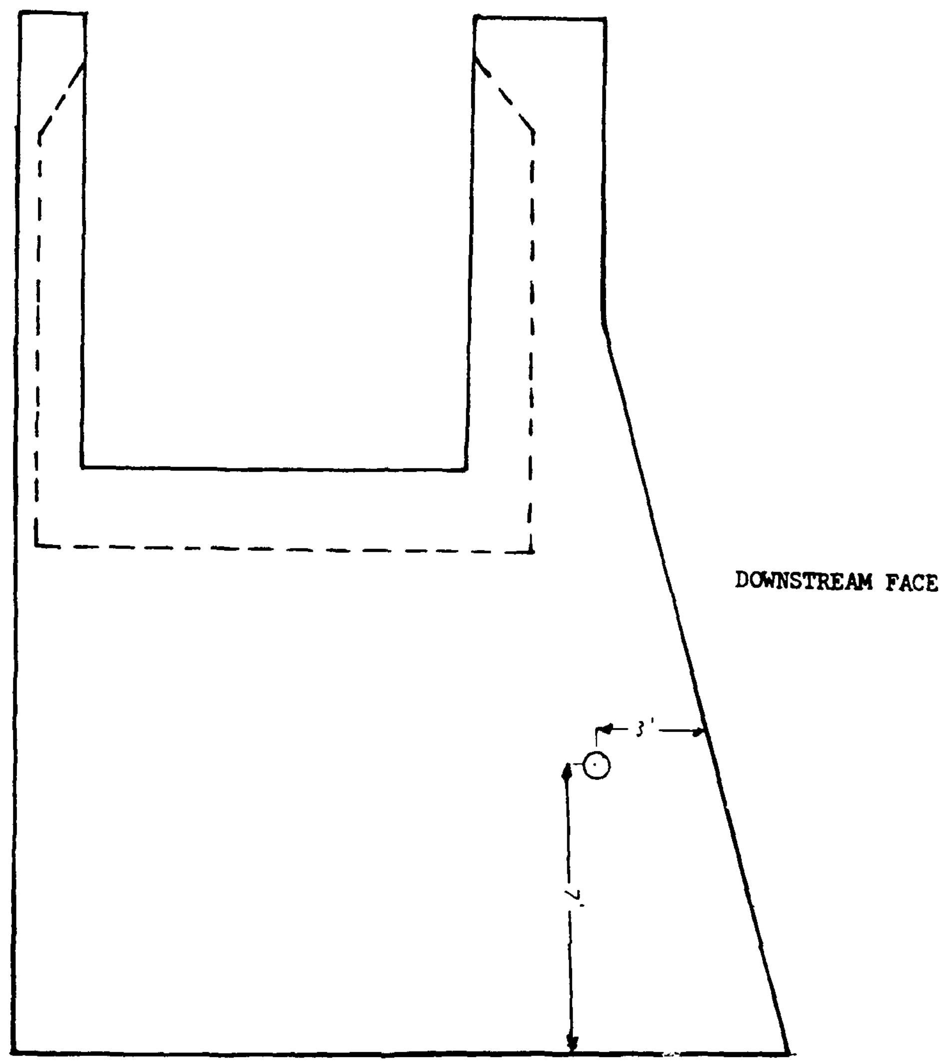
6-inch DIA. CONCRETE CORE
LOCK AND DAM 13
PIER 13
LOG OF HORIZONTAL CORE
21 AUGUST 1980


LOCK & DAM 13
PIER 13
HORIZONTAL CORE



PLAN PIER 13
DOWNSTREAM

6-inch CONCRETE CORE
LOCK AND DAM 13
PIER 13
VERTICAL CORE LOCATION
21 AUGUST 1980



ELEVATION PIER 13

6-inch DIA. CONCRETE CORE
LOCK AND DAM 13
PIER 13
HORIZONTAL CORE LOCATION
21 AUGUST 1980

DISPOSITION FORM

For use of this form, see AR 340-15, the proponent agency is TAGCEN.

REFERENCE OR OFFICE SYMBOL	SUBJECT
NCRED-D	Lock and Dam No. 13, Storage Yard Pier No. 13

~~TO~~ THRU: ED Proj-Sharp FROM ED-D DATE 9 Sep 80 CMT 1

TO: ~~OD~~ ATKINSON/psr/284

1. The initial assessment of the cause of the deterioration of Pier No. 13 at Lock and Dam No. 13, based on field observations and concrete cores taken on 21 August 1980, is that ponded water at the level of the bridge bearing seat is saturating the concrete allowing freeze-thaw action to occur. The ponded water is caused by a malfunctioning 3-inch diameter drain in the two foot high curtain wall.

2. To decrease the rate of deterioration, the following remedial work is recommended (see attached drawing):

   a. Sawcut a two-foot wide opening near the center of both curtain walls to eliminate the possibility of ponding water.

   b. Seal the top of the concrete with fiber reinforced roof cement applied so that the surface slopes to the openings made in the curtain walls.

3. This work should be accomplished before winter to reduce the impact of the next freeze-thaw season.

ATKINSON

1 Incl
Drawing No. M-L13 40/26

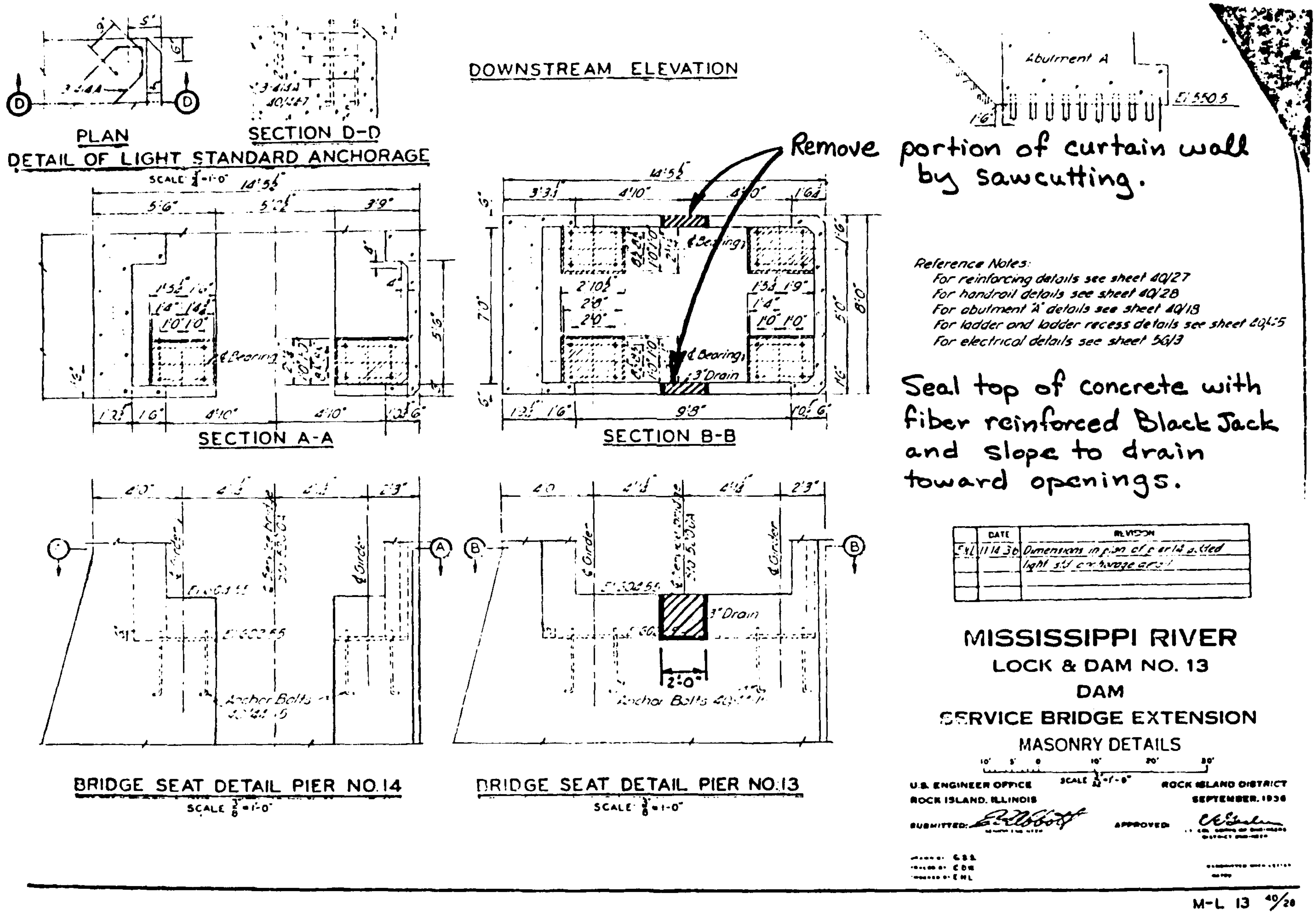
CF:
ED-D
ED-F

TO: SHARP
CHEIF PROJ. OP. BR.

ABOVE JOB COMPLETED 10/31/80

FROM: 4013

DA FORM 2496 REPLACES DD FORM 96, ... OBSOLETE. U.S GPO.1979-0-310-981/8129



PLAN
SECTION D-D
DETAIL OF LIGHT STANDARD ANCHORAGE
SCALE ½"=1'-0"
DOWNSTREAM ELEVATION
Abutment A
SECTION A-A
SECTION B-B
Remove portion of curtain wall by sawcutting.
Reference Notes:
For reinforcing details see sheet 40/27
For handrail details see sheet 40/28
For abutment 'A' details see sheet 40/18
For ladder and ladder recess details see sheet 40/25
For electrical details see sheet 56/3
Seal top of concrete with fiber reinforced Black Jack and slope to drain toward openings.
DATE
REVISION
Dimensions in plan of pier 14 altered
light std anchorage area
3" Drain
Anchor Bolts
BRIDGE SEAT DETAIL PIER NO.14
SCALE ⅜"=1'-0"
BRIDGE SEAT DETAIL PIER NO.13
SCALE ⅜"=1'-0"
MISSISSIPPI RIVER
LOCK & DAM NO. 13
DAM
SERVICE BRIDGE EXTENSION
MASONRY DETAILS
U.S. ENGINEER OFFICE
ROCK ISLAND, ILLINOIS
ROCK ISLAND DISTRICT
SEPTEMBER, 1936
SUBMITTED:
APPROVED:
M-L 13 40/20

NCRED-G

/ THRU: ED

TO: OD

Trip Report of Lock and Dam No. 13, Bridge Pier No. 13

ED-G

30 Mar 83

SCHULTZ/sap/6238

1. References:

a. NCRED-G DF of 19 September 1980.

b. NCRED-G DF of 5 November 1980.

2. Mr. Schultz (ED-G) visited Lock and Dam No. 13 on 2 March 1983.

3. The purpose was to investigate the adequacy of the asphalt waterproofing that had been previously applied to the top of bridge pier no. 13.

4. Bridge pier no. 13 is the only pier at Lock and Dam 13 that appears to have advanced deterioration of the concrete. Efflorescence is quite evident on the exterior surfaces.

5. The asphalt coating was in good condition. No surface cracking or debonding has occurred to this coating. Drainage of the pier top appears to be adequate. The entire top surface was dry with no areas of ponded water.

6. The condition of bridge pier no. 13 should be monitored on a periodic basis to determine the rate of deterioration.

7. If further remedial measures are needed at a later time, accessibility to pier no. 13 is eased by the location of the pier in the storage yard of the dam bulkheads.

MAS

MIKE SCHULTZ
Geotechnical Branch

CF:
ED-G
ED-D
L&D 13 (Lockmaster)

APPENDIX B

Drilling Logs for Cores Removed Prior to Epoxy Injection

DRILLING LOG

DIVISION	NCD
INSTALLATION	
SHEET	OF SHEETS
1. PROJECT	L+D 13 PIER 13
2. LOCATION (Coordinates or Station)	IOWA FACE 9' BELOW C.J. 5' ĿS OF US FACE
3. DRILLING AGENCY	ED-G
4. HOLE NO. (As shown on drawing title and file number)	13-4-1A
5. NAME OF DRILLER	WICKERSHAM-HOTCHKISS
6. DIRECTION OF HOLE	☐ VERTICAL ☐ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	
8. DEPTH DRILLED INTO ROCK	
9. TOTAL DEPTH OF HOLE	23.3"
10. SIZE AND TYPE OF BIT	4" THIN WALL
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	TRUCO MILWAUKEE
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED: UNDISTURBED:
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	
16. DATE HOLE	STARTED: COMPLETED:
17. ELEVATION TOP OF HOLE	
18. TOTAL CORE RECOVERY FOR BORING	%
19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH IN. b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–2		NUMEROUS FREEZE-THAW CRACKS TO 6"			
	6		FRACTURE - BREAK THRU C.A. $CaCO_3$ ON SURFACE			
	8		NATURAL GRAVEL + SAND AGGREGATE, MAX SIZE C.A. 1½" 70% CARBONATES 30% OTHER.			
	12		BROKEN TO PEMOUG CORE BREAK THRU C.A., $CaCO_3$ ON SURFACE, REACTION RIMS. FREEZE-THAW DAMAGE TO 13.3"			
	22		BROKEN TO REMOVE CORE BREAK THRU C.A. COME $CaCO_3$ ON SURFACE, FEW REACTION RIMS ON C.A.			

Hole No. 9-IA

DRILLING LOG	DIVISION NCD	INSTALLATION	SHEET OF SHEETS

1. PROJECT L&D 13 PIER 13
2. LOCATION (Coordinates or Station) IOWA FACE 5' BELOW C.J. 13' DS OF US FACE
3. DRILLING AGENCY ED-G
4. HOLE NO. (As shown on drawing title and file number) 13-9-1A
5. NAME OF DRILLER WICKERSHAM - HOTCHKISS
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED 90° DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK
9. TOTAL DEPTH OF HOLE 27.0"
10. SIZE AND TYPE OF BIT 4" THIN WALL
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL TRUCO MILWAUKEE
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN | DISTURBED | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE | STARTED | COMPLETED
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH IN. b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–2		EXTREME FREEZE-THAW DAMAGE TO 8"			
	8		FRACTURE CACO3 ON SURFACE REACTION RIMS ON C.A. BREAK THRU MOST C.A.			
	14		FRACTURE CACO3 ON SURFACE REACTION RIMS ON C.A. BREAK THRU C.A			
	16		NATURAL GRAVEL + SAND AGGREGATE. C.A. MAX SIZE 1.5" C.A 75% CARBONATES 25% OTHER.			
	24		EVIDENCE OF FREEZE-THAW DAMAGE FOR FULL LENGTH			
	26		BROKEN TO REMOVE CORE BREAK THRU C.A. CACO3 ON FRACTURE SURFACE REACTION RIMS			

Depth scale: 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28

Hole No. 4 - IL

DRILLING LOG	DIVISION NCD	INSTALLATION	SHEET OF SHEETS

1. PROJECT L+D 13 PIER 13	10. SIZE AND TYPE OF BIT 4" THIN WALL
2. LOCATION (Coordinates or Station) ILL FACE, 9' BELOW C.J., 5' DS FROM US FACE	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY ED-G	12. MANUFACTURER'S DESIGNATION OF DRILL TRUCO MILLWAUKEE
4. HOLE NO. (As shown on drawing title and file number) 13 4-IL	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER WICKERSHAM - HOTCHKISS	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☒ INCLINED 90° DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 22 7"	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH INCHES b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0–3		NUMEROUS SUB-PARALLEL FRACTURES 0.5" SPACED IN TOP 3"; 1.0" SPACED FROM 3-6.5"			
	4		FRACTURE SURFACE $CaCO_3$ COATED			
	5–8		NATURAL GRAVEL AND SAND AGGREGATE. C.A. MAX SIZE 2". C.A. 75% CARBONATES 25% IGNEOUS OR OTHER.			
	10		FRACTURE SURFACE $CaCO_3$ COATED			
	12		OCCASIONAL SMALL AIR VOIDS NOT ENTRAINED			DETERIORATED AT LEAST TO DEPTH OF 12"
	21		BROKEN TO REMOVE CORE BREAK THRU C.A.			

Hole No. 9 - IL

DRILLING LOG	DIVISION NCD	INSTALLATION	SHEET OF SHEETS

1. PROJECT L+D 13 PIER 13	10. SIZE AND TYPE OF BIT 4" THIN WALL
2. LOCATION (Coordinates or Station) ILL FACE 5' BELOW C.J. 13' DS FROM US FACE	11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
3. DRILLING AGENCY	12. MANUFACTURER'S DESIGNATION OF DRILL TRUCO MILLWAUKEE
4. HOLE NO. (As shown on drawing title and file number) 13-9-IL	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN — DISTURBED — UNDISTURBED
5. NAME OF DRILLER WICKERSHAM · HOTCHKISS	14. TOTAL NUMBER CORE BOXES
6. DIRECTION OF HOLE ☐ VERTICAL ☐ INCLINED 90° DEG. FROM VERT.	15. ELEVATION GROUND WATER
	16. DATE HOLE — STARTED — COMPLETED
7. THICKNESS OF OVERBURDEN	17. ELEVATION TOP OF HOLE
8. DEPTH DRILLED INTO ROCK	18. TOTAL CORE RECOVERY FOR BORING %
9. TOTAL DEPTH OF HOLE 25.7"	19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH IN. b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	2		EXTREME FREEZE-THAW DAMAGE TO 6"			
	4		FRACTURES NATURAL GRAVEL + SAND AGGREGATE, C.A. 70% CARBONATES 30% IGNEOUS OR OTHER			
	6					
	8		FRACTURE, $CaCO_3$ ON SURFACE EXTENSIVE REACTION RIMS ON C.A.			
	10					
	12		OCCASIONAL AIR VOID NOT ENTRAINED			
	14					
	16		FRACTURE, $CaCO_3$ ON SURFACE REACTION RIMS ON C.A.			
	18		EVIDENCE OF FREEZE-THAW DAMAGE TO AT LEAST 17.5"			
	20					
	22		BROKEN TO REMOVE CORE $CaCO_3$ ON FRACTURE SURFACE BREAK THRU C.A. REACTION RIMS ON C.A.			
	24					
	26					

APPENDIX C

Drilling Logs for Cores Removed After Epoxy Injection

DRILLING LOG

HOLE NO. IA-4

Project: L&D 13, Pier 13

Size and type of bit: 4" Thin wall

Location: Iowa face, 8' below C.J., 6' from US face

Name of driller: Wickersham

Date: 8-31-88

Comments: Core taken after pier was injected with epoxy

Direction of hole: 90° from vertical

Total depth of hole: 20½"

Log by: R. Webster, BNL

Elev.	Depth, in.		Description			Remarks
	2		epoxy visable in cracks down to 6" depth, some unfilled cracks noted at 4½-5 in. depth, ~~unfilled cracks~~			
	4					
	6					
	8		BROKEN TO REMOVE CORE			
	10					
	12		unfilled cracks visable @ 11 to 12 in. depth. BROKEN TO REMOVE CORE BREAK THROUGH C.A.			
	14					
	16					
	18					
	20					
	22					
	24					

DRILLING LOG

HOLE NO. IA-9

Project: L&D 13, Pier 13

Size and type of bit: 4" Thin wall

Location: Iowa face, 4'3" below C.J., 12'7" from US face

Name of driller: Wickersham

Date: 8-31-88

Comments: Core taken after pier was injected with epoxy

Direction of hole: 90° to vertical

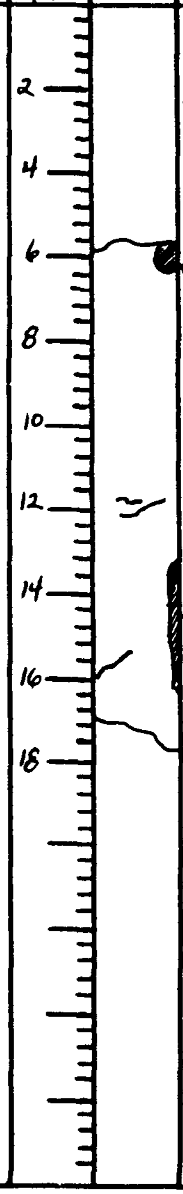
Total depth of hole: 17"

Log by: R. Webster, BNL

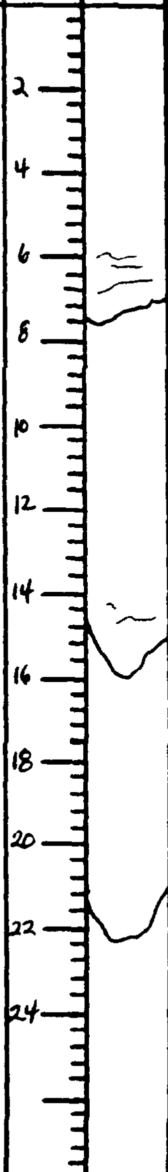
Elev.	Depth, in.		Description			Remarks
	2		Cracks in top 7" appear to be filled with epoxy, below this depth the cracks do not appear to be filled			
	4					
	6					
	8					
	10		BROKEN TO REMOVE CORE			
	12					
	14					
	16					
	18					

DRILLING LOG	HOLE NO. IA-11
Project: L&D 13, Pier 13	Size and type of bit: 4" Thin wall
Location: Iowa face, 23" below C.J., 14'4" from US face	
Name of driller: Wickersham	Comments: Core taken after pier was injected with epoxy
Date: 8-31-88	
Direction of hole: 90° to vertical	
Total depth of hole: 17½"	Log by: R. Webster, BNL

Elev.	Depth, in.		Description			Remarks
			Most of the crack network is confined to top 8 to 10" and these cracks appear to be filled with epoxy			
			BROKEN TO REMOVE CORE Rebar			
			isolated unfilled cracks between 12 & 16", epoxy is visable in cracks down to a depth of 15"			
			piece of wood			



DRILLING LOG	HOLE NO. IL-4
Project: L&D 13, Pier 13	Size and type of bit: 4" thin wall
Location: ILL face, 7'9" below C.J., 5'3" from US face	
Name of driller: Wickersham	Comments: Core taken after pier was injected with epoxy
Date: 8-31-88	
Direction of hole: 90° from vertical	Log by: R. Webster, BNL
Total depth of hole: 22½"	



Elev.	Depth, in.		Description			Remarks
			Cracking limited to top 7" of core, all but a few isolated cracks appear to be filled with epoxy.			
			BROKEN TO REMOVE CORE			
			BROKEN TO REMOVE CORE BREAK THROUGH C.A.			

DRILLING LOG	HOLE NO. IL-9
Project: L&D 13, Pier 13	Size and type of bit: 4" Thin Wall
Location: ILL face, 4' below C.J., 12'7" from US face	
Name of driller: Wickersham	Comments: Core taken after pier was injected with epoxy
Date: 8-31-88	
Direction of hole: 90° from vertical	
Total depth of hole: 21"	Log by: R. Webster - BNL

Elev.	Depth, in.		Description			Remarks
	2		All cracks in top 9" appear to be filled with epoxy			
	8		break is through existing crack, face of break is coated with epoxy → BROKEN TO REMOVE CORE			
	10		cracks between 9" and 17" do not appear to contain any signs of epoxy			
	15		BROKEN TO REMOVE CORE			

APPENDIX D

Technical Information and Material Safety Data Sheets

EPOXY RESIN SYSTEM FOR CONCRETE AND MORTAR

1. DESCRIPTION

Deltapox VM is a 99-percent solids, two-component epoxy resin system designed as a versatile material for repair and restoration. When mixed, it has an easy-to-spread grease-like consistency.

2. USES & LIMITATIONS

USES: Deltapox VM has been primarily designed for patching and repairing floor, wall, and ceiling surfaces, yet it is a versatile adhesive. It is efficient as a gap-filing adhesive to repair concrete and many other materials, particularly in vertical and overhead applications. It can be used for underside sealing of cracks prior to filling or injection from the top.

LIMITATIONS: Deltapox VM should be applied on dry surfaces only and at ambient and substrate temperatures not below 40 °F. Avoid contact with skin and eyes. Wash hands thoroughly with soap and water. Clean equipment with Deltasolv or xylene.

3. MANUFACTURER'S TECHNICAL DATA

Physical properties:*

Mixing ratio	10 parts A to 1 part B (by weight)
Mixture viscosity	gel
Mixture density	9.2 lb/gal
Pot life	30 min @ 70 °F
Tack-free (thin film)	25 min @ 70 °F
Adhesion to concrete	superior to concrete cohesion
Coverage, as adhesive	1 lb covers 9.8 to 16.3 sq ft, depending on surface roughness

* All values are approximate and will vary with temperature and humidity. Mixing of material at temperatures below 50 °F is not recommended.

Packaging: Deltapox VM is available in 0.25- and 5.5-gal units.

4. MANUFACTURER'S GUIDANCE FOR APPLICATION

Surface preparation: The surface must be clean, dry, and sound. Remove dust, laitance, grease, curing compounds, impregnations, waxes, foreign particles, and disintegrated materials.

Application: Slowly mix Deltapox VM components A and B until a uniform gel is obtained. Apply by brush, roller, or putty knife to surface.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME: DE NEEF AMERICA INC.	EMERGENCY TELEPHONE NUMBER: (517) 681-5791
ADDRESS (Number, Street, City, State and Zip Code): 122 North Mill Street - St. Louis, Michigan 48880	
CHEMICAL NAME AND SYNONYMS:	TRADE NAME AND SYNONYMS: DELTAPOX VM - A Component
CHEMICAL FAMILY: Epoxy Resin	FORMULA:

SECTION II — HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES AND SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
Epoxy Resin (Aver. mo. weight $\leq$ 700)		
Phenol	< 1	

SECTION III — PHYSICAL DATA

BOILING POINT (°F)	275	SPECIFIC GRAVITY (H_2O = 1)	> 1
VAPOR PRESSURE (mm Hg.)		PERCENT, VOLATILE BY VOLUME (%)	N/A
VAPOR DENSITY (AIR = 1)	> 1	EVAPORATION RATE	N/A
SOLUBILITY IN WATER	None		
APPEARANCE AND ODOR	Thixotropic amber and translucent liquid with turpentine odor		

SECTION IV — FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used): 77 (COC)	FLAMMABLE LIMITS	Lel	Uel
EXTINGUISHING MEDIA: Dry Powder, Halon, CO2			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARDS			

(Continued on reverse side)

SECTION V — HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

SECTION VI — REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		
	STABLE	XX	

INCOMPATABILITY (Materials to avoid)
Water

HAZARDOUS DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		
	WILL NOT OCCUR	XX	

SECTION VII — SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Soak in absorbant material and dispose of according to local regulations

WASTE DISPOSAL METHOD

SECTION VIII — SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)

VENTILATION	LOCAL EXHAUST XX	SPECIAL
	MECHANICAL (General)	OTHER

PROTECTIVE GLOVES XX	EYE PROTECTION XX

OTHER PROTECTIVE EQUIPMENT Coveralls

SECTION IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE
Store in dry conditions

OTHER PRECAUTIONS
NO EATING DRINKING OR SMOKING ON THE JOB

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME: DE NEEF AMERICA INC.	EMERGENCY TELEPHONE NUMBER: (517) 681-5791
ADDRESS (Number, Street, City, State and Zip Code): 122 North Mill Street - St. Louis, Michigan 48880	
CHEMICAL NAME AND SYNONYMS	TRADE NAME AND SYNONYMS: DELTAPOX VM - B Component
CHEMICAL FAMILY: Amine Compounds	FORMULA

SECTION II — HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES AND SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
Contains Diethylenetriamine		

SECTION III — PHYSICAL DATA

BOILING POINT (°F)	400	SPECIFIC GRAVITY (H_2O = 1)	< 1
VAPOR PRESSURE (mm Hg.) 70° F	0,5	PERCENT, VOLATILE BY VOLUME (%)	N/A
VAPOR DENSITY (AIR = 1)	> 1	EVAPORATION RATE	
SOLUBILITY IN WATER	Good		
APPEARANCE AND ODOR	Clear low viscosity liquid with pungent amine smell		

SECTION IV — FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used): 215° F (COC)	FLAMMABLE LIMITS	Lel	Uel
EXTINGUISHING MEDIA: CO2, Halon, Powder, Alcohol resistant foam			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARDS			

(Continued on reverse side)

SECTION V — HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE
Inhalation: Shortness of breath; very strong irritant to skin and eyes; can cause burn injuries

EMERGENCY AND FIRST AID PROCEDURES
ALWAYS CALL A PHYSICIAN
Inhalation: Get into fresh-air Eyes: Rinse with copious water and see a doctor
Skin: Smooted clothes should be removed and skin rinsed with copious water
Ingestion: Rinse mouth, drink copious water and immediately get to a Hospital

SECTION VI — REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		
	STABLE	XX	

INCOMPATABILITY (Materials to avoid)
Acids and oxidating compounds

HAZARDOUS DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		
	WILL NOT OCCUR	XX	

SECTION VII — SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Collect in sealable vessels, rest should be rinsed away with copious water

WASTE DISPOSAL METHOD

SECTION VIII — SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)

VENTILATION		
	LOCAL EXHAUST: XX	SPECIAL
	MECHANICAL (General)	OTHER

PROTECTIVE GLOVES	EYE PROTECTION
XX	XX

OTHER PROTECTIVE EQUIPMENT
Coveralls

SECTION IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE
Keep away from acids and oxidizing agents

OTHER PRECAUTIONS

EPOXY RESIN SYSTEM FOR CONCRETE REPAIR

1. DESCRIPTION

Denepox 40 is a 100 percent solids, ultra-low viscosity two-component epoxy resin system.

2. USES & LIMITATIONS

Uses: Denepox 40 is designed specifically for pressure injection. It is also excellent for repair of cracks by gravity feeding. When applied with standard injection equipment or with the balloon injection for concrete structures (BICS) system, it will effectively grout and seal cracks in horizontal, vertical, and overhead surfaces.

Limitations: Denepox 40 is not to be used when ambient or surface temperatures are below 50 °F. After the components are mixed, the material must be used within 60 min.

3. MANUFACTURER'S TECHNICAL DATA

Mixing ratio (A/B) by weight 100/30

Mixing viscosity					
Temperature, F deg	77	68	59	50	41
Viscosity, cps	40	75	95	130	170

	After 7 Days @ 68 °F	After 7 Days @ 41 °F
Compressive strength, psi	15,250	1,450
Compressive modulus, psi	39.15×10^4	----
Tensile strength, psi	9,000	1,000
Tensile elongation, percent	9	160
Bend strength, psi	14,400	130

Slant shear bond strength, ASTM C 882	
Air-dried concrete	1,985 psi
Water-saturated concrete	1,110 psi
Splitting tensile strength, ASTM C 496	
Air-dried concrete	923 psi
Water-saturated concrete	703 psi
Concrete with water bearing cracks*	539 psi
Bonding strength to concrete, after 7 days @ 77 °F	
Dry concrete (100% concrete crack)	870 psi
Wet concrete (100% concrete crack)	520 psi

* Cracks contained 90 to 100% adhesive.

4. MANUFACTURER'S GUIDANCE FOR APPLICATION

Surface preparation: Surfaces to be repaired or sealed must be clean and sound. Concrete must be free of dust, laitance, sealers, grease, and other bond inhibiting contaminants. Drilling of cracks for injection ports must be accomplished with a vacuum attached swivel drill chuck (no drilling necessary with BICS System). Entry ports for injecting should be approved devices spaced at appropriate intervals to accomplish the full penetration of the resin.

Mixing: Denepox 40 is supplied as a two-component system in 2.5-gal units (1.85 Component A and 0.65 Component B). Mix materials with a low-speed drill and paddle for approximately 4 minutes to ensure thorough mixing.

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

MATERIAL SAFETY DATA SHEET

Required under **USDL** Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking **(29 CFR 1915, 1916, 1917)**

SECTION I

MANUFACTURER'S NAME: DE NEEF AMERICA INC.	EMERGENCY TELEPHONE NUMBER: (517) 681-5791
ADDRESS (Number, Street, City, State and Zip Code): 122 North Mill Street - St. Louis, Michigan 48880	
CHEMICAL NAME AND SYNONYMS	TRADE NAME AND SYNONYMS: DENEPOX 40 - A Component
CHEMICAL FAMILY: Epoxy Resin	FORMULA

SECTION II — HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES AND SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
Epoxy resin (aver. mol. weight $\leq$ 700)		

SECTION III — PHYSICAL DATA

BOILING POINT (°F)	$>$400	SPECIFIC GRAVITY (H_2O = 1)	
VAPOR PRESSURE (mm Hg.)		PERCENT, VOLATILE BY VOLUME (%)	
VAPOR DENSITY (AIR = 1)		EVAPORATION RATE	
SOLUBILITY IN WATER			
APPEARANCE AND ODOR			

SECTION IV — FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used)	FLAMMABLE LIMITS	Lel	Uel
EXTINGUISHING MEDIA			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARDS			

PAGE (1)

(Continued on reverse side)

FORM OSHA-20
Rev. May '72

SECTION V — HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE

EMERGENCY AND FIRST AID PROCEDURES

SECTION VI — REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		
	STABLE	XX	

INCOMPATABILITY (Materials to avoid)
Water

HAZARDOUS DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		
	WILL NOT OCCUR	XX	

SECTION VII — SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Soak in absorbant material and dispose of according to local regulations

WASTE DISPOSAL METHOD

SECTION VIII — SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)

VENTILATION		
	LOCAL EXHAUST XX	SPECIAL
	MECHANICAL (General)	OTHER

PROTECTIVE GLOVES	EYE PROTECTION
XX	XX

OTHER PROTECTIVE EQUIPMENT

SECTION IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE
Store in dry conditions

OTHER PRECAUTIONS

NO EATING, DRINKING OR SMOKING ON THE JOB

U.S. DEPARTMENT OF LABOR
Occupational Safety and Health Administration

MATERIAL SAFETY DATA SHEET

Required under USDL Safety and Health Regulations for Ship Repairing, Shipbuilding, and Shipbreaking (29 CFR 1915, 1916, 1917)

SECTION I

MANUFACTURER'S NAME: DE NEEF AMERICA INC.	EMERGENCY TELEPHONE NUMBER: (517) 681-5791
ADDRESS (Number, Street, City, State and Zip Code): 122 North Mill Street - St. Louis, Michigan 48880	
CHEMICAL NAME AND SYNONYMS	TRADE NAME AND SYNONYMS: DENEPOX 40 - B Component
CHEMICAL FAMILY	FORMULA

SECTION II — HAZARDOUS INGREDIENTS

PAINTS, PRESERVATIVES AND SOLVENTS	%	TLV (Units)	ALLOYS AND METALLIC COATINGS	%	TLV (Units)
PIGMENTS			BASE METAL		
CATALYST			ALLOYS		
VEHICLE			METALLIC COATINGS		
SOLVENTS			FILLER METAL PLUS COATING OR CORE FLUX		
ADDITIVES			OTHERS		
OTHERS					

HAZARDOUS MIXTURES OF OTHER LIQUIDS, SOLIDS, OR GASES	%	TLV (Units)
Contains an organic amine mixture		

SECTION III — PHYSICAL DATA

BOILING POINT (°F)	400	SPECIFIC GRAVITY (H_2O = 1)	< 1
VAPOR PRESSURE (mm Hg) 70° F	0,5	PERCENT, VOLATILE BY VOLUME (%)	N/A
VAPOR DENSITY (AIR = 1)	> 1	EVAPORATION RATE	
SOLUBILITY IN WATER	Good		
APPEARANCE AND ODOR	Clear low viscosity liquid with pungent amine smell		

SECTION IV — FIRE AND EXPLOSION HAZARD DATA

FLASH POINT (Method used): 215° F (COC)	FLAMMABLE LIMITS	Lel	Uel
EXTINGUISHING MEDIA: CO2, Halon, Powder, Alcohol resistant foam			
SPECIAL FIRE FIGHTING PROCEDURES			
UNUSUAL FIRE AND EXPLOSION HAZARDS			

(Continued on reverse side)

SECTION V — HEALTH HAZARD DATA

THRESHOLD LIMIT VALUE

EFFECTS OF OVEREXPOSURE
Inhalation: Shorness of breath; very strong irritant to skin and eyes
Can cause burn injuries

EMERGENCY AND FIRST AID PROCEDURES
Always call a physician
Inhalation: Get into fresh air
Skin: Smooted clothes should be removed and skin rinsed with copious water
Eyes: Rinse with copious water and get to a doctor
Ingestion: Rinse mouth, drink copious water and get immediately to a Hospital

SECTION VI — REACTIVITY DATA

STABILITY			CONDITIONS TO AVOID
	UNSTABLE		
	STABLE	XX	

INCOMPATABILITY (Materials to avoid)
Acids and oxidating compounds

HAZARDOUS DECOMPOSITION PRODUCTS

HAZARDOUS POLYMERIZATION			CONDITIONS TO AVOID
	MAY OCCUR		
	WILL NOT OCCUR	XX	

SECTION VII — SPILL OR LEAK PROCEDURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED
Collect in sealable vessels, rest should be rinsed away with copious water

WASTE DISPOSAL METHOD

SECTION VIII — SPECIAL PROTECTION INFORMATION

RESPIRATORY PROTECTION (Specify Type)

VENTILATION		
	LOCAL EXHAUST XX	SPECIAL
	MECHANICAL (General)	OTHER

PROTECTIVE GLOVES	EYE PROTECTION
XX	XX

OTHER PROTECTIVE EQUIPMENT Coveralls

SECTION IX — SPECIAL PRECAUTIONS

PRECAUTIONS TO BE TAKEN IN HANDLING AND STORAGE
Keep away from acids adn oxidizing agents

OTHER PRECAUTIONS

* *
*   C H E M I N F O   *
*   *
*   Canadian Centre for Occupational Health and Safety   *
* *

*** IDENTIFICATION ***

RECORD NUMBER	30E
CCOHS CHEMICAL NAME	Acetone
SYNONYM(S)	* Dimethyl ketone * Methyl ketone * 2-Propanone * Ketone propane * Dimethyl formaldehyde
CAS REGISTRY NUMBER	67-64-1
PIN - UN/NA NUMBER(S)	1090

* Information on chemicals contained in the CHEMINFO Database is drawn from a number of publicly available sources. The sources used are available on request. *

RTECS NUMBER(S)	AL3150000
CHEMICAL FAMILY	Aliphatic ketone
MOLECULAR FORMULA	C3-H6-O
STRUCTURAL FORMULA	CH3-CO-CH3
LAST REVISION DATE	1988-03-31

*** DESCRIPTION ***

APPEARANCE AND ODOUR	Clear, colourless, volatile liquid with a characteristic sweetish (mint-like) odour.
ODOUR THRESHOLD	200 - 400 ppm
WARNING PROPERTIES (ODOUR AND IRRITATION)	Good - Odour detectable well below concentrations considered harmful; acclimatization can occur.
COMPOSITION/PURITY	Technical: 99.5% plus 0.5% water
USES AND OCCURRENCES	Used as a solvent in processes involving resins, lacquers, fats, waxes, adhesives, printing inks, plastics and varnishes; degreasing agent; in the manufacture of paints, varnishes, varnish removers, rubbers, plastics, dyes, explosives, artificial silk, synthetic rubber and photographic chemicals.

*** HUMAN HEALTH HAZARD DATA ***

* EFFECTS OF SHORT-TERM (ACUTE) EXPOSURE *

INHALATION	At low concentrations, there are no acute effects. At high concentrations (approx. 1000 ppm), slight irritation of the nose and throat occurs. At very high concentrations (greater than 10000 ppm), headache, weakness, drowsiness, nausea, a feeling of drunkeness and vomiting may result. Higher concentrations can cause collapse, coma and death. Exposure to extremely high concentrations is unusual
EYE CONTACT	At high concentrations (1000 ppm), the vapour can cause slight, temporary eye irritation. Liquid acetone is moderately irritating to the eyes.
SKIN CONTACT	Direct contact may cause slight irritation.

	The risk of absorption through intact skin is considered slight.
INGESTION	Irritation of the throat, esophagus (tube leading to the stomach) and stomach. Ingestion of a large amount will cause symptoms similar to inhalation (e.g. headache, weakness, drowsiness, etc.)

* EFFECTS OF LONG-TERM (CHRONIC) EXPOSURE *

HEALTH EFFECTS	SKIN: Prolonged or repeated contact may cause defatting of the skin and produce dermatitis (dryness, irritation, redness and cracking). INHALATION: Workers exposed to 1000 ppm for 3 hours per day for 7 to 15 years complained of nose and throat irritation, dizziness and loss of strength.
CARCINOGENICITY	No human information. Negative in one animal test.
REPRODUCTIVE EFFECTS	No human information. Negative in two tests.
MUTAGENICITY	No human information. Negative in two tests.
POTENTIAL FOR ACCUMULATION	None. Large doses of acetone are mostly excreted, unchanged, in exhaled air. Small doses are mostly oxidized to carbon dioxide and excreted via exhaled air and urine.

* EFFECTS OF LONG-TERM (CHRONIC) EXPOSURE *

HEALTH HAZARD COMMENTS	NOTE: Exposure to acetone may enhance the liver toxicity of chlorinated solvents, such as 1,1-dichloroethylene and 1,1,2-trichloroethane.

*** FIRST AID ***

INHALATION	Remove source of contamination or move victim to fresh air. If breathing has stopped, properly trained personnel should begin artificial respiration or cardiopulmonary resuscitation (CPR) immediately. Obtain medical attention immediately.
EYE CONTACT	Immediately flush the contaminated eye(s) with lukewarm, gently flowing water for 10 minutes, by the clock, holding the eyelid(s) open. Obtain medical attention immediately.
SKIN CONTACT	As quickly as possible, flush contaminated area with lukewarm, gently running water for at least 10 minutes, by the clock. Under running water, remove contaminated clothing, shoes, and leather goods (e.g. watchbands, belts). If irritation persists, obtain medical advice immediately.
INGESTION	Never give anything by mouth if victim is rapidly losing consciousness or is unconscious or convulsing. Rinse mouth thoroughly with water. DO NOT INDUCE VOMITING. Have victim drink 8 to 10 ozs. (240 to 300 ml) of water to dilute material in stomach. Obtain medical attention immediately.
FIRST AID COMMENTS	Provide general supportive measures (comfort, warmth, rest). Consult a physician and/or the nearest Poison Control Centre for all exposures except minor instances of

inhalation or skin contact.

*** ANIMAL TOXICITY DATA ***

ANIMAL TOXICITY DATA — LD50 (oral, rat) = 9750 mg/kg LD50 (oral, mouse) = 3000 mg/kg LD50 (oral, rabbit) = 5300 mg/kg LD50 (dermal, rabbit) = 20000 mg/kg LCLO (inhalation, rat) = 64000 ppm, duration 4 hours LDLO (inhalation, mouse) = 46400 ppm, duration 62 minutes Irritant dose (eye, rabbit) = 3950 micrograms - severe eye irritant Irritant dose (skin, rabbit) = 395 mg (open irritation test) - mild skin irritant Small doses of acetone administered on the surface of the skin (percutaneously) (0.5 ml) or under the skin (subcutaneously) (0.05 ml) over 3 to 8 weeks produced cataracts in the eyes of guinea pigs. In a later study, conducted similarly, acetone produced cataracts in guinea pigs, but not rabbits. Rats exposed to 19000 ppm of acetone for 3 hours per day, 5 days per week, for 8 weeks were sacrificed at 2, 4, 8, and 10 weeks. No toxic effects were noted. No evidence of teratogenicity was found when 39 or 78 mg of acetone was injected into the yolk sacs of fertile chick eggs prior to incubation. No evidence of cellular transformation was noted when 0.2% acetone was added to the growth medium of cultured Syrian hamster embryonic cells. Acetone did not produce tumors when applied to the skin of mice 3 times per week for 1 year.

*** OCCUPATIONAL EXPOSURE LIMITS ***

* THRESHOLD LIMIT VALUES (TLVS) / AMERICAN CONFERENCE OF GOVERNMENTAL INDUSTRIAL HYGIENISTS (ACGIH) / 1987-88 *

TIME-WEIGHTED AVERAGE (TLV-TWA) — 750 ppm (1780 mg/m3)

SHORT-TERM EXPOSURE LIMIT (TLV-STEL) — 1000 ppm (2375 mg/m3)

EXPOSURE LIMIT COMMENTS — NOTE: Since the manner in which exposure limits are established, interpreted and implemented can vary among the jurisdictions, detailed information should be sought from the appropriate government agency in each jurisdiction.

*** SAMPLING AND ANALYSIS ***

SAMPLING & ANALYSIS — PASSIVE DOSIMETRY: long-term analysis DETECTOR TUBES: short- and long-term analysis INFRARED: continuous monitor GAS CHROMATOGRAPHY: continuous monitor SAMPLING PUMP WITH APPROPRIATE COLLECTING MEDIUM: NIOSH Method P&CAM 127. NIOSH Manual of Analytical Methods. Second edition. Volume 1, 1977. NIOSH Method: 1300 - NIOSH Manual of Analytical Methods. 3rd ed. Vol. 2

*** EXPOSURE CONTROL ***

* Note: Exposure to this material can be controlled in many ways. The measures appropriate for a particular worksite depend on how this material is used and on the extent of

exposure. Use this general information to help develop specific control measures. Ensure that control systems are properly designed and maintained. Comply with occupational, environmental, fire, and other applicable regulations. *

* ENGINEERING CONTROLS *

ENGINEERING CONTROLS	Engineering control methods to reduce hazardous exposures are preferred. General methods include mechanical ventilation (dilution and local exhaust), process or personnel enclosure, control of process conditions and process modification (e.g., substitution of a less hazardous material). Administrative controls and personal protective equipment may also be required. Use a non-sparking, grounded ventilation system separate from other exhaust ventilation systems. Exhaust directly to the outside. Supply sufficient replacement air to make up for air removed by exhaust systems.

* PERSONAL PROTECTIVE EQUIPMENT *

RESPIRATORY PROTECTION	If engineering controls and work practices are not effective in controlling exposure to this material, then wear suitable personal protective equipment including approved respiratory protection. Have appropriate equipment available for use in emergencies such as spills or fire. If respiratory protection is required, institute a complete respiratory protection program including selection, fit testing, training, maintenance and inspection. Refer to the CSA Standard Z94.4-M1982, "Selection, Care, and Use of Respirators," available from the Canadian Standards Association, Rexdale, Ontario, M9W 1R3.
RESPIRATORY PROTECTION GUIDELINES	NIOSH RECOMMENDATIONS FOR ACETONE CONCENTRATIONS IN AIR: UP TO 1000 ppm: Chemical cartridge respirator with organic vapour cartridge(s); or powered air-purifying respirator with organic vapour cartridge(s); or SAR; or SCBA. UP TO 6250 ppm: SAR operated in a continuous flow mode. UP TO 12,500 ppm: Gas mask with organic vapour canister; or full-facepiece SAR; or full-facepiece SCBA. UP TO 20,000 ppm: Positive pressure, full-facepiece SAR. EMERGENCY OR PLANNED ENTRY INTO UNKNOWN CONCENTRATION OR IDLH CONDITIONS: Positive pressure, full-facepiece SCBA; or positive pressure, full-facepiece SAR with an auxiliary positive pressure SCBA. ESCAPE: Gas mask with organic vapour canister; or escape-type SCBA. NOTE: The IDLH concentration for acetone is 20,000 ppm. NOTE: Substance reported to cause eye irritation or damage; may require eye protection. ABBREVIATIONS: SAR = supplied-air respirator; SCBA = self-contained breathing apparatus. IDLH =

Immediately Dangerous to Life or Health. NOTE: In these recommendations the IDLH concentration is defined as the maximum concentration which would not cause any escape-impairing symptoms or irreversible health effects to a person exposed for 30 minutes if the respirator failed.

EYE/FACE PROTECTION
Splash-proof chemical safety goggles or face-shield (eight-inch minimum), as required.

SKIN PROTECTION
Impervious gloves, coveralls, boots, etc., as required.

RESISTANCE OF MATERIALS FOR PROTECTIVE CLOTHING
GOOD: Butyl rubber, Teflon, polyurethane, polyvinyl acetate, Silvershield. FAIR/POOR: Natural rubber, neoprene, nitrile rubber/polyvinyl chloride, neoprene/styrene-butadiene rubber, nitrile rubber, polyethylene, chlorinated polyethylene, Viton, polyvinyl alcohol, polyvinyl chloride, styrene-butadiene rubber, neoprene/natural rubber, Saranex. NOTE: Resistance of specific materials can vary from product to product. Evaluate resistance under conditions of use and maintain clothing carefully.

PERSONAL PROTECTION COMMENTS
NOTE: Eyewash fountains and safety showers should be located near any area where this compound is used. Remove contaminated clothing promptly. Keep contaminated clothing in closed containers. Discard or launder before rewearing. Inform laundry personnel of contaminant's hazards. Do not smoke, eat or drink in work areas. Wash hands thoroughly after handling this material. Maintain good housekeeping.

*** STORAGE AND HANDLING ***

STORAGE CONDITIONS
Store in a cool, dry, well-ventilated area, out of direct sunlight. Store away from heat and ignition sources. Store away from incompatible materials such as materials that support combustion (oxidizing materials) and corrosive materials (strong acids or bases). Use grounded, non-sparking ventilation systems and electrical equipment that does not provide a source of ignition. Store in suitable, labelled containers. Keep containers tightly closed when not in use and when empty. Protect from damage. Use suitable, approved storage cabinets, tanks, rooms and buildings. Have appropriate fire extinguishers available in and near the storage area. Comply with all applicable regulations for the storage and handling of flammable materials.

HANDLING
Use approved flammable liquid storage containers in work area. Keep away from sources of heat or flame. Lighted cigarettes, matches or any other ignition sources should not be allowed in and around storage or usage areas indoor or outdoor. Do

not use near welding operations, flames or hot surfaces. Containers should be grounded during transfer or mixing. Whenever possible, fire-resistant containers should be used. Use smallest possible amounts in designated areas with adequate ventilation. Have emergency equipment (for fires, spills, leaks, etc.) readily available. Label containers. Keep containers closed when not in use. Empty containers may contain residues which are hazardous.

*** SPILL AND LEAK PROCEDURES ***

PRECAUTIONS	Restrict access to area. Provide adequate protective equipment and ventilation. Remove sources of heat and flame. Notify occupational and environmental authorities.
CLEANUP	Stop or reduce discharge if it can be done safely. Contain material. Material should be recovered, if possible, or collected on absorbent materials such as dry clay, sand, or sawdust. Prevent entry into water or sewer systems.

*** DISPOSAL ***

DISPOSAL	Review federal, provincial, and local regulations prior to disposal. May be possible to burn small amounts of liquid in an approved solvent burner, or larger quantities in an approved incinerator. May be possible to dispose of absorbent material containing acetone in an approved landfill site.

*** FIRE AND EXPLOSION ***

FLASH POINT	-9 deg C (15 deg F) Tag Open Cup; -18 deg C (0 deg F) Closed Cup; Flammable liquid
LOWER EXPLOSIVE LIMIT (LEL)	2.6%
UPPER EXPLOSIVE LIMIT (UEL)	12.8%
AUTOIGNITION TEMPERATURE	465 deg C (869 deg F)
FIRE EXTINGUISHING AGENTS	Dry chemical, "alcohol" foam, carbon dioxide
FIRE FIGHTING PROCEDURES	Water may be ineffective in putting out a fire, but should be used to keep fire-exposed containers cool. If a leak or spill has not ignited, water may be used to disperse the vapours. Water spray may be used to flush spills away from exposures and to dilute spills to non-flammable mixtures. The vapour can travel a considerable distance to a source of ignition and "flash back" to a leak or open container. Dilute solutions of acetone in water may be flammable.

COMBUSTION (THERMAL DECOMPOSITION) PRODUCTS
Carbon monoxide, carbon dioxide

* NATIONAL FIRE PROTECTION ASSOCIATION (NFPA) HAZARD INDEX *

HEALTH	1 - Slightly hazardous
FIRE	3 - Can be ignited under almost all normal temperature conditions
REACTIVITY	0 - Normally stable

*** CHEMICAL REACTIVITY ***

STABILITY	Normally stable
INCOMPATIBILITY - MATERIALS TO AVOID	Reacts violently with oxidizing agents (e.g. peroxides, nitrates and perchlorates) and chlorinated solvent/alkali mixtures (e.g. chloroform and sodium hydroxide). Reacts vigorously with hexachloromelamine, sulfur dichloride and potassium tert-butoxide.

*** CHEMICAL REACTIVITY ***

HAZARDOUS POLYMERIZATION	Does not occur
CORROSIVITY TO METALS	Not corrosive to metals.

*** PHYSICAL PROPERTIES ***

MOLECULAR WEIGHT	58.08
CONVERSION FACTOR	1 ppm = 2.37 mg/m3; 1 mg/L = 422 ppm at 25 deg C
MELTING POINT	-95.4 deg C (-139.7 deg F)
BOILING POINT	56.2 deg C (133.2 deg F) at 760 mm Hg
RELATIVE DENSITY (SPECIFIC GRAVITY)	0.791 at 20 deg C (water = 1)
SOLUBILITY IN WATER	Readily soluble in all proportions.
SOLUBILITY IN OTHER LIQUIDS	Readily soluble in all proportions in alcohol, dimethylformamide, chloroform, ether and most oils.
VAPOUR DENSITY	2.0 (air = 1)
VAPOUR PRESSURE	180 mm Hg @ 20 deg C
SATURATION VAPOUR CONCENTRATION	237000 ppm @ 20 deg C
EVAPORATION RATE	High
CRITICAL TEMPERATURE	235 deg C

*** WORKPLACE HAZARDOUS MATERIALS INFORMATION SYSTEM (WHMIS) CLASSIFICATION ***

WHMIS CLASSIFICATION, PROPOSED	Flammable and combustible material - Flammable liquid Poisonous and infectious material - Other effects - Toxic
WHMIS HEALTH EFFECTS INDEX	Eye irritation - toxic - other
WHMIS INGREDIENT DISCLOSURE LIST	Confirmed A; meets criteria for disclosure at 1% or greater

* DETAILED CLASSIFICATION ACCORDING TO CRITERIA *

WHMIS INFORMATION	CLASS A - COMPRESSED GAS: Does not meet criteria CLASS B - FLAMMABLE & COMBUSTIBLE MATERIAL: Meets criteria for "Flammable liquid"; flash point: -18 deg C (closed cup) CLASS C - OXIDIZING MATERIAL: Does not meet criteria CLASS D - POISONOUS AND INFECTIOUS MATERIAL. DIVISION 1 - IMMEDIATE AND SERIOUS TOXIC EFFECTS: Does not meet criteria Acute Lethality: Does not meet criteria; LD50 (oral, rat) 9750 mg/kg; LD50 (dermal, rabbit) 20000 mg/kg CLASS D - POISONOUS AND INFECTIOUS MATERIAL. DIVISION 2 - OTHER TOXIC EFFECTS: Meets criteria for "Toxic material"; see detailed evaluation below.

CHRONIC HEALTH EFFECTS: Does not meet criteria
CARCINOGENICITY: Does not meet criteria; not in reference lists.
TERATOGENICITY AND EMBRYOTOXICITY: Insufficient information
REPRODUCTIVE TOXICITY: Insufficient information
MUTAGENICITY: Does not meet criteria
RESPIRATORY TRACT SENSITIZATION: Does not meet criteira; not reported as human respiratory sensitizer.
SKIN IRRITATION: Does not meet criteria; mild irritant.
EYE IRRITATION: "Toxic"; severe irritant
SKIN SENSITIZATION: Does not meet criteria
CLASS E - CORROSIVE MATERIAL: Does not meet criteria
CLASS F - DANGEROUSLY REACTIVE MATERIAL: Does not meet criteria

*** TRANSPORTATION OF DANGEROUS GOODS (TDG) SHIPPING INFO ***
* (Source: Transport Canada, Transportation of Dangerous Goods Regulations) *

TDG INFORMATION

DESCRIPTION AND SHIPPING NAME: Acetone
PRODUCT IDENTIFICATION NUMBER (PIN): 1090
CLASSIFICATION: 3.1 - Flammable liquid, flash point less than -18 deg C
SPECIAL PROVISIONS: 99
IMO CLASSIFICATION: 3.1
ICAO CLASSIFICATION: 3
PACKING GROUP: II

*** SELECTED BIBLIOGRAPHY ***

BIBLIOGRAPHY

Acetone. In: Clayton, G.D.; Clayton, F.E., eds. Patty's industrial hygiene and toxicology. 3rd revised edition. Vol. 2C : toxicology. New York; Toronto : John Wiley and Sons, Inc., 1982. p. 4720-4727

Acetone (hazard data bank sheet number 52). The Safety Practitioner. (February 1985). p. 6-7

Acetone. Canada Safety Council data sheet no. F-1. Ottawa, Ontario : Canada Safety Council, 1982

Ross, D.S. Acute acetone intoxication involving eight male workers. Annals of Occupational Hygiene. Vol. 16 (1973). p. 73-75

Raleigh, R.L., et al. Effects of short, high-concentration exposures to acetone as determined by observations in the work area. Journal of Occupational Medicine. Vol. 14, no. 8 (Aug. 1972). p. 607-610

NIOSH pocket guide to chemical hazards.