FIELD EVALUATION OF A

CORROSION INHIBITING DEICER

INITIAL REPORT 90 - 1

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16. Abstract

The Vermont Agency of Transportation was invited to participate in the field evaluation of a new proprietary deicing product reported to have inhibited salt-induced corrosion of reinforced concrete samples in an extensive laboratory research program.

An 8.5 mile section of Vermont Route 14 which featured a bare deck with an extensive corrosion history was selected as the test site. Baseline rate of corrosion values obtained with a 3LP-NB2 corrosion rate meter averaged 3.2 mils per year (MPY) in November 1988 prior to the application of the experimental deicer on Bridge 124.

Approximately 240 tons of the treated salt was applied on 52 "snow days" for an application of 920 pounds on the bridge deck.

The testing in the spring of 1989 disclosed the rate of corrosion was more than twice the initial fall values but subsequent tests in August, September, October, and November revealed a gradual decrease to an average of 3.9 MPY.

Significant decreases were recorded in October at all five test locations on the southbound lane with November values average only 0.3 MPY at the same locations. Such results may indicate the experimental deicer has reduced the corrosion activity on the southbound lane, although it is not clear why the product has not produced the same effect at some of the less active northbound locations.

Further field testing will be required to confirm the effectiveness of the corrosion inhibiting deicer and determine the benefits which may be derived from it's use.

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deicing product rate of corrosion, mils per year (MPY)	No restrictions

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INTRODUCTION

In early 1988, representatives of DOMTAR'S SIFTO SALT Division, a Canadian company headquartered in Mississauga, Ontario approached the Vermont Agency of Transportation regarding the possibility of field testing a corrosion inhibiting deicer. The treated sodium chloride known as TCI, had minimized salt-induced corrosion in reinforced concrete and also reduced the half-cell potential and the rate of corrosion in chloride contaminated specimens evaluated in an extensive laboratory research program.

After several meetings, which included the review of the product information and approval by the Vermont Agency of Natural Resources, for the use of the treated salt, agreement was reached to search for a suitable test site. Cooperation of the Maintenance Division was assured when DOMTAR agreed to provide sufficient material to cover the entire plow route of one maintenance truck. That procedure guaranteed there would be no mix-up between standard and treated salt applications.

This report describes the experimental location selected, the evaluations conducted and the performance of the treatment through the first year of testing.

PRODUCT INFORMATION

The sodium chloride provided for the field test was supplied from the Montreal region of DOMTAR'S Sifto Salt Division. The inhibitor was applied at a rate of 2.5% by weight of the applied material.

Laboratory testing of the TCI had been carried out at DOMTAR'S Senneville, Quebec Research Center and at the University of Western Ontario. Reports on the inhibitor test results included the following:

Test	Material	Corrosion Rate In Mils Per Year (MPY)
Immersion	Salt Only	1.87
Immersion	Salt & Inhibitor	0.88
Linear Polorization	Salt Only	2.00
Linear Polarization	Salt & Inhibitor	0.85
A C Impedance	Salt Only	8.01
A C Impedance	Salt & Inhibitor	2.53

Macrocell corrosion tests on reinforced concrete samples tested for up to 240 days revealed results similar to those noted above.

Environmental tests for aquatic toxicity, oxygen demand, mammalian toxicity, and effect on vegetation and soil revealed the TCI was no more toxic than standard road salt.

COST INFORMATION

The Inhibitor treated salt is available at a cost of $150.00 per ton FOB Montreal, Quebec. In comparison, Sifto Salt Division was awarded the July 1989 - June 1990 contract to supply District 9 with 10,500 tons of standard road salt at a delivered price of $38.60 per ton.

As noted earlier, the inhibitor treated salt was supplied free of charge for this field evaluation.

STUDY LOCATION

A number of conditions had to be met to insure the field test could take place. Some of the more important requirements included the following:

1. Location of a route with one or more bridge decks with active corrosion;
2. Agreement that the bridge deck(s) selected would not be programmed for rehabiitation prior to the completion of the study;
3. Availability of a salt storage shed where the TCI could be kept seperate from the standard winter salt;
4. Complete cooperation of the Maintenance personnel in the District chosen.

A number of sites were considered but only one met all of the major requirements. It also included a bare PC concrete deck on which an extensive corrosion potential history had been recorded during 11 of the 20 years since it had been reconstructed.

The site selected is a 8.5 mile section of Vermont Route 14 located in Orleans County in Maintenance District No. 9. The test section includes one mile in Albany beginning at MM 5.7+ and continues north for 7.35 miles in Irasburg and 0.1 mile in Coventry. The treated salt is being stored in a new covered salt shed at a Maintenance Garage located approximately one mile south of the Route 14 junction with US Route 5 in Coventry. On an average winter, the 8.5 mile section of roadway would require approximately 150 tons of salt to maintain satisfactory driving conditions.

The 8.5 mile route includes two decks with bituminous overlays, BR 118 at MM 6.09 in Albany and BR 123 at MM 2.34 in Irasburg, plus an exposed PC concrete deck, BR 124 at MM 3.13, in Irasburg.

A brief description of the three bridges and their condition follows:

Bridge 118 is an 89' simple span over the Black River, constructed (33 years ago) in 1956. A deck survey conducted in 1977 by Materials and Research personnel disclosed corrosion activity of -0.35 volts or greater on 52% of the deck area. Rehabilitation by maintenance forces in August 1977, included removal of the bituminous overlay, patching of 20 minor spalls and 3 larger areas totaling 70+ square feet, plus and 18" wide area along both curblines. The work was completed with the application of tar emulsion and 2 courses of bituminous pavement.

Bridge 123 is a 90' by 27.8' wide simple span constructed (30 years ago) in 1959. The deck is covered with several courses of bituminous pavement totaling 3 1/2 to 5 inches in thickness.

Bridge 124 is an 86' by 27.3' wide simple span initially constructed in 1939 and rehabilitated with a new P C concrete deck (21 years ago) in 1968. Corrosion surveys were conducted on the bare deck during 11 of the 14 years between 1972 and 1985. At the time of the 1985 survey, 67% of the deck had active corrosion, concrete delamination was present on approximately 15% of the surface area and chloride levels averaged over 10 lbs. per cubic yard in the top inch of concrete at the locations tested.

The test site is located in an area which has a mean freezing index of 1450. Freeze-thaw cycles average 90 per year and snowfall averages 130 inches.

Average daily traffic at the three bridge sites ranges from 830 to 1,200 with 10% truck traffic.

FIELD TESTING

Preliminary field testing on Bridge 118 on September 2, 1988, revealed corrosion potential activity of -0.35 volts or greater on only 10% of the deck. Similar testing was completed on Bridge 123 on October 12, 1988. The 29 year old simple span had severe concrete deterioration and rebar corrosion visible along both curbless facias but only one active location was recorded on the interior portion of the deck. The combination of bituminous courses and chip seals totaling up to five inches plus a two+ percent grade appears to have been successful in keeping chloride from the interior reinforcing steel.

The lack of corrosion activity on Bridges 118 and 123 led to a decision to concentrate product performance testing on Bridge 124. The latter deck also offered the advantage of having the corrosion potential history available and the absence of a bituminous overlay would be expected to allow the TCI quicker access to the area of the reinforcing steel.

In late October and early November of 1988, corrosion rate measurements were made at eight locations on the northbound lane and five locations on the southbound lane. The values were obtained with a 3LP-NB2 corrosion rate meter manufactured by K. C. Clear, Inc. Unit GG 201 Davis Drive, Sterling, Virginia 22170, telephone (703) 430-2786. The equipment measures the rate of corrosion using a test procedure based upon the "three electrode linear polarization" technique or a slight test variation known as the "polarization resistance" method with ohmic resistance compensation.

The results of the first test series, to be considered the base line values, can be seen in Table 1, following. They revealed corrosion currents, expressed as ICORR, ranging from 1.65 to 8.61 milliamps (MA) per square foot of rebar surface area. Assuming that a constant rate is maintained, the ICORR for steel can be converted to a mils per year (MPY) loss by multiplying ICORR by 0.492. Thus, the corrosion rate in terms of metal loss per year ranged from 0.8 to 4.2 with an average of 2 MPY. After adjustment for temperature, the rate averaged 3.2 MPY. Such losses could be expected to result in damage to the concrete within six years if the concrete quality and cover were typical.

TABLE 1
Corrosion Rate On Route 14
BR 124, Fall 1988

Location	Potential mV ($Cu/CuSO_4$)	R_p ohms	ICORR mA/sq. ft.	Cor. Rate MPY
A	429	18.91	2.16	1.1
B	375	10.71	3.81	1.9
C	330	24.71	1.65	0.8
D	390	8.32	4.89	2.4
E	433	11.23	3.63	1.8
F	611	4.73	8.61	4.2
G	382	15.03	2.71	1.3
H	462	8.48	4.81	2.4
I	382	10.27	3.97	2.0
J	427	8.61	4.73	2.3
K	145	20.69	1.97	1.0
L	517	21.02	1.94	1.0
M	562	5.62	7.25	3.6

Rebar corrosion potentials taken at the same time on a five foot grid spacing revealed an average value of -0.45 volts with 78% of the 126 readings equal to or greater than -0.35 volts.

The concrete delamination which had been recorded at approximately 15% of the deck in 1985 had resulted in the development of several new potholes. A number of the larger potholes had been patched with bituminous mix.

The application of the TCI proceeded without incident throughout the winter and spring seasons. Snow or freezing precipitation on 52 days during the winter of 1988-89 resulting in 69 salt applications. A total of 240 tons of the treated salt was applied over the 8.5 mile route. The quantity was 60% above the normal usage due to a high number of ice storms. The usage resulted in the application of 920+ pounds of TCI directly on the deck of Bridge 124 for an average application of 0.39 pounds per square foot of deck area.

The maintenance personnel did express a concern about the amount of "dust" which came off the treated salt when it was being loaded into the five cubic yard dump truck. Photographs were taken during the loading operation and the concern was expressed to DOMTAR research personnel. The latter did not feel that a significant amount of the anti-corrosion additive was being lost but did state that they would look into methods of improving adhesion of the additive to the chloride particles.

The first of a series of five rate of corrosion retests was completed on June 8, 1989. The results revealed a dramatic increase in the rate of corrosion with rates ranging from 1.6 to 17.6 MPY. The average June value after adjustment for ambient temperature variation was 6.9 MPY which was more than twice the 3.2 MPY average rate recorded the previous fall.

Corrosion potentials were also taken on June 8, 1989. The values averaged -0.52 volts which was an increase of 0.07 volts over the 1988 fall average. The area of the deck with active corrosion now totaled 90%, up from 78% the previous fall.

The June survey included the approximate measurement of all potholes and bituminous patches. A total of 16 were noted ranging from one to 15 square feet in area with an average of 6.75 square feet per location. Nine of the larger areas were concentrated in the right wheel path of the northbound lane.

The second test series of 1989 was completed on August 24. The rate of corrosion had decreased to an average of 4.2 MPY and the average potential value was also down by 0.04 volts.

The third test series was completed on September 19, 1989. That series revealed an increase in the rate of corrosion to an average of 6.6 MPY due in part to values of 11.7, 13.1 and 24.8 at test locations L, M, and F on the northbound lane.

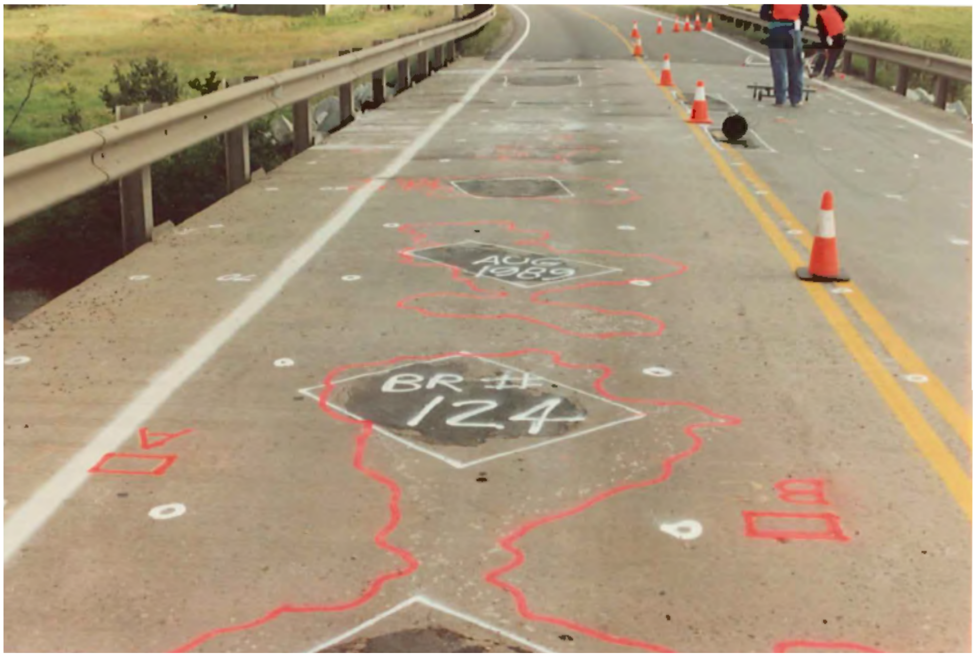
The fourth and fifth test series conducted on October 23 and November 7, 1989 both averaged a 3.9 MPY loss even though individual test location values varied by as much as 7.7 MPY in the two test series.

DISCUSSION

The increase in corrosion rates recorded after the first winter's application of TCI suggests the product did not have a significant impact on the level of corrosion activity during the first seven months of the study. At least part of the increase may have been due to the higher electrical conductivity of the concrete resulting from the winter salt still present in the upper surface of the deck.

Differences in the physical condition of the northbound (NB) and southbound (SB) lanes were visually apparent and also documented by the corrosion rate and corrosion potential testing. The August 24th testing series revealed the NB lane was 98% active with an average value of -0.51 volts while the SB lane was 73% active with an average value of -0.44 volts.

A number of different factors may have caused the difference in the extent of deterioration of the two lanes. Since the deck was reconstructed one lane at a time to allow maintenance of one-way traffic, differences in the water - cement ratio and the resulting concrete permeability and resistivity would have resulted in different chloride penetration rates on the two lanes. The difference in concrete cover over the top mat of reinforcing steel is a major factor. Cover on the SB lane averages approximately 2 1/2 inches while the NB lane is in the range of 1 3/4 inches.



Condition of NB lane on August 24, 1989. Red lines indicate the perimeter of concrete delaminations. White rectangles outline areas to be saw cut and patched.

Following the August 24 test series, maintenance personnel squared up the potholed areas and patched them with bituminous mix. Thirteen patches were made ranging from 1 to 34 square feet in area with an average size of 11 square feet. Seventy-seven percent of the patched area was in the NB lane. The majority of the patched area on the SB lane occurred along the centerline adjacent to the longitudinal construction joint.

The September 19, 1989 test series documented an increase in the rate of corrosion at 9 of the 13 test locations. In general, the increases was small except for locations F, L, and M on the NB lane which rose by 18.3, 6.4 and 5.1 MPY respectively. Following completion of the corrosion testing, soundings made with a hammer revealed that concrete delamination was present at location F. It could be assumed that the fracture plane in the concrete contributed to the extremely high reading at that test location. Soundings made at the other 12 locations revealed no audible delamination. However, delamination was noted along the west and south edges of location M and within four inches of location L. Since both locations were much more active in September and location L was even higher in November it is possible that delamination has occurred but the fracture plane is not yet severe enough to detect by sounding. All other test locations were at least 12 inches away from the nearest audible delamination.

With the completion of the October testing, it became apparent that the corrosion rate activity had decreased significantly at the five locations on the SB lane. The results can be seen in Table 2.

TABLE 2
Summary Of Corrosion Rates (MPY) Adjusted To 20°C (70°F)

Location	Nov 88	June 89	Aug 89	Sept 89	Oct 89	Nov 89
			North Bound			
A	1.8	4.4	4.8	6.2	5.6	5.0
B	3.1	2.6	4.4	3.6	4.8	4.2
C	1.3	2.3	1.3	1.8	1.3	1.2
D	3.9	7.5	5.9	7.8	4.6	6.6
E	2.9	8.7	6.8	8.0	13.4	7.2
F	6.8	17.6	6.5	24.8	**	---
L	1.6	4.0	5.3	11.7	9.2	16.9
M	5.9	9.5	8.0	13.1	5.8	4.8
Avg.	3.4	7.1	5.4	9.6	6.4	6.5
			South Bound			
G	2.1	5.3	1.8	2.0	0.5	0.3
H	3.9	14.1	2.3	2.1	0.5	0.3
I	3.3	5.0	2.5	1.9	0.4	0.3
J	3.7	7.0	4.2	2.0	0.5	0.3
K	1.6	1.6	0.36	0.8	0.4	0.2
Avg.	2.9	6.6	2.2	1.8	0.5	0.3
Avg All Tests	3.2	6.9	4.2	6.6	3.9	3.9

** Delaminated

Further reductions were recorded on the November 7, 1989 test series with the values averaging less than 0.3 MPY. Such a low rate could continue for 20 or more years before corrosion damage might be expected. It is assumed that the reductions in the rate of corrosion have occurred due to the application of the non-corrosive deicer. However, it is not clear why the material has not had a similar positive effect on the NB lane. Although variations in the rate of corrosion between lanes would appear reasonable due to the differences noted in the condition of the two lanes, no significant reductions beneath the base values were achieved on any of the NB test locations. As a minimum, reductions in the rate of corrosion below 1 MPY should have been achievable on NB points A and C since they were lower initially and also in the spring test series than the five SB test locations.

Due in part to the discrepancy in the rate of corrosion between lanes, further field testing will be required to confirm the effectivenes of the experimental deicer and determine the benefits which may be derived from its use.

SUMMARY

The major activities completed and results obtained during the first year of this research project include the following:

The Agency agreed to undertake a field study designed to evaluate the effectiveness of a corrosion inhibiting deicer.

The field site selected included a bare concrete bridge deck that had been tested for corrosion potentials during 11 of it's 20 years of service.

Prior to the application of the treated salt, 78% of the deck had active potentials and the rate of corrosion averaged 3.2 MPY at the 13 locations tested. The continuation of corrosion at this rate would be expected to result in damage to a concrete within six years.

Approximately 240 tons of TCI were applied in 69 salt applications during the winter of 1988-89. The usage resulted in the application of approximately 920 pounds of TCI directly on the bridge deck for an average of 0.39 pounds per square foot of deck area.

The spring of 1989 testing disclosed an additional 12% of the deck had active potentials and the rate of corrosion had more than doubled to an average of 6.6 MPY.

Four additional test series revealed a general decrease in both potentials and the rate of corrosion through November 1989.

The October and November testing indicated a very low rate of corrosion was occurring at all southbound test locations while the northbound locations were still approximately double the initial 1988 values.

PRELIMINARY CONCLUSION

Significant reductions in the rate of corrosion have been documented on the SB lane of the bridge deck under study. The only factor known to have changed during the test period was the application of the experimental corrosion inhibiting deicer and, it is assumed that the product was responsible for the reduction in corrosion activity. However, because similar reductions in the rate of corrosion have not occurred on the NB lane, the overall effectiveness of the product remains in question and will require further study.

FOLLOW UP

Further field testing will continue and be expanded to include additional rate of corrosion test locations, identification of all concrete delaminations, and determination of chloride content at the rebar level.