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POLYMER CONCRETE OVERLAY ON SH-51 BRIDGE DECK

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MARCH, 1982

POLYMER CONCRETE OVERLAY

on

SH 51 BRIDGE DECK

INTERIM REPORT

by

Tim M. Borg, P.E.

Project Engineer

STATE OF OKLAHOMA

DEPARTMENT OF TRANSPORTATION

RESEARCH AND DEVELOPMENT DIVISION

Project No. 80-03-1, Item 2409

Under the Supervision

of

C. Dwight Hixon, P.E.

Research and Development Engineer

in

cooperation

with

FEDERAL HIGHWAY ADMINISTRATION

under

Basic Agreement DOT-FH-11-9124

March 1982

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16. ABSTRACT This report discusses OKLAHOMA's first polymer concrete bridge deck overlay. The objective of this project was to place a <u>thin resinous overlay</u> on a sound bridge deck and evaluate its performance over one year using various physical tests. The evaluation will show how well the overlay protects the reinforcing steel from corrosion due to deicing salts. The steps leading to the construction of the overlay are detailed as well as the actual placing of the overlay. The results of various physical tests are reported for both before and after the overlay. The protection of a bridge deck with a polymer concrete overlay appears to be a rather complicated procedure. Besides constraints of weather, temperature, aggregate and resin availability, machinery needs to be developed that can accurately and efficiently mix and lay polymer concrete.					
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3/4" vinyl est with 50% styrene

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
LENGTH				
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (weight)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
teaspoon	teaspoons	5	milliliters	ml
tablespoon	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cup	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (exact)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Mon., Publ. 216, Units of Weights and Measures, Price \$2.25, SD Catalog No. C13.10-100.

Approximate Conversions from Metric Measures

When You Know	Multiply by	To Find	Symbol	
LENGTH				
millimeters	0.04	inches	in	
centimeters	0.4	inches	in	
meters	3.3	feet	ft	
meters	1.1	yards	yd	
kilometers	0.6	miles	mi	
AREA				
square centimeters	0.16	square inches	in ²	
square meters	1.2	square yards	yd ²	
square kilometers	0.4	square miles	mi ²	
hectares (10,000 m ²)	2.5	acres		
MASS (weight)				
grams	0.035	ounces	oz	
kilograms	2.2	pounds	lb	
tonnes (1000 kg)	1.1	short tons		
VOLUME				
milliliters	0.03	fluid ounces	fl oz	
liters	2.1	pints	pt	
liters	1.06	quarts	qt	
liters	0.26	gallons	gal	
cubic meters	35	cubic feet	ft ³	
cubic meters	1.3	cubic yards	yd ³	
TEMPERATURE (exact)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

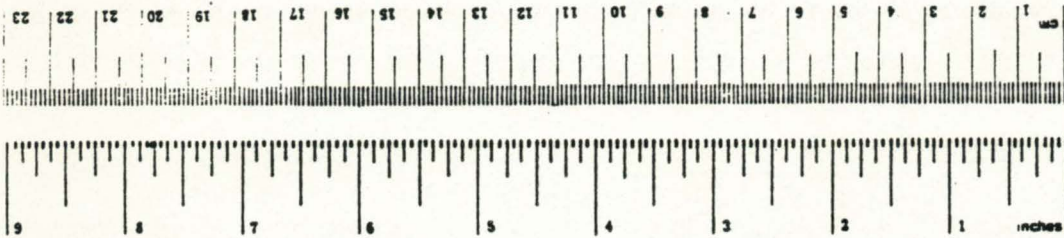
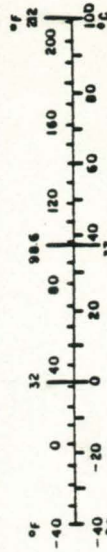


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The author wishes to thank R. L. Stringer, Division IV Engineer, S. C. "Pete" Byers, Division IV Maintenance Engineer, and the personnel of Division IV Headquarters, Perry, for their efforts in completing this project.

Oklahoma Department of Transportation (ODOT) will show how well the polymer concrete overlay protects the reinforcing steel from corrosion due to deicing salts. This project is authorized by the Federal Highway Administration Task Order No. 7, entitled, "Polymer Concrete Overlay" under Basic Agreement No. DOT-FH-11-9124. The FHWA contributed \$20,000 toward this project. Interim User Manuals were distributed by the FHWA to inform engineers in highway agencies of the current state-of-the-art of polymer concrete overlays and to encourage field trials of these systems by state highway agencies.(1)

Background

The Oklahoma Department of Transportation has installed two types of systems to seal bridge decks that are similar. A single eastbound span of a SH 3 bridge east of Shawnee over the North Canadian River was poured with wax beads mixed in the Portland cement concrete.(2) On I-35, southbound, in Noble County, the bridge over Cow Creek had wax beads placed in the top 2 in (50mm) of the deck.(3) Using an electric blanket heating system provided by the FHWA, the wax beads were melted to seal the concrete, thus protecting the reinforcing steel from salt corrosion. Both appear to be working quite well.

PREPARATION

Test Bridge

A bridge in Division IV was sought as a test location as they had agreed to provide manpower and equipment to place the overlay. A test bridge was sought as close to the Central Office as practical to make frequent monitoring more convenient for the Engineering Test Branch of the Research and Development Division. In addition to the FHWA physical requirements for the structure, Division IV personnel suggested finding a bridge on a four lane, divided highway so traffic could be detoured easily.

The structure selected is the westbound bridge on SH 51 in Payne County, 5 mi (8 km) east of I-35. The bridge was built in 1975 as Project No. F-198(53), part of an improvement to widen SH 51 between I-35 and Stillwater from a two lane to a four lane, divided highway. Crossovers between roadways were at section mile roads on either side of the bridge. In 1981 the average daily traffic (ADT) was estimated at 5,000 vehicles on SH 51.

The structure was built as three spans supported by prestressed concrete beams. The deck was poured 7½ in (190 mm) thick with the top mat of reinforcing steel placed 2½ in (64 mm) below the surface. The bridge was skewed 45° to the left, was 138.53 ft (42 m) long, and designed with a clear roadway width of 40 ft and 9 in (12.4 m).

CONSTRUCTION MATERIALS

Polymer concrete uses a plastic to bind the aggregate instead of Portland cement and water. The plastic is made by combining a resin with other chemicals to harden the plastic. The resin is a viscous liquid plastic consisting of unconnected, long hydrocarbon molecule chains. The chemical reaction that connects the long hydrocarbon molecule chain to form a rigid plastic is called "polymerization".

Polymer

At the suggestion of the FHWA contract manager, the originally recommended polyester styrene was replaced by a vinyl ester resin. Vinyl ester had been found by the FHWA to perform as well as polyester styrene but to be less sensitive to water. Therefore, this vinyl ester (containing 50 percent styrene) was used to make polymer concrete for the project overlay. Moisture/compressive strength test comparisons can be seen in Table 1.

Table 1

Comparative Compressive Strengths, PSI*

<u>% Moisture</u>	<u>Polyester Styrene</u>	<u>Vinyl Ester</u>
0	9575	8140
1.5	4465	5210
3.0	2460	2720
4.5	1150	1590

*kPa = (PSI) (6.8948)

Aggregate

Vinyl ester polymer was tested with aggregate sources in Field Division IV. The quarry between Cushing and Drumright produces a durable limestone aggregate which failed to polymerize completely. The four hour cure compressive strength with dried aggregate was less than 2500 PSI (17.2 MPa). Microscopic examination of the limestone revealed many extremely fine clay lenses bedded in the matrix. It was suggested that clay has an absorptive effect on some of the chemical used to polymerize the vinyl ester resin, hence retarding the reaction.

An aggregate from a quarry 6 mi (10 km) northeast of Pawnee was tested and found to produce four hour cure compressive strengths in the 8000 PSI (55 MPa) range. This excellent result only occurred when the 3/8 in (10 mm) limestone chips and concrete sand were oven dried. The tolerable limit for moisture was held to one-half percent by weight, the measured moisture content of a sample of the 3/8 in (10 mm) limestone chips dried on an asphalt parking area.

The Chemical Engineering Department at the University of Oklahoma, Norman, assisted in formulating the correct portions of catalyst to be used with the vinyl ester. Also time-temperature curves were established to determine the relationship of temperature and catalyst concentrations to

the quantity estimated was increased by almost thirty percent. The density of successful test cylinders made at the University of Oklahoma were found to be as high as 143 lbs/ft³ (2145 kg/m³). Approximately 5470 lbs (2461 kg) of vinyl ester and 54,700 lbs (24.62 Mg) of aggregate were needed for the design mix of 10 percent by weight of dry aggregate. To each of 14 drums of vinyl ester resin, 1.7 pt (800 ml) of dimethyl aniline was added as a promoter.

Fifteen tons (13.5 Mg) of 3/8 in (10 mm) limestone chip were purchased from a local Perry concrete plant in July and spread on an asphalt paved parking area in the Division IV yard to dry in the sun. After turning the aggregate daily for three consecutive days, a sample had a moisture content of 0.2 percent. It was then loaded into two surplus dump beds set on wood blocks. Each chip loaded bed was then covered with a plastic sheet and heavy canvas.

Thirteen tons (11.7 Mg) of Class "A" concrete sand were purchased from the same source and similarly spread to dry. By mid-week, the daily turning had sufficiently dried the sand. A sample of the sand had a 0.2 percent moisture content. The silica flour was then blended with the concrete sand at the rate of 50 lbs (22.5 kg) of flour with 325 lbs (146 kg) of sand. Blending was done with a portable drum concrete mixer prior to storage. A third surplus dump bed had been modified with side boards to hold the sand mixture.

was loaded onto the Concrete-Mobile from the protected dump beds. Using a freight scale, the rock and then sand gates were set to deliver aggregate at a pre-determined rate of 90 lbs (40 kg) per minute of each material.

An agreement was made with U.S. Concrete in Norman to supply their machine and operator for \$640 per day. This was the only available machine in Oklahoma to our knowledge.

Two resin pumps and a rheostat were shipped from the FHWA in Washington. They were to be used to transfer the resin into the Concrete-Mobile. The resin pump was calibrated to deliver 18 lbs (8.1 kg) of resin/minute (10 percent of the delivery rate of aggregate) to the Concrete-Mobile. The other pump, a constant speed pump, removes resin from the barrels into an open holding tub. It is in this tub that the catalyst (benzoyl peroxide) is added. Also a Bidwell paving machine was loaned for the project by the Bureau of Land Management in Denver. The paver, modified for use with polymer concrete, was trucked in by common carrier.

Preparation

While personnel were staging in the Division yard, other maintenance workers and traffic control personnel were preparing the bridge.

The detour crossovers between the eastbound and westbound roadways were not sufficient for large trucks to turn. Using motor graders, the radii of the crossovers were widened with asphalt. Also, maintenance personnel thoroughly sand blasted the bridge deck on Tuesday, October 20.

Traffic control was provided by Division IV personnel. Sign posts were erected and the necessary detour signs readied.

filled with resin. The chemical engineer from the University of Oklahoma weighed the benzoyl peroxide catalyst using one-half percent catalyst by weight to resin. Laboratory experiments had suggested that one-half percent benzoyl peroxide catalyst on a 50°F (10°C) day would give approximately thirty minutes of working time. As it was determined that more catalyzed resin was needed, catalyst was added to a tub, and stirred with a wooden paddle. When the previous tub was emptied, the hose from the calibrated resin pump was transferred to the waiting tub. Hence, polymer concrete production at the Concrete-Mobile could continue uninterrupted. Polymer concrete was discharged onto the tackcoated deck immediately in front of the paver. The tackcoat mixer and his two broom men worked beneath the long mixing trough of the Concrete-Mobile.

The vibrating screeds of the paver could not work directly against the parapet wall; therefore, a man with a tamping tool stood on the back of the paver, compacting and leveling a 4 in (100 mm) wide section of overlay along the parapet. The paver could not finish the last 3 ft (.9 m) of the lane because of the 45 degree skew. The parapet wall stopped before the paver could pass over the end of the lane. The remaining area in the right lane was placed and compacted by hand. After paving the right lane, the Concrete-Mobile was flushed with solvent along with the resin pumps. This removed residual catalyzed resin before it hardened.

Delay

Thursday, October 22, was spent in the Division yard. By afternoon, the sky had cleared and temperatures returned to the high 50°F (10°C). The afternoon was spent re-calibrating the resin pump and discharge gates of the Concrete-Mobile in an attempt to improve the quality of the polymer concrete.

Return to the Bridge

Early Friday morning, October 23rd, crews and equipment returned to the bridge. Paver rails were set up to finish the inside lane. In the remaining portion of this lane, pump failure occurred five times. Three times, clots of gelled resin from previously emptied tubs jammed the impellers of the pump. Once, a fuse in the rheostat burned out, and finally, a clot was discovered so large, that it clogged the 3 in (75 mm) diameter delivery hose. When the resin failed to be pumped to the Concrete-Mobile, it usually was not discovered until quantities of too dry and bone-dry polymer concrete were discharged onto the deck. This aggregate was unusable and was thrown over the side of the bridge.

Center Section

With the two 16 ft (4.8 m) wide passes on the inside and outside lanes of the bridge completed, the remaining

rate of the resin pump or to the inability of the Concrete-Mobile to consistently deliver the specified rate of aggregate. Perhaps it was a combination of both.

test revealed over 100 ft. (12 ft. of overlay) that did not bond to the deck. Also, in the center area about 12 ft. from the west end of the bridge, a portion of the overlay 8 ft. (12 ft.) long failed to adhere completely. However, this about 12 ft. (12 ft.) thick on top of the overlay did adhere, probably due to air-violet radiation from the sun. A plan of the deck showing the location and relative size of the delaminated areas and resulting patches is shown in Appendix C.

Expansion Joints

It had been used to fill the two expansion joints as paving proceeded across the deck. A concrete saw and crew sawed out the 2 in (50 mm) wide groove material resulting on the sand. Filled the joint with a two component rubber compound, was poured into the joint to level out. It was not trucked and was finished very well.

First Patching Attempt

Independent of the weather project attempts to get out of the area vinyl ester (CEM #1-0-0) quickly in order to repair the rough riding bridge. However, this was not possible; suppliers were out of stock and the factory was

delayed in getting production started. However, Shell Development in Houston donated 55 gal (209 l) of their vinyl ester resin (DPV-706) to the project.

The aggregate used in patching was surplus silica gravel which passed a 1/4 in (6.4 mm) sieve but was retained on a No. 6 sieve. Coarse flint and very fine silica sand were combined with the No. 6 for aggregate. Fearing a drop in temperature that would prohibit the patching attempts, the hastily acquired aggregate did not meet the FHWA required gradation.

On Wednesday, November 4th, the delaminations were removed with jackhammers. To mix the polymer concrete, a portable drum mixer was used. As before, one half percent by weight of benzoyl peroxide was added as catalyst.

After the first batch had been placed and work proceeded, it was noticed that the polymer concrete was not setting up. While the concentration of catalyst should have been sufficient to gel the resin during the upper 40°F (4°C) day, it was not gelling. The next batches were made with one percent benzoyl peroxide. As work progressed, it became apparent that one and one-half percent benzoyl peroxide would be needed. One or two of the last patches received polymer concrete with the strong concentration of catalyst.

The polymer concrete that would not set was disposed of. Only a couple of small patches appeared to have

(\$15.77 per Mg) for the wet aggregate from the original source, only 7 tons (6.3 Mg) of bagged aggregate was purchased as opposed to 30 tons (27 Mg) originally acquired to make a practice run and overlay the bridge. Test cylinders exceeded 4000 PSI (27.6 MPa) in four hours.

Anticipating the low 40°F (4°C) weather, the barrels of resin and trucks of bagged aggregate were stored inside heated garages. While the hardening would be slowed by the cold deck, the use of warm materials could counteract that effect.

A screed was made by bolting a common electric vibrating concrete "snake" to an 8 in (200 mm) I-beam. Though heavy, four men were able to utilize the device most successfully.

On Tuesday, December 1st, Research Division personnel using air hammers, removed all the overlay that was not securely bonded to the deck. The deck was carefully sounded and over 400 ft² (36 m²) of overlay was removed. These areas were then sand blasted.

The next two days, December 2 and 3, these areas were patched while traffic was detoured. The original one half percent benzoyl peroxide gelled in 30 to 40 minutes as planned. The hand screed had a tendency to tear the surface more than the power screed on the paver because the contact surface had not been carefully machined smooth.

PRELIMINARY TEST RESULTS

Skid Tests

Five skid tests were performed in each of the westbound lanes of the bridge at 40 mph (64 kph) in March of 1982. The results are shown in Table 4. The test conform to ASTM E274. Inconsistency in the polymer concrete (rich, lean, or patches) could account for the variations in skid resistance.

TABLE 4

Skid Test Results

<u>Westbound Roadway</u>	<u>Avg. Skid No.</u>	<u>Std. Deviation</u>
Right Shoulder, left wheelpath	31.2	1.3
Right Lane, Left wheelpath	52.4	1.5
Left Lane, Right wheelpath	30.0	6.4
Left Lane, Left wheelpath	46.2	1.8

Ninety Day Chloride Ponding Test

The 6 in (152 mm) cores were tested according to AASHTO T-259 by the Materials Division of the Oklahoma Department of Transportation. The chloride content of the deck immediately adjacent to the core location was taken to provide a basis for comparison of the relative

COST ANALYSIS

These estimates were based on quarterly summary billing reports to the end of February 1982. Costs from work performed after the end of February were estimated by comparing charges of work performed before February.

Estimated Cost of Entire Research Project

Payroll (plus additives)	\$46,865	
Materials	\$16,639	
Actual construction materials plus incidental supplies.		
Equipment Rental	\$10,475	
Concrete-Mobile (\$640/day) plus ODOT equipment rental rates.		
Travel	\$ 1,426	
Room & board for Research Division personnel in Perry (6 nights).		
Tests & Professional Fees	\$ 7,031	
Field testing by Division IV personnel, lab testing by Materials Division, and consulting by University of Oklahoma.		
 TOTAL		 \$82,436

SUMMARY AND CONCLUSIONS

The objective of this project was to place a thin, resinous overlay on a sound bridge deck to protect the steel reinforcing bars from corrosion. This method of protection has led to several observations.

1. The resin is sensitive to the aggregate content. Clay in the limestone or in poorly washed sand inhibits the reaction of the chemicals. Using sandblasting flint, acquired from lead mine chat piles, also appeared to inhibit the reactions and produce a very weak concrete. The lower the moisture content of the aggregate, the stronger the concrete. The problem of drying and storing aggregate is a handicap.
2. Meeting the optimum gradation of the aggregate sizes by using a two component aggregate to reduce the amount of resin needed was not possible.
3. The 40°F to 90°F (4°C to 32°C) range of ambient temperature in which the polymer concrete can be laid restricts the scheduling of construction. July and August, two of the most desirable months of the construction season, are virtually eliminated.
4. The supply of resin and catalyst was not reliable, orders must be made far in advance of construction. This problem would diminish if polymer concrete were a common construction material. The resin also has a limited shelf life of only three months.

8. It would be unfair to draw any conclusions as a result of the patching attempts with the Shell product. No experiments had been conducted with the Shell resin to verify the promoter and catalyst concentrations for the best results as had been done with the Dow product at the University of Oklahoma. Also no test had been done to verify the use of flint as an alternate aggregate.

The protection of a bridge deck with a polymer concrete overlay appears to be a rather complicated procedure. Beside constraints of weather, temperature, aggregate, and resin availability, machinery needs to be developed that can accurately and efficiently mix and lay polymer concrete.

APPENDIX A
PROJECT PHOTOGRAPHS

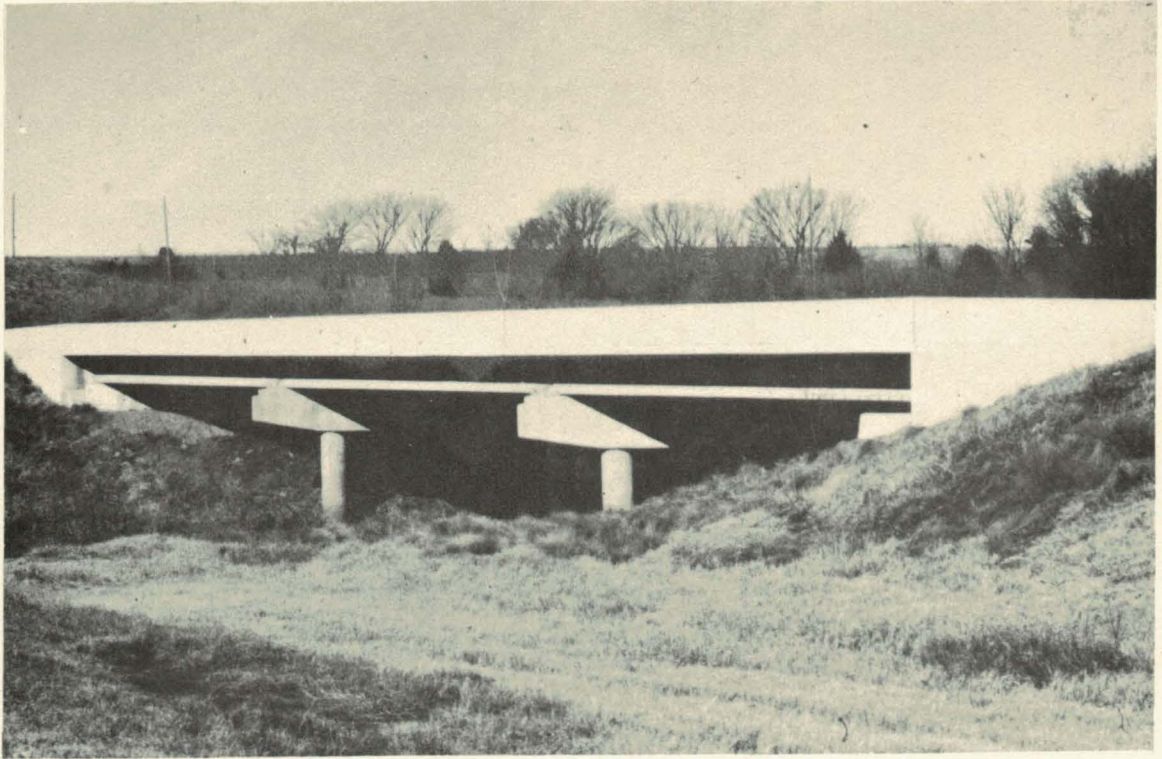


Figure 1. The original bridge on westbound SH 51, Payne County.



Figure 2. Dried sand was blended with silica flour.

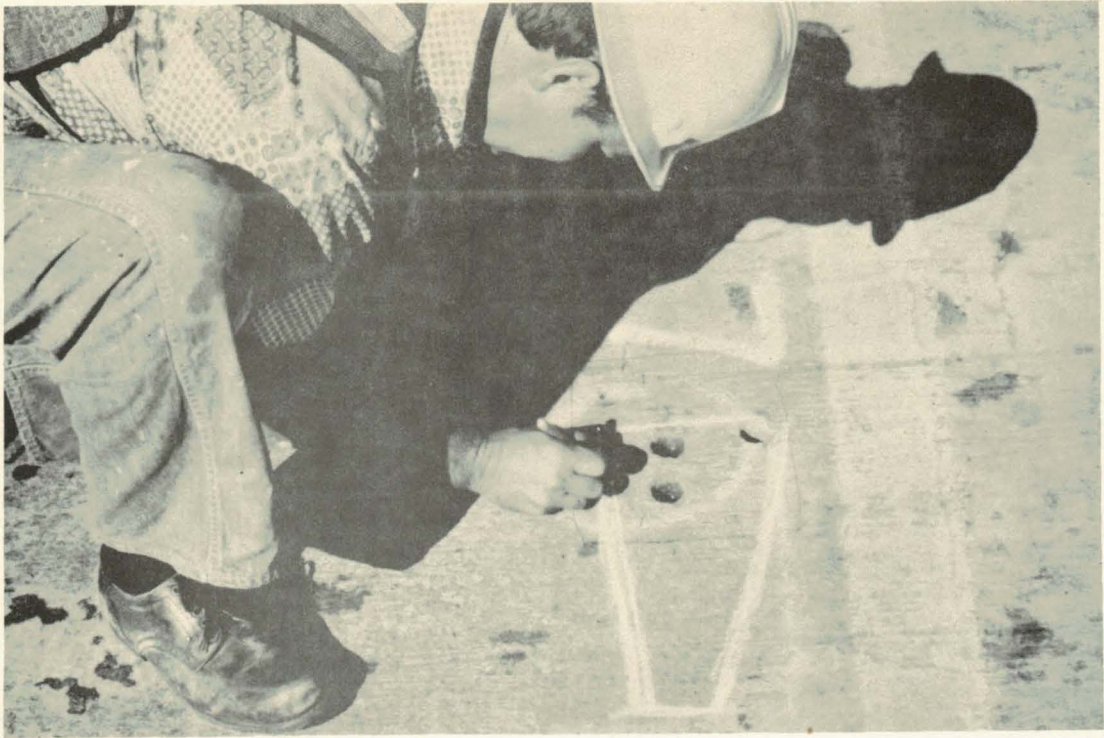


Figure 3. Corrosometer probe locations were marked and probes installed.

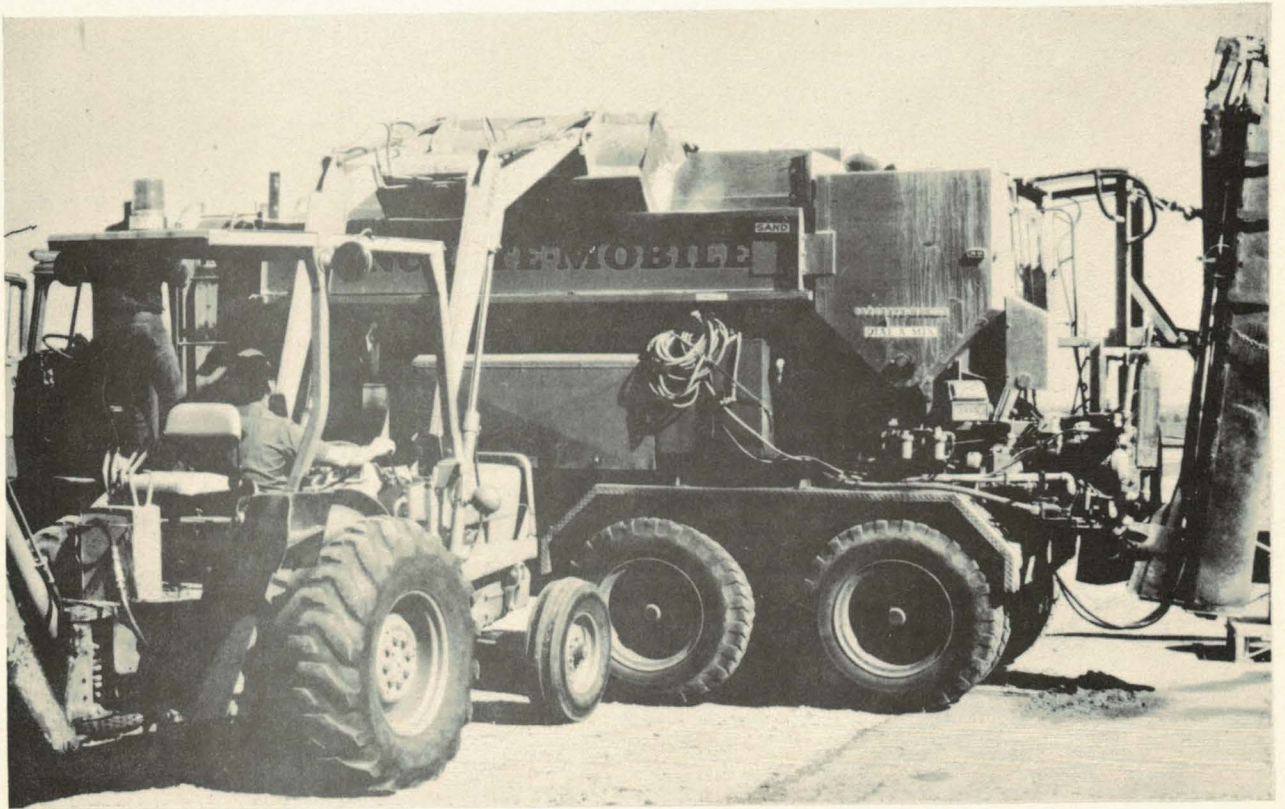


Figure 4. Concrete-Mobile was loaded with the dried aggregate.

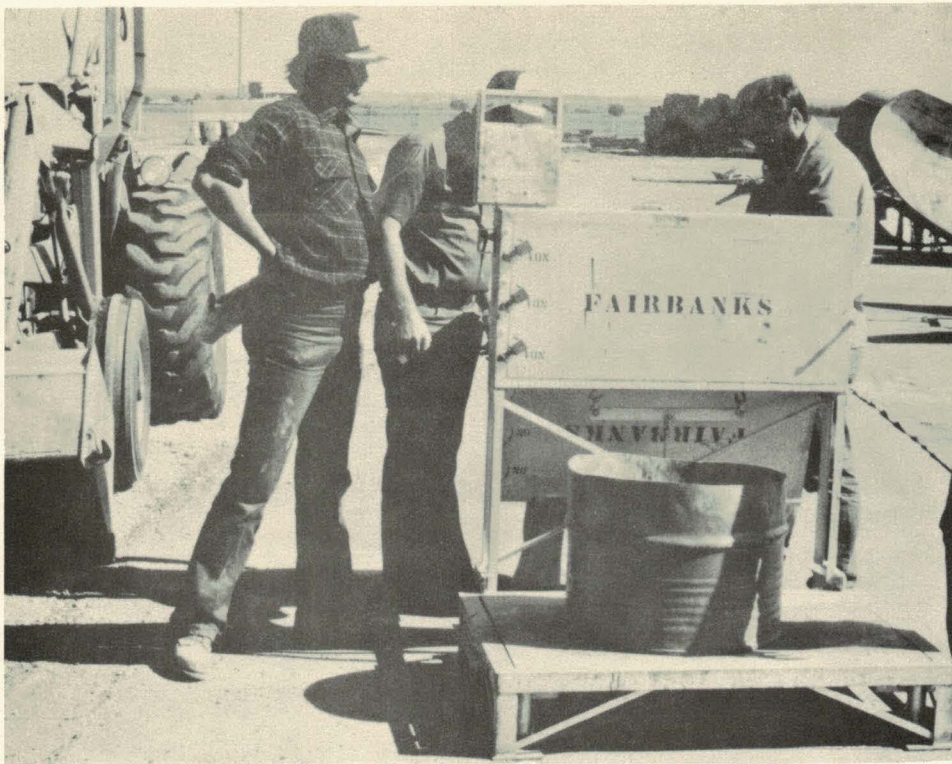


Figure 5. Sand, then chip, discharges were calibrated.



Figure 6. The resin pump was calibrated to deliver the specified amount.

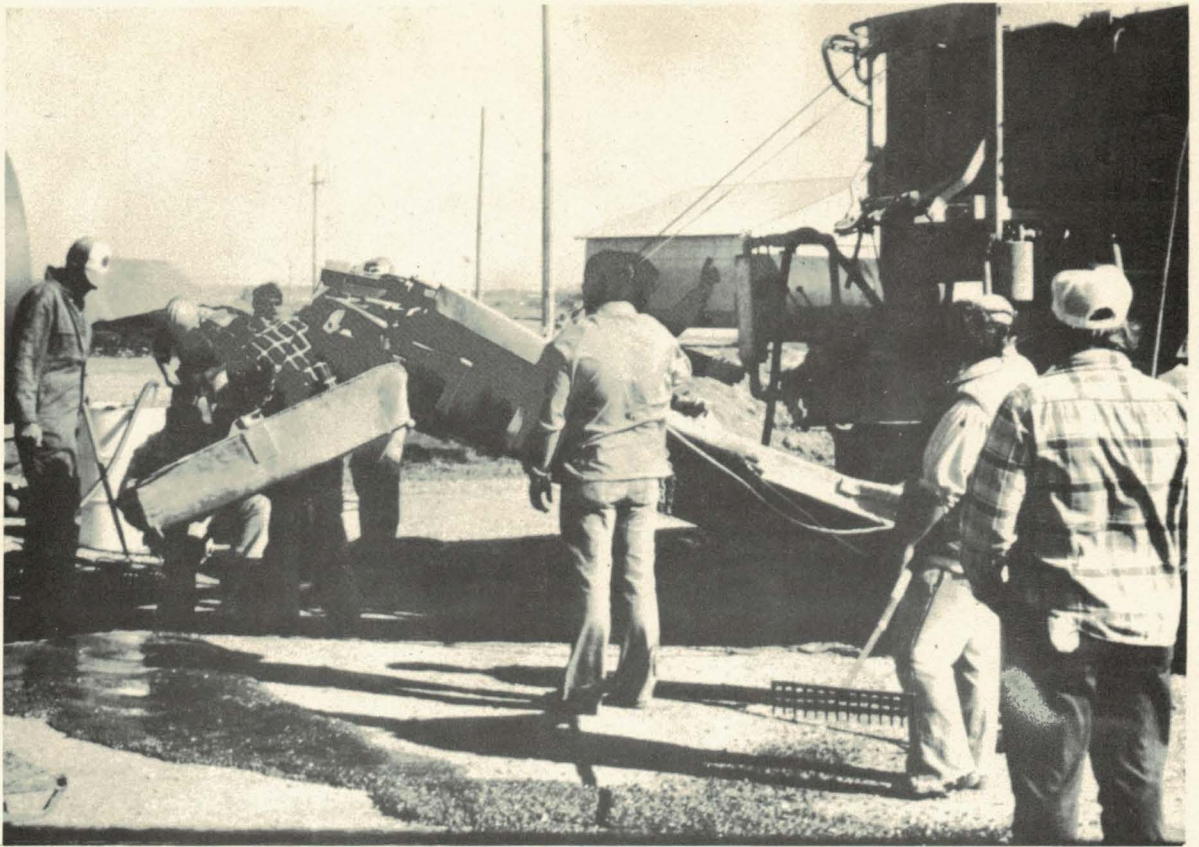


Figure 7. A trial run was made in the yard.



Figure 8. The deck was thoroughly sandblasted clean.

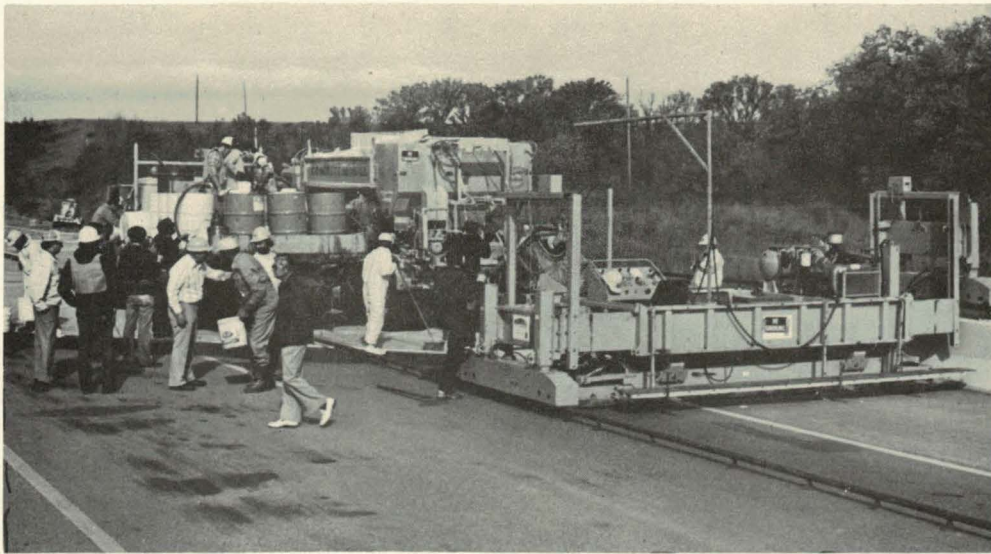


Figure 9. The paving train was first assembled in the right lane.



Figure 10. The chemical truck held the resin, catalyst and pumps.



Figure 11. Polymer concrete was discharged onto a tackcoated surface before the paving machine.

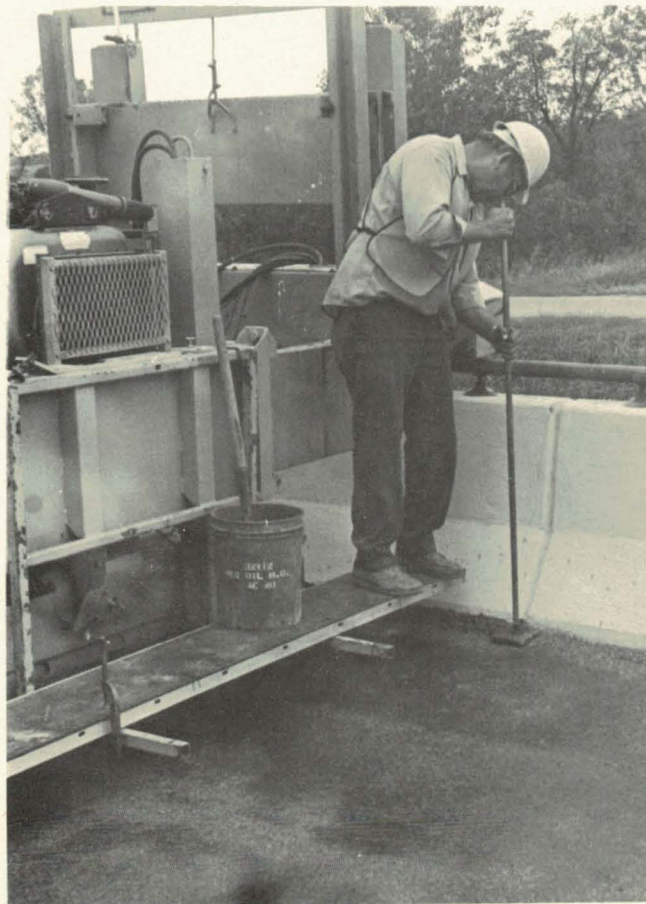


Figure 12. The paving machine could not compact the last 4 in (10cm) against the parapet wall.

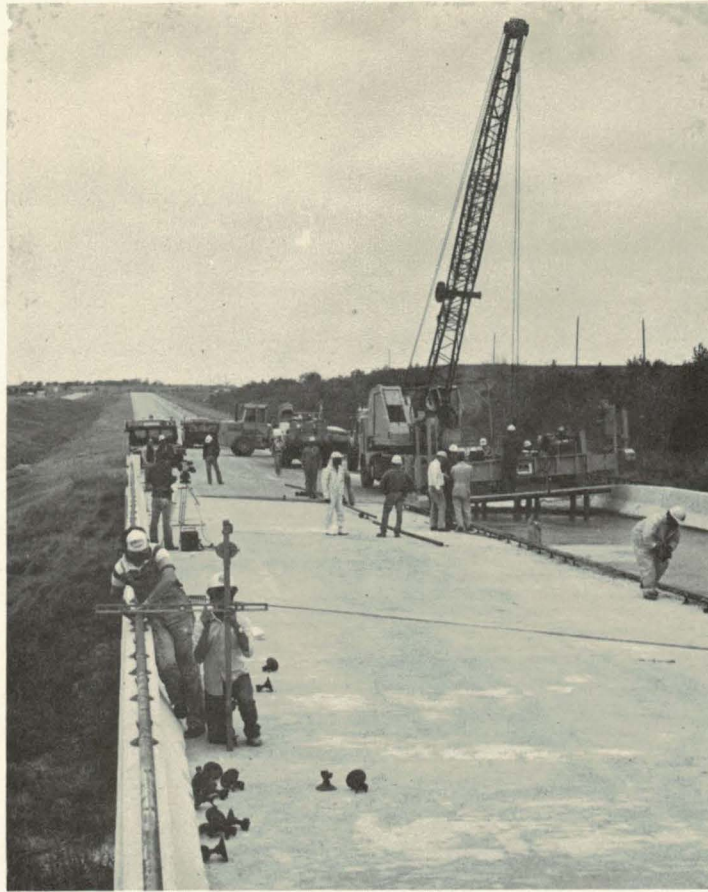


Figure 13. With the right lane paved, the equipment was moved to the left lane.

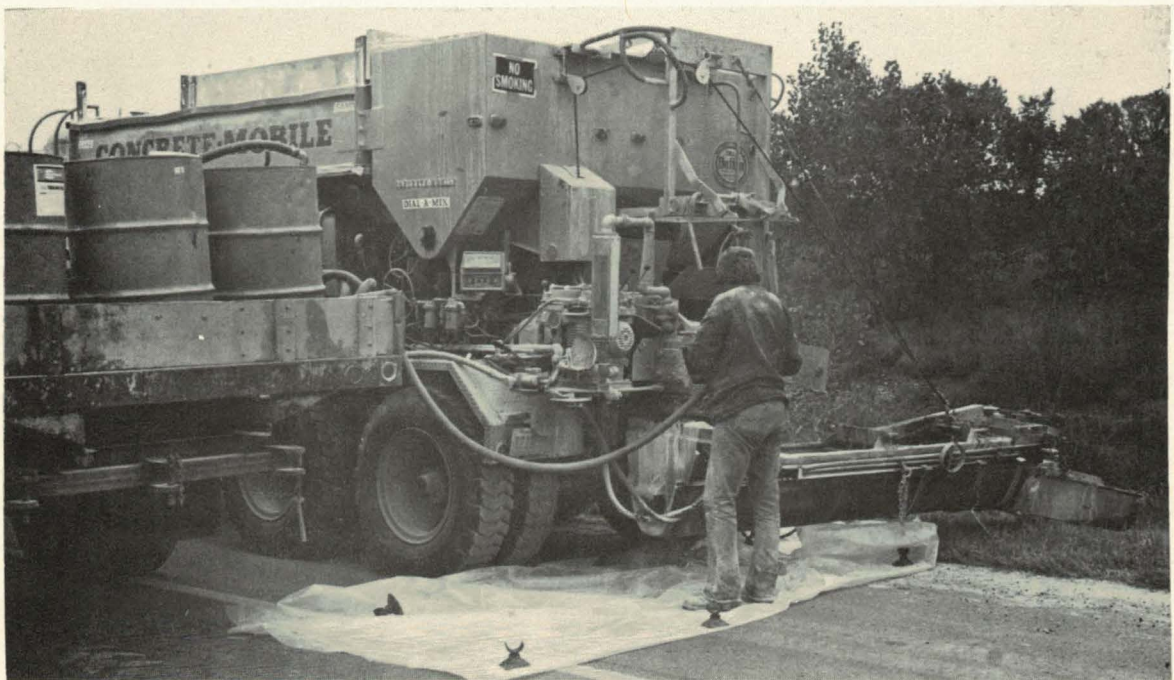


Figure 14. After each extended shutdown, the Concrete-Mobile and resin pumps were flushed.



Figure 15. Areas having lean resin content were squeegeed with additional resin.

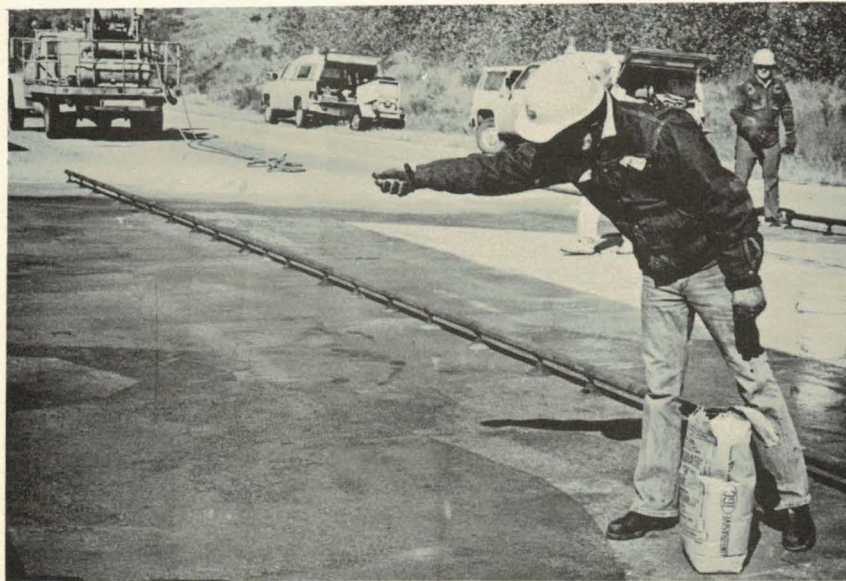


Figure 16. Additional sand sprinkled on the gelled surface provided traction.

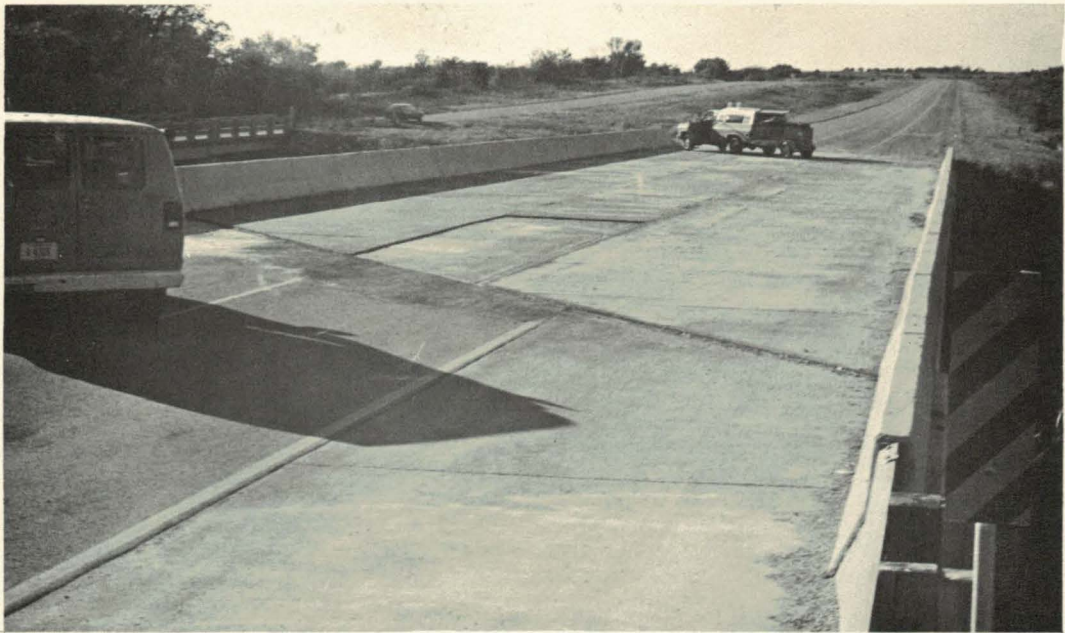


Figure 17. The bridge was nearly completed.

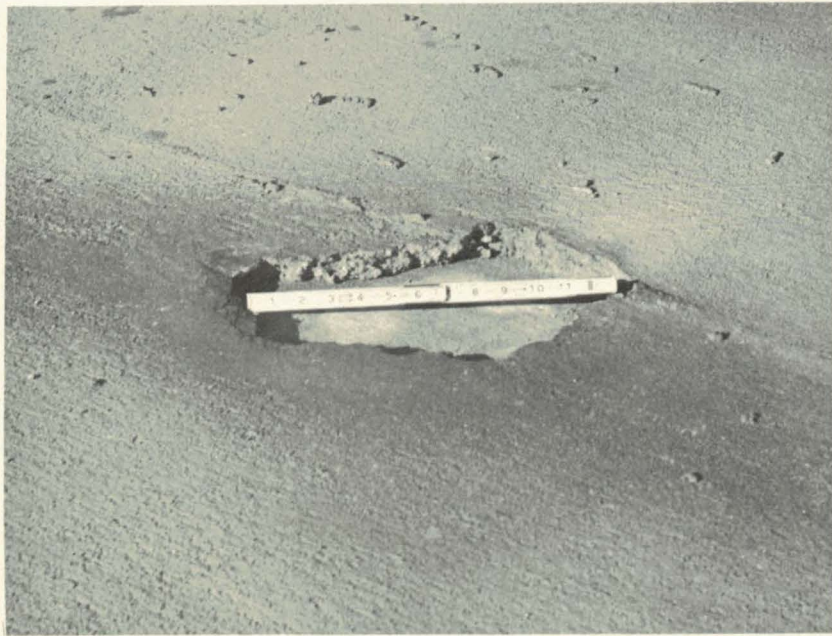


Figure 18. Delaminations ranged from small to large.

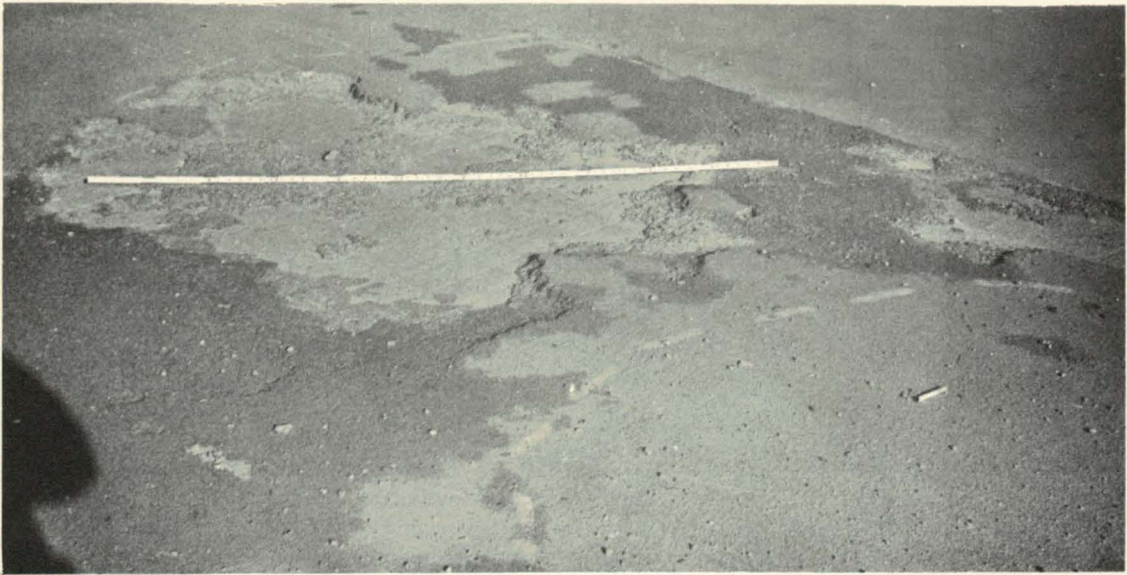


Figure 19. Some delaminations were very large; an 8 ft (2.4m) measuring stick.



Figure 20. Expansion joints were filled with a rubber-like material.



Figure 21. Unsound polymer concrete was jackhammered away.



Figure 22. For patching, polymer concrete was mixed with a portable mixer and placed by hand.



Figure 23. Delaminations were generously tackcoated.



Figure 24. A shopbuilt screed compacted the patches.

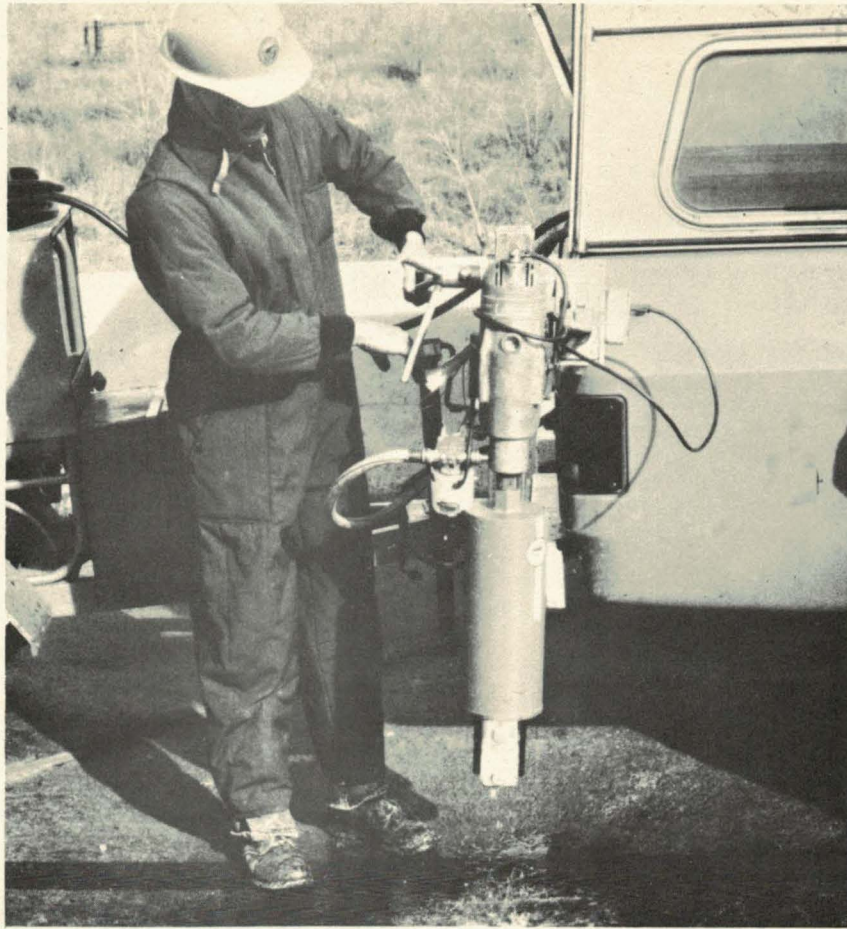


Figure 25. Core samples were taken from the deck.



Figure 26. The bridge with its multi-colored patches as it appeared three months after initial construction.

APPENDIX B

PRE-OVERLAY TEST RESULTS

 *
 * MATERIALS DIVISION *
 * CHLORIDE ANALYSIS *
 *

PROJECT NO.: FAP 198(53)
 DATE RECEIVED : 7-17-81
 DATE SAMPLED : N.A.
 COUNTY : PAYNE
 BRIDGE : 18-NX0560
 COMMENTS : S.H. 51 LOCATION: 5.6 MILES EAST OF LOGAN COUNTY LINE.

REPORT DATE ...09-08-81

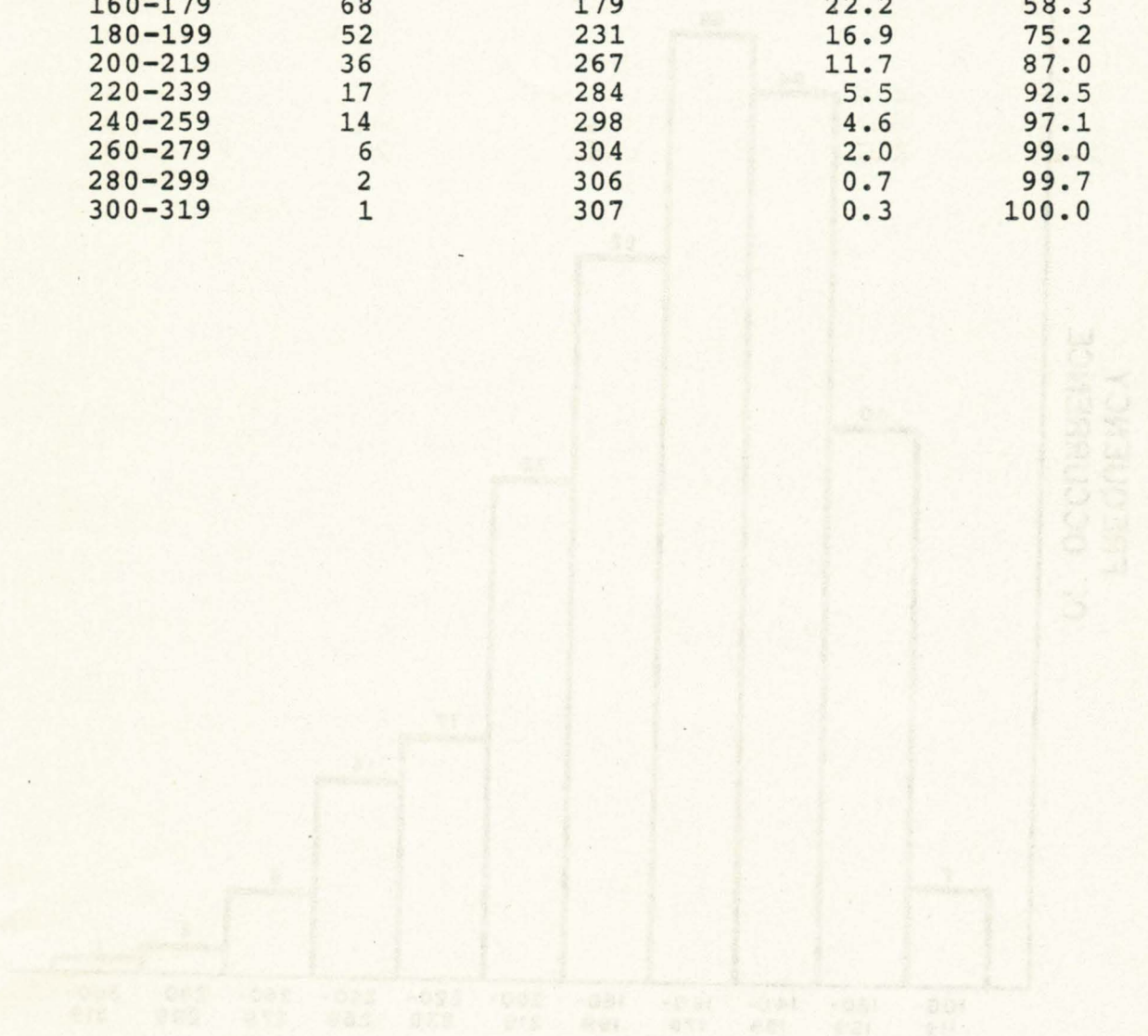
% LOSS(<.625) = 0.0 % LOSS(>0.625) = 0.0 % LOSS(ALL DEPTHS) = 0.0

SAMPLE (1)	STA. (2)	LANE (2)	HALF CELL	SAMPLE DEPTH	STEEL DEPTH	% CL- (RECD)	% CL- (DRY)	% H2O	% LOSS	ADJ. % CL- (3)	CL-LBS. / CU.YD. (3)
1A	406+40	1	126	0.375 TO 1.375	1.750	0.0802	0.0821	2.370	14.77	0.0680	2.6603
1B	406+40	1	126	1.375 TO 2.375	1.750	0.0415	0.0427	2.924	14.04	0.0363	1.4193
2A	406+30	1	128	0.625 TO 1.625	2.000	0.0415	0.0427	2.787	12.13	0.0430	1.6828
2B	406+30	1	128	1.625 TO 2.625	2.000	0.0312	0.0321	2.814	11.65	0.0328	1.2850
3A	406+75	1	158	0.750 TO 1.750	2.125	0.0485	0.0500	3.064	11.57	0.0515	2.0149
3B	406+75	1	158	1.750 TO 2.750	2.125	0.0381	0.0392	2.766	12.41	0.0376	1.4717
4A	406+85	1	158	0.500 TO 1.500	1.875	0.0635	0.0654	3.036	11.21	0.0714	2.7941
4B	406+85	1	158	1.500 TO 2.500	1.875	0.0415	0.0426	2.535	13.23	0.0383	1.5006
5A	407+15	1	188	0.375 TO 1.375	1.750	0.0369	0.0380	2.998	13.04	0.0356	1.3950
5B	407+15	1	188	1.375 TO 2.375	1.750	0.0288	0.0298	3.483	10.99	0.0323	1.2646

- (1) THE NUMBER IS THE HOLE FROM WHICH THE SAMPLE WAS TAKEN. THE LETTER IS THE POSITION WITHIN THE HOLE. A=TOP OR FIRST. B=SECOND ETC.
 (2) LANES ARE NUMBERED FROM LEFT TO RIGHT FACING IN THE DIRECTION OF STATIONING.
 (3) THE VALUES ARE ADJUSTED FOR DIFFERENCES IN THE AMOUNT OF AGGREGATES IN INDIVIDUAL SAMPLES.

Range of Copper/Copper Sulfate Half-Cell Readings
(Millivolts)

<u>Range</u>	<u>Frequency</u>	<u>Cum. Freq.</u>	<u>Percent</u>	<u>Cum. Percent</u>
100-119	7	7	2.3	2.3
120-139	40	47	13.0	15.3
140-159	64	111	20.8	36.2
160-179	68	179	22.2	58.3
180-199	52	231	16.9	75.2
200-219	36	267	11.7	87.0
220-239	17	284	5.5	92.5
240-259	14	298	4.6	97.1
260-279	6	304	2.0	99.0
280-299	2	306	0.7	99.7
300-319	1	307	0.3	100.0



APPENDIX C
POST-OVERLAY TEST RESULTS

Results of 90 Day Chloride Pounding Test
(Pounds of Chloride per Cubic Yard of Concrete)

Upper Level

Adjacent to Core	Core after Test
4.6	4.3
1.6	2.1
4.0	1.9
5.8	2.1
$\bar{X}_1 = 4.0$	$\bar{X}_2 = 2.6$
$S_1 = 1.8$	$S_2 = 1.2$
$N_1 = 4$	$N_2 = 4$

Test Hypothesis: that the mean of the two populations is equal. $\mu_1 = \mu_2$

At 90% confidence level, the critical region for six degrees of freedom is $T < -1.943$ and $T > 1.943$

$$S_p = \sqrt{\frac{(N_1 - 1)(S_1^2) + (N_2 - 1)(S_2^2)}{(N_1 + N_2 - 2)}} = 1.53$$

$$T = \frac{(\bar{X}_1 - \bar{X}_2) - d_0}{S_p \sqrt{1/N_1 + 1/N_2}} = 2.80$$

Conclusion: There is insufficient evidence to indicate a difference in the means of the two sample populations. Hence, we are 90% confident that there was a change in the chloride content of the concrete at the level above the steel.

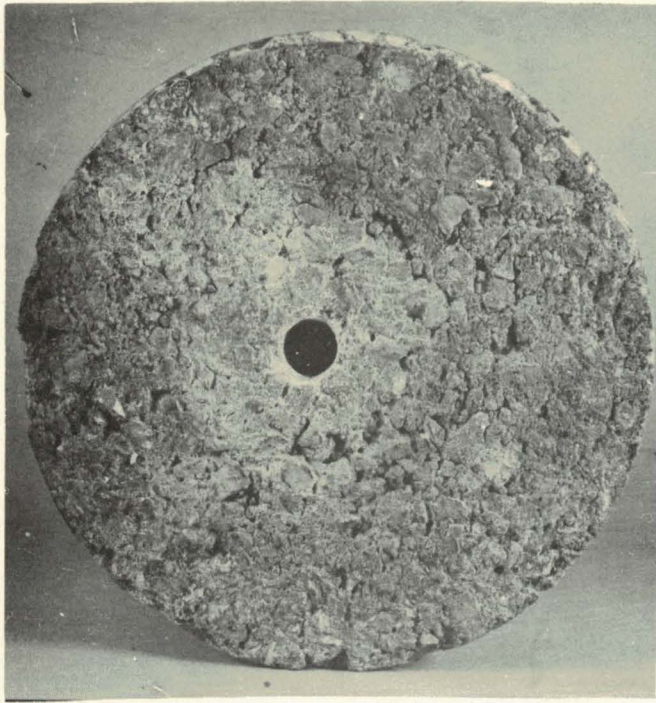


Figure 1. Resin Lean Polymer Concrete

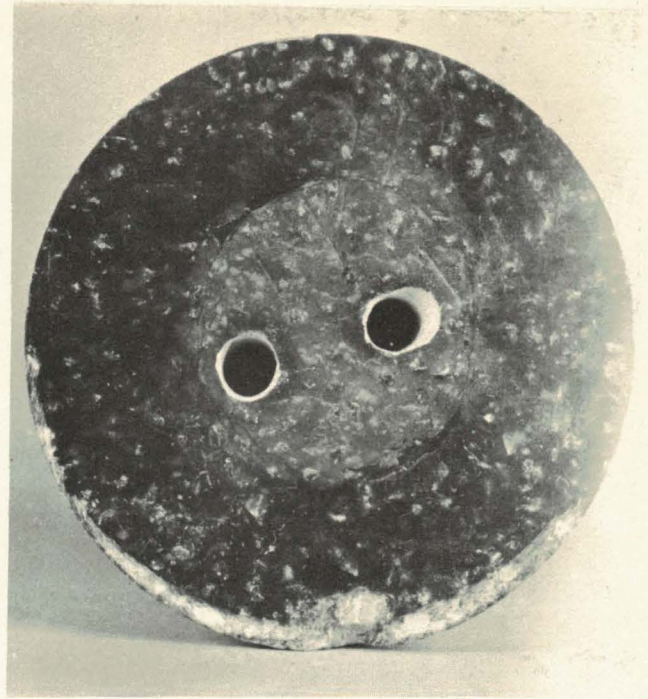


Figure 1. Resin Rich Polymer Concrete

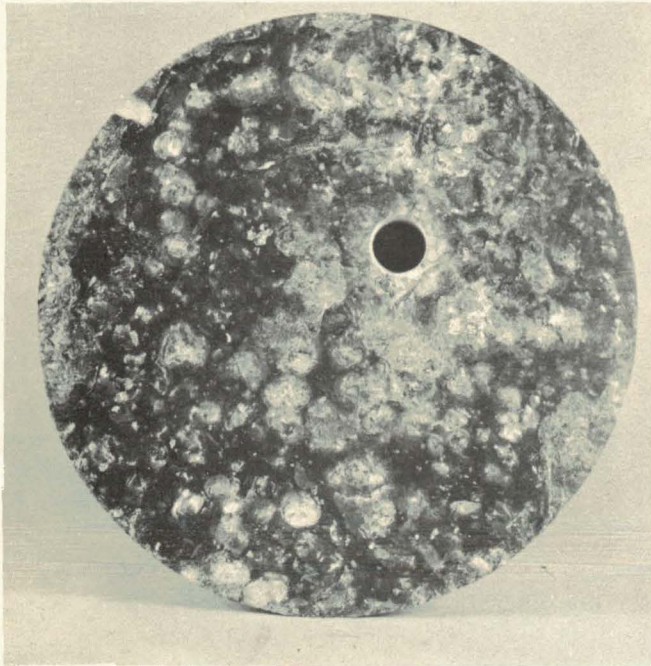


Figure 3. Polymer Concrete Patch

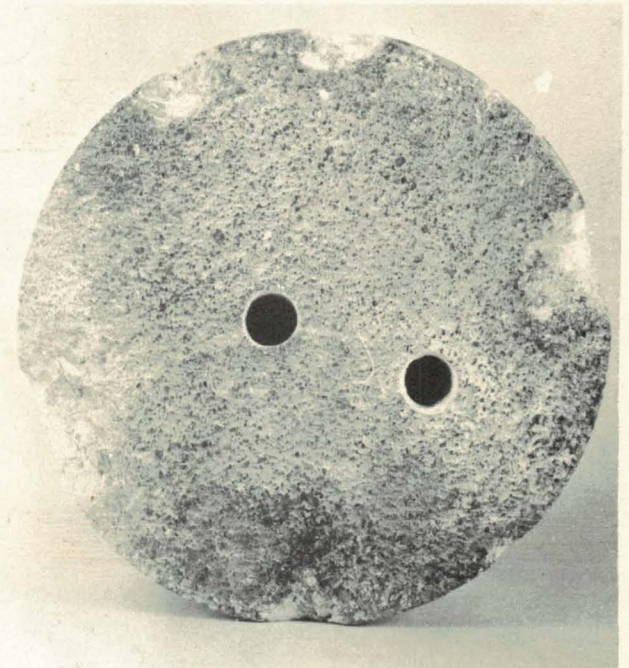


Figure 4. Excellent Polymer Concrete

The four cores taken from the bridge deck for the 90 day chloride ponding test.

SHEAR-BOND STRENGTH TEST
 TYPE B POLYMER CONCRETE
 STATE HIGHWAY NO. 51 WB BRIDGE
 5.5 MILES EAST OF I-35
 (AMOUNTS IN P.S.I.) ****

CORE	NO. OF FREEZE-THAW CYCLES	BOND STRENGTH	CONC. STRENGTH	AVERAGE BOND STRENGTH	AVERAGE CONC. STRENGTH
B	0	909	781	890	822
D	0	606	714	-	-
F	0	1232	*	-	-
K	0	941	909	-	-
N	0	761	882	-	-
H	50	303	663	453	704
I	50	337	882	-	-
O	50	438	485	-	-
R	50	357	581	-	-
T	50	832	909	-	-
C	100	488	628	161	559
J	100	**	540	-	-
L-2	100	**	522	-	-
P	100	318	566	-	-
W	100	**	540	-	-
E	150	***	***	269	485
L-1	150	**	451	-	-
Q	150	236	488	-	-
U	150	303	838	-	-
V	150	835	731	-	-
X	150	239	401	-	-

* CORE TOO SHORT TO TEST

** TOP OFF DUE TO FREEZE-THAW CYCLING

*** CORE DESTROYED DUE TO FREEZE-THAW CYCLING

**** kPa = (PSI) (6.8948)

C-5

SHEAR-BOND STRENGTH TEST
 TYPE B POLYMER CONCRETE
 STATE HIGHWAY NO. 51 WB BRIDGE
 5.5 MILES EAST OF I-35

CORE	DESCRIPTION OF BOND BREAK
B	CLEAN BREAK AT BOND
C	CLEAN BREAK AT BOND
D	CLEAN BREAK AT BOND
E	*
F	CLEAN BREAK AT BOND
H	CLEAN BREAK AT BOND
I	CLEAN BREAK AT BOND
J	**
K	CLEAN BREAK AT BOND
L-1	**
L-2	CLEAN BREAK AT BOND
N	CLEAN BREAK AT BOND
O	CLEAN BREAK AT BOND
P	CLEAN BREAK AT BOND
Q	CLEAN BREAK AT BOND
R	CLEAN BREAK AT BOND
T	10% OF BREAK IN CONCRETE
U	5% OF BREAK IN CONCRETE
V	80% OF BREAK IN CONCRETE
W	**
X	CLEAN BREAK AT BOND

* CORE DESTROYED DUE TO FREEZE-THAW CYCLING
 ** TOP OFF DUE TO FREEZE-THAW CYCLING

TG 325.6 .B67 1982

Borg, Tim M.

Polymer concrete overlay on
SH-51 bridge deck

TG 325.6 .B67 1982

Borg, Tim M.

Polymer concrete overlay on
SH-51 bridge deck

DATE DUE	BORROWER'S NAME

LIBRARY

M.D.O.T.
**RESEARCH LABORATORY
MATERIALS & TECHNOLOGY
DIVISION**