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14. Supplementary Notes

15. Abstract

Objective
The main goal of the monitoring activities was to determine if partial replacement of Portland cement with an optimized quantity of locally available fly ash or GGBFS can extend the service life of bridge structures.

Scope
These bridges are being monitored for corrosion of the reinforcing steel, chloride penetration into the concrete, and temperature changes in the top five inches of the concrete deck.
A Gecor 6 instrument was used to measure corrosion rate and concrete resistivity four times each year. Stainless steel inserts connected to the rebar were cast into the bridge deck to facilitate the Gecor 6 measurements. Temperature was measured on a continuous basis using cast-in-place thermocouples. Chloride was measured by collecting concrete samples from the decks at various depths and analyzing for the chloride content.

Summary
Based on some of the results obtained, it appears that the concrete that contained the mineral admixtures did perform better than the plain concrete. The chloride data in particular indicates that after the first year of the project, the plain concrete consistently contained the highest chloride levels at 0.5, 3 and 5 inches of depth into the deck. The Icorr corrosion measurements indicated a similar trend, however the differences in the Icorr values were fairly small and the values clearly showed that all three decks were in a passive condition at all locations where the measurements were collected. The temperature data collected indicated that all the bridges experienced similar numbers of freeze/thaw cycles during the project, so it can be concluded that freeze/thaw effects were not a major variable in terms of the overall performance of the three bridge decks.

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UNIVERSITY OF NORTH DAKOTA
Grand Forks, ND

Bridge Monitoring Project - Final Report

Submitted to:
North Dakota Department of Transportation

By:
Dr. Charles Moretti

October 2008

(Revised October 2009)

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT	EXPERIMENTAL PROJECT NO. 1 STATE: ND YEAR: 2008 - NUMBER: SURF:	CONSTRUCTION PROJ NO 8 SPR-R025(001)	LOCATION 28 CASS
	EVALUATION FUNDING 48 1 HP&R 3 DEMONSTRATION 2 CONSTRUCTION 4 IMPLEMENTATION	NEEP NO. 49	PROPRIETARY FEATURE? X Yes 51 No
SHORT TITLE	TITLE 52 Bridge Monitoring Project – Final Report		
THIS FORM	DATE 140 MO. October -- YR. 2008	REPORTING 1 INITIAL 2 ANNUAL 3 X FINAL	
KEY WORDS	KEY WORD 1 145 Bridge deck	KEY WORD 2 167 Corrosion	
	KEY WORD 3 189 Chloride	KEY WORD 4 211	
	UNIQUE WORD 233	PROPRIETARY FEATURE NAME 255	

CHRONOLOGY	Date Work Plan Approved	Date Feature Constructed:	Evaluation Scheduled Until:	Evaluation Extended Until:	Date Evaluation Terminated:
	277 June 2000	281 Summer 2002	285 June 2008	289	293 June 2008

QUANTITY AND COST	QUANTITY OF UNITS (ROUNDED TO WHOLE NUMBERS)	UNITS	UNIT COST (*Dollars, Cents*)
	297 1	305 1 LIN. FT 2 SY 3 SY-IN 4 CY 5 TON 6 LBS 7 EACH 8 X LUMP SUM	306 $119,171.00

AVAILABLE EVALUATION REPORTS	CONSTRUCTION	PERFORMANCE	FINAL
	315		X

EVALUATION	CONSTRUCTION PROBLEMS	PERFORMANCE
	318 1 NONE 2 SLIGHT 3 X MODERATE 4 SIGNIFICANT 5 SEVERE	319 1 EXCELLENT 2 X GOOD 3 SATISFACTORY 4 MARGINAL 5 UNSATISFACTORY

APPLICATION	
320	1 X ADOPTED AS PRIMARY STD. 2 PERMITTED ALTERNATIVE 3 ADOPTED CONDITIONALLY 4 PENDING 5 REJECTED 6 NOT CONSTRUCTED *(Explain in remarks if 3, 4, 5, or 6 is checked)*

REMARKS	
321	The corrosion rate and concrete resistivity measurements did not generate any strong conclusions. The chloride analyses indicated that the concrete with admixtures performed better than the plain concrete. The temperature data showed similar freeze/thaw cycles and was not considered a variable in the performance of the bridges.

Disclaimer

The contents of this report reflect the views of the author or authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not reflect the official views of the North Dakota Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Executive Summary

This report summarizes the results of corrosion monitoring activities carried out at three bridges on I-29 in Fargo, North Dakota. The areas being monitored are south bound spans on the 9^{th} Avenue South Bridge, the Texas Turn Bridge, and the 17^{th} Avenue South Bridge. All three bridges are located just north of the point where I-29 intersects I-94. These bridges are being monitored for corrosion of the reinforcing steel, chloride penetration into the concrete, and temperature changes in the top five inches of the concrete deck. The bridge decks were constructed in summer of 2002 and this report contains the results of various monitoring activities conducted from then until June 2008.

A Gecor 6 instrument was used to measure corrosion rate and concrete resistivity four times each year. Stainless steel inserts connected to the rebar were cast into the bridge deck to facilitate the Gecor 6 measurements. Temperature was measured on a continuous basis using cast-in-place thermocouples. Chloride was measured by collecting concrete samples from the decks at various depths and analyzing for the chloride content.

The main goal of the monitoring activities was to determine if partial replacement of Portland cement with an optimized quantity of locally available fly ash or GGBFS can extend the service life of bridge structures. Some general information about the locations of the bridges and the instrumentation is contained in the following table.

Locations of Monitoring Instruments on I–29 Bridges in Fargo, North Dakota

Bridge Name	Overpass Location	General Location of Instruments	Type of Cement Replacement Used for Deck	Bridge Deck Construction Date
9th Avenue South Overpass	I–29, Southbound	Reference Point 064.555	None	6/27/02
Texas Turn Overpass	I–29, Southbound	Reference Point 064.129	Fly Ash (38% by wt.)	8/01/02
17th Avenue South Overpass	I–29, Southbound	Reference Point 064.788	GGBFS (35% by wt.)	7/19/02

The following types of cementitious materials were used for the bridge decks:

- The portland cement was Lafarge Type I/II, supplied from Exshaw, Alberta Canada.
- The fly ash was Type C from the Coal Creek Station in Underwood, North Dakota.
- The GGBFS was Holcim GranCem 100, from the Skyway Terminal in Chicago, Illinois.

The concrete mix design requirements for the three bridge decks are summarized below.

Concrete Mix Design Requirements for the Bridge Decks

	17th Avenue S.	Texas Turn	9th Avenue S.
Cementitious Material (lb./cy)	611	611	611
Portland Cement (lb./cy)	397	379	611
Fly Ash (lb./cy)	0.0	232	0.0
GGBFS (lb./cy)	214	0.0	0.0
Coarse Aggregate Size	No.3	No.3	No.3
Max. Water/Cement (gals./sack)	5.41	5.00	5.00
Max. w/c Ratio	0.480	0.443	0.443
Air Content (%)	5.0 – 8.0	5.0 – 8.0	5.0 – 8.0
Max. Slump (inches)	3	3	3
Design 28-Day Comp. Strength (psi)	4000	4000	4000

The results of chloride analyses done on the concrete samples taken from the bridges indicated that chloride levels are increasing over time in the top five inches of the decks. As expected, the highest chloride levels were found in the top 0.5 inches. However there were also measurable increases in chloride levels at depths of 3 and 5 inches into the deck. In general, the highest chloride levels were measured for the 9th Avenue Bridge, the next highest chloride levels were measured for the 17th Avenue Bridge, and the lowest chloride levels were measured for the Texas Turn Bridge. The Texas Turn Bridge was the only one of the three where the average chloride level in the concrete was below 1.0 lb/cu.yd. at a depth of 5 inches in the most recent (August 2007) samples. (See Figure 9 on page 35 of this report.)

Based on the Icorr corrosion rate measurements, it appears that all of the rebar at the locations tested on the three bridge decks were in a passive (non-corroding) condition as of July 2008. The Icorr measurements are roughly in line with the chloride measurements in terms of which bridges exhibited the higher corrosion potential. The 9th Avenue Bridge generally produced the highest Icorr readings and the Texas Turn Bridge produced the lowest readings. However, since the differences in the Icorr values measured for the three bridges were not very large and all of the decks were in a passive condition, it is difficult to draw any strong conclusions from the Icorr data when comparing the relative corrosion rates in the three decks.

The concrete resistivities measured on the three decks varied widely. Some of the values were in the range from 10 to 50 kΩ cm, which indicates moderate to high corrosion potential when the steel is not in a passive condition. It should be noted however that these resistivity measurements do not indicate that the rebar is in danger of corroding, because the corresponding Icorr measurements showed that the rebar was in a passive condition.

The numbers of freeze/thaw cycles that occurred at various depths in each bridge deck were estimated from the temperature data collected. The data was collected at three locations in the far left traffic lane and three locations close to the jersey barrier on each bridge deck. In general, more freeze thaw cycles occurred in the traffic lane as compared to the areas closer to the jersey barrier, and more freeze thaw cycles occurred closer to the surface of the concrete deck (i.e., 0.5 inches below the surface) as compared to points deeper in the deck (i.e., 3 inches and 5 inches below the surface). The results show that the number of freeze/thaw cycles that occurred in the decks varied significantly from year to year. However, comparing results within the same year suggests that there is no clear trend to indicate that any one of the bridges consistently experienced more freeze/thaw cycles than the others.

One of the key questions that this project sought to answer was whether the addition of fly ash or GGBFS to the concrete reduced the rate of intrusion of environmental contaminants such as chloride. Based on some of the results obtained, it appears that the concretes containing the mineral admixtures did perform better than the plain concrete. The chloride data in particular indicates that after the first year of the project, the plain concrete consistently contained higher chloride levels at 0.5, 3 and 5 inches of depth into the deck. The Icorr corrosion measurements indicated a similar trend, however the differences in the Icorr values were fairly small and the values clearly showed that all three decks were in a passive condition at all locations where the measurements were collected. The temperature data collected indicated that all the bridges experienced similar numbers of freeze/thaw cycles during the project, so it appears that freeze/thaw cycles were not a major variable in terms of the overall performance of the three bridge decks.

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1.0 Introduction

This report summarizes the results of corrosion monitoring activities carried out at three bridges on I-29 in Fargo, North Dakota. The areas being monitored are south bound spans of the 9th Avenue South Bridge, the Texas Turn Bridge, and the 17th Avenue South Bridge. All three bridges are located just north of the point where I-29 intersects I-94. These bridges are being monitored for corrosion of the reinforcing steel, chloride penetration into the concrete, and temperature changes in the top five inches of the concrete deck. The bridge decks were constructed in summer of 2002 and this report contains the results of various monitoring activities conducted from then until June 2008.

2.0 Background

A major cause of deterioration of reinforced-concrete bridges is corrosion of the steel reinforcement caused by penetration of moisture and chloride into the concrete matrix. Corrosion reduces the cross-sectional area of the steel, which decreases the stiffness and strength of the structure. The rust formed as the steel corrodes can also cause the concrete to crack, due to expansive forces inside the concrete. In many cases, the damaging chloride comes from deicing salt used for controlling snow and ice on the bridge deck. Since use of deicing salts is likely to continue, it is important that new bridges be designed to be resistant to chloride-induced corrosion. This can be accomplished by preventing chloride from reaching the surface of the reinforcing steel or by making the reinforcing steel resistant to corrosion.

The NDDOT requires the use of epoxy coated reinforcing steel in bridge decks to help prevent corrosion. Coating the steel with a protective layer is an excellent means of preventing corrosion, but it does not prevent the movement of moisture and chloride from the deck surface to the reinforcing steel. Thus, if and when the protective layer breaks down, the steel may be vulnerable to attack.

To help restrict the movement of moisture and chloride through the concrete, researchers must find an acceptable concrete mix design that will lower the permeability of the concrete with no loss in strength. Lowering the permeability of the concrete has several beneficial effects. Since chloride usually has to be dissolved in water in order to migrate through the concrete matrix, restricting the movement of water will also help to restrict the movement of chloride. Moisture penetration is also a major cause of cracking in concrete. Cracks form when moisture in the pores of the concrete freezes and expands. Thus, by reducing the permeability of the concrete, moisture intrusion into the pores is restricted and freeze/thaw cracking is reduced.

One method of lowering the permeability of concrete is to utilize mineral admixtures such as fly ash or ground granulated blast furnace slag (GGBFS) in the concrete mix design. For this research, three highway bridge decks were constructed in Fargo, North Dakota to evaluate the use of mineral admixtures for reducing corrosion and other types of deterioration related to moisture penetration. One of the decks was made with conventional Portland cement concrete (i.e., concrete that did not contain any mineral admixtures), one was made with a modified concrete containing GGBFS, and one was made with a modified concrete containing fly ash. These bridges were monitored to evaluate corrosion of the reinforcing steel, chloride content in the concrete, and freeze/thaw frequency. To do the monitoring, the decks were constructed with instruments embedded in the concrete to measure the temperature and also to determine corrosion rates in the reinforcing steel. Additionally, samples were extracted to determine the chloride ion concentration in the concrete deck. The results of these tests were used to determine if the durability of the concrete was enhanced by the addition of the mineral admixtures.

2.1 Causes of Corrosion in Concrete

Corrosion of steel reinforcement (i.e., rebar) in concrete bridges is an electrochemical process, similar to what happens in a battery. Corrosion results from a flow of electrons between anodic and cathodic sites on the rebar. In order for corrosion to proceed, the anode and the cathode must be connected by an electron conductor. The rebar usually serves as the conductor. There must also be an electrolyte present and in contact with the rebar to complete the electrochemical circuit. The electrolyte is a medium capable of conducting electric current by ionic current flow. Environmental constituents such as chloride and oxygen can establish a suitable electrolyte solution within the concrete matrix when they penetrate the concrete along with moisture. (1)

Reinforcing steel in concrete does not corrode extensively under normal conditions due to the formation of a surface film of iron oxide. The highly alkaline environment (i.e., pH >12) normally found within the concrete matrix stabilizes the oxide film on the surface of the rebar and tends to prevent further corrosion as long as the alkaline environment exists. When the protective iron oxide film remains intact on the surface of the steel, the rebar is said to be in a passive condition. However, there are two commonly occurring situations that promote the corrosion of rebar in concrete. These are carbonation and chloride contamination.

Carbonation is a process by which carbon dioxide from the air moves into the concrete matrix and neutralizes the alkalinity. Carbonation can reduce the pH within the concrete to 8 or 9. At this pH, the protective iron oxide film on the rebar is no longer stable. When the

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1. Article abstracted from Corrosion Protection Association monograph, Primary author: Paul Lambert, at www.azom.com/details.asp?articleID=1318

protective iron oxide film breaks down, the surface of the steel is exposed to the surrounding concrete matrix. If an adequate supply of oxygen and moisture exist at the exposed surface of the rebar, corrosion will occur. Carbonation is usually a slow process that is controlled by the rate at which carbon dioxide can penetrate into the concrete. The rate of carbon dioxide penetration is controlled by the porosity and permeability of the concrete.

Chloride ions also cause corrosion by disrupting the passive iron oxide film on the reinforcing steel. Two major sources of chloride contamination to concrete are from deicing salts or from seawater in marine environments. Other sources include certain concrete admixtures, contaminated aggregates, contaminated mixing water, air-born salts, and salts in ground water. The chloride concentration required to initiate corrosion in concrete is relatively low. Field experience and research have shown that on existing structures exposed to chloride ions, a threshold concentration of about 0.026% (by weight of concrete) is sufficient to break down the passive film and initiate corrosion on the reinforcing steel. This chloride concentration equates to 260 parts per million or about 1.0 lb/ cu.yd. of concrete.(2) Another reference indicates that a chloride content of 1.5 lb/cu.yd. would actively support corrosion.(3) The porosity and permeability of the concrete are important factors relating to the penetration of chloride into the concrete.

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2. Steven F. Daily, "Understanding Corrosion and Cathodic Protection of Reinforced Concrete Structures," Corrpro Company, Concrete Services Group, 1055 West Smith Road, Medina, Ohio 44256.

3. Richard Kessler, SHARP PRODUCT 2001: "Corrosion Rate Based on Polarization Resistance," http://leadstates.tamu.edu/car/shrp_products/2001.stm

In summary, the factors that determine the corrosion rate of steel in concrete are, (1) the condition of the passive oxide film on the steel; (2) the presence of ionically conducting pore water (i.e., an electrolyte) in contact with the steel; (3) the existence of anodic and cathodic sites on the steel in contact with the electrolyte; and (4) the availability of oxygen to enable the corrosion to proceed. The permeability of the concrete is also an important factor in determining how rapidly external substances can enter the concrete to support the corrosion.

2.2 Methods of Monitoring Corrosion in Concrete

Four methods were used to monitor corrosion in concrete bridge decks for this research. These included measurement of steel corrosion rate, concrete resistivity, concrete chloride content, and temperature in the concrete. A Gecor 6 instrument was used to measure corrosion rate and concrete resistivity four times each year. Stainless steel inserts connected to the rebar were cast into the bridge deck to facilitate the Gecor 6 measurements. Temperature was measured on a continuous basis using cast-in-place thermocouples. Chloride was measured by collecting concrete samples from the decks at various depths and analyzing the chloride content.

The Gecor 6 instrument measures the corrosion rate in the rebar using the linear polarization resistance (LPR) technique. It has been established with laboratory studies that corrosion current is linearly related to polarization resistance. The LPR measurement is done with a central reference electrode, surrounded by an external counter electrode. A guard ring and external electrode system confines the area of the rebar tested. [4]

4. "Rebar Corrosion and Its Effects," NDT James Instruments Inc., at www.ndtjames.com.

The Gecor 6 gives the corrosion rate (Icorr), which is a quantitative measurement of the amount of steel turning into oxide at the time of the measurement. Icorr is defined by the following equation:

$$Icorr = B/R_p$$

Where: R_p is the polarization resistance. R_p is defined as the change in potential, as measured by Gecor 6, divided by the applied current. And B is a constant equal to 26 mV.

In general, the higher the measured Icorr values, the higher the corrosion rate. Gecor 6 measurements should be taken at strategic locations. Corrosion rates will vary depending on conditions such as concrete moisture content, chloride concentration, and temperature. Thus measurements should be carried out over time in order to obtain average Icorr values.

Since corrosion is an electrochemical process, an ionic current must flow through the concrete for corrosion of the rebar to occur. The electrical resistivity of the concrete affects the ionic flow and the rate at which corrosion can occur. In general, a high concrete resistivity restricts the current flow. Conversely, a low concrete resistivity can cause an increased corrosion rate when steel rebar is not in a passive condition. Concrete resistivity is related to the moisture content, pore structure, and composition of the concrete.

Concrete resistivity is also measured with the Gecor 6. Concrete resistivity is defined with the following formula:

$$Resistivity = 2 \times R \times D$$

Where: R is the electrical resistance of a pulse between the counter-electrode and the rebar network. And D is the diameter of the counter-electrode.

Temperature has competing effects on corrosion rate. Oxidation of steel increases as the amount of available heat energy increases. In this respect, increased temperature tends to increase corrosion rate. However, relative humidity also tends to decrease with increasing temperature. Thus increased temperature can tend to decrease corrosion rate, since relative humidity influences the amount of moisture present in the concrete pores to sustain the corrosion reaction. Air temperature and relative humidity were both measured with the Gecor 6 when corrosion rate measurements were being taken.

Measuring the chloride ion content in the concrete is important because it indicates the ionic strength of the electrolyte provided by the pore water. Samples of powdered concrete were collected at various locations and depths on the bridge decks. The samples were obtained by drilling into the concrete and collecting the drill dust. Most of the samples were analyzed by the NDDOT for chloride ion content using the procedures contained in AASHTO T 260-97 (Procedure A Chloride content).

Evaluating the physical condition of the concrete is also an important activity for monitoring corrosion potential. The presence of cracks in the bridge deck may create routes for rapid entry of moisture, chloride, and oxygen; which promote the corrosion reactions. Since temperature change and associated freeze/thaw activity is a major cause of crack formation in concrete, the temperature in the top five inches of the bridge decks was continuously measured to estimate the numbers of freeze/thaw cycles occurring. In addition, visual examination of the concrete was done to detect the presence of cracks on the surface of the decks.

3.0 Experimental Procedures

3.1 Bridge Deck Construction

During the summer of 2002, instruments were placed in the decks of three bridges being constructed on southbound I-29 in Fargo, North Dakota. The instruments were used to monitor corrosion rates in the reinforcing steel and temperature changes in the concrete bridge decks. The goal of the monitoring activities was to determine if partial replacement of Portland cement with an optimized quantity of locally available fly ash or GGBFS can extend the service life of bridge structures. Some general information about the locations of the bridges and the instrumentation is contained in Table 1.

Table 1: Locations of Monitoring Instruments on I–29 Bridges in Fargo, North Dakota

Bridge Name	Overpass Location	General Location of Instruments	Type of Cement Replacement Used for Deck	Bridge Deck Construction Date
9th Avenue South Overpass	I–29, Southbound	Reference Point 064.555	None	6/27/02
Texas Turn Overpass	I–29, Southbound	Reference Point 064.129	Fly Ash (38% by wt.)	8/01/02
17th Avenue South Overpass	I–29, Southbound	Reference Point 064.788	GGBFS (35% by wt.)	7/19/02

The following types of cementitious materials were used for the bridge decks:

- The portland cement was Lafarge Type I/II, supplied from Exshaw, Alberta Canada.
- The fly ash was Type C from the Coal Creek Station in Underwood, North Dakota.
- The GGBFS was Holcim GranCem 100, from the Skyway Terminal in Chicago, Illinois.

The concrete mix design requirements for the three bridge decks are summarized in Table 2.

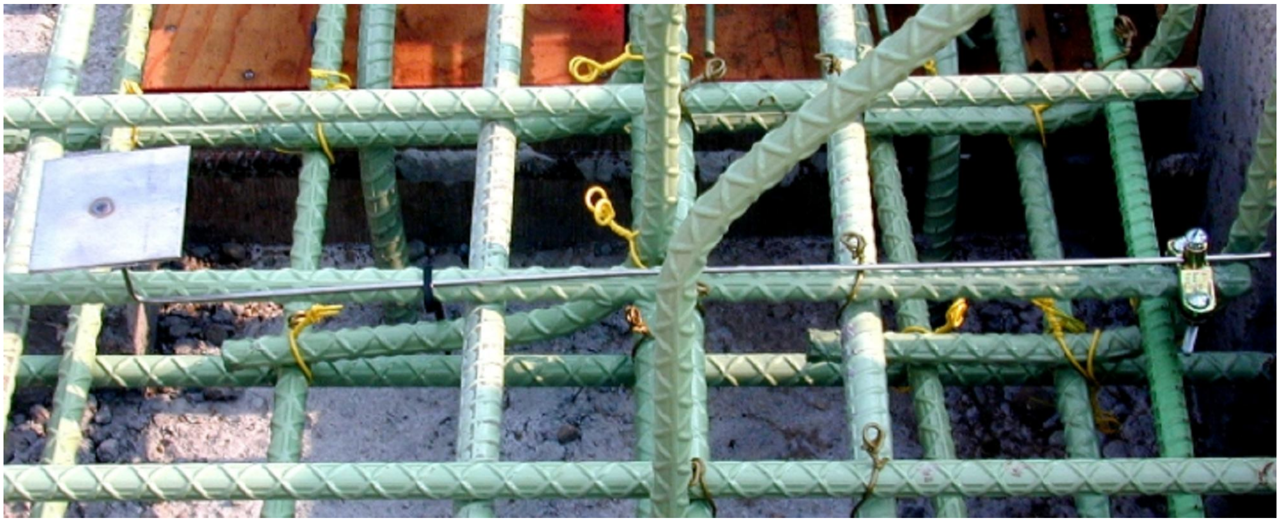
Table 2: Concrete Mix Design Requirements for the Bridge Decks

	17th Avenue S.	Texas Turn	9th Avenue S.
Cementitious Material (lb./cy)	611	611	611
Portland Cement (lb./cy)	397	379	611
Fly Ash (lb./cy)	0.0	232	0.0
GGBFS (lb./cy)	214	0.0	0.0
Coarse Aggregate Size	No.3	No.3	No.3
Max. Water/Cement (gals./sack)	5.41	5.00	5.00
Max. w/c Ratio	0.480	0.443	0.443
Air Content (%)	5.0 – 8.0	5.0 – 8.0	5.0 – 8.0
Max. Slump (inches)	3	3	3
Design 28-Day Comp. Strength (psi)	4000	4000	4000

3.2 Bridge Deck Instrumentation

To allow the use of the Gecor 6 corrosion field test instrument, electrical contacts were attached directly to the rebar close to the points where the corrosion rate measurements were to be taken. To monitor the bridges, fifteen contacts were attached to each bridge at approximately equidistant intervals along the east edge of the deck. Each contact consisted of a stainless steel rod attached to a small square stainless steel plate. The rod was attached directly to the rebar and the plate was set level with the deck surface so that it could be accessed for the Gecor 6. When the contact was attached to the rebar, a clamp was used to penetrate the epoxy coating and make electrical contact with the steel reinforcing bar. A picture of a contact attached to the deck rebar is shown in Figure 1.

Figure 1: Stainless Steel Contact Attached to Bridge Deck Rebar



When a Gecor 6 corrosion measurement was taken on a bridge, an electrical lead from the Gecor 6 was attached to the contact plate on the bridge deck and another probe was placed on the concrete over the rebar connected to the contact. All of the contacts were connected to rebar that run transverse to the length of the deck. To take a measurement, the Gecor 6 probe was placed at least four inches away from the contact plate on a line with the plate and perpendicular to the jersey barrier. The probe was placed on the side of the plate away from the jersey barrier. When a measurement was taken with the Gecor 6, the diameter of the rebar was used for the corrosion rate calculation. The following rebar diameters were used for the corrosion calculations:

- 9th Ave. South – 5/8 inch diameter rebar
- Texas Turn – 3/4 inch diameter rebar
- 17th Ave. South – 5/8 inch diameter rebar

Temperature monitoring equipment was installed in the bridge decks to record changes in concrete temperature over time. Six sets of thermocouples were installed at various points on each of the three bridge decks. Two sets of thermocouples were installed over the abutment at the north end of the deck; one set was in the shoulder of the deck close to the jersey barrier and the other set was in the east lane approximately 22 feet from the jersey barrier. Two sets of thermocouples were installed at the midpoint of the span length, and two sets at the south end of the span over the north pier. The general locations of the thermocouples on each deck are shown in Figure 2. (See Table 14 on page 38 for the exact locations of the thermocouples.) Each set consisted of three thermocouples placed at depths of 0.5 inch, 3 inches, and 5 inches below the surface of the concrete. Two redundant thermocouples were installed at each depth in case one was damaged during construction. A picture of the thermocouple arrangement is shown in Figure 3.

Each Teflon-insulated thermocouple is attached to a wire that runs through a conduit to a data collection apparatus located below the bridge deck. The data logger is an Omega OM-320 microprocessor equipped with an Omega OM-320-HLIM-1 analog interface module. The data logger is capable of storing > 32,000 data points. Each data logger is housed in a steel box attached to a bridge pier, and a 100-watt heater is installed in the storage box to protect the equipment from cold temperatures. The temperature collecting equipment is still in place and operating at the bridges. Each of the units probably has enough memory left to continue collecting data until fall of 2008.

Figure 2: General Location of Thermocouples on Bridge Deck

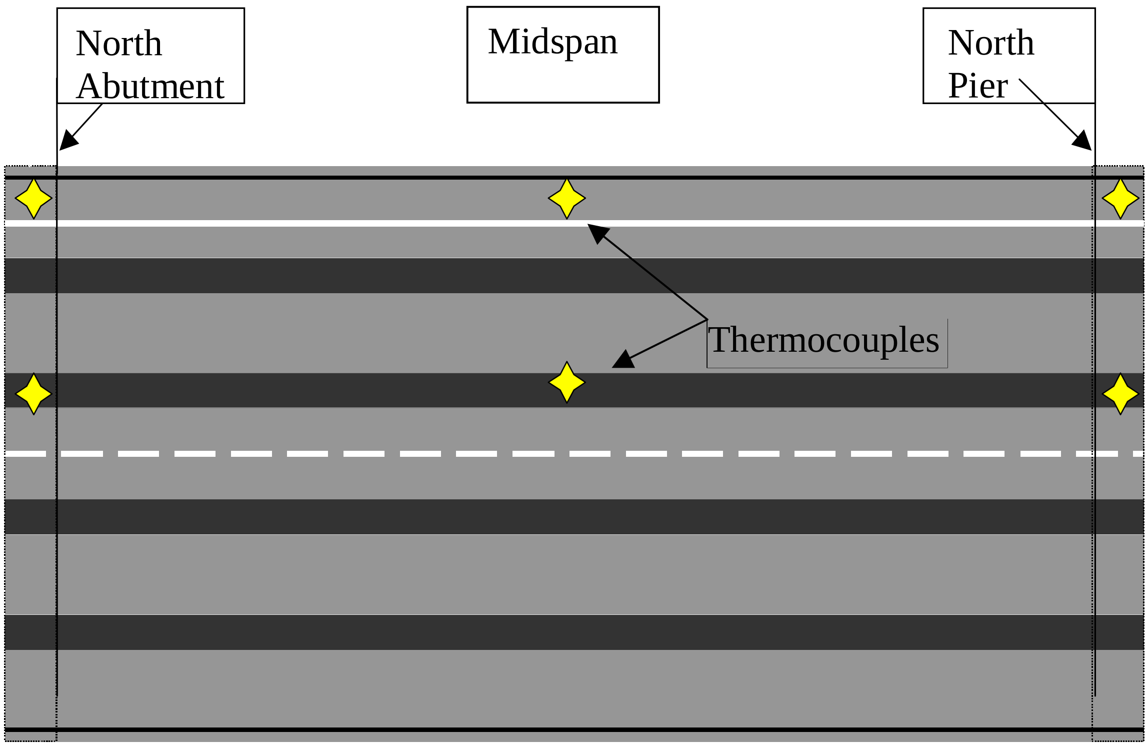


Figure 3: Arrangement of Redundant Thermocouples

The data collection systems are programmed to take temperature readings in degrees Fahrenheit from the eighteen points where thermocouples are inserted in each bridge deck. To maximize use of the computer memory in the data loggers, they have been programmed to collect more data as the temperature approaches freezing and as the rate of change of temperature increases. When the temperature is well above freezing, data is collected every half hour from three thermocouples located at a single collection point at midspan in the traffic lane. For the rest of the thermocouples, when the temperature drops to within about five degrees of freezing the data loggers begin to collect data. If the temperature is close to freezing and the rate of temperature change is high, the data logger can collect temperature readings as often as one per minute.

4.0 Results and Discussion

4.1 Corrosion Rate Data

Icorr data obtained with the Gecor 6 meter are a quantitative measure of the amount of steel turning into oxide at the time of measurement. The following broad criteria have been established to interpret corrosion information provided by the Gecor 6:[4]

Icorr less than 0.2 $\mu A/cm^2$	Passive condition
Icorr between 0.2 and 0.5 $\mu A/cm^2$	Low corrosion rate
Icorr between 0.5 and 1.0 $\mu A/cm^2$	Moderate corrosion rate
Icorr greater than 1.0 $\mu A/cm^2$	High corrosion rate

The average Icorr measurements taken on the bridge decks over the past five years are listed in Tables 3, 4 and 5. Measurements were taken at fifteen approximately equal spaced locations on each bridge deck. The locations are numbered 1 through 15, with 1 situated at the north end of the deck and the increasing numbers extending sequentially along the span to the north pier. The locations where the measurements were taken are close to the jersey barrier on the east side of the deck. The sampling plan specified that four Icorr measurements be taken at each location between August and June each year. The values in Tables 3, 4 and 5 are annual averages of measurements taken at the bridges over the past five years. A complete list of the Icorr data collected over the past five years is contained in Appendix A. Air temperature and relative humidity were also recorded on the bridges when the Icorr measurements were taken. The temperature and humidity data corresponding to the various sampling dates are also listed in Appendix A.

All of the Icorr values in Tables 3, 4, and 5 are below 0.2 $\mu A/cm^2$. These results indicate that the rebar at all measurement locations are in a passive (i.e., non-corroding) state. This is reasonable because the decks were only constructed about five years ago and the rebar has an epoxy coating to protect it from corrosion.

The overall corrosion rates for the rebar in the bridge decks were estimated by averaging the Icorr values collected from all locations on the deck for each sampling date. The overall corrosion rates are listed in Table 6 and the values are plotted in Figure 4. The trend lines on Figure 4 were generated by linear regression on the overall data from each bridge. These lines indicate how corrosion is progressing with time. The trend lines suggest that the corrosion rate is slowly increasing with time. This is expected because environmental factors which support corrosion such as moisture, oxygen, and chloride, tend to diffuse deeper into the concrete over time. The general pattern with respect to corrosion rates appears to be that the rate is highest in the 9th Ave. Bridge, next highest the 17 Ave. Bridge, and lowest in the Texas Turn Bridge.

Even though the trend lines in Figure 4 indicate a gradual increase in Icorr values over the five years of the project, some of the highest average values occurred in years three and four. A possible reason for this is that Icorr measurements are influenced by several factors. The most important of these is probably the moisture content of the concrete. Icorr measurements were taken on several occasions after it had rained the night before and it appeared that, at least close to the surface, the concrete had relatively high moisture content. Care was taken not to take measurements when the surface was actually wet, but the moisture below the surface could have influenced the Icorr measurements. The relative humidities recorded in Appendix A give some indication of the moisture conditions when the measurements were taken.

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5 . Protection of Metals in Concrete Against Corrosion, reported by ACI Committee 222, ACI 222R-01, American Concrete Institute, P.O. Box 9094, Farmington Hills, Michigan 48333-9094, 2001.

Table 3: 9th Avenue Bridge – Annual (July through June) Icorr Corrosion Rates
(Values Averaged for Various Measurement Locations on the Bridge Deck)

Measurement Location	July 2003 to June 2004 Ave. ± S.D. (μA/cm²)	July 2004 to June 2005 Ave. ± S.D. (μA/cm²)	July 2005 to June 2006 Ave. ± S.D. (μA/cm²)	July 2006 to June 2007 Ave. ± S.D. (μA/cm²)	July 2007 to July 2008 Ave. ± S.D. (μA/cm²)
9th -1	0.022 ± .008	0.035 ± .029	0.019 ± .011	0.037 ± .016	0.018 ± .020
9th -2	0.022 ± .025	0.024 ± .018	0.030 ± .015	0.044 ± .021	0.032 ± .014
9th -3	0.043 ± .022	0.023 ± .015	0.041 ± .028	0.060 ± .017	0.025 ± .005
9th -4	0.022 ± .016	0.019 ± .013	0.067 ± .061	0.095 ± .144	0.019 ± .011
9th -5	0.030 ± .018	0.032 ± .033	0.048 ± .009	0.078 ± .040	0.034 ± .018
9th -6	0.032 ± .030	0.024 ± .013	0.022 ± .013	0.022 ± .010	0.021 ± .017
9th -7	0.022 ± .012	0.018 ± .013	0.036 ± .018	0.043 ± .042	0.024 ± .007
9th -8	0.030 ± .011	0.029 ± .010	0.046 ± .026	0.031 ± .010	0.031 ± .019
9th -9	0.014 ± .006	0.012 ± .012	0.018 ± .012	0.023 ± .005	0.019 ± .014
9th -10	0.022 ± .019	0.012 ± .013	0.025 ± .014	0.045 ± .002	0.034 ± .017
9th -11	0.006 ± .005	0.013 ± .009	0.033 ± .022	0.047 ± .027	0.030 ± .013
9th -12	0.023 ± .022	0.016 ± .005	0.033 ± .021	0.039 ± .032	0.042 ± .019
9th -13	0.023 ± .024	0.004 ± .003	0.011 ± .009	0.066 ± .072	0.027 ± .006
9th -14	0.023 ± .027	0.016 ± .008	0.016 ± .011	0.070 ± .063	0.016 ± .003
9th -15	0.024 ± .013	0.028 ± .009	0.037 ± .027	0.053 ± .009	0.031 ± .011

Table 4: Texas Turn Bridge – Annual (July through June) Icorr Corrosion Rates (Values Averaged for Various Measurement Locations on the Bridge Deck)

Measurement Location	July 2003 to June 2004 Ave. ± S.D. ($\mu A/cm^2$)	July 2004 to June 2005 Ave. ± S.D. ($\mu A/cm^2$)	July 2005 to June 2006 Ave. ± S.D. ($\mu A/cm^2$)	July 2006 to June 2007 Ave. ± S.D. ($\mu A/cm^2$)	July 2007 to June 2008 Ave. ± S.D. ($\mu A/cm^2$)
TT -1	0.016 ± .006	0.019 ± .004	0.023 ± .028	0.013 ± .003	0.016 ± 0.013
TT -2	0.010 ± .003	0.029 ± .033	0.021 ± .035	0.006 ± .002	0.005 ± .002
TT -3	0.020 ± .013	0.021 ± .006	0.030 ± .027	0.007 ± .003	0.009 ± .005
TT -4	0.013 ± .012	0.007 ± .005	0.005 ± .001	0.010 ± .004	0.012 ± .005
TT -5	0.018 ± .020	0.009 ± .005	0.033 ± .021	0.017 ± .011	0.028 ± .006
TT -6	0.007 ± .005	0.010 ± .007	0.024 ± ND	0.026 ± .027	0.013 ± .002
TT -7	0.016 ± .015	0.010 ± .007	0.03 ± .008	0.017 ± .010	0.011 ± .006
TT -8	0.007 ± .004	0.012 ± .011	0.035 ± .029	0.013 ± .008	0.029 ± .022
TT -9	0.009 ± .005	0.008 ± .004	0.043 ± .019	0.023 ± .022	0.017 ± .007
TT -10	0.014 ± .013	0.012 ± .013	0.023 ± .024	0.010 ± .007	0.006 ± .001
TT -11	0.009 ± .003	0.006 ± .001	0.039*	0.030 ± .021	0.015 ± .011
TT -12	0.018 ± .019	0.011 ± .005	0.135*	0.048 ± .045	0.018 ± .011
TT -13	0.004 ± .003	0.003 ± .002	0.033 ± .013	0.016 ± .009	0.026 ± .034
TT -14	0.011 ± .004	0.013 ± .011	0.035 ± .022	0.018 ± .019	0.014 ± .006
TT -15	0.011 ± .006	0.014 ± .002	0.027 ± .012	0.012 ± .007	0.012 ± .005
	* Only one Icorr value was obtained during the sampling year for this location.				

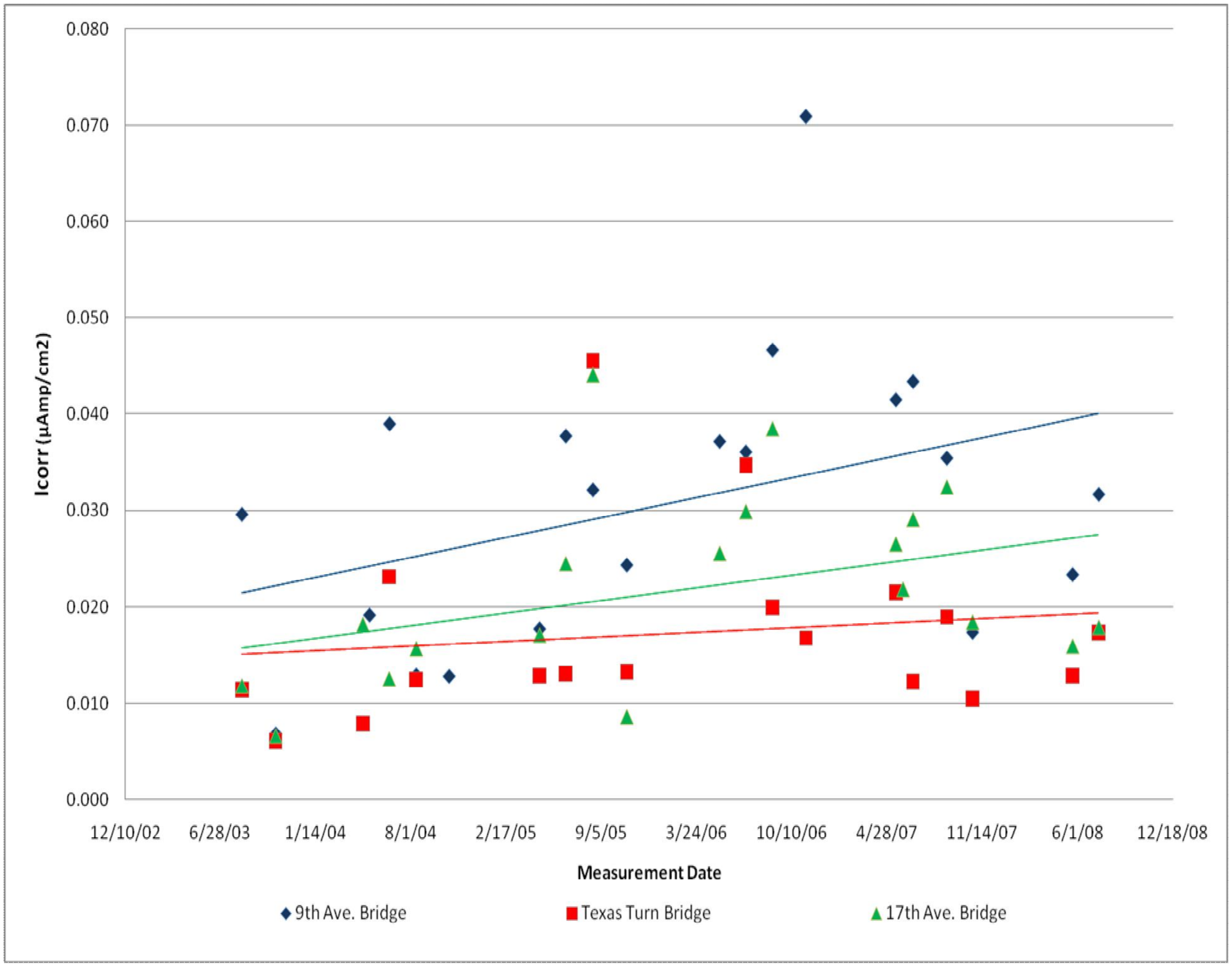
Table 5: 17th Avenue Bridge – Annual (July through June) Icorr Corrosion Rates
(Values Averaged for Various Measurement Locations on the Bridge Deck)

Measurement Location	July 2003 to June 2004 Ave. ± S.D. ($\mu A/cm^2$)	July 2004 to June 2005 0.008 ($\mu A/cm^2$)	July 2005 to June 2006 Ave. ± S.D. ($\mu A/cm^2$)	July 2006 to June 2007 Ave. ± S.D. ($\mu A/cm^2$)	July 2007 to June 2008 Ave. ± S.D. ($\mu A/cm^2$)
17th -1	0.017 ± .013	0.037 ± .021	0.022 ± .014	0.031 ± .021	0.034 ± .020
17th -2	0.021 ± .023	0.017 ± .002	0.033 ± .041	0.041 ± .024	0.016 ± .010
17th -3	0.008 ± .003	0.019 ± .009	0.017 ± .005	0.014 ± .007	0.010 ± .004
17th -4	0.011 ± .005	0.013 ± .007	0.013 ± .008	0.018 ± .007	0.022 ± .008
17th -5	0.010 ± .006	0.012 ± .006	0.020 ± .009	0.035 ± .031	0.0137 ± .010
17th -6	0.009 ± .004	0.011 ± .004	0.025 ± .003	0.032 ± .018	0.020 ± .013
17th -7	0.007 ± .004	0.015 ± .003	0.039 ± .020	0.018 ± .004	0.023 ± .009
17th -8	0.013 ± .003	0.014 ± .002	0.027 ± .019	0.040 ± .026	0.031 ± .025
17th -9	0.014 ± .004	0.020 ± .010	0.038 ± .022	0.020 ± .007	0.012 ± .006
17th -10	0.009 ± .003	0.018 ± .008	0.018 ± .010	0.042 ± .026	0.017 ± .004
17th -11	0.009 ± .004	0.024 ± .004	0.028 ± .014	0.032 ± .018	0.023 ± .021
17th -12	0.014 ± .003	0.021 ± .014	0.045 ± .05	0.039 ± .027	0.024 ± .008
17th -13	0.015 ± .014	0.016 ± .005	0.057 ± .017	0.028 ± .009	0.019 ± .014
17th -14	0.010 ± .003	0.017 ± .008	0.035 ± .026	0.021 ± .006	0.027*
17th -15	0.014 ± .011	0.034 ± .008	0.077 ± .031	0.040 ± .022	0.026 ± .013
	* Only one Icorr value was obtained during the sampling year for this location.				

Table 6: Overall Icorr Values Measured on Various Sampling Dates from August 2003 to July 2008 (Values Averaged for All Measurement Locations on Bridge)

9th Ave. Bridge		Texas Turn Bridge		17th Ave. Bridge	
Sample Date	Ave. Icorr (μA/cm^2)	Sample Date	Ave. Icorr (μA/cm^2)	Sample Date	Ave. Icorr (μA/cm^2)
8/12/2003	0.03	8/12/2003	0.011	8/12/2003	0.012
10/22/2003	0.007	10/22/2003	0.006	10/22/2003	0.007
5/6/2004	0.019	4/22/2004	0.008	4/22/2004	0.018
6/17/2004	0.039	6/16/2004	0.023	6/16/2004	0.013
8/12/2004	0.013	8/12/2004	0.012	8/12/2004	0.016
10/20/2004	0.013	10/26/2004	No data	10/26/2004	No data
4/28/2005	0.018	4/28/2005	0.013	4/28/2005	0.017
6/22/2005	0.038	6/22/2005	0.013	6/22/2005	0.024
8/18/2005	0.032	8/18/2005	0.046	8/18/2005	0.044
10/28/2005	0.024	10/28/2005	0.013	10/28/2005	0.009
5/11/2006	0.037	5/11/2006	No Data	5/11/2006	0.026
7/5/2006	0.036	7/5/2006	0.035	7/5/2006	0.03
8/30/2006	0.047	8/30/2006	0.02	8/30/2006	0.038
11/8/2006	0.071	11/8/2006	0.017	5/16/2007	0.027
5/16/2007	0.042	5/16/2007	0.022	5/31/2007	0.022
6/21/2007	0.043	6/21/2007	0.012	6/21/2007	0.029
8/31/2007	0.035	8/31/2007	0.019	8/31/2007	0.032
10/24/2007	0.017	10/24/2007	0.011	10/24/2007	0.018
5/21/2008	0.023	5/21/2008	0.013	5/21/2008	0.016
7/15/2008	0.032	7/15/2008	0.017	7/15/2008	0.018

Figure 4: Overall Icorr Values Measured on the Bridges with Linear Regression Lines (Values Averaged for All Measurement Locations on Bridge)



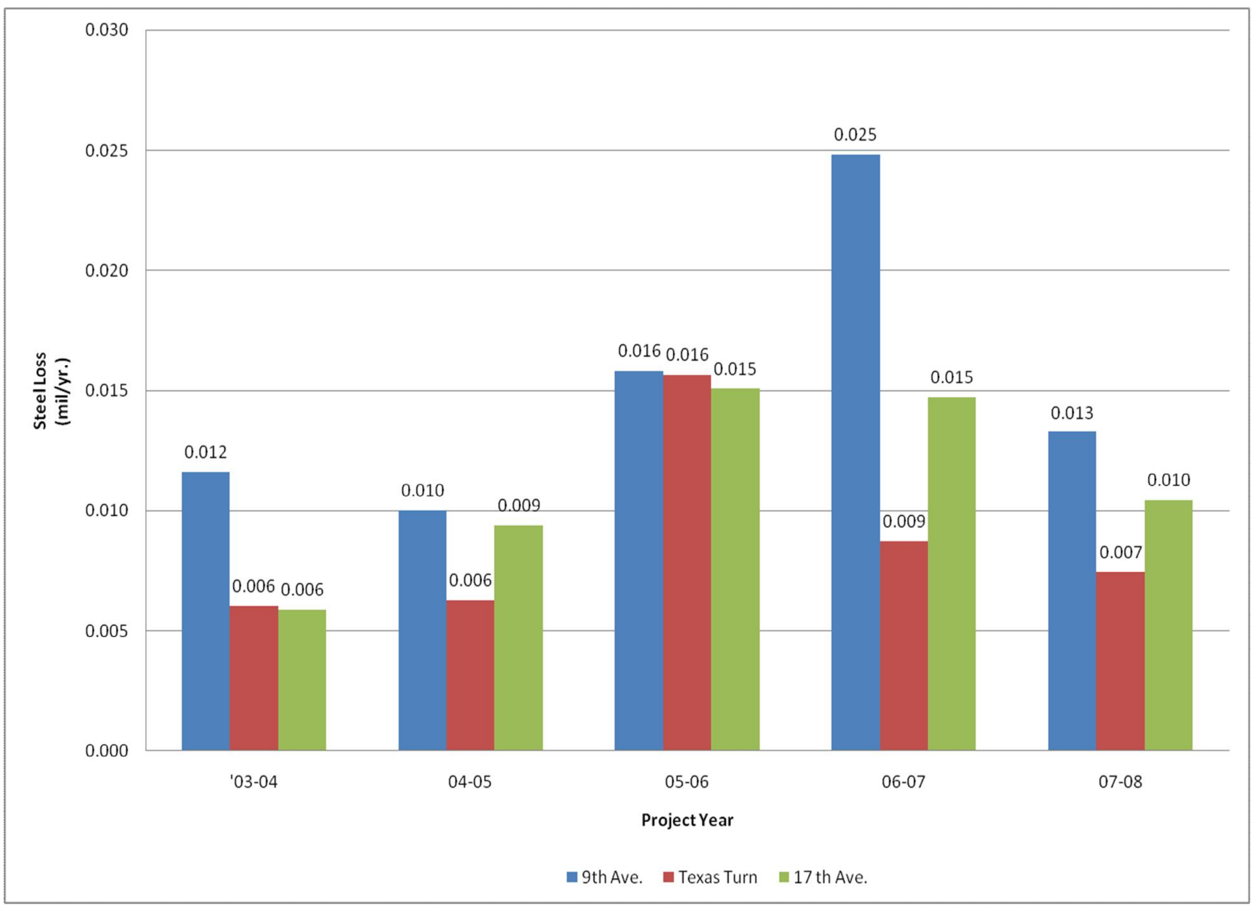
An Icorr value can be converted to a rate of metal thickness loss using Faraday's law

$M = ItA_w/nF$

where: M = mass of metal dissolved or converted to oxide (grams)
I = current (Amps)
t = time (seconds)
A_w = atomic weight
n = valency
F = Faraday's constant (96,500 coulombs/equivalent mass)

For iron in reinforcing steel, a factor of 0.492 can be used to convert Icorr values to thickness loss in units of mils/yr.[5] Rates of steel loss for the rebar were calculated based on overall Icorr values averaged over each year of the project. These values are compared in Figure 5.

Figure 5: Estimated Rate of Steel Loss from Rebar in the Bridge Decks
(Based on Icorr Measurements Averaged for Each Year of the Project)



4.2 Concrete Resistivity Data

Concrete resistivity measurements were also taken using the Gecor 6 instrument. The following broad criteria have been established to interpret resistivity information provided by the Gecor 6:[3]

Resistivity greater than 100 kΩ cm	Very low corrosion rate even with high chloride concentration or carbonation
Resistivity between 50 and 100 kΩ cm	Low corrosion rate
Resistivity between 10 and 50 kΩ cm	Moderate to high corrosion rate when steel is not in passive condition
Resistivity less than 10 kΩ cm	Resistivity is not the controlling parameter of the corrosion process

The average annual concrete resistivity measurements taken on the bridge decks over the past five years are listed in Tables 7, 8 and 9. Resistivity measurements were taken at the same locations and the same times as the Icorr measurements discussed in Section 4.1. A complete set of the concrete resistivity data collected in the past five years is contained in Appendix A.

It can be seen From Tables 7, 8 and 9 that the concrete resistivities measured on the three decks varied widely. Some of the values were in the range from 10 to 50 kΩ cm, which indicates moderate to high corrosion rate when the steel is not in a passive condition. Note however that these resistivity measurements do not actually indicate a high corrosion rate because the corresponding Icorr measurements showed that all the rebar tested were in a passive condition.

Table 7: 9th Avenue Bridge – Annual (July to June) Concrete Resistivity
(Values Averaged for Various Measurement Locations on the Bridge Deck)

Measurement Location	03-04 Resistivity Average ± S.D. (kΩ cm)	04-05 Resistivity Average ± S.D. (kΩ cm)	05-06 Resistivity Average ± S.D. (kΩ cm)	06-07 Resistivity Average ± S.D. (kΩ cm)	07-08 Resistivity Average ± S.D. (kΩ cm)
9th -1	59.4 ± 4.9	168.4 ± 100.7	51.1 ± 25.0	184.2 ± 71.1	74.0 ± 9.4
9th -2	158.1 ± 138.5	177.0 ± 105.9	74.9 ± 35.4	149.1 ± 91.4	120.7 ± 58.9
9th -3	156.9 ± 162.8	97.4 ± 61.5	73.3 ± 10.9	102.9 ± 105.9	91.7 ± 120.7
9th -4	387.9 ± 384.9	165.7 ± 144.9	65.8 ± 27.6	172.0 ± 158.7	36.8 ± 39.2
9th -5	61.6 ± 31.4	100.4 ± 59.1	48.6 ± 5.1	53.8 ± 24.4	48.2 ± 10.8
9th -6	51.4 ± 40.8	68.9 ± 26.4	62.4 ± 22.8	53.5 ± 19.8	66.9 ± 57.2
9th -7	18.3 ± 7.6	90.4 ± 63.7	61.1 ± 25.8	59.8 ± 26.3	81.4 ± 3.7
9th -8	19.6 ± 10.0	67.0 ± 30.8	44.1 ± 1.4	112.5 ± 118.8	70.7 ± 33.6
9th -9	88.6 ± 79.0	395.9 ± 186.4	132.5 ± 87.5	204.8 ± 118.6	419.5 ± 282.5
9th -10	163.4 ± 174.6	459.5 ± 435.4	76.8 ± 48.5	85.0 ± 49.7	272.1 ± 125.2
9th -11	32.2 ± 3.1	135.7 ± 98.3	61.5 ± 14.5	319.1 ± 424.6	84.7 ± 38.0
9th -12	43.5 ± 7.1	117.7 ± 40.4	39.0 ± 15.4	86.5 ± 32.2	72.8 ± 24.2
9th -13	43.8 ± 10.0	357.8 ± 254.1	119.7 ± 92.7	180.0 ± 176.1	180.0 ± 136.2
9th -14	28.2 ± 1.3	115.2 ± 134.1	60.5 ± 43.9	289.7 ± 394.2	570.0 ± 858.1
9th -15	208.6 ± 253.8	185.5 ± 215.5	44.0 ± 12.6	54.3 ± 54.3	74.0 ± 15.4

Table 8: Texas Turn Bridge – Annual (July to June)) Concrete Resistivity
(Values Averaged for Various Measuring Locations on the Bridge Deck)

Measurement Location	03-04 Resistivity Average ± S.D. (kΩ cm)	04-05 Resistivity Average ± S.D. (kΩ cm)	05-06 Resistivity Average ± S.D. (kΩ cm)	06-07 Resistivity Average ± S.D. (kΩ cm)	07-08 Resistivity Average ± S.D. (kΩ cm)
TT -1	98.9*	133.3 ± 104.9	87.7 ± 33.6	57.1 ± 3.0	58.8 ± 75.3
TT -2	86.8*	117.4 ± 89.8	90.8 ± 32.7	145.2 ± 85.2	138.0 ± 39.4
TT -3	87.4 ± 1.6	93.5 ±1 3.9	105.1 ± 70.4	73.8 ± 37.5	141.1 ± 84.2
TT -4	39.6*	273.2 ± 142.2	120 ± 33.7	124.4 ± 52.3	332.6 ± 342.1
TT -5	20.2*	206.9 ± 162.0	137.9 ± 137.3	91.7 ± 80.5	150.0 ± 82.5
TT -6	21.2*	220.0±156.1	100.8 ± 44.5	84.4 ± 60.7	704.1 ± 900.0
TT -7	44.9 ± 21.3	298.9 ± 199.4	161.1*	92.8 ± 75.7	82.8 ± 82.0
TT -8	125.2 ± 157.3	116.4 ± 73.9	103.4 ± 38	90.9 ± 56.2	155.4 ± 93.4
TT -9	256.1 ± 56.9	400.6 ± 290.4	136.8 ± 99	199.0 ± 144.5	316.7 ± 153.3
TT -10	55.5*	143.1 ± 86.0	106.1 ± 23.4	109.3 ± 74.8	132.8 ± 43.1
TT -11	32.2 ± 30.9	134.9 ± 44.6	130.9 ± 2.4	68.7 ± 55.6	233.5 ± 101.1
TT -12	44.0*	310.8 ± 345.3	78.1 ± 44.2	56.9 ± 38.5	105.9 ± 51.6
TT -13	73.8*	195.4 ± 124.1	135.5 ± 83	147.9 ± 129.9	129.6 ± 77.8
TT -14	92.2*	131.9 ± 106.9	156.8 ± 29.5	93.9 ± 41.6	124.2 ± 71.7
TT -15	60.3 ± 38.7	134.7 ± 77.9	67.9 ± 59.1	58.7 ± 33.7	73.4 ± 44.7
	* Only one resistivity value was obtained during the sampling year for this location.				

Table 9: 17th Avenue Bridge – Annual (July to June) Concrete Resistivity
(Values Averaged for Various Measurement Locations on the Bridge Deck)

Measurement Location	03-04 Resistivity Average ± S.D. (kΩ cm)	04-05 Resistivity Average ± S.D. (kΩ cm)	05-06 Resistivity Average ± S.D. (kΩ cm)	06-07 Resistivity Average ± S.D. (kΩ cm)	07-08 Resistivity Average ± S.D. (kΩ cm)
17th -1	10.6*	144.3 ± 105.2	87.1 ± 33.5	86.4 ± 68.7	256.6 ± 338.5
17th -2	31.5 ± 2.1	225.7 ± 169.3	136.6 ± 91.3	89.8 ± 82.8	155.8 ± 110.1
17th -3	40.2 ± 36.0	117.4 ± 59.3	79.3 ± 35.0	76.1 ± 49.9	135.3 ± 88.4
17th -4	12.3*	147.1 ± 98.4	93.0 ± 24.1	64.6 ± 29.2	168.5 ± 18.5
17th -5	8.6*	144.1 ± 55.0	85.0 ± 18.6	68.8 ± 101.3	226.3 ± 69.2
17th -6	7.8*	177.7 ± 121.7	58.2 ± 37.7	84.1 ± 39.1	307.2 ± 16.4
17th -7	4.6*	105.9 ± 89.1	51.2 ± 6.9	51.1 ± 2.6	630.9 ± 704.1
17th -8	5.8*	178.7 ± 128.9	63.3 ± 24.1	70.2 ± 12.6	173.9 ± 93.4
17th -9	3.8*	82.2 ± 36.9	41.7 ± 4.6	89.6 ± 30.8	106.5 ± 23.9
17th -10	10.0 ± 10.9	91.8 ± 27.3	82.5 ± 30.3	69.5 ± 17.3	63.1 ± 61.5
17th -11	30.3*	44.7 ± 40.5	40.2 ± 15.7	36.0 ± 31.4	66.9 ± 6.3
17th -12	36.8*	55.2 ± 13.5	51.7 ± 18.2	41.8 ± 13.1	56.6 ± 1.1
17th -13	8.7*	88.4 ± 38.2	69.4 ± 36.6	55.4 ± 9.8	74.0 ± 12.8
17th -14	61.5*	117.8 ± 63.9	81.8 ± 56.5	103.4 ± 26.0	136.0 ± 34.2
17th -15	47.4*	115.0 ± 110.8	27.9 ± 6.7	39.7 ± 6.8	812.1 ± 1032.2
* Only one resistivity value was obtained during the sampling year for this location.					

4.3 Concrete Chloride Content

Concrete samples were collected once per year from each bridge deck for chloride testing. The samples were obtained by drilling into the concrete decks and collecting drill dust at depths of approximately 0.25 to 0.75 inches, 2.5 to 3.0 inches, and 4.5 to 5.0 inches. Three samples (one at each depth) were collected at six different locations on each deck.

Levels of chloride required to initiate corrosion in rebar are reported to be very low. Reference 2 states that field experience and research have shown that on existing structures subjected to chloride, a threshold concentration of about 0.026% (by weight of concrete) is sufficient to break down the passive film and subject the steel rebar to corrosion.(2) This threshold chloride concentration equates to about 1.0 lb/cu.yd. of concrete. Another reference indicates that a chloride content of 1.5 lb/cu.yd. would actively support corrosion. (3)

The results of all the chloride analyses performed on concrete samples obtained from the three bridge decks are listed in Tables 10, 11 and 12. Averaged annual chloride concentrations of samples from the three bridge decks obtained between August 2002 and August 2007 are listed in Table 13. The values in Table 13 are averages of results from chloride analyses performed on the sample sets collected each year at the various depths below the deck surface. The results contained in Table 13 are plotted in Figures 6, 7 and 8. Looking at the figures, it appears that the chloride levels in samples taken at all depths are increasing over time. This is expected since chlorides are applied to the bridges each winter for deicing.

The average chloride concentrations measured in the most recently collected concrete samples (August of 2007) are shown in Figure 9. Clearly, the highest average chloride levels were measured for the 9th Avenue Bridge.

Table 10: Texas Turn Bridge Deck – Measured Chloride Content

Sampling Location on the Texas Turn Bridge Deck	Depth (inches)	Chloride (lb/cu.yd.) Oct. 2002	Chloride (lb/cu.yd.) Aug. 2003	Chloride (lb/cu.yd.) Aug. 2004	Chloride (lb/cu.yd.) Aug. 2005	Chloride (lb/cu.yd.) Aug. 2006	Chloride (lb/cu.yd.) Aug. 2007
North end of deck, in lane	0.25 – 0.75	0.41	0.43	0.22	2.15	2.64	3.17
Station 3387+48, 8.2'Rt	2.5 – 3.0	1.10	0.90	0.30	0.90	1.45	0.82
	4.5 – 5.0	0.96	0.90	0.18	0.70	1.29	0.74
North end of deck, east edge	0.25 – 0.75	0.96	0.89	0.57	1.25	8.61	0.94
Station 3387+49.2, 16.3'Rt	2.5 – 3.0	0.62	0.59	0.32	0.94	3.09	0.98
	4.5 – 5.0	1.08	1.01	0.35	0.74	1.64	1.06
Mid-span of deck, in lane	0.25 – 0.75	0.45	0.45	0.34	8.06	1.29	5.01
Station 3387+17.1, 7.5'Rt	2.5 – 3.0	0.56	0.62	0.17	1.33	1.17	1.21
	4.5 – 5.0	0.23	0.30	0.61	1.02	1.14	0.86
Mid-span of deck, east edge	0.25 – 0.75	0.75	1.04	3.66	2.31	2.04	10.61
Station 3387+16.6, 17.6'Rt	2.5 – 3.0	0.51	0.42	0.46	0.74	2.04	1.49
	4.5 – 5.0	0.54	0.59	0.19	0.90	1.41	1.21
North Pier, in lane	0.25 – 0.75	0.35	0.42	1.65	3.25	2.58	2.54
Station 3387+9.6, 8.1'Rt	2.5 – 3.0	0.48	0.45	0.30	1.10	1.61	1.17
	4.5 – 5.0	0.76	0.69	0.20	1.14	3.17	0.98
North Pier, east edge	0.25 – 0.75	0.35	0.31	5.07	3.19	2.07	11.90
Station 3386+98.9, 15.3'Rt	2.5 – 3.0	0.60	0.55	0.30	1.88	1.25	1.10
	4.5 – 5.0	0.70	0.62	0.27	0.72	1.70	1.02

Table 11: 17th Avenue Bridge Deck - Measured Chloride Content

Sampling Location on 17th Avenue Bridge Deck	Depth (inches)	Chloride (lb/cu.yd.) Oct. 2002	Chloride (lb/cu.yd.) Aug. 2003	Chloride (lb/cu.yd.) Aug. 2004	Chloride (lb/cu.yd.) Aug. 2005	Chloride (lb/cu.yd.) Aug. 2006	Chloride (lb/cu.yd.) Aug. 2007
North end of deck, in lane	0.25 – 0.75	0.48	0.52	0.19	2.31	2.51	1.53
Station 3368+95.6, 9.4'Rt	2.5 – 3.0	0.62	0.66	0.26	1.10	1.29	0.90
	4.5 – 5.0	0.33	0.38	0.38	0.78	1.37	0.67
North end of deck, east edge	0.25 – 0.75	0.54	0.56	0.26	1.02	6.26	1.57
Station 3368+95, 16.5'Rt	2.5 – 3.0	0.33	0.38	0.23	0.74	5.72	1.06
	4.5 – 5.0	0.60	0.62	0.19	0.94	2.60	1.37
Mid-span of deck, in lane	0.25 – 0.75	0.82	0.78	0.41	1.49	4.56	1.76
Station 3368+65.2, 10.1'Rt	2.5 – 3.0	0.75	0.71	0.51	1.17	3.25	1.14
	4.5 – 5.0	0.56	0.66	0.25	0.90	1.41	1.02
Mid-span of deck, east edge	0.25 – 0.75	0.90	0.97	0.56	3.41	3.05	1.57
Station 3368+64.2, 17.7'Rt	2.5 – 3.0	0.64	0.69	0.16	1.06	2.00	1.84
	4.5 – 5.0	0.85	0.83	0.24	1.02	1.14	3.01
North pier, in lane	0.25 – 0.75	0.73	ND	2.24	1.45	1.92	1.17
Station 3368+50.2, 10'Rt	2.5 – 3.0	0.53	ND	1.31	1.17	1.25	1.21
	4.5 – 5.0	0.53	ND	0.16	1.80	1.02	1.17
North pier, east edge	0.25 – 0.75	0.68	ND	6.48	1.49	3.21	11.67
Station 3368+48.9, 18'Rt	2.5 – 3.0	0.82	ND	1.14	0.98	0.74	5.36
	4.5 – 5.0	ND	ND	0.47	1.21	1.02	1.37

***ND – No Data**

Table 12: 9th Avenue Bridge Deck – Measured Chloride Content

Sampling Location on the 9th Avenue Bridge Deck	Depth (inches)	Chloride (lb/cu.yd.) Oct. 2002	Chloride (lb/cu.yd.) Aug. 2003	Chloride (lb/cu.yd.) Aug. 2004	Chloride (lb/cu.yd.) Aug. 2005	Chloride (lb/cu.yd.) Aug. 2006	Chloride (lb/cu.yd.) Aug. 2007
North end of deck, in lane	0.25 – 0.75	0.35	0.56	0.86	3.05	5.32	8.34
Station 3409+32, 10.3'Rt	2.5 – 3.0	0.42	0.42	0.19	0.90	1.53	3.01
	4.5 – 5.0	0.56	0.62	0.43	1.06	0.96	1.21
North end of deck, east edge	0.25 – 0.75	0.34	0.73	0.38	6.07	9.79	12.80
Station 3409+33.2, 16.5'Rt	2.5 – 3.0	0.88	0.83	0.20	1.14	1.14	6.34
	4.5 – 5.0	0.40	0.42	0.12	1.14	1.25	1.17
Mid-span of deck, in lane	0.25 – 0.75	0.64	0.64	0.84	7.67	8.57	6.97
Station 3409+16.5, 8.1'Rt	2.5 – 3.0	0.35	0.38	0.16	1.14	2.74	1.49
	4.5 – 5.0	0.44	0.48	0.17	1.17	1.57	0.86
Mid-span of deck, east edge	0.25 – 0.75	0.69	0.71	7.31	3.99	11.61	11.75
Station 3409+16, 17.1'Rt	2.5 – 3.0	0.48	0.59	0.28	0.74	3.92	4.78
	4.5 – 5.0	1.12	1.03	0.24	0.94	1.96	1.72
North Pier, in lane	0.25 – 0.75	0.63	1.90	3.79	7.44	6.58	11.43
Station 3408+84.1, 7.4'Rt	2.5 – 3.0	0.76	0.80	0.21	1.25	2.19	3.86
	4.5 – 5.0	0.56	0.62	0.24	1.25	1.45	1.14
North Pier, east edge	0.25 – 0.75	0.69	0.76	3.59	3.33	12.65	7.75
Station 3408+83.7, 15.4,Rt	2.5 – 3.0	0.55	0.59	0.39	1.02	2.11	3.88
	4.5 – 5.0	0.62	0.64	0.24	1.57	0.78	2.68

Table 13: Average Chloride Concentrations of Samples Collected from the Three Bridge Decks Each Project Year from October 2002 to August 2007

	9th Avenue Bridge Deck Average Chloride Level Measured Each Year (lb/cu.yd.)					
Sample Depth	Oct-02	Aug-03	Aug-04	Aug-05	Aug-06	Aug-07
0.25 – 0.75 in.	0.56	0.88	2.80	5.26	9.09	9.84
2.5 – 3.0 in.	0.57	0.60	0.24	1.03	2.27	3.91
4.5 – 5.0 in.	0.62	0.64	0.24	1.19	1.33	1.46
	Texas Turn Bridge Deck Average Chloride Level Measured Each Year (lb/cu.yd.)					
Sample Depth	Oct-02	Aug-03	Aug-04	Aug-05	Aug-06	Aug-07
0.25 – 0.75 in.	0.55	0.59	1.92	3.37	3.21	5.70
2.5 – 3.0 in.	0.65	0.59	0.31	1.15	1.77	1.13
4.5 – 5.0 in.	0.71	0.69	0.30	0.87	1.73	0.98
	17th Avenue Bridge Deck Average Chloride Level Measured Each Year (lb/cu.yd.)					
Sample Depth	Oct-02	Aug-03	Aug-04	Aug-05	Aug-06	Aug-07
0.25 – 0.75 in.	0.69	0.71	1.69	1.86	3.59	3.21
2.5 – 3.0 in.	0.62	0.61	0.60	1.04	2.38	1.92
4.5 – 5.0 in.	0.57	0.62	0.28	1.11	1.43	1.44

Figure 6: Average Chloride Content at Various Depths in the 9th Avenue Bridge Deck

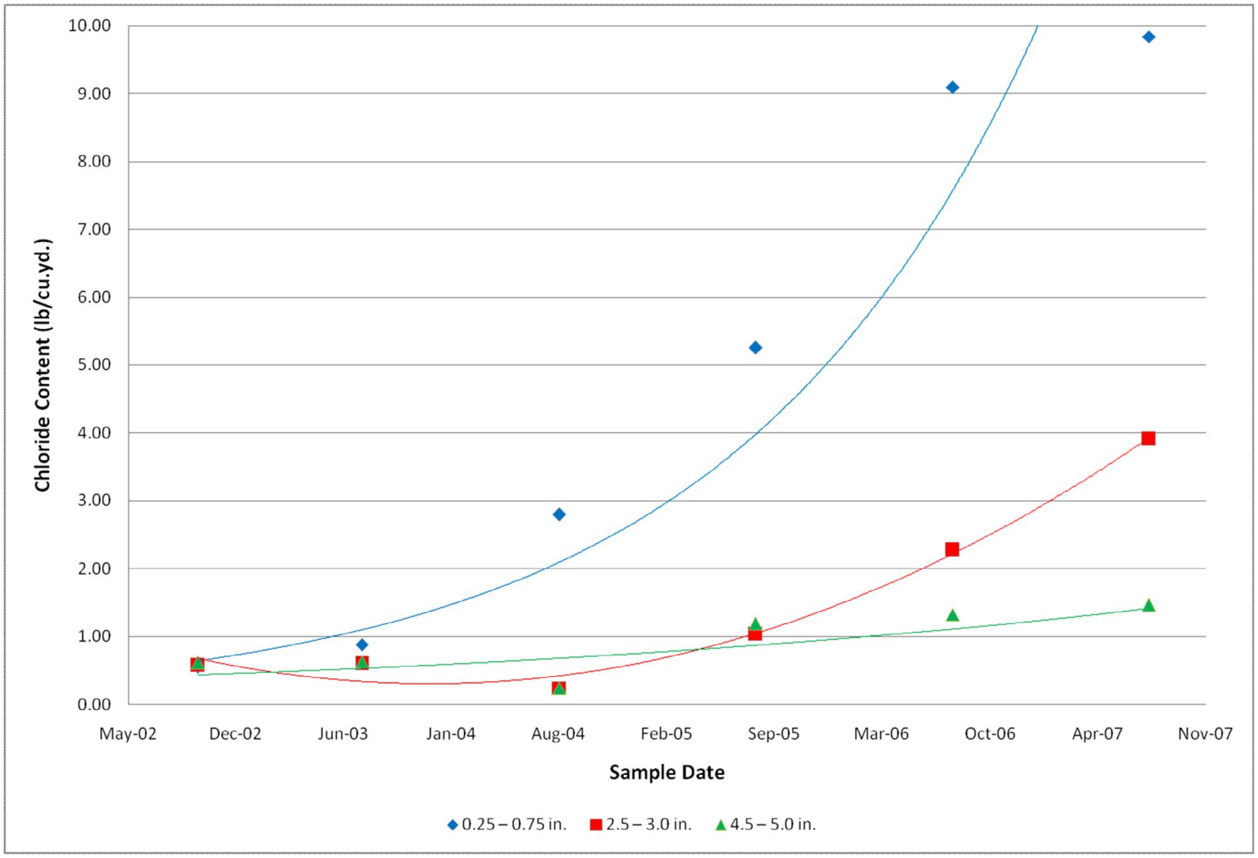


Figure 7: Average Chloride Content at Various Depths in the Texas Turn Bridge Deck

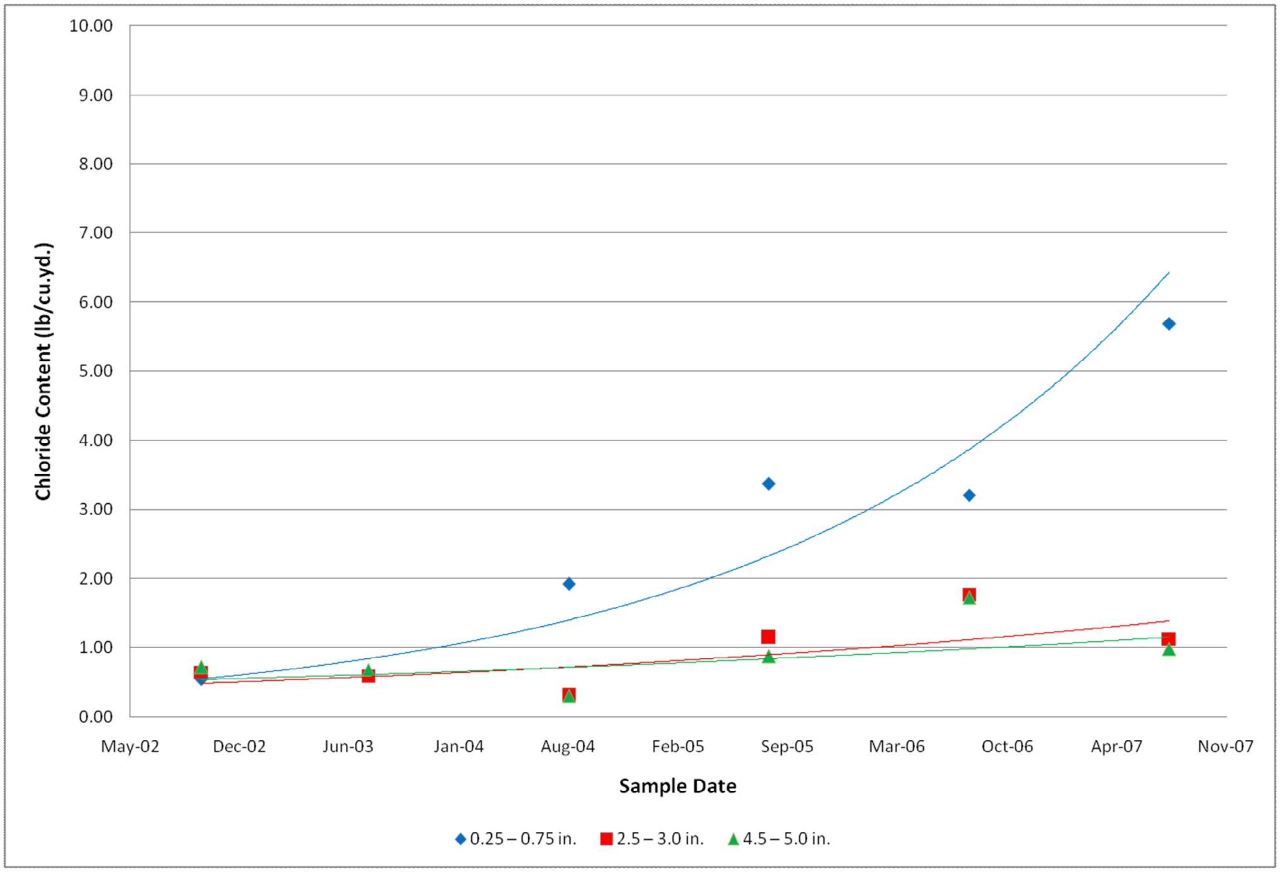


Figure 8: Average Chloride Content at Various Depths in the 17th Avenue Bridge Deck

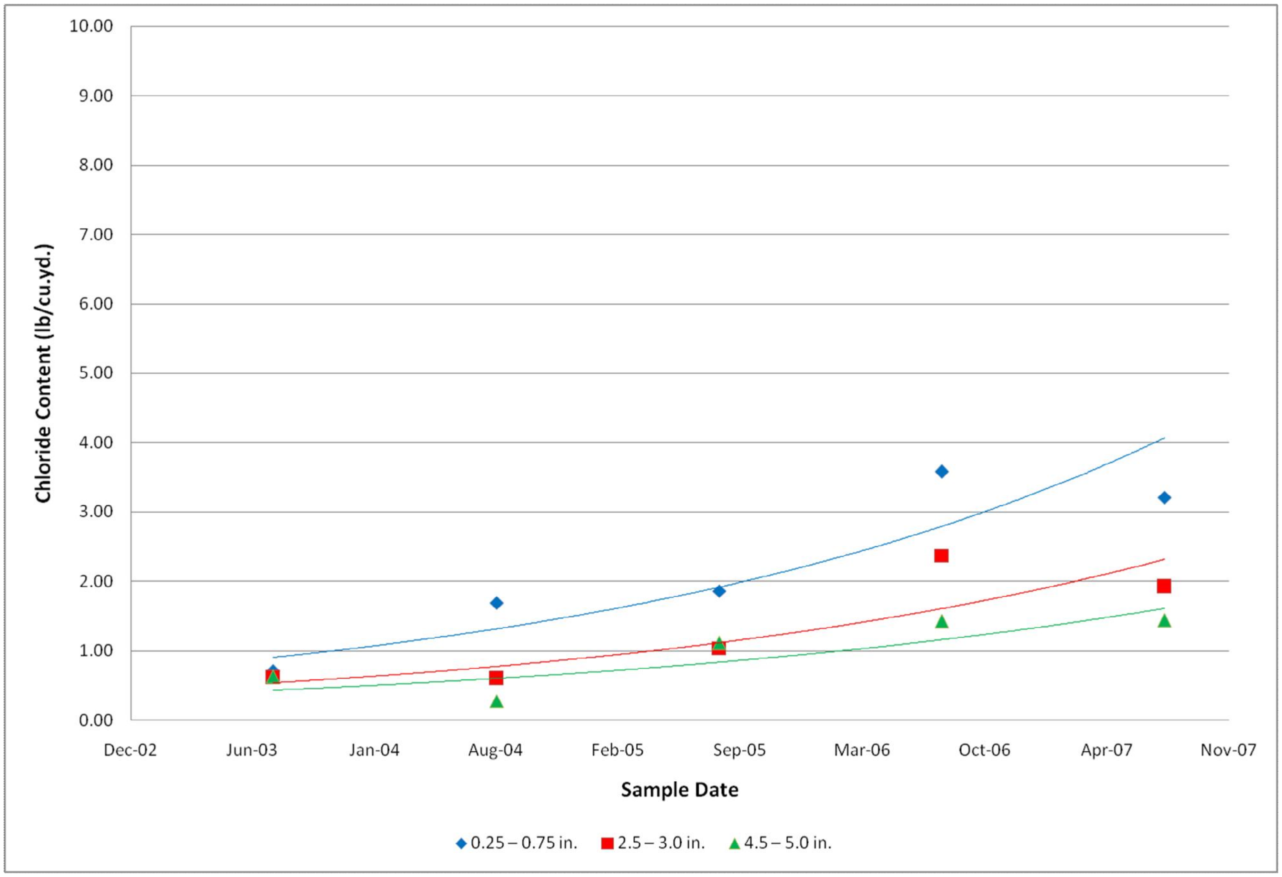
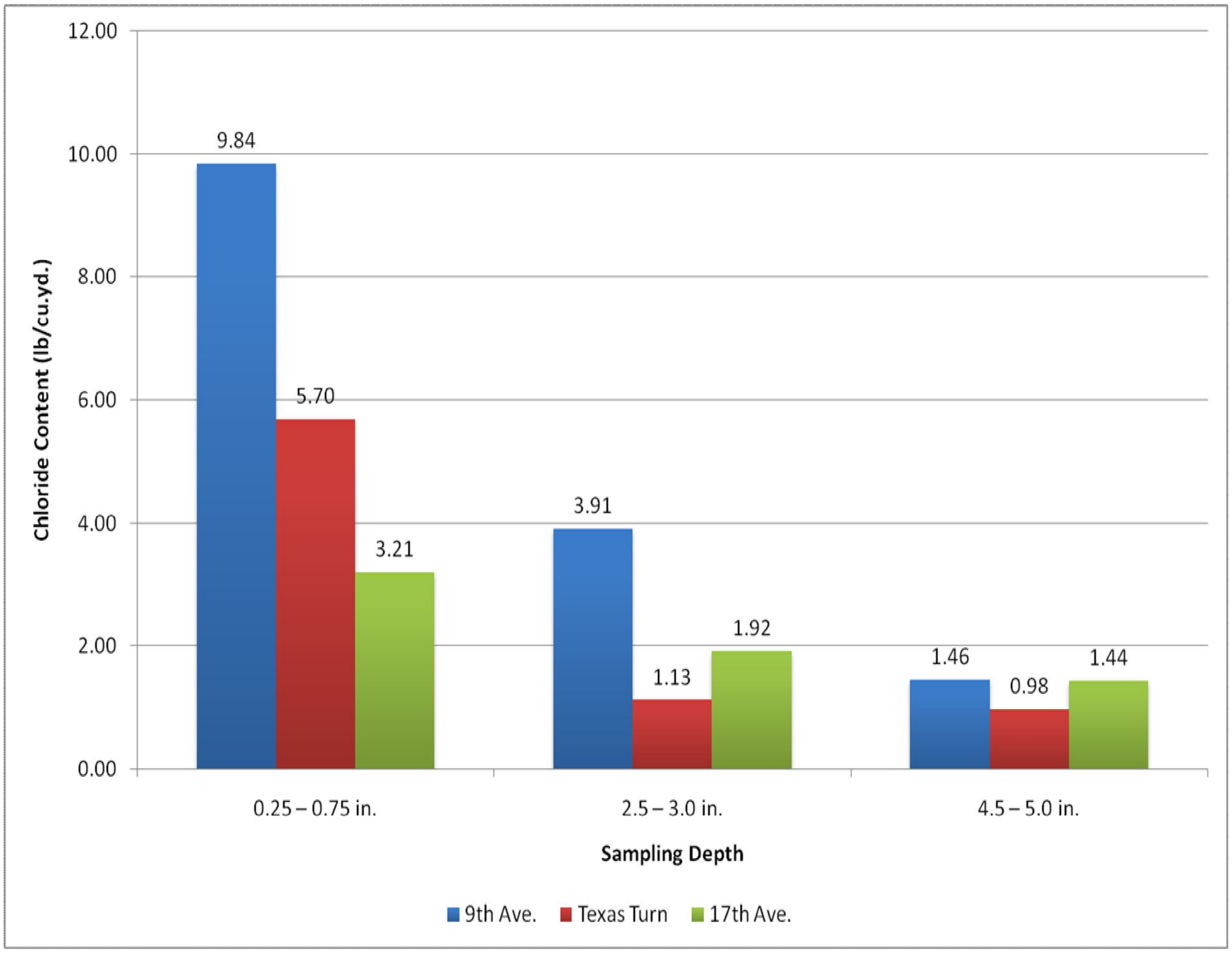


Figure 9: Comparison of Average Chloride Levels Measured at Three Depths in the Bridge Decks in August 2007



4.4 Temperature Data

Collection of temperature data from thermocouples cast in the three bridge decks was started during the summer of 2002. The major reason for collecting temperature data is to determine how many freeze/thaw cycles the concrete is subjected to over time. Repeated freezing and thawing is a concern because it can cause cracks to form in the concrete. Cracking can accelerate corrosion of the steel rebar if it permits entry of moisture, air, and chloride into the concrete matrix.

Six sets of thermocouples were installed at various points on each of the three bridge decks. Two sets of thermocouples were installed over the abutment at the north end of the deck; one set was close to the jersey barrier and the other set was in the left lane approximately 22 feet from the east barrier. Two sets were installed at the midpoint of the span length, and two sets over the north pier. The general locations of the thermocouples on the deck are shown in Figure 10 and the exact locations are listed in Table 14. Referring to Figure 10, the positions of thermocouples A1, A4, B1, B4, C1, and C4 are indicated. These six thermocouples are positioned 0.5 inch below the surface of the concrete deck. Thermocouples A2 and A3 are positioned directly below A1, 3 inches and 5 inches below the surface respectively. Thermocouples A5 and A6 are positioned below A4, 3 inches and 5 inches below the surface respectively. Similar designation were used for the thermocouple sets designated B and C.

The thermocouples are connected to data loggers, which store the temperature data until it is downloaded to a portable computer. In order to conserve storage memory, the data loggers are programmed to collect more data when the temperature is close to freezing. The number of freeze/thaw cycles recorded with the thermocouples is determined by reading through the data files and counting the number of times the temperature went below 32^{o} F and then rose above

32^{o} F. The complete temperature data files downloaded from the data loggers are contained on a CD included with this report.

Figure 10: Thermocouple Designations on Bridge Deck

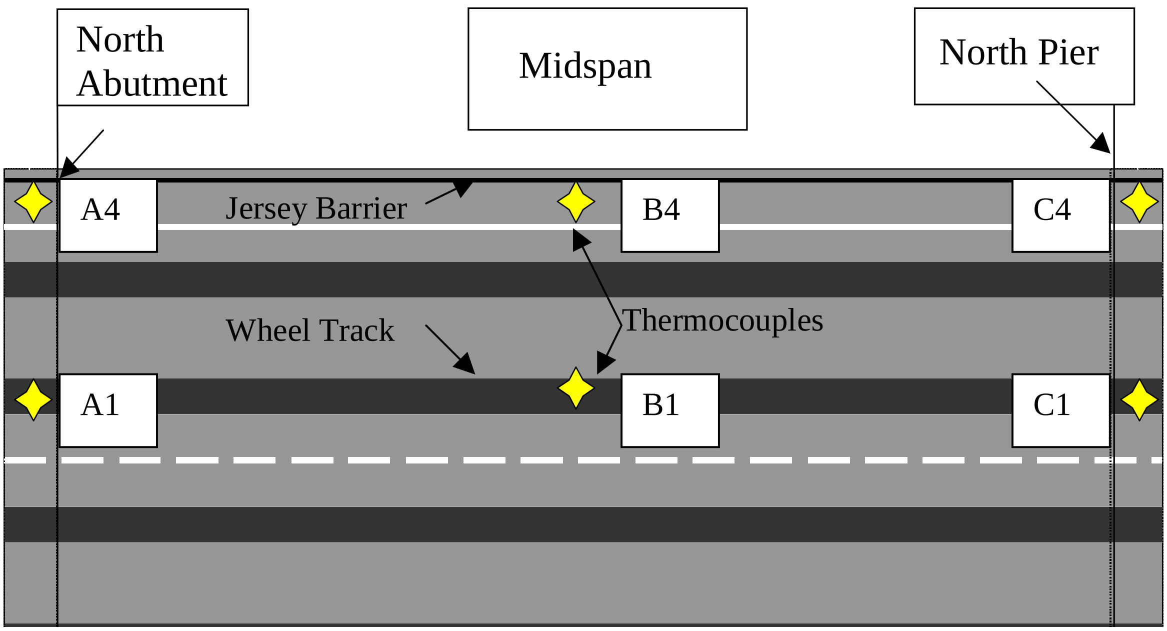


Table 14: Exact Locations of Thermocouples on Bridge Decks

Bridge	Thermocouple Designation	Distance from North Edge of Deck	Distance from East Edge of Deck
9th Avenue	A 1 to 3	8 ½”	14’–1½”
	A 4 to 6	9 ½”	1’–10”
	B 1 to 3	26’–7”	14’–0”
	B 4 to 6	26’–¼”	1’–10½”
	C 1 to 3	51’–6”	14’–4”
	C 4 to 6	51’–0”	2’–0”
Texas Turn	A 1 to 3	1’–11”	14’–4”
	A 4 to 6	1’–1”	1’–8”
	B 1 to 3	23’–2”	14’–2”
	B 4 to 6	23’–0”	1’–8”
	C 1 to 3	50’–6”	14’–4”
	C 4 to 6	50’–2”	1’–9”
17th Avenue	A 1 to 3	1’–4”	14’–4”
	A 4 to 6	1’–3½”	1’–9”
	B 1 to 3	25’–1½”	14’–3”
	B 4 to 6	25’–8½”	1’–9”
	C 1 to 3	50’–1½”	14’–4”
	C 4 to 6	49’–8½”	1’–9½”

The number of freeze/thaw cycles observed for the three bridge decks are listed in Tables 15, 16 and 17. The maximum and minimum concrete temperatures recorded for each deck at probes B1, B2, and B3 are listed in Table 18. These particular probes are located at depths of 0.5 inches, 3 inches, and 5 inches below the surface of the deck at approximately midspan in the left lane of each bridge. Temperature ranges are reported for these particular probes because they are the only ones that continuously record data.

Table 15: Number of Freeze/Thaw Cycles That Occurred at Different Depths in the 9th Avenue Deck

	Sensor Depth (inches)	F/T Cycles between July 2002 - June 2003 Wheel Track	Jersey Barrier	F/T Cycles between July 2003 - June 2004 Wheel Track	Jersey Barrier	F/T Cycles between July 2004 - June 2005 Wheel Track	Jersey Barrier	F/T Cycles between July 2005 - June 2006 Wheel Track	Jersey Barrier	F/T Cycles between July 2006 - June 2007 Wheel Track	Jersey Barrier	F/T Cycles between July 2007 - June 2008 Wheel Track	Jersey Barrier
9th Ave.	0.5	60	33	67	22	53	38	59	38	90	32	63	21
North End	3	38	26	43	14	38	26	47	24	58	26	35	12
	5	29	25	28	11	33	22	38	15	48	24	19	10
9th Ave.	0.5	56	36	72	24	51	38	61	17	100	53	69	18
Mid Span	3	35	27	53	16	40	38	52	18	73	46	44	15
	5	48	25	44	14	40	36	49	16	60	37	37	13
9th Ave.	0.5	50	41	53	23	48	37	53	19	78	54	48	19
North Pier	3	36	29	34	18	38	36	46	19	59	41	31	11
	5	29	29	31	19	37	34	40	19	54	41	21	12

Table 16: Number of Freeze/Thaw Cycles That Occurred at Different Depths in the Texas Turn Bridge Deck

	Sensor Depth (inches)	F/T Cycles Between Construction and June 2003		F/T Cycles Between July 2003 to June 2004		F/T Cycles Between July 2004 to June 2005		F/T Cycles Between July 2005 to June 2006		F/T Cycles Between July 2006 to June 2007		F/T Cycles Between July 2007 to June 2008	
		Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier
Texas Turn	0.5	63	37	70	19	57	37	74	19	93	38	57	15
North End	3	36	20	36	16	40	27	54	18	65	30	39	7
	5	35	20	25	14	35	21	48	19	59	26	25	7
Texas Turn	0.5	53	28	63	25	48	38	67	22	83	38	49	13
Mid Span	3	35	26	31	16	40	36	50	22	59	34	35	10
	5	30	25	23	14	46	35	43	22	48	34	23	10
Texas Turn	0.5	43	26	64	19	50	36	67	23	78	41	49	15
North Pier	3	32	26	32	16	37	34	49	21	61	34	30	7
	5	25	25	28	15	35	32	42	19	49	34	22	8

Table 17: Number of Freeze/Thaw Cycles That Occurred at Different Depths in the 17th Avenue Deck

		F/T Cycles between July 2002 - June 2003		F/T Cycles between July 2003 - June 2004		F/T Cycles between July 2004 - June 2005		F/T Cycles between July 2005 - June 2006		F/T Cycles between July 2006 - June 2007		F/T Cycles between July 2007 - June 2008	
	Sensor Depth (inches)	Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier	Wheel Track	Wheel Track	Jersey Barrier	Jersey Barrier	Wheel Track	Jersey Barrier	Wheel Track	Jersey Barrier
17th Ave. North End	0.5	60	28	66	27	54	38	59	19	72	46	46	13
	3	39	21	36	21	40	26	50	18	53	25	28	12
	5	30	22	30	14	34	22	42	19	46	23	18	7
17th Ave. Mid Span	0.5	56	30	62	32	51	38	60	27	81	36	53	28
	3	47	28	49	26	40	38	53	26	60	35	38	15
	5	36	26	45	21	40	36	45	27	54	31	36	11
17th Ave. North Pier	0.5	45	27	54	31	46	39	56	26	70	42	45	17
	3	33	25	37	29	38	36	46	25	55	34	26	9
	5	30	26	34	30	34	34	40	22	45	36	20	14

Table 18: Maximum and Minimum Temperatures Recorded for the Bridge Decks

Bridge	Probe B1– Max/Min Temperature (^{0}F)	Probe B2– Max/Min Temperature (^{0} F)	Probe B3– Max/Min Temperature (^{0}F)
9th Avenue July 2003 to June 2004	118.7/-18.2	108.5/-16.0	101.2/-14.7
9th Avenue July 2004 to June 2005	119.4/-14.0	110.5/-11.2	105.7/-9.5
9th Avenue July 2005 to June 2006	121.6/-12.3	112.8/-9.7	107.8/-8.8
9th Avenue July 2006 to June 2007	127.2/-13.0	115.2/-10.8	107.5/-9.5
9th Avenue July 2007 to June 2008	124.7/-16.4	115.4/-14.4	110.8/-13.3
Texas Turn July 2003 to June 2004	115.6/-15.7	106.9/-13.4	103.2/-11.6
Texas Turn July 2004 to June 2005	116.6/-9.7	107.5/-5.8	103.4/-2.9
Texas Turn July 2005 to June 2006	118.1/-9.1	108.2/-6.0	103.5/-4.0
Texas Turn July 2006 to June 2007	125.0/-10.1	111.0/-7.6	103.0/-5.4
Texas Turn July 2007 to June 2008	121.7/-10.8	111.5/-7.9	106.6/-5.8
17th Avenue July 2003 to June 2004	111.7/-16.5	105.6/-14.6	103.7/-12.7
17th Avenue July 2004 to June 2005	113.3/-12.9	106.4/-10.8	103.2/-8.9
17th Avenue July 2005 to June 2006	113.8/-10.2	107.2/-8.1	103.8/-6.4
17th Avenue July 2006 to June 2007	122.0/-11.0	111.4/-9.1	106.5/-7.2
17th Avenue July 2007 to June 2008	119.4/-14.1	111.4/-12.4	108.3/-10.3

The average numbers of freeze/thaw cycles that occurred at each bridge deck are plotted in Figures 11 through 16. The numbers are averaged separately for the probes located in the left-most traffic lane and the probes located close to the left jersey barrier. Each plot compares freeze/thaw numbers for the three decks at a specific depth and location. The figures show that the number of freeze/thaw cycles that occurred varied significantly from year to year. However looking at all of the figures, there does not appear to be a clear trend to suggest that any one bridge experienced significantly more cycles than the others.

Figure 11: Average Number of Freeze/Thaw Cycles in the Bridge Decks (Samples Collected in the Wheel Track of the Far Left Lane at a Depth of 0.5 Inches)

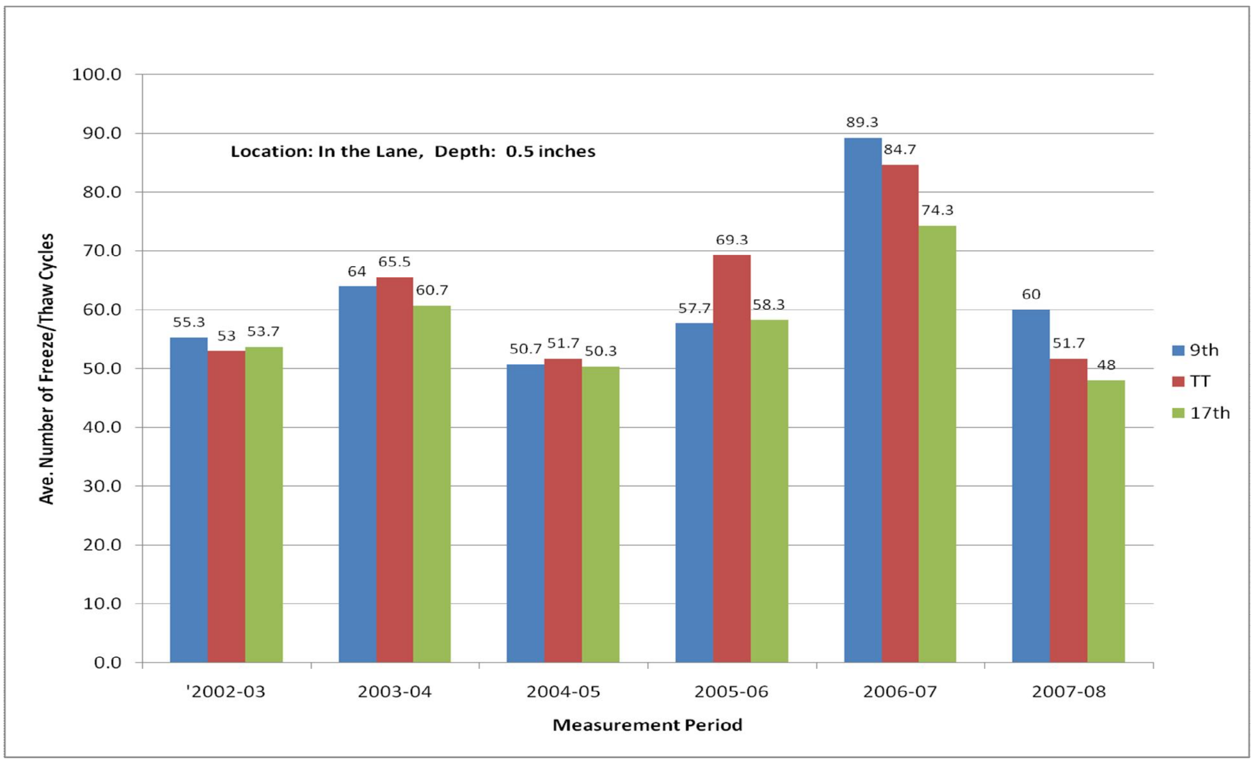


Figure 12: Average Number of Freeze/Thaw Cycles in the Bridge Decks (Samples Collected in the Wheel Track of the Far Left Lane at a Depth of 3 Inches)

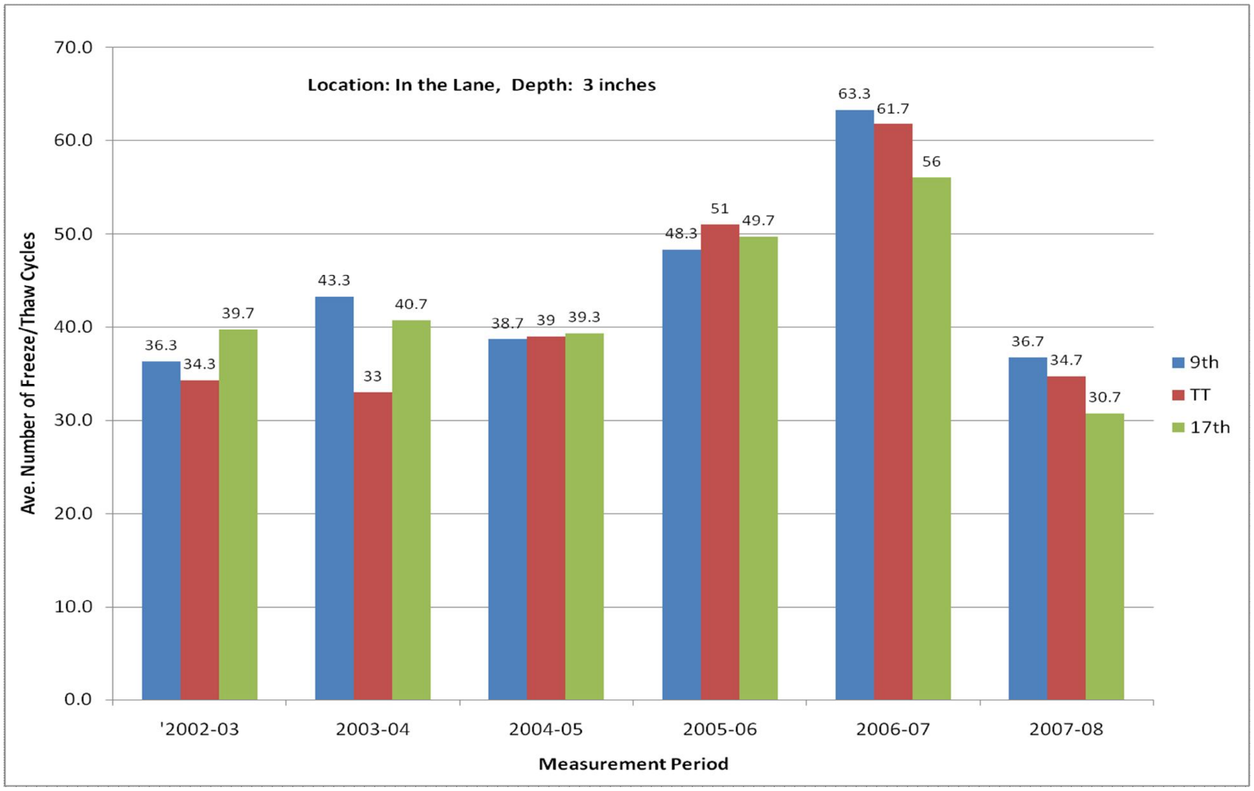


Figure 13: Average Number of Freeze/Thaw Cycles in the Bridge Decks (Samples Collected in the Wheel Track of the Far Left Lane at a Depth of 5 Inches)

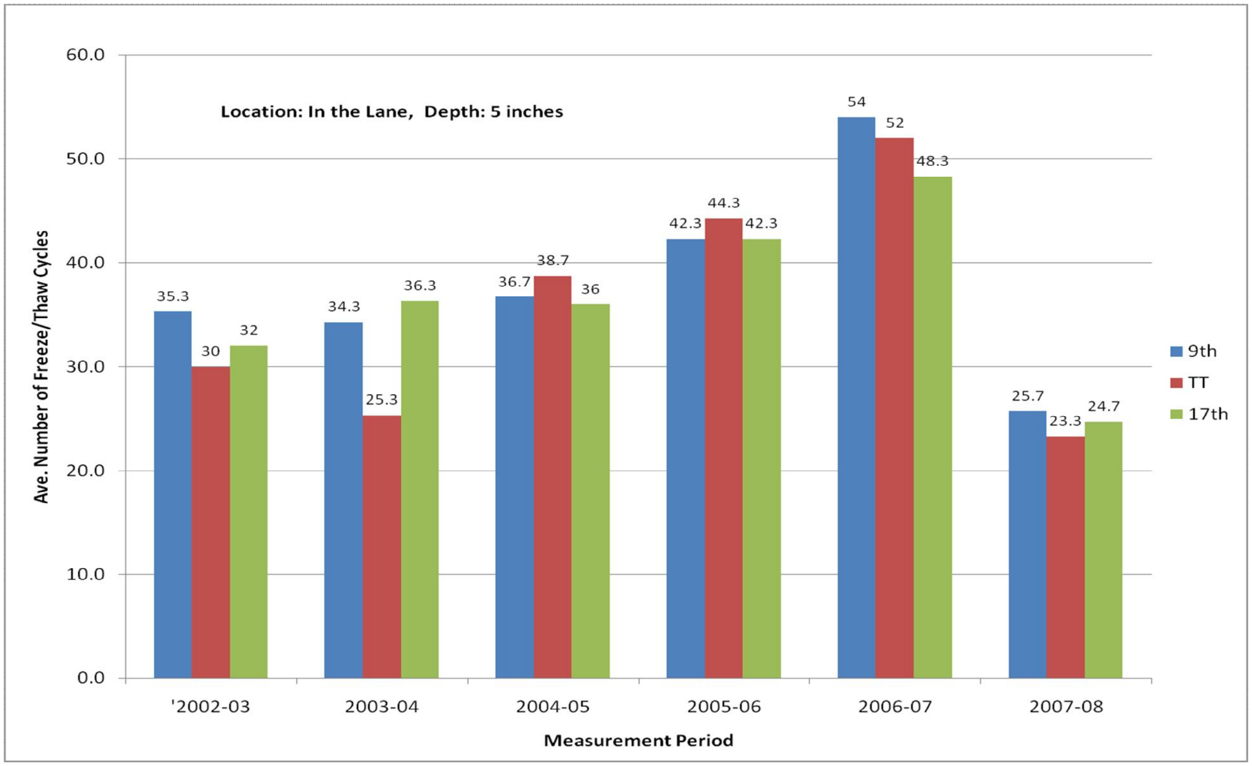


Figure 14: Average Number of Freeze/Thaw Cycles in the Bridge Decks (Samples Collected Close to the Left Jersey Barrier at a Depth of 0.5 Inches)

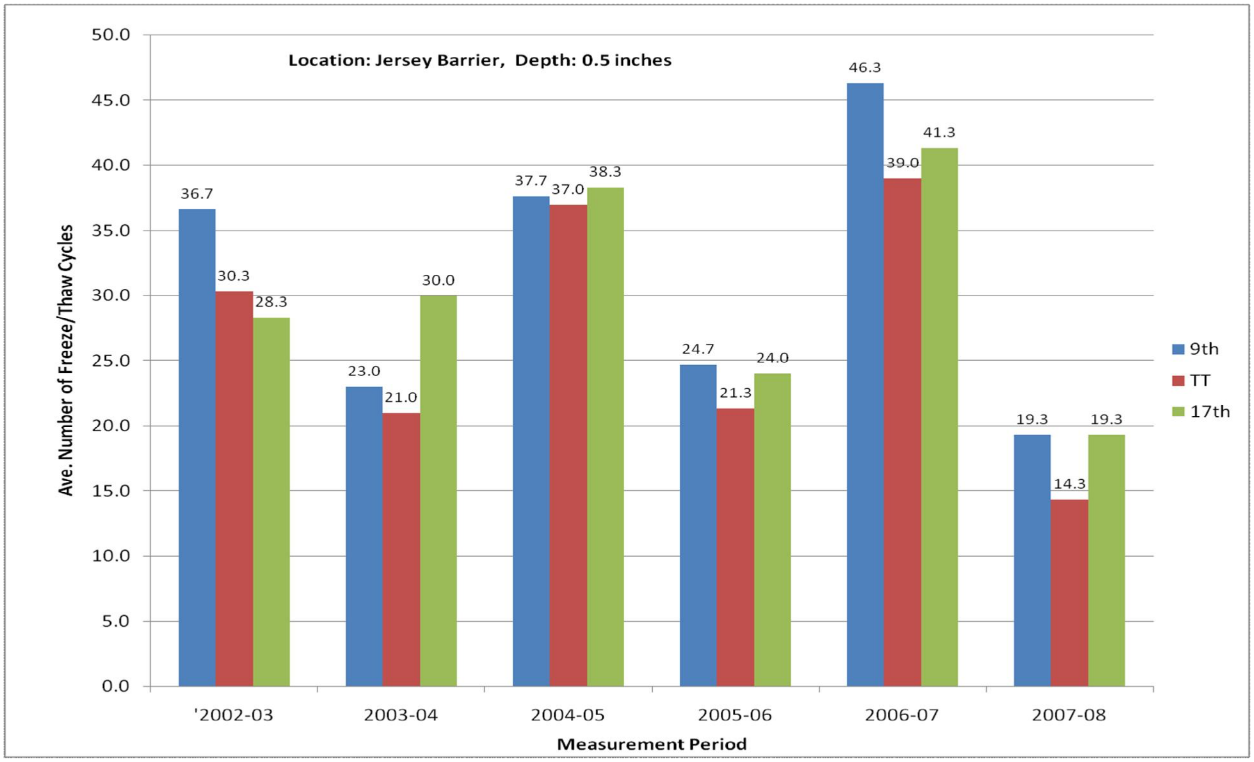


Figure 15: Average Number of Freeze/Thaw Cycles in the Bridge Decks (Samples Were Collected Close to the Left Jersey Barrier at a Depth of 3 Inches)

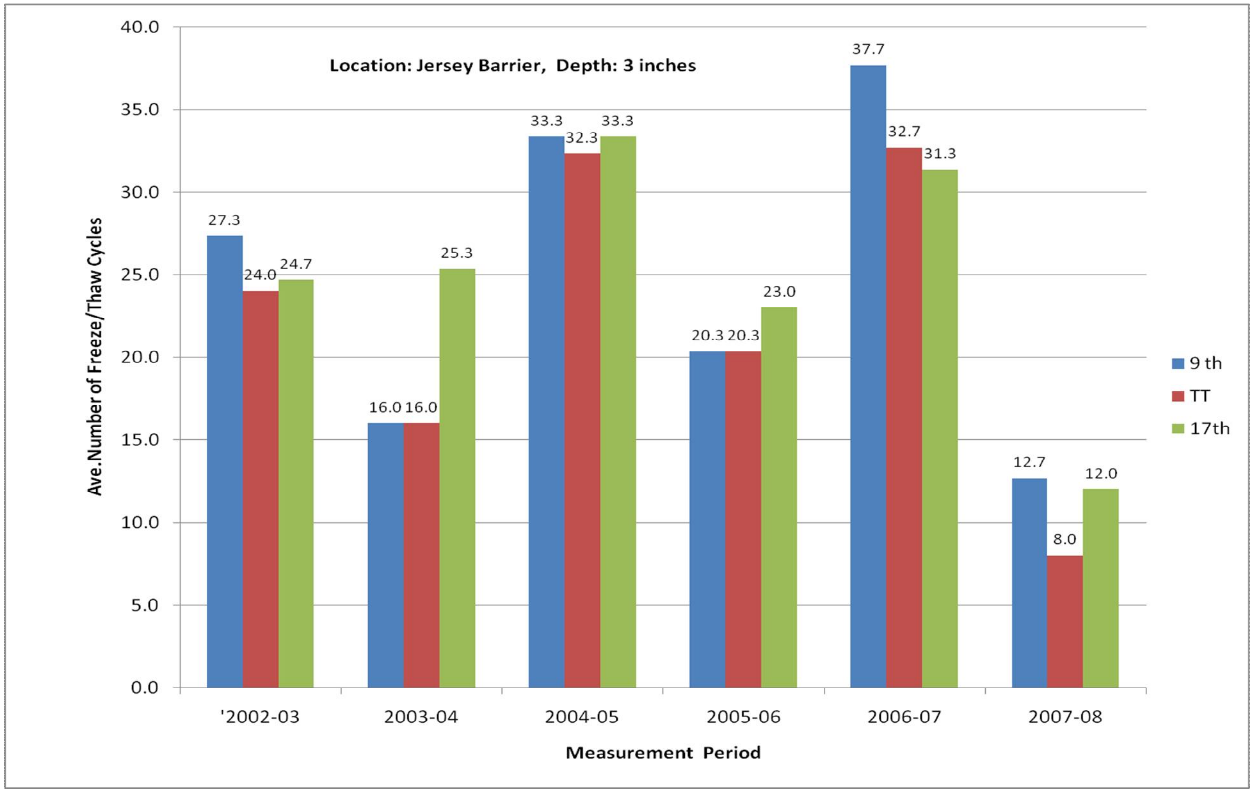
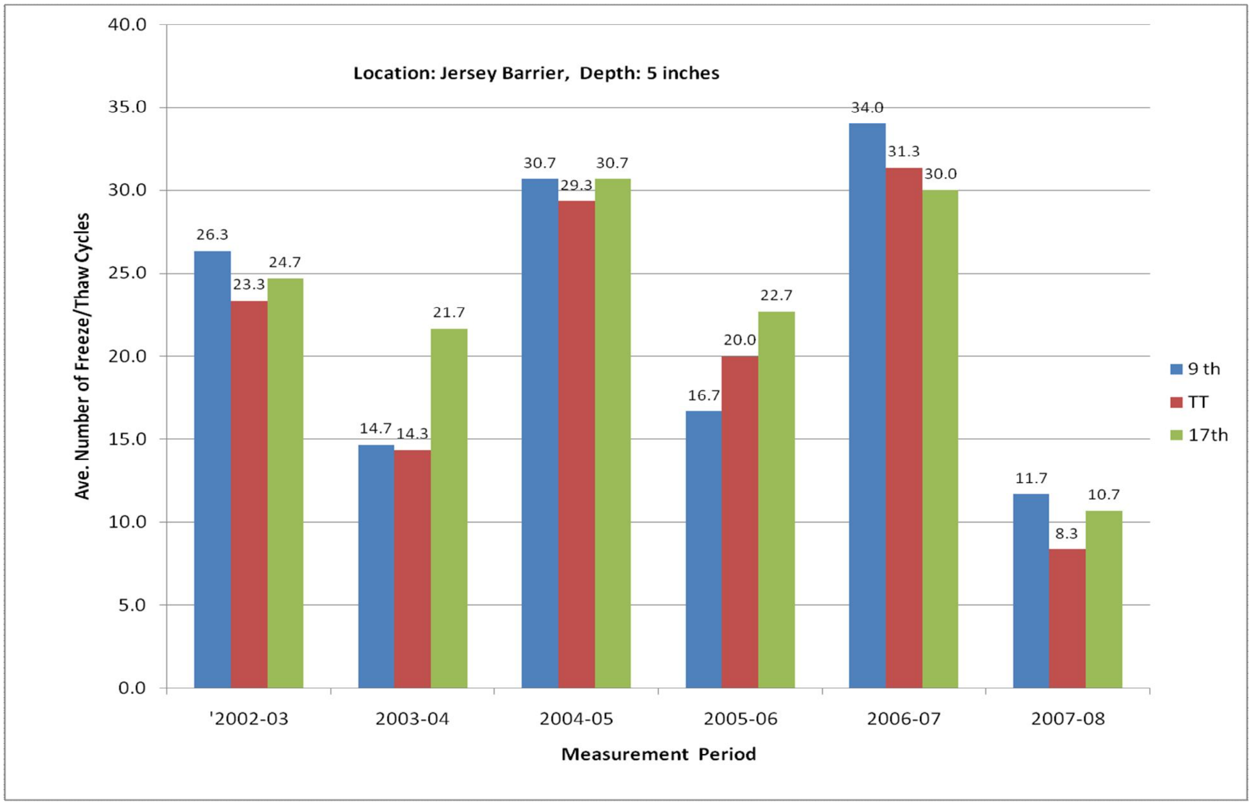


Figure 16: Average Number of Freeze/Thaw Cycles in the Bridge Decks (Samples Were Collected Close to the Left Jersey Barrier at a Depth of 5 Inches)



On some occasions in the first few years of the project, the storage space of data loggers filled up before the data was downloaded. When this happened, some temperature data was lost and had to be estimated from daily temperature data available for the NOAA National Climate Data Center. This temperature data was for Hector International Airport located a few miles from the project site.

5.0 Visual Observations on the Bridges

Each summer a visual examination of the bridge decks was made to note any obvious deterioration that may have occurred during the previous year. The observations were made on each deck at the span where the corrosion measurement contacts were placed.

After the first year of the project, several hair line cracks were observed in each of the bridge decks. In fact, the North Dakota DOT indicated that these cracks were present soon after the jersey barrier was constructed. These cracks tended to radiate out from the jersey barrier into the left traffic lane. All of the bridge decks had cracks typically spaced 5 to 10 feet apart. None of the bridges had any cracks that appeared to represent any significant structural damage. Over the course of the five year project, the number of cracks on each bridge did not appear to increase nor did they expand in length or width. In general, cracking did not seem to be a serious problem on any of the bridges.

6.0 Summary and Conclusions

This report summarizes the results of corrosion monitoring activities carried out at three bridges on I-29 in Fargo, North Dakota between 2002 and 2008. The deck sections being monitored were constructed in the summer of 2002 on the south bound 9th Avenue South Bridge, the south bound Texas Turn Bridge, and the south bound 17th Avenue South Bridge.

Two of the bridges used mineral admixtures for reducing corrosion and other types of deterioration related to moisture penetration. The 9th Avenue bridge was made with conventional Portland cement concrete (i.e., concrete that did not contain any mineral admixtures), the Texas Turn Bridge was made with a modified concrete containing fly ash, and the 17th Avenue Bridge was made with a modified concrete containing GGBFS. These bridges were monitored to evaluate corrosion of the reinforcing steel, chloride content in the concrete, and freeze/thaw frequency. For the monitoring, the decks were constructed with thermocouples embedded in the concrete to measure the temperature and also to determine corrosion rates in the reinforcing steel. Additionally, concrete samples were extracted to determine the chloride ion concentration in the deck. The main purpose of the monitoring activities was to determine whether the durability of the concrete was enhanced by the addition of the mineral admixtures.

Based on the Icorr corrosion rate measurements, it appears that all of the rebar at the locations tested on the three bridge decks were in a passive (non-corroding) condition as of July 2008. The Icorr measurements are roughly in line with the chloride measurements in terms which bridges exhibited the highest corrosion potential. The 9th Avenue Bridge generally produced the highest Icorr readings and the Texas Turn Bridge produced the lowest readings. However since the differences in the Icorr values measured for the three bridges were relatively small and all of the decks were in a passive condition, it is difficult to draw any strong conclusions from the Icorr data when comparing the relative corrosion rates in the three decks.

The concrete resistivities measured on the three decks varied widely. Some of the values were in the range from 10 to 50 kΩ cm, which indicates moderate to high corrosion potential when the steel is not in a passive condition. It should be noted however that these resistivity measurements do not indicate that the rebar is in danger of corroding, because the corresponding Icorr measurements showed that the rebar were in a passive condition.

The results of the chloride analyses done on concrete samples taken from the bridges indicated that chloride levels are increasing over time in the top five inches of the decks. As expected, the highest chloride levels were found in the top 0.5 inches. However there were also measurable increases in chloride levels at depths of 3 and 5 inches into the deck. In general, the highest chloride levels were measured for the 9th Avenue Bridge, the next highest chloride levels were measured for the 17th Avenue Bridge, and the lowest chloride levels were measured for the Texas Turn Bridge. The Texas Turn Bridge was the only one of the three where the average chloride level in the concrete was below 1.0 lb/cu.yd. at a depth of 5 inches in the most recent (August 2007) samples.

The numbers of freeze/thaw cycles that occurred at various depths in each bridge deck were estimated from the temperature data collected. The data was collected at three locations in the far left traffic lane and three locations close to the jersey barrier on each bridge deck. In general, more freeze thaw cycles occurred in the traffic lane as compared to the areas closer to the jersey barrier, and more freeze thaw cycles occurred closer to the surface of the concrete deck (i.e., 0.5 inches below the surface) as compared to points deeper in the deck (i.e., 3 inches and 5 inches below the surface). The results show that the number of freeze/thaw cycles that occurred in the decks varied significantly from year to year. However, comparing results within the same year suggests that there is no clear trend to indicate that any one of the bridges consistently experienced more freeze/thaw cycles than the others.

One of the key questions that this project sought to answer was whether the addition of fly ash or GGBFS to the concrete reduced the rate of intrusion of environmental contaminants such as chloride. Based on some of the results obtained, it appears that the concrete that contained the mineral admixtures did perform better than the plain concrete. The chloride data in particular indicates that after the first year of the project, the plain concrete consistently contained the highest chloride levels at 0.5, 3 and 5 inches of depth into the deck. The Icorr corrosion measurements indicated a similar trend, however the differences in the Icorr values were fairly small and the values clearly showed that all three decks were in a passive condition at all locations where the measurements were collected. The temperature data collected indicated that all the bridges experienced similar numbers of freeze/thaw cycles during the project, so it can be concluded that freeze/thaw effects were not a major variable in terms of the overall performance of the three bridge decks.

Appendix A – Summary of Icorr, Concrete Resistivity, and Temp./Humidity Test Results

Icorr Data Collected at the 9th Ave. Bridge (micro amp/cm^2)

	8/12/03	10/22/03	5/6/04	6/17/04	8/12/04	10/20/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/16/07	06/21/07	8/31/2007	10/24/2007	5/21/2008	7/15/2008
9th -1	0.031	0.013	0.018	0.026	0.022	0.022	0.024	0.077	0.015	0.008	0.018	0.034	0.027	No Data	0.056	0.029	0.048	0.009	0.006	0.008
9th -2	0.058	0.003	0.011	0.016	0.009	0.011	0.025	0.049	0.042	0.008	0.036	0.035	0.068	0.048	0.018	0.042	0.052	0.021	0.026	0.029
9th -3	0.073	0.001	0.031	0.065	0.018	0.005	0.028	0.041	0.050	0.010	0.030	0.075	0.072	0.060	0.035	0.071	0.022	0.026	0.021	0.032
9th -4	0.040	0.006	0.012	0.029	0.006	0.017	0.015	0.036	0.044	0.136	No Data	0.021	0.012	0.310	0.018	0.041	0.016	0.010	0.014	0.034
9th -5	0.045	0.008	0.022	0.044	0.013	0.021	0.013	0.081	0.040	0.048	0.060	0.044	0.070	0.132	0.036	0.072	0.059	0.016	0.027	0.032
9th -6	0.027	0.006	0.020	0.075	0.017	0.009	0.032	0.037	0.029	0.005	0.035	0.020	0.029	0.025	0.007	0.027	No Data	0.003	0.022	0.037
9th -7	0.028	0.007	0.035	0.018	0.015	0.009	0.011	0.038	0.038	0.020	0.060	0.024	0.105	0.022	0.012	0.032	0.025	0.021	0.018	0.033
9th -8	0.037	0.015	0.038	0.030	0.024	0.026	0.022	0.043	0.073	0.048	0.010	0.052	0.031	0.028	0.021	0.044	0.018	0.015	0.033	0.057
9th -9	0.019	0.006	0.013	0.018	0.009	0.005	0.004	0.029	0.034	0.012	0.020	0.007	0.029	0.020	0.017	0.025	0.035	No Data	0.014	0.008
9th -10	0.010	0.007	0.021	0.048	0.004	0.007	0.006	0.031	0.034	0.009	0.018	0.040	0.047	0.047	0.042	0.044	0.050	0.013	0.026	0.046
9th -11	0.013	0.003	0.003	0.004	0.006	0.010	0.010	0.026	0.015	0.020	0.063	0.033	0.047	0.021	No Data	0.074	0.044	0.015	0.025	0.036
9th -12	0.025	0.003	0.009	0.053	0.017	0.009	0.017	0.022	0.021	0.021	0.026	0.064	0.074	0.017	0.006	0.058	0.056	0.022	0.029	0.059
9th -13	0.022	0.004	0.008	0.057	0.001	0.003	0.007	0.006	0.014	0.001	No Data	0.018	0.011	0.047	0.172	0.034	0.025	0.035	0.024	0.022
9th -14	0.006	0.003	0.019	0.062	0.025	0.010	No Data	0.014	0.017	0.005	No Data	0.026	0.024	0.153	0.086	0.017	0.014	0.014	0.018	0.019
9th -15	0.010	0.017	0.027	0.040	0.015	0.028	0.034	0.036	0.016	0.014	0.070	0.048	0.054	0.063	0.055	0.041	0.032	0.023	0.047	0.023

Icorr Data Collected at the Texas Turn Bridge (micro amp/cm2)

	8/12/03	10/22/03	4/22/04	6/16/04	8/12/04	10/26/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/16/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
TT -1	0.012	0.017	0.011	0.024	0.023	0.015	0.015	0.022	0.043	0.003	No Data	No Data	0.010	0.016	0.012	0.014	0.014	No Data	0.004	0.029
TT -2	0.012	0.006	No Data	0.012	0.021	0.007	0.009	0.078	0.061	0.002	No Data	0.004	0.003	0.006	0.007	0.007	0.003	No Data	No Data	0.006
TT -3	0.030	0.007	0.009	0.032	0.016	No Data	0.018	0.028	0.069	0.021	0.007	0.021	0.010	0.004	0.005	0.009	0.011	0.014	0.004	0.006
TT -4	0.003	0.011	0.008	0.030	0.003	No Data	0.006	0.012	No Data	0.004	No Data	0.005	0.014	No Data	0.007	0.010	0.015	0.008	0.008	0.017
TT -5	0.018	0.006	0.003	0.046	0.009	No Data	0.013	0.004	0.040	0.009	No Data	0.050	0.031	0.018	0.004	0.015	0.032	0.028	0.031	0.019
TT -6	0.003	0.002	0.012	0.010	0.010	No Data	0.017	0.004	No Data	No Data	No Data	0.024	0.055	No Data	0.020	0.002	0.012	0.015	0.011	0.014
TT -7	0.012	0.003	0.013	0.037	0.014	No Data	0.015	0.002	0.035	No Data	No Data	0.024	0.029	0.009	0.008	0.022	0.012	0.008	0.004	0.018
TT -8	0.011	0.002	0.004	0.010	0.011	No Data	0.024	0.002	0.055	No Data	No Data	0.014	0.023	0.015	0.005	0.007	0.058	0.005	0.031	0.020
TT -9	0.012	0.006	0.004	0.014	0.012	No Data	0.009	0.004	0.033	0.031	No Data	0.064	0.012	0.019	0.054	0.006	0.021	0.006	0.018	0.022
TT -10	0.007	0.007	0.010	0.033	0.027	No Data	0.004	0.005	0.051	0.008	No Data	0.011	0.019	0.007	0.010	0.003	0.007	0.007	0.016	0.005
TT -11	0.010	0.005	0.009	0.012	0.006	No Data	0.006	0.005	No Data	No Data	No Data	0.039	0.023	0.061	0.019	0.016	0.031	0.008	0.005	0.014
TT -12	0.012	0.006	0.008	0.046	0.008	No Data	0.017	0.008	No Data	No Data	No Data	0.135	0.016	0.028	0.115	0.032	0.011	0.012	0.009	No Data
TT -13	0.007	0.001	0.003	0.006	0.004	No Data	0.001	0.005	0.042	No Data	No Data	0.024	0.022	No Data	0.006	0.019	No Data	No Data	0.012	0.050
TT -14	0.010	0.009	0.008	0.016	0.011	No Data	0.025	0.003	0.034	0.014	No Data	0.057	0.013	0.002	0.045	0.013	0.021	0.009	0.028	0.011
TT -15	0.013	0.004	0.009	0.019	0.012	No Data	0.015	0.015	0.038	0.028	No Data	0.014	0.020	No Data	0.006	0.009	0.018	0.006	0.013	0.012

Icorr Data Collected at the 17th Ave. Bridge (micro amp/cm2)

	8/12/03	10/22/03	4/22/04	6/16/04	8/12/04	10/26/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/16/07	5/31/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
17th -1	0.016	0.004		0.030	0.012	No Data	0.073	0.026	0.031	0.003	0.018	0.035	0.062	No Data	0.021	0.026	0.015	0.015	0.062	0.026	0.032
17th -2	0.016	0.007	0.055	0.006	0.013	No Data	0.017	0.021	0.023	0.002	0.015	0.093	0.025	0.028	0.083	0.032	0.036	0.029	0.018	0.005	0.010
17th -3	0.011	0.004	0.007	0.011	0.008	No Data	0.035	0.013	0.019	0.021	0.010	0.016	0.015	No Data	0.005	0.014	0.022	0.015	0.007	No Data	0.008
17th -4	0.018	0.006	0.013	0.008	0.008	No Data	0.007	0.023	0.015	0.004	0.022	0.011	0.025	0.011	0.012	0.025	0.016	0.033	0.018	0.021	0.014
17th -5	0.008	0.005	0.018	0.010	0.013	No Data	0.005	0.019	0.030	No Data	0.014	0.016	0.012	0.077	0.021	0.007	0.060	0.017	No Data	0.002	0.022
17th -6	0.008	0.003	0.012	0.012	0.010	No Data	0.007	0.016	No Data	No Data	0.023	0.024	0.059	0.019	No Data	0.029	0.022	0.034	No Data	0.009	0.017
17th -7	0.012	0.004	No Data	0.005	0.016	No Data	0.011	0.017	0.021	No Data	0.061	0.034	0.020	No Data	0.017	0.012	0.022	0.033	No Data	0.018	0.017
17th -8	0.013	0.011	0.017	0.010	0.014	No Data	0.011	0.016	0.048	No Data	0.018	0.014	0.069	No Data	No Data	0.019	0.031	0.068	0.013	0.025	0.018
17th -9	0.012	0.010	0.014	0.020	0.012	No Data	0.011	0.036	0.034	No Data	0.061	0.018	0.027	No Data	No Data	0.014	0.019	No Data	0.007	0.019	0.009
17th -10	0.008	0.005	0.012	0.012	0.010	No Data	0.012	0.031	0.033	0.013	0.012	0.012	0.072	No Data	No Data	0.025	0.029	No Data	0.013	0.021	0.018
17th -11	0.011	0.004	0.012	0.007	0.026	No Data	0.018	0.027	0.043	No Data	0.017	0.023	0.034	No Data	No Data	0.049	0.013	0.038	0.008	No Data	No Data
17th -12	0.011	0.014	0.017	0.012	0.013	No Data	0.008	0.042	0.098	No Data	0.000	0.036	0.070	No Data	No Data	0.021	0.025	0.031	0.017	0.018	0.030
17th -13	0.007	0.007	No Data	0.032	0.012	No Data	0.012	0.024	0.069	No Data	No Data	0.045	0.027	No Data	No Data	0.020	0.037	0.035	No Data	0.011	0.012
17th -14	0.014	0.008	0.010	0.006	0.010	No Data	0.011	0.031	0.054	No Data	0.061	0.016	0.017	No Data	No Data	0.017	0.028	No Data	No Data	No Data	0.027
17th -15	0.012	0.007	0.031	0.007	0.058	No Data	0.018	0.025	0.099	No Data	No Data	0.055	0.043	No Data	No Data	0.017	0.061	0.041	0.021	No Data	0.016

9th Avenue Concrete Resistivity Data (kilo ohm cm)

	8/12/03	10/22/03	5/6/04	6/16/04	8/12/04	10/26/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/16/07	6/21/07	3/31/07	5/16/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
9th -1	0.0	0.0	55.9	62.8	200.4	No Data	249.2	55.5	22.2	65.3	No Data	65.7	261.2	No Data	170.4	121.0	78.1	170.4	121.0	78.1	63.3	No Data	80.6
9th -2	0.0	0.0	256.0	60.2	270.4	108.2	264.4	64.9	34.2	No Data	92.6	98.0	182.6	30.6	247.6	135.6	55.1	247.6	135.6	55.1	169.0	No Data	138.0
9th -3	0.0	0.0	272.0	41.7	72.9	No Data	167.4	52.0	No Data	No Data	81.0	65.6	260.0	31.9	49.9	69.7	228.4	49.9	69.7	228.4	46.7	No Data	0.0
9th -4	0.0	0.0	660.0	115.7	128.4	No Data	325.6	43.2	40.5	No Data	61.5	95.3	178.0	30.2	392.0	88.0	25.3	392.0	88.0	25.3	80.5	No Data	4.6
9th -5	0.0	0.0	83.8	39.4	168.2	No Data	73.5	59.6	No Data	No Data	52.2	45.0	73.3	26.0	40.7	75.3	58.4	40.7	75.3	58.4	36.9	No Data	49.4
9th -6	0.0	0.0	22.5	80.2	41.3	No Data	93.8	71.7	No Data	No Data	78.5	46.2	55.7	26.0	72.8	59.4	29.5	72.8	59.4	29.5	38.5	No Data	132.8
9th -7	0.0	0.0	12.9	23.7	76.8	No Data	159.8	34.7	50.9	90.4	No Data	42.0	47.7	29.1	87.0	75.5	0.0	87.0	75.5	No Data	78.8	No Data	84.0
9th -8	0.0	0.0	12.5	26.7	53.7	No Data	102.3	45.1	45.1	No Data	No Data	43.1	248.4	No Data	61.1	28.1	0.0	61.1	28.1	No Data	47.0	No Data	94.4
9th -9	0.0	0.0	32.7	144.4	564.4	No Data	427.6	195.6	40.2	No Data	143.2	214.2	183.2	48.2	320.0	267.6	173.6	320.0	267.6	173.6	728.0	No Data	356.8
9th -10	0.0	1608.0	286.8	39.9	417.2	No Data	914.4	46.8	39.5	No Data	59.3	131.6	60.2	34.3	96.9	148.8	405.6	96.9	148.8	405.6	157.2	No Data	253.6
9th -11	0.0	0.0	34.4	30.0	235.4	No Data	132.8	38.8	No Data	No Data	71.7	51.3	70.5	198.8	948.8	58.3	47.6	948.8	58.3	47.6	82.7	No Data	123.6
9th -12	0.0	0.0	48.5	38.5	108.7	No Data	161.8	82.5	No Data	No Data	28.1	49.9	50.4	91.3	127.6	76.7	55.7	127.6	76.7	55.7	89.9	No Data	No Data
9th -13	0.0	0.0	50.8	36.7	622.4	No Data	335.2	115.7	33.7	107.5	No Data	217.8	111.4	23.2	431.2	154.2	82.9	431.2	154.2	82.9	121.4	No Data	335.6
9th -14	0.0	0.0	29.1	27.2	270.0	No Data	38.8	36.7	29.5	No Data	No Data	91.6	26.2	869.2	205.8	57.7	1560.4	205.8	57.7	1560.4	71.1	No Data	77.1
9th -15	0.0	0.0	388.0	29.1	433.6	No Data	77.5	45.3	35.1	No Data		52.9	NoData	5.9	113.0	44.1	56.4	113.0	44.1	56.4	80.4	No Data	85.2

Concrete Resistivity Data Collacted at the Texas Turn Bridge (kΩ cm)

	8/12/03	10/22/03	4/22/04	6/16/04	8/12/04	10/26/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/31/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
TT -1	0.0	0.0	0.0	98.9	85.5	No Data	253.6	60.8	53.5	120.7	No Data	89.0	59.3	No Data	No Data	55.0	32.6	143.7	No Data	0.0
TT -2	0.0	0.0	No Data	86.8	76.2	No Data	220.4	55.7	53.3	No Data	113.5	105.5	238.5	No Data	71.6	125.6	No Data	165.8	No Data	110.1
TT -3	0.0	0.0	86.3	88.5	106.4	No Data	95.4	78.8	No Data	No Data	154.9	55.3	118.9	34.6	53.0	88.5	53.6	221.6	No Data	148.2
TT -4	0.0	0.0	0.0	39.6	289.2	No Data	406.8	123.7	No Data	No Data	143.8	96.2	174.4	No Data	70.1	128.8	63.6	717.6	No Data	216.6
TT -5	0.0	0.0	0.0	20.2	385.6	No Data	165.4	69.7	40.8	No Data	No Data	235.0	32.7	25.9	110.3	198.0	63.6	228.0	No Data	158.0
TT -6	0.0	0.0	0.0	21.2	242.0	No Data	364.0	54.1	69.3	No Data	No Data	132.2	75.9	16.6	80.9	164.2	1742.8	210.6	No Data	158.8
TT -7	0.0	0.0	59.9	29.8	412.4	No Data	415.6	68.6	No Data	No Data	No Data	161.6	196.3	14.5	84.6	75.8	82.8	164.8	No Data	0.9
TT -8	0.0	0.0	236.4	14.0	112.5	No Data	192.2	44.5	76.5	No Data	No Data	130.2	111.8	16.5	85.5	149.8	89.4	No Data	No Data	221.4
TT -9	770.8	0.0	167.0	86.5	444.8	No Data	666.4	90.6	66.8	No Data	No Data	206.8	228.2	12.6	192.2	363.2	196.6	264.0	No Data	489.4
TT -10	0.0	0.0	0.0	55.5	190.0	No Data	195.4	43.9	No Data	No Data	89.5	122.6	191.6	17.3	86.7	141.8	86.4	140.4	No Data	171.6
TT -11	0.0	0.0	10.3	54.0	164.0	No Data	157.2	83.5	No Data	No Data	132.6	129.2	136.1	2.7	54.5	81.6	124.8	250.8	No Data	324.8
TT -12	0.0	0.0	0.0	44.0	702.4	No Data	180.0	50.0	46.8	No Data	No Data	109.3	103.1	8.8	58.4	57.3	60.6	95.1	No Data	162.0
TT -13	0.0	0.0	0.0	73.8	219.0	No Data	306.0	61.1	76.8	No Data	No Data	194.2	132.2	37.9	334.0	87.5	51.1	131.2	No Data	206.6
TT -14	0.0	0.0	0.0	92.2	149.6	No Data	228.8	17.2	No Data	129.6	188.1	152.6	71.1	142.0	No Data	68.7	60.5	110.3	No Data	201.8
TT -15	0.0	0.0	32.9	87.7	183.0	No Data	176.2	44.8	96.5	No Data	107.3	0.0	38.3	30.6	105.7	60.0	38.0	58.5	No Data	123.6

Concrete Resistivity Data Collected at the 17th Avenue Bridge (kΩ cm)

	8/12/03	10/22/03	4/22/04	6/16/04	8/12/04	10/26/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/31/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
17th -1	0.0	0.0	No Data	10.6	129.8	No Data	256.0	47.1	49.7	No Data	97.2	114.4	105.9	10.0	No Data	143.2	No Data	496.0	No Data	17.2
17th -2	0.0	0.0	32.9	30.0	308.0	No Data	338.0	31.0	39.1	No Data	150.5	220.2	203.8	8.6	58.8	87.8	No Data	216.2	28.7	222.5
17th -3	0.0	0.0	65.6	14.7	130.4	No Data	169.2	52.7	42.2	No Data	111.8	83.9	131.4	10.6	75.3	87.3	No Data	187.0	33.2	185.6
17th -4	0.0	0.0	0.0	12.3	97.5	No Data	260.4	83.5	No Data	120.6	76.2	82.3	103.3	34.4	53.1	67.7	No Data	155.4	No Data	181.6
17th -5	0.0	0.0	0.0	8.6	158.8	No Data	190.2	83.2	No Data	98.2	No Data	71.8	214.6	0.0	0.0	60.7	No Data	275.2	No Data	177.4
17th -6	0.0	0.0	0.0	7.8	221.8	No Data	271.2	40.2	31.5	No Data	No Data	84.9	129.1	No Data	58.9	64.4	No Data	318.8	No Data	295.6
17th -7	0.0	0.0	No Data	4.6	188.2	No Data	118.2	11.4	No Data	No Data	56.1	46.3	53.2	No Data	48.2	52.0	No Data	1128.8	No Data	133.0
17th -8	0.0	0.0	0.0	5.8	227.6	No Data	276.0	32.6	40.3	No Data	88.4	61.1	82.5	No Data	70.9	57.3	No Data	240.0	No Data	107.9
17th -9	0.0	0.0	0.0	3.8	124.0	No Data	68.1	54.4	44.9	No Data	No Data	38.5	123.8	No Data	81.1	64.0	No Data	89.6	No Data	123.4
17th -10	0.0	0.0	17.7	2.3	71.2	No Data	122.8	81.5	No Data	103.9	No Data	61.0	51.5	No Data	71.0	86.0	No Data	19.7	No Data	106.6
17th -11	0.0	0.0	0.0	30.3	83.6	No Data	47.7	2.8	51.3	No Data	No Data	29.2	50.6	No Data	0.0	57.5	No Data	62.4	No Data	71.3
17th -12	0.0	0.0	0.0	36.8	56.7	No Data	67.8	41.0	58.2	No Data	65.8	31.2	54.3	No Data	28.1	43.0	No Data	55.8	No Data	57.3
17th -13	0.0	0.0	No Data	8.7	75.2	No Data	131.4	58.6	No Data	No Data	95.3	43.6	65.6	No Data	46.1	54.6	No Data	83.1	No Data	65.0
17th -14	0.0	0.0	0.0	61.5	180.6	No Data	119.8	52.9	44.7	No Data	146.8	54.0	133.4	No Data	87.0	89.7	No Data	111.9	No Data	160.2
17th -15	0.0	0.0	0.0	47.4	242.8	No Data	55.6	46.6	32.7	No Data	No Data	23.2	31.9	No Data	44.3	42.8	No Data	1542.0	No Data	82.2

Air Temp., Deg.	8/12/03	10/22/03	5/6/04	6/17/04	8/12/04	10/20/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/16/07	5/31/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
1	20.4	19.1	8.4	20.7	15.8	4.5	5.9	25.8	27.0	11.0	10.8	32.1	24.4	12.2	10.2	14.8	24.3	23.2	11.2	16.1	26.1
2	27.5	18.7	9.4	25.5	17.6	7.2	5.3	24.7	27.3	16.0	11.5	33.0	24.3	17.2	12.2	15.0	26.5	24.7	12.7	18.9	27.2
3	29.5	18.1	16.0	24.7	18.4	9.4	6.4	28.7	30.0	17.0	11.8	31.0	24.9	21.1	16.1	23.3	27.2	26.4	15.4	20	27.8

Rel. Hum., %	8/12/03	10/22/03	5/6/04	6/17/04	8/12/04	10/20/04	4/28/05	6/22/05	8/18/05	10/28/05	5/11/06	7/5/06	8/30/06	11/8/06	5/16/07	5/31/07	6/21/07	8/31/07	10/24/07	5/21/08	7/15/08
1	74	27	43	46	39	70	43	58	62	69	58	20	44	60	51	64	43	59	48	30	39
2	50	21	25	32	41	74	51	55	61	46	55	20	39	58	51	60	31	57	38	25	41
3	37	24	21	30	40	66	44	53	81	40	56	21	34	41	35	48	32	50	35	19	40

Appendix B – Lab Results for Chloride Samples

REPORT OF TEST ON SAMPLE
Department of Transportation, Materials & Research

COPY

MATERIAL Pulverized PCC from Bridge Deck	PROJECT IM-NH-8-029(050)062 Low Permeability Concrete for Bridge Decks
LAB NO. Misc. 50-67	COUNTY Bridge 29-064.555 L, 9th Ave SB
FIELD SAMPLE NO. A1 thru F3	SAMPLE FROM Deck locations & sample depths listed below
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride Content	
DATE RECEIVED 10-14-02 / DATE SAMPLED 10-8-02	SUBMITTED BY B. Fuchs

Lab No.	FS No.	Station Location		Depth, Inches	Chloride Content lb/cy.yd
50	A1	3409+32	10.3' Rt	.25-.75	0.35
51	A2	"	"	2.5-3.0	0.42
52	A3	"	"	4.5-5.0	0.56
53	B1	3409+33.18	16.5' Rt	.25-.75	0.34
54	B2	"	"	2.5-3.0	0.88
55	B3	"	"	4.5-5.0	0.40
56	C1	3409+16.48	8.1' Rt	.25-.75	0.64
57	C2	"	"	2.5-3.0	0.35
58	C3	"	"	4.5-5.0	0.44
59	D1	3409+15.96	17.1' Rt	.25-.75	0.69
60	D2	"	"	2.5-3.0	0.48
61	D3	"	"	4.5-5.0	1.12
62	E1	3408+84.10	7.4' Rt	.25-.75	0.63
63	E2	"	"	2.5-3.0	0.76
64	E3	"	"	4.5-5.0	0.56
65	F1	3408+83.72	15.4' Rt	.25-.75	0.69
66	F2	"	"	2.5-3.0	0.55
67	F3	"	"	4.5-5.0	0.62

November 25, 2002
Date

Dennis J. Blasl
Laboratory Supervisor

Distribution:
Laboratory
Bryon Fuchs

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

COPY

MATERIAL Pulverized PCC from Bridge Deck		PROJECT IM-NH-8-029(050)062 Low Permeability Concrete for Bridge Decks
LAB NO. Misc. 58-85		COUNTY Bridge 29-064.129 L Texas Turn (SB)
FIELD SAMPLE NO. G1 thru L3		SAMPLE FROM Deck locations & sample depths listed below
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride Content		
DATE RECEIVED 10-14-02	DATE SAMPLED 10-8-02	SUBMITTED BY B. Fuchs

Lab No.	FS No.	Station Location		Depth	Chloride Content lb/cy.yd
68	G1	3387+47.95	8.2' Rt	.25-.75	0.41
69	G2	"	"	2.5-3.0	1.10
70	G3	"	"	4.5-5.0	0.96
71	H1	3387+49.25	16.3'Rt	0.25-.75	0.96
72	H2	"	"	2.5-3.0	0.62
73	H3	"	"	4.5-5.0	1.08
74	I1	3387+17.15	7.5'Rt*	.25-.75	0.45
75	I2	"	"	2.5-3.0	0.56
76	I3	"	"	4.5-5.0	0.23
77	J1	3387+16.65	17.6'Rt	.25-.75	0.75
78	J2	"	"	2.5-3.0	0.51
79	J3	"	"	4.5-5.0	0.54
80	K1	3387+09.65	8.1' Rt	.25-.75	0.35
81	K2	"	"	2.5-3.0	0.48
82	K3	"	"	4.5-5.0	0.76
83	L1	3386+98.95	15.3' Rt	.25-.75	0.35
84	L2	"	"	2.5-3.0	0.60
85	L3	"	"	4.5-5.0	0.70

November 25, 2002
Date

Dennis J. Blasl
Laboratory Supervisor

Distribution:
Laboratory
Bryon Fuchs

*8/18/03 revised

REPORT OF TEST ON SAMPLE
Department of Transportation, Materials & Research

COPY

MATERIAL Pulverized PCC from Bridge Deck	PROJECT IM-NH-8-029(050)062 Low Permeability Concrete for Bridge Decks
LAB NO. Misc. 86-102	COUNTY Bridge 29-063.788 L, 17th Ave SB
FIELD SAMPLE NO. M1 thru R2	SAMPLE FROM Deck locations & sample depths listed below
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A	
DATE RECEIVED 10-14-02 DATE SAMPLED 10-8-02	SUBMITTED BY B. Fuchs

Lab No.	FS No.	Station Location		Depth	Chloride Content lb/cy.yd
86	M1	3368+95.61	9.45' Rt	.25-.75	0.48
87	M2	"	"	2.5-3.0	0.62
88	M3	"	"	4.5-5.0	0.33
89	N1	3368+94.96	16.55' Rt	.25-.75	0.54
90	N2	"	"	2.5-3.0	0.33
91	N3	"	"	4.5-5.0	0.60
92	O1	3368+65.16	10.15' Rt	.25-.75	0.82
93	O2	"	"	2.5-3.0	0.75
94	O3	"	"	4.5-5.0	0.56
95	P1	3368+64.17	17.75' Rt	.25-.75	0.90
96	P2	"	"	2.5-3.0	0.64
97	P3	"	"	4.5-5.0	0.85
98	Q1	3368+50.19	10.05' Rt	.25-.75	0.73
99	Q2	"	"	2.5-3.0	0.53
100	Q3	"	"	4.5-5.0	0.53
101	R1	3368+48.87	18.0' Rt	.25-.75	0.68
102	R2	"	"	2.5-3.0	0.82

November 25, 2002
Date

Dennis J. Blasl
Laboratory Supervisor

Distribution:
Laboratory
Bryon Fuchs

REPORT OF TEST ON SAMPLE
Department of Transportation, Materials & Research

COPY

MATERIAL	PROJECT
Pulverized PCC from Bridge Deck	Portland Cement
LAB NO. Misc. #'s 137-154	COUNTY Bridge # 29-064.555 L., 9th Ave. (S.B.)
FIELD SAMPLE NO. 2A1 thru 2F3	SAMPLE FROM Deck locations & Spl. Depths listed below
SPECIFICATION AASHTO T-260-97, Procedure A - Chloride Content	
Cass Co./Fargo District	
DATE RECEIVED 8-18-03; DATE SAMPLED 8-12-03	SUBMITTED BY B. Fuchs

Misc. Lab No.	FS No.	Station Location	Depth	Chloride Content lb/cy.yd
137	2A1	3409+32.10, 3'Rt	0.25-0.75	0.56
138	2A2	"	2.5-3.0	0.42
139	2A3	"	4.5-5.0	0.62
140	2B1	3409+33.18, 16.5'Rt	0.25-0.75	0.73
141	2B2	"	2.5-3.0	0.83
142	2B3	"	4.5-5.0	0.42
143	2C1	3409.16.48, 8.1'Rt	0.25-0.75	0.64
144	2C2	"	2.5-3.0	0.38
145	2C3	"	4.5-5.0	0.48
146	2D1	3409+15.96, 17.1'Rt	0.25-0.75	0.71
147	2D2	"	2.5-3.0	0.59
148	2D3	"	4.5-5.0	1.03
149	2E1	3408+84.10, 7.4'Rt	0.25-0.75	1.90
150	2E2	"	2.5-3.0	0.80
151	2E3	"	4.5-5.0	0.62
152	2F1	3408+83.72, 15.4'Rt	0.25-0.75	0.76
153	2F2	"	2.5-3.0	0.59
154	2F3	"	4.5-5.0	0.64

Dennis J. Blasl
Laboratory Supervisor
October 17, 2003

Distribution:
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REPORT OF TEST ON SAMPLE
Department of Transportation, Materials & Research

COPY

MATERIAL Pulverized PCC from Bridge Deck	PROJECT Portland Cement and Ground Granulated Blast Furnace Slag
LAB NO. Misc. #'s 173-190	COUNTY Bridge # 29-063.788 L., 17th Ave. (S.B.)
FIELD SAMPLE NO. 2M1 thru 2R2	SAMPLE FROM Deck locations & Spl. Depths listed below
SPECIFICATION AASHTO T-260-97, Procedure A - Chloride Content	
Cass Co./Fargo District	

DATE RECEIVED	DATE SAMPLED	SUBMITTED BY
8-18-03	8-12-03	B. Fuchs

Misc. Lab No.	FS No.	Station Location	Depth	Chloride Content lb/cy.yd
173	2M1	3368+95.61, 9.45'Rt	0.25-0.75	0.52
174	2M2	"	2.5-3.0	0.66
175	2M3	"	4.5-5.0	0.38
176	2N1	3368+94.96, 16.55'Rt	0.25-0.75	0.56
177	2N2	"	2.5-3.0	0.38
178	2N3	"	4.5-5.0	0.62
179	2O1	3368+65.16, 10.15'Rt	0.25-0.75	0.78
180	2O2	"	2.5-3.0	0.71
181	2O3	"	4.5-5.0	0.66
182	2P1	3368+64.62, 17.75"Rt	0.25-0.75	0.97
183	2P2	"	2.5-3.0	0.69
184	2P3	"	4.5-5.0	0.83
185	2Q1	3368+50.19, 10.05'Rt	0.25-0.75	*
186	2Q2	"	2.5-3.0	*
187	2Q3	"	4.5-5.0	*
188	2R1	3368+48.87, 18' Rt	0.25-0.75	*
189	2R2	"	2.5-3.0	*
190	2R3	"	4.5-5.0	*

*Samples at locations 2Q and 2R were combined making the results not representative for either location.

Dennis J. Blasl
Laboratory Supervisor
October 17, 2003

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REPORT OF TEST ON SAMPLE
Department of Transportation, Materials & Research

COPY

MATERIAL Pulverized PCC from Bridge Deck		PROJECT Portland Cement and Flyash
LAB NO. Misc. #'s 155-172		COUNTY Bridge # 29-064.129L., Texas Turn (S.B.)
FIELD SAMPLE NO. 2G1 thru 2L3		SAMPLE FROM Deck locations & Spl. Depths listed below
SPECIFICATION AASHTO T-260-97, Procedure A - Chloride Content		
Cass Co./Fargo District		
DATE RECEIVED 8-18-03	DATE SAMPLED 8-12-03	SUBMITTED BY B. Fuchs

Misc. Lab No.	FS No.	Station Location	Depth	Chloride Content lb/cy.yd
155	2G1	3387+47.95, 8.2'Rt	0.25-0.75	0.43
156	2G2	"	2.5-3.0	0.90
157	2G3	"	4.5-5.0	0.90
158	2H1	3387+49.25, 16.3'Rt	0.25-0.75	0.89
159	2H2	"	2.5-3.0	0.59
160	2H3	"	4.5-5.0	1.01
161	2I1	3387+17.15, 7.5'Rt	0.25-0.75	0.45
162	2I2	"	2.5-3.0	0.62
163	2I3	"	4.5-5.0	0.30
164	2J1	3387+16.65, 17.6'Rt	0.25-0.75	1.04
165	2J2	"	2.5-3.0	0.42
166	2J3	"	4.5-5.0	0.59
167	2K1	3387+09.65, 8.1'Rt	0.25-0.75	0.42
168	2K2	"	2.5-3.0	0.45
169	2K3	"	4.5-5.0	0.69
170	2L1	3386+98.95, 15.5'Rt	0.25-0.75	0.31
171	2L2		2.5-3.0	0.55
172	2L3		4.5-5.0	0.62

Dennis J. Blasl
Laboratory Supervisor
October 17, 2003

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Chloride Sample Locations and Corresponding Designations for the Minnesota Valley Testing Laboratories Reports

North Dakota Department of Transportation
Chloride Analysis

	Depths	Sample Number 9th Ave.	Sample Number Texas Turn	Sample Number **17th Ave.
North end of deck, in lane	.25 - .75	M-390	M-408	M-426
	2.5 - 3.0	M-391	M-409	M-427
	4.5 - 5.0	M-392	M-410	M-428
N. end of deck, close to East wall	.25 - .75	M-393	M-411	M-429
	2.5 - 3.0	M-394	M-412	M-430
	4.5 - 5.0	M-395	M-413	M-431
Mid-span of deck, in lane	.25 - .75	M-396	M-414	M-432
	2.5 - 3.0	M-397	M-415	M-433
	4.5 - 5.0	M-398	M-416	M-434
Mid-span of deck, close to East wall	.25 - .75	M-399	M-417	M-435
	2.5 - 3.0	M-400	M-418	M-436
	4.5 - 5.0	M-401	M-419	M-437
North Pier, in lane	.25 - .75	M-402	M-420	M-438
	2.5 - 3.0	M-403	M-421	M-439
	4.5 - 5.0	M-404	M-422	M-440
North Pier, close to east wall	.25 - .75	M-405	M-423	M-441
	2.5 - 3.0	M-406	M-424	M-442
	4.5 - 5.0	M-407	M-425	M-443

**CONTAINS BLAST FURNACE SLAG
Content needs to be reported in Lb./Cu.yd.

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
300 Airport Road
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-375

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M767	9th Ave. M-390 Chloride Water Soluble	0.86 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M768	9th Ave. M-391 Chloride Water Soluble	0.19 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M769	9th Ave. M-392 Chloride Water Soluble	0.43 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M770	9th Ave. M-393 Chloride Water Soluble	0.38 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M771	9th Ave. M-394 Chloride Water Soluble	0.20 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M772	9th Ave. M-395 Chloride Water Soluble	0.12 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M773	9th Ave. M-396 Chloride Water Soluble	0.84 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M774	9th Ave. M-397 Chloride Water Soluble	0.16 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M775	9th Ave. M-398 Chloride Water Soluble	0.17 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M776	9th Ave. M-399 Chloride Water Soluble	7.31 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M777	9th Ave. M-400 Chloride Water Soluble	0.28 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M778	9th Ave. M-401 Chloride Water Soluble	0.24 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M779	9th Ave. M-402 Chloride Water Soluble	3.79 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M780	9th Ave. M-403 Chloride Water Soluble	0.21 lbs/cu.yd Analyzed on 05/04/05 at 09:00

Approved by: D. Zander

MAY 16 2005

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
300 Airport Road
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-375

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M781	9th Ave. M-404 Chloride Water Soluble	0.24 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M782	9th Ave. M-405 Chloride Water Soluble	3.59 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M783	9th Ave. M-406 Chloride Water Soluble	0.39 lbs/cu.yd Analyzed on 05/04/05 at 09:00
05-M784	9th Ave. M-407 Chloride Water Soluble	0.24 lbs/cu.yd Analyzed on 05/04/05 at 09:00

Approved by: D. Zander

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
300 Airport Road
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-376

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M785	Texas Turn M-408 Chloride Water Soluble	0.22 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M786	Texas Turn M-409 Chloride Water Soluble	0.30 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M787	Texas Turn M-410 Chloride Water Soluble	0.18 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M788	Texas Turn M-411 Chloride Water Soluble	0.57 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M789	Texas Turn M-412 Chloride Water Soluble	0.32 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M790	Texas Turn M-413 Chloride Water Soluble	0.35 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M791	Texas Turn M-414 Chloride Water Soluble	0.34 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M792	Texas Turn M-415 Chloride Water Soluble	0.17 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M793	Texas Turn M-416 Chloride Water Soluble	0.61 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M794	Texas Turn M-417 Chloride Water Soluble	3.66 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M795	Texas Turn M-418 Chloride Water Soluble	0.46 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M796	Texas Turn M-419 Chloride Water Soluble	0.19 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M797	Texas Turn M-420 Chloride Water Soluble	1.65 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M798	Texas Turn M-421 Chloride Water Soluble	0.30 lbs/cu.yd Analyzed on 05/09/05 at 09:00

Approved by: D. Zorda

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Scott Wutzke
ND Department of Transportation
300 Airport Road
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-376

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M799	Texas Turn M-422 Chloride Water Soluble	0.20 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M800	Texas Turn M-423 Chloride Water Soluble	5.07 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M801	Texas Turn M-424 Chloride Water Soluble	0.30 lbs/cu.yd Analyzed on 05/09/05 at 09:00
05-M802	Texas Turn M-425 Chloride Water Soluble	0.27 lbs/cu.yd Analyzed on 05/09/05 at 09:00

Approved by: O. Zaider

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
300 Airport Road
Bismarck ND 58504

Report Date: May 13 2005
Work Order #: 81-377

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M803	17th Ave. M-426 Chloride Water Soluble	0.19 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M804	17th Ave. M-427 Chloride Water Soluble	0.26 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M805	17th Ave. M-428 Chloride Water Soluble	0.38 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M806	17th Ave. M-429 Chloride Water Soluble	0.26 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M807	17th Ave. M-430 Chloride Water Soluble	0.23 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M808	17th Ave. M-431 Chloride Water Soluble	0.19 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M809	17th Ave. M-432 Chloride Water Soluble	0.41 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M810	17th Ave. M-433 Chloride Water Soluble	0.51 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M811	17th Ave. M-434 Chloride Water Soluble	0.25 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M812	17th Ave. M-435 Chloride Water Soluble	0.56 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M813	17th Ave. M-436 Chloride Water Soluble	0.16 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M814	17th Ave. M-437 Chloride Water Soluble	0.24 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M815	17th Ave. M-438 Chloride Water Soluble	2.24 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M816	17th Ave. M-439 Chloride Water Soluble	1.31 lbs/cu.yd Analyzed on 05/11/05 at 09:00

Approved by: D. Zander

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1411 S. 12th St. ~ Bismarck, ND 58502 ~ 800-279-6885 ~ Fax 701-258-9724
35 W. Lincoln Way ~ Nevada, IA 50201 ~ 800-362-0855 ~ Fax 515-382-3885
www.mvtl.com

MEMBER ACIL

Scott Wutzke
ND Department of Transportation
300 Airport Road
Bismarck ND 58504

Report Date: May 13 2005
Work Order #: 81-377

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M817	17th Ave. M-440 Chloride Water Soluble	0.16 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M818	17th Ave. M-441 Chloride Water Soluble	6.48 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M819	17th Ave. M-442 Chloride Water Soluble	1.14 lbs/cu.yd Analyzed on 05/11/05 at 09:00
05-M820	17th Ave. M-443 Chloride Water Soluble	0.47 lbs/cu.yd Analyzed on 05/11/05 at 09:00

Approved by: D. Zander

Page: 2

MAY 2 3 2005

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
Materials 7 Research
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-375

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M776	9th Ave. M-399	
	Chloride Water Soluble	7.76 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Approved by: D. Zander

Amended Report

MVTL

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
Materials 7 Research
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-376

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M800	Texas Turn M-423 Chloride Water Soluble	 4.99 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Amended Report

Approved by: O. Zander

MVTL

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
Materials 7 Research
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-375

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M779	9th Ave. M-402	
	Chloride Water Soluble	3.78 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Amended Report

Approved by: D. Zander

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
Materials 7 Research.
Bismarck ND 58504

Report Date: May 13 2005
Work Order #: 81-377

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M818	17th Ave. M-441 Chloride Water Soluble	 6.49 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Approved by: D. Zander

Amended Report

MINNESOTA VALLEY TESTING LABORATORIES, INC.
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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
Materials 7 Research
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-375
Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M782	9th Ave. M-405 Chloride Water Soluble	3.59 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Amended Report

Approved by: D. Zander

MINNESOTA VALLEY TESTING LABORATORIES, INC.

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MEMBER ACIL

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ND Department of Transportation
Materials 7 Research
Bismarck ND 58504

Report Date: May 13 2005
Work Order #: 81-377

Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M815	17th Ave. M-438 Chloride Water Soluble	 2.22 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Approved by: D. Zander

Amended Report

MINNESOTA VALLEY TESTING LABORATORIES, INC.

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MEMBER ACIL

Scott Wutzke
ND Department of Transportation
Materials 7 Research
Bismarck ND 58504

Report Date: May 11 2005
Work Order #: 81-376
Date Received: 5/ 3/05

LAB NUMBER	SAMPLE DESCRIPTION	RESULTS - AS RECEIVED
05-M794	Texas Turn M-417 Chloride Water Soluble	 3.75 lbs/cu.yd Analyzed on 05/18/05 at 13:00

Approved by: D. Zander

Amended Report

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL Pulverized PCC from Bridge Deck		**PROJECT** UND
LAB NO. M49 – M66		**COUNTY** 9th Avenue Bridge
FIELD SAMPLE NO. *see designations below		**SAMPLE FROM** Deck locations & sample
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride Content		
DATE RECEIVED 8/30/2005	**DATE SAMPLED** 8/18/2005	**SUBMITTED BY** B. Fuchs

Lab No.	Station Location	Depth, Inches	Chloride Content lb/ cu.yd.
M-49	ML	0.5"	7.67 lb/cu.yd.
M-55	ML	3.0"	1.14 lb/cu.yd.
M-60	ML	5.0"	1.17 lb/cu.yd.
M-50	MW	0.5"	3.99 lb/cu.yd.
M-56	MW	3.0"	0.74 lb/cu.yd.
M-61	MW	5.0"	0.94 lb/cu.yd.
M-51	NL	0.5"	3.05 lb/cu.yd.
M-65	NL	3.0"	0.90 lb/cu.yd.
M-66	NL	5.0"	1.06 lb/cu.yd.
M-52	NW	0.5"	6.07 lb/cu.yd.
M-57	NW	3.0"	1.14 lb/cu.yd.
M-62	NW	5.0"	1.14 lb/cu.yd.
M-53	SL	0.5"	7.44 lb/cu.yd.
M-58	SL	3.0"	1.25 lb/cu.yd.
M-63	SL	5.0"	1.25 lb/cu.yd.
M-54	SW	0.5"	3.33 lb/cu.yd.
M-59	SW	3.0"	1.02 lb/cu.yd.
M-64	SW	5.0"	1.57 lb/cu.yd.

Date: February 21, 2006 Scott W. Wutzke

Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Bryon Fuchs
UND

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL Pulverized PCC from Bridge Deck		**PROJECT** UND
LAB NO. M67-M84		**COUNTY** Texas Turn Bridge
FIELD SAMPLE NO. *see designations below		**SAMPLE FROM** Deck locations & sample depths
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride Content		
DATE RECEIVED 8/30/2005	**DATE SAMPLED** 8/18/2005	**SUBMITTED BY** B. Fuchs

Lab No.	Station Location	Depth	Chloride Content lb/cu.yd.
M-67	ML	0.5"	8.06 lb/cu.yd.
M-73	ML	3.0"	1.33 lb/cu.yd.
M-79	ML	5.0"	1.02 lb/cu.yd.
M-68	MW	0.5"	2.31 lb/cu.yd.
M-74	MW	3.0"	0.74 lb/cu.yd.
M-80	MW	5.0"	0.90 lb/cu.yd.
M-69	NL	0.5"	2.15 lb/cu.yd.
M-75	NL	3.0"	0.90 lb/cu.yd.
M-81	NL	5.0"	0.70 lb/cu.yd.
M-70	NW	0.5"	1.25 lb/cu.yd.
M-76	NW	3.0"	0.94 lb/cu.yd.
M-82	NW	5.0"	0.74 lb/cu.yd.
M-71	SL	0.5"	3.25 lb/cu.yd.
M-77	SL	3.0"	1.10 lb/cu.yd.
M-83	SL	5.0"	1.14 lb/cu.yd.
M-72	SW	0.5"	3.19 lb/cu.yd.
M-78	SW	3.0"	1.88 lb/cu.yd.
M-84	SW	5.0"	0.72 lb/cu.yd.

Date: February 21, 2006

Scott W. Wutzke

Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Bryon Fuchs
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REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL	PROJECT
Pulverized PCC from Bridge Deck	UND
LAB NO.	**COUNTY**
M85-M102	17th Avenue Bridge
FIELD SAMPLE NO.	**SAMPLE FROM**
*see designations below	Deck locations & sample depths

SPECIFICATION
AASHTO T-260-97 Chloride Content, Procedure A

DATE RECEIVED	DATE SAMPLED	SUBMITTED BY
8/30/2005	8/18/2005	B. Fuchs

Lab No.	Station Location	Depth	Chloride Content lb/cu.yd.
M-85	ML	0.5"	1.49 lb/cu.yd.
M-91	ML	3.0"	1.17 lb/cu.yd.
M-97	ML	5.0"	0.90 lb/cu.yd.
M-86	MW	0.5"	3.41 lb/cu.yd.
M-92	MW	3.0"	1.06 lb/cu.yd.
M-98	MW	5.0"	1.02 lb/cu.yd.
M-87	NL	0.5"	2.31 lb/cu.yd.
M-93	NL	3.0"	1.10 lb/cu.yd.
M-99	NL	5.0"	0.78 lb/cu.yd.
M-88	NW	0.5"	1.02 lb/cu.yd.
M-94	NW	3.0"	0.74 lb/cu.yd.
M-100	NW	5.0"	0.94 lb/cu.yd.
M-89	SL	0.5"	1.45 lb/cu.yd.
M-95	SL	3.0"	1.17 lb/cu.yd.
M-101	SL	5.0"	1.80 lb/cu.yd.
M-90	SW	0.5"	1.49 lb/cu.yd.
M-96	SW	3.0"	0.98 lb/cu.yd.
M-102	SW	5.0"	1.21 lb/cu.yd.

Date: February 21, 2006

Scott W. Wutzke

Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Bryon Fuchs
UND

REPORT OF TEST ON SAMPLE
Department of Transportation, Materials & Research

MATERIAL Pulverized PCC from Bridge Deck		PROJECT UND
LAB NO. M183 – M200		COUNTY 9th Avenue Bridge
FIELD SAMPLE NO. *see designations below		SAMPLE FROM Deck locations & sample depths listed below
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride Content		
DATE RECEIVED 8/30/2006	DATE SAMPLED 8/30/2006	SUBMITTED BY B. Fuchs/ Chuck Moretti, UND

Lab No.	Station Location	Depth, Inches	Chloride Content lb/ cu.yd.
M-183	NL	0.5"	5.32 lb/cu.yd.
M-184	NL	3.0"	1.53 lb/cu.yd.
M-185	NL	5.0"	0.96 lb/cu.yd.
M-186	ML	0.5"	8.57 lb/cu.yd.
M-187	ML	3.0"	2.74 lb/cu.yd.
M-188	ML	5.0"	1.57 lb/cu.yd.
M-189	SL	0.5"	6.58 lb/cu.yd.
M-190	SL	3.0"	2.19 lb/cu.yd.
M-191	SL	5.0"	1.45 lb/cu.yd.
M-192	NW	0.5"	9.79 lb/cu.yd.
M-193	NW	3.0"	1.14 lb/cu.yd.
M-194	NW	5.0"	1.25 lb/cu.yd.
M-195	MW	0.5"	11.61 lb/cu.yd.
M-196	MW	3.0"	3.92 lb/cu.yd.
M-197	MW	5.0"	1.96 lb/cu.yd.
M-198	SW	0.5"	12.65 lb/cu.yd.
M-199	SW	3.0"	2.11 lb/cu.yd.
M-200	SW	5.0"	0.78 lb/cu.yd.

L = Lane W = Wall
N = north end span M = middle span S = south end

Date: December 1, 2006

Scott W. Wutzke

Testing Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Bryon Fuchs
UND

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL Pulverized PCC from Bridge Deck		PROJECT UND
LAB NO. M147-M164		COUNTY Texas Turn Bridge
FIELD SAMPLE NO. *see designations below		SAMPLE FROM Deck locations & sample depths listed below
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride Content		
DATE RECEIVED 8/30/2006	DATE SAMPLED 8/30/2006	SUBMITTED BY B. Fuchs/ Chuck Moretti, UND

Lab No.	Station Location	Depth	Chloride Content lb/cu.yd.
M-147	NL	0.5"	2.64 lb/cu.yd.
M-148	NL	3.0"	1.45 lb/cu.yd.
M-149	NL	5.0"	1.29 lb/cu.yd.
M-150	ML	0.5"	1.29 lb/cu.yd.
M-151	ML	3.0"	1.17 lb/cu.yd.
M-152	ML	5.0"	1.14 lb/cu.yd.
M-153	SL	0.5"	2.58 lb/cu.yd.
M-154	SL	3.0"	1.61 lb/cu.yd.
M-155	SL	5.0"	3.17 lb/cu.yd.
M-156	NW	0.5"	8.61 lb/cu.yd.
M-157	NW	3.0"	3.09 lb/cu.yd.
M-158	NW	5.0"	1.64 lb/cu.yd.
M-159	MW	0.5"	2.04 lb/cu.yd.
M-160	MW	3.0"	2.04 lb/cu.yd.
M-161	MW	5.0"	1.41 lb/cu.yd.
M-162	SW	0.5"	2.07 lb/cu.yd.
M-163	SW	3.0"	1.25 lb/cu.yd.
M-164	SW	5.0"	1.70 lb/cu.yd.

L = Lane W = Wall
N = north end span M = middle span S = south end

Date: December 1, 2006

Scott W. Wutzke

Testing Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Bryon Fuchs
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REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL Pulverized PCC from Bridge Deck		PROJECT UND
LAB NO. M165-M182		COUNTY 17th Avenue Bridge
FIELD SAMPLE NO. *see designations below		SAMPLE FROM Deck locations & sample depths listed below
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A		
DATE RECEIVED 8/30/2006	DATE SAMPLED 8/30/2006	SUBMITTED BY B. Fuchs/ Chuck Moretti, UND

Lab No.	Station Location	Depth	Chloride Content lb/cu.yd.
M-165	NL	0.5”	2.51 lb/cu.yd.
M-166	NL	3.0”	1.29 lb/cu.yd.
M-167	NL	5.0”	1.37 lb/cu.yd.
M-168	ML	0.5”	4.56 lb/cu.yd.
M-169	ML	3.0”	3.25 lb/cu.yd.
M-170	ML	5.0”	1.41 lb/cu.yd.
M-171	SL	0.5”	1.92 lb/cu.yd.
M-172	SL	3.0”	1.25 lb/cu.yd.
M-173	SL	5.0”	1.02 lb/cu.yd.
M-174	NW	0.5”	6.26 lb/cu.yd.
M-175	NW	3.0”	5.72 lb/cu.yd.
M-176	NW	5.0”	2.60 lb/cu.yd.
M-177	MW	0.5”	3.05 lb/cu.yd.
M-178	MW	3.0”	2.00 lb/cu.yd.
M-179	MW	5.0”	1.14 lb/cu.yd.
M-180	SW	0.5”	3.21 lb/cu.yd.
M-181	SW	3.0”	0.74 lb/cu.yd.
M-182	SW	5.0”	1.02 lb/cu.yd.

L = Lane W = Wall

N = north end span M = middle span S = south end

M-181 & 182 were both submitted as 5.0” depth.

Date: December 1, 2006

Scott W. Wutzke

Testing Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Bryon Fuchs
UND

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL Pulverized PCC from Bridge Deck	**PROJECT** UND
LAB NO. CL41 – CL58	**COUNTY** 9th Avenue Bridge
FIELD SAMPLE NO. *see designations below	**SAMPLE FROM** Deck locations & sample
SPECIFICATION AASHTO T-260-97 Chloride Content, Procedure A Chloride	

DATE RECEIVED	**DATE SAMPLED**	**SUBMITTED BY**
11/19/2007	Unknow	T. Bold / Chuck Moretti, UND

Lab No.	Station Location	Depth, Inches	Chloride Content lb/ cu.yd.
CL-41	North Lane	0.5"	8.34 lb/cu.yd.
CL-42	North Lane	3.0"	3.01 lb/cu.yd.
CL-43	North Lane	5.0"	1.21 lb/cu.yd.
CL-44	Middle Lane	0.5"	6.97 lb/cu.yd.
CL-45	Middle Lane	3.0"	1.49 lb/cu.yd.
CL-46	Middle Lane	5.0"	0.86 lb/cu.yd.
CL-47	South Lane	0.5"	11.43 lb/cu.yd.
CL-48	South Lane	3.0"	3.86 lb/cu.yd.
CL-49	South Lane	5.0"	1.14 lb/cu.yd.
CL-50	North Side	0.5"	12.80 lb/cu.yd.
CL-51	North Side	3.0"	6.34 lb/cu.yd.
CL-52	North Side	5.0"	1.17 lb/cu.yd.
CL-53	Middle Side	0.5"	11.75 lb/cu.yd.
CL-54	Middle Side	3.0"	4.78 lb/cu.yd.
CL-55	Middle Side	5.0"	1.72 lb/cu.yd.
CL-56	South Side	0.5"	7.75 lb/cu.yd.
CL-57	South Side	3.0"	3.88 lb/cu.yd.
CL-58	South Side	5.0"	2.68 lb/cu.yd.

Date: January 22, 2008 Scott W. Wutzke

Testing Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Tom Bold
UND

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL		PROJECT
Pulverized PCC from Bridge Deck		UND
LAB NO.		COUNTY
CL59 – CL76		Texas Turn Bridge
FIELD SAMPLE NO.		SAMPLE FROM
*see station locations		Deck locations & sample
SPECIFICATION		
AASHTO T-260-97 Chloride Content, Procedure A Chloride		
DATE RECEIVED	DATE SAMPLED	SUBMITTED BY
11/19/2007	Unknown	T. Bold / Chuck Moretti,

Lab No.	Station Location	Depth	Chloride Content lb/cu.yd.
CL-59	North Lane	0.5"	3.17 lb/cu.yd.
CL-60	North Lane	3.0"	0.82 lb/cu.yd.
CL-61	North Lane	5.0"	0.74 lb/cu.yd.
CL-62	Middle Lane	0.5"	5.01 lb/cu.yd.
CL-63	Middle Lane	3.0"	1.21 lb/cu.yd.
CL-64	Middle Lane	5.0"	0.86 lb/cu.yd.
CL-65	South Lane	0.5"	2.54 lb/cu.yd.
CL-66	South Lane	3.0"	1.17 lb/cu.yd.
CL-67	South Lane	5.0"	0.98 lb/cu.yd.
CL-68	North Side	0.5"	0.94 lb/cu.yd.
CL-69	North Side	3.0"	0.98 lb/cu.yd.
CL-70	North Side	5.0"	1.06 lb/cu.yd.
CL-71	Middle Side	0.5"	10.61 lb/cu.yd.
CL-72	Middle Side	3.0"	1.49 lb/cu.yd.
CL-73	Middle Side	5.0"	1.21 lb/cu.yd.
CL-74	South Side	0.5"	11.90 lb/cu.yd.
CL-75	South Side	3.0"	1.10 lb/cu.yd.
CL-76	South Side	5.0"	1.02 lb/cu.yd.

Date: January 22, 2008 Scott W. Wutzke

Testing Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
Tom Bold
UND

REPORT OF TEST ON SAMPLE

Department of Transportation, Materials & Research

MATERIAL		**PROJECT**
Pulverized PCC from Bridge Deck		UND
LAB NO.		**COUNTY**
CL23 - CL40		17th Avenue Bridge
FIELD SAMPLE NO.		**SAMPLE FROM**
*see station locations		Deck locations & sample
SPECIFICATION		
AASHTO T-260-97 Chloride Content, Procedure A – with Bottom Ash		
DATE RECEIVED	**DATE SAMPLED**	**SUBMITTED BY**
11/19/2007	Unknown	T. Bold / Chuck Moretti, UND

Lab No.	Station Location	Depth	Chloride Content lb/cu.yd.
CL-23	North Lane	0.5"	1.53 lb/cu.yd.
CL-24	North Lane	3.0"	0.90 lb/cu.yd.
CL-25	North Lane	5.0"	0.67 lb/cu.yd.
CL-26	Middle Lane	0.5"	1.76 lb/cu.yd.
CL-27	Middle Lane	3.0"	1.14 lb/cu.yd.
CL-28	Middle Lane	5.0"	1.02 lb/cu.yd.
CL-29	South Lane	0.5"	1.17 lb/cu.yd.
CL-30	South Lane	3.0"	1.21 lb/cu.yd.
CL-31	South Lane	5.0"	1.17 lb/cu.yd.
CL-32	North Side	0.5"	1.57 lb/cu.yd.
CL-33	North Side	3.0"	1.06 lb/cu.yd.
CL-34	North Side	5.0"	1.37 lb/cu.yd.
CL-35	Middle Side	0.5"	1.57 lb/cu.yd.
CL-36	Middle Side	3.0"	1.84 lb/cu.yd.
CL-37	Middle Side	5.0"	3.01 lb/cu.yd.
CL-38	South Side	0.5"	11.67 lb/cu.yd.
CL-39	South Side	3.0"	5.36 lb/cu.yd.
CL-40	South Side	5.0"	1.37 lb/cu.yd.

Date: January 22, 2008

Scott W. Wutzke

Testing Laboratory Supervisor

Distribution:

Central Laboratory
Ryan Johnson
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