PERFORMANCE OF WATERPROOFING MEMBRANES ON CHLORIDE CONTAMINATED BRIDGE DECKS

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16. Abstract

A field evaluation program was established to determine the effectiveness of Vermont's bridge deck rehabilitation procedures. The major objective was to monitor areas of the decks which had high chloride(Cl-) levels and active corrision potentials but were not repaired due to the absence of any concrete delamination.

Initial research documented two cases where corrosion activity had been greatly reduced on high Cl- content deck concrete that had been waterproofed 11 and 13 years earlier without the benefit of any concrete repair.

The current study includes decks ranging from 17 to 36 years in age containing Cl- levels ranging from 0.1 to 16.6 lbs per cy at the rebar level. Surveillance included detailed monitoring of corrosion voltage potentials at a one foot grid interval prior to the application of the waterproofing system and pavement overlay with yearly evaluation intervals thereafter.

The field testing has revealed a 105 millivolt average reduction during the first year of protection on 5 of the 6 decks. Potentials were reduced below the -0.35 volt active level at 94% of the locations. Smaller but continued reductions were recorded after the second and third year of service. Membrane waterproofing did not reduce corrosion potentials on a bridge deck which exhibited significant bottom mat corrosion.

If the reduction in corrosion potentials is being accompanied by a corresponding drop in the rate of corrosion, partial deck repair and waterproofing will provide a much longer service life than most Agencies are anticipating.

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DISCLAIMER

INTRODUCTION

The desire to provide at least 50 years of corrosion-free service life for new reinforced concrete bridge decks has resulted in the development of numerous protective strategies including epoxy-coated reinforcement, low slump, dense or latex modified concrete, waterproofing membranes, increased rebar cover depth, and others. Sufficient performance information exists to suggest that, under suitable conditions and proper installation, the protective strategies can provide the desired service or at least a reasonable maintenance free life.(1)

In contrast, little can be found documenting the actual or predicted service life of treatments applied on Cl- contaminated bridge decks where the Cl- content exceeds the 1.3 lb/cy corrosion threshold level at the top mat of reinforcing steel. In fact, most investigations have concluded that rehabilitation procedures which remove part but not all of the Cl- contaminated concrete will result in failure unless other technologies, such as cathodic protection, are included in the treatment.

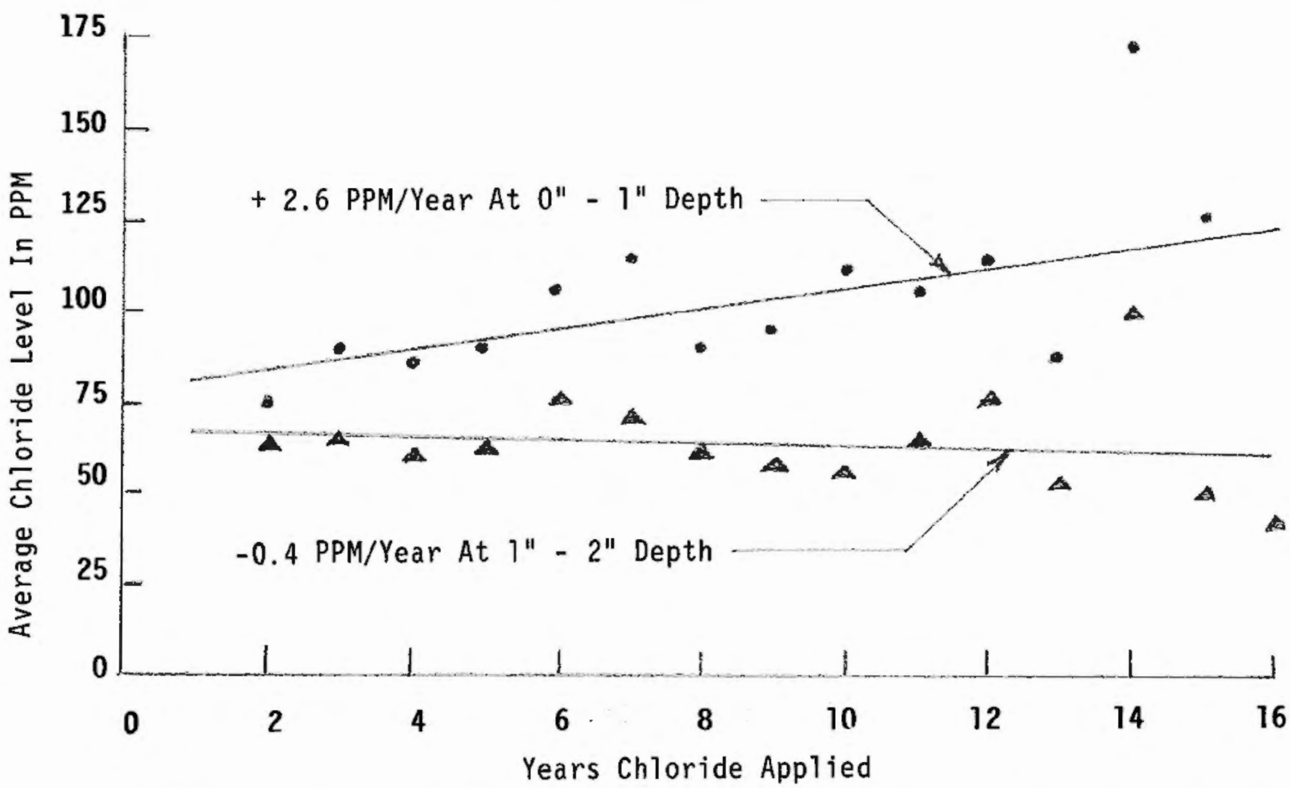
Due in large part to the lack of adequate funds, state and local highway agencies have generally specified removal of only the distressed concrete, even though only a relatively short maintenance free life could be anticipated. Vermont and a few other states have also chosen to remove concrete from areas with corrosion potentials of -0.35 volts or greater assuming such areas would eventually develop fracture planes due to the presence of rebar corrosion. In Vermont, such treatment is followed by the placement of a waterproofing membrane and asphalt overlay since it has been well documented(2) that such treatment is capable of preventing the intrusion of significant additional chlorides (see Figure 1).

FIGURE 1

Performance Of Waterproofing Membranes On New Bridge Decks

Rate Of Change In Chloride

Contamination Levels



Results based on 2558 field samples taken from 69 bridge decks project that Cl- contamination will reach the 325 ppm corrosion threshold level in the top inch of concrete after 85 years of service. The contamination levels are not increasing at the 1" - 2" depth.

As the deck rehabilitation program increased in size, it became more important to know how effective the treatment policy was and how many years of maintenance free life it would provide. Of additional concern was the escalating cost of concrete removal, which had risen from $29.00 per s.y. in 1983 to an average of $140.00 per s.y. in 1987, even though many of the contractors had switched over to the use of hydrodemolition which was less labor intensive.

Although good correlation was found between active corrosion values and concrete deterioration, close inspection often revealed that areas with potentials under -0.40 volts had not yet resulted in the development of fracture planes in the concrete. Such conditions raised the question: Was it necessary to remove Chloride contaminated concrete where rebar corrosion was present but the concrete was still sound? The answer, of course, would depend on whether the rehabilitation treatment used would retard or stop ongoing corrosion activity. If it couldn't, then fracture planes would develop and maintenance would be required.

WATERPROOFING PERFORMANCE

A search of the available literature on the performance of waterproofing on Chloride contaminated decks revealed studies in Kansas (3) and Illinois (4) that concluded such treatment was cost effective. However, neither study identified a definite reduction or elimination of ongoing corrosion where Cl- contaminated concrete remained in place.

The first experience (5), which suggested waterproofing could reduce corrosion activity, involved a 35 year old deck containing an average of 3.6 pounds of Cl- at the rebar level and corrosion activity on 84% of the area. Although the deck had been waterproofed in 1973 without benefit of any concrete repair, removal of the pavement and membrane 13 years later revealed that corrosion activity had decreased from the 84% level to less than 10% of the deck area. The reduction in corrosion activity had occurred even though 75%± of the rebar exposed during concrete repair revealed visual signs of corrosion, including sufficient loss of rebar cross section to require replacement of some bars.

A second case (6) involved a three span structure which was rehabilitated by District maintenance forces in 1976. Problems with the deck included severe scaling of the concrete, corrosion activity on 1/3 or more of the deck and Cl- levels up to 6.1 pounds per c.y. at the 2" to 3" depth. The rehabilitation treatment included removal of some but not all of the delaminated areas and shallow patching of scaled areas along the curb line. When the structure was let for contract rehabilitation 11 years later in 1987, a detailed study was conducted on the area of the deck which had been waterproofed with a performed sheet membrane. The study revealed the protected area was free of concrete delamination. Corrosion activity had dropped from 34% to 2%, despite the fact that the concrete contained an average of 2.9 pounds of Cl- per c.y. of concrete at the rebar level. The area of the deck not protected with the sheet membrane had continued to deteriorate with virtually all of the earlier patches suffering delamination and corrosion activity remaining on over 90% of the area.

Based on the results obtained in the two case studies, a number of bridges under contract for deck rehabilitation were selected for inclusion in a detailed performance study.

The decks selected ranged from 17 to 36 years in age at the time of repair. They had been exposed to deicing salt applications averaging 30 tons per two-lane mile per year, which had resulted in Cl- levels ranging up to a maximum of 22 lbs. per c.y. at the rebar level. Typical areas which were not repaired contained Cl- contents ranging from 0.1 to 16.6 pounds per c.y. at the 1" to 2" depth.

EVALUATION PROCEDURE

The surveillance included detailed monitoring of the extent of concrete repair and copper-copper sulfate half-cell readings at a 1 foot grid interval before repair and after rehabilitation just prior to the application of a performed sheet membrane waterproofing system.

The follow-up testing was carried out at locations where Cl- contaminated concrete was not removed and active corrosive values had been recorded prior to waterproofing. In many cases, the retests were taken at locations immediately adjacent to areas which had been repaired due to the presence of concrete delamination.

Because the presence of the membrane prevented completion of the circuit, it was necessary to modify the standard method of obtaining the half-cell potentials of the reinforcing steel. The procedure was accomplished by boring a 3/4" hole through the bituminous pavement and membrane to the concrete deck. A plastic pipe nipple with sponge insert was utilized to provide the necessary electrical circuit without saturating the sample hole with water. After testing, the holes were blown dry and sealed with a self leveling, one-part polyurethane sealant.

PERFORMANCE RESULTS

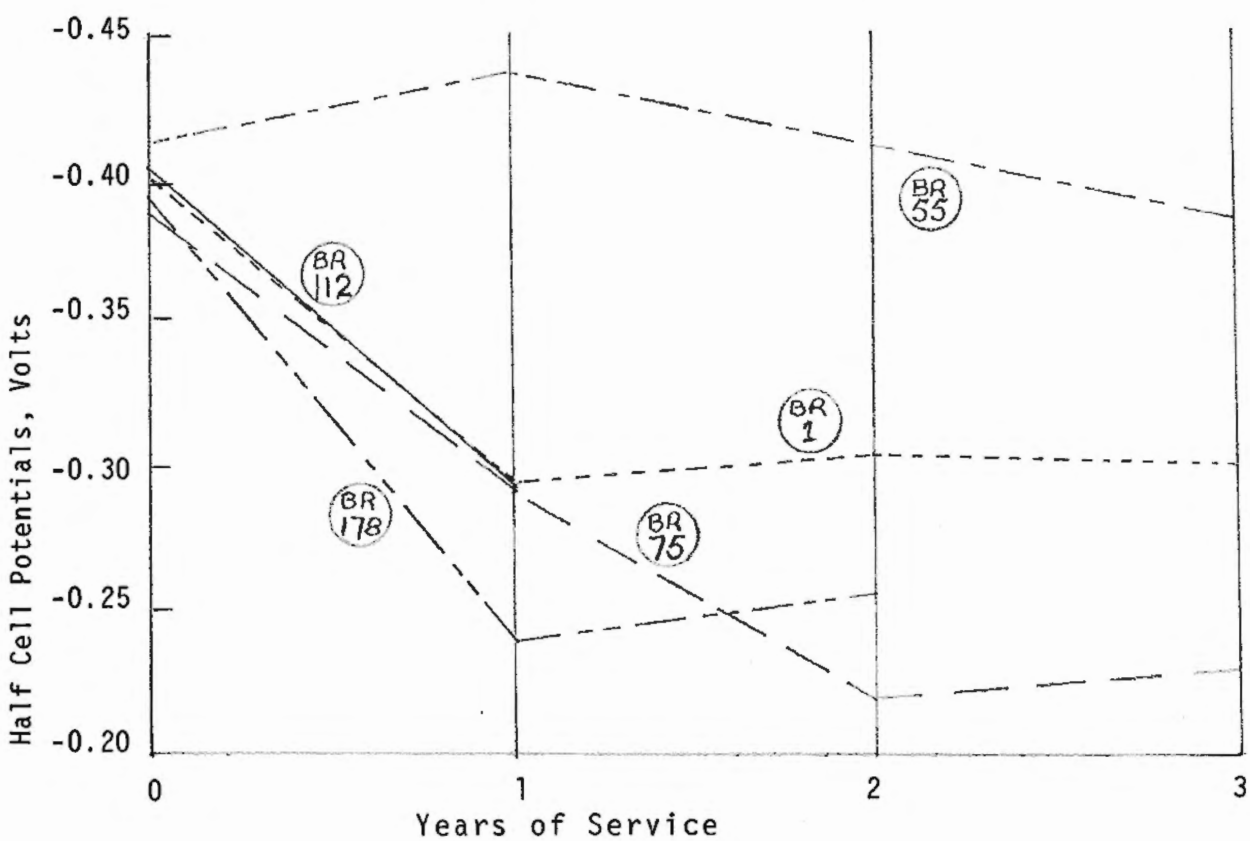
The results of the first retests obtained in 1987 were very promising since all corrosion readings had dropped on two of the three decks tested. Additional decks were added to the study in 1987 and 1988. The first year of service resulted in a 0.105 volt reduction of corrosion activity from the initial average value of -0.389 volts to -0.284 volts on five of the six decks tested. Active potentials of -0.35 volts or greater were only recorded at six of the 98 test locations.

The second year of testing produced a further average reduction of 0.034 volts with the 72 locations tested averaging -0.250 volts. Two of the three decks tested the third year revealed average reductions of 0.004 volts and 0.036 volts from the previous year.

It is believed that the reductions in the corrosion potentials are the results of reducing the oxygen and moisture supply available at the rebar. However, other researchers have suggested that passive protective treatments applied over salt contaminated decks have reduced the level of corrosion activity for a year or more but then the potential levels have rebounded. Knowing that more long term exposure information was needed, testing was carried out on I91 BR 8N which had been rehabed 49 months earlier. Thirty-eight tests were taken within areas which previously had active corrosion. The resulting retest values averaged -0.214 volts with only one value over -0.300 volts. Such results indicate no rebound in corrosion potential activity and suggest that the potentials are decreasing in ratio to the length of time the deck surface has been sealed from the penetration of moisture and the re-supply of oxygen.

FIGURE 2

Change In Corrosion Potentials



One of the seven decks under study, Bridge 55 on Route 2, did not respond to the rehabilitation treatment with the same positive results. In contrast, the corrosion potentials increased at most test locations after one year of service with the average values up 0.019 volts.

A slight decrease was recorded after three years of service but only 4 of the 19 locations tested had dropped below the 0.35 volt level.

The poor performance occurring on Bridge 55 is believed to be due to bottom mat corrosion. Full depth repairs at some locations during the rehabilitation revealed significant corrosion on some bottom mat bars. In addition, cracks and corrosion stains remain visible at many locations on the bottom of the deck.

The experience gained on Bridge 55 does serve to caution that partial repair and waterproofing may not provide long term performance on decks where corrosion and Cl- are present at both top and bottom mats of steel. In such cases, it may be necessary to seal the bottom of the deck to reduce corrosion activity by preventing the movement of oxygen to the bottom mat of steel. Such treatment could be achieved with the spray application of a polyurethane or similar material.

PRELIMINARY FINDINGS AND CONCLUSIONS

Significant findings documented to date include the following:

1. Corrosion potentials were reduced an average of 105

millivolts during the first year of protection on five study decks which had been exposed to deicing chemicals for an average of 24 years.

2. Corrosion potentials were reduced below the -0.35 volt level at 94% of the test locations after one year of protection.

3. Smaller but continued reductions were recorded after the second and third year of protection.

4. Corrosion potentials were not reduced by a significant amount on a bridge deck which exhibited a serious amount of bottom mat corrosion.

If it can be assumed that the reduction in corrosion potentials is being accompanied by a corresponding drop in the rate of corrosion, the following conclusions may be drawn:

1. A properly selected and applied waterproofing system can lower corrosion activity to non-destructive levels in chloride contaminated bridge decks.

2. Concrete removal is not required where active corrosion is present in sound concrete if the rehabilitation includes waterproofing.

3. The difference in chloride content between the old concrete and new concrete patches will not accelerate corrosion in the old concrete if the deck is sealed properly.

4. Partial repair and waterproofing will provide a much longer service life than the 15 years estimated by most agencies utilizing the treatment.

FOLLOW-UP

Future research will include rate of corrosion measurements using a 3LP-NB2 Corrosion Rate Meter and the installation of corrosion probes in rehabilitated bridge decks to determine if the waterproofing treatment is reducing the rate of corrosion. A minimum of five additional decks will be included in the study and corrosion potentials will also be recorded on the bottom of the decks to complement surface readings.

RECOMMENDATIONS

Additional research is needed to quantify the oxygen and moisture levels required to support the corrosion of steel in concrete. Such information might explain the successes reported in this field study and could result in more widespread use of rehabilitation procedure which appears to be an economically feasible method of saving, or at least extending the life of, the thousands of bridge decks built before the use of present day protective systems.

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