SILANE PENETRATING WATERPROOFING SEALERS

Final Report
November 1996

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16. ABSTRACT

The Oklahoma Department of Transportation has been applying silane penetrating water sealers since the late 1970's to prevent the intrusion of chloride contaminated water in bridge decks. This contaminated moisture causes severe corrosion in reinforcing steel and costly damage to the bridge deck.

To determine how silanes perform in the field, Research, Development and Technology Transfer established an evaluation plan. The primary objectives of this study were to monitor the chloride ion content and corrosion activity in the top mat of reinforcing steel and to evaluate the performance of Portland cement penetrating sealers over five years. Ten bridges treated with silanes were selected for this study along with one untreated bridge. This report discusses the findings as they pertain to these objectives.

Tests were performed to assess the physical characteristics of the bridge deck over time and ascertain the presence of silanes years after application. In order to obtain a true picture of the performance of water penetrating silanes over time, it is necessary to have initial data. There was little initial information recorded at the onset of this evaluation. In short, absence of initial conditions makes it difficult to evaluate the long term performance of silane penetrating sealers.

Since the time of this evaluation, modifications have been made to the specifications and conditions by which silanes may be applied to bridge decks. Continued monitoring of these bridges decks without critical initial information will not yield more reliable results or information that will be applicable to bridges currently treated with silanes.

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SI (METRIC) CONVERSION FACTORS

Approximate Conversions to SI Units					*Approximate Conversions from SI Units*				
Symbol	When you know	Multiply by	To Find	Symbol	Symbol	When you know	Multiply by	To Find	Symbol
		LENGTH					LENGTH		
in	inches	25.40	millimeters	mm	mm	millimeters	0.0394	inches	in
ft	feet	0.3048	meters	m	m	meters	3.281	feet	ft
yd	yards	0.9144	meters	m	m	meters	1.094	yards	yd
mi	miles	1.609	kilometers	km	km	kilometers	0.6214	miles	mi
		AREA					AREA		
in^2	square inches	645.2	square millimeters	mm	mm^2	square millimeters	0.00155	square inches	in^2
ft^2	square feet	0.0929	square meters	m^2	m^2	square meters	10.764	square feet	ft^2
yd^2	square yards	0.8361	square meters	m^2	m^2	square meters	1.196	square yards	yd^2
ac	acres	0.4047	hectares	ha	ha	hectares	2.471	acres	ac
mi^2	square miles	2.590	square kilometers	km^2	km^2	square kilometers	0.3861	square miles	mi^2
		VOLUME					VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL	mL	milliliters	0.0338	fluid ounces	fl oz
gal	gallons	3.785	liters	L	L	liters	0.2642	gallons	gal
ft^3	cubic feet	0.0283	cubic meters	m^3	m^3	cubic meters	35.315	cubic feet	ft^3
yd^3	cubic yards	0.7645	cubic meters	m^3	m^3	cubic meters	1.308	cubic yards	yd^3
		MASS					MASS		
oz	ounces	28.35	grams	g	g	grams	0.0353	ounces	oz
lb	pounds	0.4536	kilograms	kg	kg	kilograms	2.205	pounds	lb
T	short tons (2000 lb)	0.907	megagrams	Mg	Mg	megagrams	1.1023	short tons (2000 lb)	T
		TEMPERATURE (exact)					TEMPERATURE (exact)		
°F	degrees Fahrenheit	(°F-32)/1.8	degrees Celsius	°C	°C	degrees Celsius	9/5+32	degrees Fahrenheit	°F
		FORCE and PRESSURE or STRESS					FORCE and PRESSURE or STRESS		
lbf	poundforce	4.448	Newtons	N	N	Newtons	0.2248	poundforce	lbf
lbf/in^2	poundforce per square inch	6.895	kilopascals	kPa	kPa	kilopascals	0.1450	poundforce per square inch	lbf/in^2

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Executive Summary

The Oklahoma Department of Transportation (ODOT) has been applying silane penetrating water sealers since the late 1970's to prevent the intrusion of chloride contaminated water in bridge decks. This contaminated moisture causes severe corrosion in reinforcing steel and costly damage to the bridge deck.

In order to determine how silanes perform in the field, Research, Development and Technology Transfer established an evaluation plan. The primary objectives of this study were to monitor the chloride ion content and corrosion activity in the top mat of reinforcing steel and to evaluate the performance of Portland cement penetrating sealers over five years. Ten bridges treated with silanes were selected for this study along with one untreated bridge. This report discusses the findings as they pertain to these objectives.

Electrical half cell potential, chloride analysis, delamination sounding and visual surveys were conducted to measure corrosion activity, chloride levels and the physical condition of the bridge decks. At the end of this evaluation, depth of penetration and forty-eight hour moisture absorption tests were performed to ascertain the presence of silanes in concrete.

Testing was not performed on each bridge deck every year of this evaluation and some of the data collected is inconsistent. From the data available at the end of this study, the chloride ion content levels were low for each bridge. In addition, depth of penetration testing revealed that silanes were still present in concrete more than ten years after application.

In order to obtain a true picture of the performance of water penetrating silanes over time, it is necessary to have initial data and a record of the preexisting conditions on each bridge deck as well as consistent testing. There was little information recorded at the onset of this evaluation. Only the initial chloride content recorded prior to silane treatment.

Since the time of this evaluation, significant changes have been made to ODOT specifications with respect to silane application. Currently, bridge decks are treated with silanes using seasonal constraints. Further research based on data from these bridges will not reveal information that will be applicable in most cases to bridges currently treated with silanes since practices have updated.

Introduction

The Oklahoma Department of Transportation (ODOT) has been using silane chemical water and chloride repellent agents for concrete since the late 1970's. Moisture and salt cause severe corrosion in reinforcing steel and damage to bridge decks. Silanes penetrate concrete and form a waterproof seal that impedes moisture seepage in concrete structures. Hindering these elements should extend the bridge life and reduce maintenance costs.

Silane Chemical Protection of Bridge Decks, written by Mitchell D. Smith in 1986, and published by ODOT, details the chemical properties of silanes and the application of these products to nine bridges and a control bridge that was not treated with a silane. The ODOT Research, Development and Technology Transfer observed these bridges from 1989 to 1993 and the control bridge treated in Pontotoc County, Oklahoma.

These bridges were monitored to accomplish the following objectives:

1. To detect corrosion activity in the top mat of reinforcing steel.
2. To measure the chloride ion content of the concrete at the level of the top mat of reinforcing steel.
3. To evaluate the general condition of the bridge deck.
4. To determine the performance of the Portland cement penetrating sealers.

This report discusses the results of the field data obtained from 1989 until 1993 as they pertain to these objectives.

Background

Silanes

Organosilanes, or silanes, are a group of silicon hydrides with the general chemical formula SiH. They are isostructural with organic hydrocarbons; a silicon atom replaces a carbon atom.

The products used in this field study are Chemtrete BSM, Sil-Act ATS 42, and Hydrozo Clear 30 M. Dynamit Nobel of America, Advanced Chemical Technologies and Hydrozo Coatings Company market and manufacture these products respectively. Each of these products contains a solution whose primary genetic material is isobutyl trimethoxy silane. This is the active substance that makes up forty percent of the waterproofing solution. The isobutyl trimethoxy silane is dissolved in a solvent of anhydrous alcohol to make up the rest of the solution.

Deck Preparation and Silane Application

Prior to silane application, surfaces were prepared using one of the following methods: sand blasting, hot water pressure washing, high pressure cold water washing or steam cleaning, then allowed to dry. The chemicals are applied to bridges using a hand held spray wand or low pressure airless spray equipment fitted with fan spray nozzles that have been adjusted to accommodate wet spray conditions. Silanes penetrate concrete surfaces in approximately one hour depending on weather conditions.

The majority of the bridges used in this study were treated with silanes during the 1980's. One bridge in Rogers County was treated in 1977. The method employed to clean the decks in this study was not documented. Table 1 lists the year of construction and silane application as well as the the name of silane product used for each bridge deck. Four bridges were treated within a year after construction. The remaining six were treated more than three years after construction.

Since silanes were applied to these test bridges, practices for deck preparation and silane application have changed radically. Weather and seasonal limitations to application times are enforced to ensure favorable surface conditions, silane depth of penetration tests are performed to ascertain the presence of silanes, and 48 hour absorption tests are conducted to determine if silane products meet the ODOT standards. Silanes are currently applied to bridge decks, parapet walls and pier caps.

Project Locations

The bridges under evaluation are located in eight different counties from the northeast to southern regions of Oklahoma. Four are located on the interstate highway system; others are located in less heavily travelled areas. The bridges in Garvin and Pontotoc Counties are adjacent to each other. Figure 1 shows their geographical positions and Table 2 lists the locations of the bridge decks.

Table 1. Bridge Decks.

BRIDGE DECKS SELECTED FOR STUDY AND EVALUATION
1989 - 1994

BRIDGE NUMBER	COUNTY	CONSTRUCTION YEAR	APPLICATION YEAR	PRODUCT
0080 X	CADDO	1984	1985	SIL-ACT
0210 X	CUSTER	1987	1987	HYDROZO
1039 EX	GARVIN	1968	1982	CHEMTRETE BSM
1039 WX	GARVIN	1968	1982	CHEMTRETE BSM
0292 NX	MUSKOGEE	1972	1983	CHEMTRETE BSM
0233 NX	OKFUSKEE	1984	1985	SIL-ACT
0541 NX	OKLAHOMA	1973	1983	CHEMTRETE BSM
0570 NX	OKLAHOMA	1978	1983	CHEMTRETE BSM
0038 NX	PONTOTOC	1980	CONTROL	
0038 SX	PONTOTOC	1980	1981	CHEMTRETE BSM
0281 WX	ROGERS	1974	1977	CHEMTRETE BSM

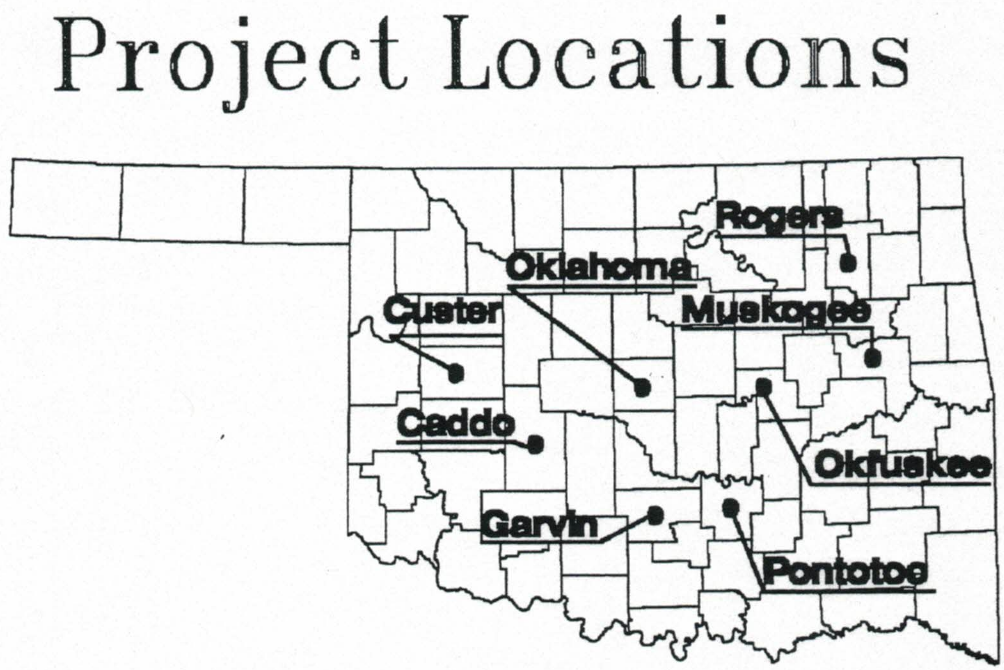

Figure 1. Project Locations.

Table 2. Geographical Location of Bridges.

Geographical Location of Bridges

BRIDGE	COUNTY	LOCATION
0080X	CADDO	SH 137: 1 mile north of Cogar
0210X	CUSTER	SH 183: 1 mile north of Arapaho
1039EX	GARVIN	I-35: Over SH 29
1039WX	GARVIN	I-35: Over SH 29
0292NX	MUSKOGEE	US 62: 0.5 miles east of SH 26
0233NX	OKFUSKEE	I-40: over North Canadian River
0541NX	OKLAHOMA	US 66: over Grand Blvd. in Oklahoma City
0571NX	OKLAHOMA	I-44: over Belle Isle in Oklahoma City
0038NX	PONTOTOC	SH 3: 0.4miles east of SH1 in Ada
0038SX	PONTOTOC	SH 3: 0.4miles east of SH1 in Ada
0281WX	ROGERS	SH 167: over Bird Creek

Testing Procedures

Since silanes impede chloride intrusion, tests were used to measure corrosion activity and chloride levels in the bridge deck. These tests also verify the presence of silanes in concrete and illustrate visual changes occurring on the bridge deck. All tests were performed and will be presented in the customary US units. They are listed below:

- Electrical Half Cell Potential Survey
- Chloride Analysis Survey
- Depth of Penetration Test
- Forty-eight Hour Absorption Test
- Delamination Sounding or Chain Drag Survey
- Visual Inspection Survey.

The electrical half-cell potential of the reinforcing steel in the concrete is measured using the ASTM C 876 testing standard and results are recorded in millivolts (mV). This data is used to determine the probability of corrosion activity in the bridge deck.

The chloride analysis survey was conducted following the AASHTO T260 testing procedure. Thirteen millimeter (0.5 inch) diameter holes are cut into the deck 13 millimeters (0.5 inches) above and 13 millimeters (0.5 inches) below the location of reinforcing steel. Samples are then taken to the ODOT Materials Division for evaluation. Results of this test yield the chloride ion content of the concrete in kilograms per cubic meter (pounds per cubic yard). This data is used to measure the chloride content present in the top mat of reinforcing steel.

Cores are cut and retrieved from the bridge decks to ascertain the presence of silanes. Laboratory testing measures the depth of silane penetration and the percentage of water absorption in the cores during a 48 hour period. These tests are conducted in the ODOT Materials Division in accordance with ODOT OHD L39 testing specifications.

Areas of delamination are located by dragging several chains back and forth across the bridge deck in the chain drag survey. Delaminated areas are recorded in square meters (square feet). These areas are noted in the visual inspection survey. Procedures are outlined in the ASTM designation D 4508.

Finally, a visual inspection is made of each structure to identify surface damage and defects such as cracking, scaling, or spalling. Abnormalities are noted in the survey report diagrams and on film wherever possible.

Discussion and Analysis of Data

Table 3 lists a summary of testing information. Grids marked indicate the type of test and year that each was performed. Most tests were performed at least two different years on each bridge deck. Bridges in Oklahoma County were tested once. The only information recorded are readings at the time of application and in 1989. The bridges in Muskogee, Okfuskee, Pontotoc and Rogers Counties were tested most frequently and produce the most information. Test results and observations are noted under the appropriate heading in the sections that follow. Visual and delamination surveys were performed each year that half cell surveys were conducted unless otherwise indicated in this text.

The original nine bridges that were selected for examination were initially tested for chloride ion content and corrosion. At the onset of this evaluation, there were a number of initial values such as depth of silane penetration and 48 hour moisture absorption that were not documented. The 48 hour moisture absorption test measures the chemical's ability to repel chloride contaminated moisture. Changes in penetration depths determine if silanes penetrate concrete surfaces at greater depths or leach out over time. Initial, intermediate and final results of these tests are essential in determining how silanes behave over time. Without these preliminary values, it is difficult to establish a base line for comparison at a given time after the bridge decks were treated. Depth of penetration and 48 hour absorption tests were performed during the last year of this study.

Electrical Half Cell Potential Survey

Electrical half cell readings were taken on each bridge deck in the years indicated in Table 3. Readings that are more positive than -200 mV indicate that there is a greater than 90% probability that no reinforcing steel corrosion is occurring in the test area. For readings that fall between the -200 mV and -350 mV range, the probability that there is corrosion occurring in the area is not certain. Any reading that is more negative than -350 mV has a probability of greater than 90% that corrosion is in the area of the reading. For purposes of this evaluation, the readings that are most significant in this survey are those that are more negative than -350 mV.

Table 4 lists corrosion readings recorded in the field that were more negative than -350 mV. Using the most recent information available for each bridge, four out of ten bridges are showing some signs of corrosion. However, corrosion activity is present on less than 11 percent of the total bridge deck area for each of these bridges.

There are some erratic readings for the Okfuskee bridge deck that indicate increased corrosion activity for three of the four years tested. The most recent test results show no signs of corrosion activity.

Neither the control nor treated bridge in Pontotoc County is showing signs of corrosion. A complete graphical representation of the annual readings for each bridge is located in Appendix A.

Table 3. Summary of Testing Information.

SUMMARY OF TESTING INFORMATION

BRIDGE	DATA COLLECTED																			
	Half Cell					Depth of Penetration					Chloride Ion Content					48 Hour Absorption				
	89	90	91	92	93	89	90	91	92	93	89	90	91	92	93	89	90	91	92	93
CADDO	●	●	●		●						■	■	■							
CUSTER	●	●	●		●						■	■								
GARVINEX	●				●					◆	■									
GARVINWX	●				●					◆	■									*
MUSKOGEE	●	●	●	●	●					◆	■	■	■	■						*
OKFUSKEE	●	●	●		●					◆	■	■								*
OKLAHOMA1N	●										■									
OKLAHOMA2N	●										■									
CONTROL	●	●	●		●					◆	■	■	■							*
PONTOTOC	●	●	●		●					◆	■	■	■							*
ROGERS	●	●	●								■	■	■	■						

The table lists the tests that were performed on each bridge deck and the year that the information was collected.

Table 4. Half Cell Corrosion.

HALF CELL CORROSION READINGS

Readings More Negative than -350 Millivolts

BRIDGE	PERCENTAGE OF BRIDGE DECK CORROSION				
	1989	1990	1991	1992	1993
CADDO	0.0	0.0	0.0		10.5
CUSTER	0.0	0.0	0.0		0.0
GARVINEX	0.0				0.0
GARVINWX	0.0				0.0
MUSKOGEE	0.9	0.4	0.4	2.5	2.9
OKFUSKEE	1.9	58.5	44.3		0.0
OKLAHOMA1N	7.9				
OKLAHOMA2N	0.0				
CONTROL	0.0	0.0	0.0		0.0
PONTOTOC	0.0	0.0	0.0		0.0
ROGERS	0.0	0.1	0.6		

Blank spaces indicate that no readings were taken that year.

Chloride Content

Corrosion in bridge decks is usually an indication that chlorides are present. In general, when chloride ion content readings are less than 1.5 kilograms per cubic meter (2.5 pounds per cubic yard), a bridge deck is in fair condition; that is, corrosion levels are low.

Table 5 lists the chloride ion content readings from each deck for the years that data was collected. The values are presented in customary non-metric units. Initial readings in column two of this table are the chloride ion content levels taken the year that the bridge decks were treated. The year of application is listed in Table 1.

With the exception of the bridge deck in Custer County, initial chloride samples were taken from each bridge deck from arbitrarily selected areas. When samples were retrieved from 1989 until 1993, they were taken from areas on the deck that registered a high, low, or average half cell reading for the deck. Samples were not always taken from the same areas each year since the electrical half cell readings sometimes fluctuated. At least two samples were taken from each deck for an average reading. In some instances, up to five samples were taken from a deck for testing.

The bridge decks that were treated with the sealers show no significant signs of chloride intrusion; but, this is also true of the control bridge. All of the readings taken between 1991 and 1992 show a decrease in the average chloride ion content. With the exception of these years, the readings do not show a general trend, higher, lower, or the same, in chloride levels from one year to the next year. This could be a result of random sampling.

Figure 2 shows the layout of a bridge deck in Custer County with information from the half cell results and chloride sampling locations. This figure is provided as a sample of this data.

Table 5. **Chloride Ion Content Readings.**

AVERAGE CHLORIDE CONTENT
(1989 - 1992)

BRIDGE	INITIAL	1989	1990	1991	1992
	lbs./yd³	lbs./yd³	lbs./yd³	lbs./yd³	lbs./yd³
CADDO	0.5247	0.34020	0.43505	0.13900	
CUSTER	❖	0.53209	0.32343		
GARVINEX	0.3658	0.21453			
GARVINWX	0.6657	0.20098			
MUSKOGEE	1.1618	0.34693	1.98771	0.23800	0.31973
OKFUSKEE	0.7758	0.35755	0.21415		
OKLAHOMA1N	0.812	0.32745			
OKLAHOMA2N	0.3227	0.41188			
CONTROL	0.5469	0.27185	0.36688	0.19795	
PONTOTOC	0.4992	0.34863	0.29405	0.19288	
ROGERS	0.9794	1.13943	0.24788	0.13308	0.41608

❖ An initial reading was not taken from this bridge deck.

ELECTRICAL HALF CELL POTENTIAL GRID OF CUSTER BRIDGE DECK
1989

	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0	10	2	1	2	2	7	2	1	0	2	1	4	0	1	1	8	0	1	1	1	4
2½	5	4	2	2	1	6	4	1	0	1	0	0	2	2	1	3	6	4	7	5	6
5	9	3	3	5	8	***5***	2	2	3	1	2	2	6	2	2	5	5	11	9	5	9
10	18	11	10	10	11	13	7	7	5	5	6	7	7	7	7	8	10	11	8	11	13
15	21	12	11	9	9	11	7	8	6	7	8	8	11	10	9	***10***	11	10	8	11	8
20	23	15	14	10	13	9	9	11	11	8	10	8	14	12	11	11	13	11	11	12	11
25	19	15	12	11	18	***13***	10	11	9	8	10	8	11	10	11	13	10	12	12	14	13
30	14	15	9	9	7	14	10	9	7	7	8	8	12	9	8	10	6	10	15	17	10
35	4	9	7	5	14	7	2	1	2	2	0	1	12	4	3	***11***	3	4	6	5	9
37½	9	4	7	2	10	1	4	2	4	2	3	2	1	3	2	7	4	3	6	4	0
40	5	4	3	3	2	5	6	1	4	13	5	1	10	4	4	5	3	4	3	5	0

The grid shown above illustrates a half cell corrosion survey. The left most and top lines are where the deck is marked off in feet. Readings noted above are taken every five feet on the bridge deck and 2½ feet from the parapet walls. This bridge deck is 100 ft. by 40 ft. The numbers in the grids are recordings taken in the field. The reading at 20 ft. by 40 ft. (shaded area) is 11. This means that the area surrounding this section has an electrical half cell potential reading of -110 millivolts. The numbers that are in italics and bold on the chart (e.g., ***13*** at 25 feet by 25 feet) are the electrical half cell potential readings where chloride samples were taken.

Figure 2. Sample Bridge Deck Grid.: Custer Bridge Deck.

Depth of Penetration Testing and Moisture Absorption

At least two cores were taken from bridges in Garvin, Muskogee, Okfuskee and Pontotoc Counties in 1993 for indications of silanes. One core is cut, broken, or split across the diameter and dipped in a tinted solution. Areas that have been penetrated by the silanes retain their original color. The rest of the core retains the color of the dye used in the testing procedure. Then the core is photographed and measured with a planimeter to determine the depth of penetration. The second core is used to measure the 48 hour water absorption.

Currently, the minimum acceptable depth of penetration for newly constructed bridge decks treated with silanes is 3.85 millimeters (0.15 inches). Little information is available on expected or documented changes in the depth of silane penetration over time. Without initial and intermediate values, it is not possible to determine changes in penetration depths that have occurred since the time of application.

Figure 3 shows the depth of penetration of the cores. On the graph, "PENET MEAN" is the average depth of penetration for each core measured in inches. Since the control bridge was not treated, the depth of silane penetration is zero. Other cores had penetration depths ranging from 2.55 to 11.45 millimeters (0.10 to 0.45 inches) indicating that silanes were present in 1993.

Absorption is the primary indicator of the amount of water ingress into concrete. The 48 hour water absorption test is administered by taking a core sample and coating it with paraffin wax. The top of the core that was treated with the silane is left uncoated. The core is submerged in water for 48 hours. Cores are weighed without wax, with wax and after sitting in water to determine the percent of water absorption.

The current ODOT standard for the maximum amount of water acceptable at the time of silane application to new bridge decks is 1%. Unfortunately, the water absorption test results at the time of silane application are not available and like the depth of penetration tests, little information is available on changes in the water absorption over time although an increase in the percentage of moisture absorbed may be expected.

Figure 4 presents the results of this test. The numbers at the top of each bar are the percent of moisture absorption absorbed by each core. None of the cores treated with a silane met the current initial standard for maximum water absorption when tested in 1993. The bridge deck that was not treated, the control bridge, had the lowest water absorption. Laboratory results are given Appendix B.

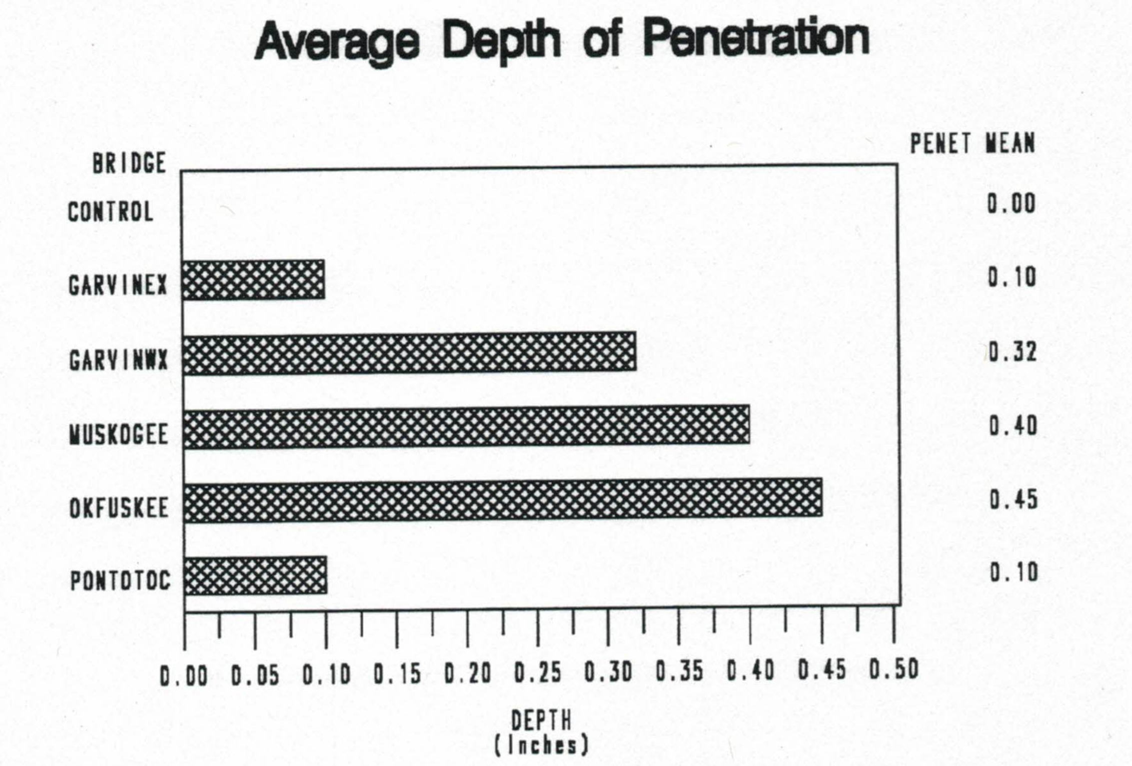

Figure 3. Depth of Penetration.

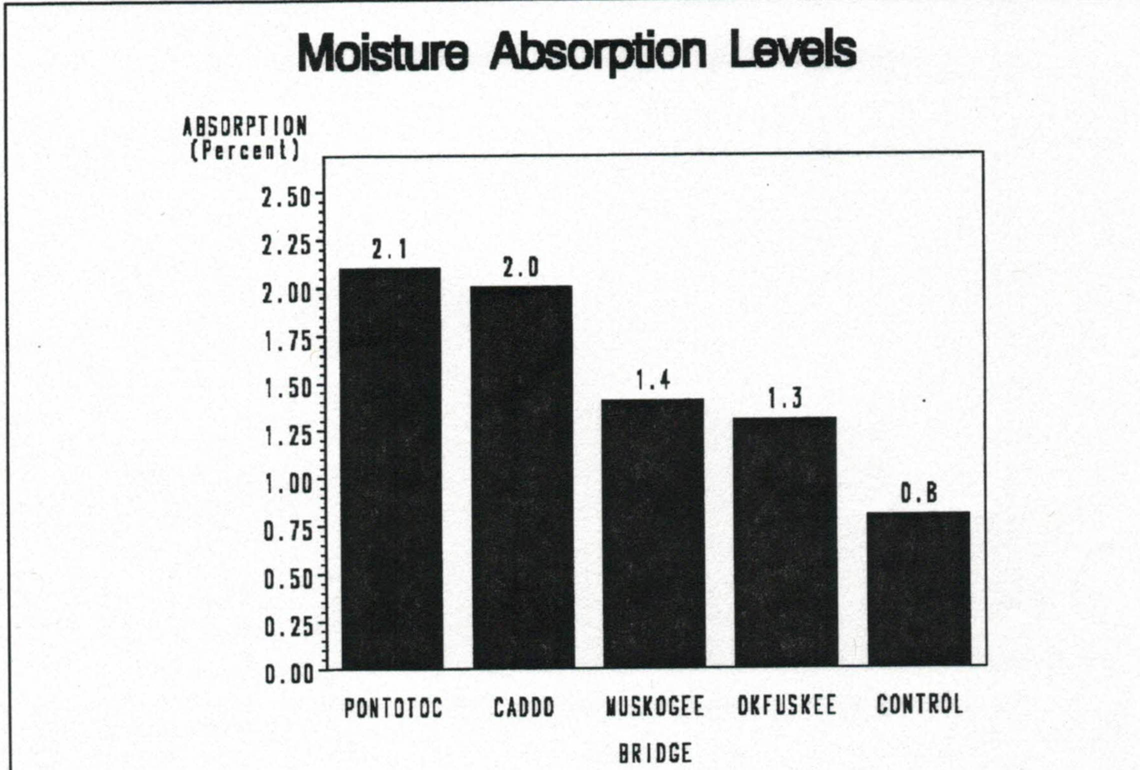

Figure 4. Moisture Absorption.

Delamination Sounding and Visual Surveys

The delamination sounding and visual surveys show the physical and surface condition of the bridge decks as they are noted in the field. Many times surface abnormalities are signs of deck corrosion or the result of chloride intrusion. These surveys were taken each time an electrical half cell potential survey was performed. Survey notes on Tables 6 and 7 are the results of the most recent surveys taken.

Normally, delaminations are outlined on the bridge deck then noted on the visual survey. There is conflicting information in some of the survey notes. The GarvinWX and Oklahoma2N bridges visual survey notes indicate delaminations on the bridge deck, but there is no record of these from the chain drag survey.

The delaminations noted on decks GarvinEX and Oklahoma2N were minor. They accounted for less than one percent of the total bridge deck area. The Muskogee bridge had delaminations on five percent of the deck in 1993.

The Rogers bridge had as much as twenty-two percent delamination in 1990, the last year of evaluation for this deck. Electrical half cell readings indicate little corrosion on this bridge deck and chloride readings are low.

As expected, the older bridges: GarvinEX, GarvinWX and Rogers have more surface flaws than the more recently constructed bridges.

Table 6. Delamination Notes.

DELAMINATIONS ON BRIDGE DECKS

BRIDGE	PERCENTAGE OF BRIDGE DECK DELAMINATION				
	1989	1990	1991	1992	1993
CADDO	0.0	0.0	0.0		0.0
CUSTER	0.0	0.0	0.0		0.0
GARVINEX	0.0				0.0
✓ GARVINWX	0.0				0.0
MUSKOGEE	0.0	0.6	1.0	1.0	5.0
OKFUSKEE	0.0	0.0	0.0		0.0
OKLAHOMA1N	0.0				
✓ OKLAHOMA2N	0.0				
CONTROL	0.0	0.0	0.0	0.0	0.0
PONTOTOC	0.0	0.0	0.0	0.0	0.0
ROGERS	10.0	22.5			

✓ Written information and field reports suggest that there are delaminations on the decks; however, delaminations are not indicated on the visual surveys.

Table 7. **Visual Survey Summary.**

VISUAL SURVEY RESULTS

BRIDGE	VISUAL INSPECTION NOTES	LAST EVALUATION
CADDO	Excellent condition; some scaling present. (5)	1993
CUSTER	Excellent condition; 2 patched areas. (5)	1993
GARVINEX	Cracking and ponding present. Exposed steel present. (3)	1993
GARVINWX	Delaminations; tire wear, ponding, exposed steel and cracking. (3)	1993
MUSKOGEE	Delaminations. (4)	1993
OKFUSKEE	Scaling. (3)	1993
OKLAHOMA1N	Transverse cracking, scaling, 1 large crack. (3)	1989
OKLAHOMA2N	Delaminations. (2)	1989
CONTROL	Minor, random, shallow, narrow cracks; good condition. (4)	1993
PONTOTOC	Minor scattered cracks; good condition. (4)	1993
ROGERS	Delaminations, cracking, exposed steel. (2)	1991

5: Excellent 4: Good 3: Fair 2: Bad 1: Poor

Conclusions

- The untreated bridge deck in this study is performing at the same level or better than treated bridge decks.
- Corrosion activity is relatively low in these bridge decks.
- Chloride levels are low.
- Trends could not be established for the test bridges based on chloride ion content testing.
- When comparing chloride ion content results from treated and untreated bridge decks they neither support nor refute the claim that silanes prevent the ingress of chlorides in concrete over long periods of time.
- Silanes are still present in bridge decks at depths of 11.45 millimeters (0.45 inches) eight years after application.
- Critical performance values, depth of silane penetration and 48 hour moisture absorption levels, can not be determined since the initial conditions were not documented.

Recommendations

Silanes should prevent the ingress of chloride contaminated water into concrete structures. To measure the performance of these products, at a minimum, it is necessary to measure the chloride ion content and the 48 hour absorption. To determine how silanes behave over time, initial, intermediate and final depth of penetration results should also be noted for changes in silane depths over time.

In this evaluation, chloride tests were conducted sporadically and samples were taken from random spots on the bridge deck; a trend from this testing could not be established. Vital information regarding initial penetration and absorption results was not obtained. Without these critical values, it is difficult to obtain a complete picture about silane performance.

In addition to not having the preexisting conditions for these decks, only one bridge deck was left untreated. The results from the tests performed indicate that the untreated bridge outperformed bridges treated with silanes. This could mean that silanes are not performing to expected standards or that the control bridge is an exceptional bridge deck. There is not enough evidence to substantiate either claim. The control bridge in this evaluation is possibly the last "new" bridge not treated with a silane product since 1980. Without another untreated deck available to observe, a fair comparison between bridges treated with silanes and those not treated with silanes over time is not possible.

Inconclusive data, the absence of initial information and few controlled situations, do not make for the best possible circumstances to evaluate silanes. Currently, bridges are treated with silanes using seasonal constraints. In most cases, the bridges in this study were treated several years after construction. Continued monitoring and evaluation of these bridge decks will not yield more reliable results than the data presently available to the Research, Development and Technology Transfer without initial information to establish some base line for comparison. Further research of these bridges will not reveal information that will be applicable to bridges treated with silanes after 1980 since practices in application procedures and times have changed drastically. Termination of this project is recommended.

Implementation

The primary objectives of this project were to detect corrosion activity, measure the chloride ion content and evaluate the general condition of each bridge deck and finally determine the performance of penetrating sealers.

While the first three objectives were met, reliable performance data was not forthcoming. Since the time that this evaluation began, application procedures, products and ODOT specifications and standards have changed.

Further research of these particular bridges will not reveal information that will be applicable to bridges treated with silanes after 1980 in Oklahoma. New specifications, procedures, or standards should not be implemented based on the findings of this evaluation.

Appendix A

Figures 1 through 11 illustrate electrical half cell potential readings more negative than -200 mV. The "PCT SUM" heading lists the percentage of the bridge deck with readings corresponding to the values under the "Readings" heading. In Figure 1 for example, 10.5 percent of the bridge deck in 1993 had readings below -300 mV. For the significance of these readings, see the appropriate listing in the previous text.

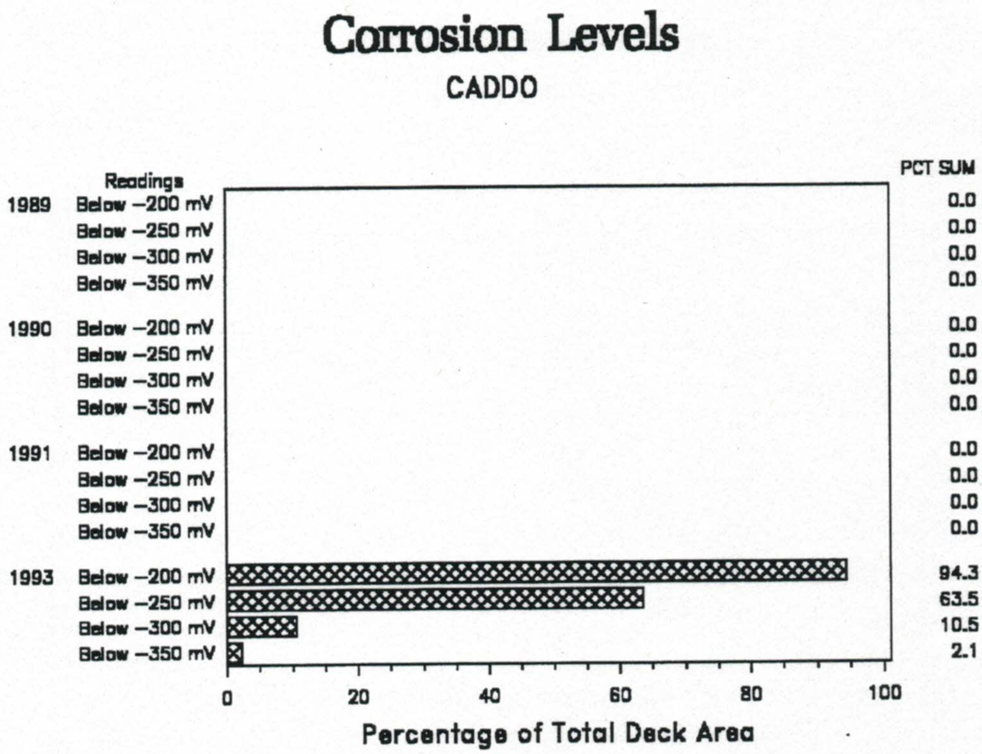

Figure 5. Corrosion Readings: Cado

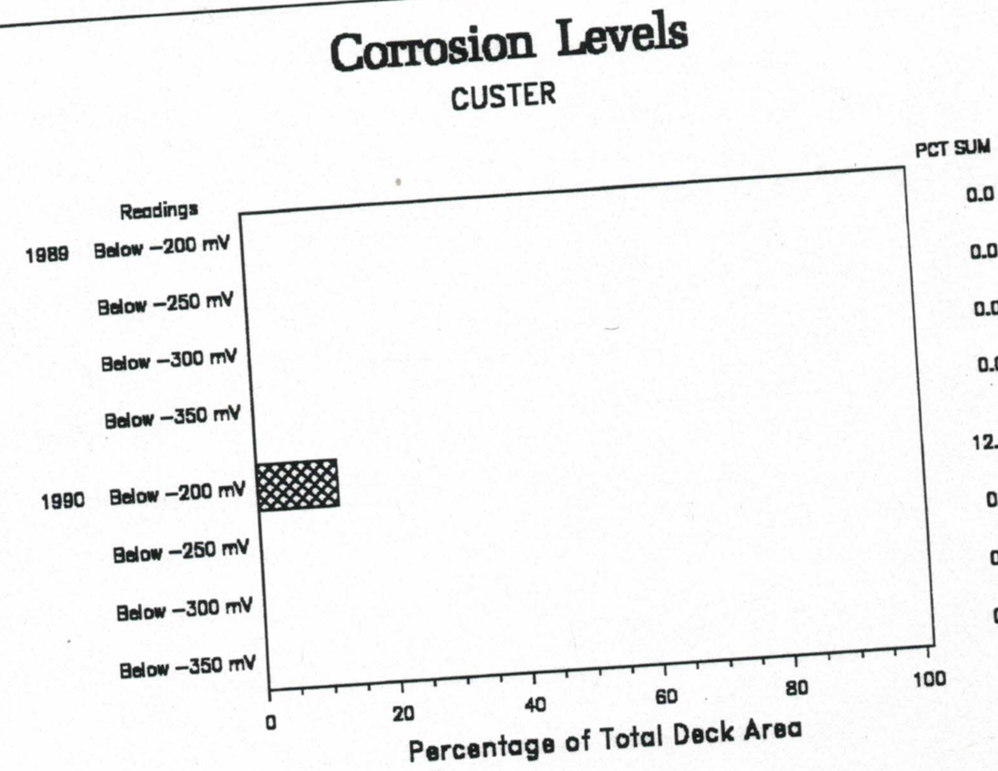

Figure 6. Corrosion Readings: Custer

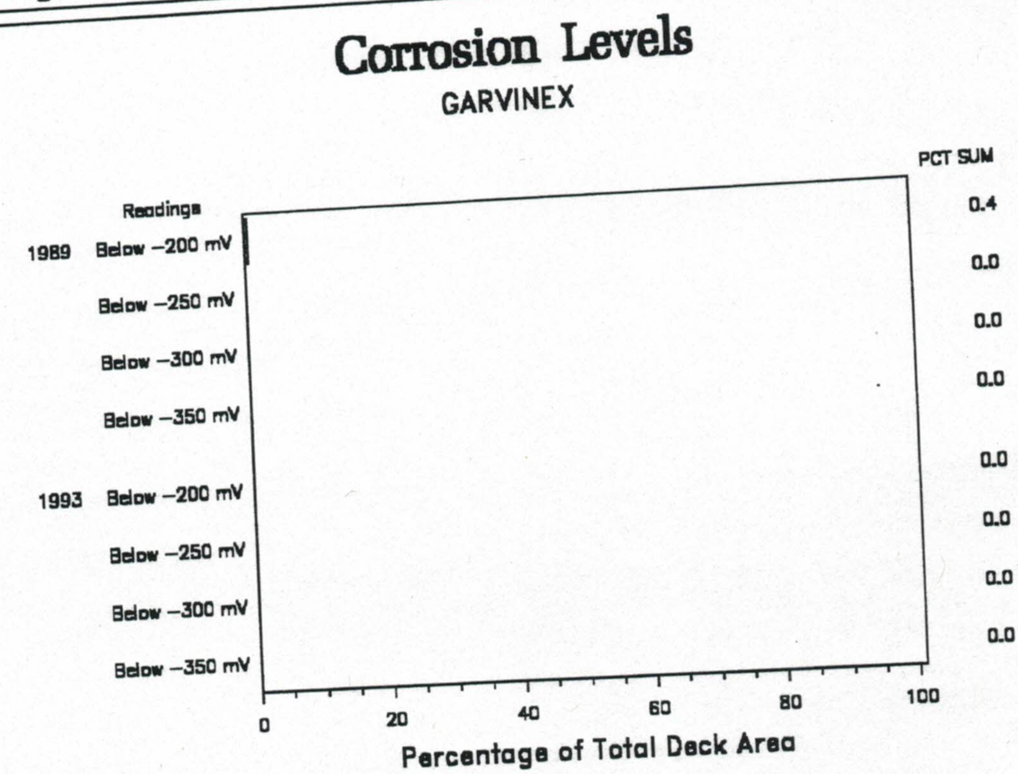

Figure 7. Corrosion Readings: GarvinEX

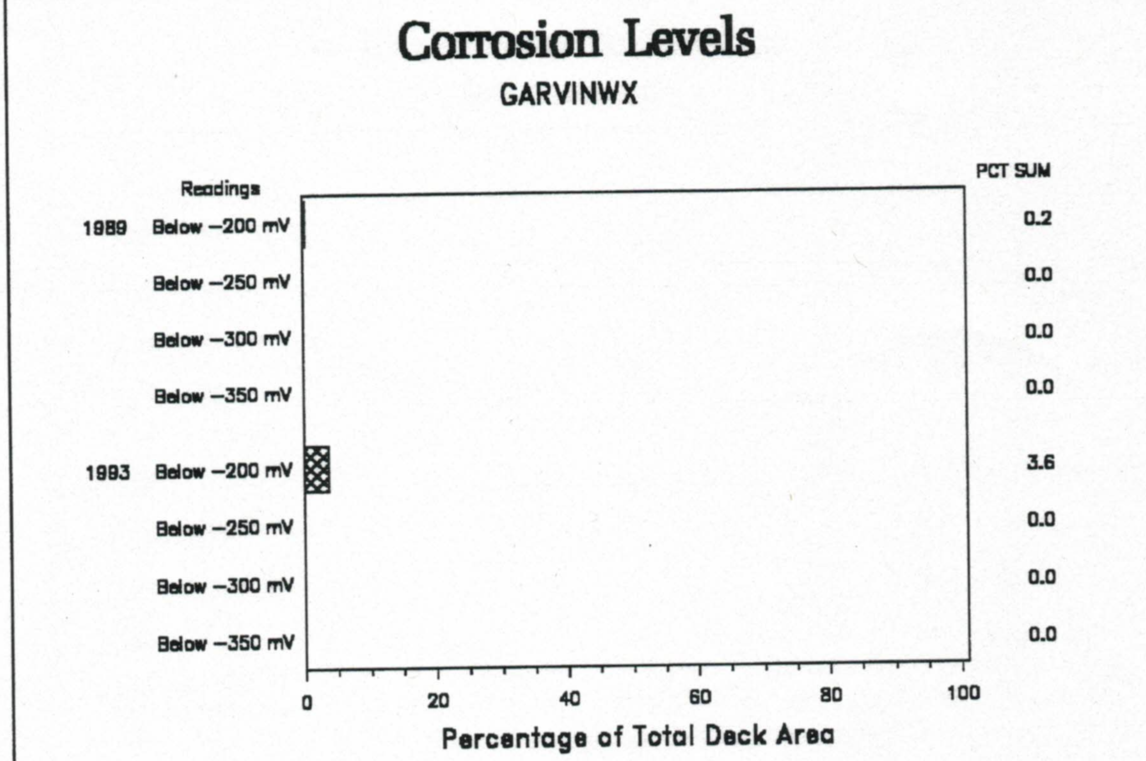

Figure 8. Corrosion Readings: GarvinWX

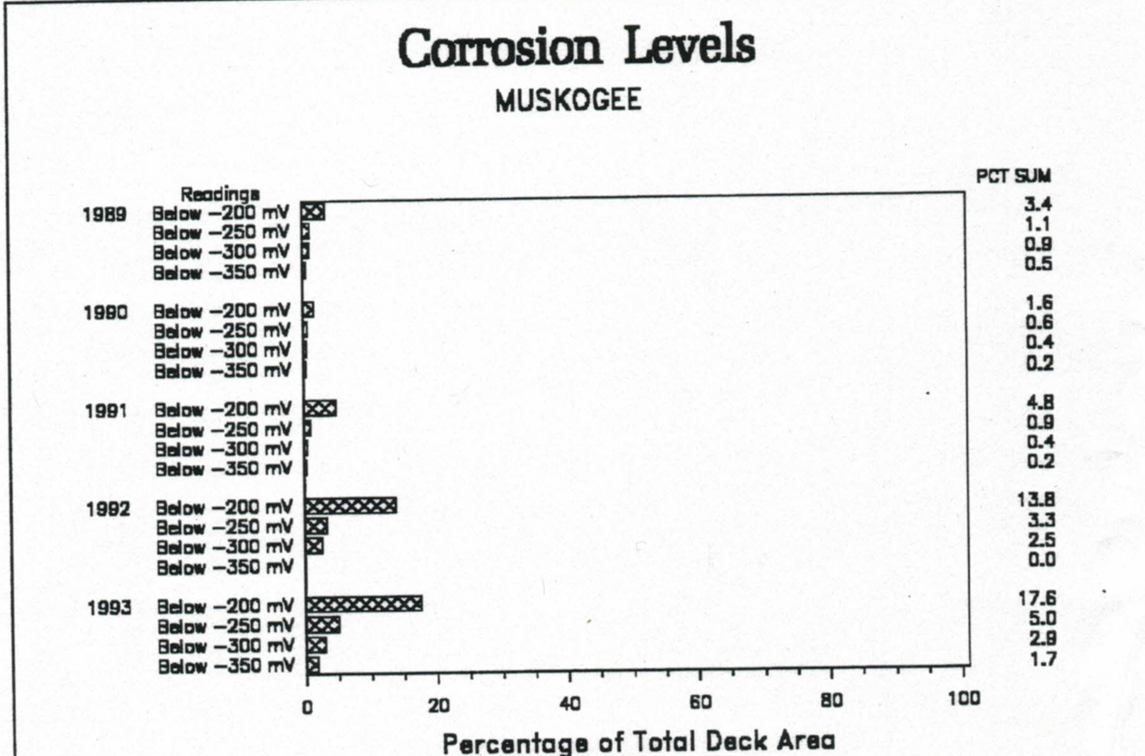

Figure 9. Corrosion Readings: Muskogee

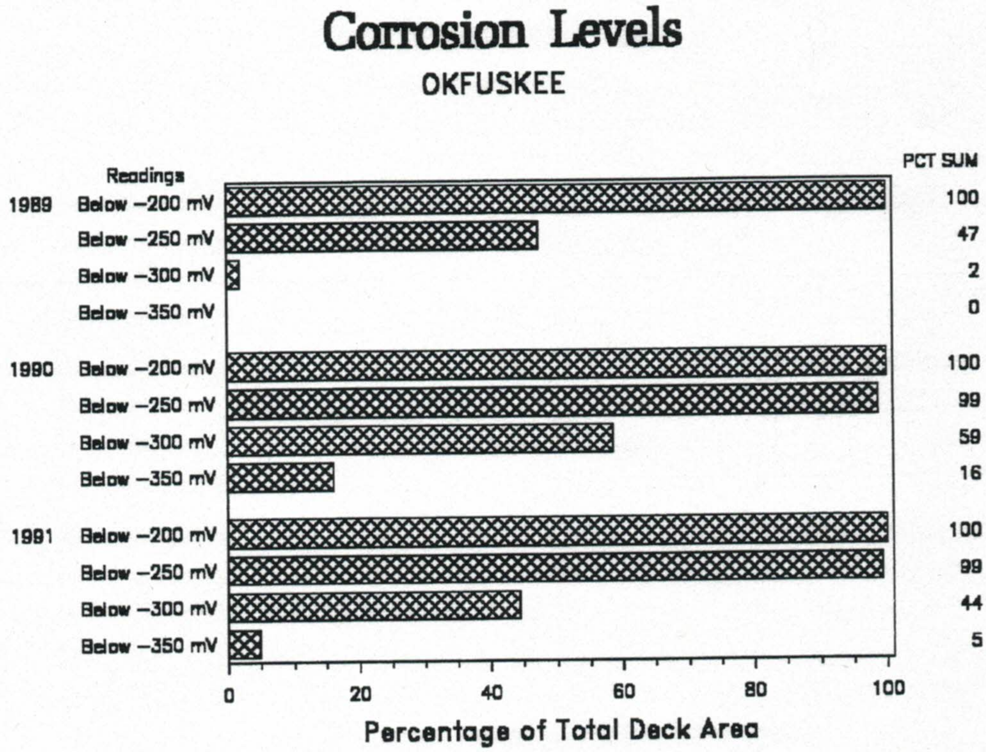

Figure 10. Corrosion Readings: Okfuskee

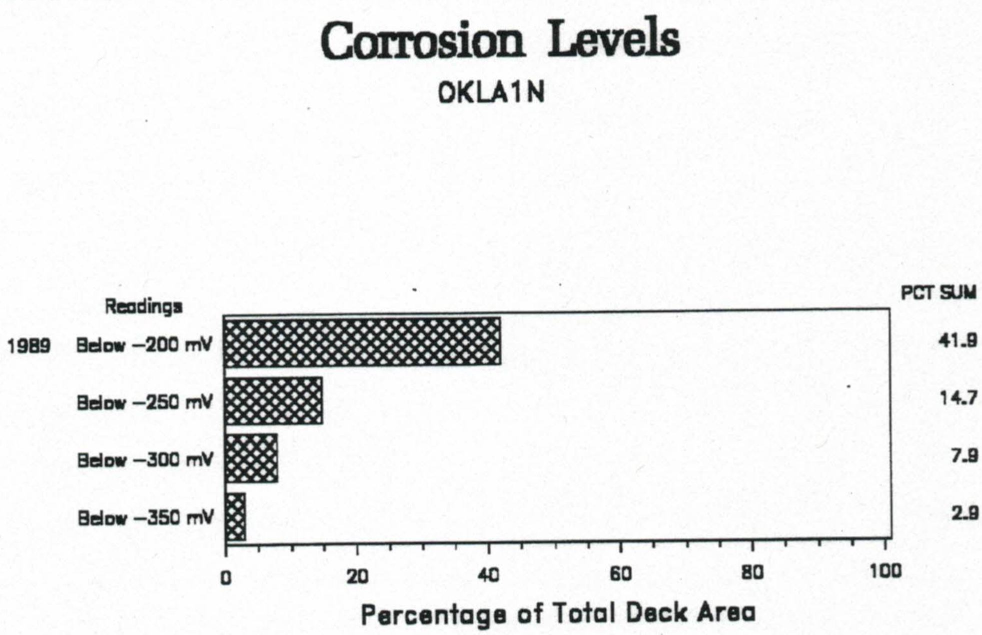

Figure 11. Corrosion Readings: Oklahoma1N

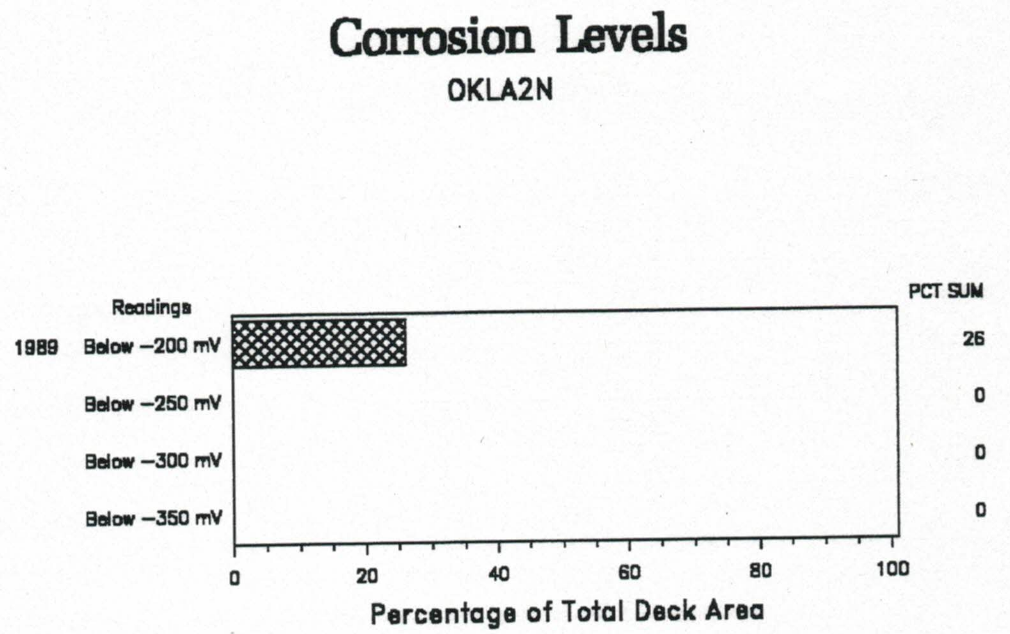

Figure 12. Corrosion Readings: Oklahoma2N

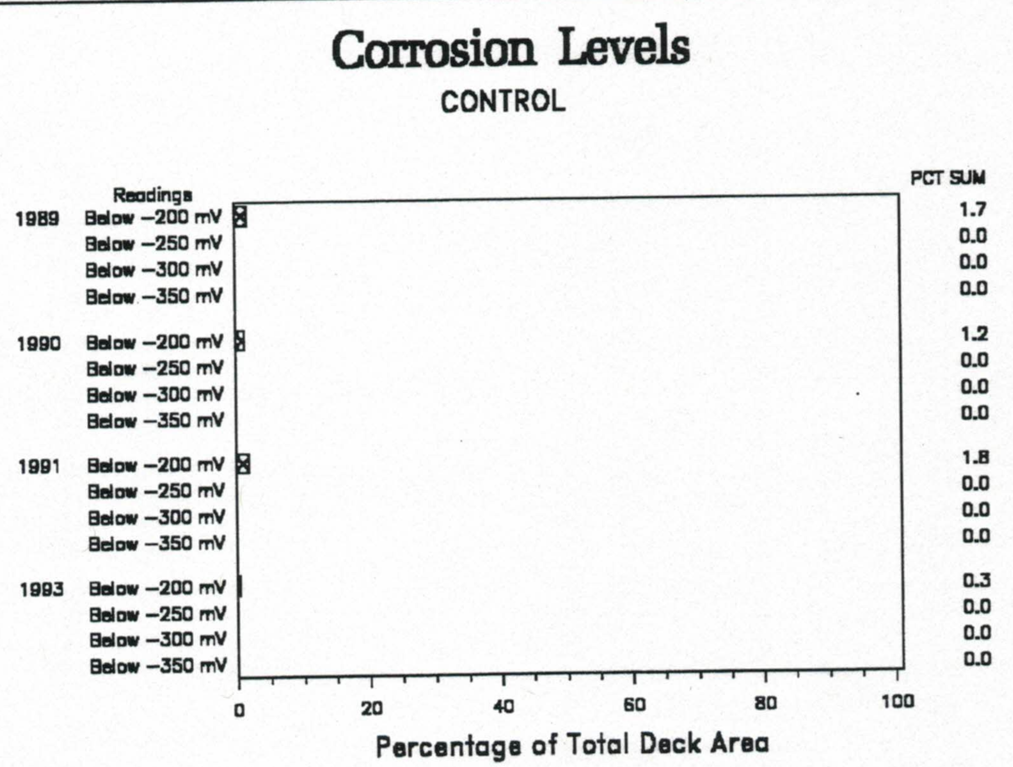

Figure 13. Corrosion Readings: Control

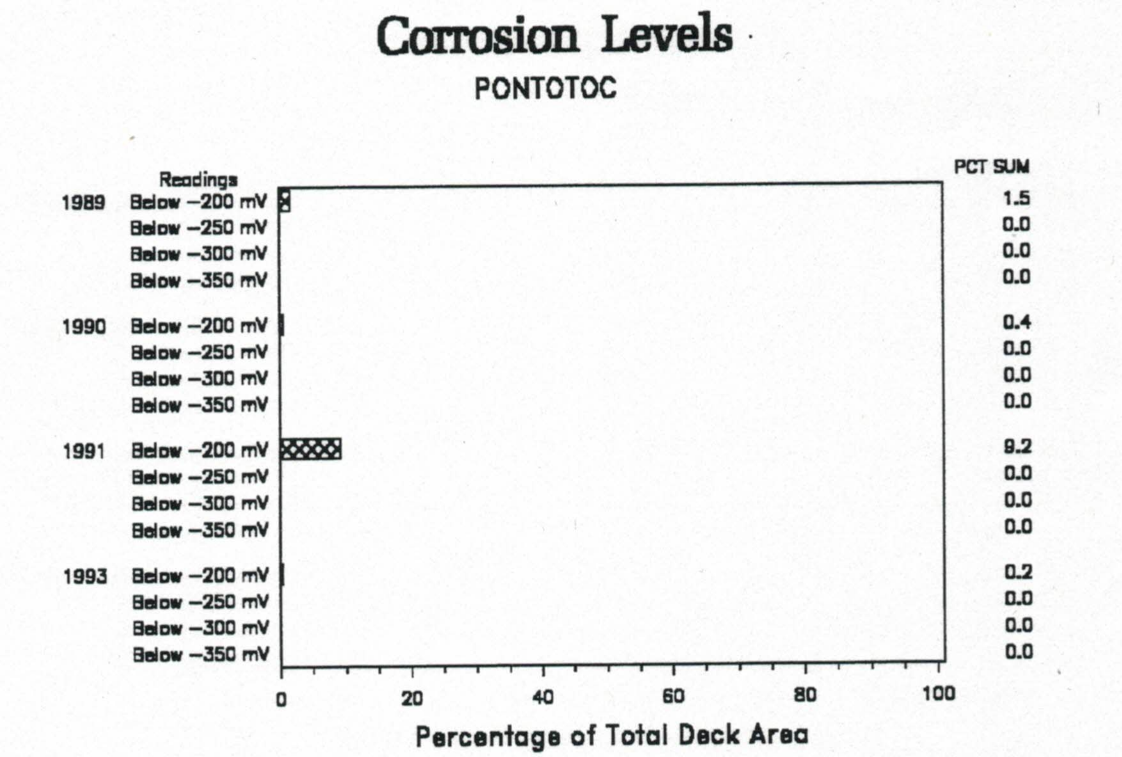

Figure 14. Corrosion Readings: Pontotoc

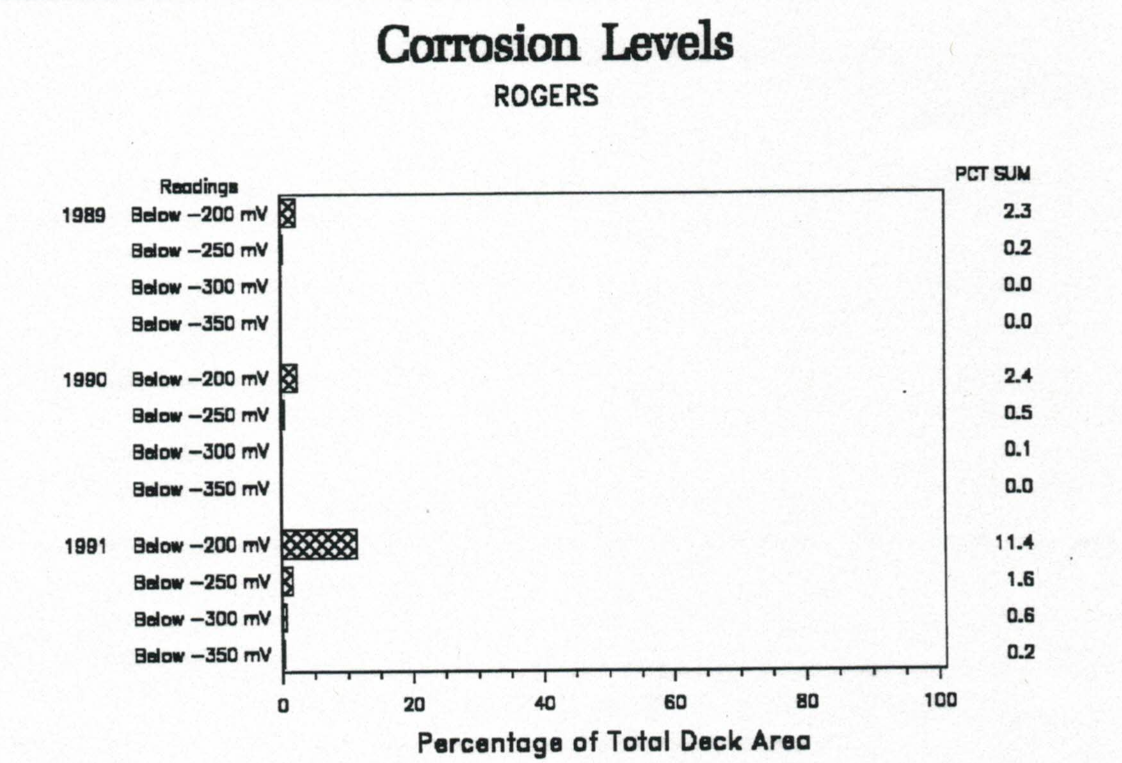

Figure 15. Corrosion Readings: Rogers

Appendix B

Table 1 is a copy of the laboratory results from the 48 hour absorption and depth of penetration tests. Table 2 lists the average depth of penetration for each core retrieved from the bridge deck. The cores were retrieved from the respective bridge decks in 1993.

ML-91 Rev. 8/93

PENETRATING WATER REPELLENT TEST

MAR 2 8 1994

Project No.: INFORMATION ONLY

Report No.

12- 4350 47963

County: VARIOUS

12-352910- 47963

INTO WATER

Material: PENT. WATER REPPELLENT

11:45 3-28-94

Source: SIL-ACT 42 & CHEMTREAT

Core Number	Dry Wt.	Waxed Wt.	Wet Wt.	48 Hr. Absorption	Station
1	1293.2	1350.8	1376.3	2.0 %	GARVIN CO. CHEM TREAT
1	1189.2	1244.2	1260.5	1.4 %	MUSKOGEE CO. " "
1	1099.7	1157.5	1180.6	2.1 %	PONTOTOC CO. SOUTH " "
1	1896.8	1959.4	1973.9	0.8 %	PONTOTOC CO. NORTH CONTROL
1	1753.3	1815.9	1838.9	1.3 %	OKFUSKEE CO. SIL-ACT 42

MAR 3 0 1994

Table 2: Depth of Penetration Test Results

Core No.	Photo Area of Penetration	Photo Width of Penetration	Scale Photo/Actual	Avg. Depth of Penetration	Comments
1X	4.47 IN²	6.75 IN	1.94 : 1	.34"	GARVIN CO. 1X .3
2X	4.61 IN²	7.12 IN	1.94 : 1	.33"	GARVIN CO. 2X
3X	3.71 IN²	6.71 IN	1.98 : 1	.28"	GARVIN CO. 3X
1 E	1.27 IN²	6.75 IN	1.98 : 1	.10"	GARVIN CO. 1E
1 N	NO VISABLE	PENT.	IN PHOTO	OR CORE	PONTOTOC CO. N (CONTROL)
1 S	1.35 IN²	7.00 IN	2.00 : 1	.10"	PONTOTOC CO. S.
1	5.89 IN²	7.39 IN	6.03 : 1	.40"	MUSKOGEE CO.
1	6.33 IN²	7.00 IN	2.00 : 1	.45"	OKFUSKEE CO.

REMARKS:

REPORTED FOR INFORMATION