EVALUATION OF CHEM-TRETE BSM

WEATHERPROOFING SOLUTION ON I-89

FAIRFAX, VERMONT

Initial Report 86-3
March, 1986

Reporting on Work Plan 82-R-20

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

SUSAN C. CRAMPTON, SECRETARY OF TRANSPORTATION
FRANK E. ALDRICH, P.E., CHIEF ENGINEER
R. F. NICHOLSON, P.E., MATERIALS & RESEARCH ENGINEER

Prepared By:

R. I. FRASCOIA
RESEARCH & DEVELOPMENT SUPERVISOR

Reviewed By:

R. F. Nicholson

R. F. Nicholson, P.E.
Materials & Research Engineer

Date: 03-21-86

ACKNOWLEDGMENT

This project was performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration as a Category II Experimental Project under the HPR-PR program.

"The information contained in this report was compiled for the use of the Vermont Agency of Transportation. Conclusions and recommendations contained herein are based upon the research data obtained and the expertise of the researchers, and are not necessarily to be construed as Agency policy. This report does not constitute a standard, specification or regulation. The Vermont Agency of Transportation assumes no liability for its contents or the use thereof."

TABLE OF CONTENTS

ABSTRACT

Based upon promising laboratory tests by the Vermont Agency of Transportation, Chem-Trete BSM was selected to seal a new Portland Cement concrete overlay placed on the middle span of Interstate 89 bridge No. 87-N located in the town of Fairfax, Vermont in September of 1982. Prior to rehabilitation, the concrete deck had experienced severe scaling and rebar corrosion believed due, in a large part, to the lack of an air entrainment additive in a portion of the initial deck construction. A high pressure water blast and acid etch was used to clean the deck surface but neither was able to remove all laitance The sealant was applied with a low pressure garden sprayer. Varying application rates were used in the hope that differences in performance could be noted in follow-up evaluations.

Field tests were conducted on the deck in May of 1985 following three winters of deicing salt applications and 3.4 million vehicle passes. Rebar half-cell potential measurements revealed active corrosion on 70 percent of the span, an increase of 536 percent over that recorded prior to treatment. Chemical analysis of recovered concrete samples revealed chloride levels at the 1/4 to one inch depth averaging 1320 parts per million in the wheel path and 934 parts per million in the breakdown lane at a point five feet from the curbline. An area left untreated contained chloride levels 26 percent higher at the 1/4 to one inch depth. Heavier applications of the sealant did not improve the waterproofing quality, however, improved performance was noted where the concrete was allowed to dry longer prior to treatment. The overall performance of Chem-Trete BSM was not considered satisfactory in this field test.

INTRODUCTION

The Vermont Agency of Transportation has routinely designed and constructed bridge decks incorporating the use of a waterproofing system and bituminous overlay since the late 1950's. In general, the protection offered by the newer class of membrane materials has been found to be satisfactory and the Agency does not anticipate switching to exposed Portland Cement concrete decks in the foreseeable future. However, under certain conditions, there are cases where it would be beneficial to omit the application of a membrane system and bituminous overlay from a deck surface. This report deals with such a case where severe surface scaling was considered easier to repair with the placement of a new Portland Cement concrete overlay rather than sawcut and jackhammer to a depth sufficient to insure that concrete patches would perform satisfactorily.

The product selected to seal the new Portland Cement concrete overlay and the underlying concrete and reinforcing steel from further chloride intrusion is discussed in detail.

CHEM-TRETE PRODUCT INFORMATION

Chem-Trete BSM weatherproofing solution is available from TRO-CAL, a division of Dynamit Nobel of America, Inc., 10 Link Drive, Kockleigh, New Jersey, 07647. The product, manufactured in Mobile, Alabama, is a 40 percent solution of an organosilane in ethyl alcohol. When applied on concrete surfaces, the BSM molecule is reported to chemically bond to individual particles in the substrate creating an entirely new hydrophobic surface. The solution does not block the pores, thereby allowing the concrete to breathe. Average penetration is reported to be 1/4 inch to 5/16 inch in concrete.

Surfaces to be treated must be free from dirt, grease, oil, coatings and other foreign materials which may interfere with penetration. Removal of contaminants or laitance may be achieved by using water blast or sand blast procedures. Chem-Trete BSM may be applied using low pressure (15 psi max) airless spray equipment such as a pump-up garden sprayer or drum-mounted pump. The spray equipment should have a fan type spray nozzle. The proper quantity is being applied to horizontal surfaces when the liquid stands for a few seconds before completely penetrating. Chem-Trete BSM may be applied on a damp surface, however, the surface should be sufficiently dry to allow the applicator to see the spray pattern. The recommended application rate for bridge decks and other surfaces subject to abrasion is 100 to 125 square feet per gallon.

VERMONT'S SPECIFICATION AND USE OF CONCRETE SEALANTS

The Agency does not have a Specification or List of Approved Materials covering penetrating sealers for Portland Cement concrete. The standard treatment specified for Portland Cement concrete is a 50-50 mixture of boiled linseed oil and mineral spirits. The construction requirements for the solution are covered in the Agency Standard Specifications for Construction under Section 514 - Water Repellent and Under Materials Section 726, Protective Coatings and Waterproofing Materials. The material is typically applied on concrete curbs on bridges and on the back walls of abutments. Reapplications of the solution are considered necessary to retain weatherproofing qualities. The overall performance of linseed oil and mineral spirits has been considered good where it has been applied on vertical or well drained concrete surfaces and a retreatment program has been faithfully maintained. Less than satisfactory results have been recorded on bridge deck surfaces treated with the material.

VERMONT'S EXPERIENCE WITH CHEM-TRETE

Chem-Trete was first introduced to the Agency by Mr. Richard R. Wolsey of Wolsey Associates, 112 Haverhill Street, North Reading, Massachusetts, 01864, in January of 1981. A sample of the product, known at that time as Chem-Trete Silane* was applied on concrete specimens and found to penetrate deeper than other penetrating sealers.

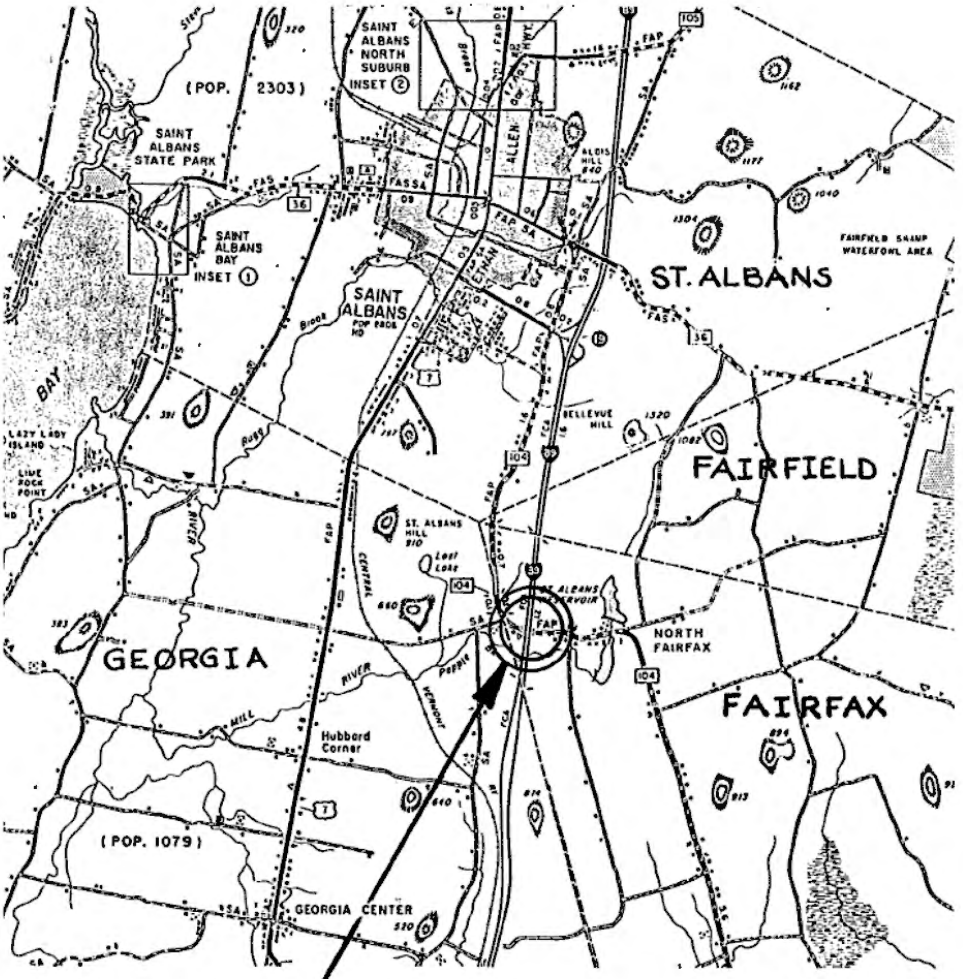
*The manufacturer advises that the product name was changed from Silane to BSM during initial marketing but there was no change in the actual composition of the material.

The FHWA Federally Coordinated Program (FCP) summarized in the 1979 annual progress report that Chem-Trete Silane surface treatment significantly reduced chloride and moisture ingress on treated slabs subjected to chloride ponding. The report cited similar results obtained in tests conducted by PCA, Ohio D.O.T. and the Oklahoma D.O.T. The report did caution that long term protection could not be anticipated where significant abrasion is expected.

Based on the promising test results obtained by others, the Agency applied Chem-Trete Silane on Vermont Route 14, Bridge No. 74 over Pekin Brook approximately 1.88 miles north of the Calais-East Montpelier town line on October 13, 1981. The experimental application was undertaken as an FHWA Category II Experimental Project under Vermont Work Plan 81-R-8. The application included 370 square feet of new deck surface and the adjacent 72 square feet of facia area. The opposite side of the deck was treated with tar emulsion and the facia received linseed oil and mineral spirits for comparison purposes. The hoizontal surfaces treated with Chem-Trete or tar emulsion were overlaid with two courses of bituminous concrete pavement. The applications were carried out without experiencing any difficulties. Performance results have not been summarized to date.

LOCATION MAP

N.T.S.



PROJECT LOCATION
I 89 BR.# 87-N

TAKEN FROM
GENERAL HIGHWAY MAP
FRANKLIN COUNTY
— VERMONT —

PRODUCT: CHEM-TRETE BSM

R&D 1986

EXPERIMENTAL WORK LOCATION

The center span of Bridge No. 87N, the Interstate 89 northbound structure over Vermont Rte 104 in Fairfax, located at MM 111.10, was selected for treatment with Chem-Trete BSM. At the time of construction in 1966, tests revealed that a portion of the Portland Cement concrete in the center span was not properly air entrained and consequently would be subject to severe scaling from freeze-thaw action. In an attempt to protect the concrete, Rambond 223, a 100 percent solid epoxy was applied in August, 1967. The epoxy seal was then covered with two courses of bituminous concrete pavement. The structure appeared to be in satisfactory condition until the biutminous surface was removed in 1982 in preparation for a new bituminous overlay. The exposed surface revealed that severe scaling of the concrete had occurred along the lower end of the span and at other random locations. The loss of up to three inches of concrete cover over a 14 foot by 20 foot area exposed

Severe scaling resulting in exposed rebars on the lower southwesterly corner of the span

much of the top mat of steel. In general, corrosion of the rebars was limited although corrosion stains on the bottom of the deck slab suggest that there may have been some corrosion on the bottom rebars also.

The noted deterioration was corrected with the placement of an "AA" Portland Cement concrete overlay on August 30, 1982. The seven and one-half bag mix was preceded by the application of a neat cement slurry for bonding purposes. The two inch overlay was wet cured until September 20, 1982, three days before the Chem-Trete BSM application was to take place.

DECK CONDITION AND PREPARATION PRIOR TO CHEM-TRETE APPLICATION

The deck surface had been finished off with a rail mounted vibratory screed. Only a slight surface texture was visible except where the concrete had been bullfloated to fill in surface voids and where the curblines were trowled following removal of the screed rails. A series of approximately 75 short transverse cracks were noted near the center of the structure covering an area 35 feet to 60 feet from the southerly end of the span. The depth of the cracks was not determined as they were not wide enough to accept a gauge of any type.

Half cell potential measurements were taken at a five foot grid interval to determine if rebar corrosion was present. Active corrosion was identified on 12 percent of the test area with values ranging from -0.35 to -0.40 volts. The active corrosion was located on the southwesterly quadrant of the deck, where the most severe concrete deterioration had occurred, and along the northerly expansion dam.

Due to the anticipated presence of laitance on the new concrete surface, the Tro-Cal technical representative, Pat Winkler, brought a high pressure water blaster to the project on September 23, 1982. The equipment was reportedly capable of applying a 3000 psi blast at the nozzle. Although the water blast was able to remove much of the surface stains, it did not remove areas of moderate to heavy laitance Approximately 120 square yards or 40 percent of the deck was blasted between 8:00 and 10:15 am. At that time, the operation was stopped and a small area was treated with muriatic acid for a comparison. When the effectiveness of the acid etching was noted to be superior to the water blast, the remainder of the deck and the area initially blasted were acid etched. A large volume of water from a 5000 gallon tanker was used to wash away the acid residue within several minutes of application. Upon completion, the concrete surface was considered satisfactory although some laitance remained as would be expected on any bridge deck not exposed to traffic and weather for a period of time.

Surface condition following water blast and acid etching treatments. Note isolated areas where all laitance has been removed due to flaking.

OBSERVATIONS MADE DURING CHEM-TRETE APPLICATION

The Tro-Cal representative stated that the Chem-Trete BSM application should begin as soon as the concrete became surface dry following the acid etch flush. The surface preparation was completed shortly after noon, however, light to moderate rain showers began shortly thereafter and continued until early evening eliminating the possiblity of treating the deck that day. Due to other commitments, the Tro-Cal representative and the regional distributor left after reviewing the proper method of application with Agency personnel.

The following morning, September 24, 1982, the sky was clear at 7 am but the deck surface remained wet with the air temperature at 55°F. Drying continued as the temperature rose and at 9:50 am, the entire surface was free of visual moisture. The application began near the northerly end of the span at that time and continued until all areas were completed at 2:20 pm. The sealer was applied with a low pressure pump-up garden sprayer equipped with a fan type spray nozzle. The application rate was varied purposely in the hope that differences in performance could be noted in follow-up evaluations. A total of 16 different applications were made including one area with a double application. In all cases, the sprayer was filled to a specific level and the area treated was measured and recorded. The locations and application rates which varied from 75 to 162 square feet per gallon can be seen in Appendix A on page 17. The overall application rate for the span was 128 square feet per gallon.

The length of time required for the surface to become dry following the Chem-Trete application varied from approximately 50 minutes when first

applied that morning to approximately 25 minutes during the afternoon. Such results suggest that when the deck was allowed to air dry for a longer period of time, the sealant was able to penetrate more quickly into the dryer concrete air void system leaving less material on the surface Air temperature may also have had an effect on the drying time ranging from 63°F at the 9:50 am start up to a high of 83°F at 1:40 pm. Skies were clear until 1:00 pm and remained partly couldy for the remainder of the afternoon. Humidity levels recorded at the deck surface ranged from 70 percent at the beginning to a low of 42 percent at mid afternoon. Winds were calm to light and variable during the application.

Traffic barriers were removed approximately one-half hour after the treatment was completed.

COST INFORMATION

At the time of shipment, Chem-Trete BSM was available in five gallon units at a cost of $51.00 per gallon FOB Winchester, Massachusetts. Prior to final billing, the price was reduced to $24.72 per gallon due to the fact that the application was considered experimental. As of December, 1985, the product may be purchased directly from RDG Associates, 75 Sylvan Road, P.O. Box 512, South Lancaster, MA. 01561, Tel: (617)368-8889 at a cost of $53.00 per gallon in five gallon units or $50.00 per gallon in 55 gallon drums, FOB Montvale, N.J.

Assuming an average application rate of 125 square feet per gallon, the material cost would be approximately $0.41 per square foot of surface treated.

FIELD EXPOSURE CONDITIONS

The test site is located in an area with a mean freezing index of approximately 1350. Snowfall averages 90 inches and 80 freeze-thaw cycles can be anticipated.

The deck was exposed to deicing chemical applications for three winters prior to conducting field tests for chloride intrusion. The applications of road salt were continuously monitored by the Agency's Maintenance Division and the records show the applications per two-lane mile included 23 tons in 1982-1983, 41 tons in 1983-1984 and 22 tons in the 1984-1985 season. Over the evaluation period, the applications have totaled 33 pounds per linear foot of structure or approximately one pound per square foot of deck surface.

Average daily traffic volumes on the bridge have ranged from 3500 in 1982 to 3600 in 1985. Total traffic volume from the date of treatment to the time of sampling, a period of two years and seven months was 3.4 million vehicle passes.

DISCUSSION OF PERFORMANCE

The test site was visually inspected and tests were conducted on May 17, 1985. There was no visual evidence of any laitance remaining on the surface or wear in the wheel path areas. New cracks in the concrete surface course included six short cracks in the breakdown lane and hundreds of feet of map and alligator cracking in both the travel and passing lanes. There were no cracks in the four foot median shoulder lane. Trace amounts of delamination

were noted with a chain drag above and adjacent to a few of the cracks. The delamination may have been promoted by surface roughness which causes a pounding action by traffic.

Physical testing included copper-copper sulfate half cell potential measurements and the recovery of concrete samples for the determination of Cl^- content using a specific ion electrode. The potential measurements revealed active corrosion on 70 percent of the span, an increase of 536 percent over that recorded prior to treatment on September 23, 1982. Active readings ranged from -0.35 volts to a high of -0.67 volts. The increase in active corrosion may be due as much to inadequate removal of chloride contaminated concrete at the time of reconstruction as to additional chloride contamination during the past three years of exposure. Some of the corrosion readings may also be related to the bottom mat of steel as evidenced by the presence of occasional corrosion stains on the bottom of the deck. The potential measurements can be seen in Appendix B on page 18.

The concrete samples were taken at locations five feet from the right hand curbline and in the right wheelpath of the travel lane, 13 feet from the curbline. A total of 16 samples were taken at the 1/4 to 1 inch depth and a similar number were taken at the 1 inch to 2 inch depth.

The results of chemical analysis can be seen in Appendix C on page 19. The average Cl^- content at the 1/4 to 1 inch depth was 1320 parts per million (ppm)* in the wheel path and 934 ppm at the five foot offset. The area without treatment revealed 1838 ppm in the wheel path and 1235 ppm at

*To convert ppm Cl^- to pounds per cubic yard of concrete, divide ppm by 250.

the five foot offset. Chloride values at the 1 to 2 inch depth averaged 446 ppm in the wheelpath and 463 ppm at the five foot offset as compared to 230 and 148 ppm in the untreated area. Such results indicate that the sealant was successful in reducing the rate of Cl^- intrusion by an average of 26 percent in the top inch of concrete but it did not reduce the contamination level at the one to two inch depth. The higher Cl^- content in the wheelpath is believed to be caused by the pumping action of the traffic rather than a suspected loss of the treatment due to traffic wear.

The test results indicate a heavier application of the material did not provide an improvement in waterproofing quality. Areas with application rates of 75, 88 and 89 square feet per gallon revealed an average of 1507 ppm in the top inch in the wheelpath as compared to a 1485 ppm average in areas treated with 121, 137 and 162 square feet per gallon.

As noted earlier, the application was made as directed by the technical representative of the product manufacturer even though the concrete had a high moisture content due to water blasting, flushing and rainfall the previous day. However, the test results indicate there was improved performance where the concrete was allowed to dry longer prior to treatment. Areas treated an average of one hour and 35 minutes after all areas were surface dry revealed an average of 1392 ppm Cl^- in the top inch of concrete. In comparison, areas treated an average of four hours and 30 minutes after all areas were surface dry revealed an average of 1052 ppm Cl^-. The longer drying time prior to treatment resulted in a 24 percent reduction in the level of Cl^- contamination. Such results are in agreement with the manufacturer's current policy

which requires that the concrete surface be allowed to dry at least 24 hours under good drying conditions before starting an application. The policy was established recently when it was determined that concrete with measurable amounts of water in the near surface region interfered with the silane reaction below the surface. The silane reaction at the surface would not provide sufficient long term protection due to the combination of traffic wear and untraviolet radiation.

CONCLUSIONS

This field test of Chem-Trete BSM Weatherproofing Solution supports the following conclusions:

1. Chem-Trete BSM was very easy to apply, however, proper preparation of the concrete surface was difficult and labor intensive.

2. Heavier applications of the material did not improve the waterproofing quality.

3. The material performed better when the concrete was allowed to dry longer prior to treatment.

4. The material reduced the rate of chloride intrusion by approximately 25 percent in the top inch of concrete.

5. The performance of Chem-Trete BSM was not satisfactory on this field test.

RECOMMENDATION

Chem-Trete BSM is not recommended for general use. The product is recommended for additional field testing if proper control of various job conditions can be assured. Such conditions would include the following:

1. Ambient and surface temperatures between 40°F and 90°F.
2. Surfaces to be treated shall be allowed to dry at least 24 hours under good drying conditions.
3. No rain forecast within six hours following the application.
4. No moderate to high winds expected during the application.

FOLLOW-UP

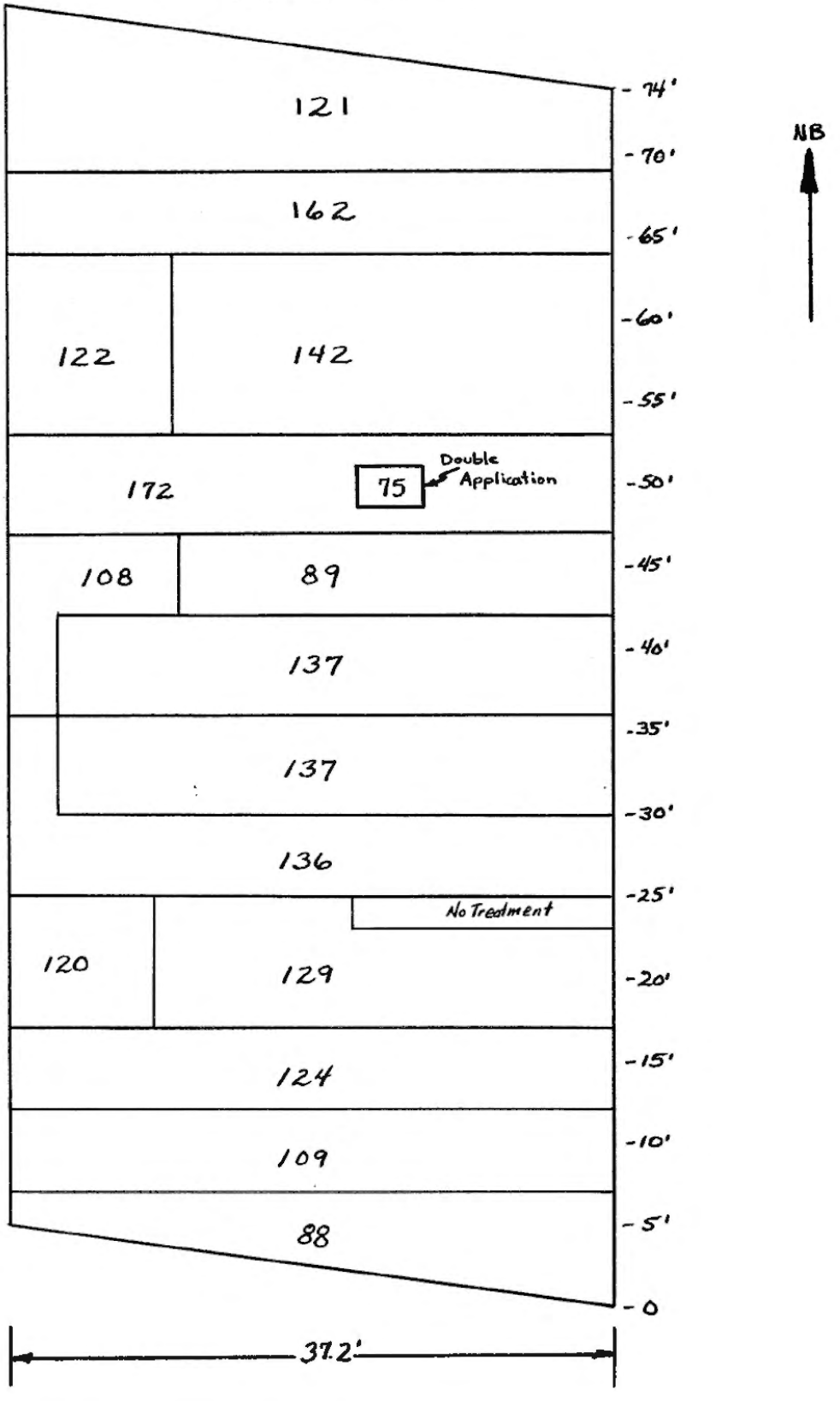
This project will continue to be monitored until retreatment or reconstruction is carried out.

CHEM-TRETE BSM

APPLICATION RATES

— INTERSTATE 89 BRIDGE # 87 N —

NOTE: FIELD APPLICATION RATES SHOWN IN SQUARE FEET PER GALLON. APPLIED 9-24-82



R&D 1986

CHEM-TRETE BSM

VT. A.O.T. - MATERIALS & RESEARCH DIVISION
STEEL POTENTIAL READINGS
SURVEY SHEET

LOCATION I 89 NB/SB RTE. 108 FAIRFAX NUMBER BR# 87N

EXPERIMENTAL FEATURE BARE DECK CENTER SPAN

GROUND CONNECTION PIN 5' OFF NORTH END, 1' OFF RT. CURB

TEST LOCATION, CURB, STATION CENTER SPAN 7'2" x 37'2"

DATE CODES

	Mo.	Day	Yr.		Mo.	Day	Yr.		Mo.	Day	Yr.
A =	04	23	82	E =				I =			
B =	05	17	85	F =				J =			
C =				G =				K =			
D =				H =				L =			

Date Codes	5' FOOT OFFSET *												10' FOOT OFFSET												18' FOOT OFFSET											
	A	B	C	D	E	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L
74.2'	16	46											32	45											35	47										
70'	12	35											18	36											20	34										
65'	15	33											23	47											24	37										
60'	09	30											16	35											18	37										
55'	08	30											16	35											15	39										
50'	10	29											14	36											15	33										
45'	09	28											12	32											14	34										
40'	08	25											10	31											11	30										
35'	10	24											12	25											13	29										
30'	13	27											12	40											10	30										
25'	12	27											13	31											15	36										
20'	16	32											20	35											22	42										
15'	16	28											17	40											18	35										
10'	14	28											16	32											18	34										
5'	16	35											16	40											15	36										
0	19	29											20	45											20	43										
AVERAGE	13	30											16	36											19	36										

STATION — 74.2' Traffic flow

VT. A.O.T. - MATERIALS & RESEARCH DIVISION - BRIDGE SURVEY SHEET
STEEL POTENTIAL READINGS

LOCATION I 89 NB FAIRFAX NUMBER BR# 87N

EXPERIMENTAL FEATURE BARE DECK

GROUND CONNECTION PIN 5' FROM NORTH END, 1' OFF RT CURB

TEST LOCATION, CURB, STATION

DATE CODES

	Mo.	Day	Yr.		Mo.	Day	Yr.		Mo.	Day	Yr.
A =	04	23	82	E =				I =			
B =	05	17	85	F =				J =			
C =				G =				K =			
D =				H =				L =			

Date Codes	25' FOOT OFFSET												30' FOOT OFFSET												36' FOOT OFFSET											
	A	B	C	D	E	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L	A	B	C	D	E	F	G	H	I	J	K	L
74.2	35	43											36	55											36	47										
70	39	55											33	47											29	43										
65'	30	52											25	46											24	43										
60'	20	53											28	44											27	47										
55'	20	51											18	48											25	50										
50'	15	40											15	34											26	44										
45'	18	40											30	39											25	49										
40'	15	34											20	36											25	49										
35'	15	34											15	37											28	52										
30'	18	34											18	51											26	50										
25'	21	35											15	35											21	49										
20'	35	43											33	39											25	50										
15'	38	45											35	40											25	48										
10'	40	54											35	45											28	47										
5'	38	51											36	48											28	49										
0	24	48											30	54											30	65										
AVERAGE	26	44											26	44											27	50										

STATION — 74.2' Traffic flow

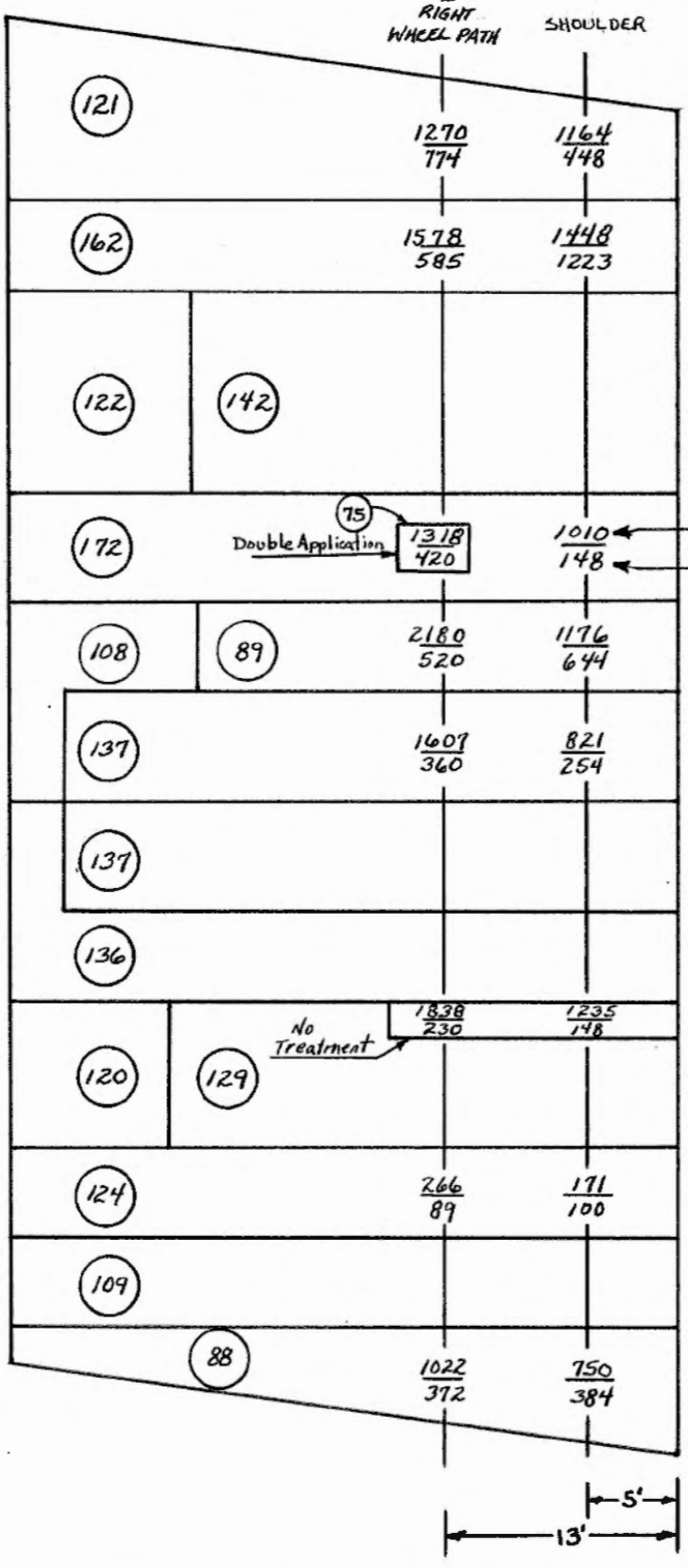
* All offsets from righthand curbline

CHEM-TRETE BSM

CHLORIDE CONTAMINATION LEVELS (PPM)

- INTERSTATE 89 BRIDGE # 87 N -

NB



NOTE:

CHEM-TRETE BSM FIELD APPLICATION RATES SHOWN IN SQUARE FEET PER GALLON ARE CIRCLED.

NOTE:

Chlroide Contamination Levels are shown in parts per million. Samples obtained on 5-17-85. Sampled @ 1/4"-1" and 1"-2" depths.

1/4"-1"

1"-2"

R&D 1986

APPENDIX D

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

WORK PLAN FOR CATEGORY II EXPERIMENTAL PROJECT PENETRATING SEALER FOR STRUCTURAL CONCRETE

WORK PLAN 82-R-20

OBJECTIVE OF EXPERIMENT

To evaluate the performance of a proprietary weatherproofing solution applied as a penetrating sealer on a new Portland Cement Concrete deck surface.

PROJECT

Georgia-Swanton IR 89-3(4).

PROJECT LOCATION

On Interstate 89 in the Towns of Georgia, Fairfax, St. Albans and Swanton.

EXPERIMENTAL WORK LOCATION

The experimental product shall be applied on the center span of Bridge No. 87-N, the I-89 northbound structure over Vermont Rte. 104 in Fairfax, an area of approximately 2700 square feet of new deck surface which will be exposed to traffic.

MATERIALS TO BE USED

Chem-Trete Silane weatherproofing solution manufactured by Dynamit Nobel of America, Inc. and distributed by Northeast AR, Inc., 780 Main Street, Box 346, Winchester, Ma. 01890. Phone (617) 729-9277.

APPLICATION PROCEDURE

Application of the weatherproofing solution shall be as recommended by the manufacturer/distributor.

CONTROL SECTION

The control section shall consist of a small area of deck left untreated for the purpose of comparing the rate of chloride penetration between treated and untreated areas.

COST

Thirty gallons of Chem-Trete Silane required at an estimated cost of $51.50 per gallon.

DATE OF APPLICATION

The application shall be completed prior to October 1, 1982.

DURATION OF STUDY

The project will be evaluated for the length of time required to obtain valid conclusions on the performance of the experimental treatment.

SURVEILLANCE

The project will be monitored at least once yearly for the duration of the study. Evaluations shall include sampling of the concrete at various depths to determine the presence of chloride and the rate of penetration. The results will be compared with permeability rates recorded on other exposed concrete decks.

REPORTS

Reports will be submitted to the Federal Highway Administration when conclusions can be drawn on the performance and cost effectiveness of the experimental treatment.

Materials & Research Division
Agency of Transportation
September 16, 1982

Reviewed By:

R.F. Nicholson

R.F. Nicholson, P.E., Materials & Research Eng.

Date: Sept. 16, 1982

* Federally Approved
9/23/82