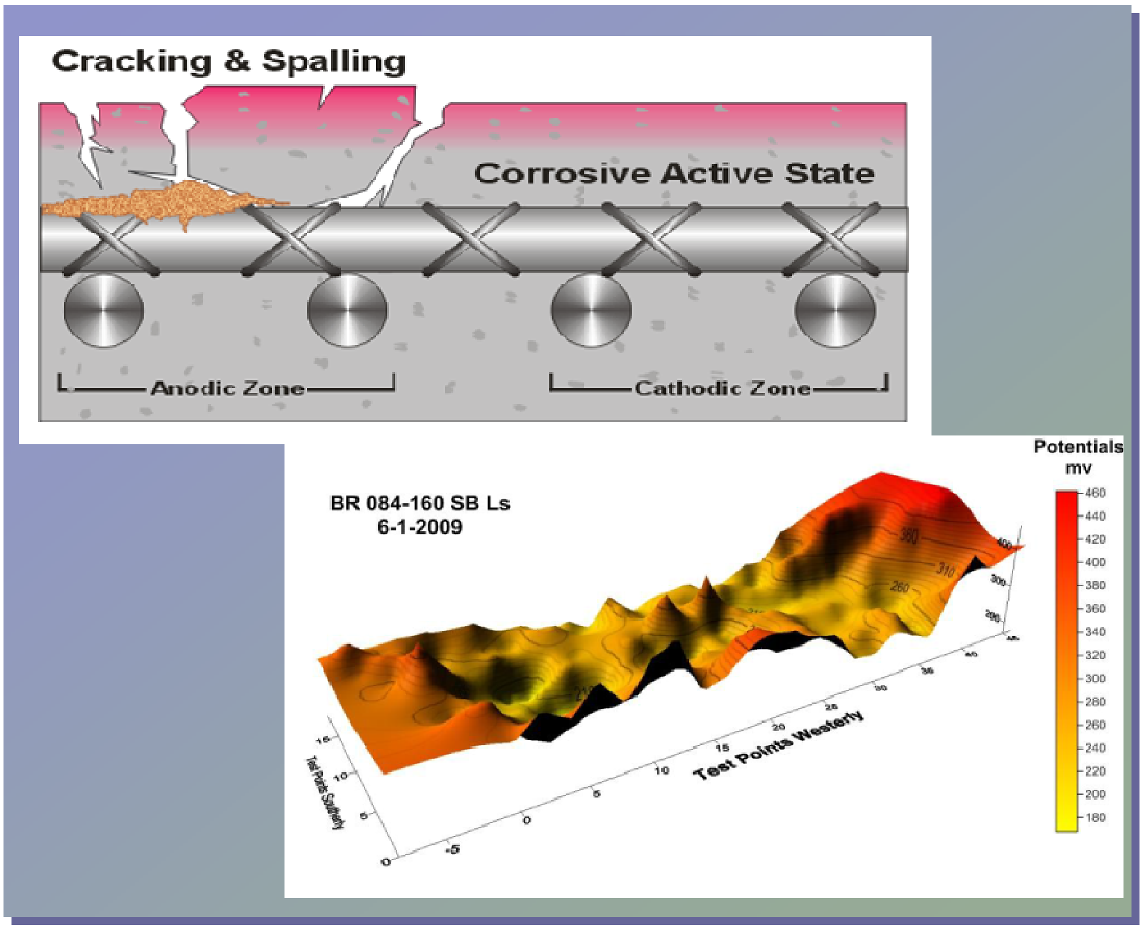
New Hampshire DOT

Research



Evaluation of Corrosion and Corrosion Control on Interstate 89 Bridge #30 and # 31

Final Report

Prepared by CD Engineering for the
New Hampshire Department of Transportation in cooperation with the
U.S. Department of Transportation, Federal Highway Administration

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16. Abstract

This report summarizes the evaluation of the performance of cathodic protection installed on I-89 bridges over Gile Pond Road (NH Route 114) during a rehabilitation project in 1987.

Control bridges of I-89 over Hominy Pot Road, approximately 1.5 miles to the northwest, were also evaluated. The Hominy Pot Road bridges received a standard-practice NHDOT rehabilitation of an overlay of 1 ½ inches of concrete and a new membrane. The Gile Pond Road bridges each received a four-zone Raychem FEREX 100 anode cathodic protection system overlaid with concrete and no membrane. This system was tested after installation and records indicate it was working properly; however, within 6 years only one of the four zones was functioning as expected. Two zones of the four appear to have failed in 1990 and the system failed completely by 1998.

Field surveys for this study took place in 2009 using an evaluation protocol as presentation in NCHRP report 558. The control bridges exhibited more substantial damage in comparison with higher rebar loss, in addition to amounts of concrete delamination and spalling.

The cathodic protection system did provide some benefit to these bridges; however, the system failed and is no longer provides protection. The particular system used in this installation proved to be unsuccessful at most installations in the U.S.

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Evaluation of Corrosion and Corrosion Control on Interstate 89 Bridges #30 and # 31

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DISCLAIMER

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Evaluation of Corrosion and Corrosion Control on Interstate 89 Bridge #30 and # 31

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Project #14511

Report #2010-10-3/062415

Evaluation of the Cathodic Protection System on Interstate 89 Bridge #30 and Comparing the Corrosion to Control Bridge # 31

Introduction

The objective of this evaluation is to assess the performance of the cathodic protection system for the I89 bridge numbers 109/144 and 0109/145 in Sutton, NH, over Gile Pond Road (Route 114) and compare the effectiveness against the control decks of the companion bridge numbers 084-160 and 085-161 over Hominy Pot Road. These bridges were rehabilitated in 1987. At that time the existing pavement and membranes were removed and the existing decks milled. The Hominy Pot Road bridge numbers 084-160, 085-161(I 89 bridge number 31) were overlaid with 1 ½ inches of concrete and a new membrane. The Gile Pond Road bridge numbers 109/144 and 019/145 (I 89 bridge number 30) received a cathodic protection system overlaid with concrete and no membrane. This system was part of a Federal Highway administration (FHWA) demonstration project. A Raychem Corporation FEREX 100 cathodic protection system was installed by the Evroks Corporation between July and September 1987. The Raychem FEREX 100 anode resembles an electrical cable and consists of a stranded copper wire encased in a proprietary flexible and electronically conductive polymer with an extruded conductive polyethylene jacket. The nominal diameter of the anode cable is approximately 8 mm. This composite anode cable was woven into two-dimensional mats in the factory and spread over the scarified and repaired bridge decks and secured with plastic cleats. Conductive cleats were installed between the individual anode strands to provide conductive redundancy to the anode mat. The system consisted of four zones; one zone per lane. Each zone consisted of three anode mats identified as phase A, B and C. Each zone was approximately 2204 $ft.^2$ and independently powered with direct current supplied to the system by a four module constant voltage rectifier (Universal Rectifier Co., Model ASP).

Silver/silver chloride reference electrodes and rebar probes were placed in the more anodic parts of the East end of each zone at phases A and B. Records indicate that the system was energized in mid October 1987. Tests were performed and open circuits were found in the anode panels and junction boxes of zone two. Transposed wires were located in zone three.

A report dated December 10, 1987 provided by Raychem Corporation that included information on tests performed and data compiled during construction of the system could not be located.

A report provided by Raychem Corporation dated October 10, 1988, indicated that E log i tests were performed on September 28, 1988. The report concluded that the FEREX 100 system was working properly and that four hour depolarization tests should be performed by the State of New Hampshire by late November 1988 or the spring of 1989. Records provided by the New Hampshire DOT Bureau of Materials and Research indicate that their quality control group began testing the system December 10, 1987 and continued through November of 1990. The data compiled on December 10, 1987 indicated that the system was working properly with depolarization of well over 100 mV. Data compiled on April 29, 1988 indicated that the system was starting to operate erratically with only zone four working properly, zone three marginally, and zones one and two inoperative. Records indicate that this trend continued until November 13, 1990 when no further data or records were available. In 1993, records were sent by New Hampshire DOT Materials and Research Bureau to Elgard Corporation for evaluation. The Elgard Corporation October 26, 1993 report confirmed that zones one and two were not receiving any electric current, zone three depolarization was acceptable and zone four appeared to be marginal. No system data was available from November 13, 1990 until August 13, 1998 when CD Engineering (CDE) began evaluation of the system. The evaluation performed on August 13, 1998 included a visual inspection of the decks, rectifier, conduits, accessible junction boxes and testing of the rectifier and gathering electrical data on all four zones. Several repairs were done between 1998 and 2009 including repairs to the rectifier modules that became erratic because of high resistance circuits. This was due to dust and corrosion products between the contacts of the adjustment windings and wipers. The system exhibited continual erratic behavior throughout this period and was de-energized and abandoned during the NHDOT I 89 bridge project number 14511.

Based on the data obtained from NHDOT, deterioration of the circuits began as early as 1990. This was also observed in various national studies of the Raychem for FEREX 100 system where some systems failed completely in as little as 1100 days. The FEREX 100 anode system was used in over 50 FHWA demonstration projects and several studies noted that by 1990 many installations were exhibiting problems with anode degradation and cracking.

Field surveys for this evaluation took place between April 13, 2009 and July 28, 2009. The evaluation protocol used in this study, is based on test methods for evaluating bridge superstructures as presented in the National Cooperative Highway Research Program (NCHRP) report number 558. The following methods were used in this study; visual, delamination, electrical continuity and corrosion potential surveys along with cover, chloride ion and petrographic analysis. These test methods were used on seven of the eight bridge decks that comprise the I89 bridge numbers 109/144 and 0109/145 in Sutton, NH, over Gile Pond Road (Route 114) and bridge numbers 084-160 and 085-161 over Hominy Pot Road. The southbound high-speed Lane of the Hominy Pot Road Bridge was not available for this study because rehabilitation had been completed. In addition to the above, the performance of the cathodic protection system on the I89 bridge numbers 109/144 and 0109/145 in Sutton, NH, over Gile Pond Road (Route 114) was evaluated. Tests conducted on these four bridge decks included performance of the rectifier, the anode system, the silver/silver chloride reference electrodes, rebar probes and surface potential surveys with the cathodic protection system "on" and "off".

Visual Surveys

After the deck surfaces were milled, gridding was laid out in two foot squares on all decks so that the location and dimension of the spalls, delaminations, patches and rebar potentials could be documented and analyzed. Patches from previous rehabilitation were documented along with spalls and delamination. A survey of cracking was limited to type and frequency and not width and depth. Photographs documented the visual survey of the deck surfaces, delaminations, cracks, concrete removal areas and depth of cover.

Electrical Continuity Survey

Rebar continuity tests were conducted on all decks where a section of reinforcing steel was exposed allowing for an electrical connection to the reinforcing steel mat. After the concrete was removed from the delaminated areas, continuity testing was done between several locations on each deck and indicated that most of the reinforcing steel was electrically continuous. In a few exposed areas, high resistance contacts (> 1ohm) were noted, however these were minimal and did not influence the surface potential survey readings significantly.

Surface potential surveys

The electrochemical process of corrosion creates an electrical potential that can be measured to indicate the status of corrosion at the measurement point at the time of measurement. The apparatus used for this study were a copper-copper sulfate (Cu-$CuSO_4$) half cell reference electrode, a high input resistance voltmeter and a conductive wetting agent. The test procedures and guidelines of ASTM C-876, "Standard Test Method for Half-Cell Potentials of Uncoated Reinforcing Steel in Concrete", were used for the surface potential surveys and evaluation of the half cell data. Equipotential contour maps were generated for these bridge decks providing a record of the areas of corrosion activity.

The ASTM C-876 guidelines state:

- If the half cell potential measurement is less than -0.200 V, there is a 90% probability that no corrosion activity exists on the reinforcing steel at the time of measurement.

- If the half cell potential measurements fall between -0.200 V and -0.350 V, there is an increasing probability of corrosion activity. This range has a moderate or uncertain probability of corrosion activity.

- If the half cell potential measurements are more negative than -0.350 V, there is a 90% probability that corrosion activity on the reinforcing steel is occurring at the time of measurement.

Depth of cover surveys

Depth of cover measurements were taken at the concrete removal areas.

The thickness of concrete cover over reinforcing steel has a significant influence on the time to initiation of corrosion when chloride ions are diffusing into the concrete element from the environment. Shallow cover on a structure will lead to more rapid accumulation of chloride ions at the steel depth in excess of the threshold required to initiate corrosion and subsequently results in faster development of concrete damage (NCHRP report 558).

Carbonation tests

Carbonation tests were conducted using a 0.15% solution of Phenolphthalein in alcohol sprayed onto freshly exposed concrete and rebar in the concrete removal areas. The Phenolphthalein indicator will exhibit a pink color on uncarbonated concrete and no color on carbonated concrete.

Chloride ion content analysis

The primary causes of corrosion of reinforcing steel are chloride ions. The primary sources of chloride ions are chloride bearing admixtures in the concrete mix and the application of deicing salts to the surface of the decks. Concrete samples were collected on site and brought to our lab to be ground and drilled into powder. The powdered samples were brought to the New Hampshire DOT Research Lab for chloride ion content analysis.

Condition evaluation results---control bridge # 31 over Hominy Pot Road.

Visual Survey

The visual survey of the Hominy Pot Road bridges noted that the membrane was disbonded, defective and punctured in several areas of the decks. The punctures were especially common at the junction of the concrete patches (Figure 1). Most cracks were also noted at these boundaries. The size and depth of the delaminations were greatest in the northbound high-speed lane followed by the northbound low-speed lane and then the southbound low-speed lane. The delamination surveys were performed using a bounce bar. Remarkable was the presence of heavy spalls and delaminations near previously patched areas. This is commonly found in bridge deck rehabilitation, where, as a result of the electrochemical nature of the corrosion process, repairs can actually accelerate corrosion. Figures 3, 4, 5 and 6, illustrates the creation of a corrosion cell between the concrete in a new **patch** and the concrete in an old patch.

It is important to consider the effect of patching practices on corrosion. The removal of loose and delaminated concrete, followed by patching of the area to restore the original surface plane, is the most frequently used method of rehabilitation. From a theoretical point of view, it would be ideal if the patch material perfectly matched the surrounding concrete composition, but this is seldom the case in practice. Whenever adjacent areas of concrete contained different electrolyte chemistry (chloride concentration, for example), a concentration cell will develop. This cell will accelerate corrosion of steel near the boundary of the patch. This accelerated corrosion soon leads to further deterioration, and patching becomes a never ending process. If the patch material is of very low conductivity, it is unlikely that the steel within the patch will experience significant corrosion. (SHRP-S-337, Pg. 58)

Figure 1. membrane defects

Figure 2. Anodic and cathodic rebar

The high alkalinity of concrete provides a protective layer or coating of oxides and hydroxides on the surface of the reinforcing steel. Without this layer, known as a 'passive' film, the steel would be exposed to air, moisture and the chlorides of salt and corrode rapidly. This layer is durable and self repairing, and can last for hundreds of years if the alkalinity is maintained.

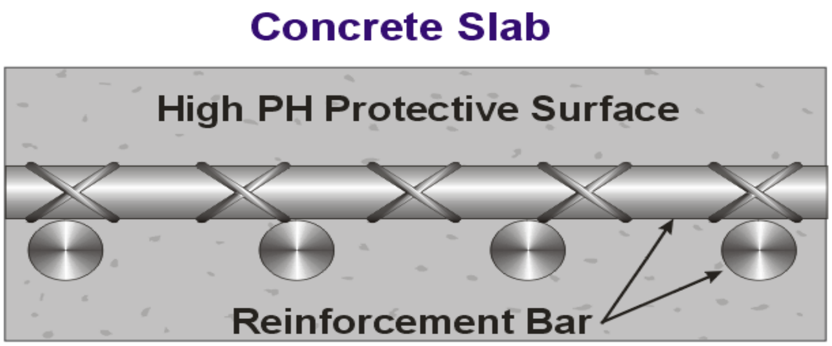


Figure 3. New reinforcing steel and concrete with a high pH passive protective film.

Cracks and defects in the membrane and concrete surface allow the penetration of deicing salts. The very mobile chloride ions disperse in solution through concrete pours and attack the passive layer on the reinforcement steel. In the absence of this passive layer, steel oxidizes in the presence of water and air to form rust that expands the volume at the reinforcing steel up to 10 times.

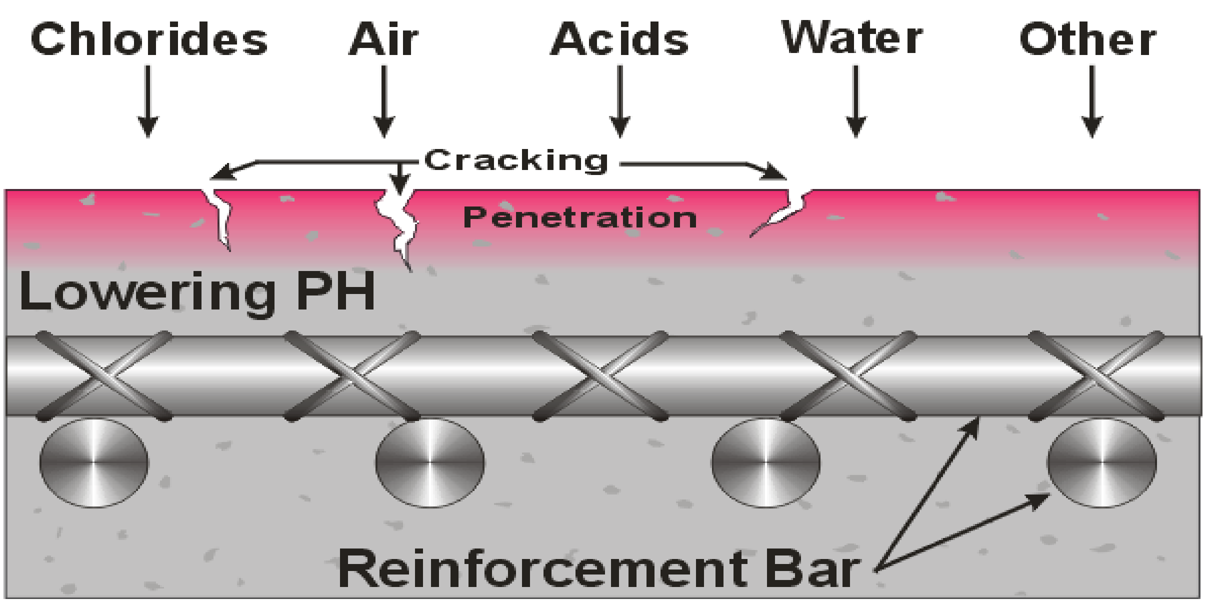


Figure 4. Cracks and defects allow the penetration of contaminants that lower pH and destroy the protective passive film

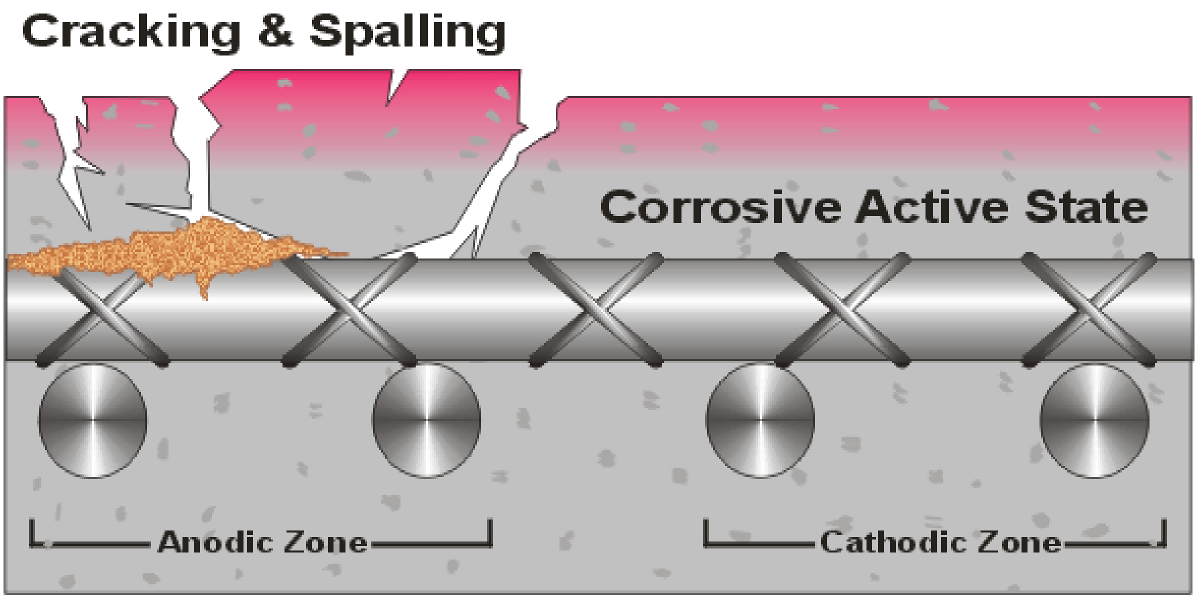


Figure 5. Cracks and spalling with anodic and cathodic areas.

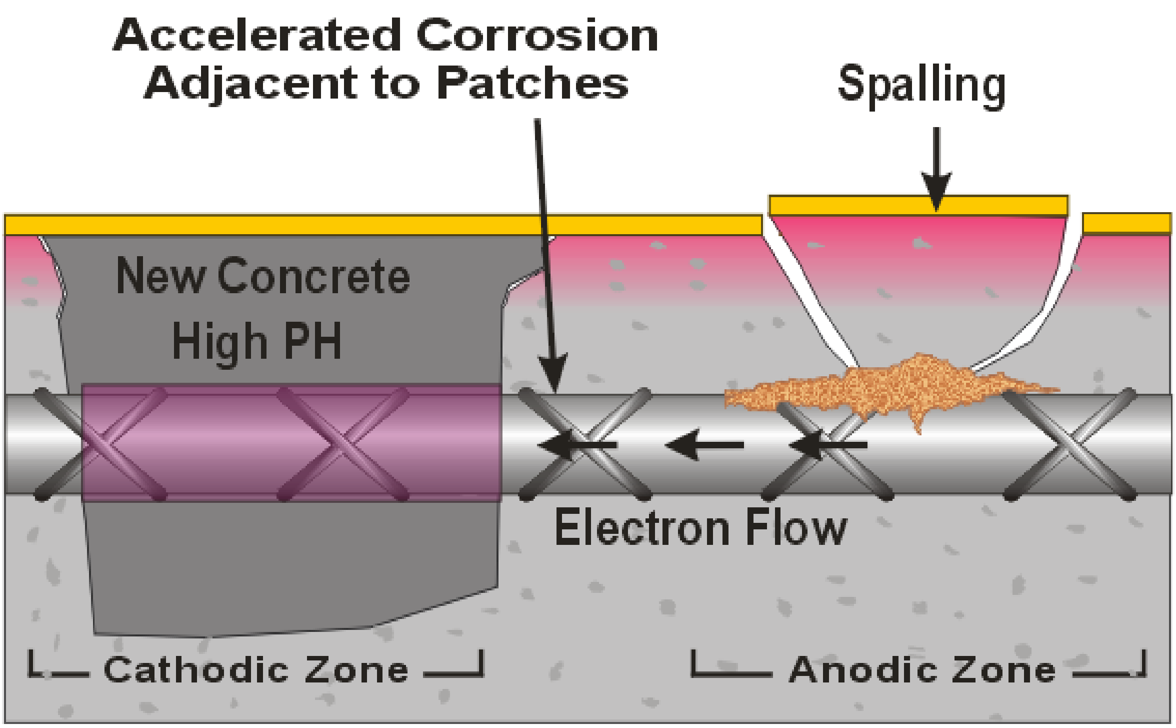


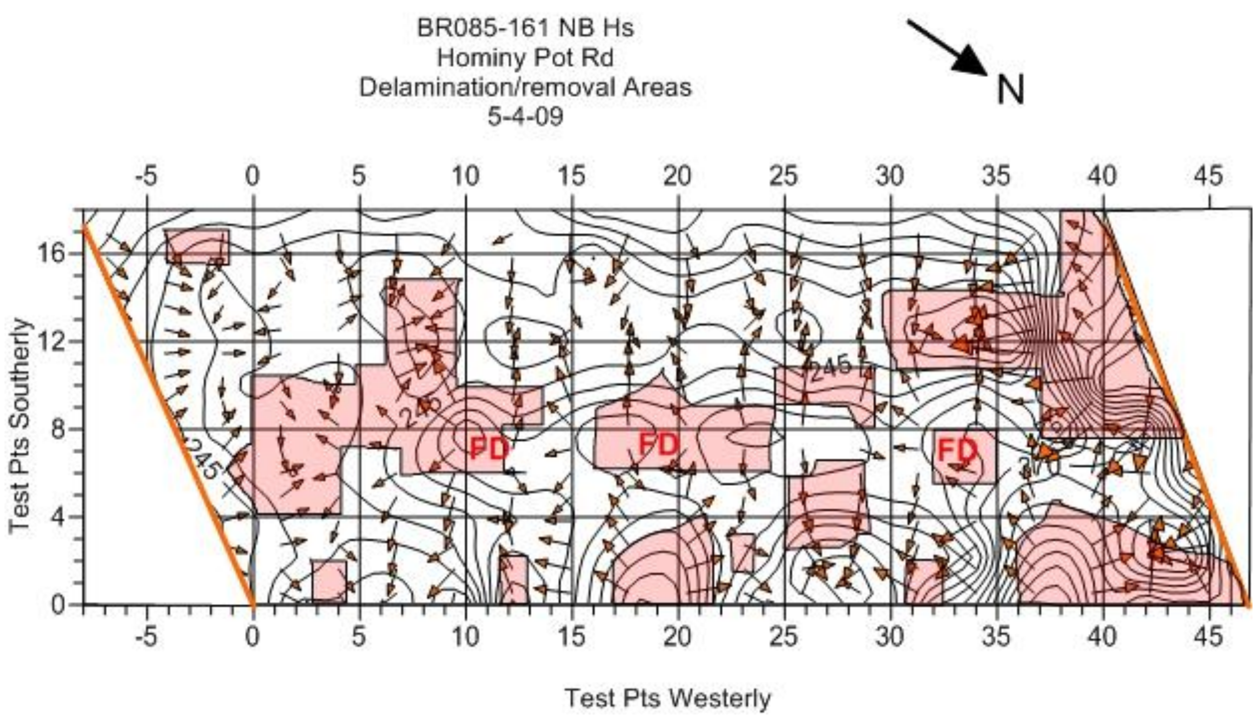
Figure 6. Anodic and cathodic areas caused by new patch.

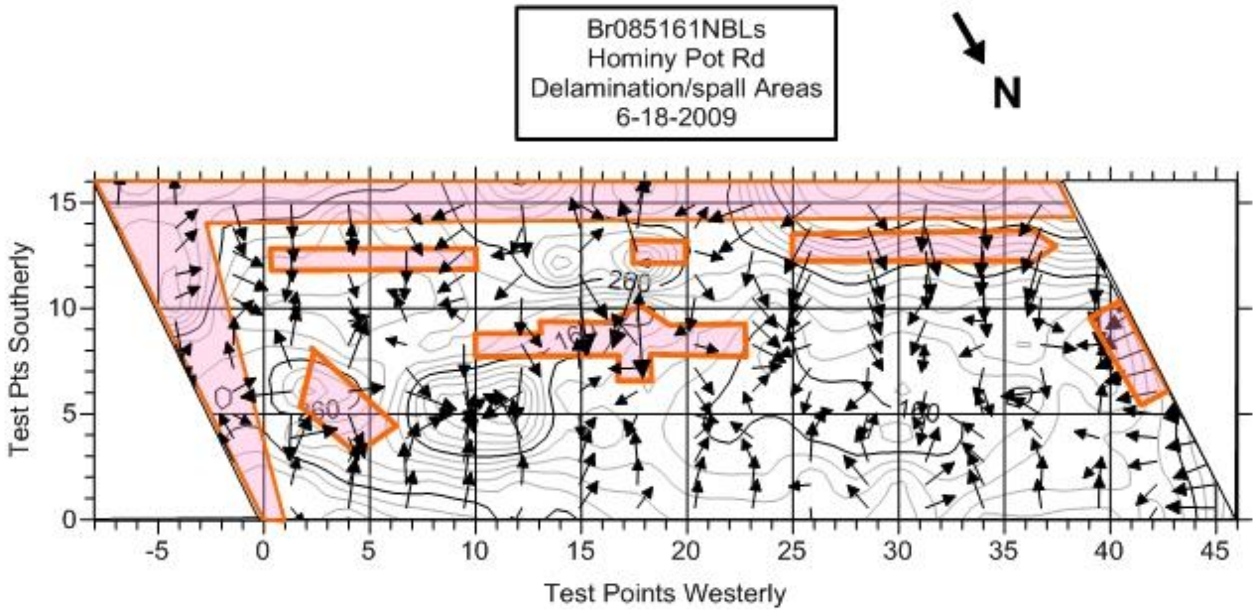
Electrical Continuity Surveys

Rebar continuity tests were conducted on all decks where the concrete was removed from the delaminated areas. The continuity testing was done between several locations on each deck and indicated that most reinforcing steel was electrically continuous. In a few exposed areas high resistance contacts (> 1ohm) were noted, however these were minimal and did not influence the surface potential survey readings.

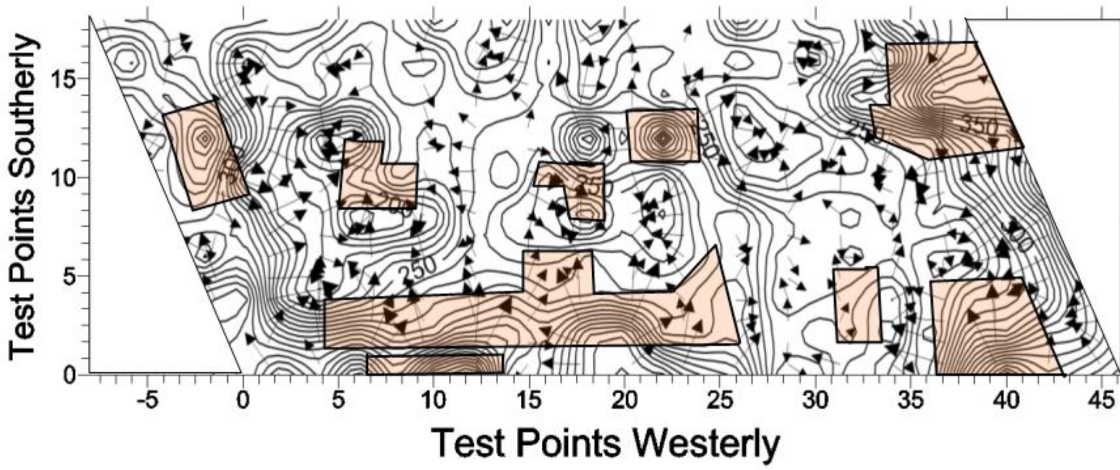
Surface potential surveys

The surface potential surveys and contour maps showed a high level of corrosion activity on all three decks tested. Appendix A contains the field data sheets for the Hominy Pot Road bridges. Contour maps were generated from the field data and overlaid with the delamination and removal areas. Arrows indicate the path of corrosion currents on the contour maps. These contour maps are illustrated below:

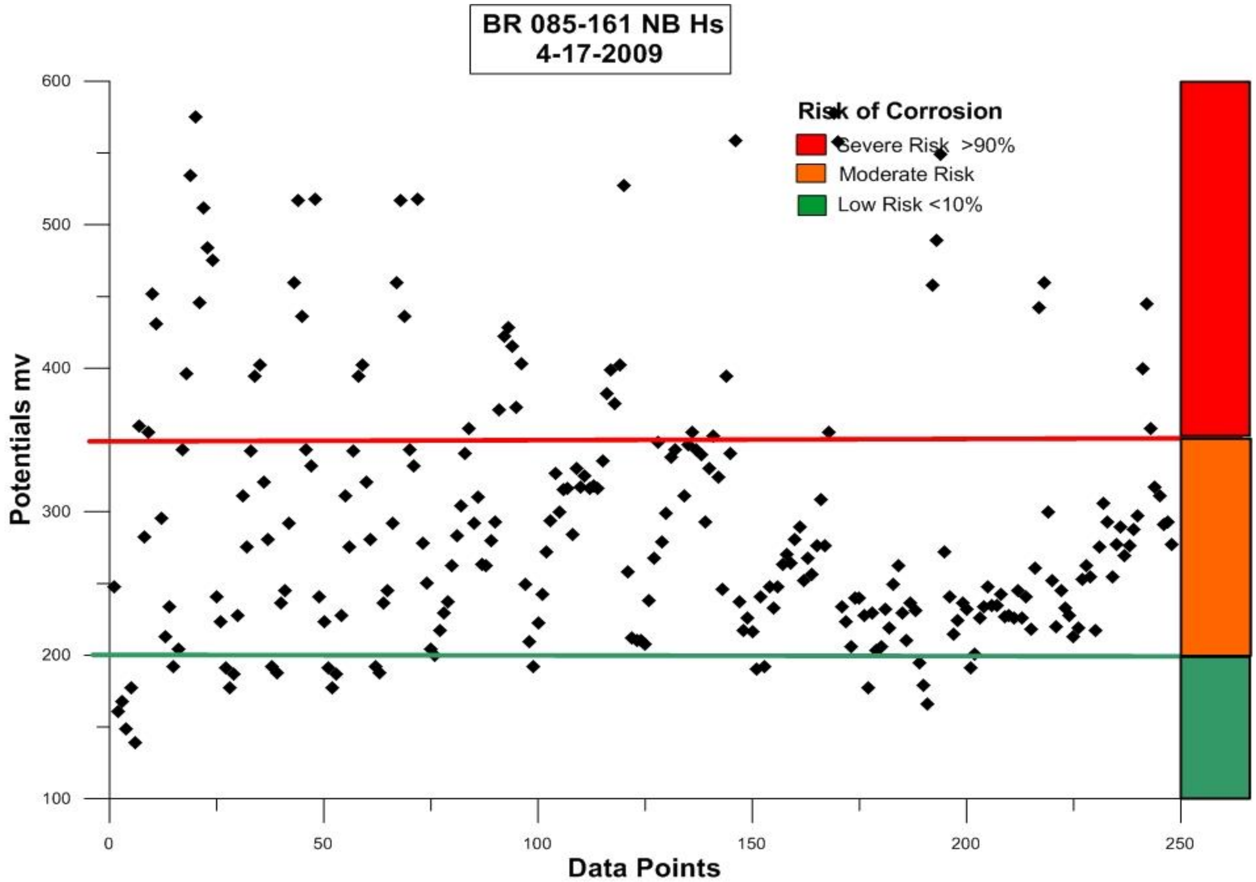


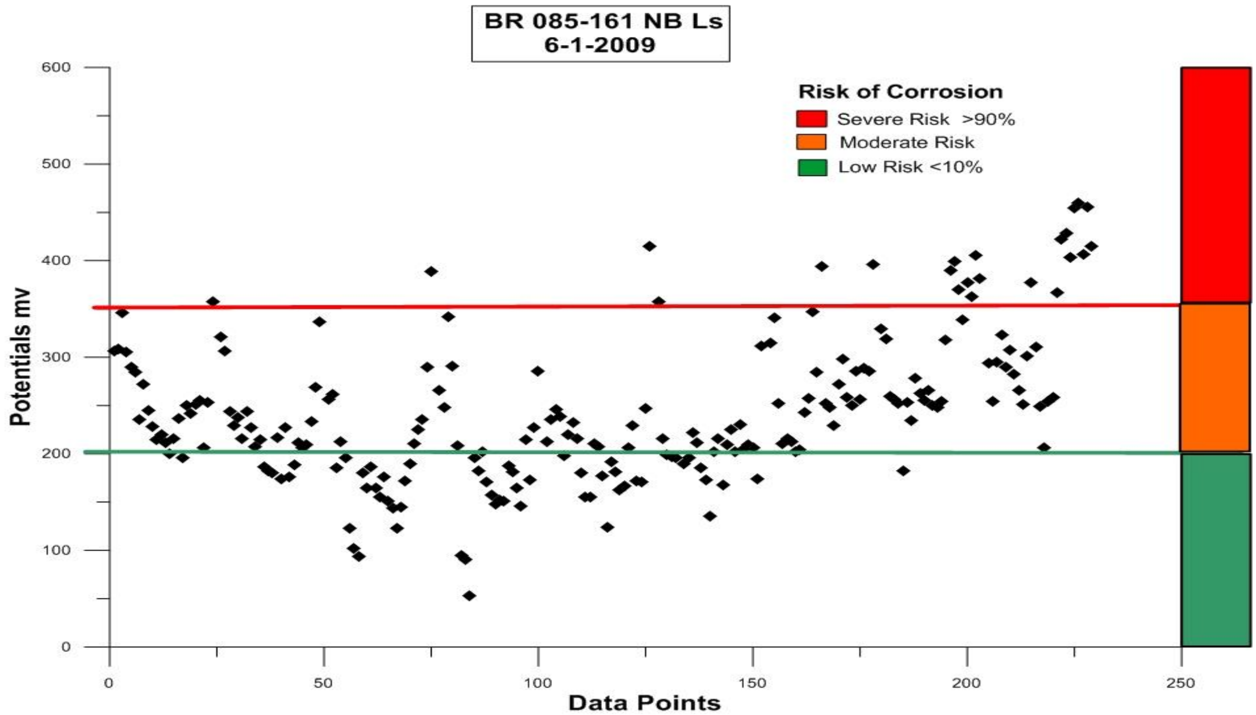


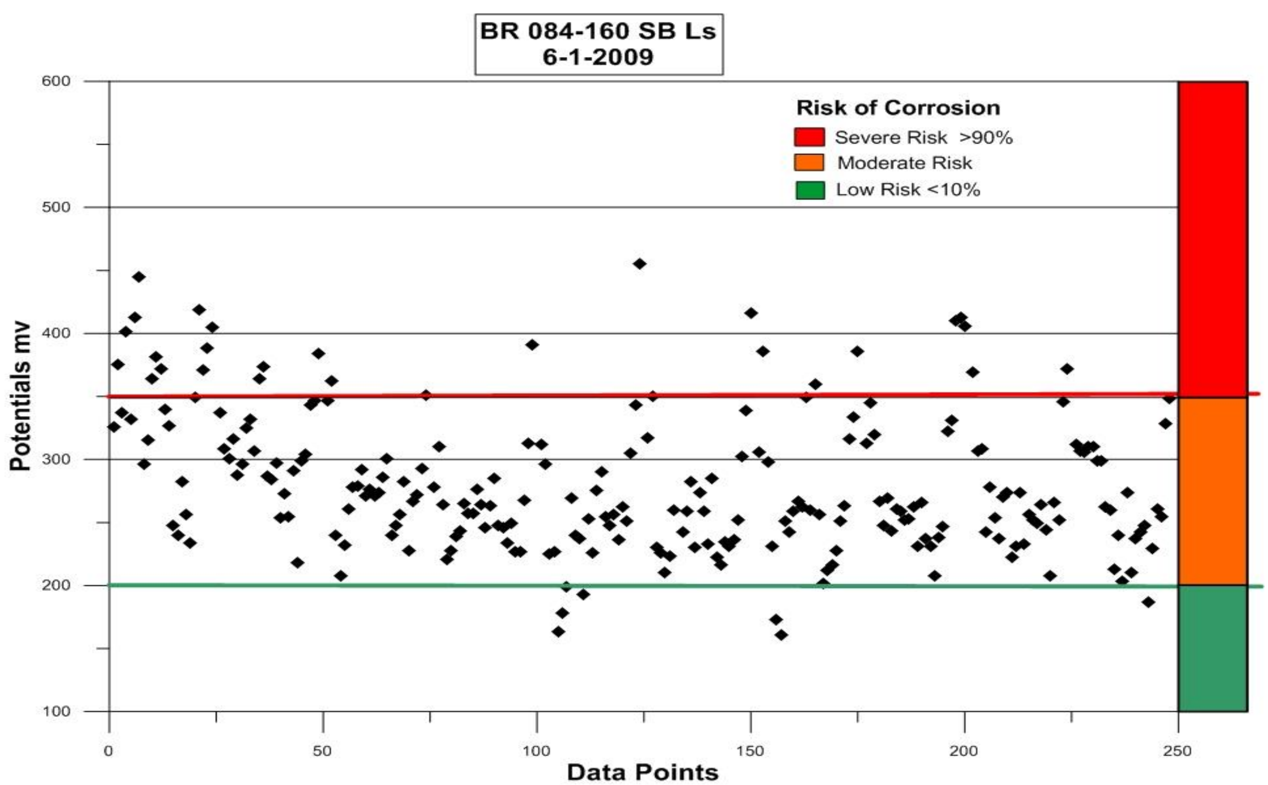
BR 084-160 SB Ls
Hominy Pot Rd.
Delamination/removal Areas
6-1-2009



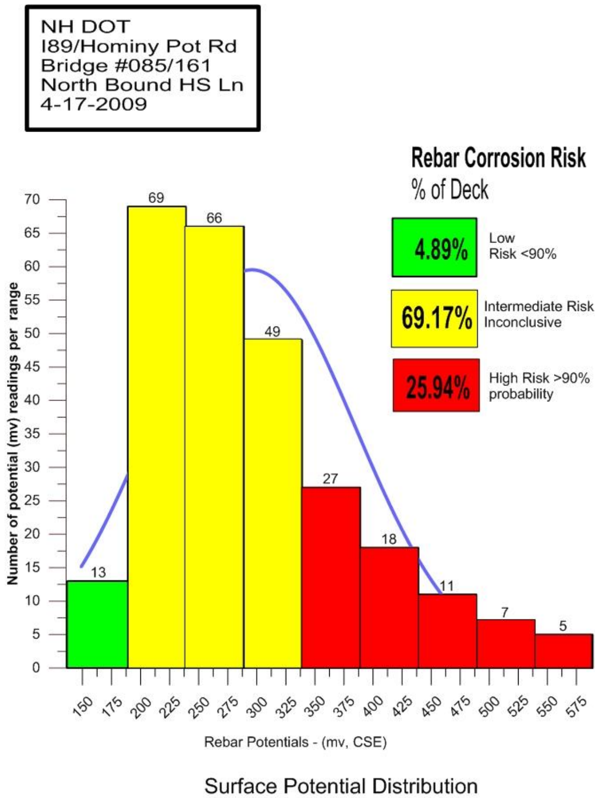
The graphs below of the data points on all three bridges tested show the corrosion probability based on the guidelines of ASTM C-876.

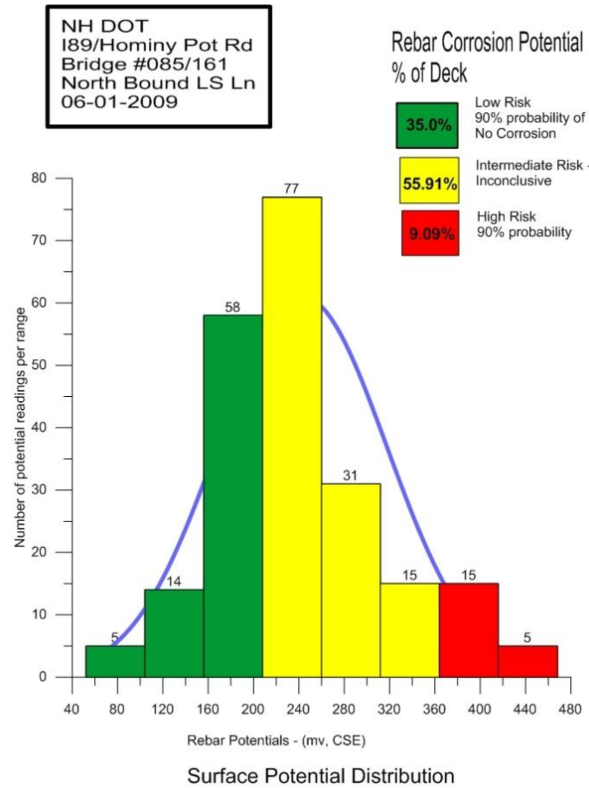


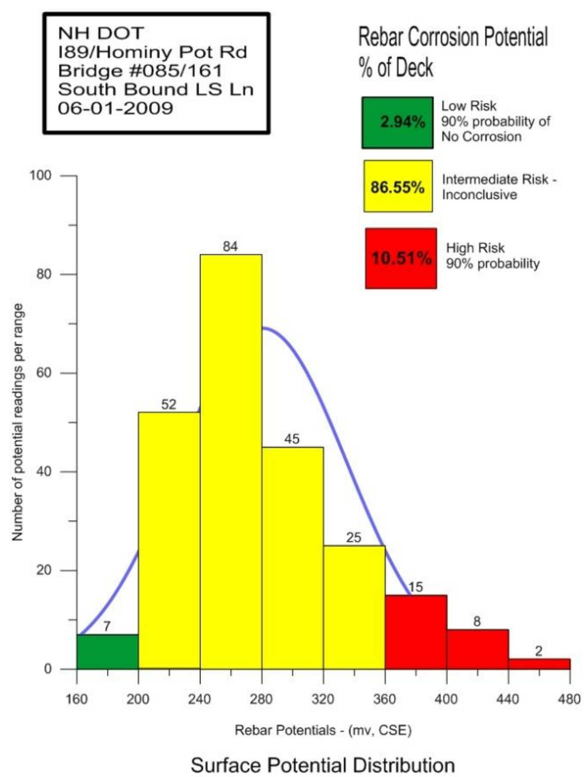

BR 085-161 NB Ls
6-1-2009
Risk of Corrosion
Severe Risk >90%
Moderate Risk
Low Risk <10%
Potentials mv
Data Points
600
500
400
300
200
100
0
0
50
100
150
200
250


BR 084-160 SB Ls
6-1-2009
Risk of Corrosion
Severe Risk >90%
Moderate Risk
Low Risk <10%
Potentials mv
Data Points
600
500
400
300
200
100
0
50
100
150
200
250

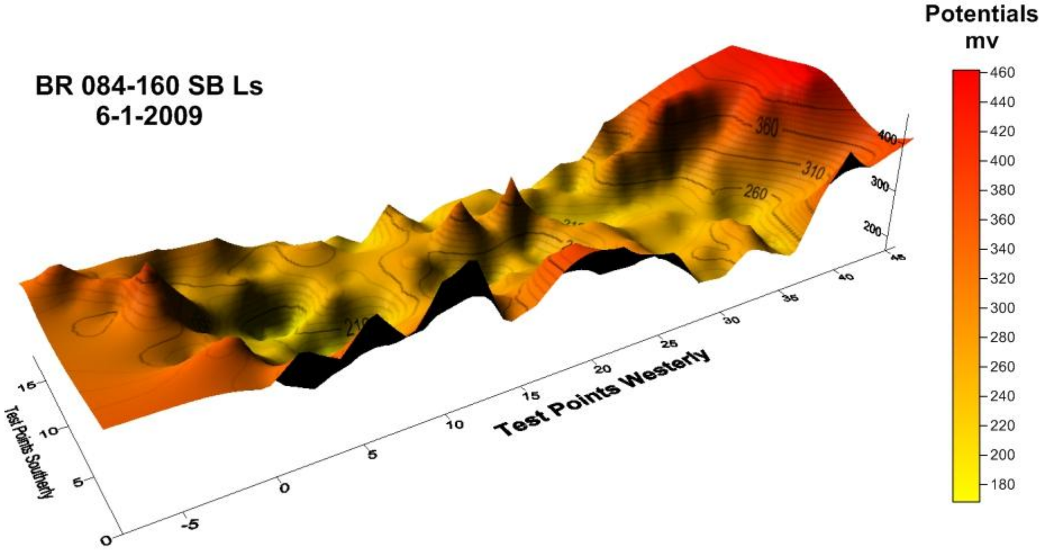
The histograms below show the corrosion probability based on ASTM C-876







The surface potential contour map of the southbound low-speed lane of the Hominy Pot Road bridge is shown below in three dimension.



Depth of cover surveys

The depth of cover surveys showed a variable cover of 1 to 2 ¼ inches above the reinforcing steel mat.

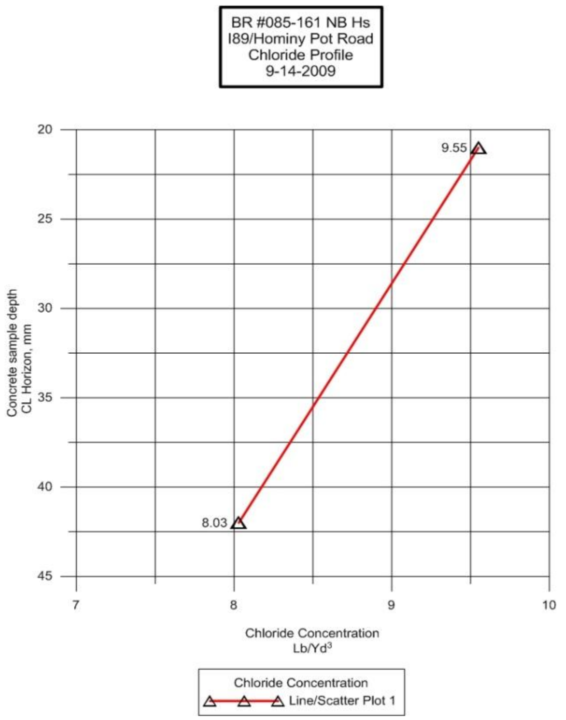
Carbonation tests

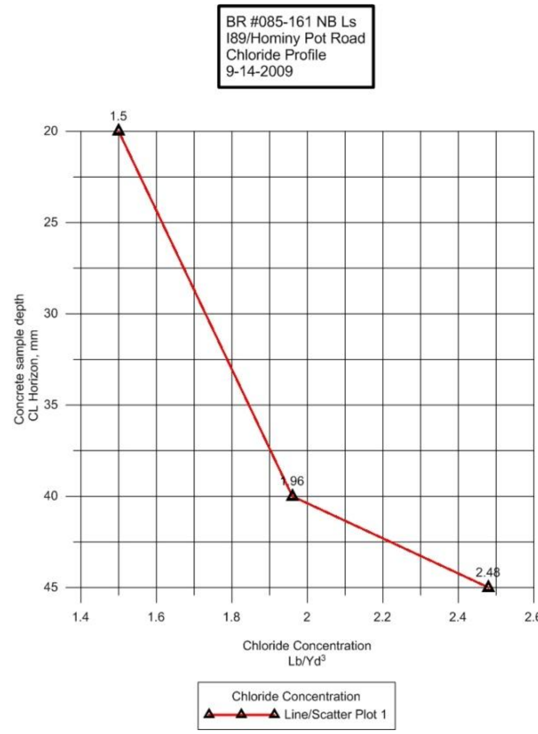
Carbonation tests did not reveal any carbonated areas.

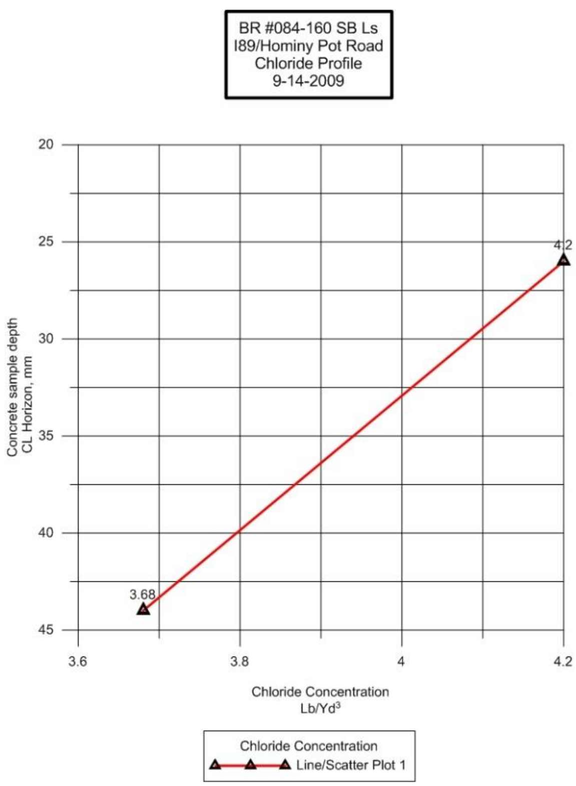
Chloride ion content analysis

Chloride Results

Bridge # Sample	Br Location	Horizon mm	Lab#	Weight, gr	End Point, ml	Cl, %	Cl, ppm	Cl, lb/yd3
BR#084-160 SB Ls	Hominy Pot Rd	26	2-1	3.0076	10.00	0.11	1073	4.20
BR#084-160 SB Ls	Hominy Pot Rd	44	2-2	3.0057	9.20	0.09	940	3.68
BR#085-161 NB Ls	Hominy Pot Rd	20	1	3.0032	5.85	0.04	383	1.50
BR#085-161 NB Ls	Hominy Pot Rd	40	2	2.9984	6.55	0.05	501	1.96
BR#085-161 NB Ls	Hominy Pot Rd	45	3	2.8811	7.20	0.06	634	2.48
BR#085-161 NB Hs,	Hominy Pot Rd	21	2-3	3.0026	18.20	0.24	2440	9.55


BR #085-161 NB Hs
I89/Hominy Pot Road
Chloride Profile
9-14-2009
Concrete sample depth
CL Horizon, mm
9.55
8.03
Chloride Concentration
Lb/Yd3
Chloride Concentration
Line/Scatter Plot 1


BR #085-161 NB Ls
I89/Hominy Pot Road
Chloride Profile
9-14-2009
Concrete sample depth
CL Horizon, mm
1.5
1.96
2.48
Chloride Concentration
Lb/Yd3
Chloride Concentration
Line/Scatter Plot 1


BR #084-160 SB Ls
I89/Hominy Pot Road
Chloride Profile
9-14-2009
Concrete sample depth
CL Horizon, mm
4.2
3.68
Chloride Concentration
Lb/Yd3
Chloride Concentration
Line/Scatter Plot 1

Condition evaluation of the cathodically protected bridge # 30 over Route 114

Cathodic Protection System -- Zone 1

Visual Surveys

This deck had no membrane applied and was in good overall condition with the exception of the South curb where rotted concrete was noted the full-length of the deck. Three longitudinal cracks were noted at mid deck.

South curb concrete removed

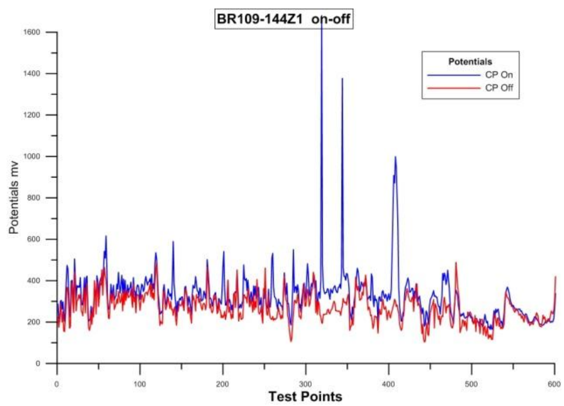
longitudinal cracks at mid deck

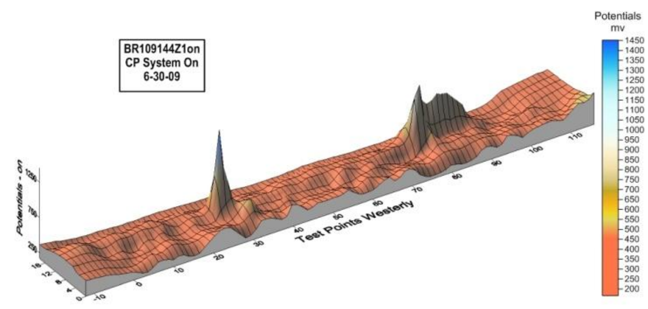
Electrical Continuity Surveys

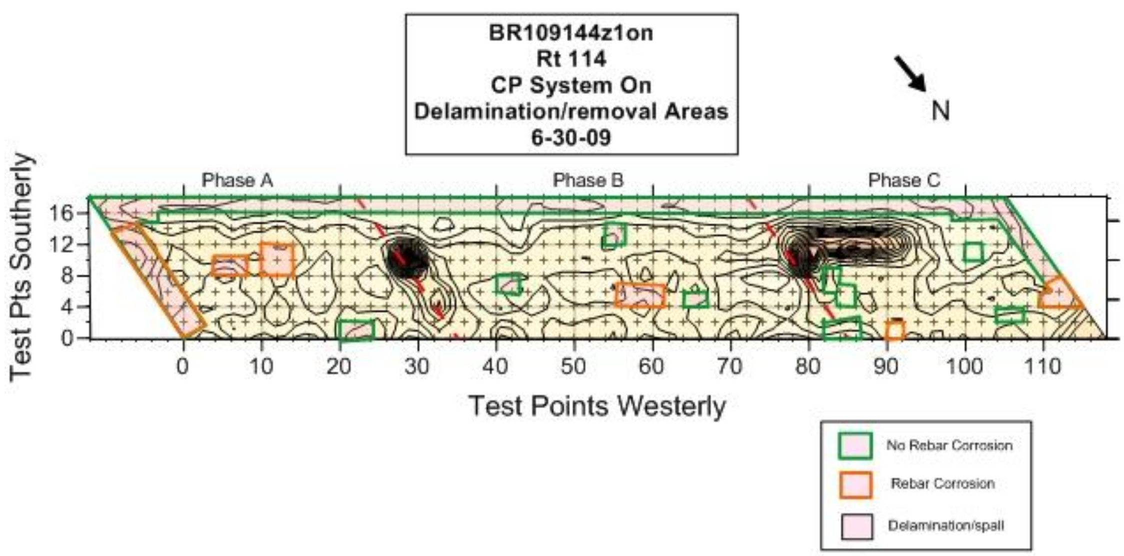
Electrical continuity test were conducted at the rectifier panel and at any exposed rebar where the concrete was removed. These tests indicated that the reinforcing steel was electrically continuous. In a couple of small isolated areas there were poor bonds between rebar causing pickup and discharge areas. (see photo below)

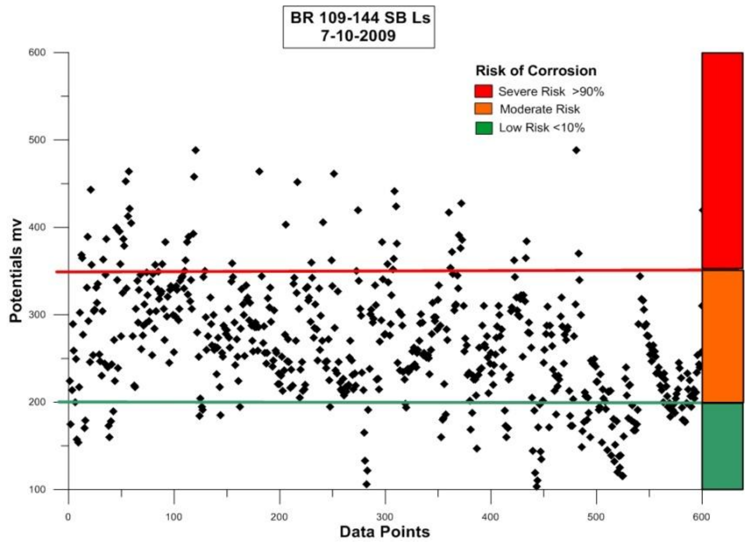
Surface potential surveys

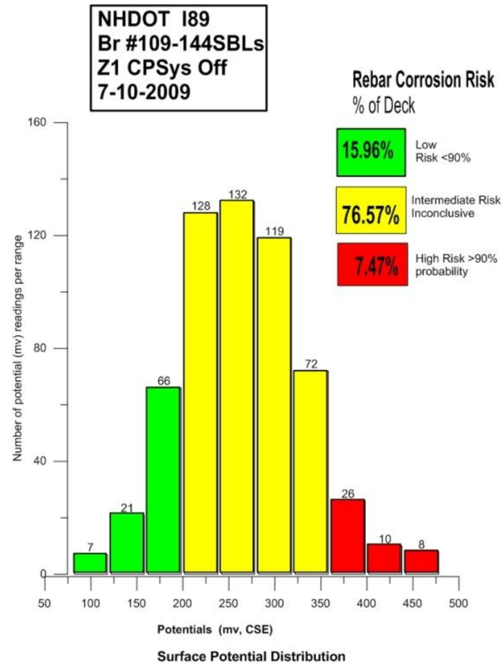
Surface potential surveys were conducted with the cathodic protection system on and off. The graph on the left shows the "off" readings in red and the "on" readings in blue. The 3-D image on the right shows the three peaks with the cathodic protection system on. Note that in the surface potential contour and delamination map below the only areas receiving protection are at the phase lines A/B and B/C.











Depth of cover surveys

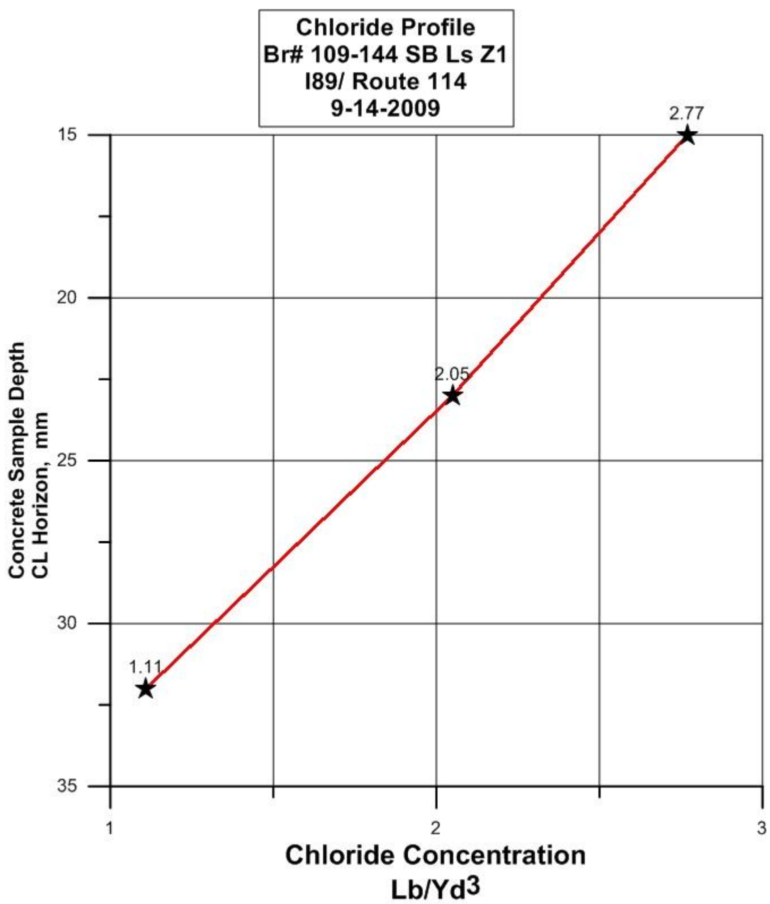
The depth of cover surveys showed a variable cover of 1 to 2 ¼ inches above the reinforcing steel mat. The cover over the anode strands was about 1 inch except that the South curb where the anode strands were exposed in the rotted concrete.

Carbonation tests

Carbonation tests did not reveal any carbonated areas.

Chloride ion content analysis

Sample	Horizon mm	Lab#	Weight, gr	End Point, ml	Cl, %	Cl, ppm	Cl, lb/yd3
BR#109-144 SB Ls Z1	15	2-4	3.0014	7.80	0.07	708	2.77
BR#109-144 SB Ls Z1	23	2-5	3.0096	6.70	0.05	524	2.05
BR#109-144 SB Ls Z1	32	2-6	3.0039	5.25	0.03	284	1.11



Cathodic Protection System -- Zone 2

Visual Surveys

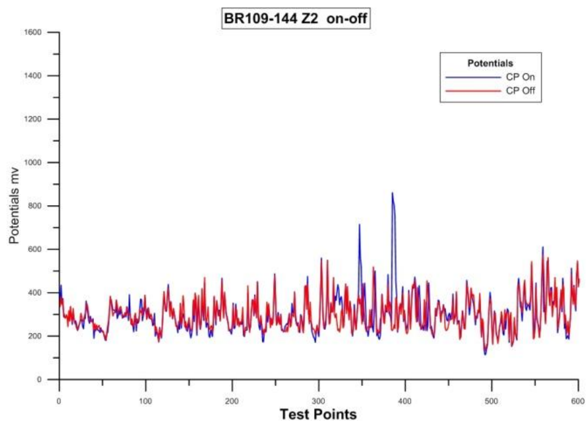
This deck had no membrane applied and was in good overall condition with the exception of the curb where rotted concrete was noted almost the full-length of the deck. The most significant crack was along the joint between the two decks. This was also the area of most delamination and most concrete removal.

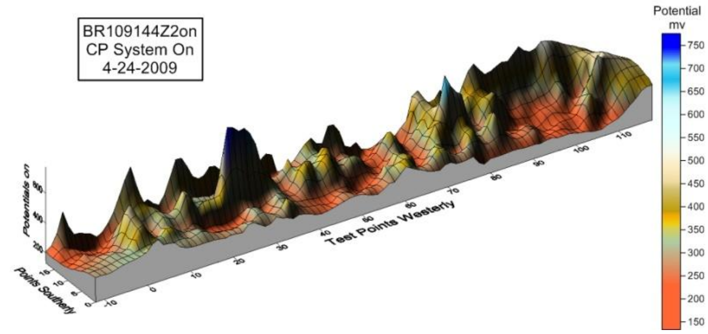
Electrical Continuity Surveys

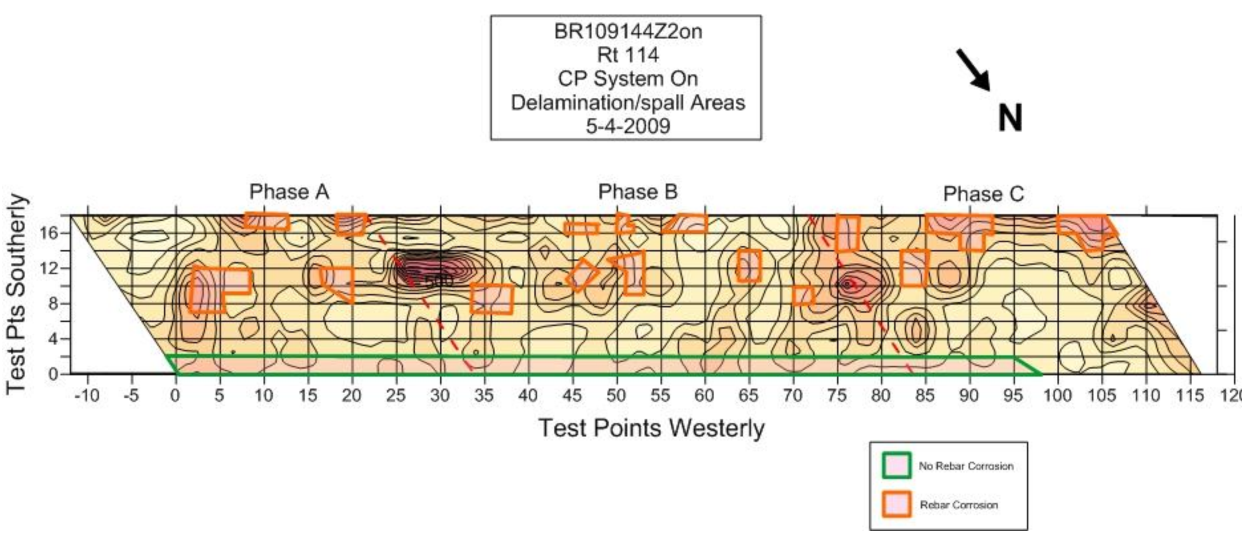
Electrical continuity tests were conducted at the rectifier panel and at any exposed rebar where the concrete was removed. These tests indicated that the reinforcing steel was electrically continuous.

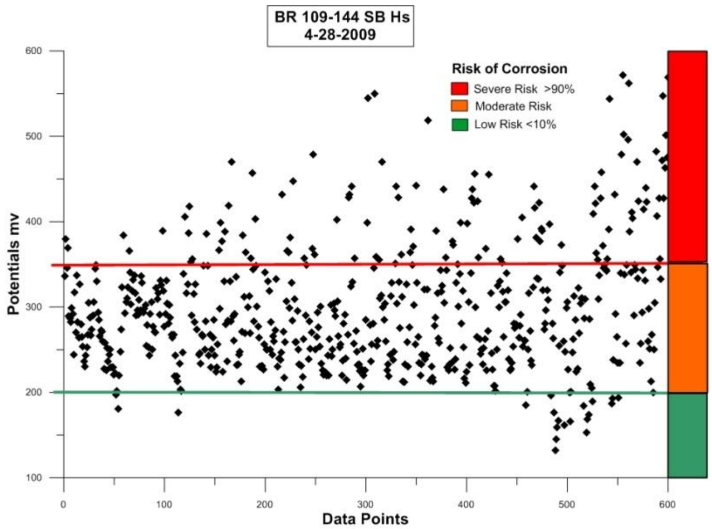
Surface potential surveys

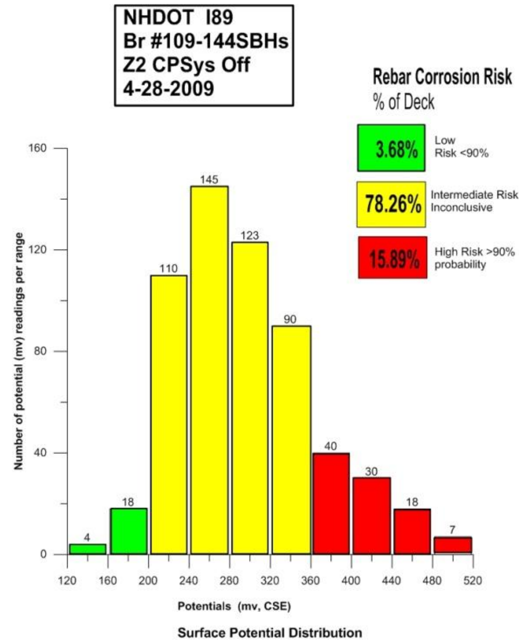
Surface potential surveys were conducted with the cathodic protection system on and off. The graph on the left shows the "off" readings in red and the "on" readings in blue. The 3-D image on the right shows only two peaks with the cathodic protection system "on". Note that in the surface potential contour and delamination map below the only areas receiving protection are at the phase lines A/B and B/C.











Depth of cover surveys

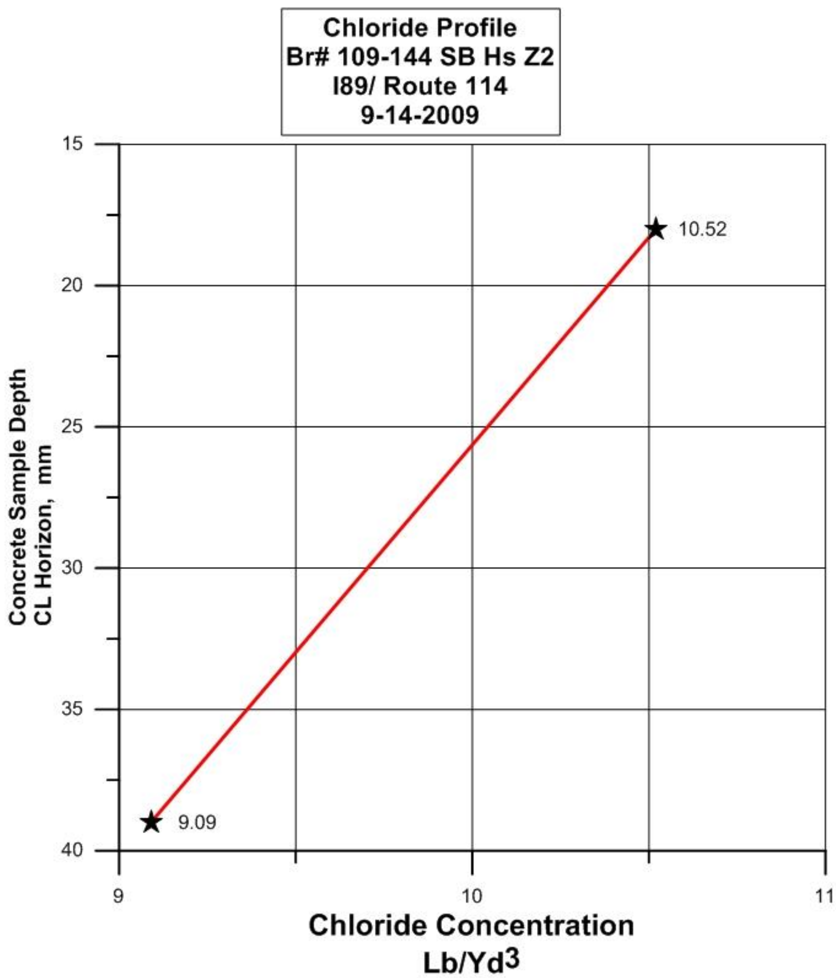
The depth of cover surveys showed a variable cover of 1 to 2 ¼ inches above the reinforcing steel mat. The cover over the anode strands was about 1 inch except that the curb where the anode strands were exposed in the rotted concrete.

Carbonation tests

Carbonation tests did not reveal any carbonated areas.

Chloride ion content analysis

Sample	Horizon mm	Lab#	Weight, gr	End Point, ml	Cl, %	Cl, ppm	Cl, lb/yd3	
BR#109-144 SB Hs	18	2-7	3.0046	19.70	0.27	2688	10.52	
BR#109-144 SB Hs	39	2-8	3.0041	17.50	0.23	2322	9.09	



Cathodic Protection System -- Zone 3

Visual Surveys

This deck had no membrane applied and was in good overall condition with the exception of the curb where rotted concrete was noted the full-length of the deck. The most significant crack was along the joint between the two decks. This was also the area of most delamination and most concrete removal.

Exposed anode strands in rotted concrete

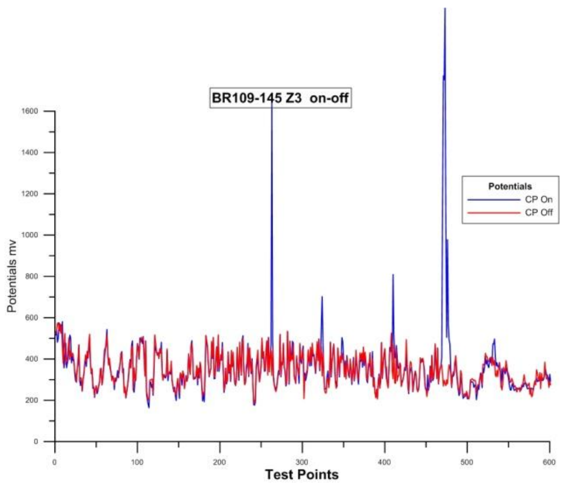
close-up of left photo, poor anode cover

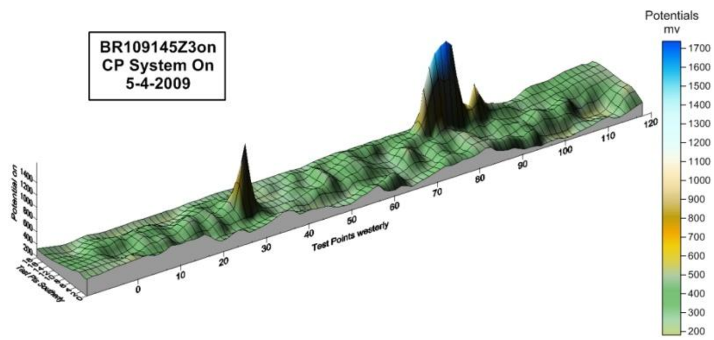
Electrical Continuity Surveys

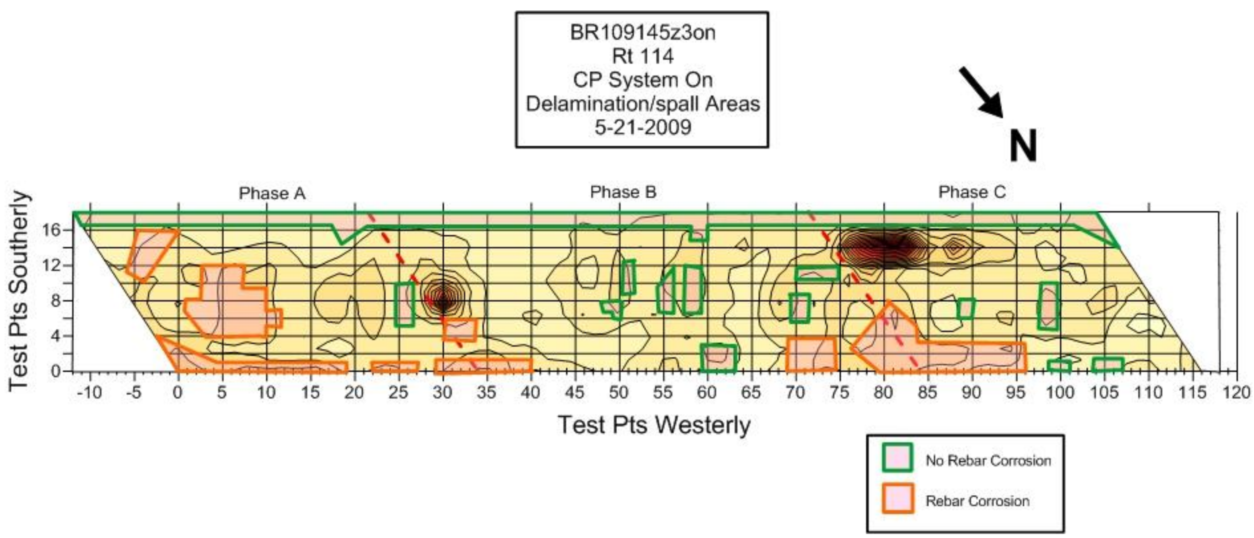
Electrical continuity tests were conducted at the rectifier panel and at any exposed rebar where the concrete was removed. These tests indicated that the reinforcing steel was electrically continuous.

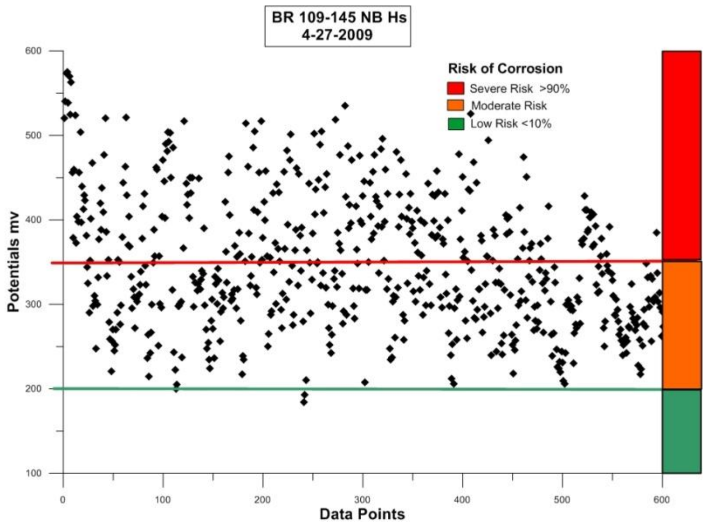
Surface potential surveys

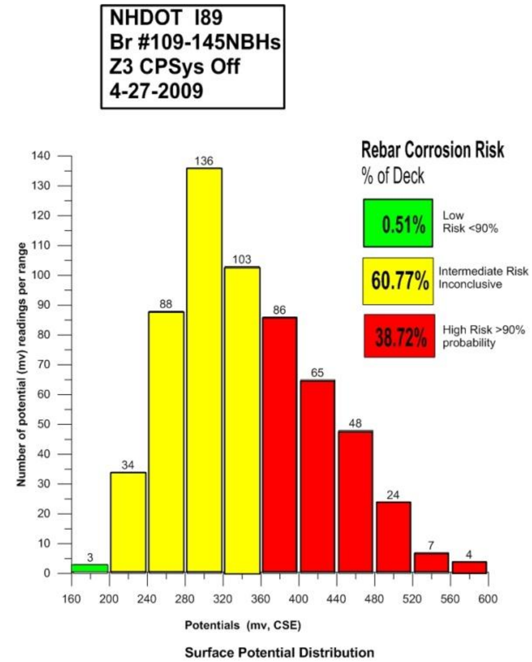
Surface potential surveys were conducted with the cathodic protection system on and off. The graph on the left shows the “off” readings in red and the “on” readings in blue. The 3-D image on the right shows only three peaks with the cathodic protection system “on”. Note that in the surface potential contour and delamination map below the only areas receiving protection are at small areas in phases B and C.











Depth of cover surveys

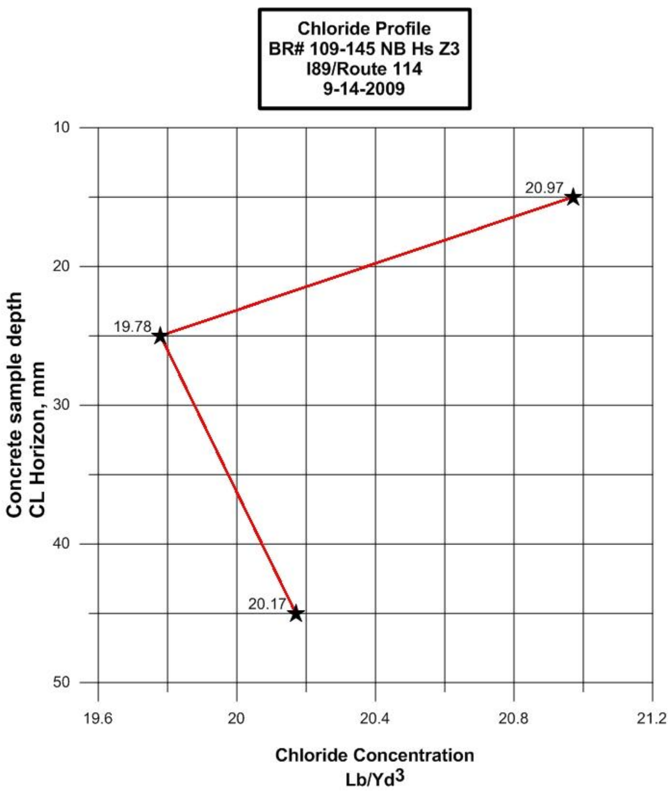
The depth of cover surveys showed a variable cover of 1 to 2 inches above the reinforcing steel mat. The cover over the anode strands was less than 1 inch except that the curb where the anode strands were exposed in the rotted concrete.

Carbonation tests

Carbonation tests did not reveal any carbonated areas.

Chloride ion content analysis

Sample	Horizon mm	Lab#	Weight, gr	End Point, ml	Cl, %	Cl, ppm	Cl, lb/yd3	
BR#109-145 NB Hs	15	4	3.0010	35.70	0.54	5356	20.97	
BR#109-145 NB Hs	25	5	3.0034	33.90	0.51	5052	19.78	
BR#109-145 NB Hs	45	2-11	3.0028	34.50	0.52	5153	20.17	



Cathodic Protection System -- Zone 4

Visual Surveys

This deck had no membrane applied and looked in good overall condition with the exception of the curb where rotted concrete was noted the full-length of the deck. The deck had a significant amount of micro cracks with a well defined pattern. Anode strands were visible in areas of poor anode cover.

Deck with crack pattern

close-up of cracks

Poor anode strand cove r <3/8 inch

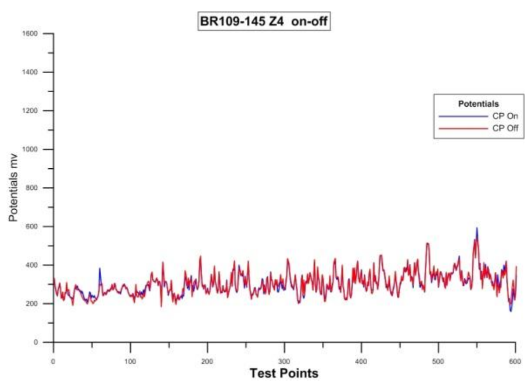
cracks caused by poor anode cover

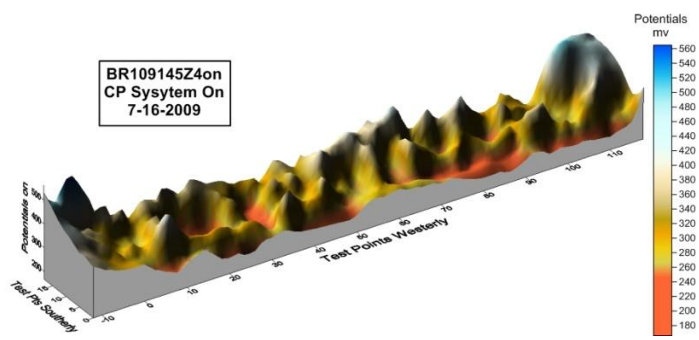
Electrical Continuity Surveys

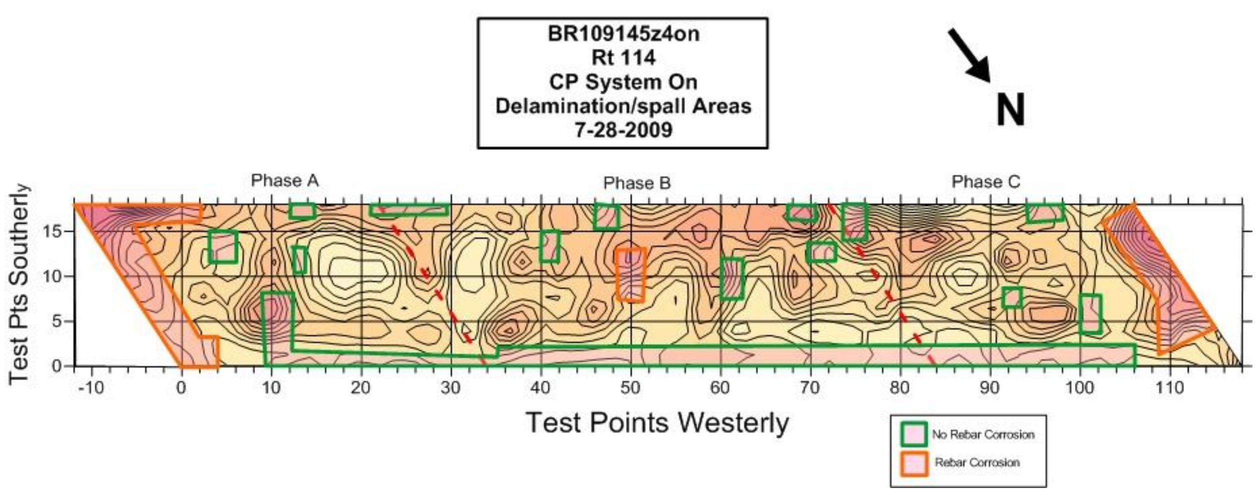
Electrical continuity tests were conducted at the rectifier panel and at any exposed rebar where the concrete was removed. These tests indicated that the reinforcing steel was electrically continuous.

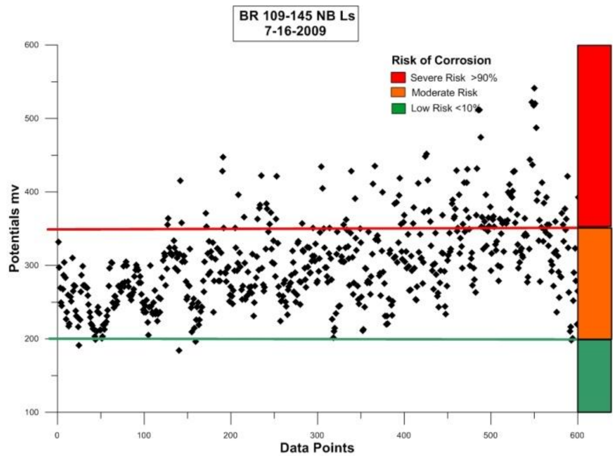
Surface potential surveys

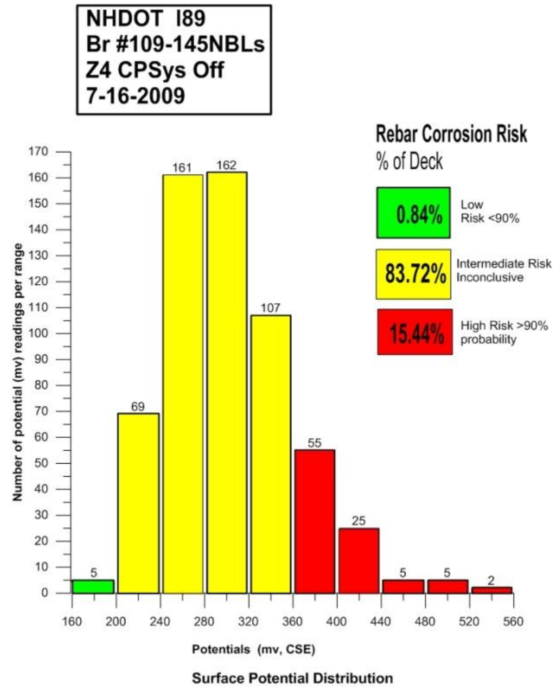
Surface potential surveys were conducted with the cathodic protection system on and off. The graph on the left shows the "off" readings in red and the "on" readings in blue. The 3-D image on the right shows only three peaks with the cathodic protection system "on". Note that in the surface potential contour and delamination map below the only areas receiving protection are at small areas in phases B and C.











Depth of cover surveys

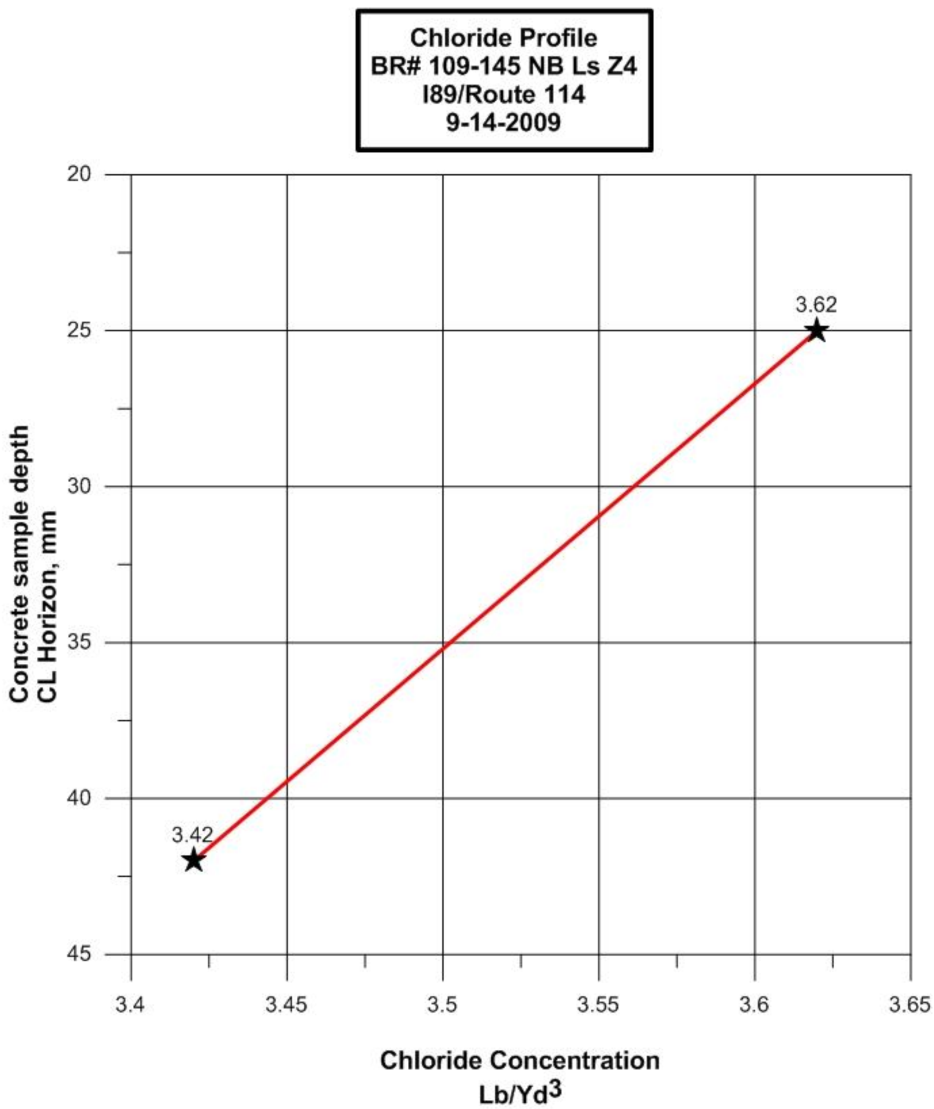
The depth of cover surveys showed a variable cover of 1 to 2 inches above the reinforcing steel mat. The cover over the anode strands was less than 1 inch in many areas and as shallow as 3/8 inch. The anode strands were exposed in the rotted concrete at the curb.

Carbonation tests

Carbonation tests did not reveal any carbonated areas.

Chloride ion content analysis

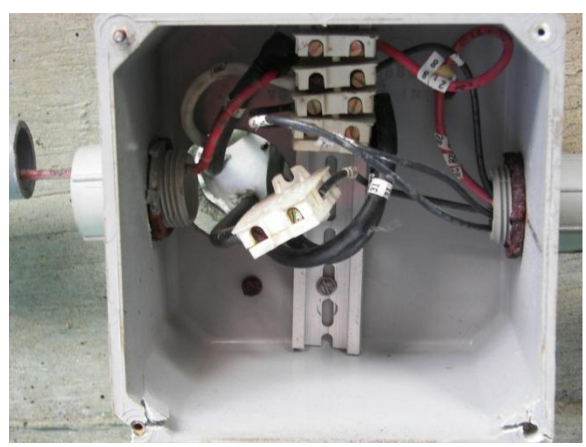
Sample	Horizon mm	Lab#	Weight, gr	End Point, ml	Cl, %	Cl, ppm	Cl, lb/yd3	
BR#109-145 NB Ls Z4	25	2-9	3.0032	9.10	0.09	924	3.62	
BR#109-145 NB Ls Z4	42	2-10	3.0027	8.80	0.09	875	3.42	



Condition evaluation --- cathodic protection system

This cathodic protection system was somewhat effective for the short time it was working properly. The rebar loss on the control bridge was much more severe than on the cathodically protected bridge. The spalls and delaminations on the control bridge were deeper and larger than on the cathodically protected bridge. Rebar corrosion was not observed in many delaminated areas on the cathodically protected bridge. Chloride ion concentration was less on the cathodically protection bridge with the exception of zone two and three which had significant cracking due to poor cover over the anode strands. Maintenance and troubleshooting of the system would have benefited if drawings or information identifying the conductor numbers and their location had been made available. CDE recommended surface potential surveys in September 1998, because, for several years the system could not be monitored effectively when the embedded reference electrodes became unreliable and defective possibly do to freeze-thaw degradation. (see photo below)

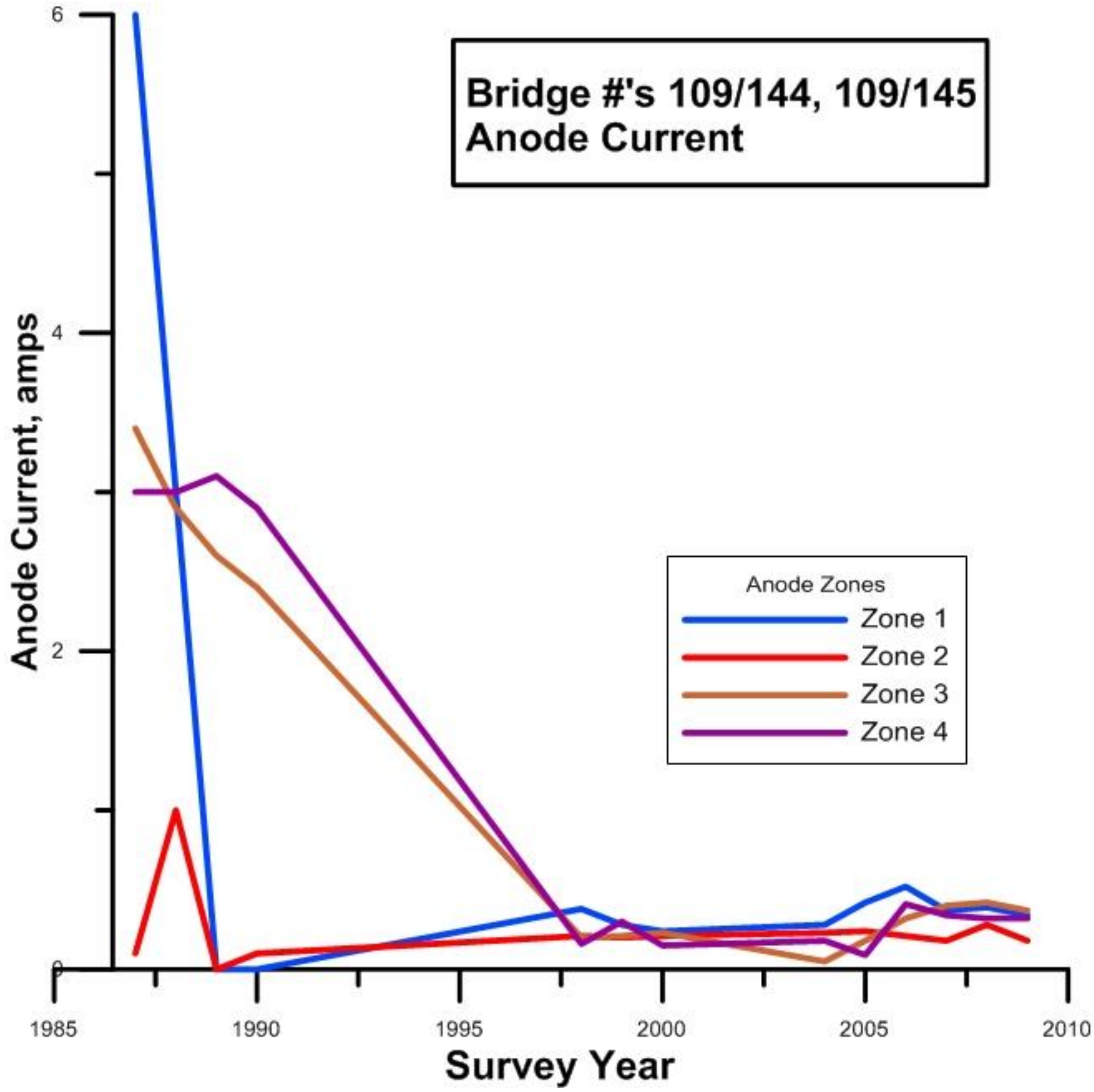
Many connections in the junction boxes were corroded, broken or disconnected through vibration.



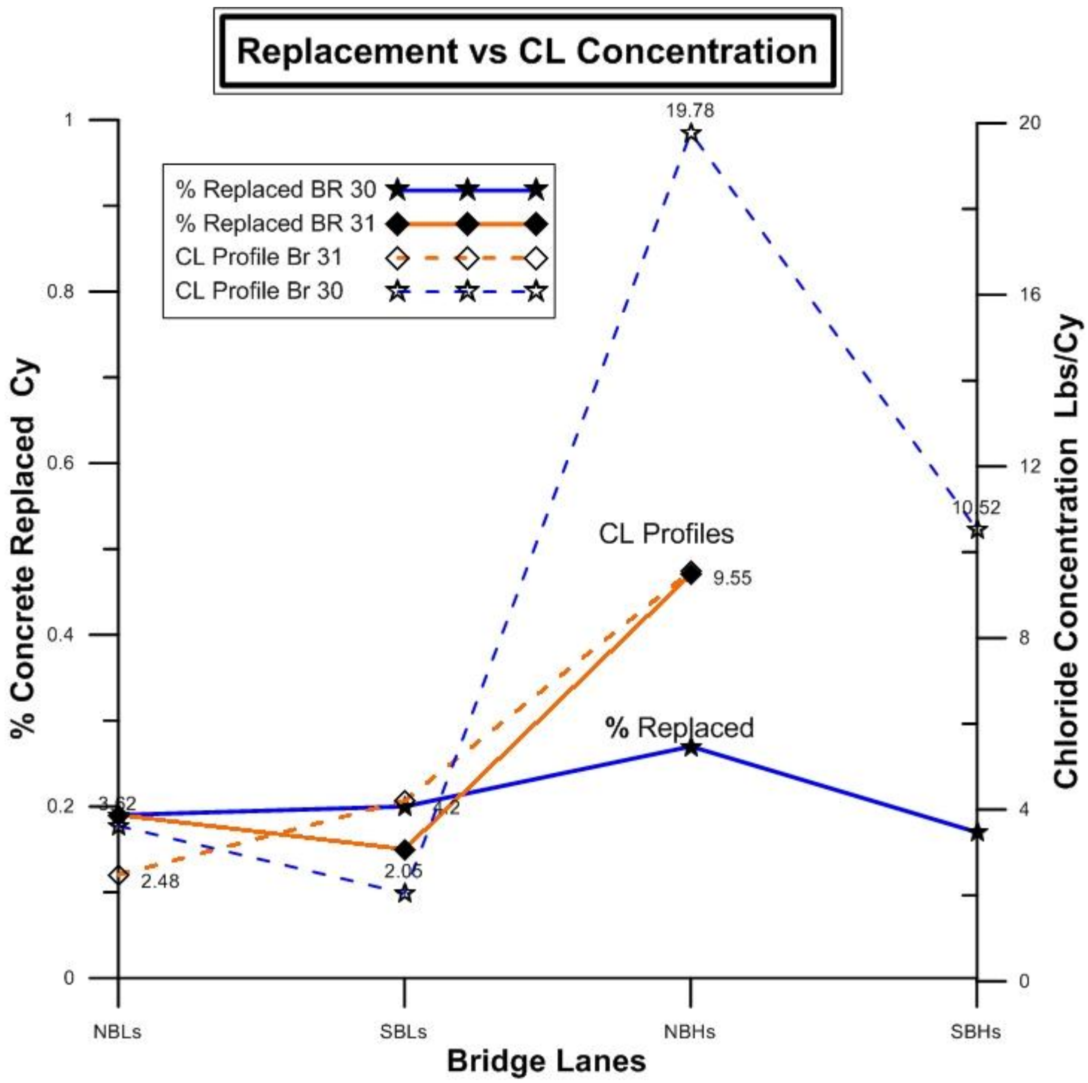
Several junction boxes were destroyed by rodents and corrosion

The major cause of the cathodic protection system failure, was degradation of the anode system. This was mostly due to the product itself and the poor cover and traffic stress over the anode strands.

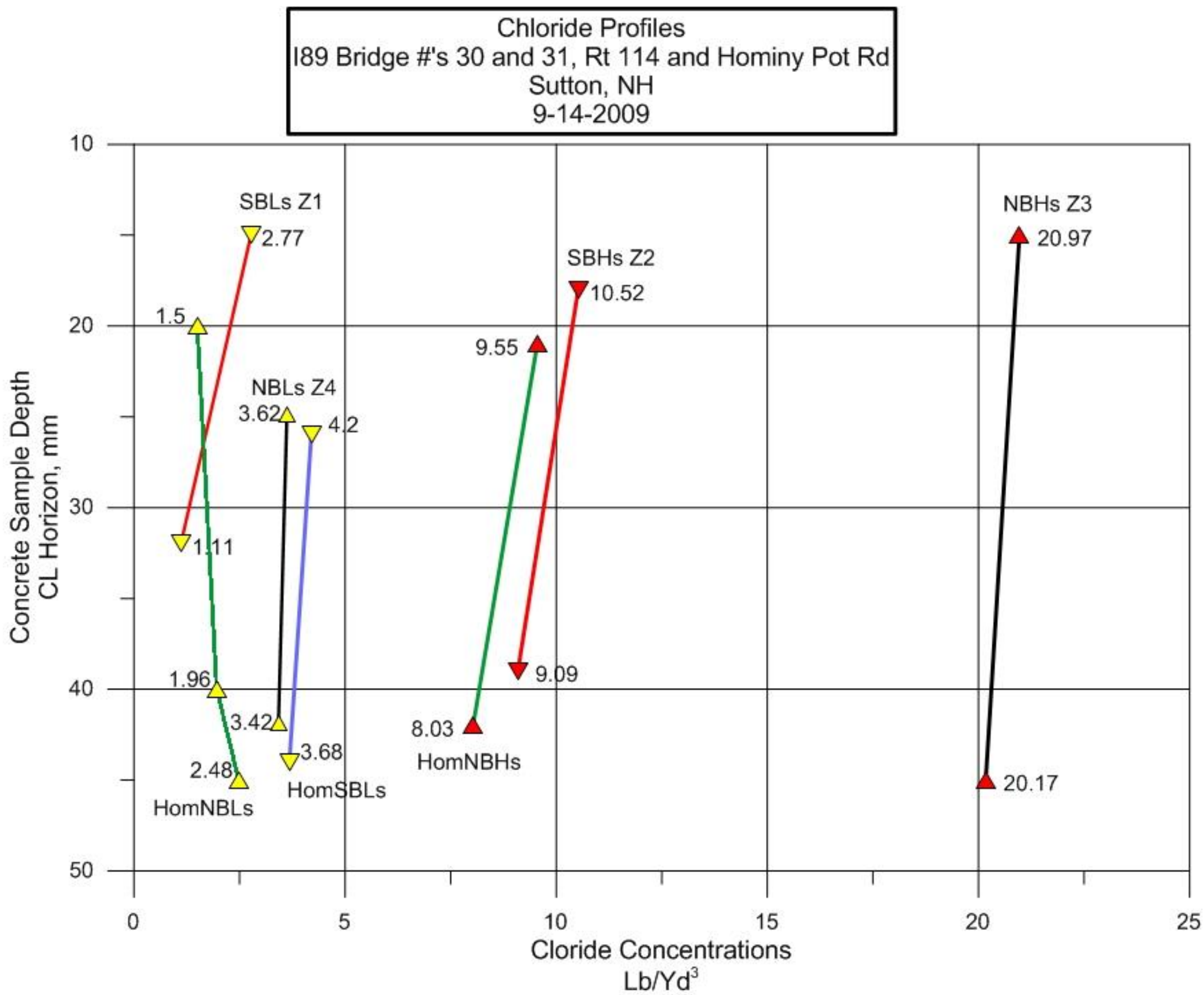
Based on field data generated by NHDOT and CD Engineering (see Appendix C), protection current to the anode system failed before 1990 in two zones with complete system failure by 1998.



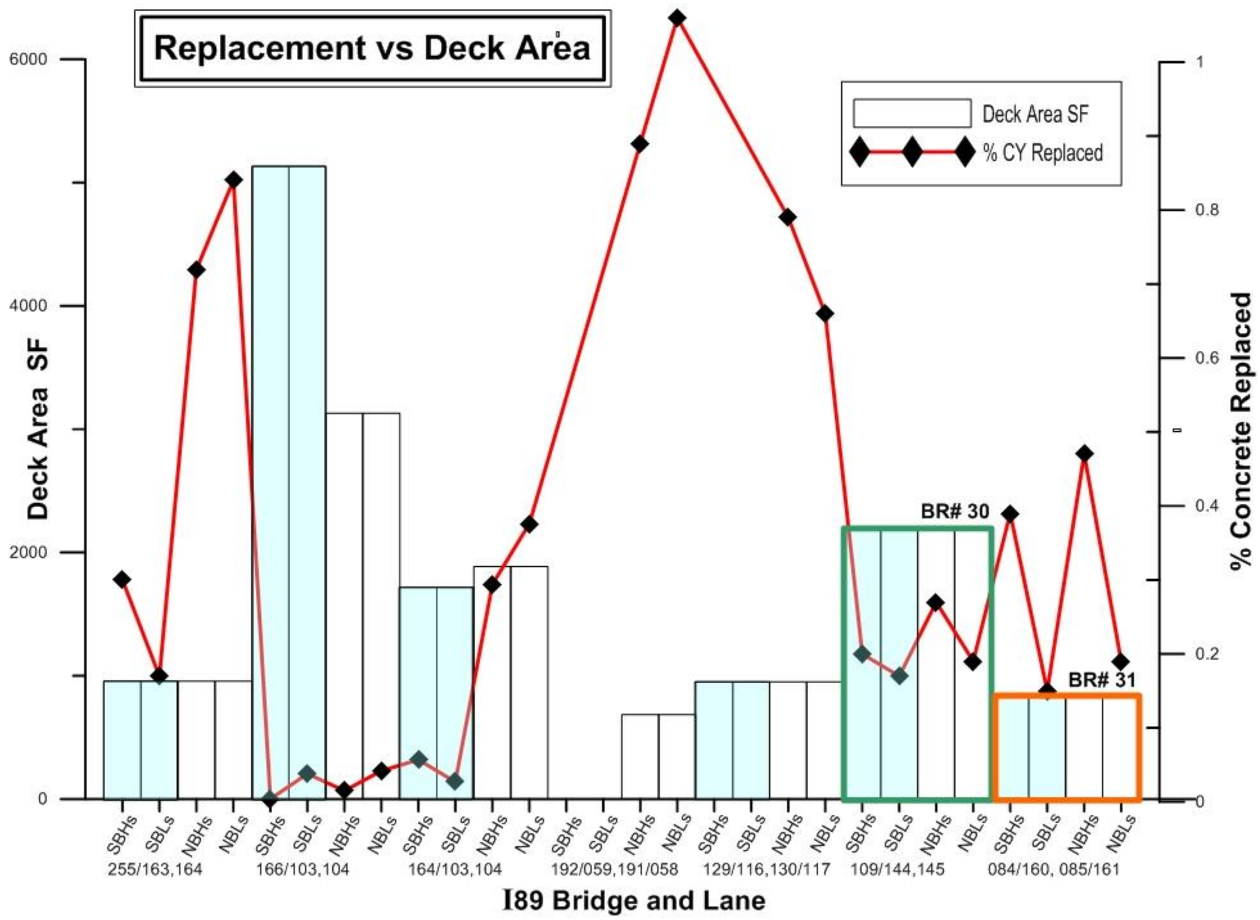
The graph below compares the concrete replacement in cubic yards versus the chloride ion concentration of the two bridge systems. It indicates that although chloride ion concentration was high for the cathodically protected bridge the concrete replacement was lower than on the control bridge. The high chloride ion concentration in zone three of the cathodically protected bridge was due to a large amount of cracking at the anode strands. This cracking was largely due to poor cover over the anode strands and traffic stresses.



Chloride profiles or bridges 30 and 31 (see Appendix D) for lab analysis

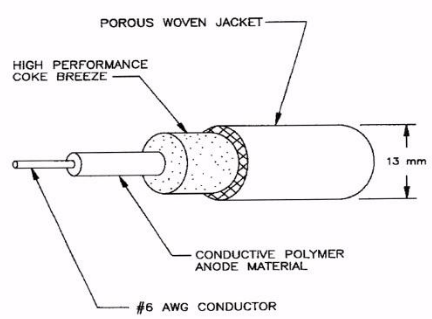


Using the bridge summary found in Appendix E for the bridges rehabilitated on the project 14511, the below graph was generated to demonstrate that based on concrete replacement versus deck area the cathodic protection on bridge number 30 was somewhat effective.



Condition evaluation --- cathodic protection system anodes

The anode used with this cathodic protection system was a Raychem FEREX 100 anode. This was one of the first commercial grid type anodes available. It consisted of a stranded copper wire encased in a proprietary flexible and electronically conductive polymer, resulting in an anode cable with a nominal diameter of approximately 8 mm. The conductive polymer outer jacket of this anode proved to be susceptible to attack by acids generated around the anode. Another disadvantage of this anode is that if the copper core wire was exposed the copper wire would corrode and cause open circuits and local loss of cathodic protection current. The FEREX 100 system was used in over 50 FHWA demonstration projects and national studies noted anode degradation and cracking was being observed in many installations. The diagram on the left below illustrates the composition of the anode. The photo on the right is a section of an anode removed from an area that was not receiving protection current.



The photo on the left shows the degradation of the jacket and conductive polymer. The photo on the right also shows cracking and leaching of the copper conductor through the jacket.

It was known that the FEREX wire material would deteriorate rapidly if overpowered but could provide long life if the anode current density was limited to the design value. Although initial tests were promising in a number of installed systems, the material proved somewhat susceptible to become brittle, causing breaks especially at bends. (SHRP-S-337, Pg. 54)

Summary

National studies have concluded that cathodic protection of reinforcing steel in concrete will arrest and mitigate corrosion. The system used in this demonstration project was one of several used for evaluation for the FHWA. However this system proved to be unsuccessful in most installations in the United States and was abandoned. There are hundreds of successful cathodically protected bridge installations in many states, such as Missouri, Florida and Texas. This system was plagued by the component itself, installation, cover and maintenance.

(Vrable, 1977) wrote that although cathodic protection ranks highest among the available ways to prevent corrosion of reinforcing steel in bridge decks, it is the only available method for arresting corrosion in existing bridge decks. Furthermore, the FHWA stated its position on cathodic protection systems in 1982 as follows:

The only rehabilitation technique that has proven to stop corrosion in salt-contaminated bridge decks regardless of the chloride content of the concrete is cathodic protection (Jackson, 1982).

When evaluating a structure for a cathodic protection system, the following parameters should be considered:

The remaining service life should be greater than 10 years.

Delaminations and spalls should be less than 50% of the deck area.

Chloride content should be less than 1.0 pounds per cubic yard.

The reinforcing steel should be electrically continuous.

Appendix A

Surface potential survey field data, Interstate 89,

Bridge numbers 084/160, 085-161, Hominy Pot Rd.

CD ENGINEERING										
		Cushing, ME					**NH DOT, Concord, NH**			
							I89 Bridges, Sutton			
							Br# 084-160, Hominy Pot Rd, SB Ls			
							Surface Potential Survey			
							Air Temp 54F, Deck Temp 68F			
							Clear, Wet deck areas			
							06/01/09			
				Potentials (mv)						
W	**S0**	**S2**	**S4**	**S6**	**S8**	**S10**	**S12**	**S14**	**S16**	**S18**
-8	X	X	X	X	X	X	X	X	X	312
-6	X	X	X	X	X	X	X	313	369	307
-4	X	X	X	X	312	317	306	345	307	306
-2	X	X	347	278	296	350	386	320	308	310
0	326	337	362	310	225	230	298	267	242	310
2	375	308	240	264	227	226	231	248	278	299
4	337	301	208	221	163	210	173	269	254	299
6	401	316	232	228	178	223	161	243	237	262
8	332	288	261	239	199	260	251	261	270	260
10	413	296	278	243	269	242	242	259	274	213
12	445	325	279	265	240	259	259	252	222	240
14	296	332	292	257	237	282	267	253	231	203
16	315	307	271	257	193	230	262	262	274	274
18	364	364	276	276	253	274	349	231	233	210
20	381	374	271	264	226	259	260	266	256	237
22	372	287	274	246	275	233	360	237	252	242
24	340	284	286	263	290	285	256	231	249	248
26	327	297	301	285	255	222	202	208	264	187
28	248	254	240	248	248	216	212	238	244	229
30	240	273	248	246	256	235	216	247	208	261
32	282	255	256	234	236	231	228	322	266	255
34	256	291	282	249	262	236	251	331	252	328
36	234	218	228	227	251	252	263	410	346	348
38	349	299	267	227	305	302	316	413	372	X
40	419	304	272	268	343	339	334	406	X	X
42	371	343	293	313	455	416	386	X	X	X
44	388	347	351	391	X	X	X	X	X	X
46	405	384	X	X	X	X	X	X	X	X

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH
I89 Bridges, Sutton
Br# 085-161, Hominy Pot Rd, NB Ls
Surface Potential Survey
Air Temp 48F, Deck Temp 47F
Clear, Deck dry
06/01/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-10	X	X	X	X	X	X	X	X	X	X
-8	X	X	X	X	X	X	X	X	294	X
-6	X	X	X	X	X	X	315	329	254	X
-4	X	X	X	X	213	357	341	319	295	X
-2	X	X	256	266	236	216	252	260	323	X
0	306	321	262	248	246	199	210	256	290	X
2	308	306	185	342	239	197	216	252	307	X
4	346	244	213	291	198	196	213	182	282	X
6	305	229	196	208	220	190	202	253	266	X
8	290	238	123	95	232	196	204	234	251	X
10	284	216	102	91	216	222	243	278	301	X
12	235	244	94	53	180	211	257	263	377	X
14	272	227	180	196	155	185	347	255	311	X
16	245	207	165	182	155	173	284	266	249	X
18	228	215	186	202	210	135	394	250	206	X
20	215	187	165	171	207	202	252	248	254	X
22	220	182	155	157	177	216	248	254	258	X
24	212	180	176	148	124	168	229	318	367	X
26	200	217	151	152	192	209	272	390	422	X
28	216	174	144	151	181	225	298	399	428	X
30	237	227	123	188	162	202	258	370	403	X
32	196	176	145	181	167	230	250	339	454	X
34	250	189	172	165	206	205	286	377	460	X
36	242	211	190	146	229	209	256	363	406	X
38	251	206	210	215	172	206	289	405	455	X
40	255	209	225	173	171	174	286	382	415	X
42	206	233	235	227	247	312	396	X	X	X
44	253	269	290	286	415	X	X	X	X	X
46	358	337	389	X	X	X	X	X	X	X

CD ENGINEERING

Cushing, ME

NH DOT
Concord, NH
Sutton Bridges, #085-161
Hominy Pot Road, I89 NB Hs
Surface Potential Survey
Air Temp 54F, Deck Temp 68F, Clear
04/17/09

Potentials (mv)

W	S0	S1	S2	S3	S4	S5	S6	S7	S8	S9
-4	X	X	X	X	X	X	X	X	X	358
-3	X	X	X	X	X	X	X	272	300	317
-2	X	X	X	X	258	237	234	241	252	311
-1	X	X	278	249	212	217	223	215	220	291
0	248	241	250	209	210	226	206	224	245	293
1	161	223	204	192	210	216	240	236	233	277
2	168	191	200	222	208	190	240	232	228	260
3	149	177	217	242	238	241	228	191	213	291
4	177	187	229	272	268	192	177	201	219	276
5	139	228	237	294	348	248	229	226	253	257
6	360	311	262	327	279	233	203	234	262	265
7	282	275	283	300	299	248	206	248	255	294
8	355	342	304	315	338	263	232	235	217	339
9	452	394	341	316	343	270	219	235	275	343
10	431	402	358	284	311	264	249	242	306	337
11	295	321	292	330	347	281	262	227	293	303
12	213	281	310	317	355	289	229	228	255	313
13	234	192	263	325	343	252	210	226	277	335
14	192	188	262	316	340	268	236	245	289	333
15	204	236	280	318	293	256	231	226	269	344
16	343	245	293	316	330	276	195	241	276	322
17	396	292	371	335	353	308	179	218	288	364
18	534	460	422	382	324	276	166	261	297	389
19	575	517	428	399	246	355	458	442	400	413
20	446	436	415	375	394	578	489	460	445	424
21	512	343	373	402	341	558	549	X	X	X
22	484	332	403	527	559	X	X	X	X	X
23	475	518	X	X	X	X	X	X	X	X

Appendix B

Surface potential survey field data, Interstate 89,

Bridge numbers 109/144, 109/145, RT 114.

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH

I89 Bridges, Sutton

Br# 109-144 z1on SB Ls Ln

Surface Potential Survey

Air Temp 62F, Deck Temp 59F

Drizzle, Fog, RH 96%

06/30/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	369
-10	X	X	X	X	X	X	X	395	328	358
-8	X	X	X	X	X	X	460	413	277	341
-6	X	X	X	X	X	482	445	396	254	316
-4	X	X	X	389	368	427	404	344	236	298
-2	X	292	334	313	283	336	348	346	228	287
0	287	262	294	316	288	326	363	353	239	277
2	223	268	238	307	318	368	394	364	232	281
4	202	318	243	277	228	387	384	362	244	272
6	301	383	253	294	228	366	371	277	225	266
8	305	321	242	327	353	416	387	349	219	258
10	263	344	354	334	313	399	374	342	221	260
12	298	378	381	343	406	364	419	385	226	255
14	230	307	331	305	293	400	366	302	223	263
16	204	320	283	263	267	316	322	293	229	262
18	300	327	291	266	280	276	311	318	241	263
20	396	383	360	314	359	337	320	326	232	252
22	474	360	338	306	284	346	326	293	220	254
24	457	440	325	294	272	315	304	268	225	243
26	341	378	337	286	321	400	433	240	200	237
28	224	340	308	358	510	1680	417	268	201	232
30	240	380	405	468	532	478	318	240	203	231
32	398	426	589	541	372	368	275	180	215	240
34	402	341	386	366	323	348	328	188	218	237
36	344	408	333	282	318	336	305	254	216	225
38	291	324	290	282	310	344	309	245	200	214
40	505	402	227	307	280	343	290	216	198	201
42	410	327	300	398	261	361	192	187	180	200
44	308	335	260	295	311	358	317	277	215	197
46	377	380	305	309	291	333	323	307	193	200
48	367	342	316	291	293	310	302	316	191	200
50	375	361	306	260	278	360	300	325	178	209
52	368	366	321	282	278	349	346	336	185	216
54	415	393	322	238	256	340	352	352	211	227
56	316	337	298	336	356	360	328	324	237	218
58	284	320	256	336	438	369	316	328	213	221
60	283	415	367	347	374	376	335	320	196	210
62	352	351	373	343	333	357	327	321	204	206
64	415	349	335	437	388	346	301	292	173	196
66	302	284	322	355	290	342	321	275	178	189
68	410	367	280	266	290	367	337	275	165	189
70	422	380	324	272	242	369	308	238	187	189
72	284	375	302	286	201	383	320	288	165	185
74	203	347	269	268	186	362	360	319	166	185
76	211	310	235	290	240	436	538	435	217	189
78	214	350	334	304	356	1377	738	402	255	194

CD ENGINEERING						NH DOT, Concord, NH			Pg 2 of 2
	Cushing, ME					I89 Bridges, Sutton			
						Br# 109-144 z1on		SB Ls Ln	
						Surface Potential Survey			
						Air Temp 62F, Deck Temp 59F			
						Drizzle, Fog, RH 96%			
						06/30/09			
				Potentials (mv)					

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	276	384	378	476	550	463	908	437	222	205
82	233	376	365	408	343	421	872	424	263	195
84	231	347	365	401	367	421	999	381	247	201
86	255	358	420	411	372	402	949	402	258	205
88	364	397	386	352	340	435	809	451	263	216
90	350	420	350	403	380	432	660	404	228	204
92	280	396	348	351	352	406	366	362	211	198
94	424	378	319	293	269	367	275	276	197	204
96	395	394	365	322	286	252	238	245	204	200
98	317	396	358	346	248	231	204	230	178	204
100	385	410	302	312	310	210	208	215	209	218
102	402	379	305	297	339	273	244	191	240	264
104	415	431	310	375	378	239	250	254	304	338
106	421	352	350	328	388	296	330	326	342	X
108	363	385	336	373	306	322	366	354	X	X
110	456	360	314	314	330	371	X	X	X	X
112	542	480	360	340	X	X	X	X	X	X
114	509	535	502	X	X	X	X	X	X	X
116	616	506	X	X	X	X	X	X	X	x

CD ENGINEERING Cushing, ME

NH DOT, Concord, NH **Pg 1 of 2**
I89 Bridges, Sutton
Br# 109-144 z1off SB Ls Ln
Surface Potential Survey
Air Temp 61F, Deck Temp 58F
Overcast, showers, deck wet
07/10/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	318
-10	X	X	X	X	X	X	X	362	370	316
-8	X	X	X	X	X	X	354	343	340	306
-6	X	X	X	X	X	358	372	320	300	287
-4	X	X	X	344	246	337	347	305	149	289
-2	X	275	280	268	239	276	305	300	167	276
0	224	219	252	287	247	289	310	298	177	275
2	175	217	184	256	272	322	312	318	211	265
4	214	307	204	244	225	352	345	322	207	255
6	289	339	195	256	195	364	330	252	180	247
8	259	291	191	319	362	441	391	322	205	260
10	200	328	343	308	333	424	376	315	188	265
12	249	346	350	331	461	381	427	365	160	258
14	157	261	297	292	285	245	386	384	248	252
16	154	276	260	241	236	303	310	280	244	233
18	217	288	275	248	233	236	258	291	244	235
20	302	312	320	305	327	300	273	279	249	240
22	368	290	289	259	246	288	265	262	241	219
24	365	348	265	256	222	235	231	205	223	230
26	277	322	300	221	215	226	234	144	223	214
28	170	293	260	233	213	198	202	190	191	200
30	179	303	263	221	227	194	169	119	195	233
32	331	338	232	230	208	238	188	103	232	226
34	389	254	262	252	217	235	230	110	154	218
36	293	347	274	213	212	238	226	171	215	207
38	246	284	217	236	217	239	226	197	204	195
40	443	357	185	277	220	239	208	143	201	199
42	357	304	256	403	251	258	147	135	192	183
44	254	329	252	247	270	262	231	202	145	191
46	304	349	288	272	248	243	262	245	212	191
48	306	318	284	246	231	240	237	260	212	197
50	331	324	278	216	215	256	239	278	213	188
52	314	327	282	237	233	260	288	288	139	204
54	335	358	307	219	219	270	310	309	172	209
56	255	307	274	335	350	290	266	171	181	215
58	247	271	262	342	420	301	262	288	132	245
60	230	383	338	270	339	291	275	277	151	239
62	304	298	359	325	307	254	251	264	178	228
64	363	321	343	452	299	256	210	237	120	194
66	244	245	291	307	234	253	244	213	138	180
68	346	328	242	205	214	251	256	230	125	179
70	387	333	272	237	165	254	233	186	139	177
72	240	331	252	246	133	250	220	218	116	199
74	173	300	224	213	106	232	242	230	116	233
76	160	257	195	215	122	260	255	226	161	215
78	178	298	284	220	191	278	274	298	227	225

CD ENGINEERING						NH DOT, Concord, NH			Pg 2 of 2
	Cushing, ME					I89 Bridges, Sutton			
						Br# 109-144 z1off		SB Ls Ln	
						Surface Potential Survey			
						Air Temp 61F, Deck Temp 58F			
						Overcast, showers, deck wet			
						07/10/09			
			Potentials (mv)						

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	243	333	329	330	238	314	287	320	240	207
82	189	328	312	332	301	297	310	287	208	195
84	271	294	300	316	306	293	300	244	182	209
86	224	307	253	320	291	297	275	277	219	215
88	400	339	334	292	295	283	283	271	220	204
90	340	342	317	360	334	317	260	282	179	211
92	239	344	320	342	311	334	241	286	196	234
94	395	330	294	274	226	288	190	213	168	254
96	358	350	314	285	227	160	173	184	176	243
98	275	362	288	312	215	180	160	173	168	240
100	325	383	270	283	269	182	170	173	175	257
102	387	323	258	248	294	221	226	203	191	310
104	379	389	286	330	383	186	231	275	289	420
106	453	315	291	260	341	283	304	312	344	X
108	330	340	286	299	277	271	308	488	X	X
110	413	307	259	270	278	417	X	X	X	X
112	464	393	286	406	X	X	X	X	X	X
114	421	458	464	X	X	X	X	X	X	X
116	405	488	X	X	X	X	X	X	X	x

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH **Pg 1 of 2**

I89 Bridges, Sutton

Br# 109-144 z2on SB Hs Ln

Surface Potential Survey

Air Temp 48F, Deck Temp 45F

Clear, deck wet, rain 2 days

04/24/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	294
-10	X	X	X	X	X	X	X	X	198	211
-8	X	X	X	X	X	X	202	235	262	249
-6	X	X	X	X	255	281	224	246	235	445
-4	X	X	X	293	281	235	192	226	141	278
-2	X	320	315	320	253	232	185	200	114	262
0	356	320	315	275	263	255	200	191	118	249
2	435	319	393	355	381	338	281	232	142	195
4	360	308	438	467	487	548	393	328	163	250
6	373	366	357	364	376	368	332	293	270	341
8	310	281	332	292	252	277	287	327	346	499
10	290	294	359	389	260	272	270	366	402	611
12	288	321	309	348	309	350	342	362	356	312
14	288	299	280	302	264	313	312	321	240	345
16	287	325	326	289	254	311	311	266	166	267
18	276	304	279	264	301	463	484	316	258	360
20	287	283	254	225	226	316	321	315	316	545
22	271	289	244	228	232	384	299	345	277	549
24	333	287	216	220	220	365	288	324	211	398
26	294	307	252	209	221	404	249	326	196	367
28	254	289	232	242	246	437	861	297	179	423
30	307	317	351	352	250	416	823	274	201	424
32	280	311	237	235	258	344	804	270	242	295
34	258	272	276	238	253	373	754	299	260	360
36	270	391	303	348	281	382	454	306	290	359
38	252	297	290	292	305	346	381	275	248	422
40	226	259	261	257	258	251	218	299	210	354
42	235	252	240	266	262	263	259	312	205	424
44	252	249	228	258	351	382	334	394	293	216
46	264	220	222	254	307	433	337	257	233	248
48	276	274	244	256	305	319	319	285	300	282
50	275	281	262	255	404	427	360	310	326	358
52	244	224	218	288	281	320	428	396	316	396
54	234	280	192	204	257	289	267	269	171	312
56	285	260	208	198	248	357	314	264	281	467
58	281	270	243	228	262	326	269	272	289	400
60	362	325	367	228	219	228	227	220	153	235
62	325	371	267	228	217	200	244	194	163	276
64	304	368	362	399	299	248	259	255	181	188
66	272	271	355	249	290	346	411	317	268	194
68	259	292	204	229	257	274	318	285	215	203
70	291	316	292	240	227	230	237	235	197	186
72	270	378	370	315	309	292	330	248	182	250
74	266	313	266	368	430	342	411	323	423	293
76	280	299	231	366	432	412	425	457	466	513
78	190	326	257	294	342	715	438	407	410	394

CD ENGINEERING					NH DOT, Concord, NH		Pg 2 of 2
	Cushing, ME				I89 Bridges, Sutton		
					Br# 109-144 z2on	SB Hs Ln	
					Surface Potential Survey		
					Air Temp 48F, Deck Temp 45F		
					Clear, deck wet, rain 2 days		
					04/24/09		

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	230	305	414	390	475	521	429	362	336	362
82	225	282	299	306	308	293	270	298	328	434
84	231	282	272	306	272	268	268	330	270	350
86	233	279	447	451	270	380	392	418	342	316
88	226	277	282	286	266	444	433	382	395	480
90	226	248	240	243	224	336	349	363	440	538
92	216	254	261	229	208	228	230	346	332	441
94	238	305	253	275	195	227	236	304	318	451
96	220	200	202	251	189	199	250	252	342	490
98	225	219	194	175	171	235	227	293	340	474
100	215	217	229	173	224	244	253	282	338	564
102	204	197	216	224	246	246	251	318	320	508
104	183	173	198	225	218	322	357	308	381	494
106	180	240	244	220	198	240	225	378	532	X
108	211	209	379	333	280	219	251	X	X	X
110	218	191	305	265	390	301	445	X	X	X
112	260	244	252	329	560	500	X	X	X	X
114	309	321	355	X	X	X	X	X	X	X
116	368	384	X	X	X	X	X	X	X	x

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH

I89 Bridges, Sutton

Br# 109-144 z2off SB Hs Ln

Surface Potential Survey

Air Temp 83F, Deck Temp 79F

Clear, Hi thin, Low Humidity

04/28/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	187
-10	X	X	X	X	X	X	X	316	196	193
-8	X	X	X	X	X	X	214	246	281	238
-6	X	X	X	X	239	279	230	227	263	432
-4	X	X	X	300	283	236	217	208	176	292
-2	X	293	316	313	251	256	213	208	132	265
0	336	306	327	269	270	281	278	202	145	235
2	380	310	387	357	368	346	288	250	159	194
4	346	323	418	457	479	550	389	325	167	235
6	369	366	353	344	361	359	316	300	255	340
8	289	341	290	283	250	255	263	330	341	479
10	287	303	356	403	265	261	258	356	373	572
12	282	319	315	348	294	355	343	352	348	502
14	299	332	282	301	276	310	318	318	260	338
16	292	337	327	277	254	314	325	265	162	257
18	244	316	274	264	301	470	438	306	248	349
20	317	290	244	230	234	300	305	306	299	496
22	270	296	246	229	226	285	358	340	306	562
24	337	291	234	231	221	304	343	320	227	388
26	282	308	268	227	224	260	229	239	200	341
28	264	296	266	256	223	226	226	226	166	411
30	327	336	348	341	220	233	233	228	201	404
32	280	328	250	250	243	219	252	235	247	290
34	265	294	283	250	220	244	235	254	262	349
36	254	298	386	330	262	313	377	281	313	344
38	236	302	348	319	302	328	373	275	285	470
40	230	255	243	250	242	238	227	280	224	334
42	243	279	268	282	250	248	239	278	228	424
44	253	253	229	244	304	351	328	380	322	235
46	268	243	250	266	296	441	350	264	269	257
48	305	292	264	260	289	304	301	278	304	294
50	288	306	285	273	402	428	339	291	310	343
52	267	250	243	333	307	329	399	405	310	414
54	274	277	224	230	266	275	281	254	184	331
56	290	271	229	203	253	361	319	261	287	440
58	306	270	256	240	256	312	253	261	309	423
60	345	322	367	238	220	213	216	185	153	260
62	349	309	298	247	237	212	211	201	169	298
64	330	316	399	432	281	233	224	250	174	251
66	294	291	377	271	291	327	398	316	286	213
68	285	331	224	217	240	259	306	272	209	268
70	266	326	330	259	215	230	232	237	205	200
72	273	389	388	307	268	276	340	232	189	250
74	271	319	280	366	428	364	427	323	409	305
76	260	277	236	364	432	391	438	441	441	482
78	228	292	284	299	324	349	422	416	421	407

CD ENGINEERING						NH DOT, Concord, NH			Pg 2 of 2
	Cushing, ME					I89 Bridges, Sutton			
						Br# 109-144 z2off		SB Hs Ln	
						Surface Potential Survey			
						Air Temp 83F, Deck Temp 79F			
						Clear, Hi thin, Low Humidity			
						04/28/09			
				Potentials (mv)					

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	258	331	419	381	441	371	456	381	363	347
82	226	304	330	328	329	302	300	334	355	427
84	252	281	283	284	257	256	265	333	309	356
86	236	302	470	447	357	442	424	422	337	333
88	244	288	289	309	272	328	358	377	427	472
90	250	268	261	259	248	265	262	392	458	547
92	229	264	292	259	232	235	245	389	372	427
94	229	268	335	295	233	220	250	320	346	463
96	229	219	232	250	225	233	233	274	349	501
98	221	243	233	233	207	244	252	281	344	475
100	222	219	244	206	227	243	262	296	342	569
102	197	213	248	231	251	321	368	320	356	502
104	202	176	213	218	220	239	226	308	391	508
106	181	234	271	262	226	243	272	397	544	X
108	220	203	384	357	285	321	455	354	X	X
110	248	202	312	290	399	519	X	X	X	X
112	274	247	269	349	545	X	X	X	X	X
114	323	339	364	X	X	X	X	X	X	X
116	384	406	X	X	X	X	X	X	X	x

CD ENGINEERING
Cushing, ME

NH DOT, Concord, NH
I89 Bridges, Sutton
Br# 109-145 z3on NB Hs Ln
Surface Potential Survey
Air Temp 63F, Deck Temp 59F
Overcast, Mod Humidity
05/04/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	326
-10	X	X	X	X	X	X	X	X	286	305
-8	X	X	X	X	X	X	315	267	252	275
-6	X	X	X	X	X	338	278	232	223	251
-4	X	X	X	446	416	426	351	323	235	249
-2	X	480	432	374	335	396	394	346	311	271
0	516	543	423	314	292	366	389	358	290	282
2	538	425	431	336	320	451	420	334	244	258
4	481	377	409	352	361	368	360	241	209	247
6	502	384	438	478	493	451	439	275	217	252
8	575	353	428	402	403	413	368	311	218	251
10	537	332	481	503	427	419	425	336	232	260
12	566	304	329	304	340	373	371	318	232	256
14	543	315	301	305	343	330	299	256	208	254
16	581	308	318	392	437	393	285	247	207	256
18	424	252	308	459	486	472	345	250	208	260
20	357	308	319	341	346	407	369	310	233	249
22	422	292	440	512	504	497	423	388	297	260
24	477	310	295	340	345	343	319	383	288	271
26	357	344	329	374	414	402	316	388	289	265
28	379	309	334	415	473	555	436	402	286	282
30	402	358	326	394	1661	702	310	378	262	284
32	454	378	374	480	487	475	310	350	274	278
34	516	426	295	346	318	338	243	259	270	267
36	505	436	270	238	273	255	216	251	203	255
38	381	335	242	267	265	255	230	243	230	258
40	416	354	264	356	251	256	214	323	275	257
42	391	240	224	279	264	316	280	249	252	259
44	396	252	199	296	313	342	327	272	294	258
46	328	211	270	435	343	277	265	366	332	259
48	295	239	303	331	324	308	295	287	304	255
50	287	274	253	367	519	482	480	418	261	247
52	356	311	209	291	314	313	306	295	359	272
54	376	363	325	439	377	386	374	304	333	289
56	469	397	325	362	375	436	423	348	361	296
58	295	357	273	412	471	473	446	465	414	308
60	271	469	325	342	359	393	355	371	375	290
62	307	488	328	284	345	298	305	349	394	296
64	244	250	260	271	269	284	286	454	369	293
66	296	239	291	300	282	266	262	279	358	306
68	320	298	320	426	532	450	348	328	382	291
70	368	310	292	374	421	389	456	357	407	306
72	402	401	309	297	278	313	438	366	380	296
74	364	475	425	463	475	404	519	406	384	297
76	419	458	365	389	401	393	398	1119	473	308
78	404	399	326	322	409	504	809	1771	473	327

CD ENGINEERING					NH DOT, Concord, NH			Pg 2 of 2
Cushing, ME					I89 Bridges, Sutton			
					Br# 109-145 z3on		NB Hs Ln	
					Surface Potential Survey			
					Air Temp 63F, Deck Temp 59F			
					Overcast, Mod Humidity			
					05/04/09			

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	442	502	465	493	486	483	519	1752	497	348
82	503	484	489	513	477	393	411	2100	408	326
84	374	505	415	355	319	314	404	1057	367	322
86	328	475	302	277	300	392	466	505	382	309
88	335	509	304	284	281	311	412	978	362	283
90	257	413	305	341	402	417	356	566	362	326
92	263	339	316	367	364	360	354	493	383	292
94	214	488	362	476	337	323	375	469	341	312
96	254	229	274	315	282	310	367	347	263	254
98	270	203	345	452	468	383	268	262	354	227
100	232	180	307	385	393	350	293	322	292	248
102	244	164	369	329	378	276	299	315	349	341
104	270	277	336	402	438	330	321	328	342	373
106	286	289	264	278	463	408	359	390	328	366
108	337	262	197	179	243	294	344	380	358	X
110	355	278	233	176	332	327	422	X	X	X
112	274	224	193	190	296	X	X	X	X	X
114	308	325	302	338	X	X	X	X	X	X
116	347	464	X	X	X	X	X	X	X	x

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH

I89 Bridges, Sutton
Br# 109-145 z3off NB Hs Ln
Surface Potential Survey
Air Temp 55F, Deck Temp 51F
Cloudy, Windy
04/27/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	336
-10	X	X	X	X	X	X	X	X	303	328
-8	X	X	X	X	X	X	324	289	264	310
-6	X	X	X	X	X	350	299	240	239	288
-4	X	X	X	463	443	444	382	352	266	287
-2	X	463	443	384	349	404	430	388	344	306
0	520	521	418	322	289	377	399	381	326	294
2	540	429	430	334	329	457	428	326	247	280
4	573	370	402	356	384	384	379	244	226	264
6	575	404	450	486	502	477	458	295	224	270
8	539	368	432	412	407	427	381	326	232	257
10	570	333	450	505	436	422	433	342	220	240
12	525	295	333	320	348	393	391	324	244	252
14	563	318	297	312	350	337	308	254	231	258
16	456	308	326	409	447	416	296	241	209	261
18	379	272	316	456	489	484	377	263	206	242
20	460	307	324	349	322	392	372	317	242	256
22	524	303	449	517	505	496	431	406	300	274
24	373	310	318	353	337	352	335	383	300	272
26	404	312	329	379	408	398	313	401	305	297
28	398	323	340	421	439	460	400	403	300	324
30	456	339	336	400	320	318	266	386	294	290
32	504	378	390	458	454	431	298	311	298	283
34	397	416	299	357	300	330	240	264	293	279
36	440	431	270	250	272	248	212	252	230	269
38	413	346	248	265	252	235	253	218	266	275
40	429	323	255	355	242	237	206	246	276	284
42	423	236	235	288	264	303	295	257	272	228
44	381	264	224	292	298	310	318	275	308	258
46	344	215	281	432	330	261	258	354	303	217
48	325	242	306	338	340	308	305	299	331	223
50	290	267	271	373	519	480	478	414	277	251
52	352	300	236	301	321	320	309	304	375	277
54	401	349	333	442	385	392	377	315	371	294
56	467	388	324	366	372	430	411	367	378	274
58	298	357	301	433	477	471	451	474	428	348
60	310	462	342	351	364	404	355	386	412	332
62	304	460	328	294	336	288	362	305	412	306
64	248	251	256	272	277	258	281	451	386	297
66	300	357	291	313	292	281	260	284	388	334
68	332	301	314	457	535	454	351	333	403	256
70	377	296	295	366	427	401	436	352	403	330
72	420	404	308	306	288	325	434	367	409	303
74	388	471	421	482	487	414	526	372	368	307
76	438	446	362	394	390	383	341	327	407	308
78	409	402	326	327	418	431	304	269	371	385

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH

I89 Bridges, Sutton

Br# 109-145 z3off NB Hs Ln

Surface Potential Survey

Air Temp 55F, Deck Temp 51F

Cloudy, Windy

04/27/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	477	490	456	471	396	398	468	297	393	337
82	520	481	475	501	471	390	284	281	323	303
84	386	504	406	346	319	315	282	271	314	314
86	334	493	304	275	298	373	444	299	345	296
88	353	503	312	288	283	303	294	279	315	262
90	279	450	307	364	416	411	318	341	357	291
92	259	317	317	388	365	361	318	372	378	274
94	221	486	369	461	348	334	381	354	336	254
96	256	243	295	322	319	317	375	325	272	243
98	270	222	356	454	476	400	267	267	250	242
100	245	200	318	381	399	358	285	316	280	256
102	252	205	385	340	395	288	297	337	360	312
104	270	298	360	391	428	332	324	330	346	403
106	290	298	281	280	446	396	357	378	340	378
108	353	301	217	184	208	299	356	416	392	X
110	350	303	239	193	317	340	494	X	X	X
112	276	237	235	210	317	443	X	X	X	X
114	299	367	351	364	X	X	X	X	X	X
116	380	517	514	X	X	X	X	X	X	x

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH
I89 Bridges, Sutton
Br# 109-145 z4on NB Ls Ln
Surface Potential Survey
Air Temp 63F, Deck Temp 59F
Overcast, Lt showers, Deck wet
07/16/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	533
-10	X	X	X	X	X	X	X	447	507	454
-8	X	X	X	X	X	X	420	402	466	523
-6	X	X	X	X	343	395	335	370	353	594
-4	X	X	X	308	365	344	326	376	361	531
-2	X	X	296	328	318	311	335	348	309	478
0	324	297	299	282	281	289	318	320	334	378
2	289	290	283	273	342	284	275	283	350	409
4	274	242	266	288	300	279	286	288	370	326
6	255	244	302	320	297	272	259	279	325	368
8	240	256	350	421	348	310	314	288	324	298
10	273	253	359	427	402	347	385	328	357	359
12	288	247	322	350	330	308	294	280	348	366
14	307	262	319	301	277	271	270	256	354	341
16	276	263	315	295	251	222	225	246	285	404
18	240	272	310	275	223	201	220	241	318	368
20	230	263	329	296	248	215	224	269	348	335
22	240	270	320	290	245	205	219	285	357	389
24	217	277	294	256	262	239	253	315	356	377
26	225	282	315	259	283	329	320	353	335	349
28	257	300	314	281	283	349	329	316	314	348
30	259	277	281	256	249	242	244	282	335	338
32	276	275	207	254	246	228	229	236	287	311
34	266	290	320	264	237	244	248	232	290	315
36	245	304	415	313	271	308	311	267	355	302
38	243	274	349	353	283	317	384	295	295	276
40	238	271	287	318	274	304	310	305	332	306
42	235	260	314	287	277	348	374	334	355	361
44	233	263	316	311	297	306	317	320	351	336
46	230	259	306	386	330	327	340	327	322	242
48	224	261	277	315	323	361	386	366	347	350
50	236	250	243	298	251	339	421	379	361	298
52	268	275	262	280	297	326	347	365	354	270
54	287	281	269	262	259	310	315	386	361	310
56	277	292	270	269	268	270	318	373	394	321
58	283	290	319	355	330	345	353	421	401	377
60	292	302	263	313	340	416	376	348	385	369
62	274	289	213	255	278	303	303	361	372	353
64	275	278	250	264	250	259	307	402	388	400
66	263	286	248	257	264	276	286	318	396	368
68	269	275	230	294	365	373	350	342	422	395
70	252	258	207	268	329	336	296	333	447	420
72	265	249	227	260	318	314	264	283	350	318
74	254	244	224	266	291	268	274	359	324	264
76	240	243	243	265	284	248	305	412	372	218
78	227	243	224	323	292	248	295	354	333	227

CD ENGINEERING						NH DOT, Concord, NH			Pg 2 of 2
	Cushing, ME					I89 Bridges, Sutton			
						Br# 109-145 z4on		NB Ls Ln	
						Surface Potential Survey			
						Air Temp 63F, Deck Temp 59F			
						Overcast, Lt showers, Deck wet			
						07/16/09			
			Potentials (mv)						

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	221	241	230	232	321	348	353	368	293	167
82	219	254	234	248	302	326	367	405	295	159
84	224	240	241	266	306	278	298	427	330	177
86	209	225	227	283	262	224	269	359	310	217
88	219	231	245	313	260	227	271	326	303	276
90	238	260	240	344	277	260	273	285	307	242
92	261	267	296	290	304	301	412	293	322	219
94	253	259	328	370	315	282	315	312	334	244
96	229	257	341	374	301	274	346	296	331	346
98	244	244	300	417	278	274	304	294	324	271
100	238	257	279	297	303	330	313	282	273	242
102	232	247	315	268	269	261	274	260	286	234
104	242	261	271	258	283	270	304	366	328	282
106	230	245	311	270	272	301	371	450	457	378
108	227	258	325	347	328	312	450	514	X	X
110	220	273	346	400	340	400	X	X	X	X
112	234	254	255	378	428	X	X	X	X	X
114	242	275	295	358	X	X	X	X	X	X
116	265	295	264	X	X	X	X	X	X	x

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH
I89 Bridges, Sutton
Br# 109-145 z4off NB Ls Ln
Surface Potential Survey
Air Temp 77F, Deck Temp 78F
Overcast, Hi Humidity
07/16/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
-12	X	X	X	X	X	X	X	X	X	522
-10	X	X	X	X	X	X	X	452	512	437
-8	X	X	X	X	X	X	435	416	474	518
-6	X	X	X	X	356	405	335	374	353	541
-4	X	X	X	323	372	350	336	375	366	520
-2	X	X	307	322	322	324	341	360	322	487
0	332	304	316	279	304	297	334	327	351	388
2	297	303	313	279	334	297	286	293	360	399
4	269	249	273	290	302	285	289	301	396	334
6	249	242	295	317	285	277	259	268	327	361
8	245	258	355	428	363	316	320	302	347	278
10	268	258	364	447	421	351	400	344	365	352
12	287	247	324	351	330	309	291	288	354	413
14	304	251	316	290	271	281	275	258	380	333
16	283	272	317	289	260	227	231	262	293	385
18	227	271	314	278	224	202	220	243	316	348
20	236	270	334	296	251	210	231	276	362	345
22	260	264	324	298	252	215	221	293	367	393
24	217	271	296	251	258	235	255	317	353	355
26	221	275	317	260	275	315	316	368	328	327
28	257	299	310	271	280	346	321	316	321	355
30	251	271	293	258	250	244	246	292	333	341
32	310	277	184	248	244	323	232	244	300	306
34	265	305	315	266	233	245	251	234	279	292
36	273	300	415	293	267	306	310	272	363	301
38	272	278	358	351	271	312	384	307	298	272
40	238	271	305	324	275	305	312	314	343	317
42	231	259	313	293	276	355	386	344	357	360
44	229	257	313	303	287	305	304	319	359	320
46	216	253	305	396	320	324	331	322	319	236
48	191	260	278	317	304	362	395	384	360	313
50	226	263	254	298	264	348	419	389	358	291
52	264	268	257	267	290	326	356	364	357	256
54	287	285	273	254	250	309	319	367	361	285
56	299	294	272	272	260	273	308	377	400	284
58	273	301	322	366	330	344	359	429	410	371
60	273	297	242	303	333	428	368	347	396	355
62	271	294	209	254	278	311	305	351	376	333
64	271	276	248	258	247	261	319	396	393	377
66	269	285	255	259	277	276	296	316	401	348
68	259	276	215	291	357	391	342	337	427	363
70	247	261	196	270	321	337	299	326	428	421
72	236	249	226	264	319	321	266	296	358	324
74	229	240	243	271	296	272	267	356	318	263
76	221	236	249	262	281	254	313	413	369	210
78	218	245	219	315	270	248	293	346	328	216

CD ENGINEERING

Cushing, ME

NH DOT, Concord, NH

I89 Bridges, Sutton

Br# 109-145 z4off NB Ls Ln

Surface Potential Survey

Air Temp 77F, Deck Temp 78F

Overcast, Hi Humidity

07/16/09

Potentials (mv)

W	S0	S2	S4	S6	S8	S10	S12	S14	S16	S18
80	214	236	226	231	325	350	357	375	296	198
82	213	253	237	249	298	331	379	413	304	201
84	203	222	243	272	324	257	296	431	320	252
86	199	205	243	283	289	211	254	365	323	290
88	210	243	279	312	290	213	253	349	314	323
90	237	300	264	363	306	243	271	300	311	279
92	243	244	305	294	313	296	412	309	341	220
94	235	236	371	378	351	295	318	317	364	265
96	212	234	353	382	313	276	342	273	343	393
98	212	249	316	422	306	279	309	296	341	294
100	201	266	288	296	329	346	310	281	277	295
102	203	234	333	274	276	276	275	263	284	272
104	219	238	291	265	279	261	304	368	322	316
106	213	224	319	270	292	285	373	432	444	439
108	220	234	311	322	309	315	448	512	X	X
110	223	256	331	384	345	411	X	X	X	X
112	231	236	236	377	434	X	X	X	X	X
114	239	255	279	346	X	X	X	X	X	X
116	272	283	308	X	X	X	X	X	X	x

Appendix C

New Hampshire DOT and CDE cathodic protection system monitoring data,

Bridge numbers 109/144, 109/145, RT 114.

NH DOT	Sutton Bridge #'s 109/144, 109/145			Historical Data			6/29/2015				
Date	**5/26/2006**	**10/30/1999**	**10/12/1998**	**8/13/1998**	**11/13/1990**	**11/14/1989**	**11/15/1988**	**11/8/1988**	**4/29/1988**	**12/10/1987**	**12/10/1987**
Data Pt.											
RC1A	-226 mv	-97.8 mv	-69.0 mv	-86.0 mv	-80.7 mv	-78.4 mv	-210.0 mv	-93.0 mv	-55.0 mv	-211.0 mv	-175.0 mv
RC1B	-214 mv	-143.2 mv	-105.0 mv	-141.0 mv	-179.0 mv	-155.2 mv	-252.0 mv	-216.0 mv	-270.0 mv	-362.0 mv	-347.0 mv
RP1	-0.0 mv	+0.01 mv	+0.00 mv	+0.02 mv	+0.00 mv	+0.00 mv				-3.20 mv	-3.20 mv
H1	+7.63 v	+2.95 Vdc	+3.21 Vdc	+0.97 Vdc	+0.07 Vdc	+0.07 Vdc	+3.57 Vdc	+1.42 Vdc	+0.77 Vdc	+4.22 Vdc	0
Shunt Z1 mv	+2.02 mv	+0.30 mv	+0.38 mv	+0.16 mv	+0.00 mv	+0.00 mv			+1.00 mv	+6.00 mv	0
Anode I amps	+1.01a	+0.15a	+0.19a	+0.08a	0.0a	0.0a			+0.5a	+3a	
Anode R ohms	7.55	19.67	16.89	12.13					1.54	1.41	
RC2A	-228 mv	-75.1 mv	-84.0 mv	-88.0 mv	-79.7 mv	-63.3 mv	-91.0 mv	-76.0 mv	-110.0 mv	-150.0 mv	-127.0 mv
RC2B	-156 mv	-83.3 mv	-103.0 mv	-103.0 mv	-162.0 mv	-95.6 mv	-168.0 mv	-133.0 mv	-147.0 mv	-304.0 mv	-295.0 mv
RP2	-0.4 mv	+0.00 mv	-0.06 mv	+0.11 mv	+0.00 mv	-0.40 mv				-2.90 mv	-2.90 mv
H2	+4.41 v	+4.63 Vdc	+4.62 Vdc	+4.60 Vdc	+0.07 Vdc	+0.07 Vdc	+4.38 Vdc	+3.29 Vdc	+0.13 Vdc	+3.55 Vdc	0
Shunt Z2	+0.31 mv	+0.20 mv	+0.21 mv	+0.25 mv	-0.10 mv	+0.00 mv			+1.00 mv	+0.10 mv	0
Anode I	+1.55a	+0.10a	+0.105a	+0.125a	-0.05a	0.0a			+0.5a	+0.05a	
Anode R	2.85	46.30	44.00	36.80	1.40				0.26	71.00	
RC3A	-62.7 mv	-66.0 mv	-69.0 mv	-184.0 mv	-258.0 mv	-150.5 mv	-177.0 mv	-175.0 mv	-193.0 mv	-85.0 mv	-67.0 mv
RC3B	-117.1 mv	-112.4 mv	-114.0 mv	-308.0 mv	-165.0 mv	-228.5 mv	-147.0 mv	-131.0 mv	-117.0 mv	-101.0 mv	-88.0 mv
RP3	-0.7 mv	+0.00 mv	-0.02 mv	+0.06 mv	-0.20 mv	-0.30 mv				-3.20 mv	-3.20 mv
H3	+9.29 v	+4.98 Vdc	+5.05 Vdc	+5.00 Vdc	+4.80 Vdc	+5.03 Vdc	+4.99 Vdc	+4.61 Vdc	+4.58 Vdc	+3.81 Vdc	0
Shunt Z3	+0.62 mv	+0.20 mv	+0.20 mv	+0.50 mv	+2.40 mv	+2.60 mv			+2.90 mv	+3.40 mv	0
Anode I	+0.314a	+0.10a	+0.10a	+0.25a	+1.2a	+1.3a			+1.45a	+1.7a	
Anode R	29.59	49.80	50.50	20.00	4.00	3.87			3.16	2.24	
RC4A	-160.2 mv	-170.2 mv	-192.0 mv	-168.0 mv	-197.0 mv	-235.6 mv	-180.0 mv	-163.0 mv	-224.0 mv	-210.0 mv	-193.0 mv
RC4B	-301 mv	-199.8 mv	-121.0 mv	-145.0 mv	-141.0 mv	-188.9 mv	-196.0 mv	-186.0 mv	-217.0 mv	-217.0 mv	-215.0 mv
RP4	-0.5 mv	+0.00 mv	-0.02 mv	+0.06 mv	-0.30 mv	-0.20 mv				-0.04 mv	-0.04 mv
H4	+6.07 v	+2.74 Vdc	+2.84 Vdc	+2.80 Vdc	+4.81 Vdc	+5.49 Vdc	+5.41 Vdc	+4.80 Vdc	+4.91 Vdc	+3.72 Vdc	0
Shunt Z4	+0.75 mv	+0.20 mv	+0.16 mv	+0.18 mv	+2.90 mv	+3.10 mv			+3.00 mv	+3.00 mv	0
Anode I	+0.375a	+0.10a	+0.08a	+0.09a	+1.45a	+1.55a			+1.5a	+1.5a	
Anode R	16.19	27.40	35.50	31.11	3.32	3.54			3.27	2.48	
Depol period	28 da	2 hr	1 min		4 hr		4 hr	4 hr	4 hr		4 hr
RC1A depol	8 mv	9.5 mv	2.0 mv		(-)0.1 mv	(-)1.9 mv	95.0 mv	(-)12.0 mv	6.0 mv		117.0 mv
RC1B depol	62 mv	5.5 mv	(-)16.0 mv		0.0 mv	(-)5.2 mv	32.0 mv	1.0 mv	3.0 mv		131.0 mv
RC2A depol	9 mv	0.8 mv	1.0 mv		0.0 mv	(-)5.9 mv	12.0 mv	6.0 mv	(-)5.0 mv		143.0 mv
RC2B depol	32 mv	8.4 mv	(-)14.0 mv		1.0 mv	(-)7.8 mv	20.0 mv	5.0 mv	(-)4.0 mv		179.0 mv
RC3A depol	8.5 mv	4.9 mv	1.0 mv		61.5 mv	68.0 mv	63.0 mv	56.0 mv	75.0 mv		160.0 mv
RC3B depol	8.8 mv	12.4 mv	(-)43.0 mv		113.3 mv	172.4 mv	144.0 mv	146.0 mv	68.0 mv		102.0 mv
RC4A depol	38.6 mv	11.5 mv	12.0 mv		90.5 mv	85.1 mv	72.0 mv	65.0 mv	106.0 mv		162.0 mv
RC4B depol	66 mv	52.1 mv	73.0 mv		76.3 mv	60.0 mv	72.0 mv	66.0 mv	83.0 mv		130.0 mv

Appendix D

New Hampshire DOT chloride analysis report,

Bridge numbers 109/144, 109/145, RT 114,

Bridge numbers 084/160, 085-161, Hominy Pot Rd.

Chloride Results								
Bridge # Sample	**Br Location**	**Horizon mm**	**Lab#**	**Weight, gr**	**End Point, ml**	**Cl, %**	**Cl, ppm**	**Cl, lb/yd3**
BR#084-160 SB Ls	Hominy Pot Rd	26	2-1	3.0076	10.00	0.11	1073	4.20
BR#084-160 SB Ls	Hominy Pot Rd	44	2-2	3.0057	9.20	0.09	940	3.68
BR#085-161 NB Ls	Hominy Pot Rd	20	1	3.0032	5.85	0.04	383	1.50
BR#085-161 NB Ls	Hominy Pot Rd	40	2	2.9984	6.55	0.05	501	1.96
BR#085-161 NB Ls	Hominy Pot Rd	45	3	2.8811	7.20	0.06	634	2.48
BR#085-161 NB Hs, S5 W20	Hominy Pot Rd	21	2-3	3.0026	18.20	0.24	2440	9.55
BR#085-161 NB Hs		42						8.03
BR#109-144 SB Ls Z1	Rt 114	15	2-4	3.0014	7.80	0.07	708	2.77
BR#109-144 SB Ls Z1	Rt 114	23	2-5	3.0096	6.70	0.05	524	2.05
BR#109-144 SB Ls Z1	Rt 114	32	2-6	3.0039	5.25	0.03	284	1.11
BR#109-144 SB Hs Z2	Rt 114	18	2-7	3.0046	19.70	0.27	2688	10.52
BR#109-144 SB Hs Z2	Rt 114	39	2-8	3.0041	17.50	0.23	2322	9.09
BR#109-145 NB Hs Z3	Rt 114	15	4	3.0010	35.70	0.54	5356	20.97
BR#109-145 NB Hs Z3	Rt 114	25	5	3.0034	33.90	0.51	5052	19.78
BR#109-145 NB Hs Z3	Rt 114	45	2-11	3.0028	34.50	0.52	5153	20.17
BR#109-145 NB Ls Z4	Rt 114	25	2-9	3.0032	9.10	0.09	924	3.62
BR#109-145 NB Ls Z4	Rt 114	42	2-10	3.0027	8.80	0.09	875	3.42

Appendix E

New Hampshire DOT bridge project number 14511 summary,

NHDOT I89 Bridge Summary					511.02	511.03	512.0201	520.01	520.02					
10/14/2009					Partial	Full Dept			Full Dept			%	%	
2-4-2010, 6-26-2015 Rev				Deck	Concrete	Concrete	Concrete	Concrete	Concrete	Total	Total	Removal	Replaced	Cl
Bridge #	Ph	Len	Width	Area	Removal	Removal	Prep	Replaced	Replaced	Removed	Replaced	Per Deck	Per Deck	lb/Cy
				SF	SY	SY	SY	CY	CY	SY	CY	SY	CY	
255/163 SBHs	1	51.25	18.63	955	24.83			2.90		24.83	2.90	2.60	0.30	
255/163 SBLs	2	51.25	18.63	955	19.40			1.60		19.40	1.60	2.03	0.17	
255/164 NBHs	1	51.25	18.63	955	1.60	10.30		0.73	6.10	11.90	6.83	1.25	0.72	
255/164 NBLs	2	51.25	18.63	955	6.87	10.30		0.70	7.30	17.17	8.00	1.80	0.84	
166/103 SBHs	1	186.5	27.5	5129	4.87			0.23		4.87	0.23	0.09	0.004	
166/103 SBLs	2	186.5	27.5	5129	5.55			1.96		5.55	1.96	0.11	0.038	
166/104 NBHs	1	156.5	20	3130	15.27			0.47		15.27	0.47	0.49	0.015	
166/104 NBLs	2	156.5	20	3130	18.08	1.67		0.89	0.42	19.75	1.31	0.63	0.042	
164/103 SBHs	1	84.75	20.25	1716	12.16			0.98		12.16	0.98	0.71	0.057	
164/103 SBLs	2	84.75	20.25	1716	15.22			0.47		15.22	0.47	0.89	0.027	
164/104 NBHs	1	84.75	22.25	1886	5.55	15.40		1.94	3.60	20.95	5.54	1.11	0.294	
164/104 NBLs	2	84.75	22.25	1886	25.34	21.43		1.71	5.38	46.77	7.09	2.48	0.376	
192/059 SBHs	1	?	?							0.00	0.00			
192/059 SBLs	2	?	?							0.00	0.00			
191/058 NBHs	1	36.5	18.75	684	33.10			6.10		33.10	6.10	4.84	0.89	
191/058 NBLs	2	36.5	18.75	684	45.44			7.23		45.44	7.23	6.64	1.06	
129/116 SBHs	1	?	?							0.00	0.00			
129/116 SBLs	2	?	?							0.00	0.00			
130/117 NBHs	1	50	19	950	37.37			7.49		37.37	7.49	3.93	0.79	
130/117 NBLs	2	50	19	950	36.00			6.27		36.00	6.27	3.79	0.66	

109/144 Z1 SBLs	2	116	19	2204	49.16			3.75		49.16	3.75	2.23	0.17	10.52
109/144 Z2 SBHs	1	116	19	2204	64.97			4.39		64.97	4.39	2.95	0.20	2.77
109/145 Z3 NBHs	1	116	19	2204	87.50			5.63	0.24	87.50	5.87	3.97	0.27	20.97
109/145 Z4 NBLs	2	116	19	2204	68.08		0.75	3.88	0.22	68.83	4.10	3.12	0.19	3.62
084/160 SBHs	1	44.3	19	842	29.00			3.25		29.00	3.25	3.45	0.39	na
084/160 SBLs	2	44.3	19	842	11.62			1.26		11.62	1.26	1.38	0.15	4.20
085/161 NBHs	1	44.3	19	842	26.94	5.98		2.60	1.33	32.92	3.93	3.91	0.47	9.55
085/161 NBLs	2	44.3	19	842	14.95		2.34	1.57		17.29	1.57	2.05	0.19	2.48
124/058		82	38.5	3157	Full Deck			Full Deck				100.00	100.00	
124/059		82	38.5	3157	Full Deck			Full Deck				100.00	100.00	

Appendix F

New Hampshire DOT Sutton Bridge project concrete mix data,

Sutton	I-IR-89-1(152)29	10093	940-87
Project	Federal No.	State No.	Lab. No.

STATE OF NEW HAMPSHIRE
DEPARTMENT OF TRANSPORTATION
BUREAU OF MATERIALS AND RESEARCH
CONCRETE MIX DESIGN

Report to X Engineer D. Digilio X Lab. Slump: 1" - 1 1/2 Inches
X Other Henniker R. M. Slump: 5-7 In. After High Range WRA
S. Dane

Non-Vibrated Vibrated Air Entrained

Type of Mix: Class X AA A B C T P Max. Water/bag cement 4.1 gals.
Source of Fine Aggregate Construction Aggregate - Henniker
Source of Coarse Aggregate Construction Aggregate - Henniker
Type of Coarse Aggregate X Gravel Rock Chem. Admix. Req. High Range Water Reduced WRA OR RETARDER

Size of Coarse Aggregate	#8-3/8			
Fine Aggregate: F.M.	2.92	Absorption	.70%	
Sp. Gr. (Sat. Surf. Dry)	2.66	Solid Wt. (lbs./c.f.(A)	166.0	
Coarse Aggregate: Rodded Weight (C)	98.6	Absorption	.71%	
Sp. Gr. (Sat. Surf. Dry)	2.73	Solid Wt. lbs./c.f. (B)	170.3	
Vol. Cse. Aggr. per Vol. of Conc.=b/bo=	.45	x27=(D)	12.15	c.f.
Wt. Cse. Aggr. per Yd. of Conc.=(D)	12.15	x(C) =(E)	1198	lbs.
Solid Vol. of Cse. Aggr.=(E)	1198	(B) =	7.03	c.f.
Solid Vol. of Cement=	8.75	bags x 0. 478 =	4.18	c.f.
Solid Vol. of Water=	35.6	gals. 7.5=	4.75	c.f.
Volume of Air=	.080	% x 27 =	2.16	c.f.
Total Solid Volume except Sand = (F)			18.12	c.f.
Solid Vol. of Sand = 27 - (F)	18.12=(G)		8.88	c.f.
Weight of Sand = (G)	8.88 x(A)	166.0 = 1474 lbs./cu. yd.		
Ratio of Sand to Total Aggr.	55 Corrected to 50	% by wt, Yield Adj. to Design Mi:		

BATCH WEIGHTS PER CU. YD.

Cement	823	
Coarse Aggregate	1385	#8-3/8
Coarse Aggregate		3/8-3/4
Coarse Aggregate		3/4-1 1/2
Fine Aggregate	1385	
Total Water	35.6	gal. cu. yd.
Wet Density	144	lbs./c.f.

Moisture content of Fine Aggregate and Coarse Aggregate should be determined and adjusted prior to batching. Total weight of S.S.D. Fine and Coarse Aggregates remains constant.

Respectfully [signature] Concrete Supervisor

Respectfully [signature] Chief of Materials Technology

6/11/87 Date Reported