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Final Report

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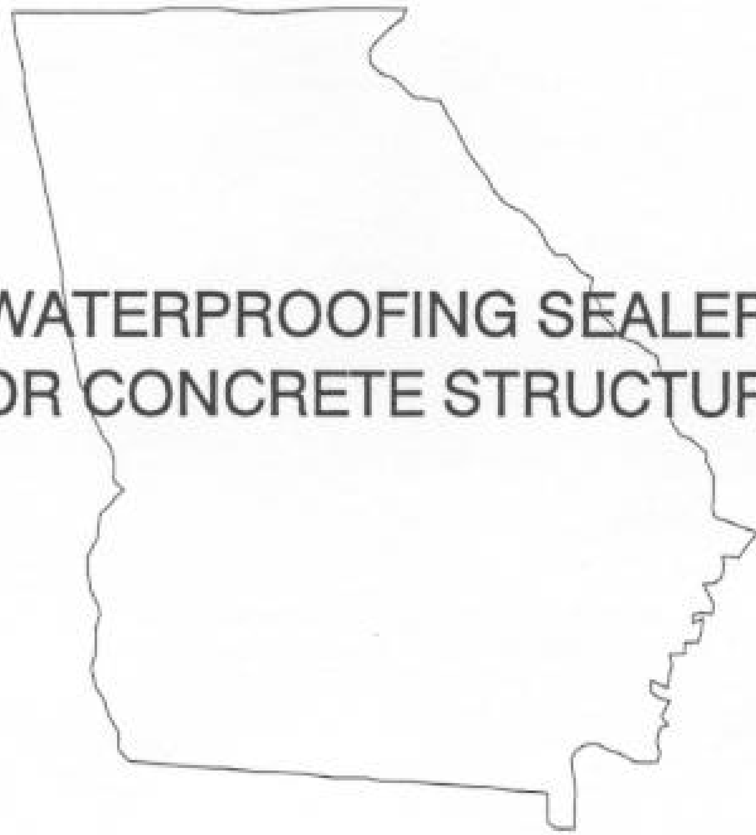

WATERPROOFING SEALERS FOR CONCRETE STRUCTURES

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WATERPROOFING SEALERS FOR CONCRETE STRUCTURES

by
Pamela L. King
Environmental Engineer

Office of Materials and Research
Georgia Department of Transportation

In cooperation with

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16. Abstract

The purpose of this project was to evaluate several different sealer materials for concrete bridge decks and to establish criteria for their use. Laboratory testing was performed on several different generic types of sealers. These tests included the 21-day saltwater soaking test and the rapid chloride permeability test. The materials which showed low chloride ion intrusion from these test were chosen to be placed in field exposure test sections. Nine sealers were placed in four field locations which included both new and existing bridge decks.

The study found that compared to other generic types, boiled linseed oil is not an effective concrete sealer. Of the generic types of sealers studied in this project, silane and siloxane were the most effective in preventing chloride and moisture intrusion. In general, the higher the concentration of active ingredient, the lower the chloride intrusion.

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INTRODUCTION

The Georgia DOT has had little previous experience in the use of waterproofing sealers for concrete structures other than linseed oil, which is used in the northern part of the state. Linseed oil is vulnerable to abrasion by traffic and quickly loses its effectiveness. Reapplications of linseed oil are difficult because it requires a lengthy drying time, during which traffic must be kept off the surface.

Several different generic types of sealers were tested in this project, including silane, siloxane, methyl methacrylate, epoxy, sodium silicate, cemetitous, and waterborne. These materials were subjected to salt water soaking testing for chloride ion absorption and rapid permeability testing in the laboratory. Materials which showed low chloride ion intrusion in the laboratory tests were chosen for field exposure test sections.

The use of waterproofing sealers is initially less expensive than other methods of controlling concrete corrosion such as using epoxy coated rebars, polymer overlays or thicker coverage over the top rebar mat. The cost effectiveness of waterproofing sealers compared to linseed oil may be realized by lower corrosion rates due to lower chloride levels, longer lifespan of the structure, and reduced maintenance costs. An ideal concrete sealer should allow vapor permeability, but prevent water and chloride intrusion for an extended period of time.

TEST PROCEDURES

LABORATORY TESTING

A 21 day salt water soaking test followed by an 18 day drying period was conducted on 25 different waterproofing sealer products in two stages. The products were applied to all sides of Class A concrete cubes measuring approximately 4"X4"X4" with a total surface area of approximately 0.667 ft^2. The mix design and physical properties of the Class A concrete were as follows:

Class A Concrete Mix	Weight in Lbs.
Cement	56.6
Fine aggregate	100.0
Coarse aggregate	177.6
Water	26.2
Physical Properties	
Water/cement ratio	0.462
Density	142.4 lb/yd^3
Air %	4.4%
Slump	4.0 in.
28 day compressive strength	4520 psi

After curing for seven days at 100% relative humidity, the cubes were allowed to air dry for 21 days. The laitance was then removed with a wire brush. A total of 24 cubes were used for the first stage of salt water soaking. Eleven different sealer materials, including boiled linseed oil, were then applied to all faces of two cubes each at the manufacturer's recommended application rate. For some materials, it was not possible to get the recommended quantity to penetrate the surface due to the high density of the concrete. For these materials, a flood coat was applied to all cube faces. Two cubes were left untreated. The materials and the approximate application rates for the first stage of testing are shown in Table 1.

After application, the cubes were allowed to dry for two weeks before immersion in a 15% by weight salt solution (NaCl). The cubes were weighed to the nearest 0.1 gram immediately before immersion and every third day during the 21 day soaking period. One of the untreated cubes was not immersed but was left to air dry throughout the 21 day period. The dry cube was also weighed every 3rd day. After the 21 day soaking period, the cubes were subjected to an 18 day drying period. The cubes were weighed every third day for the first 15 days, then weighed each day for the next three days. After the 18 day drying period was completed, the cubes were measured for chloride ion content by drilling to depths of 1/2" and 1".

The weight gain of the treated cubes was compared to the weight gain of the untreated cube during the soaking period, and the absorption was expressed in terms of percent of initial weight and percent of control (untreated). The weight loss during the drying period was compared to the weight gain during the soaking period. The greater percentage of weight lost, the greater the vapor permeability. The chloride ion content at depths of 1/2" and 1" in the treated cubes was compared to that of the immersed untreated cube. The background chloride content of the unimmersed cube was subtracted from the chloride content measured in the immersed cubes. After drilling, each treated cube was sawed in half. The inner faces were then wetted with deionized water and measured for visible depth of penetration.

A total of 34 cubes were used for the second stage of salt water testing. The concrete mix was exactly the same as for the first stage. Laitance was removed with a wire brush before sealer application. Fifteen different sealer products were applied onto two cubes each, two cubes were coated with boiled linseed oil, and two cubes were left untreated. One of the untreated cubes was not immersed in the salt solution. All materials in the second stage were applied in a flood coat to all cube faces, except for the first two products. These two products have the consistency of a cement slurry and were troweled on as recommended by the manufacturer. The cubes were weighed before and after treatment. The coverage rate (ft^2/lb) was determined from the weight difference. Any material lost to evaporation was not measured. The materials and application rates for the second stage of testing are shown in Table 2. The cubes were immersed in a 15% salt solution for 21 days, then allowed to dry for 18 days. The cubes were weighed every third day according to the same schedule as in the first stage.

TABLE 1 : SEALERS FOR SALT WATER SOAKING - FIRST STAGE

SAMPLE NO.	PRODUCT NAME	GENERIC TYPE	RATE (FT2 / GAL)
1	Professional Water Sealant	8% silicone	150
2	Sil-Act	40 % silane	125
3	Chem-Trete BSM 40	40% silane	200
4	Hydrozo Enviroseal 40	waterborne	175
5	General Polymers	50 % epoxy	300
6	E - Bond	17.8 % epoxy	300
7	Dekguard P-40	40% silane	flood
8	Brite Seal 35	35 % polysiloxane	flood
9	Polycarb 124	50 % epoxy	175
10	3M Penetrating Sealer	15 % siloxane	300
11	Boiled Linseed Oil		flood
12	Untreated Concrete		

TABLE 2 : SEALERS FOR SALT WATER SOAKING - SECOND STAGE

SAMPLE NO.	PRODUCT NAME	GENERIC TYPE	RATE (FT2 / LB)
13	Xypex	cementious	1.314
14	Xypex Modified	cementious	0.664
15	GE TWR255	10 % silicone	75.58
16	Dayton Superior J29	40 % silane	56.69
17	Deckshield HD	15 % siloxane	40.49
18	Lambert Waterban 90	15 % siloxane	57.65
19	MaFoi Topseal	waterborne	65.41
20	MaFoi Innerseal	waterborne	68.02
21	Secure Seox	epoxy	40.49
22	Fosroc Dekguard P-20	20 % silane	44.17
23	Secure Aquanox	15 % siloxane	54.86
24	Secure 329	sodium silicate	75.60
25	WBE Horsey - Set	38 % epoxy	12.41
26	Sure Klean Weatherseal	7 % siloxane	89.51
28	Okon W-2	waterborne	52.33
29	Boiled Linseed Oil		48.59
30	Untreated Concrete		

Rapid chloride permeability testing according to AASHTO T 277 was conducted on 21 sealer products, including linseed oil. The products were flood coated onto the top face of Class AA and Class B concrete cylinders measuring 4" in diameter and 2" thick. The mix designs and physical properties of the Class AA and Class B concrete mixes were as follows:

Class AA Concrete Mix	Weight in Lbs.
Cement	47.1
Fine aggregate	78.9
Coarse aggregate	140.2
Water	20.3
Physical Properties	
Water/cement ratio	0.432
Density	143.2 lb/yd^3
Air %	4.5%
Slump	3.5 in.

Class B Concrete Mix	Weight in Lbs.
Cement	34.8
Fine aggregate	81.6
Coarse aggregate	144.9
Water	22.6
Physical Properties	
Water/cement ratio	0.649
Density	144.0 lb/yd^3
Air %	4.4%
Slump	3.0 in.

The Class B mix has a higher water/cement ratio and greater porosity than the Class AA mix. The two different mixes were used to determine whether greater porosity of the concrete surface would affect permeability after sealer application.

The rapid permeability test consists of monitoring the amount of electrical current passed through concrete cylinders with the untreated end of the cylinder immersed in a 3% by weight salt (NaCl) solution and a potential difference of 60V dc is maintained across the specimen for six hours. The total charge passed is measured in coulombs. The greater the total charge, the higher the permeability.

The permeability apparatus allows four cylinders to be tested at one time. Each test run consisted of three cylinders treated with different sealer products and one untreated cylinder. The sides of the cylinders were coated with a 2-part 100% solids epoxy material to prevent the salt solution from escaping out the sides during the test. The materials subjected to the rapid permeability testing are shown in Table 3.

TABLE 3 : SEALERS FOR PERMEABILITY TESTING

SAMPLE NUMBER CLASS AA	CLASS B	PRODUCT NAME	GENERIC TYPE
26	5	3M Penetrating Sealer	15 % siloxane
27	6	Sil - Act	40 % silane
28	7	Chem - Trete	40 % silane
29	12		linseed oil
30	9	Brite - Seal 35	35 % polysiloxane
32	11	Poly Carb Mark 124	50 % epoxy
33	10	Sika Pronto 19	methyl methacrylate
34	13	Sikagaurd 70	9 % siloxane
35	14	3M 4R	methyl methacrylate
36	15	Okon	waterborne
37	19	Dekgaurd P - 40	40 % silane
38	22	Secure 329	sodium silicate
39	18	Secure Aquanox	15 % siloxane
41	20	Consolideck 10	10 % siloxane
42	21	Transpo	methyl methacrylate
43	23	Burke Shield 244	15 % siloxane
45	25	Polytrete	20 % silane
46	17	Horsey Set	38 % epoxy
47		Consolideck 15	15 % siloxane
48		Pen - Epoxy	epoxy
49		Brite - Seal 20	20 % polysiloxane

FIELD TESTING

A total of four bridges were used for field applications. Two of the bridges are located in downtown Atlanta, and two are in rural areas. Chloride samples were taken before application of sealers from the two downtown bridges. These bridge decks were subjected to at least two applications of deicing salt before final chloride samples were taken.

Bridge 1 - Decatur Street over I-75

This four lane, two span bridge was constructed in 1987. This bridge is approximately 355 feet in length and carries traffic in the East and West directions. Efflorescence was discovered leaching down onto the steel girders below the deck, probably caused by poor quality concrete. Sealers were applied to the two outer lanes in 1990. The two center lanes were left untreated. Four different materials were applied, two in each direction, using the joints between the two spans as a dividing line. The products applied were as follows:

East bound lane, East span - Sikaguard 70, 9% siloxane at 244 ft^2/gal.

East bound lane, West span - Sika Pronto 19, methyl methacrylate at 119 ft^2/gal.

West bound lane, East span - 3M 4R, methyl methacrylate at 124 ft^2/gal.

West bound lane, West span - 3M Penetrating Sealer, 15% siloxane at 186 ft^2/gal.

Bridge 2 - Martin Luther King Blvd. over I-75

This four lane, two span bridge was also constructed in 1987. This bridge is approximately 370 feet in length and carries traffic in the East and West directions. The same leaching problem that occurred in the first bridge also occurred in this bridge. Sealers were applied to the two outer lanes in 1990, with the two center lanes left untreated. Four different materials were applied as follows:

East bound lane, horizontal surfaces - Burke Shield 244, 15% siloxane at 200 ft^2/gal.

East bound lane, vertical surfaces - Weatherproof, 5% siloxane at 207 ft^2/gal.

West bound lane, East span - Sil-Act 20% silane at 148 ft^2/gal.

West bound lane, West span - Sil-Act 40% silane at 148 ft^2/gal.

Bridge 3 - SR 47 over Little River in Wilkes County

This two lane, six span bridge was constructed in 1992. This bridge is approximately 540 feet in length and carries traffic in the South direction. The concrete cover over the top rebar mat ranged from 1.25 to 2.5 inches, leaving some areas with less than the design thickness of 2.25 inches. Instead of adding extra concrete thickness, thereby delaying the opening of the bridge to traffic, a 15% siloxane sealer was applied to the entire surface area of 21,600 ft^2 at a rate of 131 ft^2/gal.

Bridge 4 - I-75 over Towaliga River, Henry/Spalding County

This three lane, eight span bridge was constructed in 1985. This bridge is approximately 250 feet in length and carries traffic in the South direction. This bridge exhibited significant cracking and spalling on the right lane. In 1991, the spalls were patched and the large cracks were filled with grout. Transpo methyl methacrylate sealer was then poured into the grouted cracks and brushed into the smaller cracks. The entire surface of one span was coated with the methyl methacrylate. After treatment, all coated areas were broadcast with sand to provide skid resistance.

RESULTS

LABORATORY RESULTS - SALT WATER SOAKING TEST

During the first stage 21 day salt water soaking period, the immersed untreated concrete control cube increased in weight by 1.79%. During the following 18 day drying period, the weight of the untreated control cube decreased by 1.19%. The weight loss/weight gain ratio for the untreated cube was 66%. The final chloride ion content of the untreated cube was 0.46819% (18.217 lb/yd^3) at a depth of 1/2" and 0.09486% (3.691 lb/yd^3) at a depth of 1". The background chloride ion content of the untreated cube that was not immersed was 0.00594% (0.231 lb/yd^3). Subtracting this background concentration from that of the immersed control cube gives a net chloride ion absorption of 0.46225% at 1/2" depth and 0.08892% at 1" depth. The data for the first stage of salt water soaking testing is summarized in Table 4. Samples are ranked from lowest to highest weight gain. All figures are an average of two cubes. The percentage of chloride ion shown has been adjusted for the background chloride concentration. The percent reduction in chloride ion intrusion was calculated by the following formula:

$$\frac{c - a}{c}$$

where c = the chloride ion content of the immersed control cube, adjusted for background

a = average chloride ion content of two treated cubes, adjusted for background

After drilling for chloride measurement, one of each of the treated cubes was sawed in half (except for linseed oil). The inner faces were then wetted with deionized water and examined visually for depth of penetration. The depth was measured to the nearest 1/16 inch at the greatest and smallest visible depths.

TABLE 4: FIRST STAGE SALT WATER SOAKING TEST RESULTS

SAMPLE NO.	% WT. GAIN	WT. GAIN, % OF CONTROL	WT.LOSS / WT. GAIN	% Cl AT 1/2"	REDUCTION IN Cl AT 1/2"	% Cl AT 1"	REDUCTION IN Cl AT 1"	DEPTH OF PENETRATION
7	0.185	10%	274	0.16301	65%	0.05213	41%	1/8"
10	0.26	15%	232	0.02567	94%	0.01601	82%	3/16" to 1/8"
3	0.28	16%	199	0.05737	88%	0.03905	56%	1/8" to 1/4"
2	0.295	16%	199	0.05989	87%	0.02318	74%	1/16" to 1/4"
4	0.305	17%	195	0.1264	73%	0.03315	63%	1/16" to 3/16"
8	0.35	19%	168	0.05808	87%	0.04338	51%	3/16"
5	0.595	33%	62	0.13826	70%	0.04692	47%	none visible
9	0.7	39%	69	0.14544	69%	0.02138	76%	none visible
11	1.425	80%	42	0.24892	46%	0.0899	-1%	not checked
1	1.49	83%	79	0.27011	42%	0.02554	71%	none visible
6	1.55	87%	55	0.34514	25%	0.04984	44%	none visible

In the second stage of salt water soaking testing, the immersed untreated control cube increased in weight by 2.97%. During the following 18 day air drying period, the immersed control cube decreased in weight by 1.16%. The weight loss/weight gain ratio for the untreated cube was 39% in the second stage compared to 66% in the first stage. All cubes were cast from the same batch, but the second stage cubes had been allowed to air dry for several months longer than the first stage cubes. The background chloride ion concentration in the unimmersed control cube was 0.00594% (0.231 lb/yd^3), the same as for the first stage. Subtracting this background from the chloride ion concentrations measured in the immersed control cube yields 0.41974% at a depth of 1/2" and 0.17970% at a depth of 1". The final results for the second stage of salt water soaking testing are summarized in Table 5. Samples are ranked from lowest to highest weight gain.

In general, the cubes with the lowest weight gain also had the highest weight loss/weight gain ratio, the lowest chloride ion concentration, and the greatest depth of penetration. The most consistently top performing generic types in all these categories were the 40% silane and 15% siloxane products (Sample Nos. 2, 3, 7, 10, 16, 17, 18 and 23). One of the 40% silanes (Sample 2) and 2 of the 15% siloxanes (10 and 17) were later used in field test sections.

TABLE 5: SECOND STAGE SALT WATER SOAKING TEST RESULTS

SAMPLE NO.	% WT. GAIN	WT. GAIN, % OF CONTROL	WT. LOSS/ WT. GAIN	% Cl AT 1/2"	REDUCTION IN Cl AT 1/2"	% Cl AT 1"	REDUCTION IN Cl AT 1"
16	0.06	2%	572	0.00843	98%	0.00254	99%
18	0.07	2%	558	0.02132	95%	0.00116	99%
26	0.08	3%	-779	0.04541	89%	0.00174	99%
23	0.11	4%	416	0.05667	86%	0.00927	95%
22	0.19	6%	183	0.01482	96%	0.00135	99%
17	0.245	8%	104	0.01337	97%	0.01809	90%
15	0.47	16%	73	0.00492	99%	0.00107	99%
14	2.165	73%	162	0.08313	80%	0.03126	84%
29	2.27	76%	37	0.21797	48%	0.11905	34%
25	2.28	77%	23	0.10164	76%	0.12488	31%
21	2.315	78%	38	0.12209	71%	0.05436	70%
28	2.48	84%	47	0.31582	25%	0.1064	41%
20	2.535	85%	48	0.21828	48%	0.07114	60%
24	2.67	90%	47	0.36263	14%	0.11352	37%
19	2.68	90%	46	0.25308	40%	0.14315	20%
13	2.755	93%	77	0.07026	83%	0.0284	84%

The 20% silane (Sample No. 22), the 7% siloxane (No. 26) and the other silicone based materials (1, 8, 15) also ranked relatively low in weight gain, high in weight loss/weight gain ratio and low in chloride ion intrusion. The weight loss/weight gain ratio for sample number 26 is negative because the average weight at the end of the 18 day drying period was less than the initial average weight of the two cubes. The waterborne materials (Sample Nos. 4, 19, 20 and 28) were highly variable in terms of weight gain, weight loss, and chloride ion intrustion. The epoxy materials (Sample Nos. 5, 6, 9, 21 and 25) ranked in the lower half in all categories and showed no visible penetration. The two cementitous products (13, 14) had high weight gain, medium weight loss/weight gain ratio and medium chloride intrustion. The sodium silicate material (24) ranked near the bottom in all categories. The cubes treated with boiled linseed oil (11, 29) were also near the bottom in all categories. Three of the products used in the field test sections were also subjected to salt water soaking. These 3 were chosen from the top performing categories, 40% silane and 15% siloxane.

The graph in Figure 1 shows a plot of percent weight gain vs. percent chloride ion at 1/2" depth for the first stage of the salt water soaking test. The line labeled 9.2% Cl represents the locus of all points where water and chloride ion are both absorbed at the same rate. A 15% NaCl solution contains 9.2% chloride ion.

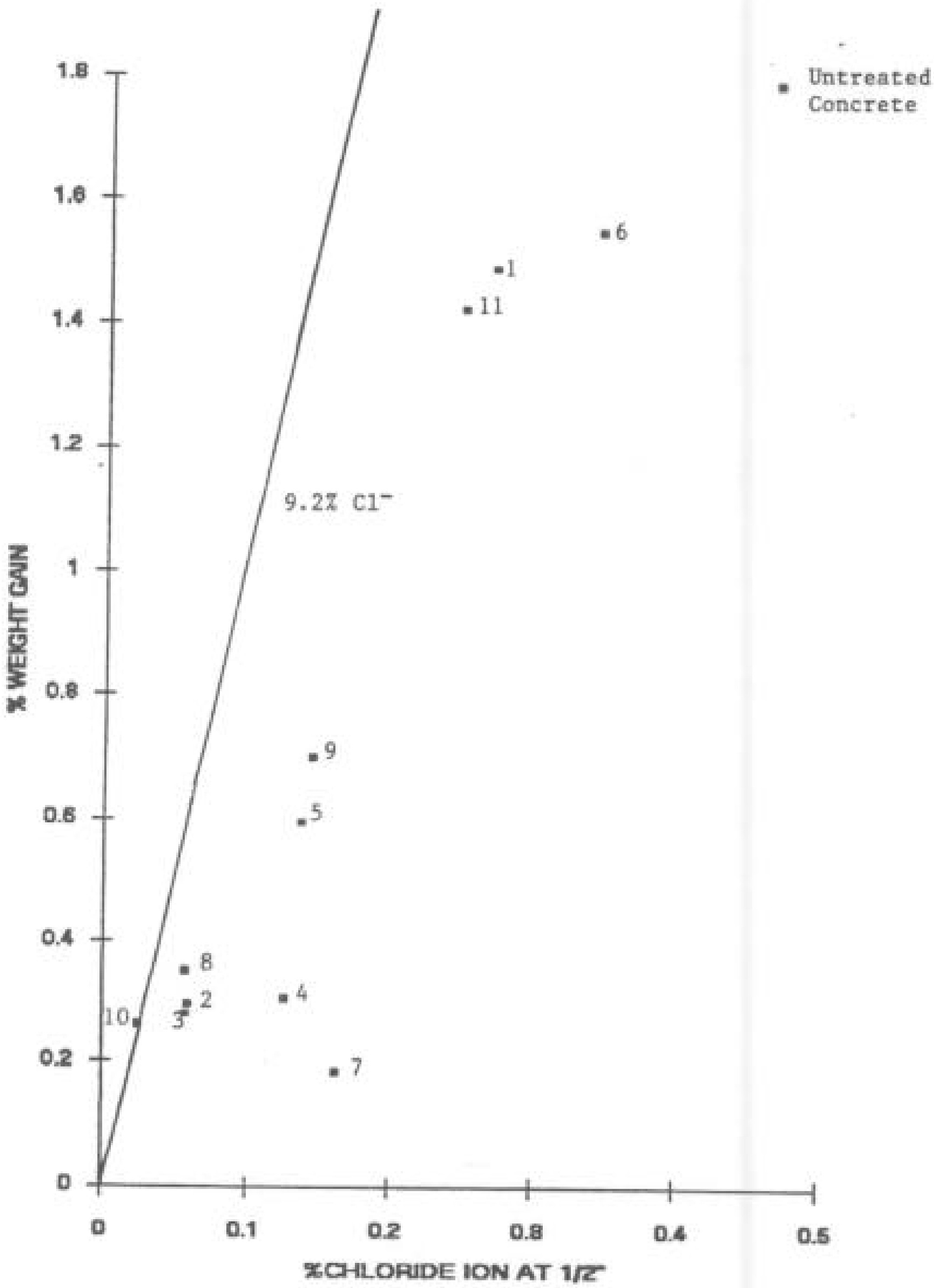

FIGURE 1 WEIGHT GAIN VS. CHLORIDE ION CONTENT AT 1/2" DEPTH FIRST STAGE

Theoretically, if a point falls above this line, the sealer material allowed more water to pass than chloride ion. If a point falls below this line, the sealer material was more permeable to chloride ion than to water[1]. The graph in Figure 2 shows percent weight gain vs. percent chloride ion at a 1" depth for the first stage of salt water soaking. At 1/2", the majority of points fell below the 9.2% line, while at 1" most points fell above the line. Figures 3 and 4 show percent weight gain vs. percent chloride ion at 1/2" and 1" depths for the second stage of salt water soaking. At 1/2", the points are about evenly divided on both sides of the line. Overall, more points fell above the 9.2% line at 1" than at 1/2". Chloride ion intrusion tends to decrease with greater depth.

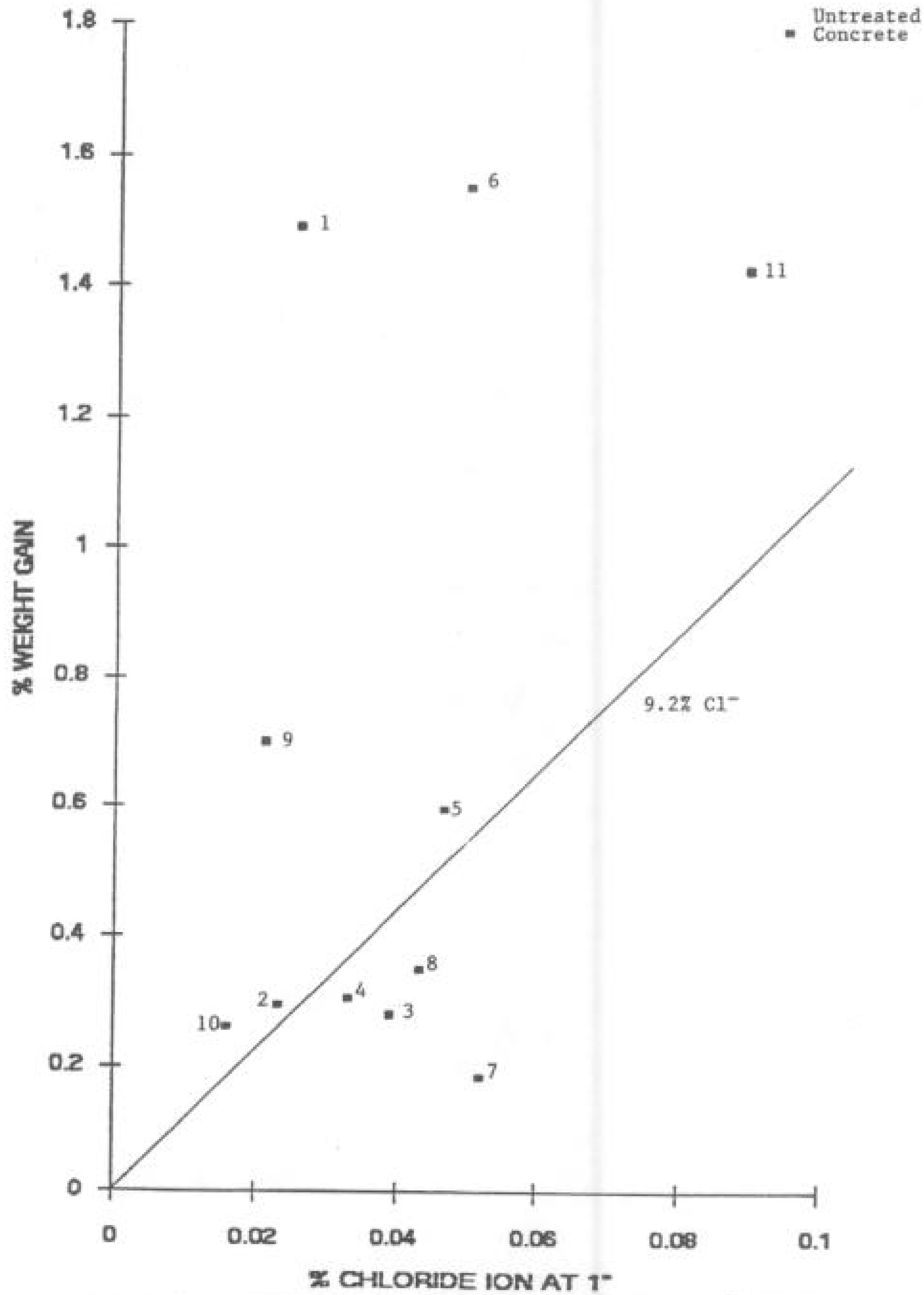

FIGURE 2 WEIGHT GAIN VS. CHLORIDE ION CONTENT AT 1" DEPTH
FIRST STACK

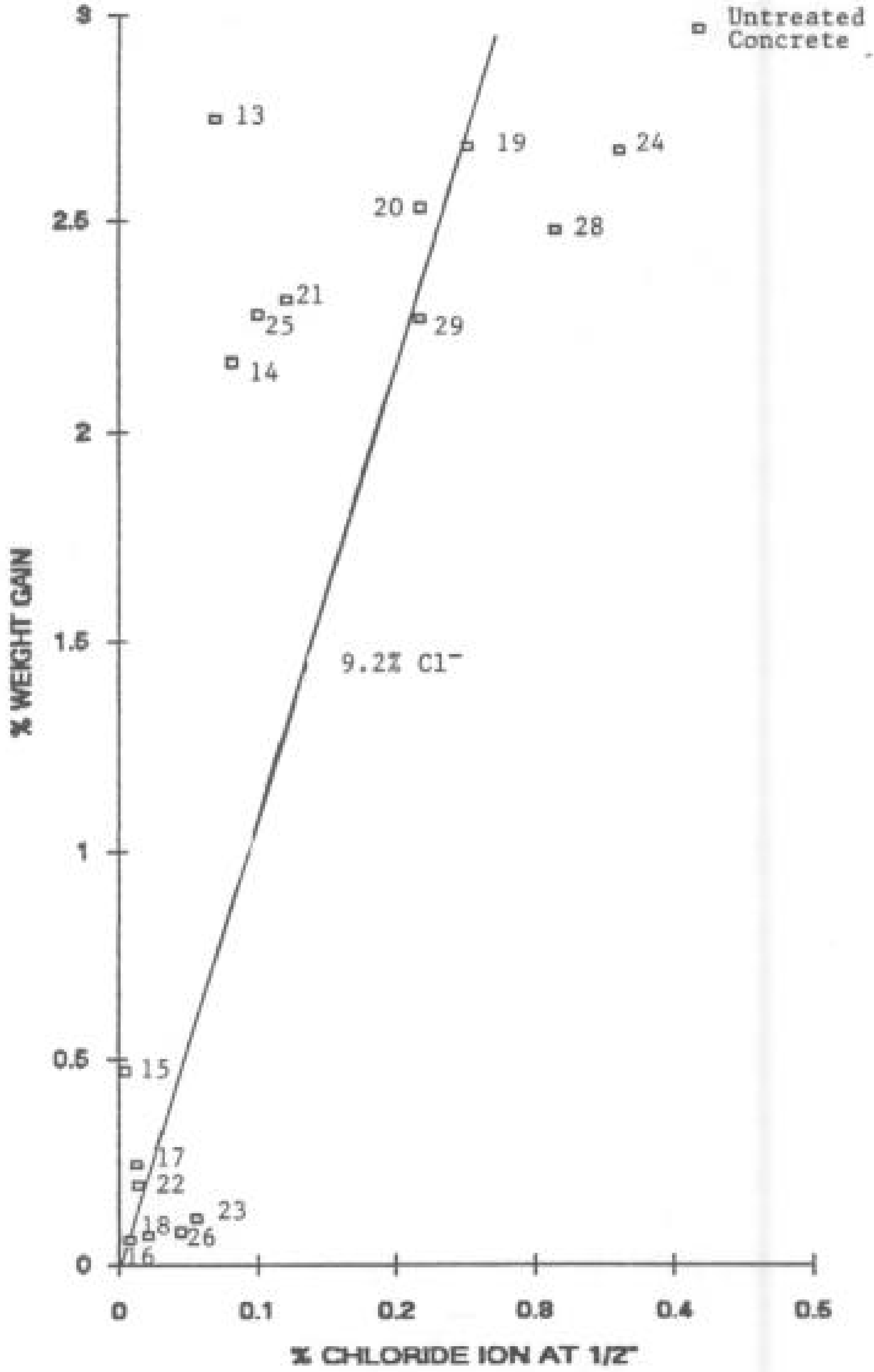

FIGURE 3 WEIGHT GAIN VS. CHLORIDE ION CONTENT AT 1/2" DEPTH SECOND STAGE

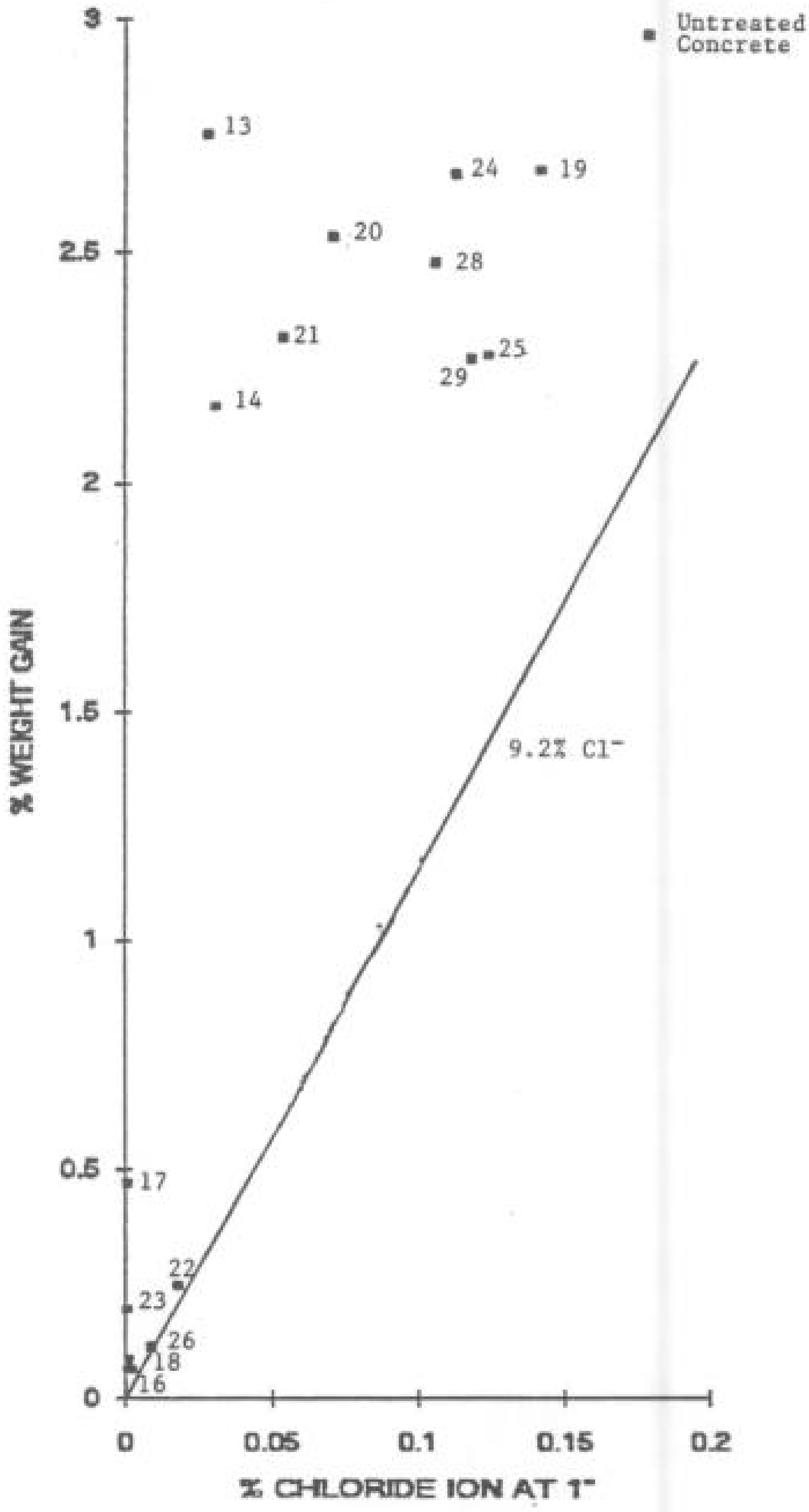

FIGURE 4 WEIGHT GAIN VS. CHLORIDE ION CONTENT
SECOND STAGE

RAPID PERMEABILITY TESTING

Rapid chloride permeability testing according to AASHTO T-277 was conducted on 21 different sealer materials applied over two types of concrete, Class AA and Class B. The testing was conducted in 13 groups of four cylinders, each group having three specimens with sealers applied and one untreated blank. Results of permeability testing are summarized in Table 6. The charge denotes the total charge in coulombs to pass through the sample over six hours of elapsed time. The greater the total charge, the more permeable the sample. The total charge passed through untreated Class AA concrete ranged from 1734 to 5730 coulombs. Figure 5 shows the charge vs. elapsed time for all measurements of untreated Class AA concrete. The total charge passed through untreated Class B concrete ranged from 3533 to 5765 coulombs. Figure 6 shows the charge vs. elapsed time for all measurements of untreated Class B concrete. For all untreated concrete blanks, the charge increase with time was nearly linear. The regression coefficient R^2 is equal to one for a perfect straight line fit. R^2 values for the Class AA blanks ranged from 0.9953 to 0.9993. R^2 values for the Class B blanks ranged from 0.9966 to 0.9994. The average total charge passed through untreated Class AA blanks was 4473 coulombs, and the average total charge passed through Class B blanks was 4621 coulombs. Although the average values were fairly close, the Class AA exhibited a wider range of values for total charge than the Class B.

The regression coefficient R^2 was also calculated for the treated samples. R^2 values for treated Class AA samples ranged from 0.9604 to 0.9990. R^2 values for treated Class B samples ranged from 0.8922 to 0.9998. Therefore, it can be concluded that the charge vs. time relationship is linear for all treated and untreated concrete samples, and it is only necessary to examine the total charge at the end of the six hour testing period.

The treated samples were highly variable in total charge values, even among materials of the same generic type applied over the same class of concrete. For example, the total charge on the 15% siloxane materials applied over Class AA concrete (Sample Nos. 26, 39, 43, and 47) ranged from 189 to 1204 coulombs, and the total charge on the 15% siloxane materials applied over Class B concrete (Sample Nos. 5, 18 and 23) ranged from 185 to 691 coulombs. The total charge on 40% silane materials applied over Class AA concrete (Sample Nos. 27, 28, and 37) ranged from 209 to 1650 coulombs, and from 46 to 291 coulombs for 40% silane materials applied over Class B concrete (Sample Nos. 6, 7, and 19). The other silicone based materials applied over Class AA concrete (Sample Nos. 30, 34, 41, 45 and 49) had total charges from 363 to 3875 coulombs, and total charges from 66 to 5004 coulombs for those applied over Class B concrete (Sample Nos. 9, 13, 20 and 25). The total charge on methyl methacrylate materials ranged from 1 to 1027 coulombs when applied over Class AA concrete (Sample Nos. 33, 35 and 42) and from 48 to 240 when applied over Class B concrete (Sample Nos. 10, 14 and 21). The methyl methacrylate, materials had the lowest range of total charge calues of all types of sealers over both classes of concrete. For this reason, all 3 of the methyl methacrylates were selected for field test applications.

The total charge on epoxy materials ranged from 291 to 3317 coulombs when applied over Class AA concrete (Sample Nos. 32, 46 and 48) and from 336 to 518 coulombs when applied over Class B concrete (Sample Nos. 11 and 17). The waterborne material had a total charge of 1898 coulombs when applied over Class AA concrete (Sample 36) and 2251 coulombs when applied over Class B (Sample 15).

TABLE 6 : RAPID PERMEABILITY TEST RESULTS

CLASS AA CONCRETE

GROUP	SAMPLE #	GENERIC TYPE	CHARGE
AA1	26	15 % siloxane	703
	27	40 % silane	1650
	28	40 % silane	879
	blank		1734
AA2	29	linseed oil	534
	30	35 % polysiloxane	1752
	32	50 % epoxy	1386
	blank		5730
AA3	33	methyl methacrylate	1027
	34	9 % siloxane	772
	35	methyl methacrylate	1
	blank		5021
AA4	36	waterborne	1898
	37	40 % silane	209
	38	sodium silicate	3877
	blank		5044
AA5	39	15 % siloxane	189
	41	10 % siloxane	363
	42	methyl methacrylate	120
	blank		3433
AA6	43	15 % siloxane	1204
	45	20 % silane	3875
	46	38 % epoxy	291
	blank		5388
AA7	47	15 % siloxane	615
	48	epoxy	3317
	49	20 % polysiloxane	1117
	blank		4961

CLASS B CONCRETE

GROUP	SAMPLE #	GENERIC TYPE	CHARGE
B1	5	15 % siloxane	185
	6	40 % silane	291
	7	40 % silane	130
	blank		5688
B2	9	35 % polysiloxane	410
	10	methyl methacrylate	240
	11	50 % epoxy	336
	blank		3999
B3	12	linseed oil	921
	13	9 % siloxane	166
	14	methyl methacrylate	48
	blank		3533
B4	15	waterborne	2551
	17	38 % epoxy	518
	18	15 % siloxane	576
	blank		3715
B5	19	40 % silane	46
	20	10 % siloxane	66
	21	methyl methacrylate	114
	blank		5026
B6	22	sodium silicate	2888
	23	15 % siloxane	691
	25	20 % silane	5004
	blank		5765

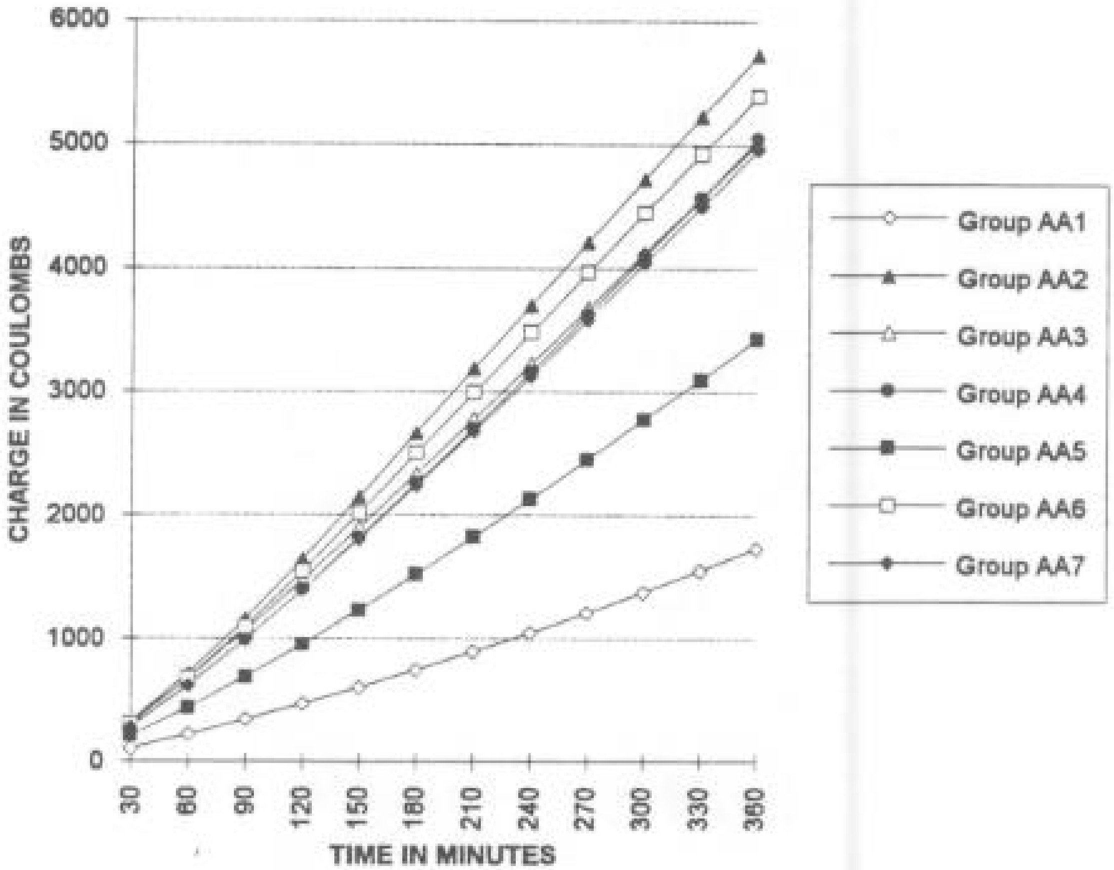

FIGURE 5: CHARGE VS. ELAPSED TIME FOR CLASS AA BLANKS

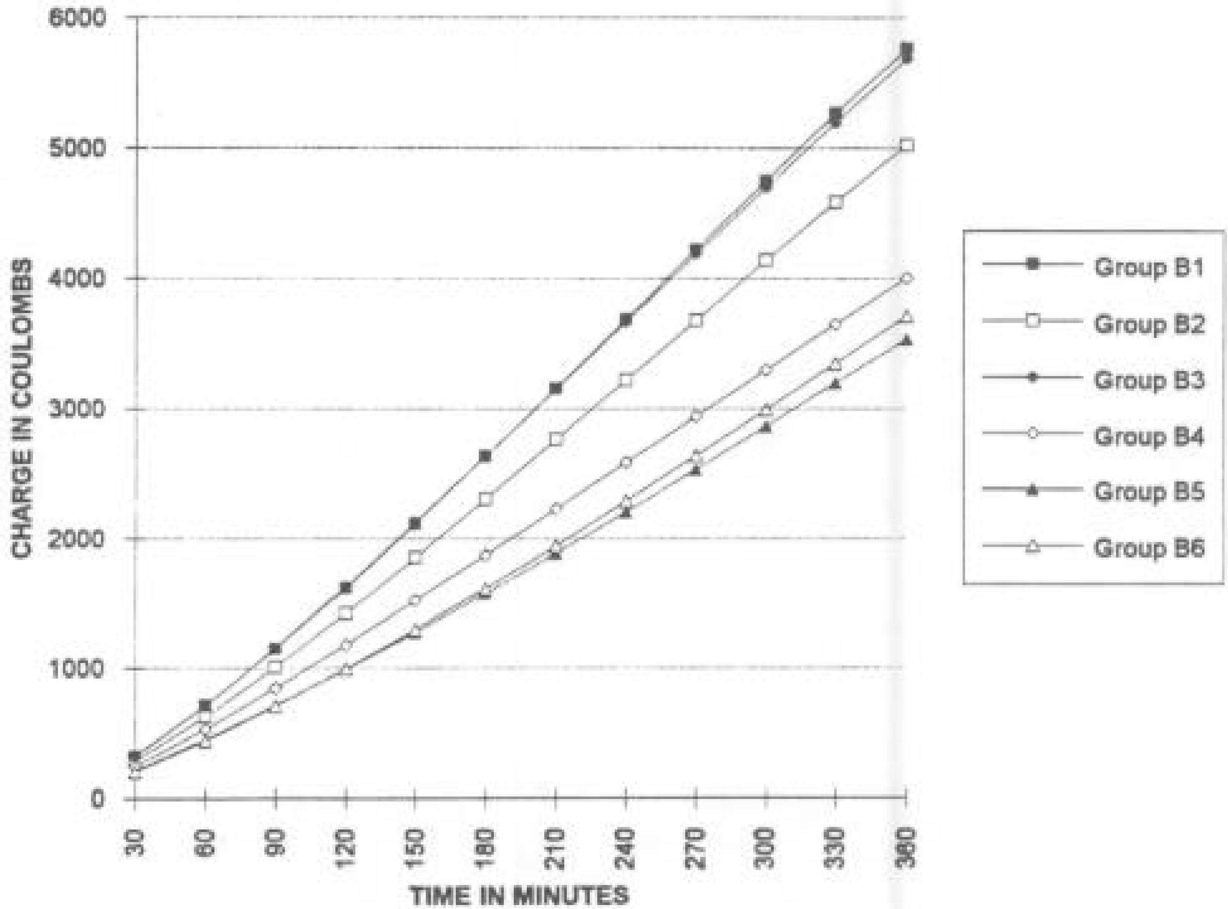

FIGURE 6: CHARGE VS. ELAPSED TIME FOR CLASS B BLANKS

The sodium silicate material was highly permeable with a charge of 3877 coulombs over Class AA (Sample 38) and 2888 coulombs over Class B (Sample 22). The linseed oil had a total charge of 534 coulombs when applied over Class AA (Sample 29) and 921 coulombs over Class B (Sample 12).

In general, treated Class B concrete usually showed lower total change values than Class AA concrete treated with the same material. The higher porosity of Class B concrete may have allowed absorption of a greater amount of sealer material.

Regardless of the type of sealer material used, treatment of the surface resulted in a decrease in permeability compared to untreated samples for both classes of concrete.

FIELD OBSERVATIONS AND RESULTS

Bridge 1 - Decatur Street over I-75

Four different sealer products were applied onto the two outside lanes on this four lane bridge. The inside lanes were not treated. All eight slabs of the bridge deck were drilled to a depth of 1" for chloride ion content sampling before application of the sealer materials in 1990. Chloride ion samples were again taken in 1993. During this interval the bridge deck had been subjected to at least three applications of deicing salt.

Approximately two weeks after sealer application, cores were taken from each of the treated test sections. Depth of penetration was determined by wetting the sides of the cores with deionized water and measuring the visible depth of sealer penetration to the nearest 1/32". Rapid chloride permeability testing was also conducted on the cores. Initial and final chloride levels, penetration depths, and the total charge from rapid permeability testing are shown in Table 7. Chloride ion levels are given in lbs/cy and the charge is in coulombs. Initial chloride ion measurements varied considerably, from 0.51 to 1.79 lbs./cy.. For the untreated areas, the final chloride ion measurements varied from 2.06 to 2.79 lbs/cy, and the percent increase in chloride content varied from 19 to 272%. The two areas treated with methyl methacrylate materials had increased chloride ion levels by 8% and 128%. These two areas had similar coverage rates and had close values for rapid permeability results, 297 and 379 coulombs. The two areas treated with siloxane materials both showed a decrease in chloride ion content. The apparent decrease reflects the wide variability in the initial measurements. The final chloride ion measurements were not taken in exactly the same spots as the initial measurements. When comparing the final chloride ion level of the treated areas vs. the untreated areas, the average chloride level of the treated areas was measured at 0.87 lbs/cy while the average chloride level for the untreated areas was 2.40 lbs.cy. During visual observations three years after sealer application, all of the treated areas clearly appeared darker than the adjacent untreated areas.

Bridge 2 - Martin Luther King Blvd. over I-75

Three different sealer products were applied onto the two outside lanes on this four lane bridge. The two inside lanes were left untreated. The vertical parapet wall adjacent to the East bound lane was treated with a 5% siloxane

TABLE 7: RESULTS FOR BRIDGE 1

LOCATION	GENERIC TYPE	RATE	INITIAL CL-	FINAL CL-	% CHANGE	PEN. DEPTH	CHARGE
East Bound Lane							
East Span - Outer Lane	9 % siloxane	244 ft2 / gal	1.71 lbs /cy	1.37 lbs /cy	-19.88%	1/32 "	828
East Span - Inner Lane	untreated		1.79 lbs /cy	2.14 lbs /cy	19.55%		
West Span - Outer Lane	methyl methacrylate	119 ft2 / gal	0.46 lbs /cy	1.05 lbs /cy	128.26%	1/32 "	379
West Span - Inner Lane	untreated		0.74 lbs /cy	2.06 lbs /cy	178.38%		
West Bound Lane							
East Span - Outer Lane	methyl methacrylate	124 ft2 / gal	0.51 lbs /cy	0.55 lbs /cy	7.84%	1/16 "	297
East Span - Inner Lane	untreated		0.75 lbs /cy	2.79 lbs /cy	272.00%		
West Span - Outer Lane	15 % siloxane	186 ft2 / gal	0.61 lbs /cy	0.50 lbs /cy	-18.03%	1/16 to 1/8 "	254
West Span - Inner Lane	untreated		0.81 lbs /cy	2.62 lbs /cy	223.46%		

material at 207 ft^2/gal. The opposite parapet wall was not treated. Chloride ion content at a depth of 1" was measured on all horizontal areas before sealer application in 1990. Chloride ion measurements were taken again in 1993. During this interval, the bridge deck had been subjected to at least three applications of deicing salt. Approximately two weeks after sealer application, three core samples were taken from each of the treated areas and one core from an untreated area. These cores were subjected to rapid permeability testing. Depth of penetration was determined by wetting the sides of the cores with deionized water and measuring the visible depth to the nearest 1/32". Test results for Bridge 2 are summarized in Table 8. As in the first bridge, the initial chloride ion measurements varied considerably, from 0.33 to 1.94 lbs/cy. The final chloride ion measurements for the untreated areas ranged from 1.64 to 2.79 lbs/cy, and the percent change in chloride ion content varied from -15% to +55%. The final chloride levels for the treated areas varied between 0.96 to 1.65 lbs/cy, and the percent change in chloride content varied from -1% to +191%. The rapid permeability measurement was a total charge of 2143 coulombs for the untreated core, while the total charge on the treated cores ranged from 690 to 1019 coulombs. During visual observations three years after sealer application, the treated areas were difficult to distinguish from the untreated areas.

Bridge 3 - SR 47 over Little River, Wilkes County

During visual observations approximately one year after sealer application, the bridge deck appeared to be in excellent condition. This bridge did not receive an application of deicing salt the first year.

Bridge 4 - I-75 over Towaliga River, Henry/Spalding Counties

During visual observations, approximately two years after sealer application, the bridge deck appeared to be in moderately good condition, except for the second span from the North. New spalling was observed on this span with standing water ponded inside the spalled areas. This bridge had received at least one application of deicing salt within the two year interval.

TABLE 8 : RESULTS FOR BRIDGE 2

LOCATION	GENERIC TYPE	RATE	INITIAL CL-	FINAL CL-	% CHANGE	PEN. DEPTH	CHARGE
East Bound Lane							
East Span - Outer Lane	15 % siloxane	200 ft2 / gal	0.69 lbs/cy	1.05 lbs/cy	52.17%	1/32 "	701
East Span - Inner Lane	untreated		1.84 lbs/cy	2.79 lbs/cy	51.63%		2143
West Span - Outer Lane	15 % siloxane	200 ft2 / gal	0.87 lbs/cy	0.86 lbs/cy	-1.15%	1/32 "	701
West Span - Inner Lane	untreated		1.94 lbs/cy	1.64 lbs/cy	-15.46%		2143
West Bound Lane							
East Span - Outer Lane	20 % silane	148 ft2 / gal	0.33 lbs/cy	0.96 lbs/cy	190.91%	1/32 to 1/16"	690
East Span - Inner Lane	untreated		1.34 lbs/cy	1.92 lbs/cy	43.28%		
West Span - Outer Lane	40 % silane	148 ft2 / gal	0.73 lbs/cy	1.65 lbs/cy	126.03%	1/16"	1019
West Span - Inner Lane	untreated		1.15 lbs/cy	1.78 lbs/cy	54.78%		

CONCLUSION

An ideal concrete sealer should allow vapor permeability, but prevent water and chloride intrusion. Compared to other generic types, boiled linseed oil is not an effective concrete sealer. Of the generic types studied in this project, silane and siloxane were the most effective in preventing chloride and moisture intrusion. In general, the higher the concentration of active ingredient, the lower the chloride intrusion. A concentration of 40% by weight silane is nearly as effective as 15% by weight siloxane. Waterborne materials usually were not as effective as materials with a solvent vehicle.

RECOMMENDATIONS

1. Due to the ineffectiveness of boiled linseed oil in preventing water and chloride ion intrusion, its use as a waterproofing sealer should be discontinued.
2. The Georgia DOT should consider revising the Standard Specifications to allow for use of silane or siloxane type waterproofing sealers as described in the Appendix. Silane or siloxane sealers are recommended for new concrete structures, especially in coastal areas and in the northern mountainous region.
3. Existing structures should be evaluated on a case by case basis. Application of waterproofing sealers onto existing structures which have not yet exhibited deterioration may prevent corrosion damage from occurring in the future.

IMPLEMENTATION PLAN

The recommendations stated herein can easily be implemented by the GDOT. The first recommendation has nearly been implemented at this time. Currently, boiled linseed oil is seldom specified as a surface treatment for new concrete construction.

The second recommendation may be accomplished by changing the GDOT Standard Specification Sub-Section 500.13.C which calls for a surface treatment of 75% boiled linseed oil and 25% mineral spirits. This Sub-Section should be deleted and replaced with the material description as written in the Appendix, which will allow for either a silane or siloxane type concrete sealer.

Currently, existing concrete structures are evaluated once every 2 years by maintenance personnel for structural adequacy and overall condition. The bridge deck condition may also be evaluated by laboratory personnel. The concrete thickness above the top rebar mat is measured and any cracking, spalling or other deficiencies are noted. Bridge deck evaluations are performed by laboratory personnel upon request, usually when an existing bridge is planned to be widened. Recommendations on protection and repair strategies are based on the outcome of these evaluations. The decision whether to use a waterproofing sealer should be considered during these evaluations depending on the condition of the individual structure.

REFERENCES

1. Pfeifer, D.W. and Scali, M.J. "Concrete Sealers for Protection of Bridge Structures", NCHRP Report 244, Transportation Research Board, Washington D.C. (December 1981)

2. American Association of State Highway and Transportation Officials (1986a) "Rapid Determination of the Chloride Permeability of Concrete", AASHTO Designation T-277-83, Washington D.C.

3. Smith, Mitchell D. "Silane Chemical Protection of Bridge Decks" Oklahoma Department of Transportation Report FHWA/OK 86 (4) Oklahoma City, OK (December 1986)

APPENDIX

PROPOSED SPECIFICATION FOR WATERPROOFING SEALERS

1. Surface Preparation

   a. Cleanliness: Waterproofing sealers must be applied to a clean dry surface without any laitance, curing compound, oil, or grease present. Any surface contamination shall be removed by shot blasting with a Wheelabrator blast track or approved equivalent method. Following cleaning, loose dut shall be removed by compressed air or vacuum.

   b. Dryness: The surface and subsurface voids shall be thoroughly dry. A minimum of 2 days without rainfall shall pass before application of the waterproofing sealer material.

   c. Cracks: Prior to application, any cracks larger than 1 mm shall be filled with grout, Type 5 epoxy or high molecular weight methyl methacrylate.

2. Materials: The waterproofing sealer solution shall be formulated according to either Type A or Type B as described below:

   a. Type A - Silane

      The silane solution shall consist of at least 38% by weight alkyl alkoxy silane. The vehicle shall be either isopropanol or mineral spirits.

   b. Type B - Siloxane

      The siloxane solution shall consist of at least 14% by weight oligomeric siloxane. The vehicle shall be either isopropanol or mineral spirits.

   c. Fugitive dye: A fugitive dye shall be added to the material so that it may be visible upon a treated surface for at least 4 hours after application. The fugitive dye shall break down upon exposure to 7 days of direct sunlight.

3. Application Requirements

   a. Weather conditions: Waterproofing sealers may not be applied unless the ambient temperature is greater than 4°C, and no rain is expected for at least 6 hours after application.

   b. Application Rate: The sealer material shall be applied between 4 m^2 to 6 m^2 per liter of material.

c. Application Procedures: All exposed joint sealant and painted steel joints shall be masked in order to prevent contact with the material. The sealer material my be applied by a low pressure pump with either a nozzle or spray bar attached, or by flood and brush techniques. Areas with inadequate coverage as determined by the appearance of the fugitive dye shall be retreated. All sealed areas shall be protected from traffic for at least 6 hours after application.

4. Measurement: Waterproofing sealers applied in accordance with this Specification and Plan details will be measured in square meters.

5. Payment: Work performed and materials furnished and used as specified in the Contract and measured as noted above will be paid for at the Contract Price bid per square meter.