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16. Abstract

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A five - year evaluation determined that Dural Flexolith and basalt aggregate and Poly-Carb Flexogrid (broadcast systems) provided very good friction characteristics. They were also crack resistant and remained bonded to the concrete. The use of sand and Dural epoxy produced a less effective surface for skid resistance, but its use is more intended for low ADT applications. The mortar system (Con/ChemCono/Crete) produced low skid numbers initially but improved slightly over the evaluation period.

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EVALUATION OF THIN EPOXY SYSTEMS OVERLAYS FOR CONCRETE BRIDGE DECKS

FINAL REPORT

by

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Four overlay systems were applied to concrete bridge decks in north Louisiana in May 1985 to evaluate their performance as friction surfaces primarily and also as concrete sealers. Dural Flexolith, Poly-Carb Flexogrid, and Con/Chem Cono/Crete were placed on three separate bridge decks; sand and Dural epoxy were placed on the fourth deck. Friction numbers were measured with the British Portable Tester and the E - 274 Skid Trailer. The sealing characteristics of each system were checked with electrical resistivity measurements.

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METRIC CONVERSION FACTORS*

To Convert from	To	Multiply by
	Length	
foot	meter (m)	0.3048
inch	millimeter (mm)	25.4
yard	meter (m)	0.9144
mile (statute)	kilometer (km)	1.609
	Area	
square foot	square meter (m^2)	0.0929
square inch	square centimeter (cm^2)	6.451
square yard	square meter (m^2)	0.8361
	Volume (Capacity)	
cubic foot	cubic meter (m^3)	0.02832
gallon (U.S. liquid)**	cubic meter (m^3)	0.003785
gallon (Can. liquid)**	cubic meter (m^3)	0.004546
ounce (U.S. liquid)	cubic centimeter (cm^3)	29.57
	Mass	
ounce-mass (avdp)	gram (g)	28.35
pound-mass (avdp)	kilogram (kg)	0.4536
ton (metric)	kilogram (kg)	1000
ton (short, 2000 lbs)	kilogram (kg)	907.2
	Mass per Volume	
pound-mass/cubic foot	kilogram/cubic meter (kg/m^3)	16.02
pound-mass/cubic yard	kilogram/cubic meter (kg/m^3)	0.5933
pound-mass/gallon (U.S.)**	kilogram/cubic meter (kg/m^3)	119.8
pound-mass/gallon (Can.)**	kilogram/cubic meter (kg/m^3)	99.78
	Temperature	
deg Celsius (C)	kelvin (K)	$t_K=(t_C+273.15)$
deg Fahrenheit (F)	kelvin (K)	$t_K=(t_F+459.67)/1.8$
deg Fahrenheit (F)	deg Celsius (C)	$t_C=(t_F-32)/1.8$

*The reference source for information on SI units and more exact conversion factors is "Metric Practice Guide" ASTM E 380.

**One U.S. gallon equals 0.8327 Canadian gallon.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Frictional properties are one of the most important characteristics of a bridge deck or highway surface. The restoration of lost friction characteristics on bridge decks is presently a primary concern of highway maintenance organizations. A secondary consideration is sealing ability. Also, the dead load of these overlay systems is less than that of conventional overlay systems. In an effort to address these problems, this research project was conducted to evaluate four different overlay systems. The four systems were selected based on their prior performance record nationwide and locally. The systems selected were Dural Flexolith and basalt aggregate (Dural and Basalt), Poly-Carb Flexogrid Mark 163 with basalt aggregate (Poly-Carb), Con/Chem Cono/Crete 101 mortar system with bauxite aggregate (Cono/Crete), and Dural Flexolith and blasting sand (Dural and sand). The Dural and sand system is more intended for low ADT applications, as it is not as durable as the other systems. It was included in this study to get a quick test on a high ADT bridge.

Each system was designed to produce a thin, durable surface with desirable frictional properties. The systems were evaluated in the laboratory for strength, durability and sealing ability and in the field for ease of application, sealing ability and friction properties. They were also evaluated for cost. The systems were applied in May 1985, separately to four concrete bridge decks along Interstate 20 in Webster and Bossier Parishes in north Louisiana. The locations of the installations are depicted in Figure 1. I-20 has a traffic volume of approximately 12,000 vehicles per day per direction of traffic.

This report covers system installation, initial field tests and five years of tests and evaluation. The information collected from this research project will be used to help select systems for future use on bridge decks that suffer from loss of frictional properties and sealing characteristics.

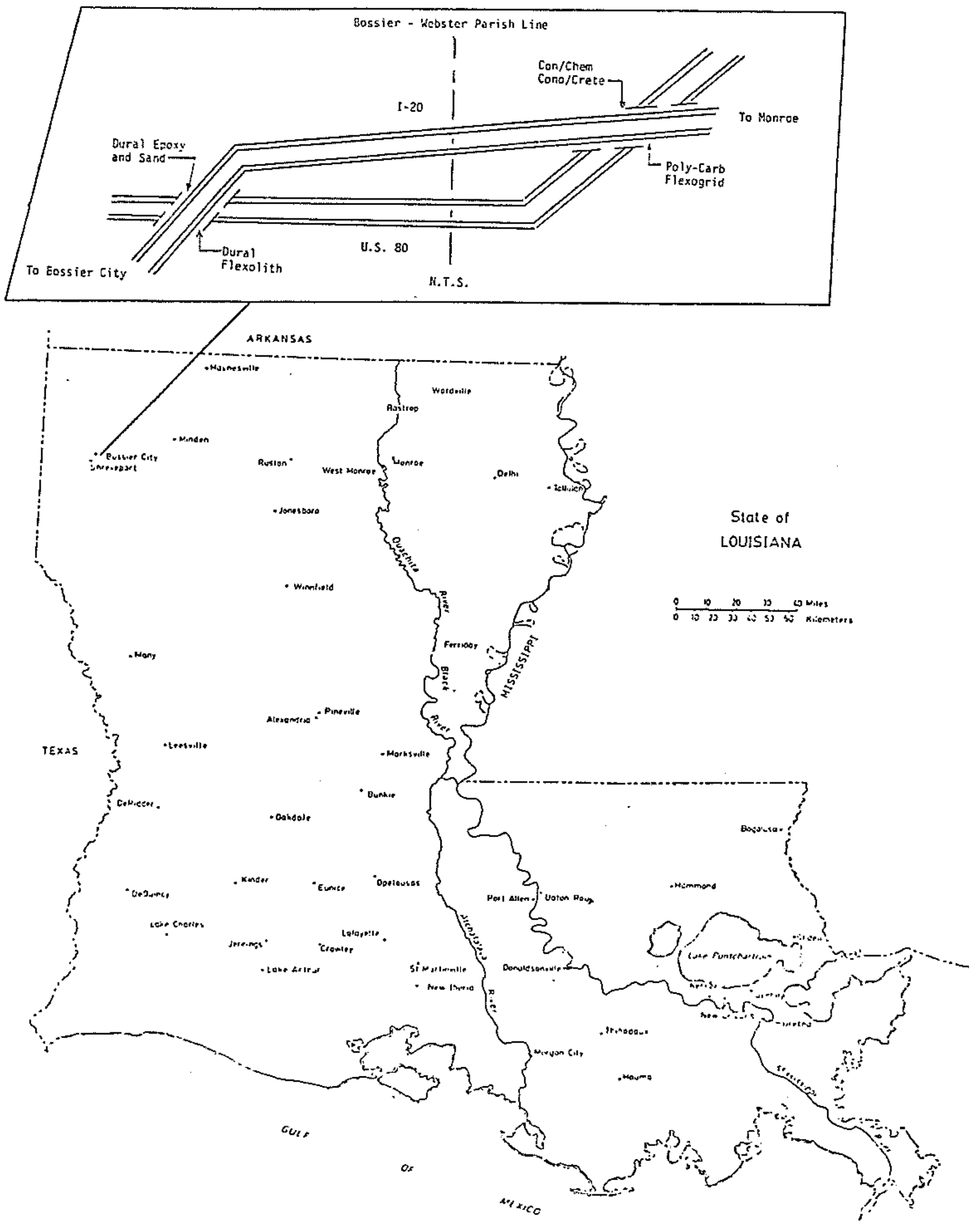

Figure 1. Installation location

PURPOSE AND SCOPE

The purpose of this research was to evaluate four different epoxy overlay systems installed separately on four north Louisiana bridges on I-20. The systems were evaluated primarily for their ability to improve the long term frictional characteristics and also for their sealing ability. The systems' ease of application, durability and cost were also of concern. ASTM E-274 friction tests were run 5 times per section and the British Portable Tester was run three times per section.

The field evaluation was comprised of monitoring the construction progress, resistivity testing, tensile bond tests and friction testing. The laboratory evaluation included the following tests:

1. Ninety-day chloride permeability test (FHWA Procedure)
2. Freeze and thaw durability test (ASTM C-666 Procedure)
3. Shear bond test (Iowa DOT method)
4. Thermal compatibility test (ASTM C-884)

METHOD OF PROCEDURE

Prior to application of the overlay, each bridge deck was tested for corrosion and delamination. (See Table 1). This was done to collect pre-application data and also to ensure that each bridge met the requirements of having a sound deck, free of corrosion and delamination. These requirements were set to minimize the preparation work to cleaning of the deck, with no patching or repairing necessary. The special provisions used for this project are provided in Appendix A.

Half - Cell Readings

ASTM C876-91 was performed to determine the corrosion activity of reinforcing steel. The copper sulfate electrode (CSE) half-cell is a device that is moved around on the surface of the bridge deck to measure electric potential of the reinforcing steel. The units of measure are volts. The results are shown in Table 1.

TABLE 1

PRELIMINARY DECK SURVEY, CHLORIDE CONTENTS AND HALF-CELL READINGS

Structure No.	Avg. Chloride Content Lbs. Chlor./Yd^3 Conc.	Half-Cell Range Volts (Copper Sulfate Electrode)	Average
4510303.141	0.452	0.02 - 0.18	0.11
4510303.142	0.340	0.02 - 0.18	0.11
4510215.501	0.940	0.02 - 0.56	0.10
4510215.502	0.761	0.02 - 0.30	0.11

Each surface was tested by the chain drag to detect areas of delamination. No delamination was found on either deck.

Interpretation of Half-Cell Results

-0.20 volts CSE or less - 90% probability that no reinforcing steel corrosion is occurring
-0.20 to -0.35 volts CSE - corrosion in this area is uncertain
-0.35 volts CSE or greater - 90% probability that reinforcing steel corrosion is occurring

Structure No. 4510215.501, which was overlaid with Dural and Basalt had corrosion readings in the high probability range, although no delamination or other signs of distress were visible. The location of the corrosion was approximately 175 feet from the west edge of the overlay and extended for about 5 feet.

<u>Chloride Content</u>

The chloride content was measured from samples of concrete taken from each bridge deck. The results are shown in Table 1. The maximum amount allowed as recommended by FHWA is 2 lbs./yd.[3]. Had the average chloride content exceeded this amount, the bridge deck(s) may have been considered unsuitable for resurfacing.

Each epoxy material was tested in the laboratory to check its conformity to the department's Type III epoxy resin. This type is used in bonding high quality, non-polishing aggregate to hardened concrete and as a binder in epoxy mortar and epoxy concrete. Table 2 shows the specification for Type III epoxies. All epoxies met specification requirements.

TABLE 2

TYPE III EPOXY SPECIFICATIONS AND TEST RESULTS

Property	Type III Epoxy Min.	Type III Epoxy Max.	Dural Flexolith	Poly-Carb Flexogrid	Con/Chem Cono/Crete 101
Consistency Grade A, #30 Spindle @ 20 RPM, Poises	-	20	8	16	6
Epoxide Equivalent of Comp. A, g/g mol.	160	275	199	274	203
Gel Time, min.	20	-	20	27	61
Tensile Bond Strength 24 hr. psi	250	-	475	540	455

Construction Procedures

The contractor for the I-20 bridge overlays was Alpha Construction Company of Shreveport, Louisiana. Each deck was prepared for the overlay as directed by the system's manufacturer representative as specified in the contract. The entire surface to be overlaid was cleaned by the shotblasting method utilizing steel shot. The bridge deck cleaning was subcontracted by Portablast Company of Oklahoma City, Oklahoma. The Portablast unit (Figure 2) generally cleaned an area about 16 inches wide at a rate of 40 feet per minute. The speed of operation was dependent on the depth the concrete to be cleaned. The vertical side of the curb was manually sandblasted clean (Figure 3); any remaining asphalt contaminants were hand-chipped from the deck. The outside lane and shoulder of each bridge were prepared and overlaid first, while traffic was diverted to the inside lane. The overlay was allowed to cure for 24 hours before traffic was allowed on the finished surface and work began on the inside lane and shoulder. Figure 4 shows one of the cleaned bridge decks immediately prior to overlay. The ambient temperature during each installation ranged from 80° to 90° F. Deck temperature during daylight hours reached 120° F.

Figure 2. Portablast unit.

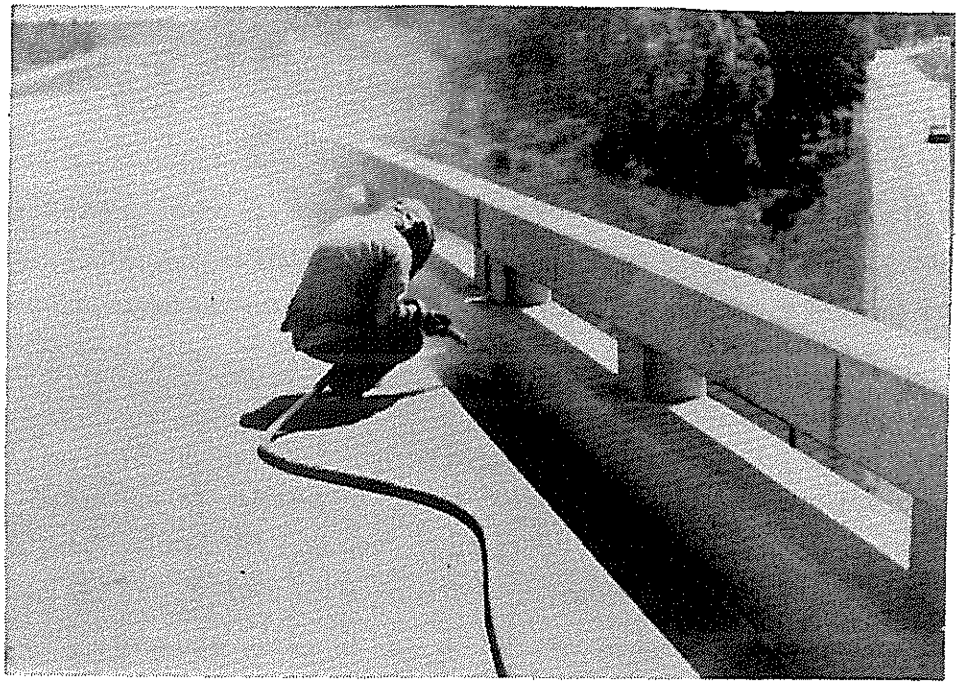

Figure 3. Sandblasting of the curb (I-20).

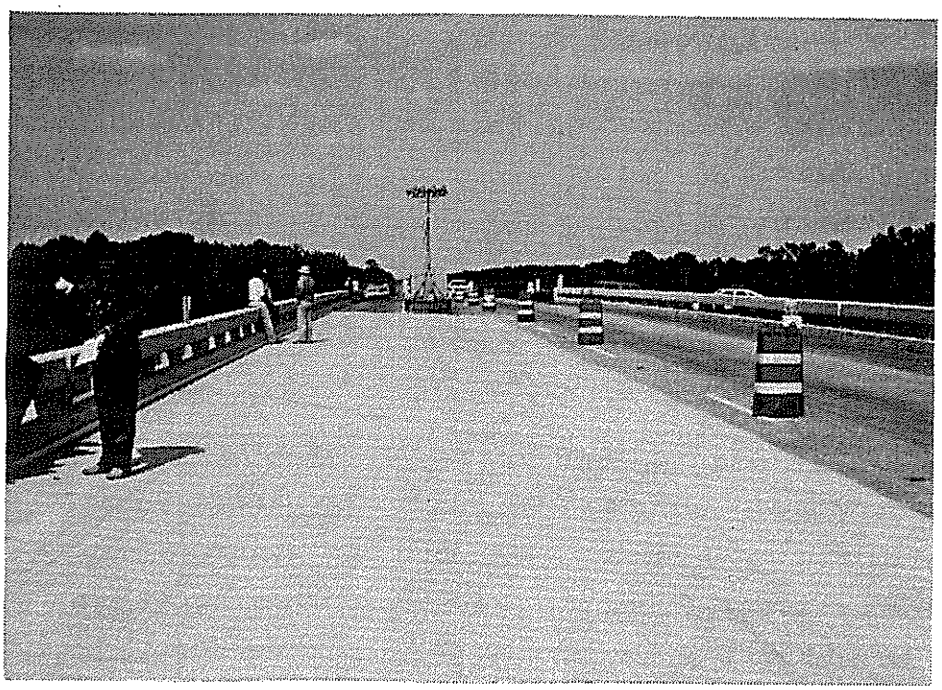

Figure 4. Cleaned bridge deck prior to overlay (I-20).

System 1, Dural Flexolith and Basalt (Broadcast System)

Dural Flexolith and basalt was the first overlay installed by the contractor on I-20 eastbound at Fillmore, Structure No. 4510215.501.

Dural Flexolith is a two-component epoxy resin and basalt aggregate surface coating described by the manufacturer as a 100% solid, low modulus, flexible, high elongation, moisture insensitive system. Material properties as reported by the manufacturer are provided in Table 17 in Appendix B.

The epoxy components were mixed at two parts component A to one part component B. A paddle attached to a 1/2 inch electric drill was used for mixing, as shown in Figures 5 and 6. All bridge test site surfaces were cleaned with the Portablast Unit before application of the epoxy overlay systems. Three gallon batches of epoxy were mixed at a time. As soon as the epoxy was mixed it was spread out with hand squeegees onto the deck within 15 minutes after mixing as shown in Figure 7. Once the spreading of each batch of epoxy was completed, basalt aggregate was broadcast by hand over the wet epoxy, as seen in Figure 8. The manufacturer's recommended rates of coverage and the actual rates of coverage for all systems are shown in Table 3. Manufacturers recommended coverage rates were used as a guideline for estimate and bid purposes. Actual coverage rates are determined visually as the application proceeds, but are usually close to manufacturer's recommended coverage rates.

Dural and basalt was applied in two lifts to obtain the desired 1/4-inch overlay. The first lift of 4000 square feet took approximately two hours. After its completion, the excess aggregate was swept from the surface. Two hours was sufficient time for the material to cure before the second lift was placed. Similar procedures were used to apply the second lift. After the second lift had been applied and the excess aggregate swept off and the overlay was allowed to cure 12 hours. All test sites were opened to traffic the next day.

TABLE 3

COVERAGE RATES

	AGGREGATE				EPOXY			
	First Layer		Second Layer		First Layer		Second Layer	
	Spec. Lb/yd^2	Actual Lb/yd^2	Spec. Lb/yd^2	Actual Lb/yd^2	Spec. Ft^2/gal	Actual Ft^2/gal	Spec. Ft^2/gal	Actual Ft^2/gal
Broadcast Systems								
Dural and Basalt	8-10	12	12-14	12	45	42	30	15
Poly-Carb	10	11	14	11	40	53	30	21
Dural and Sand	14	11	14	10	38	42	34	35
Mortar System								
Cono/Crete	20	23			33	29		
Cono/Weld 501 Primer					200	116		

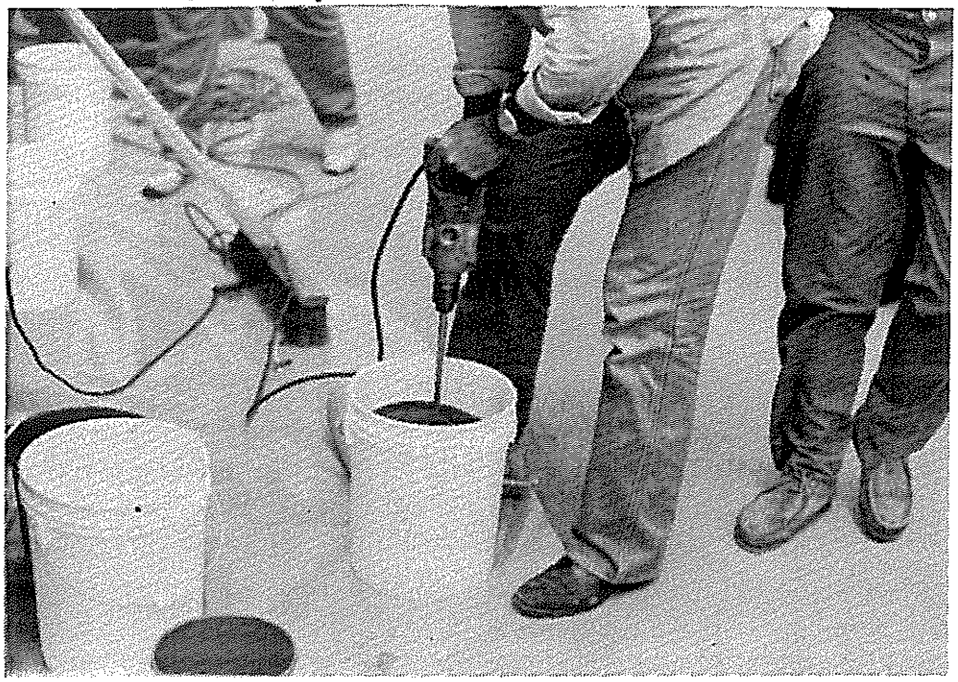

Figure 5. Mixing the two components of epoxy.

Figure 6. Dural epoxy ready for application.

Figure 7. Spreading of the epoxy (Dural).

Figure 8. Broadcasting the basalt aggregate, first coat.

System 2, Dural Flexolith and Sand (Broadcast System)

The same epoxy used with System 1 was applied to the westbound roadway of I-20 at Fillmore, Structure No. 4510215.502 (same location as System No. 1, but in the opposite direction), but with sand as an aggregate. Epoxy properties are the same as with Dural and basalt. The gradation of the sand specified is provided in the Special Provisions in Appendix A. The same procedure was used to apply Dural and sand as with System 1. Figure 9 presents the second application of the epoxy over the first lift, and Figure 10 shows the excess sand being removed after the sand broadcast of the final coat. The completed lane was opened to traffic on the following day, and work was started on the inside lane.

Figure 9. Spreading dural epoxy over the first lift.

Figure 10. Sweeping the Excess aggregate after the final coat.

System 3, Poly-Carb (Broadcast System)

Poly-Carb is a chemical combination of epoxy and urethane molecules designed to provide a flexible yet strong waterproofing and de-slicking system. Manufacturer-reported properties are listed in Table 18 in Appendix B.

Poly-Carb was applied to the eastbound roadway of I-20 over U.S. 80 at McIntyre, Structure No. 4510303.141. This material consisted of a two-part liquid, to be mixed on the job site, and a specially selected aggregate broadcast (basalt). The epoxy was mixed in the ratio of two parts of Component A to one part Component B. Mixing methods are the same as described for System 1 (Dural and basalt). The method used to apply Poly-Carb varied slightly from system 1. The mixed epoxy was spread onto the deck with notched squeegees rather than conventional flat squeegees. This appeared to distribute the epoxy more evenly over the deck. After the basalt aggregate was broadcast onto the deck, it was rolled into the epoxy with a paint roller as shown in Figure 11. After the first lift of epoxy and aggregate was spread and rolled, it was allowed to cure 12 to 15 hours before it was swept and the second lift applied. The procedure for the second lift was identical to the first. The quantities of material used on both lifts are shown in Table 3.

<u>System 4, Cono/Crete 101 (Epoxy Mortar System)</u>

Cono/Crete differs from other systems used in that it is an epoxy mortar system. Prepackaged units of epoxy and blended aggregate are mixed in a mortar mixer before placement, as shown in Figure 12. Cono/Crete was first developed as an industrial flooring system used to provide skid and chemical resistance. The wear resistant properties it demonstrated in that application led to its use as a highway overlay material. The properties of Cono/Crete as reported by the manufacturer are presented in Table 19 in Appendix B.

Figure 11. Basalt aggregate being rolled on the poly-carb epoxy.

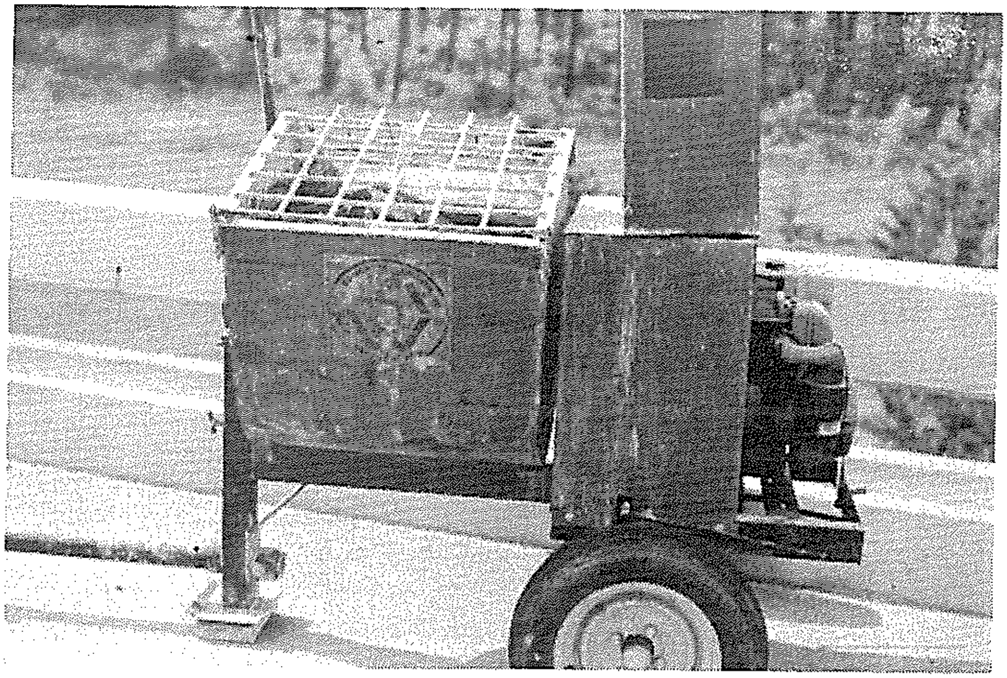

Figure 12. Mortar mixer used for Cono/Crete.

Cono/Crete was placed on the westbound lanes of I-20 at McIntyre, Structure No. 4510303.142. The surface was cleaned with the Portablast device in the same manner as the other decks.

A primer, Cono/Weld 501, was applied to the cleaned deck by squeegee. It was then mechanically scrubbed into the surface with a wire brush rotating electric floor buffer, as shown in Figure 13. Before this material could be applied, there were certain environmental conditions that had to be met. The surface and surrounding air temperatures had to be less than 100° F. The material itself required full protection from direct sunlight during application and curing. In order to comply with these conditions, the work was not started until late evening. The actual placement of the overlay was completed after sunset.

Figure 13. Application of primer for Cono/Crete.

A vibrated screed box approximately 33 inches wide was used to put down the full 1/4-inch thick layer of aggregate. After the mortar was laid down, it was finished with hand trowels as shown in Figure 14. The screed box is shown in Figure 15. The manufacturer's representative demonstrated the troweling procedure to the contractor's personnel. The material was finished until a tight surface was achieved. The finishing action caused the accumulation of epoxy paste on the surface of the overlay, giving it a shiny appearance with visible trowel tracks.

Construction Considerations

It is felt that Department of Transportation Maintenance personnel could install any of these overlay systems with the proper equipment and little training from a qualified contractor. However, Cono/Crete is the most labor intensive to install. Though the aggregate is mixed in with the epoxy and doesn't need to be broadcast, other conditions exist which make it more labor intensive. A primer must first be applied to the bridge deck in a mechanical scrubbing process. Also, the surface and surrounding air temperatures must be less than 100° F. It requires protection from sunlight during placement and curing, such that application must be performed after sunset. The mortar must then be screeded into place.

Poly-Carb requires one additional installation step over the Dural systems in that the aggregate must be rolled into the epoxy with a paint roller. Considering they are easier and less complicated to install, produce better friction numbers and cost roughly the same, Dural and basalt and Poly-Carb would be better choices for the types of jobs maintenance crews are likely to install them on.

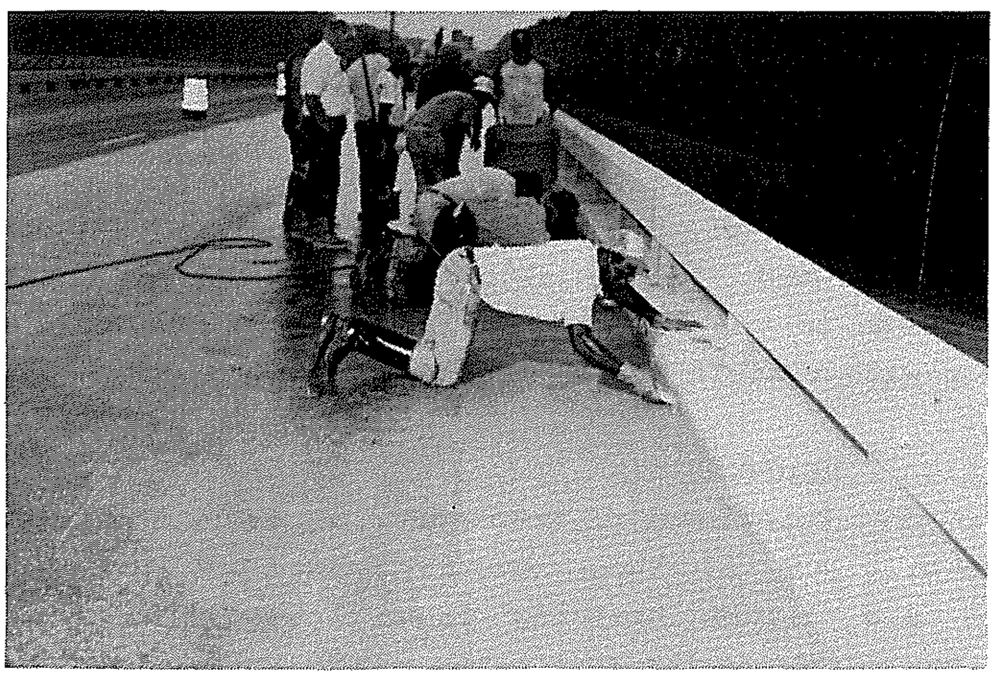

Figure 14. Hand troweling of Cono/Crete.

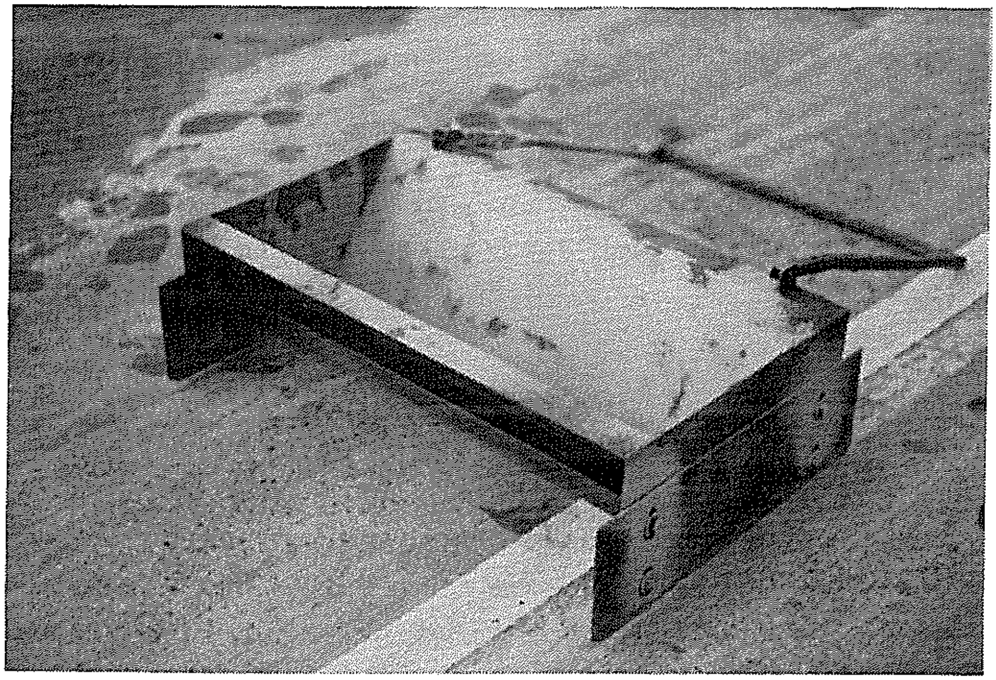

Figure 15. Screed box used for spreading mortar.

Testing Procedures

The following field and laboratory tests were performed for this study:

1. Direct pull bond test (ACI 503R)
2. Resistivity Test (Colorado DOT 6272)
3. Ninety-day chloride permeability test (FHWA procedure)
4. Freeze and thaw durability test (ASTM C-666, procedure B)
5. Thermal compatibility test (ASTM C-884)
6. Shear bond test (Iowa DOT Method)

Field Evaluation

In the direct pull bond test, force was applied vertically in tension directly to the overlay until it debonded from the existing bridge deck surface. The load was then recorded. A maximum of two cores per test section was taken to minimize the possibility of delamination.

The resistivity test was run on the overlay to determine its level of impermeability. Electrical resistance across the surface was measured with a volt-ohmmeter to detect areas that would allow moisture and chloride ions to pass into the concrete. Readings in the range from 500,000 ohms/ft.^{2} to infinity are considered impermeable and provide the desired sealing of a deck surface. Plain bridge deck concrete readings generally vary from 1000 to 8000 ohms/ft.^{2}

The instrument is primarily made up of a volt-ohmmeter, an electrolytic saturated sponge attached to a one-foot-square copper plate, and an appropriate length of wire. These components are arranged in a circuit which runs across the overlay systems. A five-foot transverse to ten-foot longitudinal grid was measured on the overlaid surface. Readings were taken at each grid intersection.

Laboratory Evaluation

For the purpose of laboratory evaluation, 3" by 9" by 15"-inch concrete blocks were brought to the job site. The surface of these blocks was sandblasted to represent the actual surface of the bridge deck being overlaid. The identical procedures and materials used to overlay the surface of the bridge decks were also applied to these concrete blocks. This was done to minimize coring of the bridge deck, which might cause damage to the continuity of the epoxy overlay.

Two blocks were made for each system. One block of each group was subjected to 90-day chloride ponding. In this test the blocks were continuously ponded with a 3 percent solution of sodium chloride for 90 days to measure the amount of chloride that could penetrate through the epoxy. After this period, the overlay was removed from the test blocks. Samples of pulverized concrete were taken from 1/16" to 1/2" and 1/2" to 1" below the surface. The amount of chloride that had accumulated in the samples was measured.

Three 4-inch diameter cores were taken from the other blocks from each system. These cores were subjected to freeze and thaw testing, thermal compatibility testing and shear bond testing.

The freeze and thaw test procedure used in this study was modified. In this modified procedure, concrete cylindrical cores taken from the test blocks were subjected to 300 cycles of rapid freezing and thawing.

The ASTM C-884 test method for thermal compatibility was used to evaluate debonding between the epoxy overlay systems and the concrete bridge decks at field temperatures. The procedure requires the cured samples to be placed in a freezer for 24 hours. The samples are then removed and kept at room temperature (73° +/- 1.8° F) for 24 hours. This constitutes one cycle and is repeated for four additional cycles. Cracks near the bond line between the concrete and the epoxy overlay constitute failure of the test material.

In the shear bond test, a load is applied to each side of the interface of the cored specimens perpendicular to the longitudinal axis of the specimen until the epoxy overlaid portion shears from the concrete or vice versa.

DISCUSSION OF RESULTS

Baseline friction numbers were gathered from all bridge decks before and after the installation of the overlays. The British Portable Tester (BPT), shown in Figure 16 was used to determine friction values for acceptance only. The specifications written for this installation required the overlay to achieve a minimum BPT value of 55. ASTM E-274 values were used for evaluation purposes of the overlay systems in this report. ASTM E-274 stipulates that the locking wheel truck be run on each surface five times to get an average value for the friction number. However, when this was attempted, the roughness of the Poly-Carb and Dural and Basalt caused trailer tires to rupture, so less than five readings were used to get initial ASTM E-274 readings on Poly-Carb and Dural and basalt systems. These readings were taken approximately one month after initial BPT readings. The BPT readings are presented in Table 4 and ASTM E-274 friction number values are shown in Tables 5 and 6. A five year performance comparison is presented in Figure 17.

Poly-Carb and Dural and basalt produced initial BPT numbers of 81 and 84, respectively. This was an average increase of 5 percent over the original concrete surface. Dural and basalt had the smallest reduction in friction number of the four systems. The Dural and sand overlay had an initial BPT value of 67 and an ASTM E-274 friction number of 53. Cono/Crete had an initial BPT friction number of 58 and an ASTM E-274 friction value of 32.4. Table 6 indicates that Cono/Crete actually showed a gradual increase in friction properties. This could be due to the fact that after the epoxy paste on the surface of the overlay wore off over time, it exposed more aggregate, thus producing a rougher surface. Cono/Crete is the only system of the four used that was applied as a mortar. The initial ASTM E - 274 friction numbers for Cono/Crete were below the measured values of the original surface.

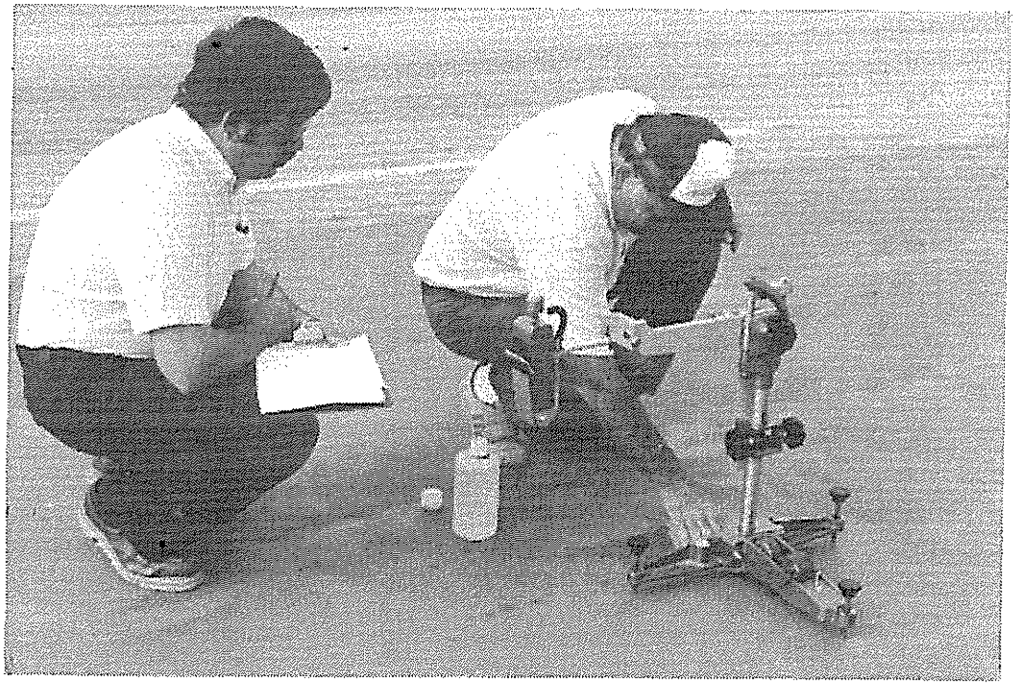

Figure 16. British portable skid tester.

TABLE 4

INITIAL BPT FRICTION NUMBERS

Dural and Basalt	84
Dural and Sand	67
Poly-Carb	81
Cono/Crete	58
Original Surface	53

TABLE 5

ASTM E-274 FRICTION NUMBERS OF EXISTING BRIDGE DECKS

Bridge to be resurfaced with:	FN
Dural and Basalt	43.1
Dural and Sand	47.1
Poly-Carb	46.6
Cono/Crete	42.5

TABLE 6

ASTM E-274 FRICTION NUMBERS

	6/12/85	3/18/86	7/14/87	4/13/88	1/19/89	1/18/90	11/15/90
Dural and Basalt	53.3	no reading	49.5	55.2	51.6	52.7	53.8
Dural & Sand	53.2	46.2	33.7	34.3	32.3	32.5	33.6
Poly-Carb	71.3	58.9	53.1	58.6	57.0	56.7	54.5
Cono/Crete	32.4	36.5	30.2	40.2	42.8	44.2	42.2

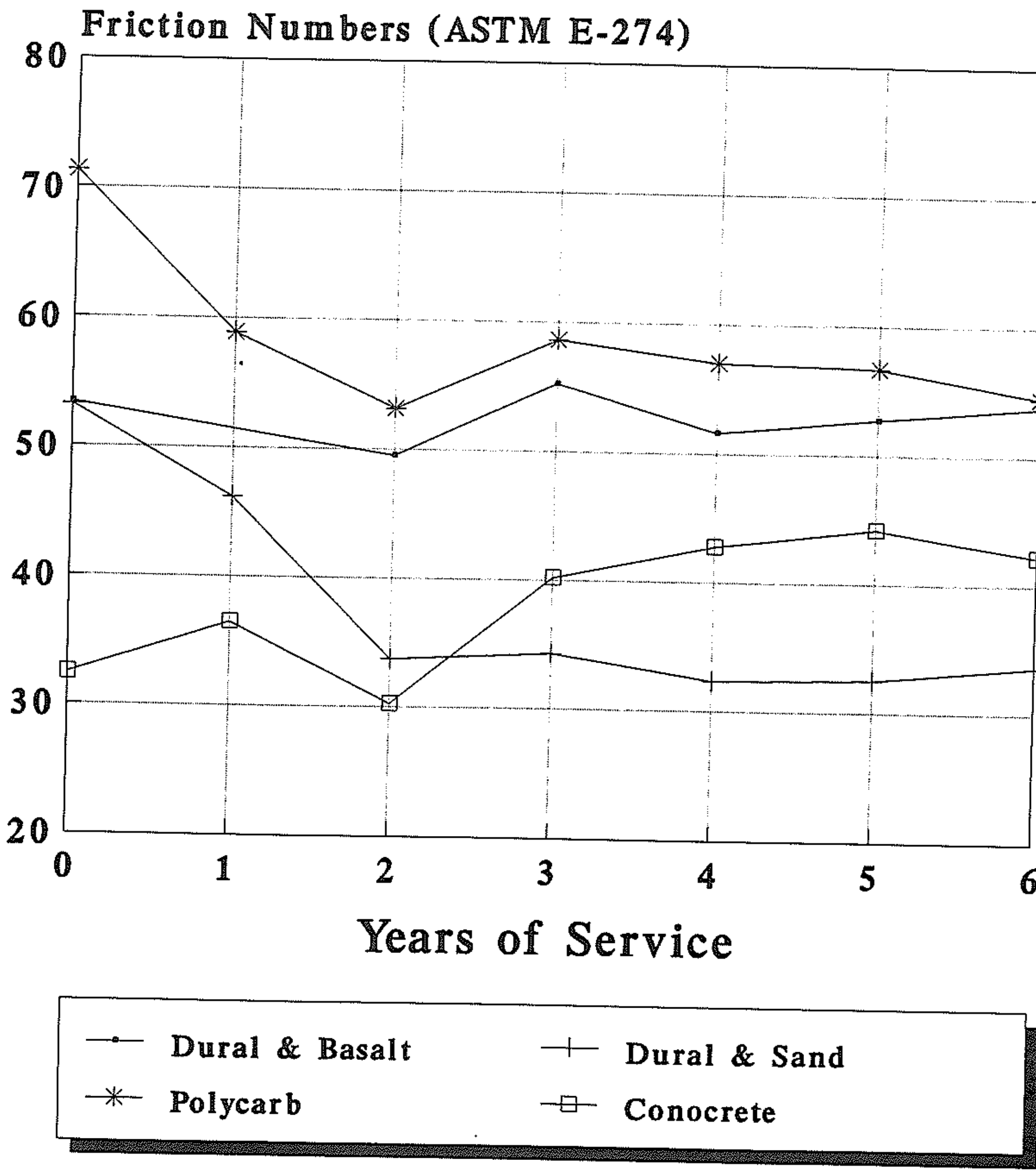

Figure 17. Friction service life.

After an evaluation period of five years, it was found that Dural and sand exhibited a friction number reduction of 36.8 percent; from 53.2 in 1985 to 33.6 in 1990. This system showed the greatest reduction of the four used on I-20.

A subjective observation was made that the quality of ride immediately after installation was good on all surfaces.

Resistivity Test Results

Cono/Crete performed the best in the impermeability test, followed by Poly-Carb, Dural and basalt, and Dural and sand, respectively. The tightness of the surface as a result of the application procedure may be a factor in the satisfactory performance of each system. The majority of the lower readings for Dural and Basalt were along the seam between the two halves of the overlay which were placed on successive days. Figure 18 shows the resistivity tests being conducted on the bridge. Resistivity readings for the I-20 Bridges are shown in Tables 7 through 10. Table 11 shows resistivity reading trends over the evaluation period. Cono/Crete was shown to be the most impervious over time based on the fact that it consistently had the lowest percentage of unacceptable resistivity readings over time.

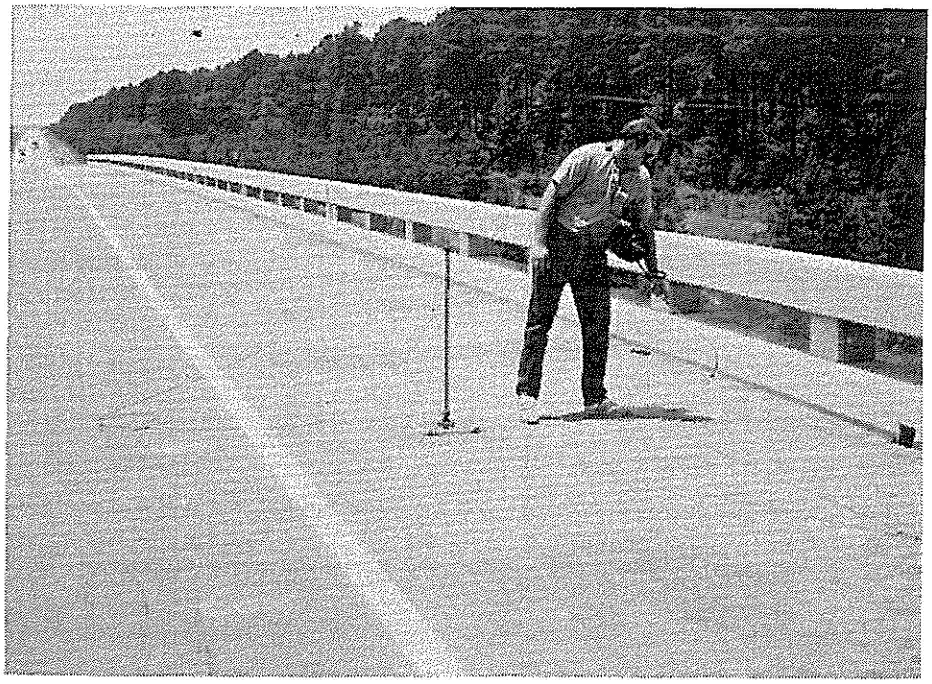

Figure 18. Resistivity testing of bridge deck overlay.

TABLE 7

I-20 RESISTIVITY READINGS
6/27/85

SYSTEM	TOTAL NO. READINGS	NO. VALUES < 500,000 OHMS/FT.^{2}	PERCENTAGE OF UNACCEPTABLE READINGS TO TOTAL NO. READINGS
Poly-Carb , Eastbound	80	4	5%
Dural and Basalt, Eastbound	90	26	29%
Cono/Crete Westbound	170	0	0%
Dural and Sand, Westbound	90	170	71%

TABLE 8

I-20 RESISTIVITY READINGS
7-30-86

SYSTEM	TOTAL NO. READINGS	NO. VALUES < 500,000 OHMS/FT.^{2}	PERCENTAGE OF UNACCEPTABLE READINGS TO TOTAL NO. READINGS
Poly-Carb, Eastbound	192	89	46%
Dural and Basalt, Eastbound	212	147	69%
Cono/Crete, Westbound	128	24	19%
Dural and Sand, Westbound	212	99	47%

TABLE 9

I-20 RESISTIVITY READINGS
10/29/86

SYSTEM	TOTAL NO. READINGS	NO. VALUES < 500,000 OHMS/FT.^{2}	PERCENTAGE OF UNACCEPTABLE READINGS TO TOTAL NO. READINGS
Poly-Carb	186	62	33%
Dural and Basalt	198	68	34%
Cono/Crete	128	28	22%
Dural and Sand	206	60	29%

TABLE 10

I-20 RESISTIVITY READINGS
11/01/89

SYSTEM	TOTAL NO. READINGS	NO. VALUES < 500,000 OHMS/FT.^{2}	PERCENTAGE OF UNACCEPTABLE READINGS TO TOTAL NO. READINGS
Poly-Carb	192	133	69%
Dural and Basalt	212	135	64%
Cono/Crete	160	79	49%
Dural and Sand	212	173	82%

TABLE 11

RESISTIVITY READING TRENDS

% OF UNACCEPTABLE READINGS

Poly-Carb	5	46	33	69
Dural and Basalt	29	69	34	64
Cono/Crete	0	19	22	49
Dural and Sand	71	47	29	82
EVALUATION NO.	1 (6/27/85)	2 (7/30/86)	3 (10/29/86)	4 (11/01/89)

Shear Bond Test

This test provides an indication of the material's relative ability to remain bonded to the concrete under traffic conditions. No minimum values have been established to indicate acceptance bond strength.

Prior experience has shown that a value of 200 psi indicates a satisfactory bond for concrete overlays. Cono/Crete displayed the strongest bond with the hardened concrete. The Dural and sand was comparable to Dural and basalt, as expected. Poly-Carb had the lowest values of shear strength. Table 12 shows the values obtained. All values were acceptable.

TABLE 12

SHEAR BOND TEST (1-20)

SYSTEM	LOAD (LBS.) (AT FAILURE)	LOAD (PSI)
Cono/Crete	7850	625
Poly-Carb	3820	304
Dural and Basalt	5800	462
Dural and Sand	6050	482

Tensile Bond Test

The tensile bond test measures the tensile strength of the bond between the overlay material and the concrete bridge deck. Cores were taken from the bridge deck in the wheel paths and on the shoulder where the overlay was placed. A plate is attached to the base concrete and the overlay material with high strength epoxy. After the epoxy has cured, the plates are placed in a hydraulic assembly and pulled apart. The numbers shown in Table 13 indicate the stress required to pull the plates apart. Values of 100 psi are considered satisfactory.

TABLE 13

TENSILE BOND TEST RESULTS (I-20)

	Shoulder (PSI)	Wheel Path	Shoulder	Wheel Path
Dural & Basalt	229	131	267	204
Poly-Carb	196	131	199	163
Cono/Crete	196	163	199	154
Dural & Sand	No Values	No Values	207	258

Thermal Compatibility Test Results

The ASTM C-884 procedure was used to evaluate debonding of each of the epoxy-resin overlays on concrete at field temperatures.

The test results indicated that after the third cycle of testing, small cracks appeared at the interface of the Cono/Crete overlay and the concrete. These cracks did not change in size after the fourth and fifth cycles. The other materials did not experience any failure through five cycles of testing.

Ninety - Day Chloride Permeability Test

Table 14 shows the accumulated chlorides for each system tested. The results of the chloride permeability test indicated that all of the epoxy samples absorbed very little chloride after 90 days of ponding.

TABLE 14

90-DAY CHLORIDE PERMEABILITY TEST (I-20)

Overlay Type	Lbs of Chloride/Yd.^{3} of Concrete 1/16" - 1/2" Depth	Lbs. of Chloride/Yd.^{3} of Concrete 1/2" - 1" Depth
Cono/Crete	2.50	1.10
Dural and Basalt	0.34	0.21
Dural and Sand	0.23	0.23
Poly-Carb	0.43	0.43

Typical Louisiana bridge deck concrete (6.5 bag cement and chert gravel) shows an average accumulation of approximately 14 pounds in the top layer and 4 pounds at the bottom layer when subjected to this test.

Freeze and Thaw Test

Cores taken from the epoxy - overlaid sample blocks were subjected to rapid freezing and thawing according to ASTM C-666, Procedure B, Resistance of Concrete to Rapid Freezing and Thawing. After 300 cycles of freezing and thawing, no damage was visible in the epoxy overlays. However, the concrete cores began to show signs of deterioration. The same test was also performed on the epoxy overlay alone (epoxy sawed off from the concrete cores). No damage was observed on these samples. It is concluded that all of the systems tested had very good durability as determined by ASTM C-666.

Appearance

Prior to application of the overlay, each bridge was tested for corrosion, delamination and friction number as previously discussed. The pre-overlay data indicated that all bridge decks selected were in good condition with the exception of friction number. This eliminated the need for patching or repairs prior to the application of the overlay. The contract work for the four

APPENDIX A

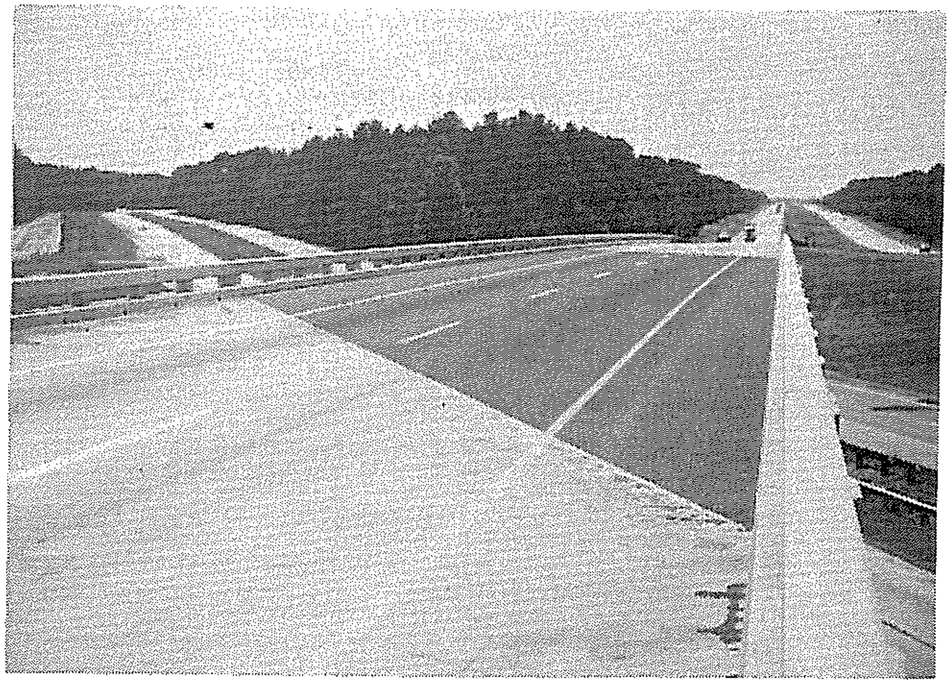

Figure 20. Completed Poly-Carb overlay.

Cono/Crete, the epoxy mortar product concrete had a more compact, dense appearance. There were no voids and protruding edges of aggregate with the Cono/Crete system. The stroke of the finishing trowel and the seam between adjoining passes of the screen box were visible after the material had cured. The completed epoxy mortar is shown in Figure 21.

The Dural and sand overlay finished with a rough surface texture. The impact of the small size aggregate particles on friction number values was a concern during the installation of this overlay. It was felt that the erosion of the exposed sand would reduce the friction numbers. After the installation of the first layer of the epoxy and sand layer, cracks in the concrete surface were visible. However, no cracks were observed after the second lift was placed.

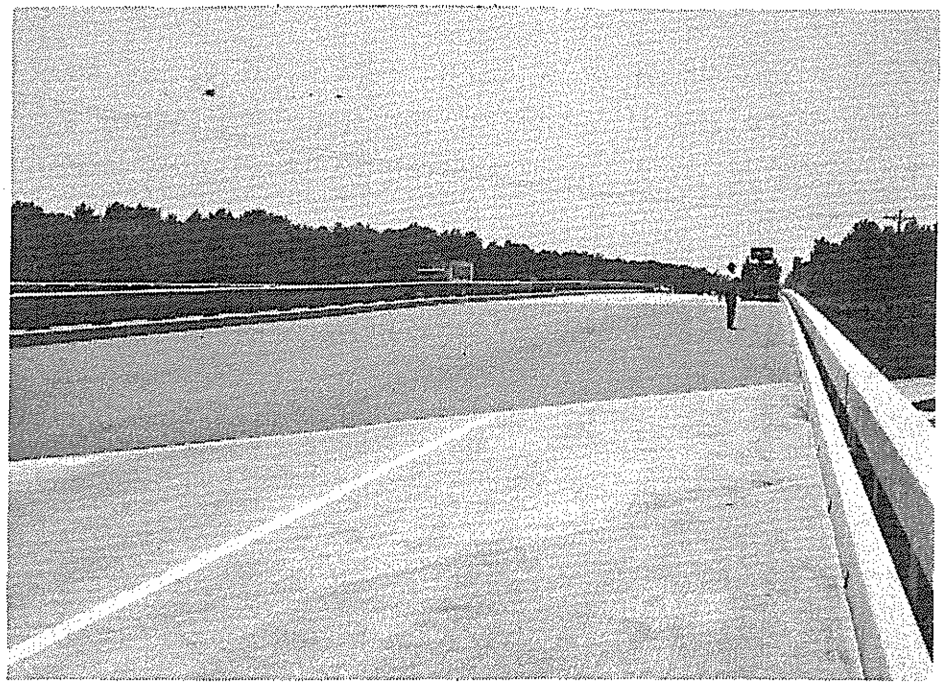

Figure 22. Completed Dural and Sand overlay.

<u>Overlay Performance Evaluation</u>

In improving friction numbers or skid resistance, Dural and basalt and Poly-Carb showed the highest numbers over time even though all systems except Cono/Crete showed a decrease in friction numbers over time. During the evaluation period, Dural and basalt experienced a delaminate spot in the overlay. It was noticed a few months after installation. A manufacturer's representative said improper mixing of the epoxy was probably the cause. The spot was repaired by removing the delaminated overlay, pouring in its place new epoxy and broadcasting aggregate.

Cono/Crete was the most impermeable system as measured by the resistivity readings followed by Poly-Carb and then the two Dural systems. All systems performed equally well in freeze-thaw resistance, resistance to chloride intrusion and thermal compatibility. Cono/Crete did experience some cracking at the interface though, after three cycles.

RECOMMENDATIONS

It is recommended that the use of epoxy coated overlays be considered as an alternative to conventional methods of resurfacing deteriorating bridge decks, especially when improving skid resistance is of primary concern. They are also effective as deck sealers and are much lower in weight than conventional overlay systems. These advantages should be weighed against the relatively high costs of these overlay systems.

The polish value of aggregate shall be a minimum of 50 when tested in accordance with DOTD Designation: TR 116, except that the above gradation shall be used in lieu of that required by this procedure.

Aggregate shall show an abrasion loss of not more than 40% and soundness loss of not more than 15% when tested in accordance with AASHTO Designations: T 96 and T 104.

Epoxy System 3 (Incorporate System): Aggregate shall consist of a blend of bauxite, granite, aluminum oxide and silica aggregates of irregular shape. Aggregates shall be clean, and shall have a Moh's hardness of 8.4 in at least 50% of the aggregates, the remainder having a Moh's hardness of at least 6.5. The gradation shall be such that there is no sticking during finishing and the material cures with no pinholes or porosity. The maximum particle size shall pass a No. 30 sieve.

Epoxy System 4 (Sand Broadcast System): Aggregate shall be an all-purpose blasting sand conforming to MS-95 Specifications elsewhere herein.

Construction:

(a) Surface Preparation: The concrete deck surface to be overlaid shall be abraded by the automatic shot-blast cleaning method using Wheelabrator-Fry's Blastrac Unit or other approved cleaning method. This unit shall be composed of a blasting unit which recycles abrasives and a vacuum unit, both self-propelled. Contaminants shall be picked up and stored in the vacuum unit and no dust shall be created that will obstruct the view of motorists in adjacent roadways. Travel speed or number of passes of the shot-blasting unit shall be adjusted to result in removal of 1/16" to 1/8" of the concrete deck surface. The shotblast unit shall be adjusted to create a transitional area of tapered depth for 3 feet on each end, resulting in the removal of 1/4" to 5/16" of concrete. Only those surfaces that can be covered by epoxy-aggregate overlay in 1 working day shall be cleaned in advance on that same day. Loose shot and other loose particles shall be removed from the deck prior to overlay application. Curb surfaces shall be abraded by sandblasting.

(b) Weather Limitations: Application of overlay will not be allowed unless the ambient temperature is 50°F and rising, the concrete deck temperature is at least 50°F, and the concrete deck surface is dry. Epoxy System 3 shall be placed and cured in accordance with the manufacturer's recommendations.

(c) Equipment: Equipment for mixing and applying the epoxy-aggregate system shall be in accordance with approved recommendations of the epoxy manufacturer.

(d) Mixing Epoxy Components: Each component shall be thoroughly stirred in its own container prior to mixing. Components shall be proportioned in accordance with the manufacturer's recommendations and thoroughly blended. No diluent, thinner or other foreign material shall be added to individual components or mixed epoxy.

Epoxy Systems 1, 2 and 4 (Broadcast Systems): A paddle attached to a 1/2" electric drill with a rated speed not exceeding 550 rpm shall be used for mixing.

Epoxy System 3 (Incorporate System): If a volumetrically proportioning continuous-type mixer is used, it shall be so equipped that the proportions of the components can be fixed by calibration of the mixer and can be readily determined by observation of the indicating devices.

The volumetrically porportioning continuous-type mixer shall be calibrated to the satisfaction of the engineer prior to starting the work and at other times the engineer deems necessary to ensure proper proportioning of ingredients. Volumetrically proportioning continuous-type mixers which entrap unacceptable volumes of air in the mixture shall not be used.

The mixer shall be kept clean and free of partially dried or hardened materials. It shall consistently produce a uniform, thoroughly blended mixture. Malfunctioning mixers shall be immediately repaired or replaced with acceptable units. The contractor shall furnish a 1/8-cubic-yard box to check the yield of the continuous mixer.

Drum type mixers shall be charged for each batch with the number of full, premeasured units of mixture components which does not exceed mixer capacity. Charging of such mixers with partial packages of components will not be allowed.

Drum type mixers shall be kept clean and free of partially dried or hardened materials.

Drum type mixers shall be maintained in good working order. Such mixers with dented drums, worn paddles or blades, bent agitator axles, or malfunctioning drive mechanisms will not be approved.

An approved finishing device complying with the following requirements shall be used for finishing all areas of work.

The finishing device shall be mechanically propelled and capable of forward and reverse movement under positive control. Provisions shall be made for raising all screeds to clear the screeded surface for traveling in reverse.

A rotating-cylinder-type finishing machine may be used. It shall be equipped with one or more rotating steel cylinders, augers and vibratory pans and span the placement transversely.

Any modifications shall be subject to approval by the engineer.

The device may also be of the vibrating screed type designed to consolidate the overlay material by vibration. Vibration frequency shall be maintained at a frequency which will remove entrapped air without causing undue lateral flow, "pumping" of mortar, or reduction of entrained air. The bottom face of screeds shall be not less than 2 1/2" wide and be metal. Screeds shall be provided with positive control of the vertical position.

The finishing machine shall be supported, outside of the area being overlaid, on adjustable rails or pads. The rails or pads shall be adequately supported so as not to deflect with the passage of the finishing devices. Supports shall be fully adjustable or tightly shimmed and fastened to obtain correct profile. In lieu of the above laydown and finishing procedure, the contractor may submit other finishing methods recommended by the manufacturer for approval by the engineer.

(e) Applying Overlay: The contractor shall provide suitable coverings, such as heavy-duty drop cloths, to protect exposed areas not overlaid with epoxy, such as curbs, sidewalks, railings, parapets and joints. Damage or defacement resulting from this application shall be cleaned or repaired by the contractor, at his expense, to the satisfaction of the engineer.

Epoxy Systems 1 and 2 (Broadcast Systems): Epoxy shall be applied to concrete surfaces by squeegee, roller, spray or combinations thereof, as approved. The method used shall apply the material smoothly, uniformly and continuously. The epoxy shall not be allowed to puddle in depressions in the deck.

a. First Coat: The epoxy shall be applied to the concrete at the rate of 40 square feet per gallon. While the epoxy is wet, aggregate shall be broadcast at the rate of 8-10 pounds per square yard in such manner that the level of the epoxy mixture is not disturbed. When this first coat has cured sufficiently to sustain working traffic, excess aggregate shall be removed by sweeping or other approved method and satisfactorily disposed of.

b. Second Coat: The second coat shall be applied in the same manner as the first coat, except that coverage of epoxy shall be 30 square feet per gallon and aggregate shall be broadcast at the rate of 12-14 pounds per square yard. When the second coat has cured sufficiently to sustain working traffic, excess aggregate shall be removed by sweeping or other approved method and satisfactorily disposed of.

Epoxy System 3 (Incorporate System): The thickness of the concrete overlay shall be a nominal 1/4" above the cleaned surface of the old deck and curb. The clearance shall be checked in the following manner prior to placement of the primer.

If the screed rail is used, a 1/4" thick filler block shall be attached to the bottom of the screed; with screed rails in place, the screed shall be passed over the area to be overlaid. As an alternate to passage of the finishing machine, an approved template, supported by the screed rails, may be passed over the overlay area.

Application to curb shall be in accordance with the epoxy manfuacturer's recommendations.

A primer consisting of a penetrating epoxy primer equal to Cono-Weld 501 primer as manufactured by Con/Chem Inc. The "B" component shall be added to the "A" component in the "A" component container and mixed for 3 to 4 minutes using a drill not exceeding 550 rpm with a PS Jiffy Mixing blade. The mixed primer shall be immediately applied to the surface at the rate of 200 square feet per gallon using a long nap roller or airless spray, and shall be mechanically scrubbed into the surface. The primed surface shall be free of puddling or voids. The primer shall set for approximately 1 hour or as recommended by the manufacturer's respresentative prior to placing the epoxy resin-aggregate overlay. Any primed surface that has not been overlaid within 24 hours and is not tacky shall be reprimed at the contractor's expense.

Overlay placement shall be a continuous operation. The overlay shall be manipulated and struck off manually to at least 3/8" thickness. It shall then be consolidated and finished at final grade by an approved finishing device. Hand finishing with a steel float will be required along the edge of the pour.

The top surface of the consolidated and finished overlay shall be smooth, uniform and tight.

Epoxy System 4 (Sand Broadcast System): Epoxy shall be applied to concrete surfaces by squeegee, roller, spray or combination thereof, as approved. The method used shall apply the material smoothly, uniformly and continuously. The epoxy shall not be allowed to puddle in depressions in the deck.

APPENDIX B

TABLE 17

DURAL FLEXOLITH
TECHNICAL DATA

	PART A	PART B
Color	Amber	Amber
Mixing Ratio	2 volumes	1 volumes
Percent Solid	100%	100%
Mixed Properties of Part A and Part B		
Pot Life @ 75°	15-30 minutes	
Tensile Strength	2,500-3,500 psi	
Tensile Elongation	20-35%	
Tensile Modulus	90,000-130,000 psi	
Compressive Strength	5,000 psi	
Compressive Modulus	90,000-130,000 psi	

TABLE 18

POLY-CARB FLEXOGRID
TECHNICAL DATA

	PART A	PART B
Color	Amber	Amber
Mixing Ratio	2 volumes	1 volume
Percent Solid	100%	100%
Shelf Life	2 years	2 years
Mixed Properties of Part A and Part B		
Pot Life @ (75 ± 2°F)	35-40 minutes	
Pot Life with Aggregate @ (75 ± 2°F)	1.5 hours	
Initial Set @ (75 ± 2°F)	6 hours	
Initial Cure @ (75 ± 2°F)	12 hours	
Final Cure @ (75 ± 2°F)	48 hours -- 7 days	
Properties of Cure Flexogrid Overlay		
Adhesion to Concrete	100% failure in concrete	ACI 503R-29
Shore D Hardness	55-75	ASTM D2240-75
Compressive Strength	7,000-9,000 psi	ASTM C-109
Tensile Strength (min.)	2,700 psi	ASTM D638-82
Tensile Elongation		
Tensile Modulus	35-45%	
Water Absorption	0.3-0.5%	ASTM 4-413
Abrasion Resistance-Wear Index CS17 Wheel, 1000 cycle, 1000 grams	47-70 mgs	ASTM C-501