AHTD TRC TRANSPORTATION RESEARCH COMMITTEE

TRC0003

Corrosion Protection Strategies

Ron Strickland

Final Report

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CORROSION PROTECTION STRATEGIES

FINAL REPORT

TRC-0003 CORROSION PROTECTION STRATEGIES

ARKANSAS STATE HIGHWAY AND TRANSPORTATION DEPARTMENT
PLANNING AND RESEARCH DIVISION

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TITLE: TRC-0003 CORROSION PROTECTION STRATEGIES

INTRODUCTION

Bridge deck deterioration continues to be a major maintenance problem for many of the older bridges still in use today. Although the true magnitude and extent of the problem has not been fully determined, indications are that many aging bridge decks which were built with shallow concrete over unprotected reinforcing steel will have to be replaced due to premature failures in the bridge deck integrity.

The three most commonly observed conditions of deterioration of bridge decks are scaling, cracking and spalling. The current method of using high quality air-entrained concrete has virtually eliminated scaling problems. Surface concrete cracking, of itself, is not considered serious but cracks do provide ready access for moisture and surface chemicals to reach the reinforcing steel. Without adequate protection from surface chemicals and moisture, spalling caused by the corrosion of reinforcing steel has proved to be the most difficult to control.

Like many States that are subject to winter conditions, ice and snow accumulations on the highways are commonly removed by repeated applications of sand and chloride compounds. Following Arkansas' two to three-week periods of ice and snow removal, many District offices take steps to mediate the chloride buildup. However, with no way to test the effectiveness of these treatments, it was generally felt that the ensuing months of spring rains would effectively serve to both wash away and neutralize what chemical residues may have remained. Unfortunately, bridges typically receive the larger amounts of deicing compounds and are more subject to the formation of shallow age cracking. To be sure, various other non-corrosive chemical applications for snow and ice removal have been tried but the least expensive treatments remain applications of sand and chloride compounds.

Various approaches to treating spalling have been researched by most highway agencies. The most common treatment is an overlay of sealants that act to prevent surface penetration and restore a smooth deck surface. Similarly, more extensive sealant applications take the added action of re-strengthening the concrete by scouring and filling the larger cracks and crevasses with high strength epoxies. Accordingly, these epoxies must meet Type Accepted requirements for Class 3 protective surface treatment detailed in Section 803.02(c) of the Standard Specifications for Highway Construction, 2003 Edition.

PROJECT PLAN

A project plan was developed to apply a combination of thin-sealant overlays to selected problematic bridge decks and measuring the amount and rate of chloride permeation for purposes of corrosion protection assessment and new product evaluations. The Federal Highway Administration and other agencies have reported good results following testing and evaluations of new bridge deck treatments and have prompted further testing on deteriorating bridge decks exhibiting progressive signs of spalling and premature failure.

Due to the hundreds of bridges and overpasses within each state, a large portion of state maintenance funds must be reserved annually towards maintenance and repairs. In an effort to attain the most benefit from these funds, highway agencies must continually evaluate those manufacturer’s products promising superior performance, particularly those that can extend the lifetime of these structures for several years.

OBJECTIVE

The objective of this research effort was to develop a process to reduce or eliminate the effects of chlorides and the spalling that occurs in aging bridge decks. Two different product applications could best be compared if both ends of the same bridge deck could receive separate treatments. This virtually eliminates any inequalities between testing on two separate bridge decks and allows for direct comparisons in the final performance and evaluation stages.

The steps to achieve these goals are described below:

1. Determine which processes or products are available that are best suited for achieving the planned results on the selected bridge deck.
2. Determine what testing method(s) is best suited for evaluating the different products or treatments that are applied to the bridge decks.
3. Arrange for application of the selected products or treatments and insuring the product installation meets all manufacturer specifications and guidelines.
4. Monitor and evaluate the results to determine if the application has performed as expected and insuring the bridge deck continues to meet existing highway standards.
5. Determine which application appears to be the most cost effective solution and determine if it can be applied statewide or if implementation must be limited due to relevant bridge deck conditions or criteria.

DESCRIPTION OF WORK

All available literature pertinent to the project has been reviewed and evaluated for achieving the desired goals. Transportation Research Information Services (TRIS) and Transportation Research Board (TRB) archives provided several approaches that appeared to minimize the possibility of future spalling but would not entirely negate past deterioration. A suitable bridge (Bridge No. 03700) on Highway 277 was located near the town of Tillar in Drew County for testing purposes. Built in 1964, it is 26-feet wide with seven spans at 45-feet each. This bridge exhibited numerous deck surface failures (almost 95%) with only short sections of centerline and lane shoulders remaining from the original construction.

It was decided that a complete deck overlay application by two vendors would offer the best method for evaluations and comparison. Typically included as part of overlay evaluations are skid tests. These tests determine that the new surfaces are sufficient to meet existing specifications for roadway safety. Two skid tests were conducted for accuracy due to the short roadway surface distances involved. See Table 1 and both test results indicated as Skid Test1 [*Skid Test2*].

Table 1

Bridge Deck	East End	West End
Eastbound Lane	52.0 [*50.0*]	54.4 [*51.5*]
Westbound Lane	38.9 [*39.6*]	54.6 [*55.9*]

In order to determine the protective qualities of the bridge deck treatments, the extricated drill materials collected at 0.5-inch depth intervals, were sampled from four test holes. Each 0.5-inch of removed samplings was then analyzed to create a baseline of the accumulated chlorides from previous snow removal efforts. A similar testing method would be used later to determine the degree of penetration and accumulation of chloride ions and, consequently, the protective abilities of the overlays. The original holes were located 1) at the centerline, 2) near the gutter, 3) in an older patch and 4) on top the curb that was close to an area exposed rebar. The curb sample was taken in the belief that spalling due to water permeation through the concrete rather than chloride residues through deck cracking could be a major contributor to the bridge's deterioration. The four original test results are shown below in Table 2.

Table 2 Chloride ions-pounds/cubic yards

Depth	Centerline	Gutter	Patch	Curb
0.0 – 0.5 inch	1.07	1.88	.68	1.14
0.5 – 1.0 inch	1.40	2.07	1.07	1.05
1.0 – 1.5 inch	1.17			
1.5 – 2.0 inch	2.73			

None of the resulting chloride test levels appeared very high with the gutter test site having the higher concentrations as was expected. It should be noted the sampling was done prior to any overlay preparations since the prerequisite detergent power washing before the overlay installations could leave chemical residues possibly skewing any test results.

PROJECT APPLICATION

Two product lines were chosen for the purpose of evaluating similar type products with slightly different methods and materials for deck sealing. Under the direction of Hills of Arkansas, an approved Sikadur contractor, the entire bridge deck was shot blasted (all seven spans) and cleaned for both product applications. The four west bridge spans received a two-course thin polymer concrete overlay (a minimum recommended depth of approximately 1.0-inches) followed by the Sikadur 22 Epoxy preparation (a minimum recommended depth of approximately 1.0-inches including an aggregate covering) that was blended according to ambient temperatures and then placed atop the concrete overlay. A surface coating of fine aggregate was then applied and excess later swept clean after allowing time to setup. Installation and surface preparation costs totaled $23,750.

E-Krete[R] BD-2000 Micro Overlay, manufactured by Polycon, Inc., was next applied to the remaining three east spans of Bridge No. 03700 under the direction of Construction Fibers, a qualified manufacturer's representative. E-Krete[R] is a mixture of liquid polymers poured over the surface, squeegeed level, and then coated with fine aggregates (Black Beauty[R]). A tined rake was used to instill small ridges in the mixture to restore surface friction retention. Installation and surface preparation costs totaled $7,800.

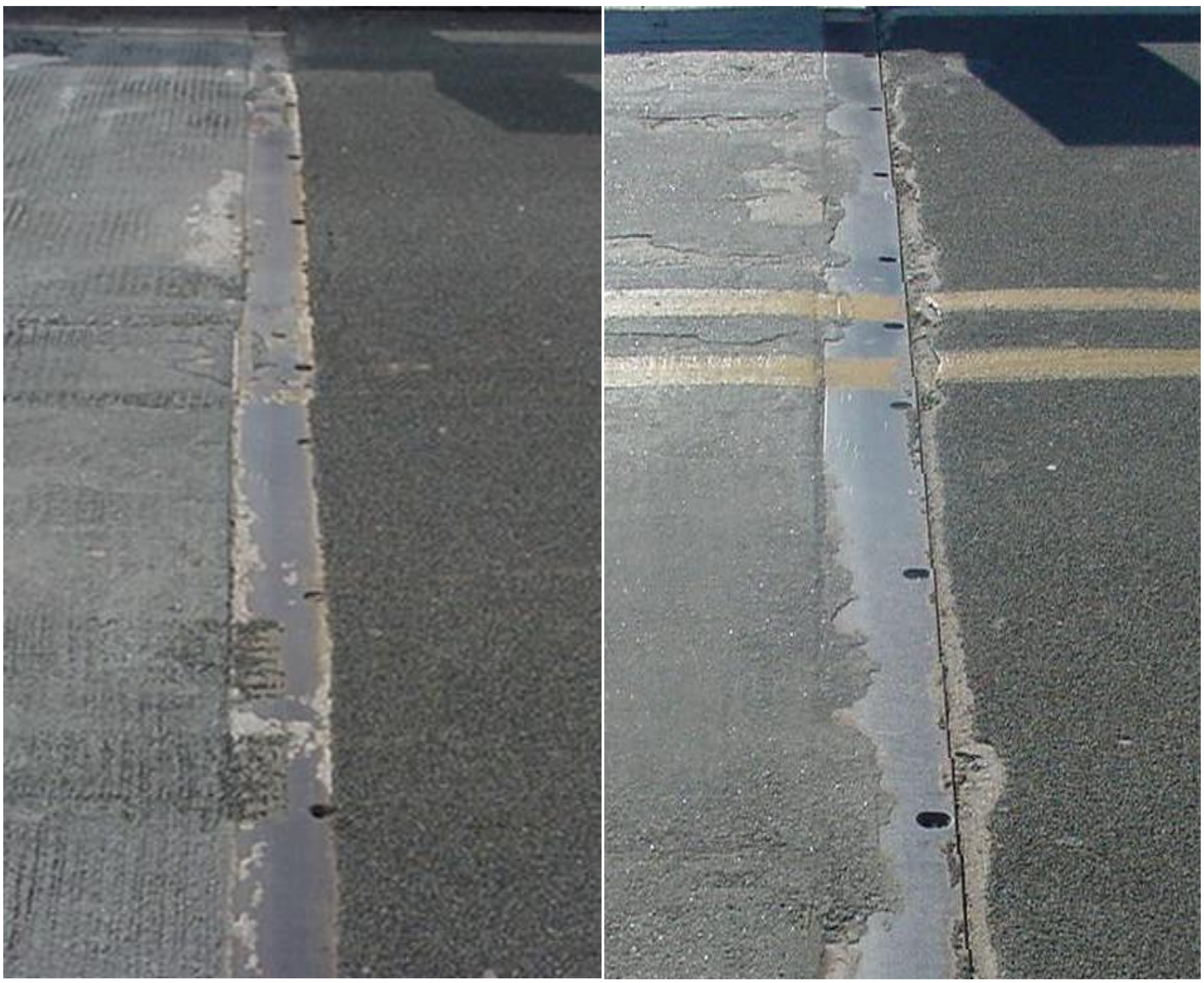
PROJECT COMPLETION

The deteriorated bridge deck received two bridge deck sealants/thin-overlays installations that were completed during late November 1999. It became apparent at installation that the Polycon product was not applied evenly nor finished properly. Claims of cold weather at the time of installation were stated as the reason for the adhesion problem and general unacceptable appearance of the Polycon product. Efforts to rectify the problem by the installer did not meet with any success. As it was, the results were not adequate enough to conduct a proper comparison between the two overlay products. Installation and performance of the Sikadur 22 product appeared to be satisfactory.

No records were available to ascertain the exact locations of the original test holes. With 95% of the traveled bridge deck having been patched, there was little hope of actually finding a section of original bridge deck to test without removing the overlay or drilling in the gutter sections. In order to be relevant, corrosion protection comparisons between each overlay requires comparative sampling be taken in close proximity to the previous test holes. Shown below in Figure 1 for easy comparison is a photo taken after the initial installation and one taken recently.

Figure 1 - Polycon (Left) and Sikadur (Right)

May 2000 **October 2005**



The photo in Figure 2 was taken in May 2000 and shows the completed bridge deck. A corresponding photo in Figure 3 was taken in October 2005.

Figure 2

Figure 3

Chloride ion samples from four test holes were taken from the gutters of the Tillar Bridge surface in October 2004. Initial project work identified the travel lanes as the locations of the highest areas of patching while the gutters were relatively devoid of patches. Without proper documentation, once the overlays were applied, there was no way to determine original deck concrete from patch material inside the travel lanes. As a result, no correlations can be drawn between samplings, however, any future gutter testing and saturation rates can be collected and monitored at points typically accumulating the highest percentages of chloride concentrations. Holes 1 and 4 were located under the Sikadur material and Holes 2 and 3 were located under the Polycon material. The latest test results are shown in Table 3. Refer to Appendix A and Figure 1A for bridge deck test locations and deck section layout.

Table 3 Sample Results

Hole #1 Sample Depth, Inches	% Chloride Ion	Pounds /Cu. Yd.
0.0 – 0.5 inch	0.055	2.144
0.5 – 1.0 inch	0.036	1.415
1.0 – 1.5 inch	0.040	1.554
1.5 – 2.0 inch	0.041	1.611
Hole #2 Sample Depth, Inches	% Chloride Ion	Pounds /Cu. Yd.
0.0 – 0.5 inch	0.074	2.913
0.5 – 1.0 inch	0.032	1.244
1.0 – 1.5 inch	0.019	0.750
1.5 – 2.0 inch	0.018	0.712
Hole #3 Sample Depth, Inches	% Chloride Ion	Pounds /Cu. Yd.
0.0 – 0.5 inch	0.038	1.499
0.5 – 1.0 inch	0.031	1.230
1.0 – 1.5 inch	0.036	1.415
1.5 – 2.0 inch	0.029	1.152
Hole #4 Sample Depth, Inches	% Chloride Ion	Pounds /Cu. Yd.
0.0 – 0.5 inch	0.100	3.932
0.5 – 1.0 inch	0.044	1.731
1.0 – 1.5 inch	0.016	0.612
1.5 – 2.0 inch	0.022	0.874

In order to meet resurfacing safety requirements before acceptance and due to its susceptibility to icing in cold weather, both bridge deck overlays were skid tested and passed existing highway safety standards. The 12-month skid test results are shown in Table 4.

Table 4 Road Skid Number

Skid Number	East Half of Bridge	West Half of Bridge
Eastbound Lane	37.2	53.4
Westbound Lane	41.0	52.7

For reporting purposes, November 2004 skid test results are shown in Table 5.

Table 5 Road Skid Number

Skid Number	East Half of Bridge	West Half of Bridge
Eastbound Lane	48.5	59.5
Westbound Lane	46.8	58.8

CONCLUSION

The project had a few problems from the start. Not the least of these was the installation and durability of the Polycon overlay. An evaluation of the product's durability could not be rated highly. Although installation costs were approximately one-third the price of the Sikadur product, no conclusions could be drawn as to its potential protective qualities.

The Sikadur product performed well and to all appearances is still performing well. Without corroborating test evidence of the bridge deck prior to the overlay, no conclusive results can be provided as to the product's corrosion protection capabilities. However, future sampling may be used to disclose the chloride ion filtration rate with the overlay installed.

No records are available of the original test hole locations nor could these be established after resurfacing. Testing outside the gutters and in the driving lanes would probably produce erroneous results due to the absence of original deck concrete (patching). Due to test hole proximities, testing could not be used to establish filtration rates nor evaluate the chloride protection properties of either overlay. No conclusions could therefore be drawn from the samples taken at this time.

Initially, the low chloride level (1.05 lb./cu. yd.) at the 0.75 to 1.0-inch hole depth at the curb location was believed indicative of deck failure attributable to high permeability more so than chloride content. Regardless, depending on environmental factors, AASHTO finds chloride ion concentrations below 2.4 lb./cu. yd. acceptable and above 4.7 lb./cu. yd. as needing replacement.

Appendix A

Figure 1A - Tillar Bridge Deck