LONG TERM DECK DETERIORATION

Experimental Feature
Final Report

OR 82-02 through OR 82-08

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by

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Prepared for

FEDERAL HIGHWAY ADMINISTRATION
Washington, D.C. 20590

September 1990

LONG TERM DECK DETERIORATION
EXPERIMENTAL FEATURE PROJECTS OR 82-02 THROUGH 82-08

I. INTRODUCTION

In May of 1981 the Oregon State Highway Division was asked by the Federal Highway Administration to participate in a long term deck deterioration study. The study, an extension of an earlier study that was finalized in 1979, was to run through 1990. Review of the data in 1987 made it apparent that further study would not produce any more meaningful information. FHWA was informed and agreed that further study was not warranted.

The Division chose seven bridges to monitor. Five of the bridges had membranes and two had test sections of epoxy coated rebar. Visual inspections were to be made annually and detailed inspections were scheduled for 1985 and 1990.

This summary report presents the work done from 1981 through 1987, including field tests, results and conclusions.

II. METHODS AND CRITERIA

The detailed surveys included visual evaluation, delamination, membrane resistivity, active corrosion by Cu-$CuSO_4$ half-cell and chloride content. For this study the following evaluation criteria was used.

Membrane resistivity estimates the effectiveness of a membrane by ranking it in one of three categories. The categories are:

1. Satisfactory (S) — 80% of all readings greater than 500,000 ohms and 100% of all readings greater than 100,000 ohms.
2. Unsatisfactory (U) — 50% of all readings less than 100,000 ohms.
3. Doubtful (D) — All other Cases.

Interpretation of Cu-$CuSO_4$ half-cell potentials are:

1. Readings more negative than -350 millivolts (mv) have greater than a 90% probability of active corrosion.
2. Readings between -350 mv and -230 mv have a 10% to 90% probability of active corrosion.
3. Readings more positive than - 230 mv have less than a 10% probability of active corrosion.

Chloride content, in pounds per cubic yard of concrete, was determined from drilled samples. The threshold value, when corrosion can occur, is approximately 1.2 # Cl^- per cubic yard of concrete at the rebar.

III MEMBRANES

1. **Rub-R-Road** on the Yaquina Bay Bridge, #1820, Hwy 9, MP 141.68, located at Newport, Oregon on the central Oregon coast. (OR 82-04)

   This is a membrane-overlay system. Three coats of liquid rubber, with a short curing time between coats, was applied to the deck to form a membrane. A latex modified asphalt concrete was placed directly over the cured membrane. This system has a high initial cost and placement problems were reported.

   Visual evaluation in 1982 and 1986 found the overlay in good shape with no apparent cracking, spalling or rutting.

   1982 wheel track resistivity measurements were:

   40 % (8)[1] greater than 500,000 ohms
   35 % (7) less than 100,000 ohms

   which ranks this system as doubtful.

   1986 half-cell potentials in the wheel tracks were:

   14% (3) with greater than 90% probability of active corrosion
   41% (9) in the 10% to 90% probability range
   45% (10) with less than 10% probability of active corrosion

   On old coastal structures, where the deck has been left bare and no de-icing salts have been used, the observed half-cell potentials tend to be more electro-positive than - 230 mv. This is due to the build up of chlorides on the bottom of the deck, making the bottom steel anodic (corroding and more electro-negative) and the top steel more cathodic (not corroding and more electro-positive).

   Two other structures have this system. Resistivity measurements on them indicated "unsatisfactory" performance.

2. **Bonifiber - Polyester Fiber Asphalt Concrete**, Mill Creek Bridge, #7769A, Hwy 162, MP 1.15 in the Mid Willamette Valley just east of Salem. (OR 82-05)

   This system consists of a standard tack coat followed by placement of a 3/4" thick polyester fibre asphalt concrete. The asphalt concrete contained .25% polyester fiber by weight of aggregate. This was followed by placement of an open graded wearing course.

   The system had very high resistance values immediately after placement (5/77). However, after two months of service, the readings were very low. This indicated the membrane failed or excessive moisture was present in the open-graded mix.

   Visual evaluation in 1982 and 1985 found the overlay in good shape with no apparent cracking, spalling or rutting.

[1] The number in the parenthesis is the actual number of readings recorded in the reported range.

The membrane resistance measurements were:

1977 - one day after construction the resistivity measurements were:

100 % (35) greater than 500,000 ohms

1977 - two months after construction the resistivity measurements were:

100 % (18) less than 100,000 ohms

1982 resistivity measurements were:

100 % (22) less than 100,000 ohms

1985 resistivity measurements were:

100 % (50) less than 100,000 ohms

which ranks this system as unsatisfactory.

100% of the half-cell potentials reported in 1985 indicate less than 10% probability of active corrosion.

3. **Asphalt Rubber Chip Seal**, Beaver Creek Bridge, #8076, Hwy 162, MP 8.88 (Mid Willamette Valley near Salem) (OR 82-06)

This system consisted of a tack coat and a two-course hot rubberized-asphalt chip seal compacted to 1/2 inch. The binder was 73%-77% asphalt and 23%-27% ground rubber by weight. A one inch asphalt concrete wearing course was put over the chip seal.

Visual evaluation in 1982 and 1986 found the overlay in good shape except for transverse cracks over the expansion joints.

1982 resistivity measurements were:

100 % (10) less than 100,000 ohms

which is unsatisfactory.

Review of the data indicated that there had been several weeks of intermittent rain prior to testing and drain grates were used for the electrical ground. The 1985 inspection found the grates not electrically continuous with the rebar in the structure.

1985 resistivity measurements were:

80 % (8) less than 100,000 ohms

which is unsatisfactory. The increase in resistivity is because the 1985 tests were done after several weeks of good weather.

1985 half-cell potentials were positive and as high as +100 mv. Adjacent, bare concrete had values to -57 mv. This phenomena has been observed elsewhere and may be associated with the oxygen balance in the deck.

4. **Superseal 4000 HT** , Irwin Road Over-crossing, #8028N, NB, Hwy 1, MP 99.53 (I-5 near Canyonville in south-central Oregon)(OR 82-07)

This system consists of Superseal 4000 HT liquid membrane and Class "M"[2] asphalt concrete compacted to 1/2 inch.

Visual examination in 1981 revealed minor rutting and cracking in the asphalt concrete. There was no evidence of spalling. Extensive cracking had been observed on the bottom of the deck but it was believed that the cracks were present before construction of the overlay.

Visual examination in 1987 revealed that there was approximately 6" of asphaltic concrete on the structure and a skin patch had been recently placed on the right lane.

1981 resistivity measurements were:

44% (7) greater than 500,000 ohms in the shoulder.
19% (3) less than 100,000 ohms in the shoulder
100% (16) less than 100,000 ohms in the wheel tracks.

1984 resistivity measurements were:

44% (7) greater than 500,000 ohms in the shoulder.
31% (5) less than 100,000 ohms in the shoulder.
100% (16) less than 100,000 ohms in the wheel track.

Note: there was evidence of moisture in the pavement at the time of the tests.

1987 resistivity measurements were:

67% (12) greater than 500,000 ohms in the right lane.
6% (1) less than 100,000 ohms in the right lane.
6% (1) greater that 500,000 ohms in the left lane.
89% (16) less that 100,000 ohms in the left lane.

which ranks this membrane as unsatisfactory. The high readings for the right lane were probably due to the skin patch.

Four chloride samples were taken in 1987. The levels found were .26 # Cl^- in the 1/8 " to 1/2 " level and the same for the 1/2" to 1" level. Uniform levels such as these can only come from the chloride ion concentration becoming constant with time or presence of chlorides at the time of construction. This indicates that there has not been chloride intrusion for a long period of time.

[2] Class "M" asphalt concrete was specifically designed for a wearing surface over membranes. The proportions of materials were to conform to the following:

Sieve Size Passing	Class "M" Percentage of Total Aggregate (by weight)
1/4"	100
No. 10	75-90
No. 40	25-40
No. 200	3-12

Asphalt Content - 7% to 11% by weight of the total mix

5. **Royston Bridge Deck Membrane #10**, Butte Creek Bridge, #8232S, Hwy 1, MP 222.42 (I-5 between the Corvallis Interchange & Eugene) (OR 82-08)

This system consists of Royston Bridge Membrane #10 with a 1/2 inch Class "M" asphalt concrete overlay.

Visual inspections revealed no spalling, some longitudinal and transverse cracking.

1982 resistivity measurements were:

100% (7) less than 100,000 ohms

1985 resistivity measurements were:

100% (42) less than 100,000 ohms

which is unsatisfactory.

Both the 1982 and 1985 measurements were taken when the decks were probably saturated with moisture, a condition that most likely invalidates the readings.

Fourteen half-cell readings were taken in 1985. Only one of the readings indicated a probability of active corrosion that was greater than 90%

IV EPOXY COATED REBAR

1. **Cookpaint 720-A-009**, Shelton Ditch Bridge, #16009, 13th St., Salem (OR 82-03)

1975 - CONSTRUCTION

Three sets of three bars each were placed transversely in the structure. Each set was wired so that easy access was possible. The first set of bars were bare. The second set, which were epoxy coated, were placed with no field repairs to the coating. The third set, also epoxy coated, were placed and the coating was field repaired by painting over the damaged areas before the concrete was placed.

1982

The chloride level at the 0 to 1 inch level was 0.2 lb/yd^3 which is insignificant.

The half-cell readings over all the test bars indicated there was less than a 10% possibility of active corrosion. No significant differences were noted between the three sets of bars.

1985

Only fine map cracking was noted.

The resistivity test procedure was used to measure the effectiveness of the epoxy on the test bars. The results from this test only give relative values and cannot be evaluated with the criteria for membranes. Eight resistivity measurements were taken down each test bar. The results are in the following table.

TABLE 1
RESISTIVITY

BARS	RESISTANCE (OHMS) AVERAGE	NUMBER OF READINGS
Plain	1,450	24
Un-repaired	2,600	24
field-repaired	16,300	24

These results indicate field repaired bars have much better electrical isolation from the envirnment then the unrepaired bars.

The half-cell readings were slightly positive indicating lack of moisture in the deck.

The chloride level (4 samples) at the 0 to 1 inch level averaged 0.45 lb/yd^3. This was an average increase of 0.28 lb/yd^3 when compared to the 1982 level. At the 1 to 2 inch level the average was 0.13 lb/yd^3.

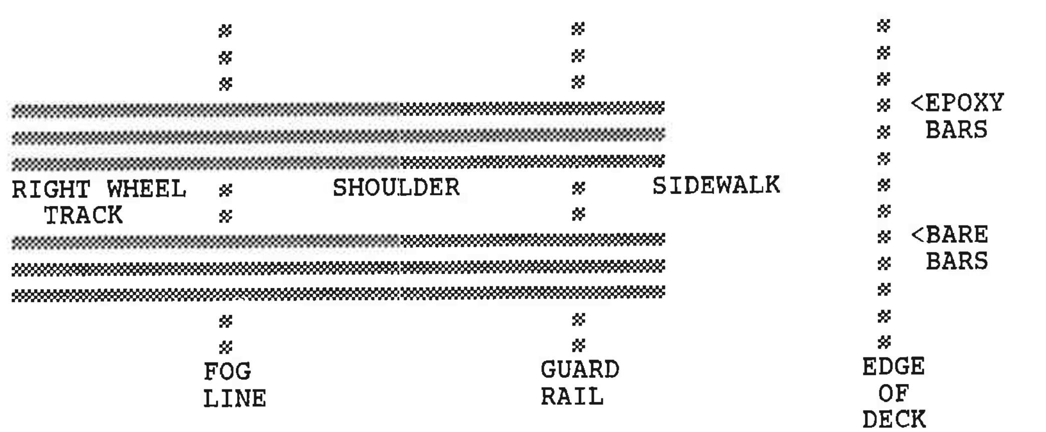
The structure was removed in 1987 for realignment.

2. **Flintflex 531-6080**, Yachats River Bridge, #1173D, Hwy 9, MP 164.73 (Yachats, 30 mi. S. of Newport) (OR 82-02)

1977 - CONSTRUCTION

Two sets of six, #5 x 20 ft. transverse test bars were placed in the deck for testing. Three bars in each set were in the top and bottom mat respectively. One set of bars were epoxy coated and the other set were bare. Leads from the bars were terminated in junction boxes on the side of the structure. Lead wires numbered 1 and 2 were from the top and bottom mat of epoxy coated bars respectively. Lead wires numbered 3 and 4 were similar for the un-coated test bars.

FIGURE 1
TOP VIEW OF THE TEST BAR LAYOUT WITH RESPECT TO THE DECK



Between 1978 and 1982 the structure was overlaid with asphalt concrete.

1978

Positive half-cell values were reported.

1982

Positive half-cell values were reported.

There is a good chance that these values should have been reported as negative. Positive values this high are much higher than could normally be attributed to a dry deck. Negative values in this range, the most negative value of -180 mv with an average of -130 mv (9 readings), are realistic.

The chloride level (4 samples) at the 0 to 1 inch level averaged 0.7 lb/yd^3. One sample from the 1 to 2 inch level was 0.1 lb/yd^3.

1987

Resistance measurements were taken between the 4 test lead wires and are reported in Table 2.

TABLE 2
RESISTANCE BETWEEN TEST BARS
OHMS

	WIRE #	1	2	3	4
EPOXY	1 top	-	300	0	0
	2 bot	300	-	400	460
	3 top	0	400	-	0
BARE	4 bot	0	460	0	-

The table indicates that the resistance between wire 1 and 2 is 300 ohms. Wire 2 (bottom mat of epoxy bars) is electrically isolated since the resistance increases from it to 1, 3 and 4, reflects the resistance of the concrete with distance. The zeros indicate that the top mat of epoxy bar is electrically continuous with the bare test bars.

Resistivity measurements were taken over the wheel tracks, on the shoulder and sidewalk. The values in table 3 are the average of 16 readings. Similar readings were taken with the half-cell and are listed in Table 4.

Table 3
Average Resistivity
Over All The Test Bars

Wheel tracks	4,400 ohms
Shoulder	370,000 ohms
Sidewalk	290,000 ohms

There was no significant difference between the bare and epoxy coated bars. These values represent the resistance contributed by the overlay. The low resistance over the wheel tracks is not explained.

Table 4
Average Half-Cell Potentials
Over The Test Bars

Wheel tracks	- 91 mv
Shoulder	-202 mv
Sidewalk	-202 mv

Normally, stable readings would not be expected over sound epoxy coated bar. These readings may be from other steel that is electrically continuous with the epoxy bar.

V. DISCUSSION

A. Bridge Deck Membranes as a Water Barrier

Conclusions about the condition of a membrane by the resistivity method are based on the membrane being waterproof. The waterproof characteristic merits further discussion.

It has been suggested that the resistivity method may show a membrane to be unsatisfactory when it is actually fine. If water in the overlay is not permitted to escape before testing, unrealistically low resistance values may be obtained.

When an overlay does trap water, the overlay becomes a reservoir where contaminated water is collected and the contaminant is concentrated by evaporation. The concentration of contaminates in the overlay can become very high as new water is repeatedly trapped and concentrated. If the contaminants have some salts that absorb water, a condition would be reached where the overlay would never dry out. In this case a good membrane could not be accurately evaluated by the resistivity method.

If something caused the membrane under a salt contaminated overlay to rupture, the contaminates would be released into the structure. The resistivity test could not detect this condition. Failure of the membrane would probably not be noted until delamination at the concrete-steel interface begins to occur.

"The location of moisture, if any is present in the exposure, vitally affects the choice of coatings for concrete and masonry. In particular, an impermeable, membrane-type coating often performs poorly on concrete if a source of water exists behind the coated surface."[3] If sufficient water vapor forms under the membrane to destroy the adhesion of the membrane to the concrete, local traffic may cause enough movement to rupture the film and permit contaminates to enter the concrete. This may explain why lower resistance values are often found on the travel lanes than on non-traffic areas.

[3] Paint Manual, Third Edition, U. S. Department of the Interior, Bureau of Reclamation, 1976

B. Bridge Deck Membranes as a Chloride Barrier

On new structures an increase in chloride content of the concrete would indicate failure of the membrane.

On old structures that had some chloride contamination before receiving a membrane, the chloride concentration versus depth will follow characteristic curves. Once an effective membrane is placed, no further increase in chloride concentration should occur. The chloride concentration versus depth curve should flatten out over time. Failure to meet this criteria would indicate a membrane failure.

VI. CONCLUSIONS

The resistivity method for evaluating membrane-overlay systems indicated unsatisfactory membrane performance on the structures evaluated. Either the membranes are not performing or the test method is unsatisfactory.

Resistance values in the wheel track that are significantly lower than the resistance values of non-traffic areas suggests that degradation of the membrane is occurring in the traffic areas.

If the resistivity test is used, care should be taken to do the evaluation only after a long dry spell.

Chloride sampling has the disadvantage of being a destructive test. However, it may be one of the definitive tests for membrane performance.

Half-cell measurements should be taken after periods of moderate, damp weather so that the corrosion activity is not effected by the lack of moisture in the deck.

Field repaired epoxy coated bars provide significantly more electrical isolation than un-repaired bars.

With electrically isolated epoxy coated bars there is a good probability that there will be holidays in the coating. This would eliminate cathodic protection as a repair strategy.

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