TECHNICAL REPORT STANDARD PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FHWA/LA-86/184		

4. Title and Subtitle	5. Report Date
EVALUATION OF THIN EPOXY SYSTEM OVERLAYS FOR CONCRETE BRIDGE DECKS	May 1986
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Masood Rasoulian and Carl Burnett	184
9. Performing Organization Name and Address	10. Work Unit No.
Louisiana Transportation Research Center P. O. Box 94245 Baton Rouge, Louisiana 70804-9245	11. Contract or Grant No. La. HPR Study No. 84-2C
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Louisiana Department of Transportation and Development P. O. Box 94245 Baton Rouge, Louisiana 70804-9245	Interim Report May 1985 - December 1985
	14. Sponsoring Agency Code

15. Supplementary Notes

Conducted in cooperation with the U. S. Department of Transportation, Federal Highway Administration.

16. Abstract

Four epoxy overlay systems were applied to concrete bridge decks in north Louisiana to evaluate their performance as skid resistant 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. Skid tests were taken with the British Portable Tester and the E-274 Skid Trailer; sealing characteristics of each system were checked with electrical resistivity measurements.

An initial evaluation determined that both Dural Flexolith and Poly-Carb Flexogrid (broadcast systems) provided very good skid resistant surfaces. The use of sand and Dural epoxy also provided a good surface for skid resistance. The mortar system (Con/Chem Cono/Crete) produced low skid numbers initially.

17. Key Words	18. Distribution Statement
Thin epoxy aggregate overlay systems, skid resistance, concrete bridge decks.	Unrestricted. This document is available to the public through the National Technical Information Service Springfield, Virginia 22161

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	52	

Form DOT F 1700.7 (8-69)

EVALUATION OF THIN EPOXY SYSTEM OVERLAYS FOR CONCRETE BRIDGE DECKS

INTERIM REPORT NO. 1

By

MASOOD RASOULIAN
CONCRETE RESEARCH ENGINEER

And

CARL BURNETT
RESEARCH ENGINEER-IN-TRAINING

Research Report No. 184

Research Project No. 84-2C

Conducted by
LOUISIANA DEPARTMENT OF TRANSPORTATION
AND DEVELOPMENT
Louisiana Transportation Research Center
In Cooperation with
U. S. Department of Transportation
FEDERAL HIGHWAY ADMINISTRATION

MAY 1986

ABSTRACT

Four epoxy overlay systems were applied to concrete bridge decks in north Louisiana to evaluate their performance as skid resistant 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. Skid tests were taken with the British Portable Tester and the E-274 Skid Trailer; sealing characteristics of each system were checked with electrical resistivity measurements.

An initial evaluation determined that both Dural Flexolith and Poly-Carb Flexogrid (broadcast systems) provided very good skid resistant surfaces. The use of sand and Dural epoxy also provided a good surface for skid resistance. The mortar system (Con/Chem Cono/Crete) produced low skid numbers initially.

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

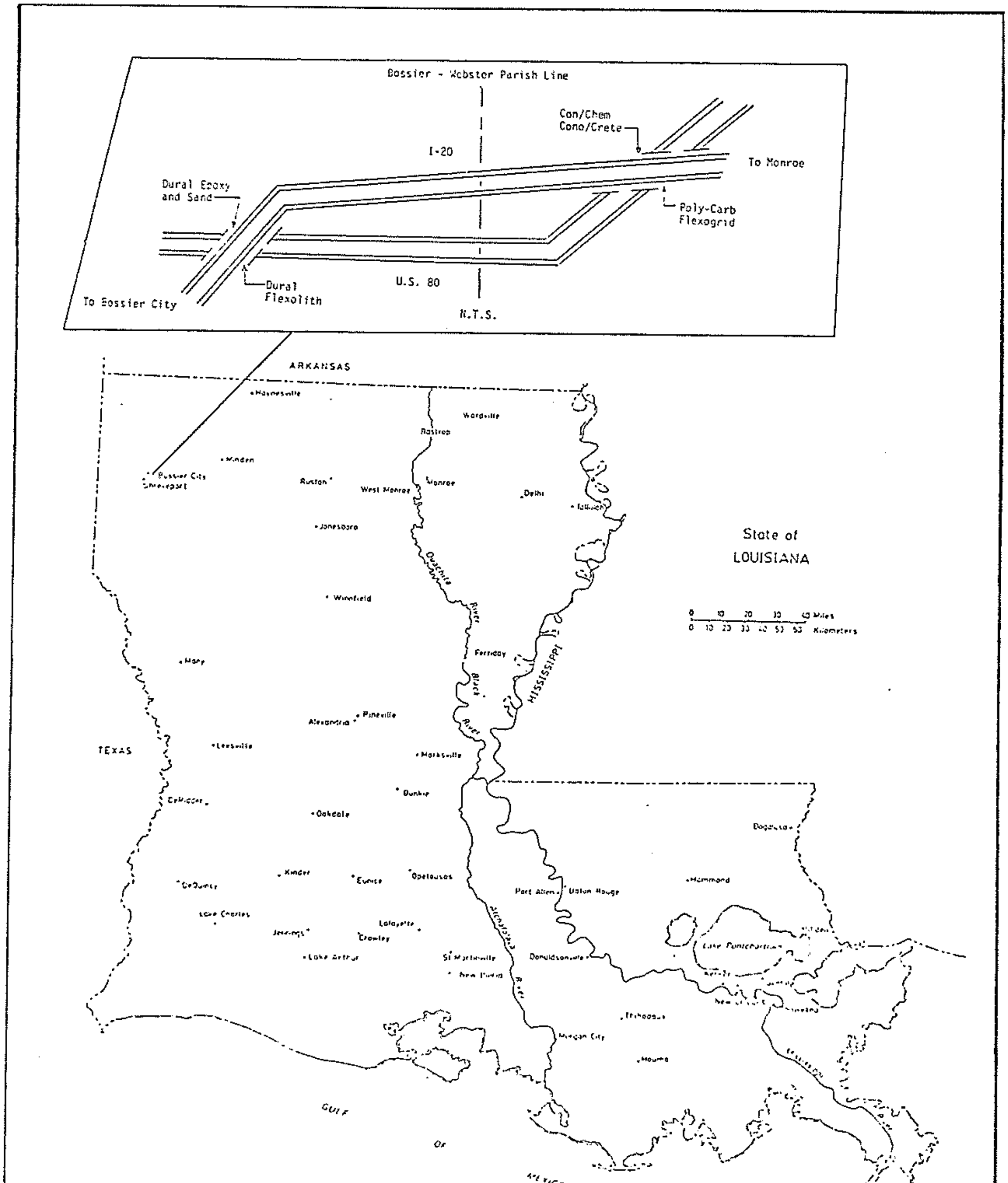
LIST OF FIGURES

INTRODUCTION

Skid resistance is one of the most important characteristics of any bridge deck or highway surface. The restoration of lost skid resistance on bridge decks is presently a primary concern of highway maintenance organizations. In an effort to address this problem, this research project is being 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 with basalt aggregate, Poly-Carb Flexogrid Mark 163 with basalt aggregate, Con/Chem Cono/Crete 101 with a select blend of aggregates, and Dural epoxy with sandblasting sand.

Each system was designed to produce a thin, durable, skid resistant surface. Different formulations of epoxy and select aggregate were utilized. The systems are being evaluated in the laboratory and the field for ease of application, durability, sealing ability, skid resistance, and cost. The systems were applied 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 roadbed.

This report covers system installation and initial field tests. 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 skid resistance.



Installation Location

FIGURE 1

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 are being evaluated primarily for their ability to improve the skid resistance and also for their sealing ability. The systems' ease of application, durability and cost are also of concern.

The field evaluation was comprised of monitoring the construction progress, resistivity testing and annual skid 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 B)
3. Shear bond test (Iowa DOT method)
4. Thermal compatibility test (ASTM C-884)

METHOD OF PROCEDURE

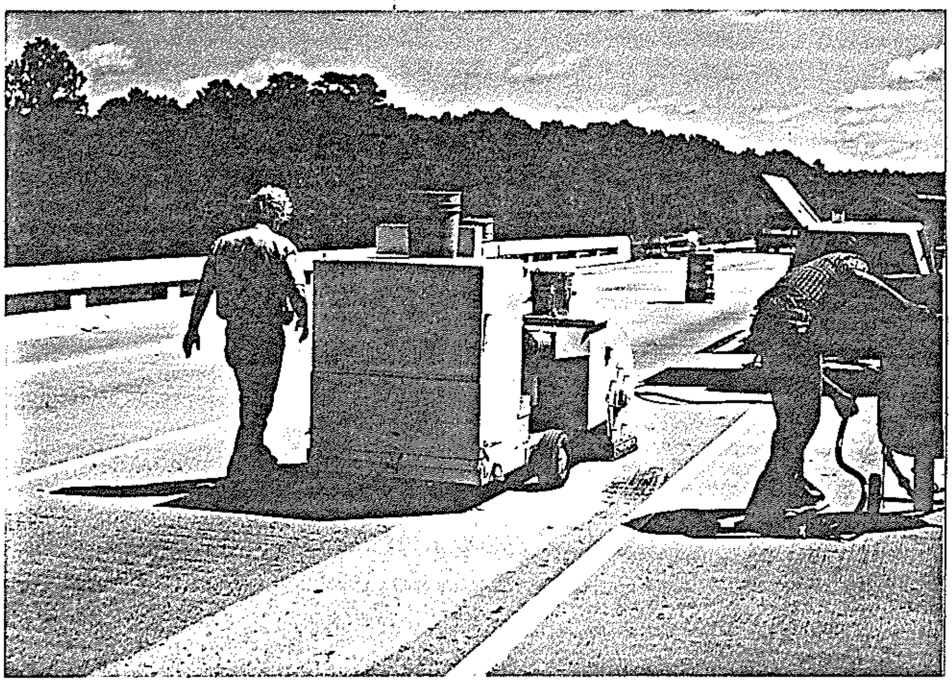
Prior to application of the overlay, each bridge deck was tested for corrosion, delamination and skid resistance (see Table 6 in Appendix B). This was done to collect pre-application data and also to ensure that each bridge met the requirements of having a sound deck, free of corrosion and delamination. These requirements were set to minimize the preparation work to just cleaning of the deck, with no patching or repairing necessary. Special provisions used for this job are listed in Appendix A.

Each material was tested in the laboratory to check its conformity to the Department's Type III epoxy resin. This type is used in bonding skid resistant material to hardened concrete and as a binder in epoxy mortar and epoxy concrete. Table 7 in Appendix B shows the specification for Type III epoxies.

(a) Construction Procedures

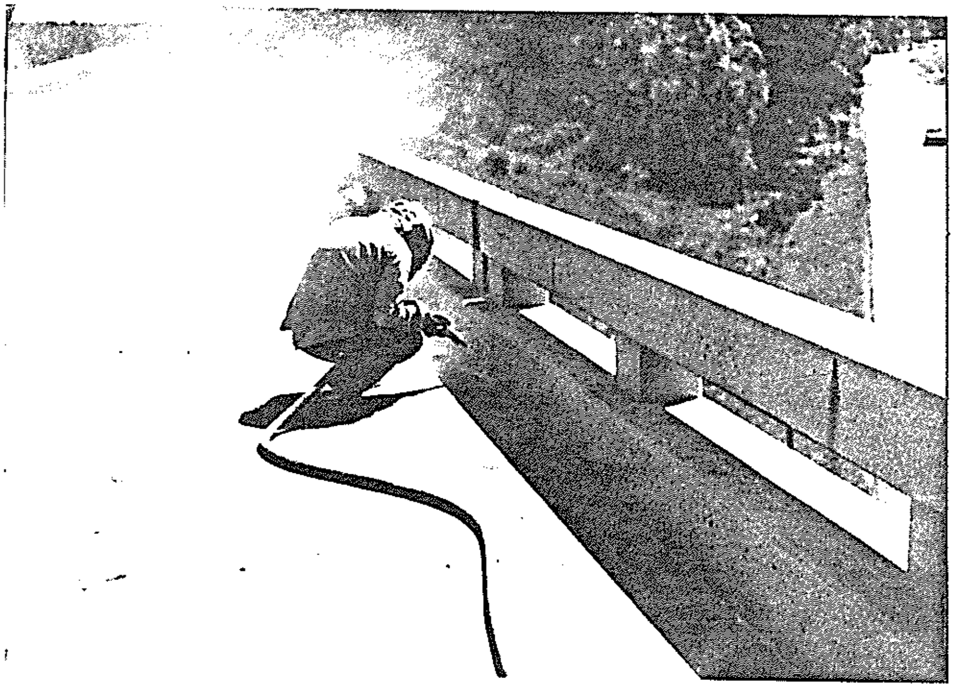
The contractor for this job was Alpha Construction Company of Shreveport, Louisiana. Each deck was prepared for the overlay as directed by the system's manufacturer representative as specified in the contract. The entire surface to be overlaid was cleaned by the shotblasting method utilizing steel shot. The bridge deck cleaning was subcontracted by Portablast Company from 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 needed to be cleaned. The vertical side of the curb was 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. The deck temperature during the daylight hours reached 120°F.



Portablast Unit

FIGURE 2



Sandblasting of the Curb

FIGURE 3

Cleaned Bridge Deck Prior to Overlay

FIGURE 4

System 1, Flexolith, Dural International (Broadcast System)

Dural Flexolith was the first overlay to be installed by the contractor. It was placed on I-20 eastbound at Fillmore, structure No. 4510215.501.

Flexolith is a two-component epoxy resin and basalt aggregate surface coating used for deck overlay. It is introduced by the manufacturer as a 100 percent solid, low modulus, flexible, high elongation, moisture insensitive system. Material properties as reported by the manufacturer are provided in Table 8, 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. Three-gallon batches of epoxy were mixed at a time. As soon as the epoxy was mixed it was spread out with hand squeegees over the cleaned surface, as shown in Figure 7. Epoxy was spread onto the deck within 15 minutes after mixing. Once the spreading of each batch of epoxy was completed, basalt aggregate was broadcast over the wet epoxy, as seen in Figure 8. The recommended rate and the actual rates of coverage for all systems are shown in Table 11 in Appendix B.

Flexolith was applied in two lifts to obtain the desired 1/4 inch overlay. The first lift on 4,000 square feet took approximately two hours. After the completion of the first lift, the excess aggregate was swept from the surface. Two hours was sufficient time for the material to cure before the second lift was placed. The same procedures were used to apply the second coat; however, the application rates were different. After the second lift had been applied and the excess aggregate swept off, the overlay was allowed to cure twelve hours before it was opened to traffic.

Mixing the Two Components of Epoxy

FIGURE 5

Dural Epoxy Ready for Application

FIGURE 6

Spreading of the Epoxy (Dural)

FIGURE 7

Broadcasting the Basalt Aggregate, First Coat

FIGURE 8

System 2, Dural Epoxy and Sand (Broadcast System)

The same epoxy used with Flexolith 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), with sand as an aggregate. The gradation of the sand specified is provided in Appendix A. The same procedure was used to apply the sand-epoxy overlay as system 1, Flexolith. 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.

System 3, Poly-Carb Flexogrid Mark 163 (Broadcast System)

Mark 163 Flexogrid 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 9 in Appendix B.

Flexogrid was applied to the eastbound roadway of I-20 over U.S. 80 at McIntyre, Structure No. 4510303.141. This material consisted of 100 percent solid two-part liquid, to be mixed on the job site, and a specially selected aggregate broadcast (basalt in this application). The epoxy was mixed in the ratio of two parts component A to one part component B. The method used to apply Flexogrid varied slightly from system 1. The mixed epoxy was spread onto the deck with notched 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

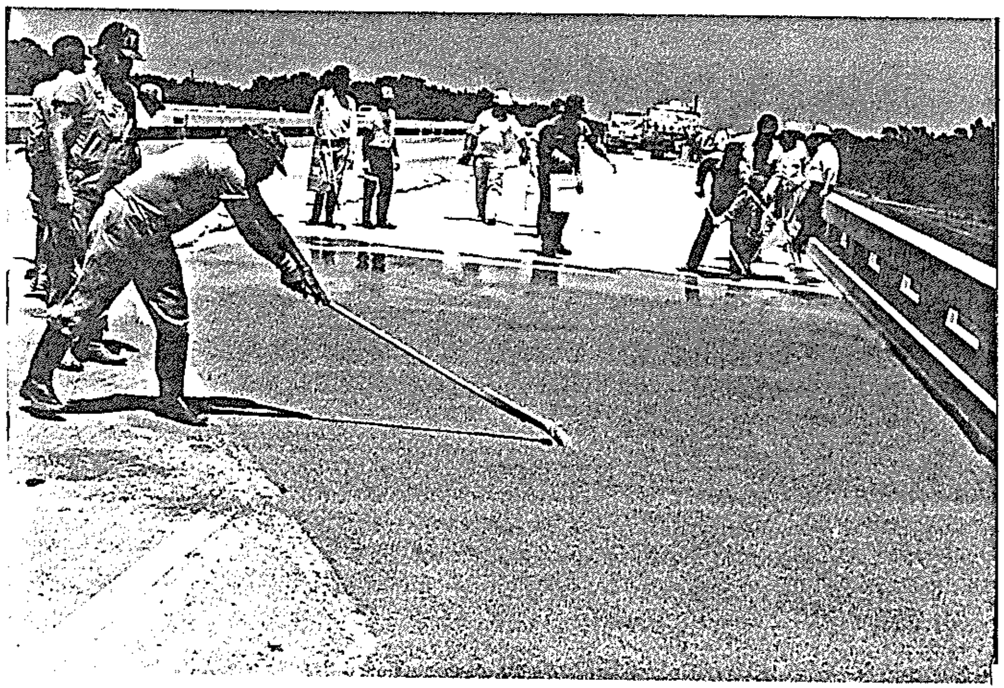
Spreading Dural Epoxy Over the First Lift

FIGURE 9

Sweeping the Excess Aggregate After the Final Coat

FIGURE 10

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 11 in Appendix B.

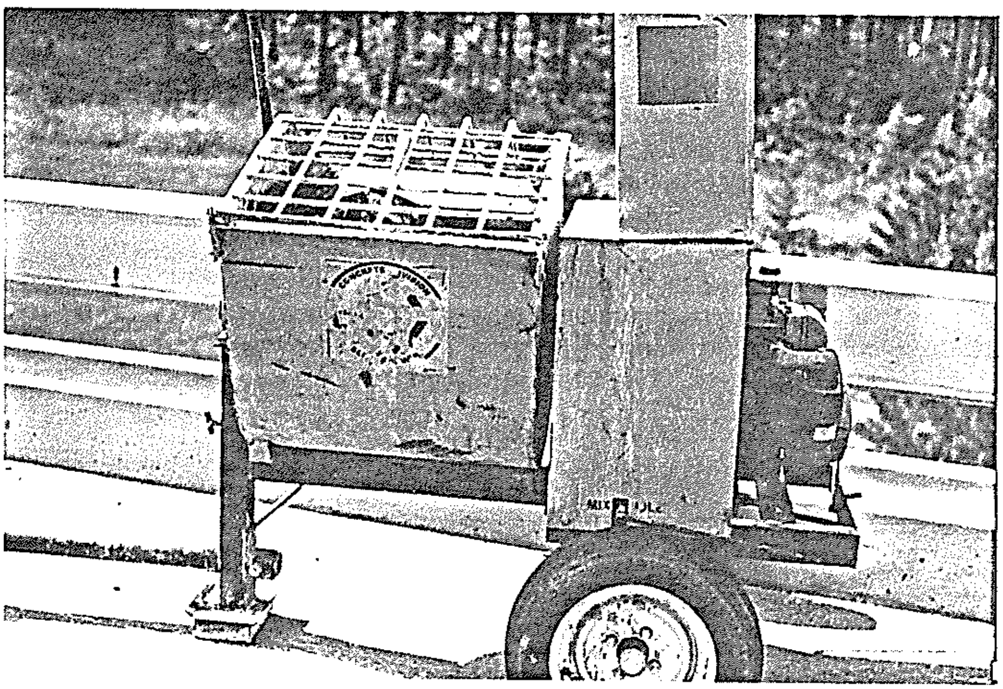


Basalt Aggregate Being Rolled Onto the Poly-Carb Epoxy

FIGURE 11

System 4, Con/Chem Cono/Crete 101 (Epoxy Mortar System)

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 that 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 10 in Appendix B.

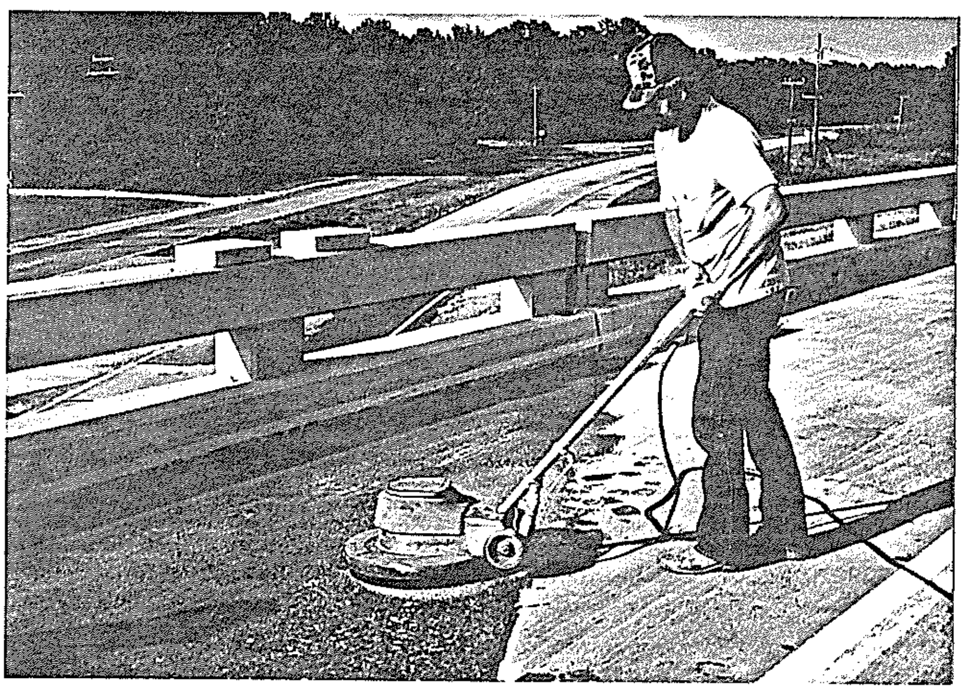


Mortar Mixer Used for Cono/Crete 101

FIGURE 12

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

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 done after sunset.



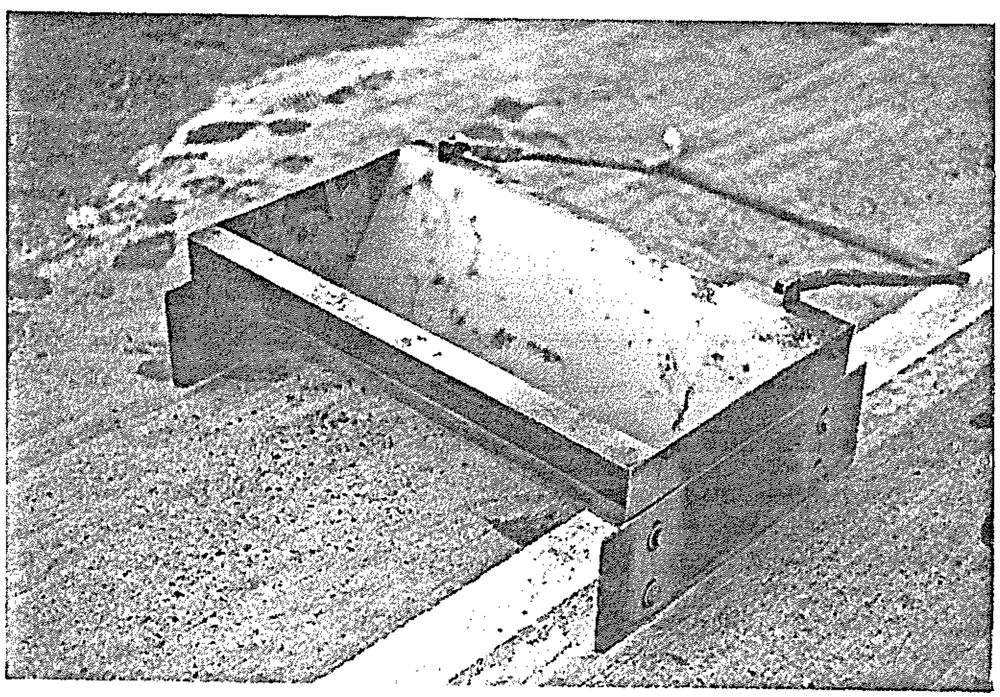
Application of Primer for Cono/Crete 101

FIGURE 13

A vibrated screed box approximately 33 inches wide was used to put down the full 1/4-inch-thick layer. 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.

Hand Troweling of Cono/Crete 101

FIGURE 14



Screed Box Used for Spreading Mortar

FIGURE 15

(b) Laboratory Evaluation

For the purpose of laboratory evaluation, 3"x9"x15" 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 eliminate 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 three percent solution of sodium chloride for 90 days. The amount of chloride which penetrated the surface of the epoxy was determined from the samples of pulverized concrete taken from beneath the epoxy. Three four-inch-diameter cores were taken from the other blocks from each system. These cores were subjected to the following testing:

1. Freeze and thaw durability test (ASTM C-666, procedure B)
2. Shear bond test (Iowa DOT procedure)
3. Thermal compatibility test (ASTM C-884)

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

In the shear bond test, force was directly applied to the overlay until the overlay was sheared and the load recorded.

The ASTM C-884 Test Method for Thermal Compatibility between Concrete and an Epoxy-Resin Overlay was used to evaluate debonding of the epoxy-resin overlays and the concrete at field temperatures. The procedure calls for 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.

DISCUSSION OF RESULTS

Skid Resistance

Skid tests were run on the designated bridge decks with the British Portable Tester (BPT) and ASTM E-274 locking wheel skid trailer before and after overlaying. Both methods indicated the concrete surface skid characteristics were in the satisfactory range before the overlay was applied. The specifications required the overlays to achieve a minimum skid value of 55, measured with the British Portable Skid Tester. Poly-Carb's and Dural's products produced a BPT number of 81 and 84, respectively. This is an average 56 percent increase in skid resistance over the original concrete surface. Normally, the locking wheel truck would be run on each surface five times to get an average value of skid resistance. However, the basalt aggregate used with Poly-Carb and Dural epoxy was so rough that the truck tire would rupture before the test could be completed. Therefore, the BPT values were used to measure skid resistance for the Poly-Carb and Dural overlays.

Cono/Crete had a BPT skid number of 58. This is greater than the original concrete surface's number and the minimum acceptable value as measured by the BPT. The locking wheel skid truck measured a value of 32.4 on the Cono/Crete. This was well below the value of 41.6 measured on the original surface. Previous installations of Cono/Crete on the Lake Pontchartrain Causeway Bridge have shown that initial values of skid resistance have been maintained with little or no reduction for several years under high traffic.

The sand and epoxy overlay produced a BPT number of 67 and a locking wheel skid number of 53. Both values are considered satisfactory. The quality of ride in an automobile at 55 mph was very good on all surfaces. There was no increase in noise even on the rougher materials. Figure 16 shows the British Portable Skid Tester used in this study.

British Portable Skid Tester

FIGURE 16

Resistivity Test

The resistivity test is run on the overlay to determine its level of impermeability. Electrical resistance across the surface is 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 concrete readings vary from 1,000 to 8,000 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. The following table presents the range of values measured for each overlay system.

TABLE 1

RESISTIVITY READINGS

System	Resistance Range Ohms/ft^2	Total No. Readings	No. Values <500,000 Ohms/ft^2
Poly-Carb Flexogrid	120 K - 100 m	80	4
Dural Flexolith	35 K - 40 m	86	26
Con/Chem Cono/Crete	6.5 m - infinity	85	0
Sand Epoxy	30 K - 8 m	90	63

Cono/Crete performed the best in the impermeability test, with Poly-Carb, Dural and sand epoxy following, 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 Flexolith were along the seam between the two halves of the overlay which were placed on successive days. Figure 17 shows the resistivity tests being conducted on the bridge.

Resistivity Testing of Bridge Deck Overlay

FIGURE 17

Shear Bond Test

The shear bond test measures the strength of the bond between the original concrete surface and the overlay material. It gives an indication of the material's relative ability to remain bonded to the concrete under traffic conditions. The following table gives the values obtained.

TABLE 2

SHEAR BOND TEST

System	Load (lbs.)	Stress (psi)
Cono/Crete	7850	625
Poly-Carb Flexogrid	3820	304
Dural Flexolith	5800	462
Sand Epoxy	6050	482

No minimum values have been established to indicate acceptable 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 epoxy used with sand was comparable to Flexolith, as expected. Poly-Carb Flexogrid had the lowest values of shear strength.

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 forth and fifth cycles. The other materials did not experience any failures through five cycles of testing.

Ninety-Day Chloride Permeability Test

This test was done to measure the amount of chloride that could penetrate through the epoxy after 90 days of ponding with a three percent solution of sodium chloride. After this period, the overlay was removed from the test blocks. Samples of pulverized concrete were taken from 1/16"-1/2" and 1/2"-1" below the surface. The amount of chloride that had accumulated in the samples was measured.

The results of the chloride permeability test indicated that all of the epoxy samples absorbed very little chloride after 90 days of ponding. Table 3 shows the accumulated chlorides for each system tested.

TABLE 3

90-DAY CHLORIDE PERMEABILITY TEST*

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 and Basalt	0.43	0.11

*The values shown contain the amount of chlorides that are naturally in the concrete.

Typical Louisiana concrete 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.

Cost

Whatever method is used to rehabilitate bridge deck surfaces must be cost effective.

As the following table shows, the lowest cost material is the sand epoxy. The sandblasting sand aggregate accounts for the major difference in price. The labor costs involved with the three broadcast systems, Flexolith, Flexogrid and sand epoxy, are essentially the same because of their similar application procedures. Because of the nature of Cono/Crete and the different application procedure, this system is more labor intensive than the other systems. Exact labor cost figures cannot be determined from the available data.

An economic analysis which relates cost of material and useful life is needed to determine which, if any, of the systems are desirable. This must be done after a useful life is determined through the evaluation of this research project.

TABLE 4

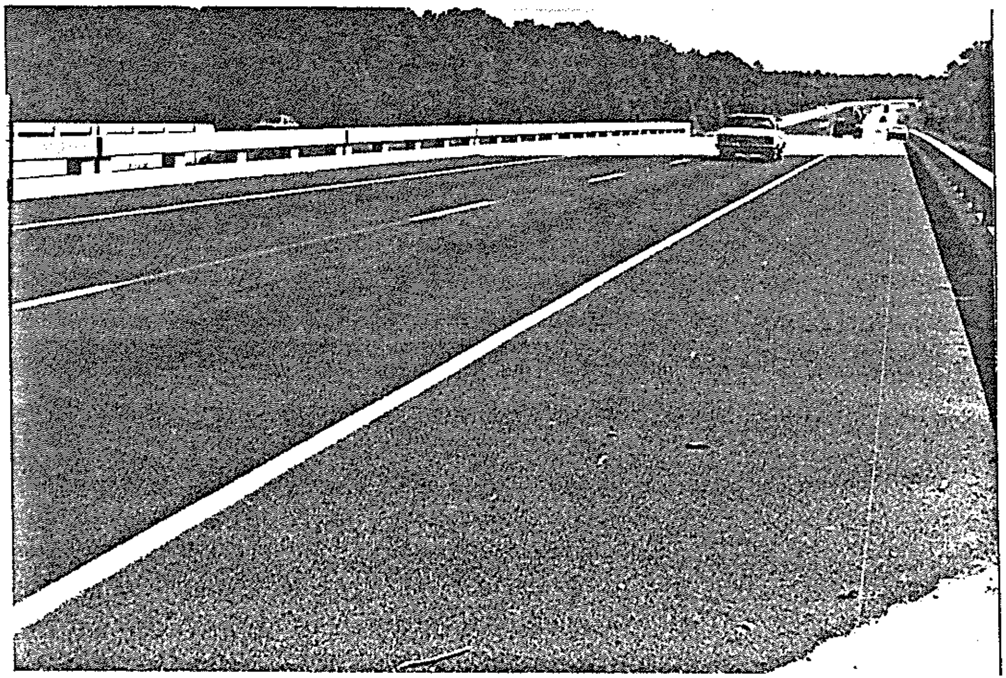
CONSTRUCTION COST

System	Estimate Material Cost/yd^2
Dural Flexolith	$26.87
Poly-Carb Flexogrid	30.00
Con/Chem Cono/Crete	25.88
Sand Epoxy	15.81

The cost of deck preparation was constant for all materials.

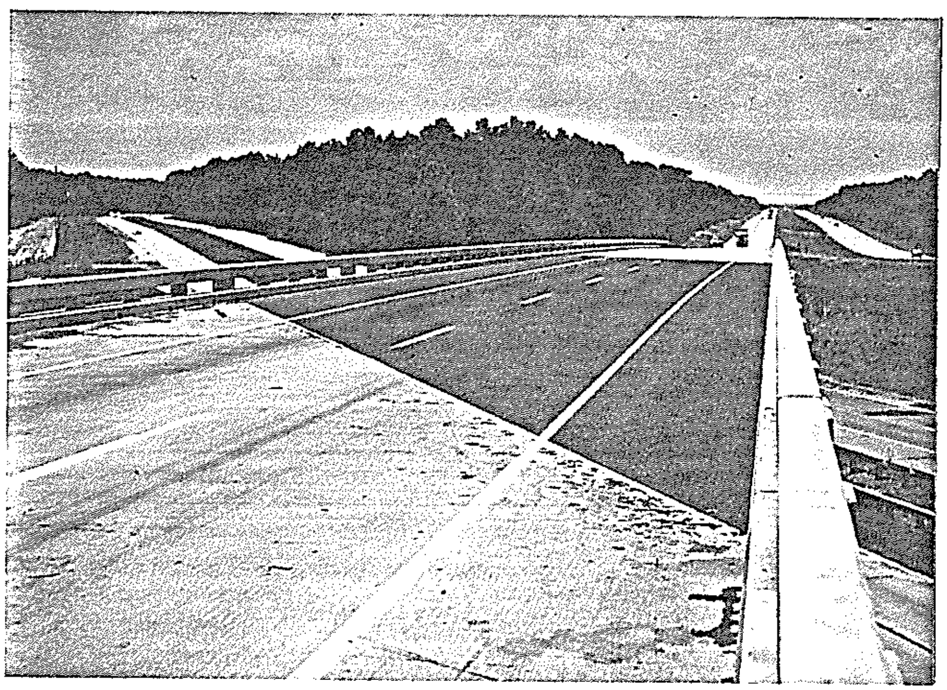
Texture and Appearance

Prior to application of the overlay, each bridge was tested for corrosion, delamination and skid resistance. The results of this survey are shown in Table 6. The preoverlay data indicated that all bridge decks selected were in good condition. This eliminated the need for patching or repairs prior to the application of the overlay. The contract work for all four sections of overlays (approximately 40,000 square feet total) was completed within two weeks. Figures 18 and 19 show the Dural and basalt system and Poly-Carb and basalt aggregate system, respectively. The appearance of Dural Flexolith and Poly-Carb Flexogrid was identical because of the basalt aggregate used for both overlays. The texture of these surfaces was very rough because of the protruding edges of the aggregate pieces.



Completed Dural Flexolith Overlay

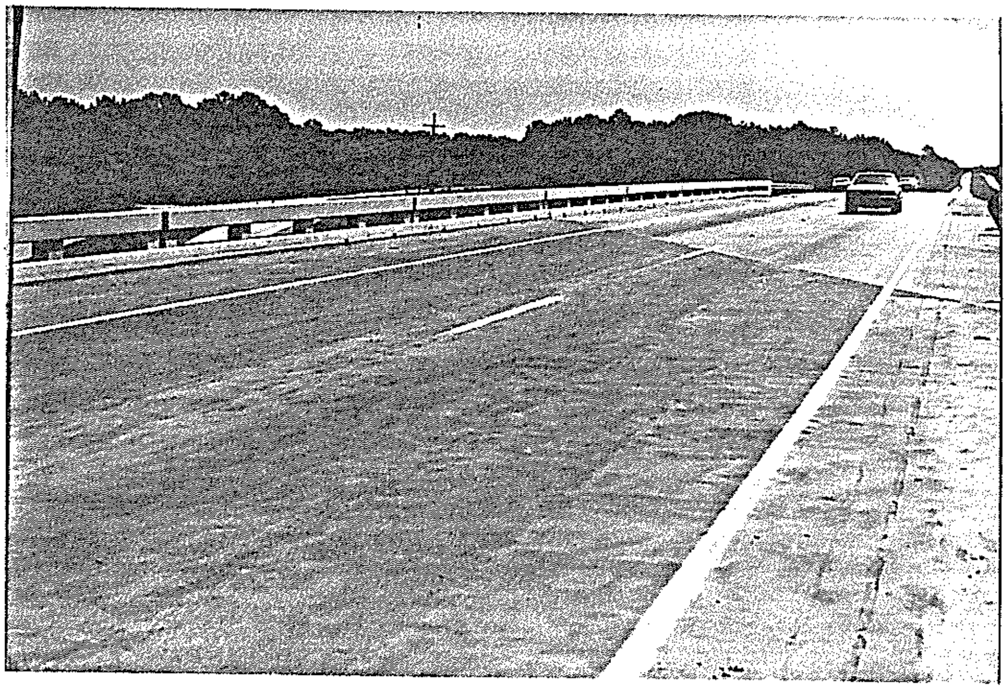
FIGURE 18



Completed Poly-Carb Flexogrid Overlay

FIGURE 19

The epoxy mortar product concrete had a more compact, dense appearance. There were no voids and protruding edges of aggregate with the Con/Chem system. The stroke of the finishing trowel and the seam between adjoining passes of the screed box were visible after the material had cured. The completed epoxy mortar is shown in Figure 20.

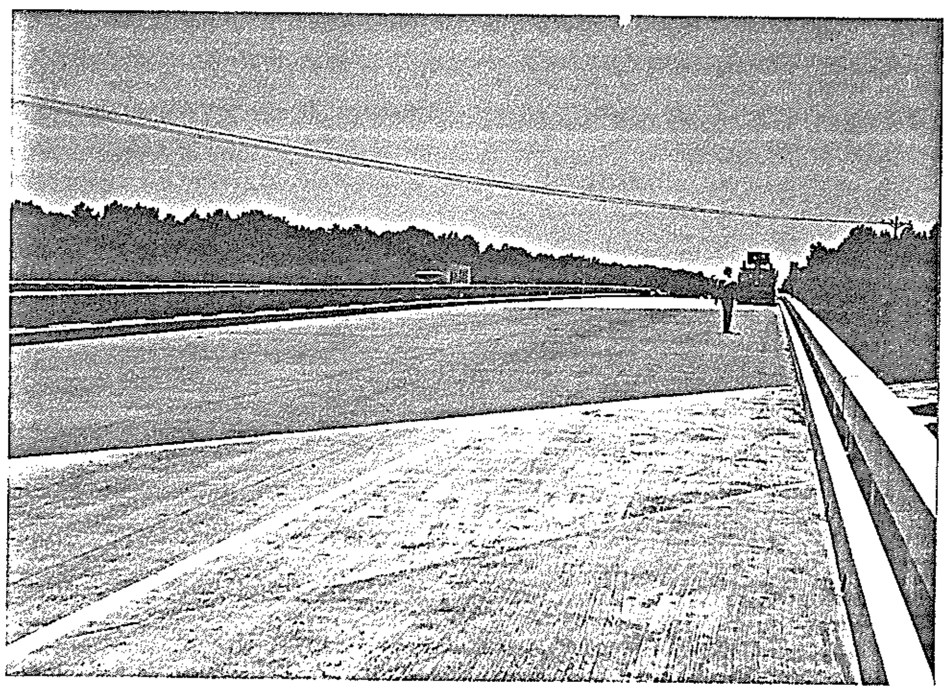


Completed Epoxy Mortar, Cono/Crete 101 Overlay

FIGURE 20

The sand epoxy overlay finished with a rough surface texture. The impact of the small size of the aggregate particles on skid resistance was a concern during the installation of this overlay. It was felt that erosion of the exposed sand would reduce the skid resistance of this system. This is being monitored for verification. After the installation of the first layer of the epoxy and sand layer, cracks in the concrete surface were visible; however, no cracks could be seen after the second lift was placed.

Figure 21 shows the completed sand epoxy system. Each system's appearance was considered satisfactory after the application.



Completed Dural and Sand Aggregate Overlay

FIGURE 21

Half-Cell Readings

Structure number 4510215.501, which was overlaid with Dural Flexolith, had corrosion readings in the high probability range, although no delamination or other signs of distress were visible. The location of the corrosion is approximately 175 feet from the west edge of the overlay and extends for about 5 feet. This area will be closely monitored during the evaluation of the overlay.

Overlay Ratings

The following chart rates each system according to its performance during initial installation and traffic use. The rating is selected from 1 to 4. The lower number indicates the best performance. This chart rates relative performance; therefore, a high number does not necessarily mean failure.

TABLE 5

EPOXY SYSTEM RATING

System	Appearance	Resistivity	Skid Resistance	Thermal Comp.	Shear Bond	Chloride	Cost	Construction	Freeze Thaw	Avg.
Dural	1	3	1	1	2	1	3	1	1	1.6
Poly-Carb	1	2	1	1	3	1	4	2	1	1.8
Cono/Crete	3	1	3	3	1	1	2	3	1	2.0
Sand Epoxy	2	4	2	1	2	1	1	1	1	1.7

How well each system performs during sustained periods of traffic will be the primary factor in determining which is the most practical for future applications. Because there is no long-term performance data available at this time, this chart cannot be used to determine the best system.

CONCLUSION

Each overlay system performed satisfactorily through installation and initial service, although some systems performed better on some tests than others.

The Dural and Poly-Carb systems both seem promising. Their ability to remain bonded to the concrete surface and resist cracking will be primary considerations for their success.

The sand epoxy's intended use is on low traffic structures. How well it maintains good skid charactertistics and stays bonded to the concrete will determine its use as an overlay material.

The Cono/Crete system started with lower initial skid numbers than any of the other systems. It will be important in its evaluation to see if these numbers are maintained for a long period of time. The screeding procedure used to apply the Cono/Crete mortar system in this project would not be effective on a large-scale operation. However, the manufacturer claims there are mechanical methods available which would enable an experienced, organized contractor to handle large installations of the broadcast systems without prolonged road closures. These methods were not demonstrated in this research project.

BIBLIOGRAPHY

1. Clear, R. C. and Choller, B. H., "Styrene-Butadiene Latex Modifiers for Bridge Deck Overlay Concrete." Federal Highway Administration, Report No. FHWA RD-78-35, Interim Report, April 1978.

2. Temple, W. H. and Rasoulian, M., "Thin Bonded PCC Resurfacing," Interim Report No. 1. Louisiana Department of Transportation and Development, Research and Development Section, June 1982.

3. Spellman, D. L., Stratfull, R. F., et al., "An Electrical Method for Evaluating Bridge Deck Coating." California Division of Highways, June 1971.

4. Con/Chem, Inc., 12923 Cerise Avenue, Hawthorne, California, 90250, Product Publication.

5. Poly-Carb, 33095 Bainbridge Road, Solon, Ohio 44139, Product Publications.

6. Dural International Corporation, 95 Brook Avenue, Dear Park, New York 11729, Product Publications.

APPENDIX A

(1) Type I sheeting shall retain at least 50 percent of the minimum reflective intensity values in Table 20 after 1000 hours weathering.

(2) Type IA sheeting shall retain at least 65 percent of the minimum reflective intensity values in Table 20A after 2200 hours weathering (500 hours for orange).

(3) Type II sheeting shall retain at least 70 percent of the minimum reflective intensity values in Table 21 after 2200 hours weathering (500 hours for orange).

ITEM S-101 THRU S-103, EPOXY-AGGREGATE BRIDGE DECK OVERLAY: These items consist of furnishing and placing an epoxy-aggregate overlay on bridge decks in accordance with plan details and the following.

Manufacturer's Representative: The contractor shall arrange and pay for the services of the epoxy manufacturer's designated representative who shall be present at all times during the work. The manufacturer's representative shall make recommendations to the engineer as to acceptability of the operations which include, but is not limited to, deck surface preparation, type of equipment and method of application and finish of the overlay system. The contractor shall submit in writing the name of the technical representative and his qualifications. Materials shall be applied in accordance with the manufacturer's written instructions. Before beginning work, the contractor shall submit his detailed work plan to the engineer for approval.

Materials: Materials shall be sampled and tested for conformance to specispecifications prior to use.

(a) Epoxy Resin Systems: Epoxy resin systems shall be the following Type III epoxy resin systems conforming to Section 1017 of the Standard Specifications and shall be moisture insensitive.

1. Flexolith manufactured by Dural International Corporation, 95 Brook Avenue, Deer Park, NY 11729.

2. Mark 163 (Flexogrid) manufactured by Poly-Carb, 33095 Bainbridge Road, Solon, OH 44139.

3. Cono/crete 101 manufactured by Con/Chem, Inc. 12923 Cerise Avenue, Hawthorne, CA 90250.

4. Same epoxy resin as indicated in No. 1.

(b) Aggregates: Aggregates shall be packaged in such manner that they arrive at the jobsite, and are maintained moisture-free.

Epoxy Systems 1 and 2 (Broadcast Systems): Aggregate shall be basalt type containing at least 20 percent aluminum oxide and conforming to the following gradation.

U.S. Sieve	% Retained	% Passing
No. 6	0 - 1	- - -
No. 10	65 - 90	- - -
No. 20	10 - 25	0 - 3

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.

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 1 1/2 pounds per square foot or until no wet spots are visible. 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 the coverage of epoxy shall be 35 square feet per gallon. Aggregate shall be broadcast at the rate of 1 1/2 pounds per square foot. 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.

(7) Curing: The overlay shall be closed to traffic for at least 24 hours or as recommended by the epoxy manufacturer.

(8) Repair of Surface Defects: The repair method for overlay surface defects shall be the same as that used for overlay application. Surface defects shall be repaired to the satisfaction of the engineer.

Skid Resistance: The overlay finish shall be tested with a British Pendulum Tester in accordance with ASTM Designation: E 303. The resulting skid number shall be a minimum of 55 (BPT).

Measurement and Payment: Quantities for payment will be the design quantities specified in the plans and approved adjustments thereto. Payment for epoxy-aggregate overlay will be made at the contract unit price per square yard under:

S-101, Bridge Deck Overlay with Flexolith (System 1),
per square yard.
S-101A, Bridge Deck Overlay with Flexolith (System 4),
per square
yard.
S-102, Bridge Deck Overlay with Mark 163 (Flexogrid),
per square yard.
S-103, Bridge Deck Overlay with Cono/crete 101,
per square yard.

CONTRACT TIME: The contractor will be issued a "Conditional Notice to Proceed" to begin purchase and assembly of materials and equipment. The "Conditional Notice to Proceed" will expire 15 calendar days after its issuance, unless the contractor requests an earlier expiration date, whereupon a "Full Notice to Proceed" will be issued; however, the "Full Notice to Proceed" will not be issued prior to submittal and approval of the contractor's Construction Progress Schedule in accordance with Subsection 108.03.

The entire contract shall be completed in all details and ready for final acceptance within twenty (20) working days after the date stipulated in the "Full Notice to Proceed."

APPENDIX B

TABLE 6

PRELIMINARY DECK SURVEY, CHLORIDE CONTENTS AND HALF-CELL READINGS

Structure No.	Avg. Chloride Content Lbs. Chlor./yd^3 Conc.	Half-Cell Range USCE	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 x CSE or less - 90% probability that no reinforcing steel corrosion is occurring

-0.20 to -0.35 x CSE - corrosion in this area is uncertain

-0.35 x CSE or greater - 90% probability that reinforcing steel corrosion is occurring

TABLE 7

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

TABLE 8

DURAL FLEXOLITH
TECHNICAL DATA

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

TABLE 9

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	35-45%	
Tensile Modulus	70,000-80,000 psi	
Water Absorption	0.3-0.5%	ASTM C-413
Abrasion Resistance-Wear Index CS17 Wheel, 1000 cycle, 1000 grams	47-70 mgs	ASTM C-501

TABLE 10

CON/CHEM CONO/CRETE 101
TECHNICAL DATA

Description	Epoxy surfacing mortar	
Percent Solids	100%	
Shelf Life	1 year	
<u>Mixed Properties</u>		
Pot Life	1 hour	
Initial Set Time	8-10 hours	
Final Cure Time	18-24 hours	
Impact Strength*	300 in/lbs	ASTM D-2794
Compressive Strength @ 7 days*	7,000 psi	ASTM D-695
Tensile Strength*	1,800 psi	ASTM D-638
Ultimate Compressive Strength*	12,000 psi	ASTM D-695
Flexural Strength*	3,500 psi	ASTM D-293
Aggregate	Hard, angular aggregate, primarily bauxite and granite	
Primer	Cono/Weld 501	
Resin Part B	Biphenol Type A epoxy	
Hardener Part A	Polyamido amine	
Shelf Life	1 year in unopened containers	

*Minimum

TABLE 11

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 Flexolith	8-10	12	12-14	12	45	42	30	15
Poly-Carb Flexogrid	10	11	14	11	40	53	30	21
Sand Epoxy	14	11	14	10	38	42	34	35
Mortar System								
Cono/Crete 101	20	23			33	29		
Cono/Weld 501 Primer					200	116		