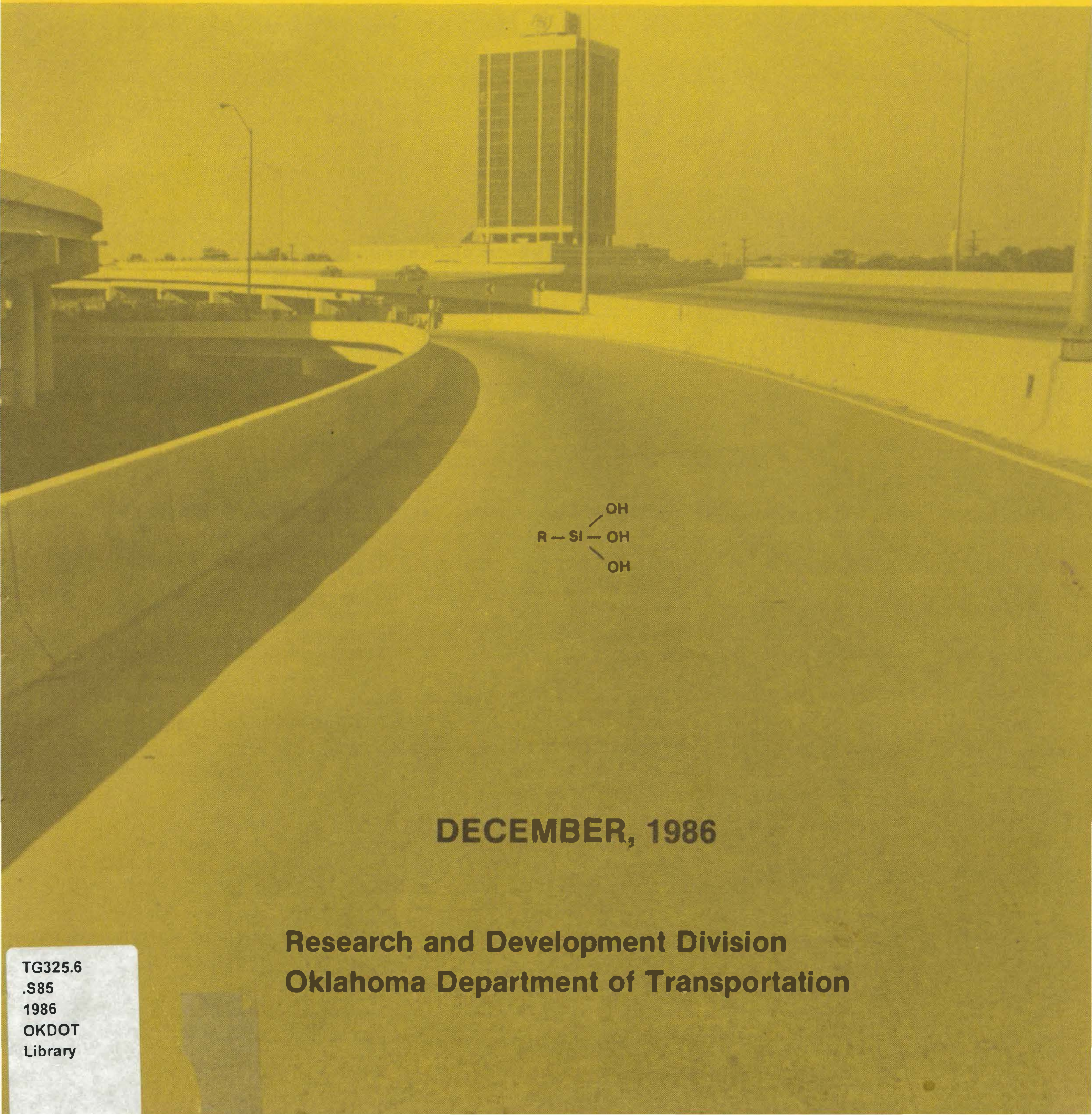
SILANE CHEMICAL PROTECTION OF BRIDGE DECKS



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16. ABSTRACT This report describes the performance of alkyltrialkoxysilane chemical products and their ability to protect bridge structures from moisture, chloride ingression, and corrosion of reinforcing steel.

As a result of the evaluation, the following recommendations are made:

1. The application of silane should be used to protect bridge structures from moisture and chloride ingression, and corrosion of reinforcing steel.

2. The silane treatment should be used on both new and existing, bridge structures in which the chloride content at the rebar depth has not exceeded 2.5 lbs/yd^3, or the corrosion potentials over the bridge deck area numerically do not exceed -350 millivolts.

3. A dry concrete surface is essential for successful application. An application rate of 125 ft^2/gal for horizontal surfaces and 175 ft^2/gal for vertical surfaces is recommended. After application, and the silane has penetrated, water should be applied to assure sufficient moisture for chemical reaction between the silane and concrete.

4. ODOT field testing of the bridge decks selected for the silane performance evaluation should be continued through 1996 to determine the long term performance.

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SILANE CHEMICAL PROTECTION OF BRIDGE DECKS

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EXECUTIVE SUMMARY

The Oklahoma Department of Transportation (ODOT) has been conducting laboratory testing and field evaluation of silane chemical treatment to protect bridge structures against corrosion since 1976.

Two particular silane products: Chem-Trete, manufactured by Dynamit Nobel, and SIL-ACT, manufactured by Advanced Chemical Technologies; have been under study by ODOT. Both contain a solution of 40 percent by weight alkyltrialkoxysilane in an anhydrous alcohol solvent. Laboratory evaluations by ODOT and others have shown that these silane chemical agents significantly reduce moisture and chloride penetration into concrete.

In 1977, ODOT applied a silane product to a bridge deck. Following the application, cores were retrieved and moisture absorption characteristics determined. Test results from the cores indicated the bridge deck was significantly resistant to moisture absorption.

Since 1977, eight more silane treated bridges and one untreated control bridge were used for the performance evaluation of the silane agents. Bridge condition surveys and tests were conducted to measure the amount of corrosion, delamination, scaling, and spalling. Samples were taken to measure the amount of salt ingression.

The following conclusions and recommendations resulted from the evaluation:

(1) On all the silane treated bridge decks evaluated the chloride content at the rebar level remained below 2.5 lbs/yd^3. All had received moderate to heavy salt applications during winter months.

(2) Electrical potential values measured with a Cu/$CuSO_4$ half cell numerically do not exceed the corrosion threshold level of -350 millivolts (-0.35V CSE).

(3) Moisture absorption tests conducted on cores taken from the Bird Creek bridge deck, nine years after treatment, indicated that moisture absorption remained below one percent after 48 hours.

(4) Condition survey results in 1987 indicated no post treatment scaling or spalling present on any of the silane treated bridge decks selected for this study.

(5) The silane does not plug the concrete pores or capillaries, but substantially prevents the chlorides and water from entering. It allows the concrete to breathe and moisture vapor to escape.

(6) Inconvenience to traffic was minimized due to the short application time.

(7) Pavement surface friction was not significantly affected by silane treatment. British Pendulum tests on treated and untreated deck panels averaged 91.3 and 92.6 respectively.

(8) Chemical reaction between silane and concrete leaves the chloride and water repellent hydrocarbon group of

the silane molecule chemically bonded to the silicate structure of the concrete.

(9) A dry concrete surface is essential for successful application. ODOT laboratory tests indicate penetration of the silane is increased 100 percent when applied to a dry rather than a wet surface. An application rate of 125 ft^2/gal for horizontal surfaces and 175 ft^2/gal for vertical surfaces is recommended. After the silane has penetrated, water sprayed on the surface assures sufficient moisture for chemical reaction between the silane and concrete.

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INTRODUCTION

During the past 30 years, the Oklahoma Department of Transportation (ODOT) has vastly improved the state system of roads, highways, and expressways. Nearly 3,000 new bridges have been constructed which make the flow of traffic safer and more efficient.

But, winter rain, snow, and sleet have created serious problems for motorists and maintenance personnel. The application of deicing salt on bridge decks greatly improves driving conditions. At the same time, the salt, along with moisture from melting ice and precipitation, threatens the very life of the concrete bridge structure.

The salt water is absorbed easily by the concrete, creating an environment conducive to corrosion. An electrochemical reaction, similar to that which occurs in an automobile battery, oxidizes the steel reinforcing bars within the concrete bridge deck.

The buildup of corrosion products on the rebars creates tremendous pressure on the surrounding concrete, causing it to crack and spall. Eventually this process, coupled with freeze-thaw and traffic action leads to massive deterioration of the deck.

Repairs are extremely costly and at the same time, very disruptive to motorists. The construction of detours or closing of traffic lanes for long periods of time during repairs adds to the expense and creates serious safety hazards for motorists.

The Oklahoma Department of Transportation has been conducting research for several years in an attempt to find methods of extending the life of concrete bridge structures.

Air entrained concrete has been produced by using an additive in the mix which creates microscopic air voids within the concrete. This type of concrete has proved successful in greatly reducing freeze-thaw scale damage on bridge deck surfaces.

Direct sealing of the concrete surface with a linseed oil coating has been used. This method reduces moisture penetration by up to 50 percent but is highly subject to wear from vehicle tires and must be reapplied every season to maintain this reduction of permeability. Oil coatings on concrete surfaces also tend to lower skid resistance.

High density, low slump concrete has been developed as an overlay material and does extend the life of bridge decks. But, the cost, at more than $60 per sq yd in 1979, coupled with the long term traffic detours required during its application, make it an expensive method.

Wax impregnated concrete, latex modified concrete, polymer impregnated concrete, epoxy moisture proofing systems, and silicone sealers also have been tried and found to have limitations or drawbacks.

Epoxy coated rebars are now being used in new construction, thus reducing rebar corrosion problems. However, Oklahoma still is faced with the need for a good method of protecting bridge deck surfaces already in existence.

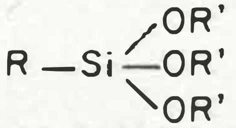
BACKGROUND

Since 1976, ODOT has been conducting laboratory testing and field evaluation of silane chemical water and chloride repellent agents for concrete.

Two particular silane chemical agents: Chem-Trete, manufactured and marketed by Dynamit Nobel Chemical; and SIL-ACT, manufactured and marketed by Advanced Chemical Technologies; have been under study and evaluation.[1,7] Both contain a solution of 40 percent alkyltrialkoxysilane by weight in an anhydrous alcohol solvent. Laboratory evaluations have shown that these silane chemical agents significantly reduce moisture and chloride penetration into concrete, thus protecting the internal reinforcing steel of bridges.

Silane Chemistry

Organosilanes are isostructural with organic hydrocarbons with a silicon atom replacing a carbon atom. The resulting compound has the general formula:

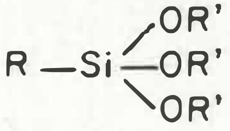


There are different ways to formulate the silane with respect to the alkyl groups (R-) linked to the Si atom within the silane molecule.[8] The manufacturer selects the R and R' groupings to prepare a silane with particular characteristics, which in this case is an alkyltrialkoxysilane. For simplicity, the term "silane" is used in this report except when the full chemical nomenclature is needed for clarity.

Silane Chemical Reaction

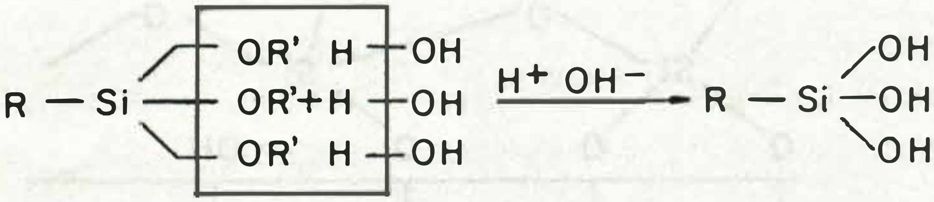
When the silane is applied to bridge concrete, a chemical reaction occurs which bonds the water and chloride repellent hydrocarbon group (R) of the silane molecule to the concrete through a Si-O chemical linkage. It is not physical bonding or adhesion, as with coatings and conventional sealers, but chemical bonding forces, which are many times stronger, that link the repellent hydrocarbon group to the concrete.

In the alkyltrialkoxysilane molecule, the silicon atom of the silane molecule is bonded to a water-repellent alkyl group on one side, and to reactive ester groups on the other side:

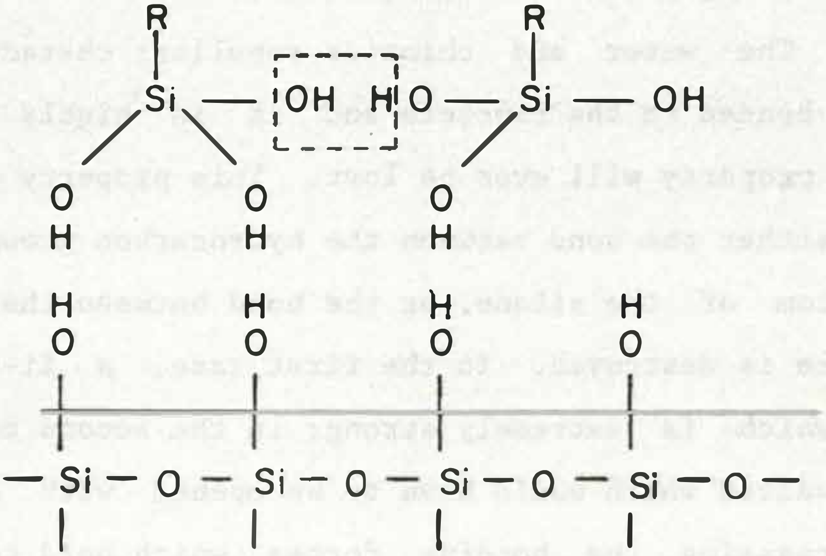


After the silane is applied to the concrete, the chemical reaction between the alkyltrialkoxysilane molecule and the silicate structure of concrete requires two steps: hydrolysis and condensation.[13]

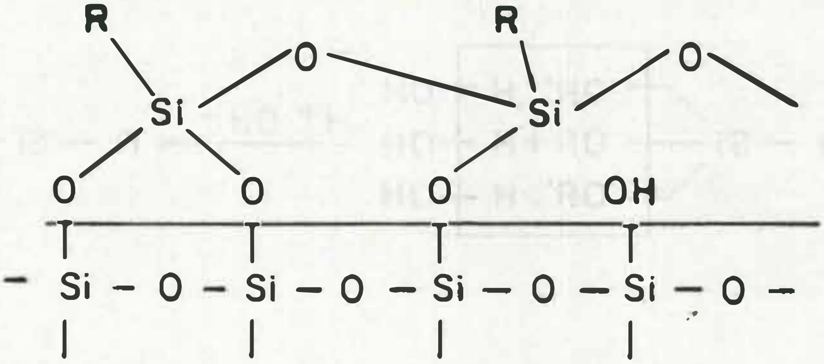
During hydrolysis, when moisture is provided to the silane molecules, unstable silanol molecules are formed.



During condensation, the unstable silanol molecules bond with the available hydroxyl groups of the silicate structure of the concrete and some cross linking can occur.



Thus, the unstable silanol molecules, which are a water and chloride repellent hydrocarbon group, chemically bond with the available hydroxyl groups of the molecules within the silicate structure of the concrete, and the silane treated concrete becomes water and chloride repellent.



The advantages of silane treatment are seen from this reaction. The water and chloride repellent characteristic is chemically bonded to the concrete and it is highly improbable that this property will ever be lost. This property can only be lost when either the bond between the hydrocarbon group and the silicon atom of the silane, or the bond between the silane and the concrete is destroyed. In the first case, a Si-C bond is involved which is extremely strong; in the second case, a Si-O bond is involved which would have to be opened with an extreme force, surpassing the bonding forces which hold together the other molecules of the silicate structure. Indeed, the only chemicals which will break the Si-O bond, belong to the same group of materials required to destroy the Si-O-Si-O linkages of the concrete itself.

Silane Molecule Size

The silane molecule has a size of only 10 Angstroms (equal to 1/1,000,000 mm). Being so small, it is able to enter the smallest pores and capillaries of concrete. Gel pores of concrete have a size of 25 Angstroms and represent 20-30 percent of the cement paste volume. Capillary pores have a size of 1 to 20 microns and air pores of 0.01 to 2 mm.[7]

LABORATORY AND PRELIMINARY FIELD TESTS

Depth of Penetration Tests

Tests on silane treated concrete blocks made in the ODOT laboratory (Class "A" concrete) and cores retrieved from silane treated bridge decks (Class "AA" concrete), indicated that the silane penetrated to a minimum depth of 0.15 inch and averaged 0.25 inch.[10] Tests on cores retrieved from a bridge deck (Class "AA" concrete) cured with linseed oil emulsion prior to treatment with silane, show that the silane penetrated into the surface of the bridge deck to an average depth of 0.19 inch. Tests were conducted by ODOT Materials Division, using ODOT test procedure L-34. See Appendix B for ODOT Laboratory Report No. 4-4350-79770 and test procedure.

Depth of Penetration Tests on Wet and Dry Concrete

An untreated concrete block was split in half after curing and dried to a constant weight. One half was allowed to remain dry and the other half was sprayed with water immediately before the silane was applied.

The silane, penetrated into the dry half of the concrete block an average of 0.453 inches, while penetration into the wet half was 0.227 inches. See Figure 1. The dry surface enabled an average 100 percent greater depth of penetration of the silane into the concrete block. The ODOT Materials Division used ODOT test procedure L-34. See Appendix B for ODOT Laboratory Report No. 2-4350-35661 and test procedure.

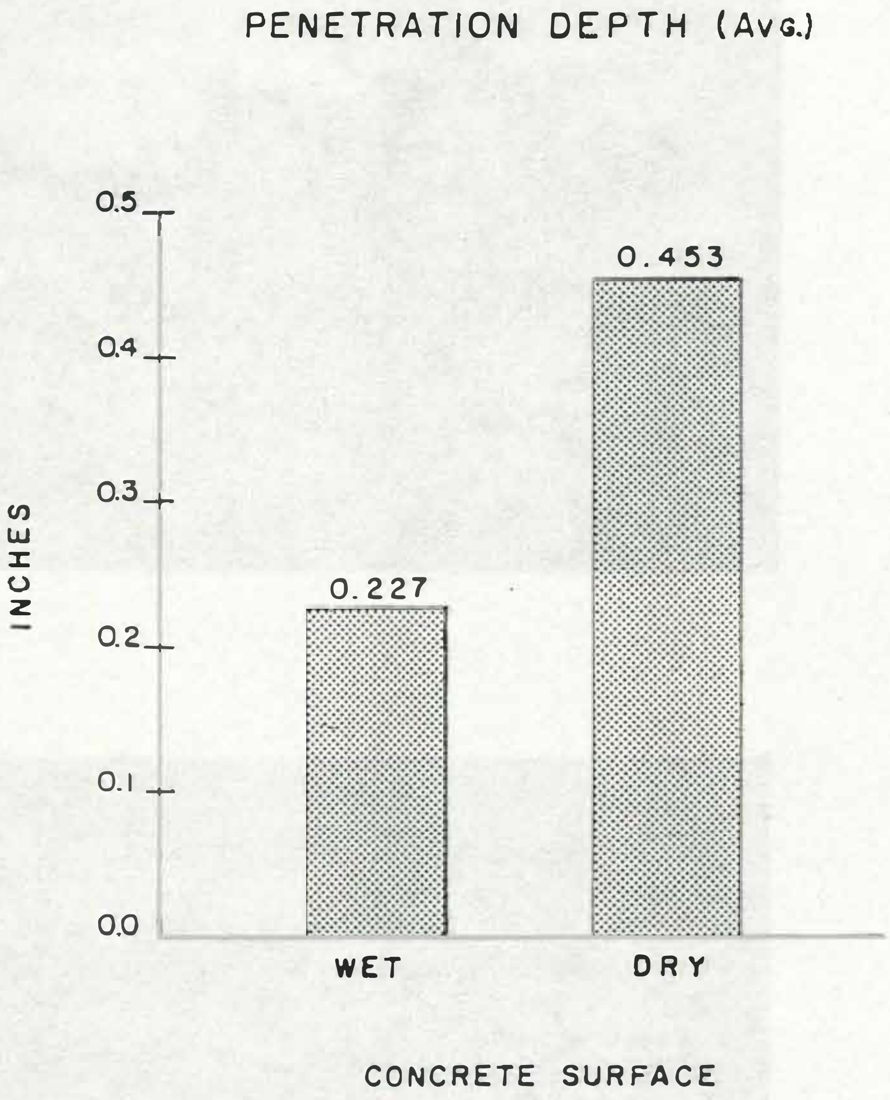
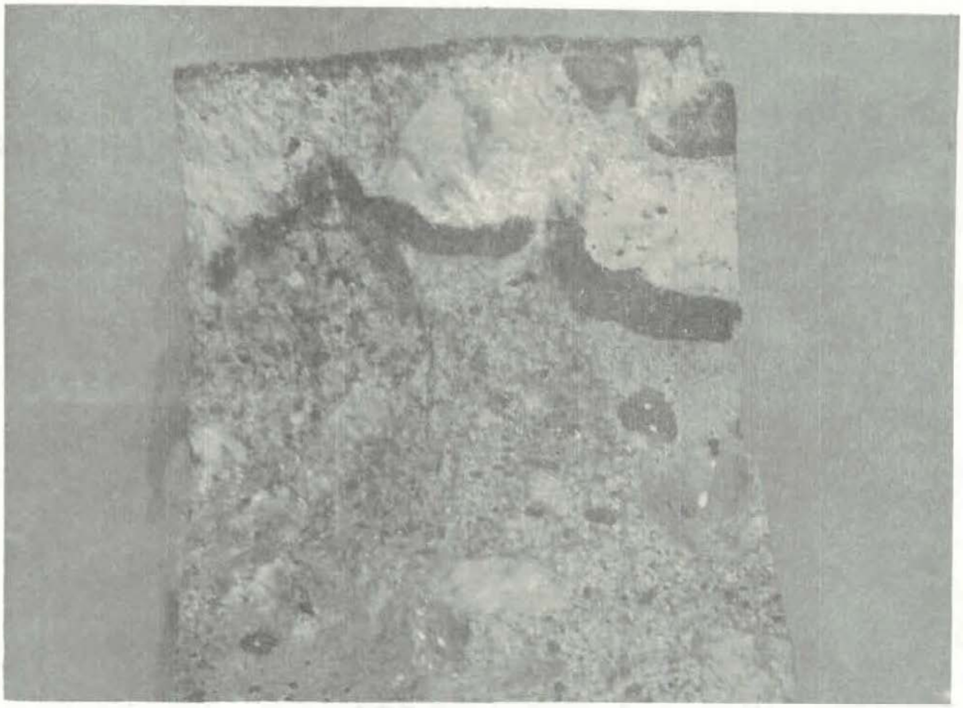


Figure 1. Effect of Moisture in Silane Penetration.



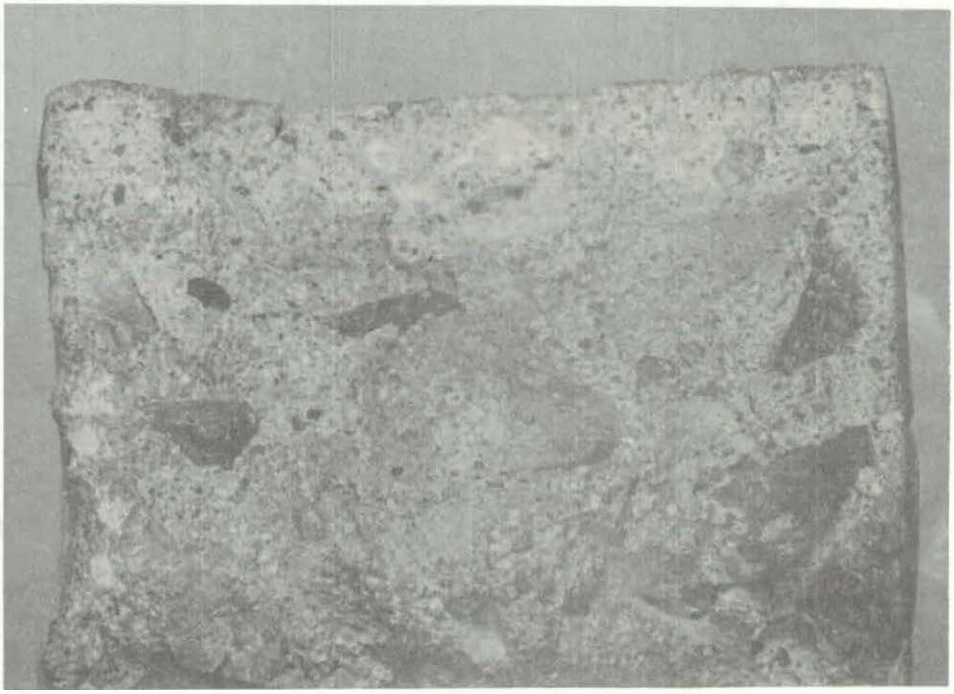


Figure 2a and b. Split Concrete Core From Silane Treated Bridge Deck Shows Penetration Depth (Light colored area at top).

Moisture Absorption Test

ODOT Materials Division tested the silane treatment, using the ASTM C-642 test procedure, on both laboratory prepared test blocks and cores retrieved from a silane treated bridge deck.[4] Results indicated that the moisture absorption rate of Class "A" and "AA" concretes (ODOT Laboratory Report No. 1-4350-34724, see Appendix B) can be reduced to less than 1 percent by weight.[10] This is significant when compared to untreated concrete with absorption rates of 5.5 to 6 percent by weight.

Electron Microscopic Examination

Examination of silane treated concrete with an electron microscope indicated, at 2000X magnification, that the concrete capillaries and pores present in the concrete were not coated or plugged as they are with coating type sealers. Typical microscopic photos are shown in Figure 3. The capillaries and pores remain open and permit the silane treated concrete to "breath" while being repellent to water and salt.[11]

ODOT Vapor Permeability Test

Oklahoma Department of Transportation tests indicated that moisture already present in the concrete prior to silane treatment escapes afterward through the open concrete capillaries and pores in the form of moisture vapor. This ability is termed "vapor permeability" by ODOT and it allows internal moisture to escape during Oklahoma's dry weather periods.

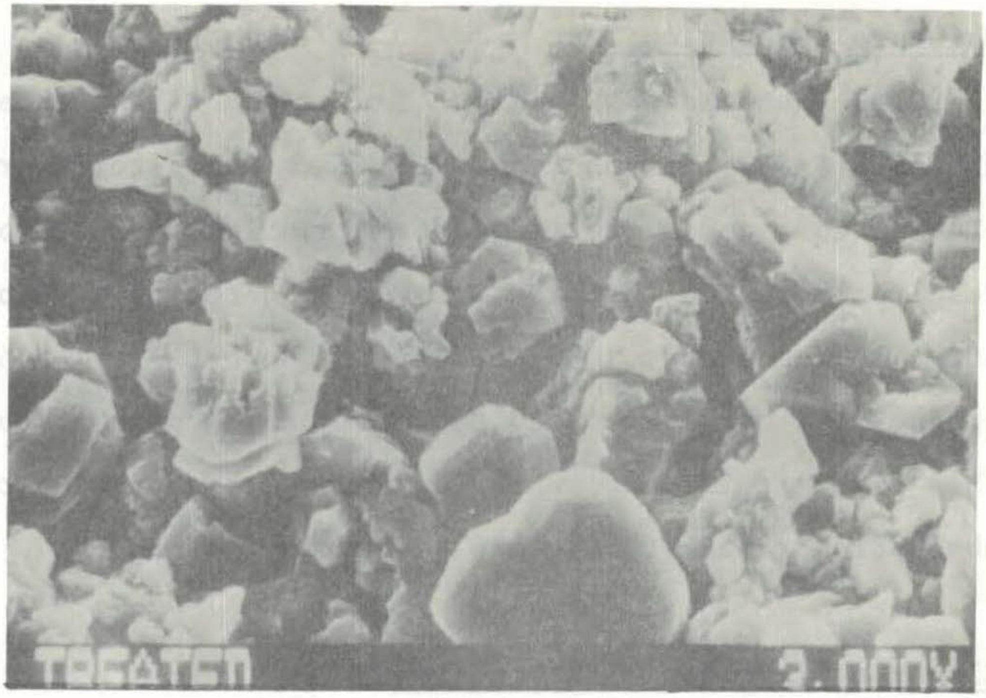


Figure 3a. Electron Microscopic Photograph (2000X magnification) of Silane Treated Concrete Shows Open Capillaries.

Figure 3b. Electron Microscopic Photograph (2000X magnification) of Untreated Concrete.

A test to determine the capabilities of silane was conducted on a concrete block prepared in the ODOT Laboratory, using the ODOT test procedure L 35 for Determining Vapor Permeability. The block was oven dried to a constant weight of 3998 grams at a temperature of 230° F, submerged in water for 24 hours, and then weighed. The wet weight of the block was 4192 grams. The water absorbed by the block was 4.85 percent by weight. The wet block was towel dried, and silane applied at the rate of 125 ft^2/gal to the six sides of the block. The block was oven dried to a constant weight at 230° F and weighed. The dry weight of the block was 3998 grams. The block was submerged in water for 24 hours, removed from the water and weighed. The wet weight of the block was 4026 grams. The percent of water absorbed by the block was 0.70 percent by weight. See Appendix B, ODOT Laboratory Report No. 4350-14562, 1-19-79.

The silane treatment reduced water absorption of the concrete block from 4.85 percent to 0.70 percent, and released 4.15 of the total 4.85 percent water present in the block.

ODOT 90 Day Chloride Ponding Tests

ODOT conducted several 90 day chloride ponding tests on silane treated test blocks using the standard test methods as designated by AASHTO T259 and T260.[2,3] All tests indicated less than 0.75 lbs/yd^3 of chloride at the 1/2 to 1 inch depth in the test blocks applied with silane. Test blocks used in a December,

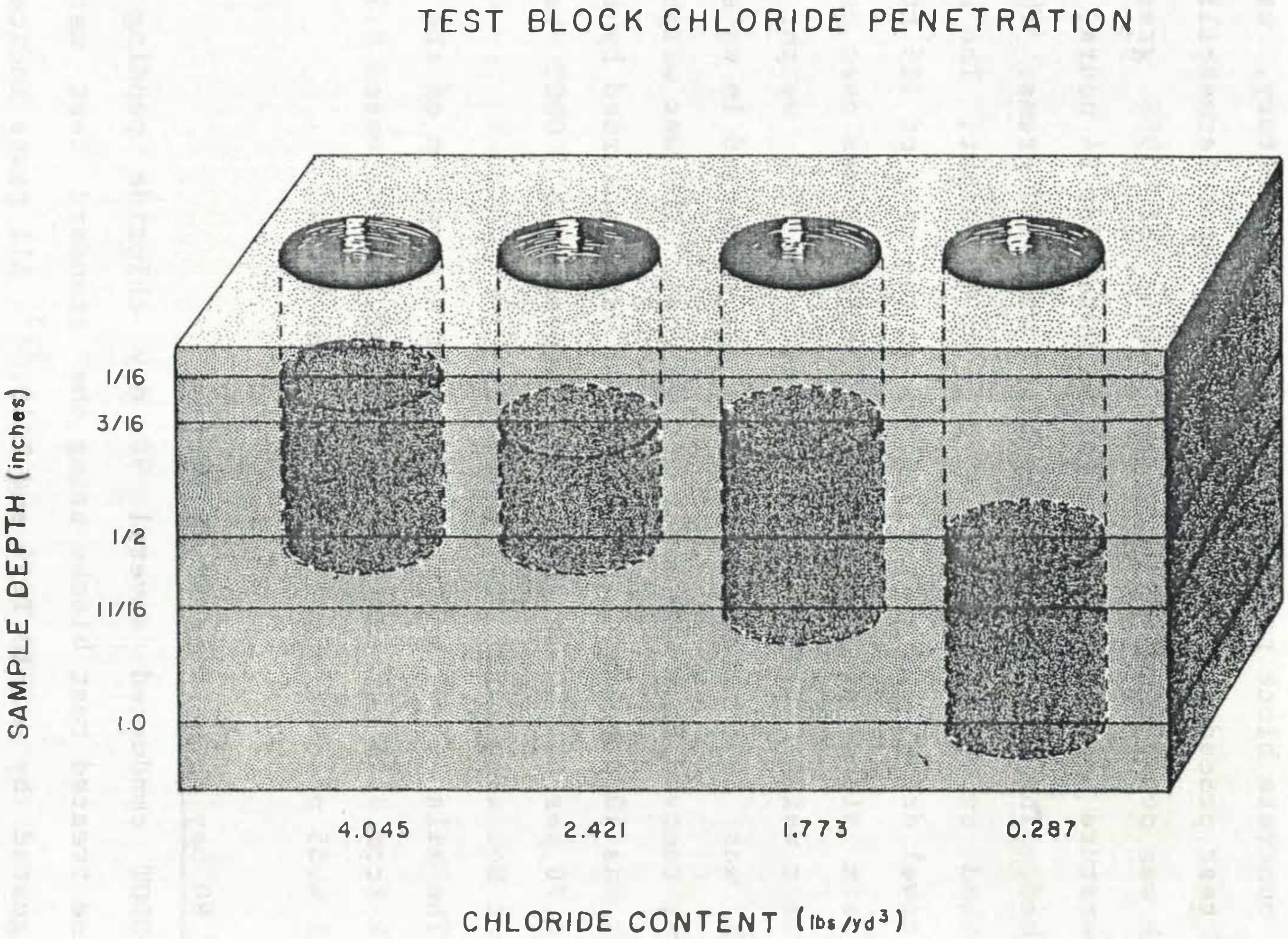


Figure 4. Results of 90-Day Chloride Ponding Test

1983, ponding test were further sampled for chloride penetration at the 3/16 to 1/2 depth, and the 3/16 to 11/16 inch depth. The amount of chloride penetration at all four depths in lbs/yd^3, after subtracting the amount found in the untreated, unponded control sample, is illustrated in Figure 4. The amount of chloride at the 1/2 to 1 inch depth was only 0.29 lbs/yd^3. See Appendix B, ODOT Laboratory Report No. 1-4350-34724 and Report No. 1-4350-35852.

FHWA 450 Day Chloride Ponding Tests

The FHWA conducted chloride ponding tests for a time period of 450 days, using AASHTO T259 and T260 test methods.[2,3] One of the silane agents was applied to three differently cured concrete test specimens. Three other cured concrete test specimens were left untreated and used for control. After 450 days of ponding a 3 percent chloride solution on top of all the specimens, test results indicated the three treated with silane had an average of 0.46 lbs/yd^3 of chloride absorption at the rebar depth 1½ to 2" below the concrete surface. This compared to an average of 6.03 lbs/yd^3 of chloride absorption for the three untreated specimens.[6] The chloride absorption rate at the rebar depth was reduced 92.4 percent with the silane treatment. See Figure 5 and Appendix B for test report.

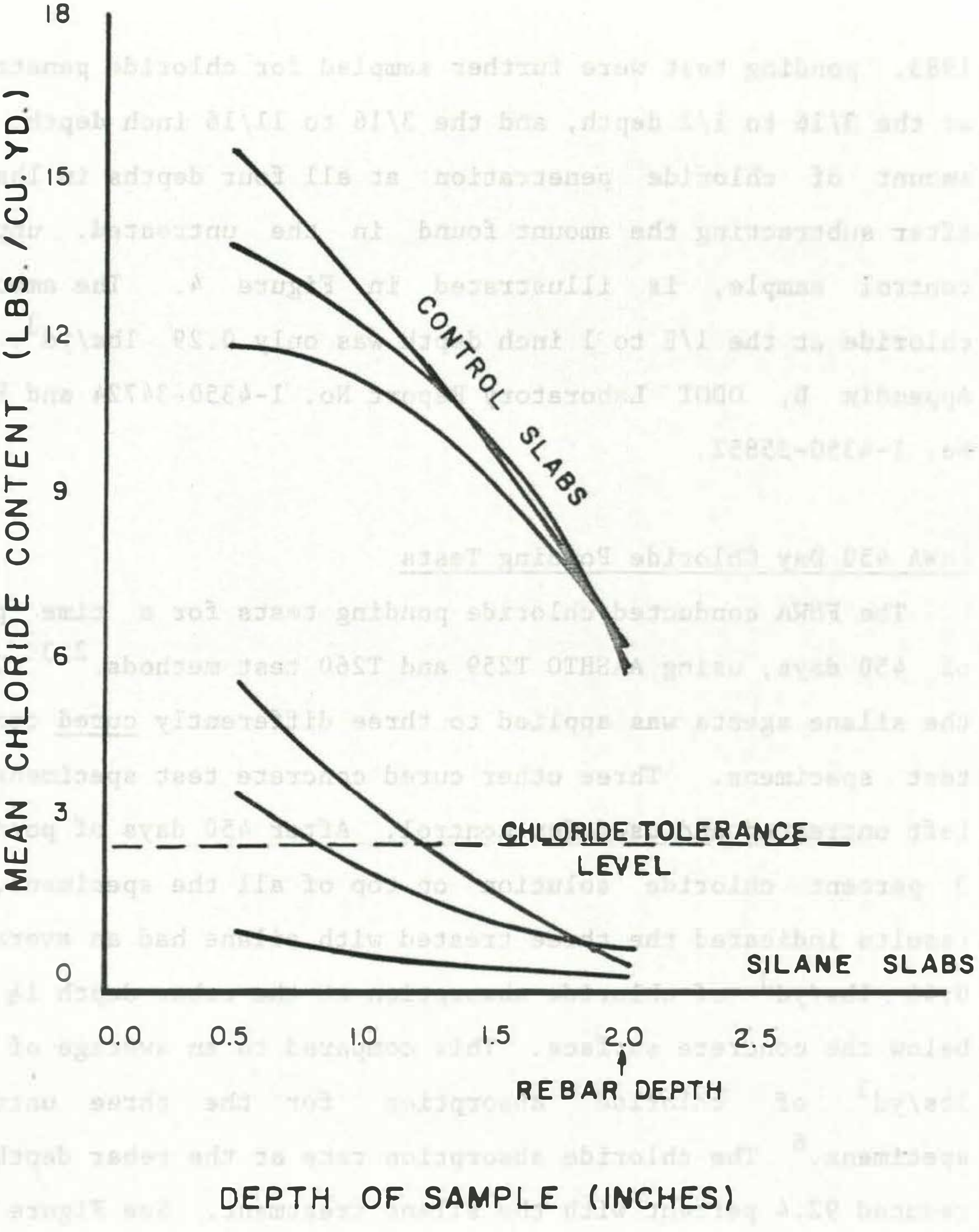


Figure 5. FHWA 450-Day Chloride Ponding Test Shows 0.46 lbs/yd^3 Chloride Absorption at Rebar Depth in Silane Treated Specimens.

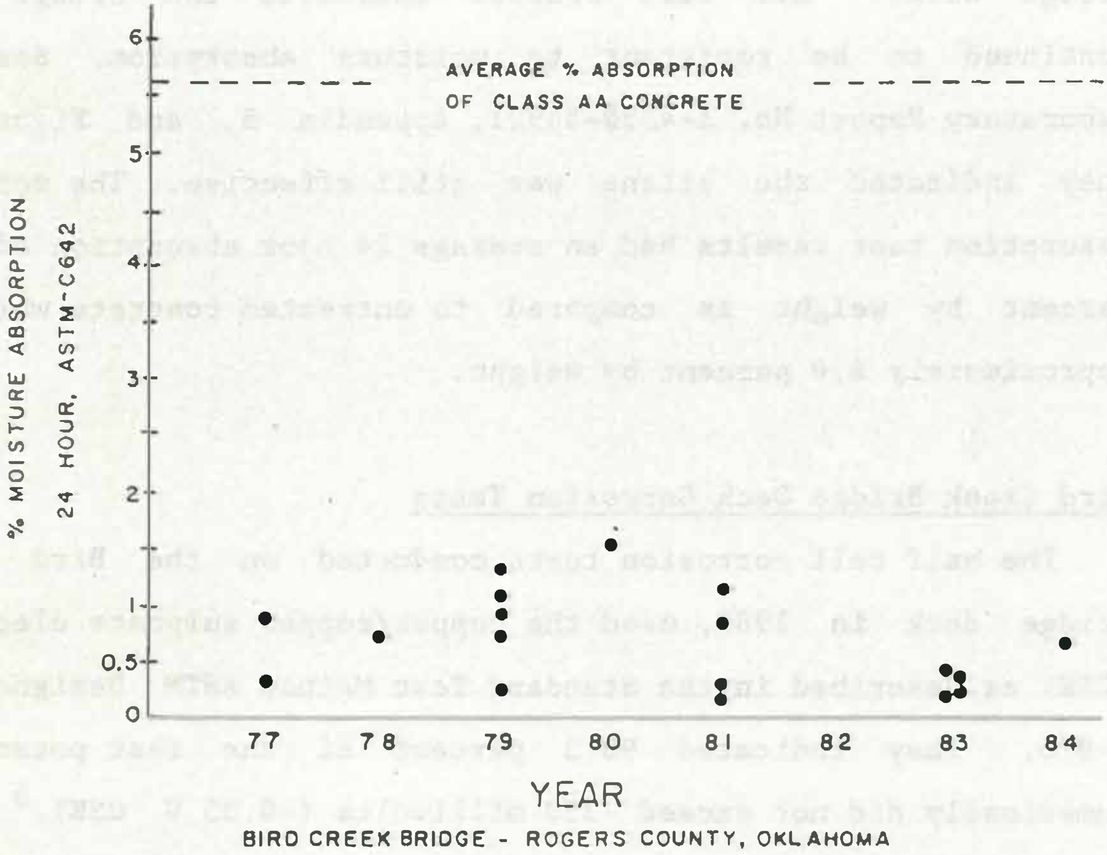


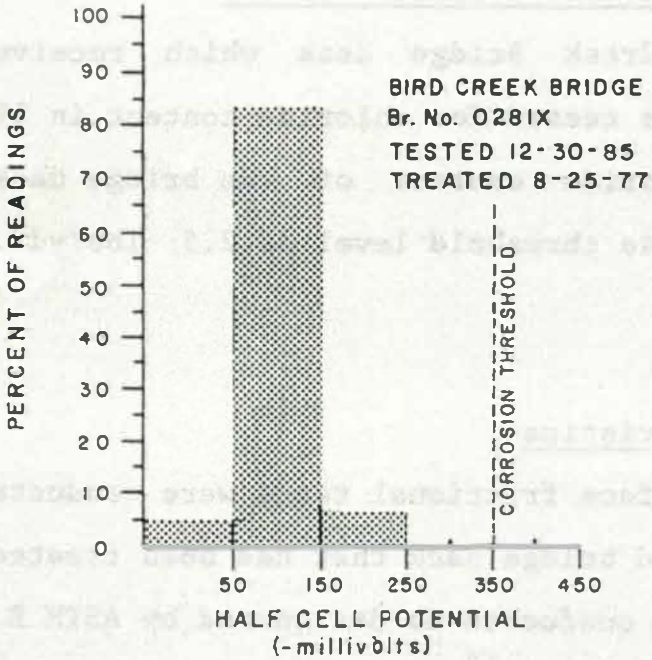
Figure 6. Moisture Absorption Test Results on Silane Treated Bird Creek Bridge Deck.

Bird Creek Bridge Deck Moisture Absorption Tests

In 1977, one of the silane agents was applied to one panel of a bridge deck located over Bird Creek near Tulsa in Rogers County, for a performance evaluation. The bridge was constructed in 1974 and receives salt applications every winter. From 1977 to 1984, ODOT conducted moisture absorption tests (ASTM C-642) on cores retrieved intermittently from the Class "AA" concrete bridge deck.[4] All test results indicated the bridge deck continued to be resistant to moisture absorption. See ODOT Laboratory Report No. 1-4350-55921, Appendix B, and Figure 6. They indicated the silane was still effective. The moisture absorption test results had an average 24 hour absorption of 0.7 percent by weight as compared to untreated concrete which is approximately 6.0 percent by weight.

Bird Creek Bridge Deck Corrosion Tests

The half cell corrosion tests conducted on the Bird Creek bridge deck in 1985, used the copper/copper sulphate electrode (CSE) as described in the Standard Test Method ASTM Designation: C-876. They indicated 98.3 percent of the test potentials numerically did not exceed -350 millivolts (-0.35 V CSE).[5] The remaining 1.67 percent consisted of two test potentials (-365 and -464 mV) taken 6 to 9 inches from a corroded armor joint device. See Figure 7a.



*One potential over an armor joint device

Figure 7a. Half Cell Potentials in Bird Creek Bridge Deck.

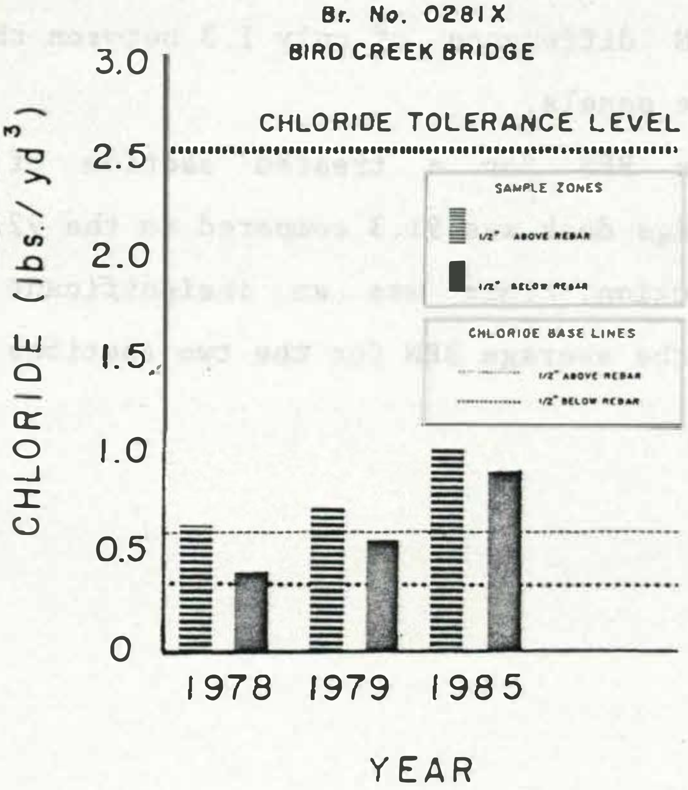


Figure 7b. Chloride Content Levels in Bird Creek Bridge Deck.

Bird Creek Bridge Deck Chloride Content

The Bird Creek Bridge deck which received heavy salt applications, was tested for chloride content in 1978, 1979, and 1985. The chloride content of the bridge deck remained well below the chloride threshold level of 2.5 lbs/yd^3. See Figure 7b.

Fricton Characteristics

Pavement surface frictional tests were conducted by ODOT on a newly constructed bridge deck that had been treated with silane. The tests were conducted as designated by ASTM E 303, using the British portable tester.[12] The bridge was located on I 40 over the North Canadian River. All of the resulting friction numbers, which are referred to as British Pendulum Numbers (BPN), showed an average BPN difference of only 1.3 between the treated and untreated bridge panels.

The average BPN for a treated section of the newly constructed bridge deck was 91.3 compared to the 92.6 average for an untreated section. This was an insignificant 1.4 percent difference in the average BPN for the two sections of the bridge deck.

OKLAHOMA FIELD EVALUATION PROGRAM

Of the approximately 3,000 bridges constructed in Oklahoma from 1959 to 1979, only 200 had any form of protection against chloride penetration other than linseed oil. Funds were not available to provide protection systems for all Oklahoma bridges using high density overlays or the then accepted waterproof membranes.[9]

During 1979 ODOT decided to field test silane as a low cost means of protection for some of the remaining unprotected bridge structures on the Oklahoma highway system.

Linseed oil was the principal protectant being used for ODOT bridge decks. The linseed oil program required application to a bridge deck immediately after construction, again after one year, and then every two years. This procedure was required because of the deterioration of the linseed oil. The cost of each application was approximately \$0.30/ft^2. This cost, was compared with the one time cost of \$0.78/ft^2 for silane treatment in 1979. After careful consideration of the preliminary test results, ODOT decided to use silane as a bridge protectant on an experimental basis to replace the linseed oil.

In Oklahoma, at the end of 1985, 245 bridges had received the silane treatment, of which 137 were existing bridges and 108 were newly constructed bridges. A total of 461,254 yds^2 of bridge deck surface were treated. All the work was done by contract at an approximate cost of \$4 million. See Table 2.

In 1979, the application cost of the silane was estimated at \$7/yd^2. By 1985, the cost had dropped to \$3.50/yd^2. The cost-benefit analysis of silane treatment, done by U.S. Federal Highway Administration (FHWA) in 1979, indicated a break even proposition if the treatment added two years life to the existing bridges.[15] The break even point has been reduced considerably since then, due to cost reduction.

Bridges for the Oklahoma field evaluation were selected in four categories:

1. Urban Interstate and expressway bridges which receive heavy salt applications.
2. Rural Interstate bridges which receive moderate to heavy salt applications during winter months.
3. Rural Primary and Secondary bridges which receive moderate to light salt usage, and
4. Interstate bridges with low slump, high density concrete overlays which receive moderate to heavy salt applications.

Each of these categories included bridges ranging from new to 5 years, 5 to 10 years, and 10 to 15 years in age when the silane agent was to be applied to them.

Prior to treatment with silane, each bridge was surveyed visually for scaling, cracks, pop-outs, and other damage. Wheel path abrasion was measured and recorded. A chain drag survey was conducted to locate any delaminated areas on the bridge deck. Chloride content samples were taken on a five foot grid pattern at two depth intervals, ½ inch above and ½ inch below the rebar level.[2,3] A copper/copper sulphate half-cell test was conducted to determine whether active corrosion was present.[5]

If any of the above procedures indicated that a bridge was (1) too badly deteriorated, or (2) the chloride content at the rebar level exceeded 2.5/lbs/yd^3 or (3) too much of the rebar mat was actively corroding, the bridge would be scheduled for rehabilitation rather than silane treatment.

After treatment, the aforementioned surveys and tests were made annually on randomly selected deck panels of the treated bridges.

Nine silane treated bridges and one untreated control bridge are being evaluated for performance. The results of the chloride sampling, corrosion activity testing, inspections, and delamination surveys are discussed in the Field Performance Evaluation section of this report.

APPLICATION OF THE SILANE TO BRIDGE DECKS

The application of the silane to a bridge deck under traffic is not difficult. Prior to application, traffic is diverted to one lane of the bridge while the other is treated. Detour construction and disruption to motorists is minimized.

Preparation

The first step in the application process is to clean the bridge surfaces to be treated. Remove all traces of curing compound, laitance, dust, dirt, salt, oil, asphalt, and other foreign materials from the concrete surface.

Since the effectiveness of the silane is related to penetration, the cleaner the concrete pores, the better the depth of penetration. The result is a deeper and more uniform water repellent layer.

Sand blasting, shot blasting, water washing, or steam cleaning may be used, although shot blasting appears best. Surface cleaning may also include the application of pretreatment cleaning agents. Solvents and hand tools are used as required to remove any bonded materials detrimental to treatment of the concrete surface.

It is important that the cleaning process does not cause any undue damage to the concrete surface, remove or alter the existing surface finish, or expose the coarse aggregate of the concrete. If areas of coarse aggregate are exposed, this could leave some areas unprotected, as the silane can not react with certain aggregates.

When water washing methods are used, a hot water pressure washer with a 160° F water temperature at 1,800 psi minimum nozzle pressure is required. A hydroblast washer with cold water at 7,000 psi minimum nozzle pressure may be used as an alternate. When steam cleaning is used, a steam cleaning unit, with a 320° F water temperature under 305 psi operating pressure is required. Detergents in proportions of 2 percent or less by weight may be added to aid in the cleaning process.

The concrete surfaces should be substantially dry prior to application of the silane solution. ODOT laboratory tests have verified that silane penetration is greater when the silane is applied to a dry surface. See Figure 1.

On new bridges, ODOT requires the concrete to be cured a minimum of 28 days prior to application of the silane.

Application

The silane is applied to the dry concrete surfaces with low pressure, airless type spray equipment, using a nozzle pressure of 15 to 40 psi. Application should not take place when the air or concrete surface temperature is below 40° F, or when wind conditions are unfavorable. Contamination of the silane with moisture prior to application should not be permitted. Moisture contamination will cause polymerization and the silane will no longer have the capability to react with concrete to cause it to be water and chloride repellent.

An application rate of 1 gallon per 125 ft^2 provides a good flood coat of silane over the concrete bridge deck surface. The application rate for the vertical concrete surfaces of the bridge is 1 gallon per 175 ft^2. The water repellant surface will remain intact even after several years of wear from vehicle tires. Surfaces subjected to wear from studded tires would not last as long.

After application, the silane is allowed sufficient time to penetrate into the concrete, then the treated surfaces are sprayed with water to provide adequate moisture for the silane to react chemically with the concrete (hydrolysis).[14] When the deck appears dry, traffic can be permitted on the treated surface.

FIELD PERFORMANCE EVALUATION

Evaluation of silane field performance indicated that the corrosion activity level (half cell potentials) of the silane treated bridge decks selected for this study, when tested using the ASTM C876 procedure, remained numerically below -350 mV (-0.35 V CSE). This indicated that active corrosion was not present. See Figure 8a and b.

In 1985, samples taken from the bridge decks under evaluation showed that chloride contents at the level of the reinforcing steel were still well below 2.5 lbs/yd^3.[2,3] See Table 1 and Figures 9 and 9b. It is not clear from the data whether the rates of accumulation of chloride have been slowed, since only decks that did not have high rates of accumulation were treated. The decks in existence prior to treatment ranged in age from 1 to 14 years when the silane was applied. The average chloride content ranged from 0.34 to 0.67 lbs/yd^3 at the rebar steel level. In 1985, the figure ranged from 0.21 to 1.06 lbs/yd^3. The average rate of increase in the chloride content at the rebar steel level for the seven bridges was low at 0.054 lbs/yd^3/yr. Continued monitoring of the chloride contents of these bridges and of the newly constructed bridges treated with silane will determine whether a similar rate of accumulation is experienced over a longer term.

Results of the 1987 condition survey of silane treated bridges selected for this study, indicated no post treatment spalling or scaling present on any of the treated portions of the bridge decks. The survey included entire bridge decks, random deck panels, and one bridge where only one panel of the deck was silane treated.

One of the bridge decks had some scaling on it prior to silane treatment. Five patched areas as large as 3 ft^2 were present but the scaled areas did not increase after treatment. Scaling was not present on the other bridge decks. One of the bridge decks had minor spalling present under the steel flanges of the bridge deck expansion devices which was caused by stress. It also contained mudball voids ranging from ½ to 3/4 inch in diameter.

The Bird Creek bridge deck had only one deck panel that received silane treatment in 1977. That panel had no post treatment spalling or scaling, but the bridge was spalled severely in one area of the untreated deck.

Also, during the survey of the bridge decks, light abrasion, shrinkage cracks, random cracks, and some tranverse cracks were noted.[16] Moisture absorption tests conducted on cores taken from the Bird Creek bridge deck nine years after treatment, indicated that moisture absorption remained below one percent after 48 hours.

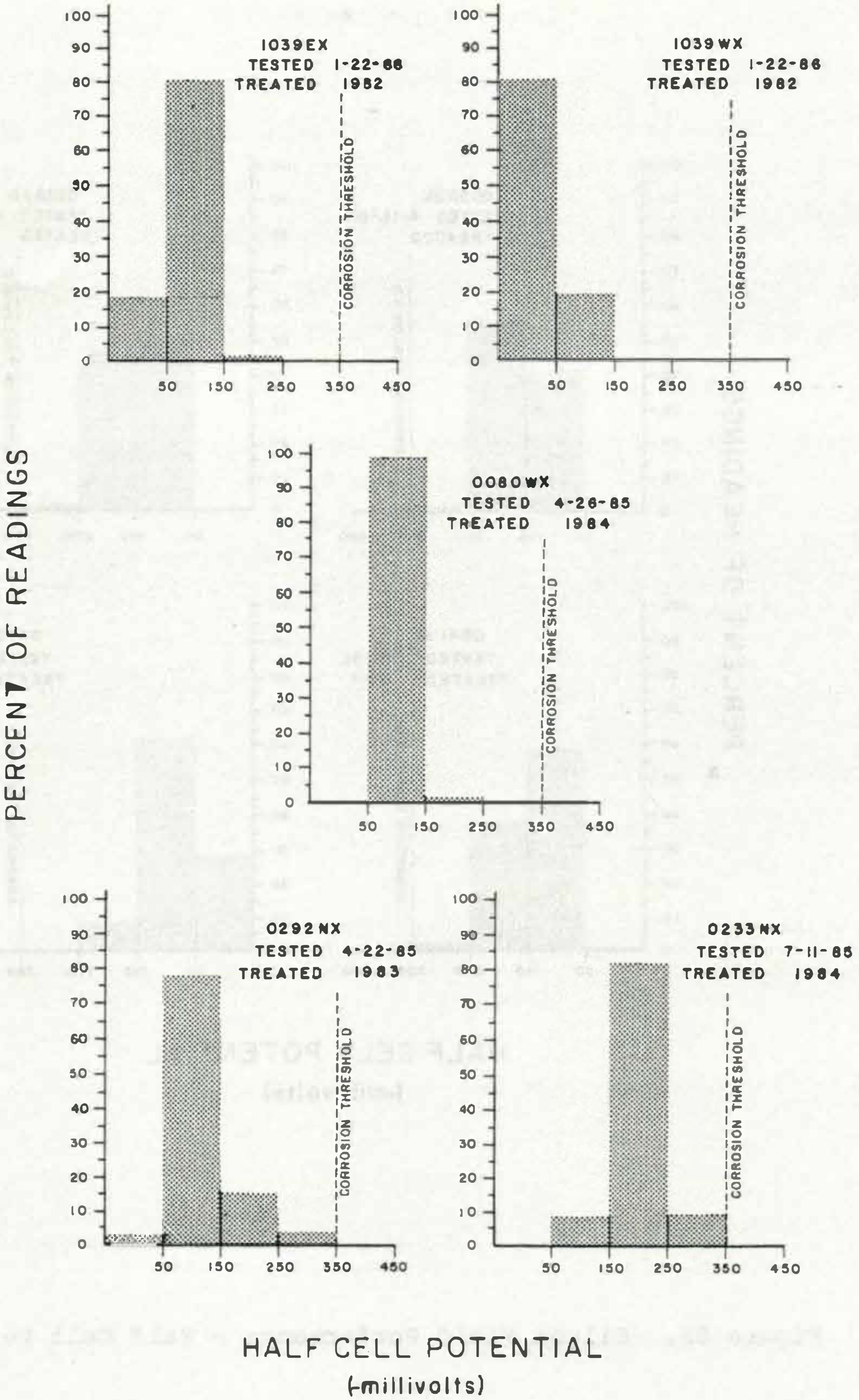


Figure 8a. Silane Field Performance - Half Cell Potentials.

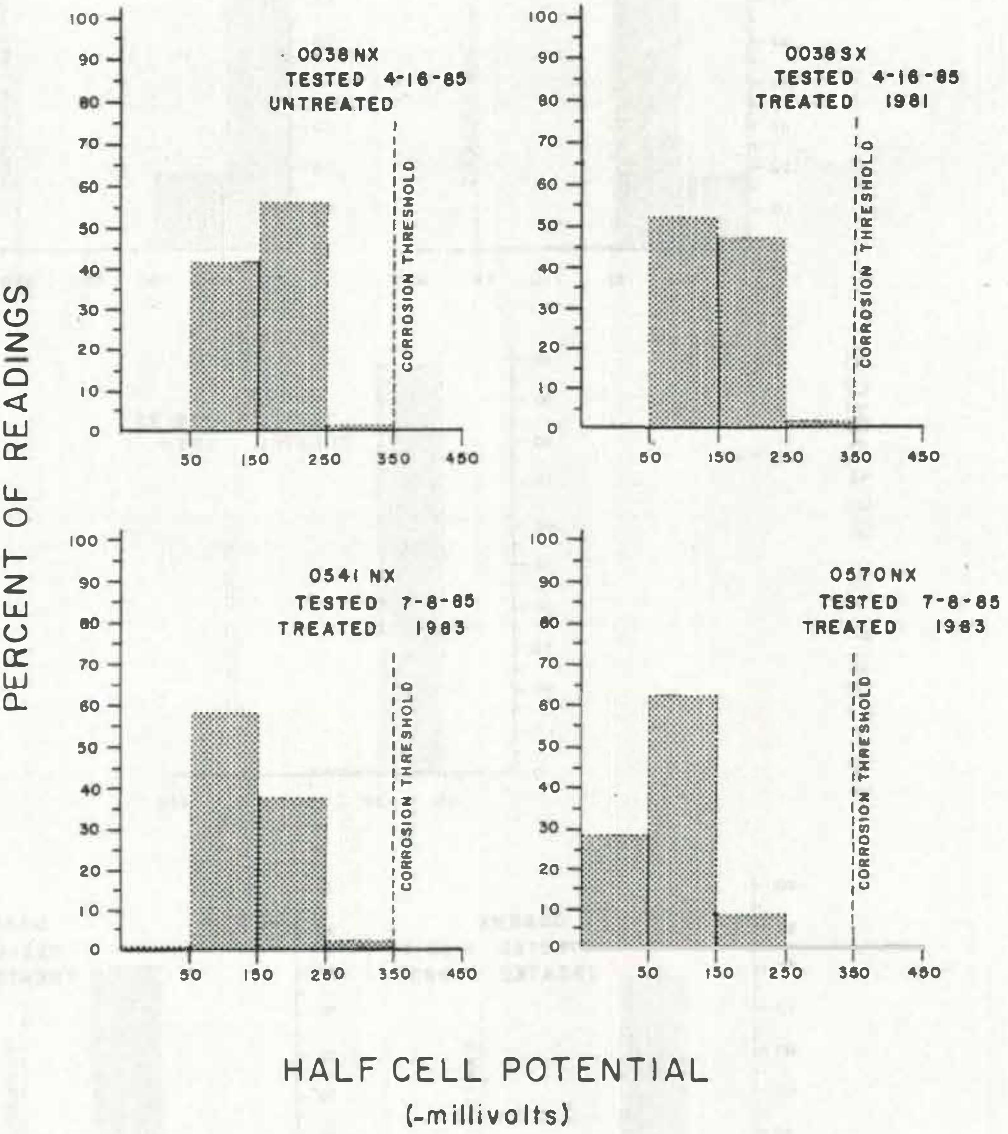


Figure 8b. Silane Field Performance - Half Cell Potentials.

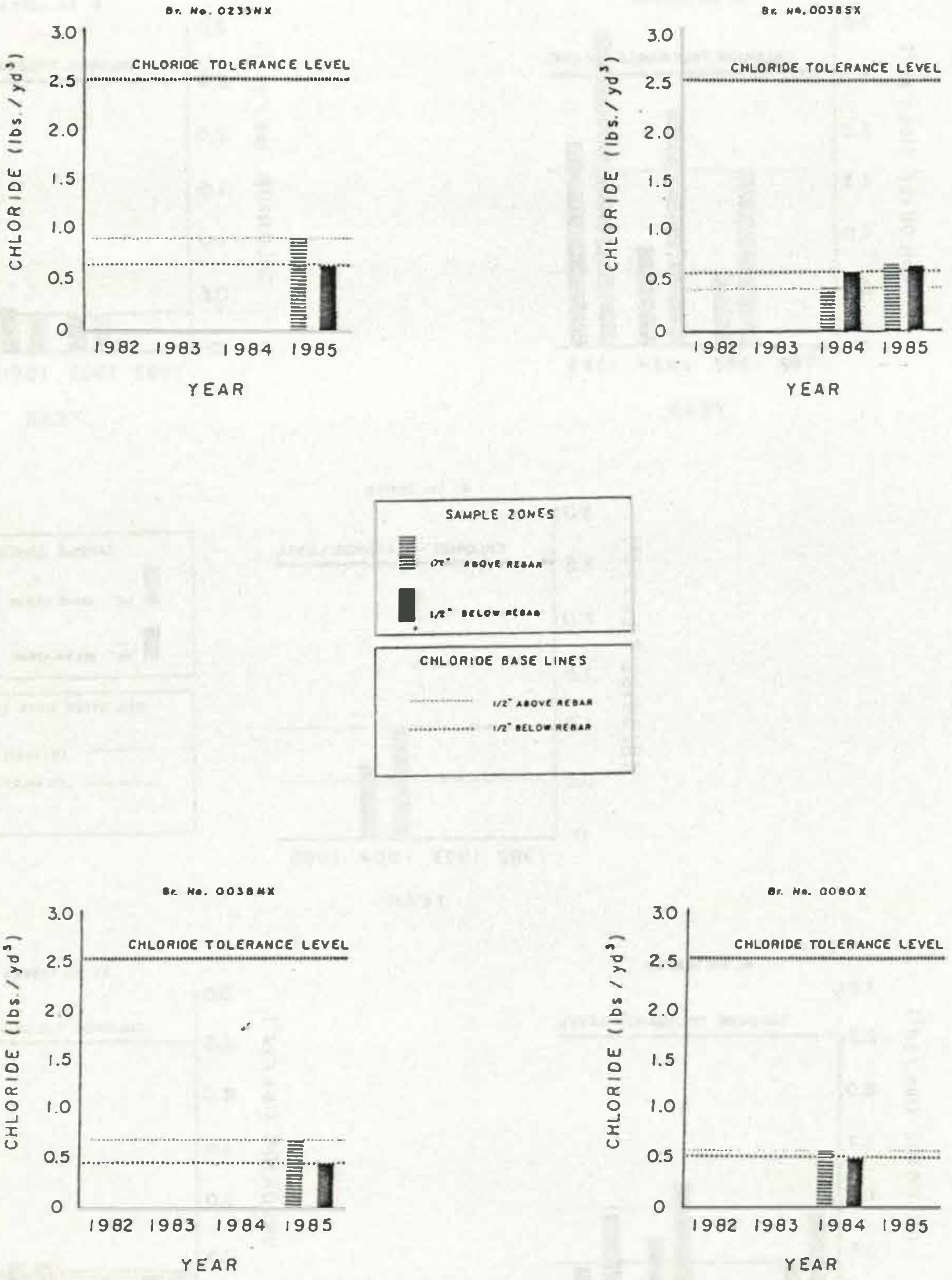


Figure 9a. Silane Field Performance - Chloride Content Levels.

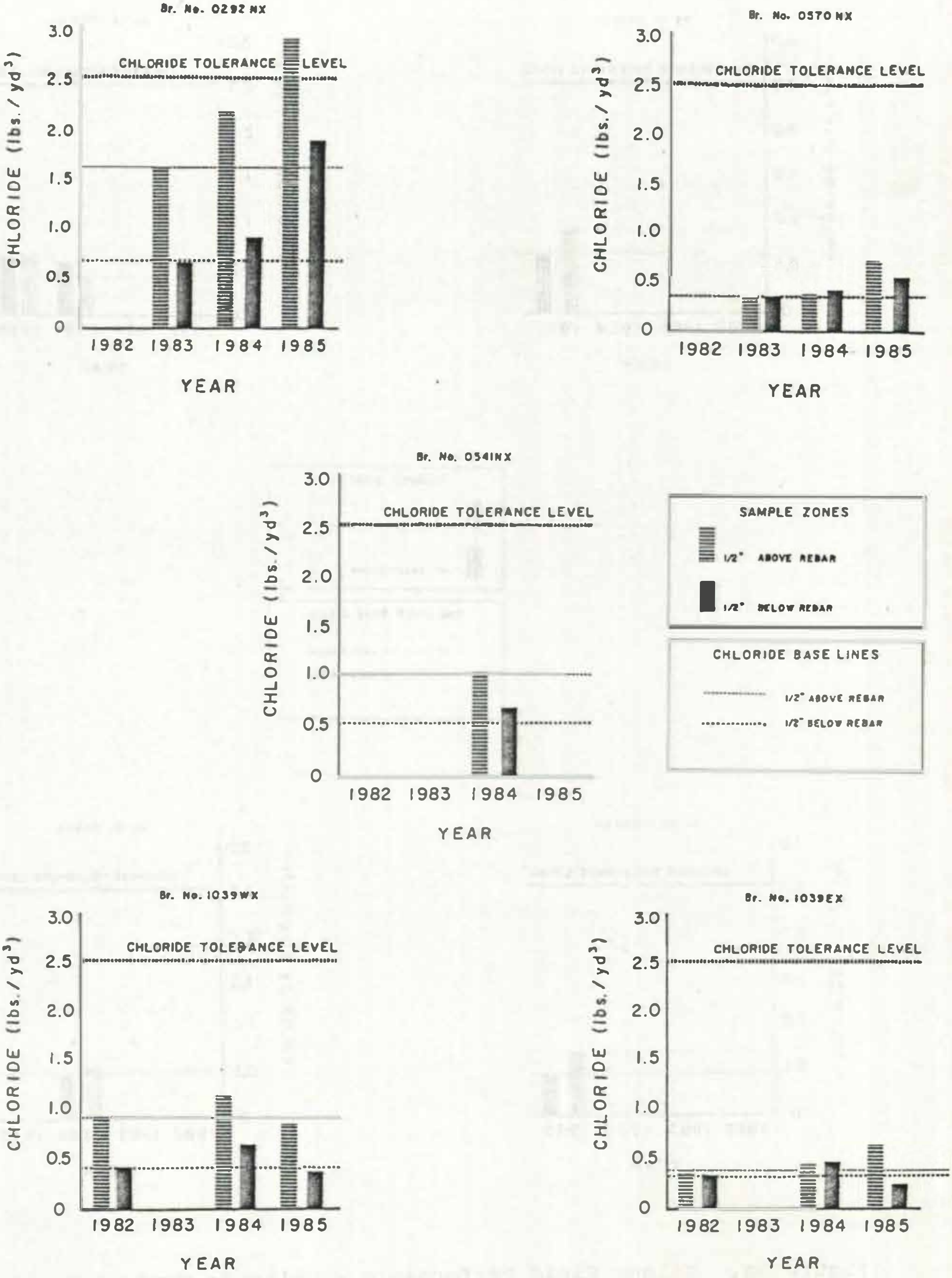


Figure 9b. Silane Field Performance - Chloride Content Levels.

TABLE 1. CHLORIDE CONTENT OF SILANE TREATED BRIDGE DECKS BEFORE AND AFTER TREATMENT

BRIDGE STRUCTURE	YEAR CONSTRUCTED	YEAR TREATED	YEAR SAMPLED	MEAN CHLORIDE CONTENT AT REBAR LEVEL (LBS/YD^3)		RATE OF ACCUMULATION (LBS/YD^3/YR)
				AFTER TREATMENT	BEFORE TREATMENT	
1039EX	1968	1982	1985	0.2083	0.3441	-0.0453
1039WX	1968	1982	1985	0.3937	0.4058	-0.0040
0281WX	1974	1977	1985	0.8489	0.3424	0.0633
0038SX	1980	1981	1985	0.6503	0.5803	0.0175
0038NX	1980	(1)	1985	(3)	0.4239	N/A
0292NX	1972	1983	1985	1.0569	0.6704	0.1933
0233NX	1985	1985	1985	(2)	0.6387	N/A
0080X	1984	1984	1984	(2)	0.5247	N/A
0570NX	1978	1983	1985	0.5157	0.3420	0.0868
0541NX	1973	1983	1984	0.6351	0.5683	0.0667

(1) Control Bridge - not treated.

(2) New Bridge - Not yet sampled after treatment.

(3) Will be sampled later.

Table 2. LOCATION OF SILANE TREATED BRIDGES

BRIDGE STRUCTURE NO.	CONTROL SECTION NO.	HIGHWAY DESIGNATION	HIGHWAY CATEGORY	AVERAGE DAILY TRAFFIC
1039EX	I035-25-46-EX1039	I-35	Rural Interstate	14,100
1039WX	I035-25-46-WX1039	I-35	Rural Interstate	14,100
0281WX	S167-66-34-WX0281	SH-167	Rural Primary	2,900
0038SX	S003-62-44-SX0038	SH-3	Rural Primary	3,300
*0038NX	S003-62-44-NX0038	SH-3	Rural Primary	3,300
0292NX	U062-51-47-NX0292	US-62	Rural Primary	19,400
0233NX	I040-54-22-NX0233	I-40	Rural Interstate	9,500
0080X	S037-08-22-X0080	SH-37	Rural Primary	400
0570NX	I044-55-07-NX0570	I-44	Urban Interstate	50,000
0541NX	S066-55-006-NX0541	SH-66	Urban Expressway	54,000

*Control Bridge - not treated

TABLE 3

OKLAHOMA SILANE TREATED BRIDGES (December, 1985)

	TREATED BRIDGES			TREATED AREA (YD^2)		
HIGHWAYS	EXISTING	NEW	TOTAL	EXISTING	NEW	TOTAL
Interstate						
Rural	42	45	87	46,498	82,650	129,148
Urban	26	25	51	169,314	21,584	190,898
Fed. Aid Primary						
Rural	27	17	44	32,759	20,722	53,481
Urban	31	7	38	42,136	7,142	49,278
Fed. Aid Secondary	4	4	8	8,029	4,884	12,913
State Highways						
Rural	1	1	2	651	967	1,618
Urban	0	1	1	0	878	878
County Roads						
Rural	1	0	1	597	0	597
City Streets						
Local Urban	5	5	10	5,384	8,736	14,120
Federal Aid	0	3	3	0	8,323	8,323
Totals	137	108	245	305,368	155,886	461,254

Table 4. ODOT BRIDGE CROSS REFERENCE

Bridge Structure No.	Control Section No.	Location
1039EX 1039WX	I035-25-46-EX1039 I035-25-46-WX1039	Garvin County, on I-35 over SH 29 west of Wynnewood.
0281X	S167-66-34-WX0281	Rogers County, on SH 167 over Bird Creek, Fourth bridge panel from north end.
0038SX 0038NX	S003-62-44-SX0038 S003-62-44-NX0038	Pontotoc County, in Ada on SH 3 over SL & SF Railroad.
0292NX	U062-51-47-NX0292	Muskogee County, in Muskogee on SH 62 over MK&T Railroad.
0233NX	I040-54-22-NX0233	Okfuskee County, on I-40 over North Canadian River.
0080X	S037-08-22-X0080	Caddo County, on SH 37 north of Cogar.
0570NX	I066-55-07-NX0570	Oklahoma County, in Oklahoma City on I-44 over old Belle Isle lake.
0541NX	U066-55-006-NX0541	Oklahoma County, in Oklahoma City on SH 66 over Grand Blvd.

CONCLUSIONS

The results of the laboratory and field evaluations indicate that silane significantly reduces moisture and chloride ingression into concrete, and provides protection of bridges against corrosion.

The chemical reaction between silane and concrete, leaves the water and chloride repellent hydrocarbon group of the silane molecule chemically bonded to the concrete. The probability of this bond breaking and the treated concrete losing this water and chloride repellent property, is very low.

The evaluation of the field performance of the bridges treated with the silane indicates freeze-thaw scaling was not induced or increased.

Newly constructed bridge decks cured with linseed oil can be cleaned and treated with silane to develop a water repellant surface. Depths of penetration averaging 3/8 inch can be achieved.

The application rate of 125 ft^2/gal. provides an adequate flood coat on the bridge deck which allows the silane to penetrate into the deck surface to a depth sufficient to protect it from normal traffic abrasion.

Pavement surface friction was not significantly affected by silane treatment. British Pendulum tests on treated and untreated deck panels averaged 91.3 and 92.6 respectively.

The results of ODOT laboratory tests on both wet and dry concrete surfaces indicate that silane penetrates to a greater depth when it is applied to a dry surface.

RECOMMENDATIONS

As a result of the ODOT study of silane treatment of bridge structures, it is recommended that:

1. The alkyltrialkoxysilane treatment should be accepted as a bridge structure protective system against the ingression of moisture and chlorides, and corrosion of the internal reinforcing steel.
2. The silane treatment should be used on both new and existing bridge structures which meet the following conditions:
    1) The chloride content at the rebar level has not exceeded 2.5 lbs/yd^3 as indicated by the procedure in AASHTO T260.
    2) The rebar corrosion in terms of the numerical value of potentials measured over an area, has not exceeded -350 mV (-0.35 V CSE) as indicated by ASTM C 876.
3. The silane should be a solution of 40 percent alkyltrialkoxysilane by weight in an anhydrous alcohol solvent. The silane should meet the laboratory test requirements listed in Table B-1.
4. The surface of the bridge deck should be clean and dry at the time of silane application. After the silane has been applied, time should be provided for maximum penetration of the silane into the concrete, then water should be sprayed on the treated surface to provide adequate

moisture for the hydrolysis part of the silane reaction with the concrete.

5. A continuing evaluation should be conducted through 1996 of the bridges selected for this study to determine the long term performance of the silane treatment.

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16. Portland Cement Association, Durability of Concrete Bridge Decks - A Cooperative Study, Final Report (EB067.10E), the state highway departments of California, Illinois, Kansas, Michigan, Minnesota, Missouri, New Jersey, Ohio, Texas, and Virginia; the Bureau of Public Roads; and Portland Cement Association, 1970.

Appendix A

Implementation

REMINDER CHECK-LIST
FOR
PERSONNEL CONDUCTING CHLORIDE SAMPLING AND HALF-CELL TESTING
OF
BRIDGE DECKS
AASHTO T259, T260 and ASTM C 876

1. Provide for traffic control during testing of the bridge.
2. Conduct the chain-drag survey of the bridge deck by dragging the device over the entire area of the bridge deck. Paint the delaminated areas. Sketch the areas on paper, showing reference points. Estimate percent of areas that are delaminated.
3. Mark 5 ft length intervals along the parapet wall or curb for reference during half-cell testing. Mark the bridge deck using spray paint from south to north, or west to east ends of the bridge.
4. Paint dots on the bridge deck to mark test sites, at 5 ft length intervals along the parapet wall or curb of the bridge. Paint one line of dots 1 ft away from each parapet, another line 2 1/2 ft away from parapet and another line 5 ft away. All painted dots should be in line with the marked intervals described in (3) above. The remaining dots should be painted at 5 ft intervals. See Figure A-1. These dots are located where the half-cell tests will be conducted, and the chloride samples will be retrieved. These dots must be wet with water during the half-cell testing.

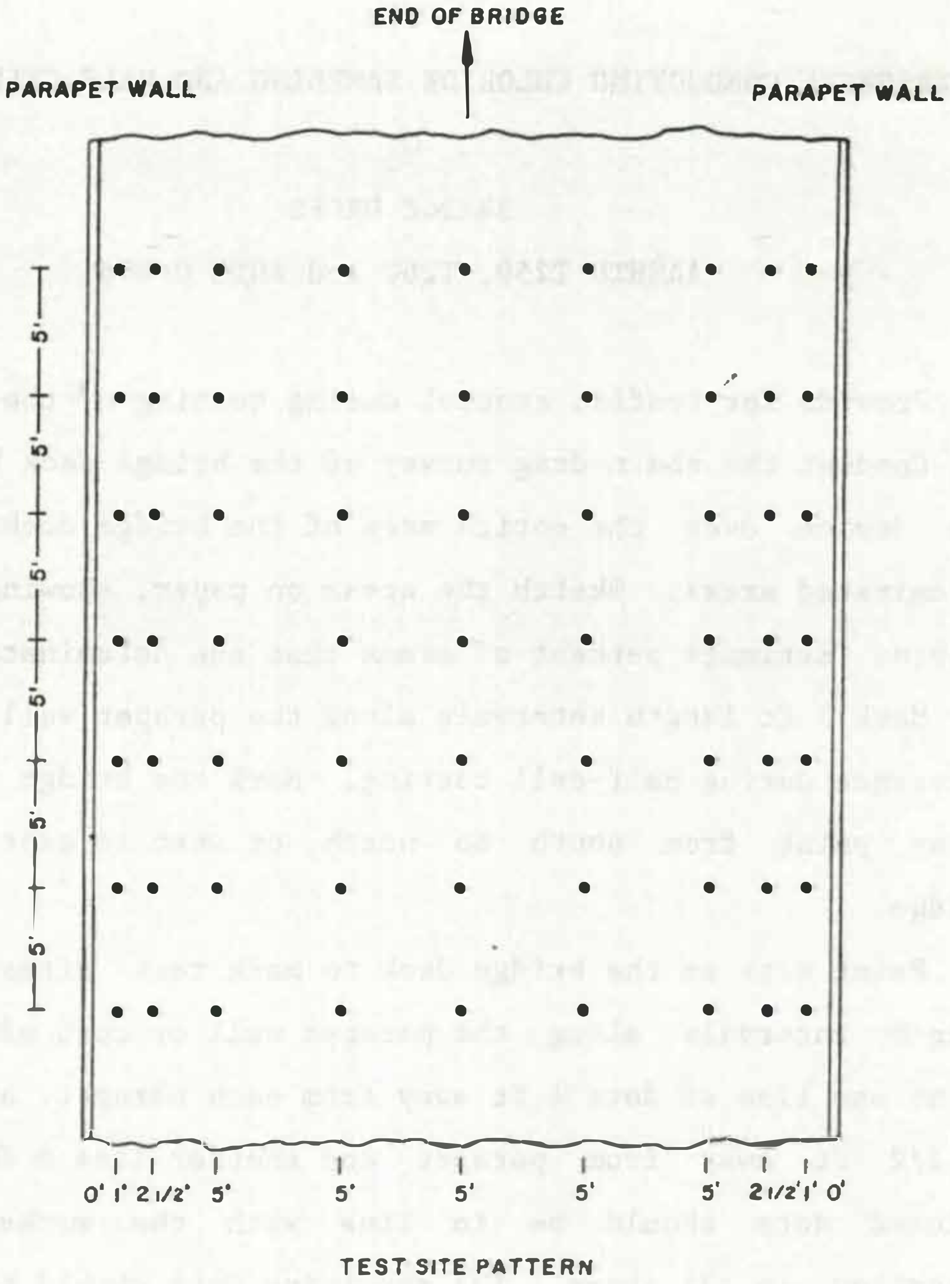

Figure A-1. Half Cell Potentials Test Pattern for Bridge Decks.

5. Prepare equipment to conduct the half-cell test (ASTM C 876)

   a. Stretch out the test lead wire.

   b. Make ground to the steel of the bridge deck.

   c. Place sponge on the half-cell testing device.

   d. Check multi-meter battery.

   e. Place the lead wire of the half-cell testing device to the positive or MA on the multi-meter Model 6000, and read on the MV scale.

   f. Place the lead wire of the half-cell testing device to the negative or common on the multi-meter.

   g. Check to determine connections are good, and that the reading on the multi-meter is stabilized.

   h. Wet each painted dot, and keep them wet.

   i. Take the readings at each painted dot with the multi-meter, using DC current.

6. Conduct half-cell test readings at each of the painted dots that are wet with water.[5] At locations where the readings numerically exceed -350 mV, take additional readings 6 inches away from the center of the spot, at 90 degree angles from each other. See Figure A-2. Record all readings on a working drawing of the bridge deck.[5]

7. Make visual inspections of cracks, spalling, popouts, and areas of delamination, and record or make a sketch of the areas on a working drawing of the bridge deck.

8. Take chloride samples at the sprayed dots, using AASHTO T260 procedures.[3] Take 25 percent of the total chloride samples where the half-cell potentials are numerically greater than -350 mV. Take 50 percent of the total chloride samples where the half-cell potentials are numerically between -200 mV and -350 mV. Take 25

percent of the total chloride samples where the half-cell potentials are numerically below -200 mV.

9. After taking chloride samples, patch the sample holes in the bridge deck with a quick concrete patching material. If the bridge deck has been treated with silane prior to chloride sampling, re-apply silane to the patched areas.

10. Determine the total chloride ion content of the concrete samples using AASHTO T260 procedure.[3]

11. Report the chloride ion content of the chloride samples using AASHTO T259 procedure.[2]

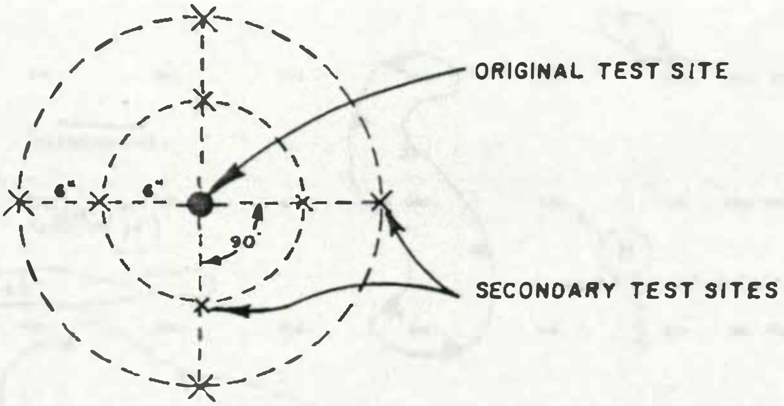

Figure A-2. Individual Half Cell Potential Test Site.

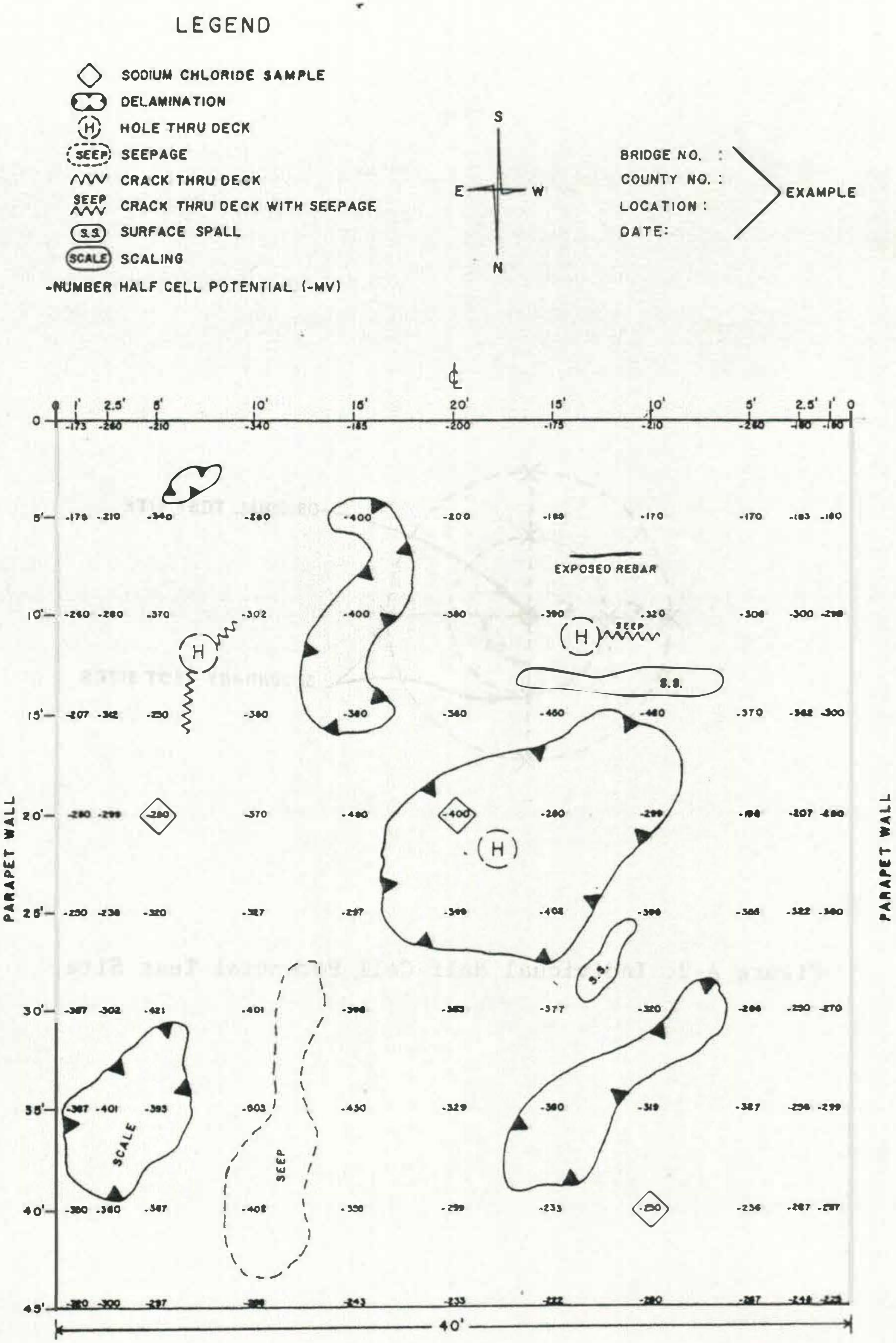

Figure A-3. Field Data Report of Typical Bridge Deck Requiring Rehabilitation.

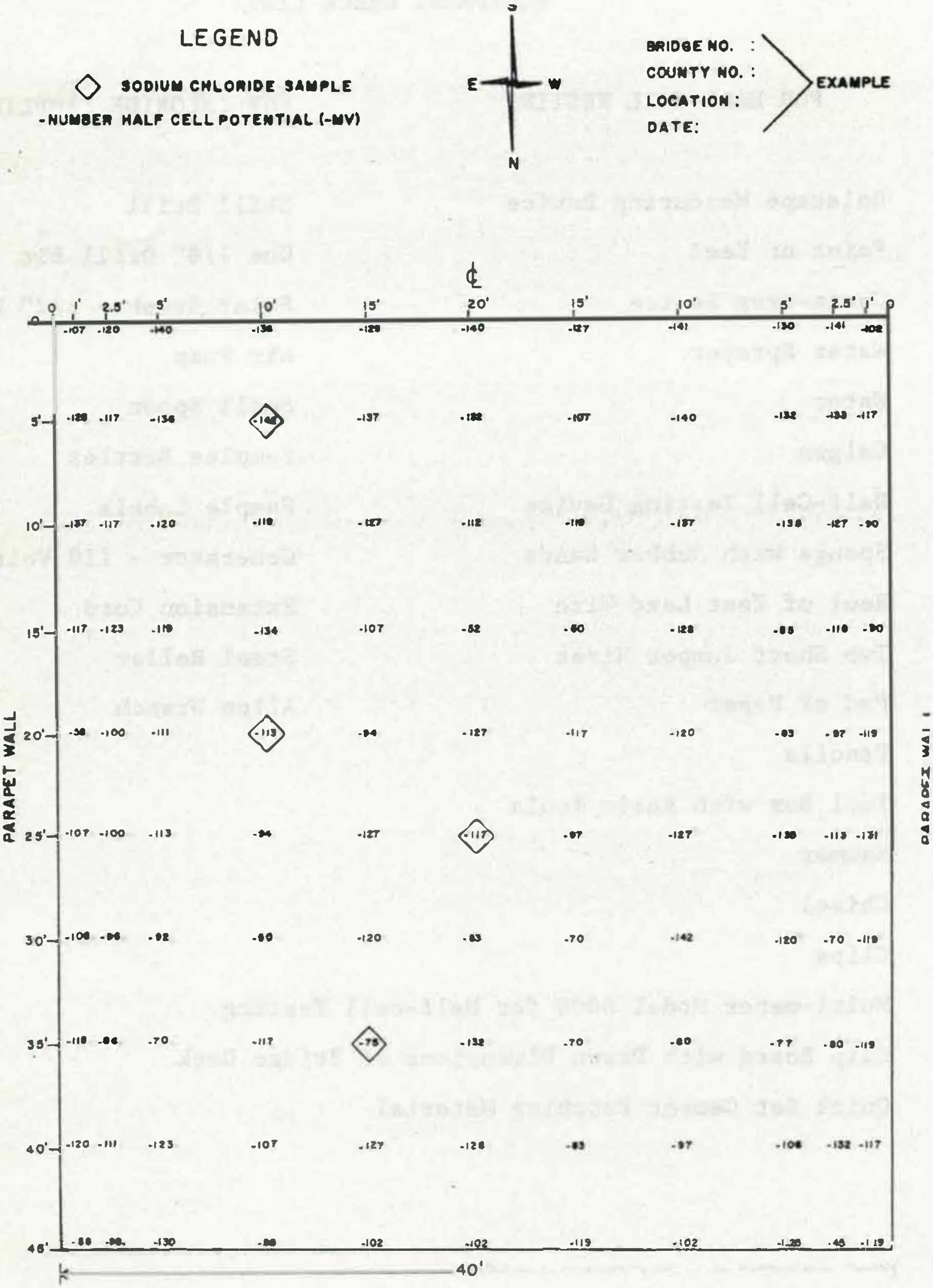

Figure A-4. Field Data Report of Typical Bridge Deck in Good Condition.

EQUIPMENT CHECK LIST

FOR HALF-CELL TESTING

Rolatape Measuring Device

Paint or Keel

Chain-drag Device

Water Sprayer

Water

Calgon

Half-Cell Testing Device

Sponge with Rubber Bands

Reel of Test Lead Wire

Two Short Jumper Wires

Pad of Paper

Pencils

Tool Box with Basic Tools

Hammer

Chisel

Clips

Multi-meter Model 6000 for Half-cell Testing

Clip Board with Drawn Dimensions of Bridge Deck

Quick Set Cement Patching Material

FOR CHLORIDE SAMPLING

Skill Drill

One 1/8" Drill Bit

Paint Brush - 1/2" Wide

Air Pump

Small Spoon

Samples Bottles

Sample Labels

Generator - 110 Volts

Extension Cord

Steel Roller

Allen Wrench

PURCHASING LIST FOR BRIDGE TESTING EQUIPMENT

EQUIPMENT	MODEL	1986 PRICE	POSSIBLE SUPPLIER
24x1¼" Drill Bit	#227791	$ 89	Midstate Ind. Supply 8400 South Shields Okla. City, OK 73149 405/632-5571
Skill Prof. Roto Hammer	#1770	$1,100	
Chapin Compression Sprayer (3 gal Galvanized)		$ 30	Contractor's Supply 20 N. E. 30th Okla. City, OK 405/525-7431
Rolatape	415D	$ 124	Triangle A & E 4361 N. W. 50th Okla. City, OK 405/947-3776
James R-Meter (Pachometer) James Electronics	C4966	$1,095	James Instruments 3727 N. Kedzie Chicago, Ill. 60618 1-800-426-6500
Beckmen, HD110 Multimeter		$ 189	Harco Corporation 7706-A N.W. 3rd Okla. City, OK 73127 405/495-1154
Deluxe Case (DC-205)		$ 29	
Deluxe Test Lead Kit (DL-243)		$ 12	
Fuse Kit		$ 3	
Chain Drag Bar			Shop Built
Lead Wire with Rubber Shield 18 gauge, Test Prod. Wire Belden No. 8899 Red 100' Black 100'			Trice Electronics 4701 North Stiles Okla. City, OK 73105 405/524-4411
Paint Brush Wooden Handle, 1" or 2"			Local Store
Sample Labels			Supply Room
Metal teaspoon 6" or 12" handle			Local Store
Reference Electrode 8" length (install on broom handle)		$ 28	Harco Corporation 7706-A N. W. 3rd Okla. City, OK 73127 405/495-1154
Bicycle Pump			Local Store

EQUIPMENT	MODEL	1986 PRICE	POSSIBLE SUPPLIER
Generator (Diesel or Gasoline) 110 volt 25 amp			
Plastic Sample Bottles with moisture tight snap lid 8 dram size		$ 24/case 650 bottle/cs.	Riekes Containers 2810 S. W. 23rd OKC, OK 73108 405/681-4607

APPENDIX B

Lab Test Procedures and Reports

TABLE B-1. LABORATORY TEST REQUIREMENTS FOR SILANE MATERIAL

(1) Absorption:

Test	Duration	Max. Absorption	Method
Water Immersion	48 hours	1% by weight	ASTM C-642
	50 days	2% by weight	ASTM C-642

(2) Chloride Ion Penetration:

Test	Duration	Max. Absorbed Cl-	Method
Salt Water Ponding*	90 days	0.75 lb per cu yd Depth: 1/2 inch (13 mm) to 1 inch (25 mm)	AASHTO T-259 AASHTO T-260

*Based on non-abraded specimens.

(3) Treatment:

Test	Minimum Depth	Method
Penetration	0.15 inch (3.81 mm)	OHD L-34*

(4) Vapor Permability. Treated concrete shall retain its moisture vapor permability as determined by OHD L-35*.

*ODOT laboratory test procedure. See pages B-2 and B-3

OKLAHOMA DEPARTMENT OF TRANSPORTATION

TEST FOR

DEPTH OF PENETRATION OF CONCRETE BY PENETRATING WATER REPELLENT TREATMENT SOLUTIONS

SCOPE: This method covers the determination of the depth a penetrating water repellent treatment solution penetrates Portland Cement concrete.

TEST SAMPLE: One 8 in. x 8 in. x 2 in. concrete block cast under laboratory conditions. The concrete shall meet the requirements for Class "A" concrete as specified in Section 701 of the Standard Specifications except the coarse aggregate shall be #7 gradation. The block shall have a broom finish on one side.

The block shall be cured for 7 days in accordance with AASHTO T 126-76.

PROCEDURE: After curing, the block shall be oven dried at 230 ± 9° F to constant weight. The block shall then be sealed with paraffin on five sides, leaving the broom finished side exposed.

The broom finished side shall then be treated with the moisture proofer and retarder at the manufacturer's recommended application rate.

Cure the treated block in accordance with the manufacturer's recommendation.

Fracture the treated and cured block into 4 sections approximately 4 in. x 4 in. x 2 in.

Soak the sections in water for approximately 1 minute to delineate the depth of penetration.

Measure the depth of penetration to the nearest 0.1 in. at 10 random locations using a depth gauge.

REPORT: Report the depth of penetration as the average of the 10 measurements.

OHD L-35
Revised 2-24-83

OKLAHOMA DEPARTMENT OF TRANSPORTATION

TEST FOR

MOISTURE VAPOR PERMEABILITY OF TREATED CONCRETE

SCOPE: This method covers the determination of the vapor permeability of Portland Cement concrete treated with a penetrating water repellent treatment solution.

TEST SAMPLES: A set of two concrete blocks 8 in. x 8 in. x 2 in. shall be cast under laboratory conditions. The concrete shall meet the requirements for Class "A" concrete as specified in Section 701 of the Standard Specifications except the coarse aggregate shall be #7 gradation. The blocks shall have a broom finish on one face. The blocks shall be cured for 7 days in accordance with AASHTO T-126. Each block shall be tested separately.

PROCEDURE: After curing, the block shall be oven dried at 230 ± 9° F to constant weight. This weight shall be recorded as "A" (dry weight of block).

The block shall be allowed to cool to room temperature and then placed in de-ionized water for 48 hrs. The block shall be brought to a surface dry condition and weighed. This weight shall be recorded as "B" (wet weight of block).

Coat the block on all six sides with the penetrating water repellent treatment solution at the manufacturer's recommended application rate.

Weigh the coated block and record this weight as "C" (wet weight of coated block). Place the speciman in an oven at 230 ± 9° F and dry to constant weight. Record this weight as "D" (dry weight of coated block).

CALCULATIONS: Calculate the percent moisture loss as follows:

$$G = \%\ \text{moisture loss} = \frac{(C-D)}{B-A} \times 100$$

Average the two samples. If the average $G \geq 99.5\%$, the treated concrete has retained its moisture vapor permeability.

DT-Form 221
Rev. 4/77

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION

Materials Division

Calculations Checked By
Proof Read By

Report No. 1-4350-55921

Report on Sample of Bridge Deck Core

Research ~~Control~~ Section No. R-1 Project No. 352910 Item 2709

Sample Received at Laboratory 9-11, 1984 County Rogers Div. 8

Received on project Sampled 9-11, 1984 By Rex, Jones, Goodner

From Identification Bird Creek Bridge Quantity

Resident Engr. Mitchell Smith Address 200 N.E. 21st Street, Oklahoma City, Ok

Contractor Tested By

Source of Material Core from Bird Creek Bridge Deck

Examined for Use in Chem-Trete Sealer Test for Specification No.

Chem-Trete was applied to bridge deck and core was retrieved from deck. Applied on bridge deck August 24, 1977, at an application rate of 125 $Ft.^2$/ gal.

24 hour absorption test run on core.
48 hour absorption test run on core.

Test Results:

After 24 hours - 0.68%
After 48 hours - 0.99%

REPORTED FOR INFORMATION

Remarks:

Transmitted 10/2, 1984

J. D. Telford, P.E.
Materials Engineer

DT-Form 221
Rev. 4/77

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION

Materials Division

Calculations Checked By

Proof Read By

Report No. 4350-14562

Report on Sample of BSM -40

Control Section No.

Project No. 35291-2709

Sample Received at Laboratory 8-10-78, 19 County Div. Research

Received on project Sampled 8-10-78, 19 By M.D. Smith

From Identification Quantity

Research ~~Resident~~ Engr. Dwight Hixon Address

Contractor Tested By

Source of Material

Examined for Use in Test for Specification No. Special

Weight of Dry Block	3998
Weight of Saturated Block	4192
Percent of Absorption	4.85%
While saturated Block was coated with BSM-40 at the rate of 125 Ft^2/gallon	
Weight of coated block after 7 day in oven at 230°F	3998
Weight of coated block after 24 hr soak in H_2O	4026
Percent of absorption of coated block	0.70%

cc:Materials ✓
M.D. Smith
Dwight Hixon
Physical Section

Remarks: INFORMATION

J. D Telford
J.D. Telford, P.E.
Materials Engineer

Transmitted 1-19-79, 19

DT-Form 221
Rev. 4/77

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION

Calculations Checked By

Proof Read By RD / Te

Materials Division

Report No. 1-4350-34724

Report on Sample of Penetrating Water Repellant Sealer for Concrete

Control Section No. **Project No.** For Information Only

Sample Received at Laboratory 7-7-83, 19 **County** **Div.**

Received on project **Sampled** , 19 **By** V. Howard Kersten

From **Identification** Chem-Trete BSM-40R **Quantity** 1 sample

Resident Engr. **Address**

Contractor **Tested By** Physical and Chemical Sections

Source of Material Dynamit Nobel

Examined for Use in Penetrating Water Repellant Sealer for Concrete **Test for Specification No.** S.P. 515-14(a-c)

On July 7, 1983, Concrete blocks were prepared by the Physical Section in accordance with AASHTO T259-80. The Salt water ponding was completed on November 17, 1983. Samples were tested chemically for CL$^-$ penetration in accordance with AASHTO T260-82. The O.D.O.T. requirement is a maximum of 1.50# yd^{-3} from 1/16" to 1/2" and 0.75# yd^{-3} maximum at a depth of 1/2" to 1" (SP. Prov. 515-14(a-c). Application rate of sealer was 125 Ft.^{2} gal^{-1} as per manufacturer's recommendations.

cc ✓ Materials
Research & Dev.
Bridge
Enriquez
Kuyk
Telford
Hartronft

Remarks: FOR INFORMATION ONLY

Transmitted 12-5-83, 19 DEC [illegible] 1983

J.D. Telford, P.E.
Materials Engineer

Identification	Sample	Depth	% Cl^-	Lbs.Cl^- yd^{-3}	Absorbed Cl^- lbs yd^{-3}
Slab "R", Control, Untreated, Not Ponded	1A	1/16" - 1/2"	0.0099	0.3876	0.3224
	2A	" "	0.0077	0.3015	(Ave.)
	3A	" "	0.0071	0.2780	
	1B	1/2" - 1"	0.0048	0.1879	
	2B	" "	0.0065	0.2545	0.2545
	3B	" "	0.0082	0.3210	(Ave.)
Slab #1, Treated And Ponded	1A	1/16" - 1/2"	0.0984	3.8524	3.5300
	2A	" "	0.1132	4.4318	4.1094
	3A	" "	0.1143	4.4749	4.1525
	1B	1/2" - 1"	0.0077	0.3015	0.0470
	2B	" "	0.0088	0.3445	0.0900
	3B	" "	0.0167	0.6538	0.3993
Slab #2, Treated And Ponded	1A	1/16" - 1/2"	0.0950	3.7193	3.3969
	2A	" "	0.1166	4.5649	4.2425
	3A	" "	0.1064	4.1656	3.8432
	1B	1/2" - 1"	0.0139	0.5442	0.2897
	2B	" "	0.0145	0.5677	0.3132
	3B	" "	0.0167	0.6538	0.3993
Slab #3, Treated And Ponded	1A	1/16" - 1/2"	0.1064	4.1656	3.8432
	2A	" "	0.0973	3.8093	3.4869
	3A	" "	0.1937	7.5834	7.2610
	1B	1/2" - 1"	0.0162	0.6342	0.3797
	2B	" "	0.0122	0.4776	0.2231
	3B	" "	0.0287	1.1236	0.8691

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Rev. 4/77

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION

Materials Division

Calculations Checked By
Proof Read By

Report No.

Report on Sample of Penetrating Water Repellant Sealer for Concrete

Control Section No.

Project No. For Information Only

Sample Received at Laboratory 7-7-83, 19 County Div.

Received on project Sampled 19 By W. Howard Kersten

From Identification Chem-Trete BSM-40R Quantity 1 Sample

Resident Engr. Address

Contractor Tested By Chemistry Section

Source of Material Dynamit Nobel

Examined for Use in Penetrating Water Repellant Sealer for Concrete Test for Specification No. Sp Prov 515-14(a-c)

At the request of Mr. Hartronft, additional tests were performed on the treated blocks of Report #34724 dated 12-5-83. The CL$^-$ depth of penetration was checked at 3/16" to 1/2" and 3/16" to 11/16". A graphic display on the following page shows the amount of CL$^-$ penetration at all four depths in pounds per cubic yard after subtracting the amount found in our untreated, unponded control sample.

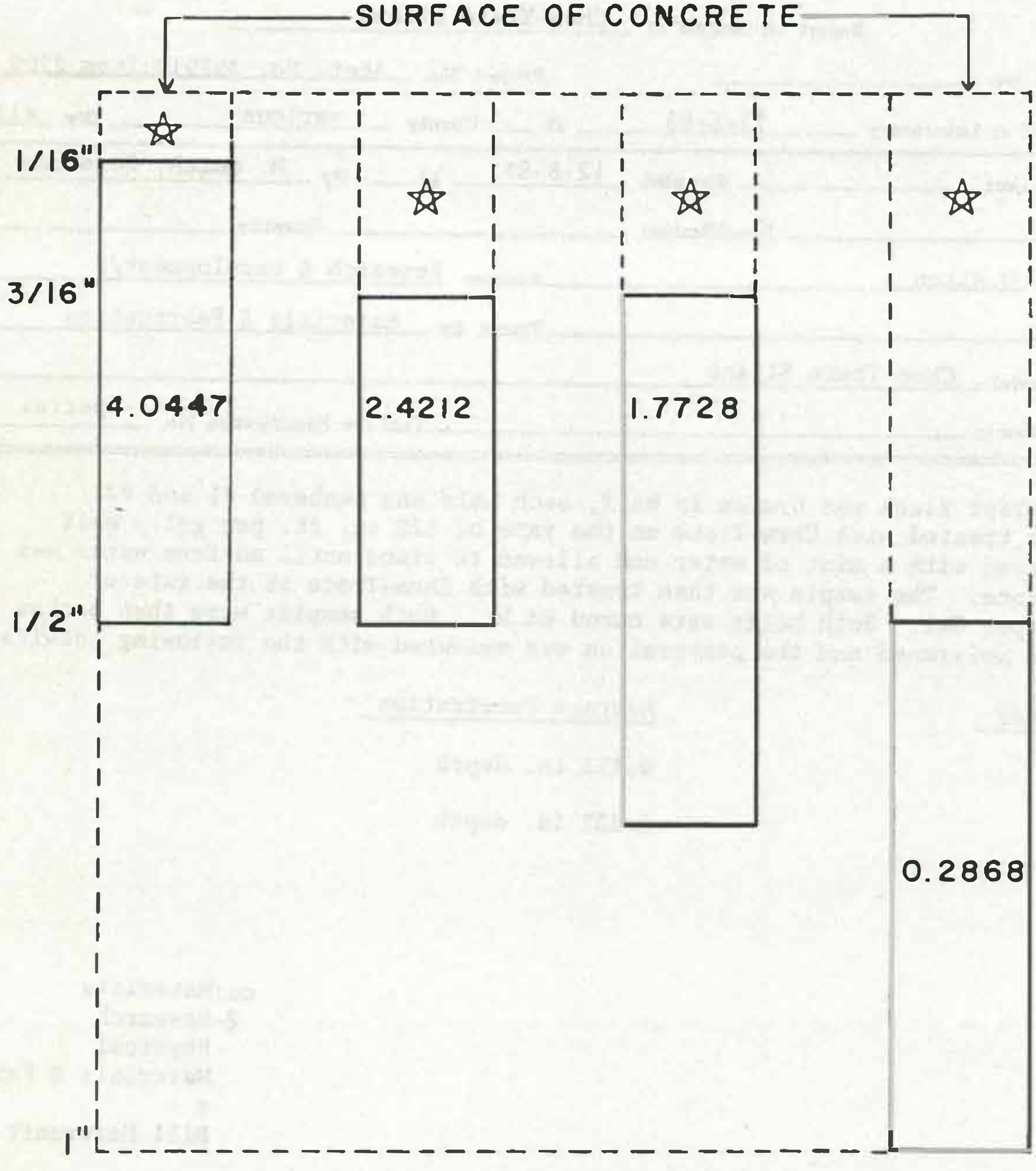
cc:Materials (5-4-1)
Research & Dev.
Bridge
Telford
Hartronft
Enriquez
Kuyk

Remarks:

Transmitted 12-27-83 19

J.D. Telford, P.E.
Materials Engineer

CHLORIDE: POUNDS/yd^3



☆ = Discarded portion of test block

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DEPARTMENT OF TRANSPORTATION

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Proof Read By BS

Materials Division

Report No. 2-4350-35661

Report on Sample of Chem-Trete Silane

Control Section No.
Project No. Acct. No. 352910 Item 2709
Sample Received at Laboratory 12-8-83, 19 County various Div. all
Received on project Sampled 12-8-83, 19 By M. Smith, Research
From Identification Quantity -
Resident Engr. D.Hixon Address Research & Development/9
Contractor Tested By Materials & Fabrication
Source of Material Chem-Trete Silane
Examined for Use in Test for Specification No. Special

A dried Test Block was broken in half, each half was numbered #1 and #2. Half #1 was treated with Chem-Trete at the rate of 125 sq. ft. per gal. Half #2 was sprayed with a mist of water and allowed to stand until no free water was on the surface. The sample was then treated with Chem-Trete at the rate of 125 sq.ft. per Gal. Both halfs were cured 64 hr. Both samples were then broken in half and moistened and the penetration was measured with the following results:

Sample Number	Average Penetration
#1	0.453 in. depth
#2	0.227 in. depth

cc:Materials
2-Research
Physical
Materials & Fabrication
s
Bill Hartronft

Remarks: REPORTED FOR INFORMATION

Transmitted 12-19-83, 19

DEC 19 1983

J.D. Telford, P.E.
Materials Engineer

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Rev. 4/77

STATE HIGHWAY COMMISSION
- RECEIVED -
APR 0 9 1982
RESIDENT ENGINEER
DUNCAN, OKLAHOMA

STATE OF OKLAHOMA
DEPARTMENT OF TRANSPORTATION

Materials Division

Calculations Checked By ____________
Proof Read By ____________

Report No. 4-4350-79770

Report on Sample of Chem-Trete

Control Section No. ____________ Project No. SAP-26(146)Br. 00113(04)

Sample Received at Laboratory 3-30-82, 19__ County Grady Div. 7

Received on project ____________ Sampled 3-30-82, 19__ By Bill Pittenridge

From Bridge Decks Identification See Below Quantity 4 Cores

Resident Engr. H.E. Croy Address Anadario

Contractor Oklahoma Paving Co. Tested By Materials & Fabrication

Source of Material Dynamit Nobel of America Inc.

Examined for Use in Chem-Trete Silane Treatment Test for Specification No. SP-515-13(a-b)

Two (2) cores taken from bridge deck of Structure "C" cured with Red cure and treated with Chem-Trete were checked for 24 Hr. absorption as per OHD-L-32 and depth of Chem-Trete penetration, Resulsts are as follows:

Core No.	Location	% Absorption	Depth of Penetration
1	350+99, 11 ft. Rt CL	0.46%	1/8 inch
2	352+43.25, 4 ft. Rt CL	0.31%	3/16 inch

Two (2) cores taken from bridge deck of Structure "A" cured with Linseed Oil Emulsion and treated with Chem-Trete were checked for 24 Hr. absorption as per OHD-L-32 and depth of Chem-Trete penetration. Results are as follows:

Core No.	Location	% Absorption	Depth of Penetration
3	249+12.16 11 ft. Lt. CL	0.31%	3/16 inch
4	250+77.71 11 ft. Rt. CL	0.26%	3/16 inch

cc:Materials
H.E. Croy
Div. 7
Bob Rose
Okla. Paving
Mitchel Smith (Research
Veldo Goins (Bridge)
John Bradshaw
Materials Branch

APR 1982
RECEIVED
RESIDENT ENGR.
Ardmore, Okla.

Remarks: MEETS SPECIFICATION REQUIREMENTS

Transmitted 4-6-82 APR 7 1982 19__

J.D. Telford
J.D. Telford, P.E.
Materials Engineer

August 22, 1900

Effect of Chem-Trete Silane Surface Treatment
FHWA Time-To-Corrosion Tests
After* 450 Daily Salt Applications
4 Ft. by 4 Ft. by 4-inch Slabs
No Surface Abrasion
Concrete w/c = 0.51, CF = 5.62
Coverage - 1 gal/32 $ft.^2$ applied and brushed around gently (with that which did not penetrate allowed to run off) @35 days of age.

Chem-Trete Treatment	Sample No.	Total Chloride-lbs/yd^3 for Indicated Depth 1/16-1/2 Inch	1/2-1 Inch	1-1-1/2 Inch	1-1/2-2 Inch
Control-1	1	10.7	9.43	8.05	5.58
	2	13.24	12.60	9.79	6.71
Control-2	1	12.99	12.70	9.92	6.69
	2	14.22	11.66	9.40	5.11
Control-3	1	13.50	9.24	9.03	5.81
	2	16.50	9.81	9.74	6.30
	AVERAGE CONTROL	13.55	10.91	9.34	6.03
Chem-Trete Fog Room 1/	1	4.03	1.42	0.61	0.52
	2	5.88	3.32	0.95	0.76
ChemTrete Air-Dry 1/	1	5.11	2.96	0.70	0.59
	2	1.28	0.66	0.62	0.52
Chem-Trete Oven Dry 1/	1	0.66	0.47	0.40	0.34
	2	0.00	0.49	0.37	0.29
	AVERAGE CHEM-TRETE	2.96	1.55	0.62	0.46

1/ Fog Room - Slabs were fog-room cured for 35 days and Chem-Trete was applied to the wet slab.

2/ Air Dry - Slabs were fog-room cured for 20 days, then cured in laboratory air for 7 days and Chem-Trete was then applied

3/ Oven Dry - Slabs were fog-room cured for 28 days, then oven-dried for 8-10 hours at 300°F. Chem-Trete was applied after cooling.

* Approximate, exact time span not available