Dense Concrete Layer As Top Course of Bridge Deck Construction

Final Report for Iowa DOT Project HR-502

Federal Highway Administration Project IA-74-01

November 1990

Highway Division
Iowa Department of Transportation

Final Report
for
Iowa Department of Transportation
Project HR-502

Dense Concrete Layer As Top Course of Bridge Deck Construction

by
Chris Anderson
515-239-1392
Office of Materials
Highway Division
Iowa Department of Transportation
Ames, Iowa 50010

November 1990

TABLE OF CONTENTS

DISCLAIMER

ABSTRACT

The use of deicing salts in this part of the country is a necessity to remove ice from our bridges. The use of these salts has always been a problem since the chloride-ions penetrate the concrete and reach the steel and cause corrosion which eventually cause deterioration of both the steel and concrete.

One method used to try to prevent this from happening was to apply a waterproof membrane to the concrete after it was placed. This method did help, but was not cost effective as the longevity of the membrane system was of relatively short duration.

For this reason, this research project was initiated. After the original deck was placed a second layer of concrete about 1 1/2" thick was placed on top.

Biennial evaluation of the decks included testing for delaminations and steel corrosion. Cores were also obtained for a chloride analysis.

Testing and observations showed the two-layer bridge deck to be effective in preventing corrosion.

Since the time this project was initiated, epoxy steel has been introduced and is a cost effective way to protect the steel from corrosion.

INTRODUCTION

Steel in concrete that has not been subject to chloride contamination does not corrode. The problem being the deicing salts that are used on our roadways and bridge contain chloride. When the chloride-ions content exceeds the threshold value, which is about 1.5 pound of chloride-ions per cubic yard of concrete, it promotes corrosion of reinforcing steel which results also in deterioration of the bridge deck.

This project was to evaluate bridge decks composed of two layers of portland cement concrete. The purpose of this was to better protect the steel from the chloride-ions and prevent corrosion. Before this project, using waterproof membranes was the method used to protect bridge decks from chloride.

OBJECTIVE

The objective was to compare the durability of the bridge deck (no waterproof membrane) consisting of high quality, low slump concrete top layer with other bridge decks in the same general area that are constructed with conventional concrete and protected by waterproofing membranes.

DESCRIPTION

The experimental bridge decks were placed on bridges on I-380 over relocated Avenue A, "C" Street over US 30, and US 30 westbound over CRI and PRR in Cedar Rapids. The bridges were variable width, continuous welded plate girder structures. The first lift of concrete on the bridge decks was Class D

concrete 7" thick intended to provide one inch of cover over the top layer of reinforcement. The materials, placement, finish and cure were in accordance with Iowa DOT Standard Construction Specifications and Supplemental Specifications except that the broom finish was not required.

The second lift was a 1 1/2" thick Iowa Method, dense P.C. concrete surface course that was placed after the curbs were placed. Scarification was not required. Sandblast cleaning of the surface of the first lift was required just prior to applying the grout and second lift.

The density of a section of the bridge deck on Avenue "A" was checked with a nuclear gauge at seven locations. The direct transmission method was used which required a 3" depth of fresh concrete. Twelve-inch pieces of 2 x 8's were used to form "holes" in the surface of the first layer and the tests were made at these spots. The following are the densities obtained and the corresponding percentages of the standard rodded unit weight.

1. 149.6 lbs/cu. ft. = 103.2%
2. 149.6 lbs/cu. ft. = 103.2%
3. 151.1 lbs/cu. ft. = 104.2%
4. 149.6 lbs/cu. ft. = 103.2%
5. 149.1 lbs/cu. ft. = 102.8%
6. 150.6 lbs/cu. ft. = 103.9%
7. 147.4 lbs/cu. ft. = 103.2%

Construction went well using the "Iowa Method Overlay System" with only slight construction problems.

DISCUSSION OF RESULTS

The decks are in good condition and have performed well. They were evaluated every two years. Tests conducted on these bridge decks were delamtect testing, electrical potential and chloride content. The results of these tests are included. Only one delamination was found, so for all intents and purposes we can say there were no delaminations or areas of loss of bond identified on these three bridges.

The electrical potential on all three bridges stayed well below 30 for the 14-year test period which would indicate no active corrosion of reinforcing steel.

The carbonate coarse aggregate used in these bridge decks had some chloride-ion content which contributed to the initial chloride-ion content of the new concrete. The initial chloride-ion content of the concrete was approximately 0.1 pounds per cubic yard in the dense concrete top course. Apparently, the carbonate coarse aggregate used in the underlying bridge deck had a higher chloride-ion content which yielded a concrete with an initial chloride-ion content of approximately 0.5 pounds per cubic yard. There was substantial variations in individual chloride-ion content test values with

apparently an erroneous high variation at 10 years for the 0.5-1.0 inch level.

The steel in these decks is, by design, suppose to have 2 1/2" of cover. Assuming this is true, the chloride content after 14 years of service is well below the threshold value. Projecting this data, it will be approximately 28 years before the chloride content at the level of the steel will reach the 1.5 threshold value. This type of construction should protect the steel for about 30 years.

The waterproof membranes were not at all effective because of the outgasing of the concrete. It was concluded that they were unacceptable because of this, therefore, there could be no comparison of the two techniques; instead, the evaluation was done to determine the effectiveness of the two-layer method. It has been evaluated that the two-layer method was a cost effective way to protect the steel in bridges and could not be compared to waterproof membranes since they were unacceptable. Since that time, epoxy coated steel has been introduced and is the current method used in bridges. The epoxy coating on the steel does not allow chloride-ion to come in contact with the steel and stops corrosion.

CONCLUSION

This research on dense concrete layers for top course of bridge deck supports the following conclusions:

1. The two-layer bridge decks would provide approximately 30 years of protection from corrosion with an initial chloride-ion content of the concrete of 0.5 pound per cubic yard.

2. Dense top course concrete would not yield the desirable 50 year protection.

3. Based on research of epoxy coated steel it would be more effective than a two-layer bridge at providing long term (50 year) protection.

Appendix A
"A" Avenue N.E.

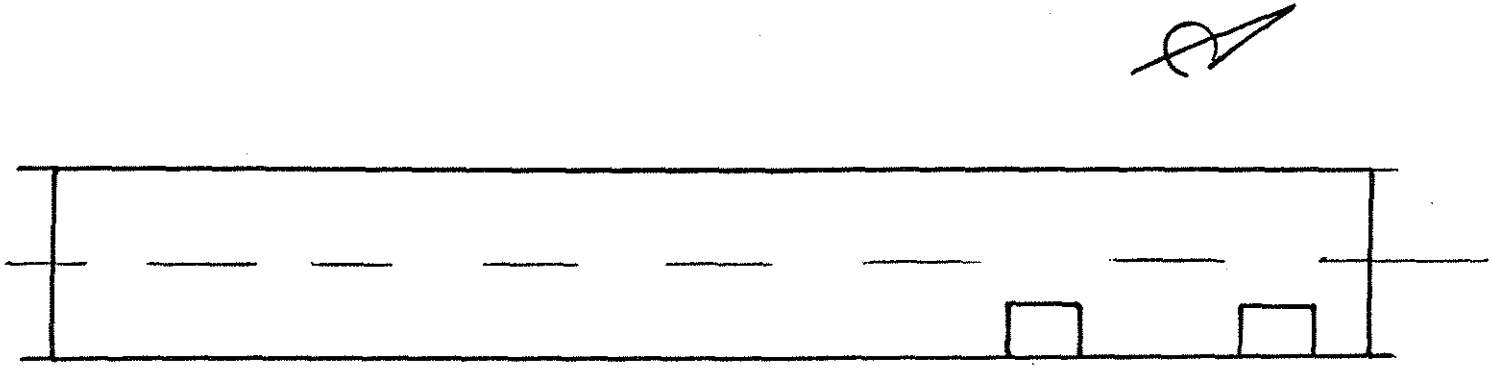
"A" Avenue N.E. over RR and 4th St. N.E.

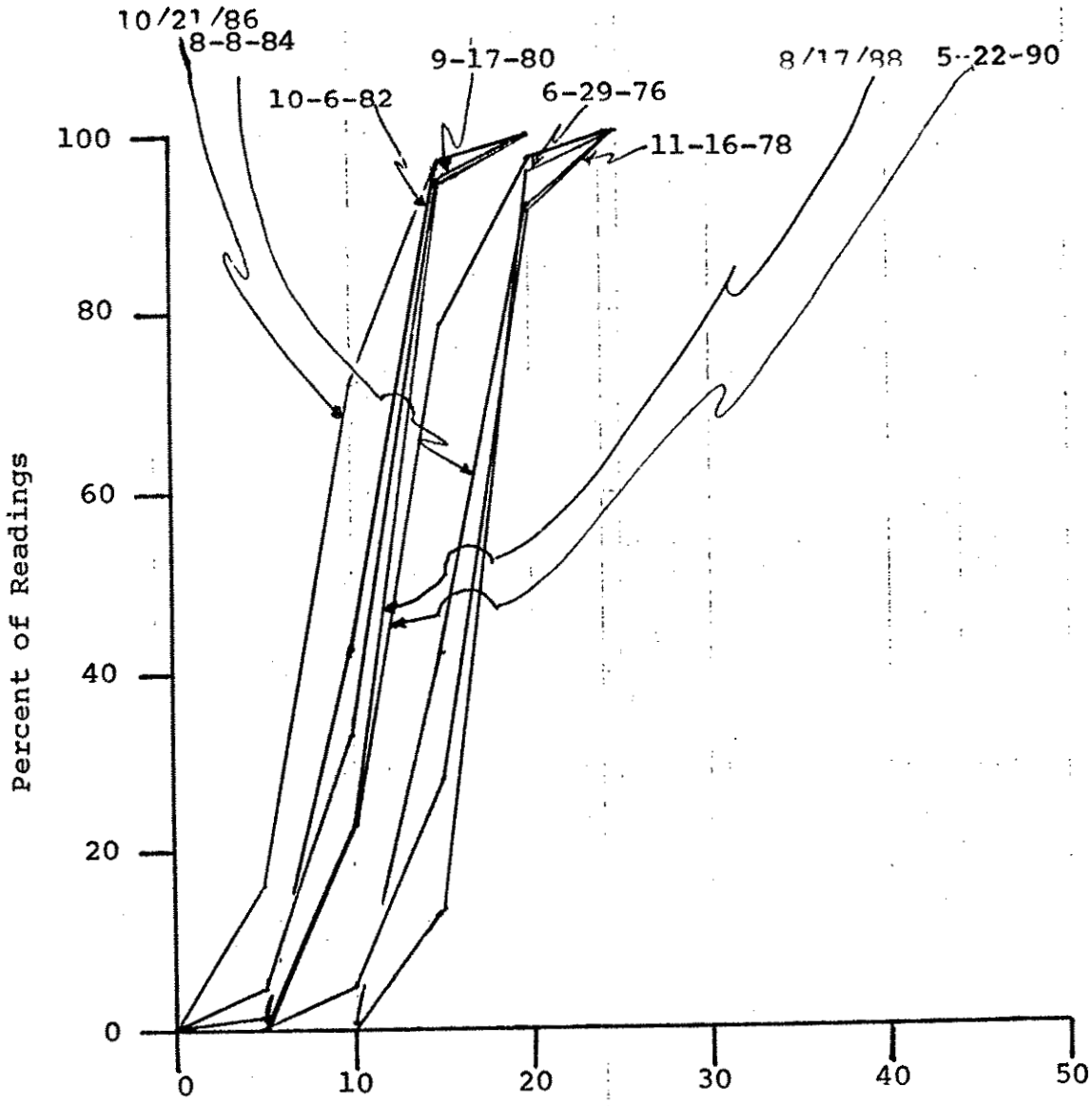
Project No. I-380-6(51)263--01-57

319' x Variable Width Continuous Welded Plate Girder Bridge

Construction 1974

Iowa Method Concrete Overlay




10/21/86
8-8-84
9-17-80
8/17/88
5-22-90
10-6-82
6-29-76
11-16-78
100
80
60
40
20
0
Percent of Readings
0
10
20
30
40
50
Electrical Potential (x .01 v)
"A" Avenue Viaduct - Cedar Rapids
Low Slump Dense Concrete

Bridge: "A" Avenue over RR & 4th ST. N.E. - Cedar Rapids

Constructed 1974 - Iowa Method Surface

CHLORIDE CONTENT - LBS/CU. YD.

Year Sampled	Sample Depth (Inches) 0 - 0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5
1976	6.5	0.3	0.1	0.1	
	5.4	0.4	0.4	0.2	
	3.7	0.3	0.3	0.2	
	3.2	0.2	0.1	0.2	
	3.0	0.5	0.4	0.5	
	4.4	0.6	0.3	0.3	
	3.0	0.4	0.5	0.8	
	4.3	0.5	0.3	0.9	
1978	4.2	0.3	0.3	0.3	0.5
	6.8	0.5	0.3	0.2	0.6
	4.1	0.9	0.2	0.2	0.5
	4.0	0.8	0.2	0.3	0.6
	2.5	0.3	0.2	0.4	0.5
	4.0	0.7	0.2	0.2	0.4
1980	3.9	0.3	0.2	0.1	0.1
	9.0	0.4	0.2	0.2	0.5
	11.0	2.8	0.2	0.4	0.6
	5.4	0.8	0.2	0.1	0.3
	9.7	1.1	0.2	0.2	-
	8.6	0.4	0.2	0.2	0.8
1982	10.89	4.12	0.23	0.19	0.72
	9.15	0.53	0.15	0.11	0.64
	4.76	0.34	0.15	0.19	0.42
	11.79	2.19	0.15	0.11	0.38
	7.64	0.57	0.23	0.11	0.26
	8.13	0.64	0.08	0.11	0.38

Bridge: "A" Avenue over RR & 4th St. N.E. - Cedar Rapids

Constructed 1974 - Two layer, Iowa Method

CHLORIDE CONTENT - LBS/CU. YD.

Year Sampled	Sample Depth (Inches) 0 - 0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5
1984	9.75	0.79	0.19	0.23	0.53
	11.08	2.19	0.19	0.26	0.45
	8.43	0.72	0.26	0.11	0.11
	14.89	3.86	0.15	0.08	0.34
	12.32	3.93	0.19	0.04	0.45
	12.17	3.18	0.15	0.11	0.26
	15.16	3.59	0.19	0.23	0.26
1986	12.59	3.97	0.38	0.30	0.49
	7.18	1.21	0.19	0.19	1.10
	11.57	3.89	0.38	0.26	0.83
	8.24	7.86	3.86	4.08	2.91
	10.66	2.87	0.26	0.11	0.83
	15.61	7.48	1.47	0.30	0.72
1988	7.41	0.72	0.53	0.19	0.76
	12.47	2.95	0.11	0.26	1.40
	13.15	4.61	0.64	0.57	0.95
	12.17	1.51	0.23	0.19	1.06
	12.17	3.10	0.49	0.23	0.76
	13.15	4.61	0.57	0.30	0.60
1990	8.43	2.27	.76	.38	.38
	14.86	4.80	.38	.26	.49
	15.12	8.20	1.63	.26	.64
	12.85	3.02	.11	.11	.49
	11.08	2.76	.23	.23	.38
	9.83	1.40	.23	.23	.49

Appendix B
"C" Street Over US 30

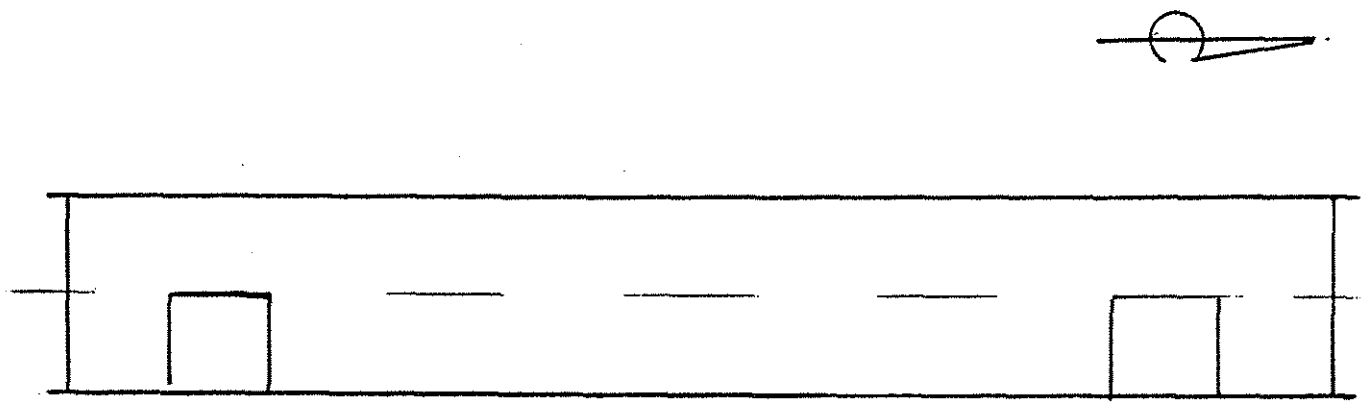
"C" Street over US 30

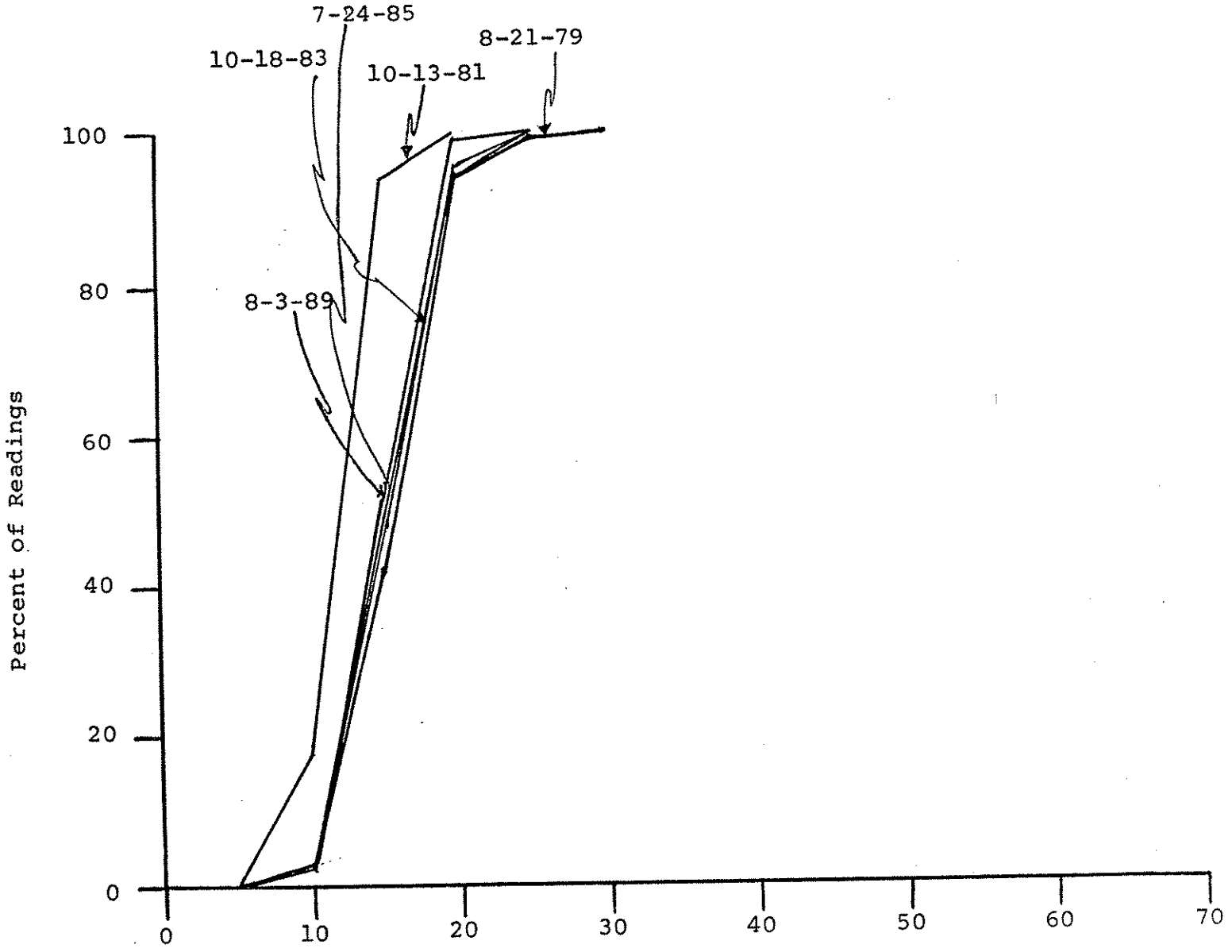
Project No. F-U-UG-30-7(29)--27-57

320' x 44' Continuous Welded Girder Bridge

Constructed 1977

Iowa Method Concrete Surface





"C" Avenue over US-30 - Linn County

Bridge: "C" Street over US-30 - Linn County

New Bridge - Iowa Method Surface

CHLORIDE CONTENT - LBS/CU. YD.

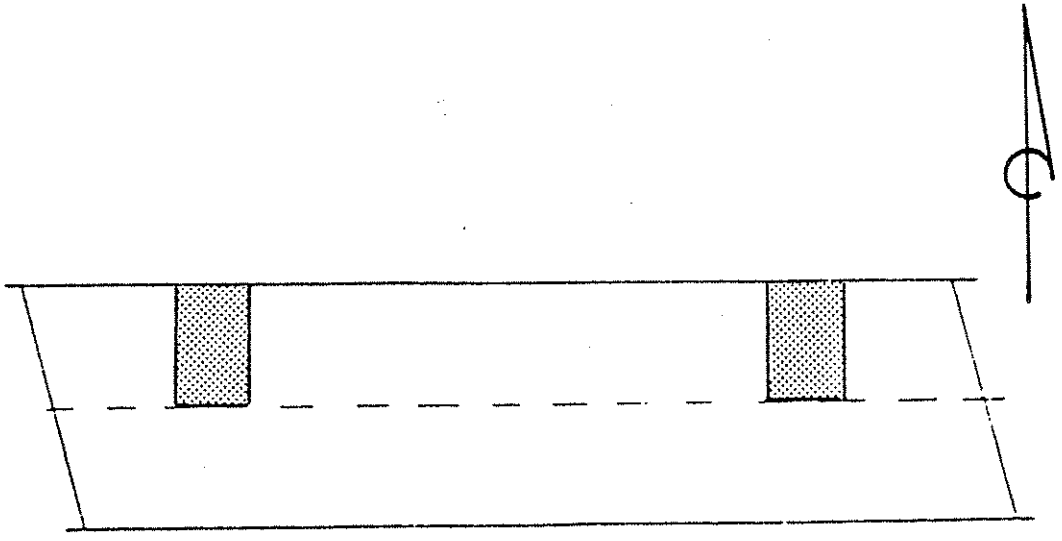
Year Sampled	Sample Depth (Inches) 0 - 0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5
1979	2.42	0.26	0.08	0.42	0.60
	5.97	2.78	0.27	0.00	0.87
1981	1.70	0.30	0.15	0.23	0.79
	4.80	1.17	0.26	0.11	0.53
	5.93	2.00	0.26	0.11	0.26
	6.12	3.70	0.38	0.11	0.60
	2.80	1.32	0.19	0.19	1.40
	6.35	2.04	0.15	0.19	0.45
1983	3.36	0.23	0.19	0.08	0.49
	8.20	4.61	1.97	0.19	0.42
	8.81	2.27	0.23	0.08	0.38
	8.62	2.12	0.26	0.42	1.70
	10.40	3.97	0.95	0.15	1.59
	6.69	3.63	0.23	0.19	0.68
1985	7.48	1.55	0.30	0.34	1.02
	7.26	2.99	0.68	0.19	0.53
	9.41	4.80	1.21	0.34	1.02
	6.84	3.86	0.38	0.34	1.10
	8.99	4.35	0.83	0.19	0.64
	12.78	7.71	3.21	0.87	0.95
1987	----	2.46	0.64	0.23	0.72
	5.86	0.91	0.08	0.15	0.60
	6.92	2.84	0.30	0.30	1.81
	8.39	1.81	0.23	0.26	0.95
	4.80	0.64	0.19	0.26	0.79
	8.96	1.70	0.34	0.30	0.76
1989	6.43	2.52	1.13	0.64	1.40
	4.80	0.76	0.49	0.38	1.40
	11.60	5.93	1.40	0.49	0.49
	12.10	6.31	3.14	1.02	2.15
	9.56	4.42	1.40	0.64	2.00
	11.07	7.07	2.00	0.49	0.76

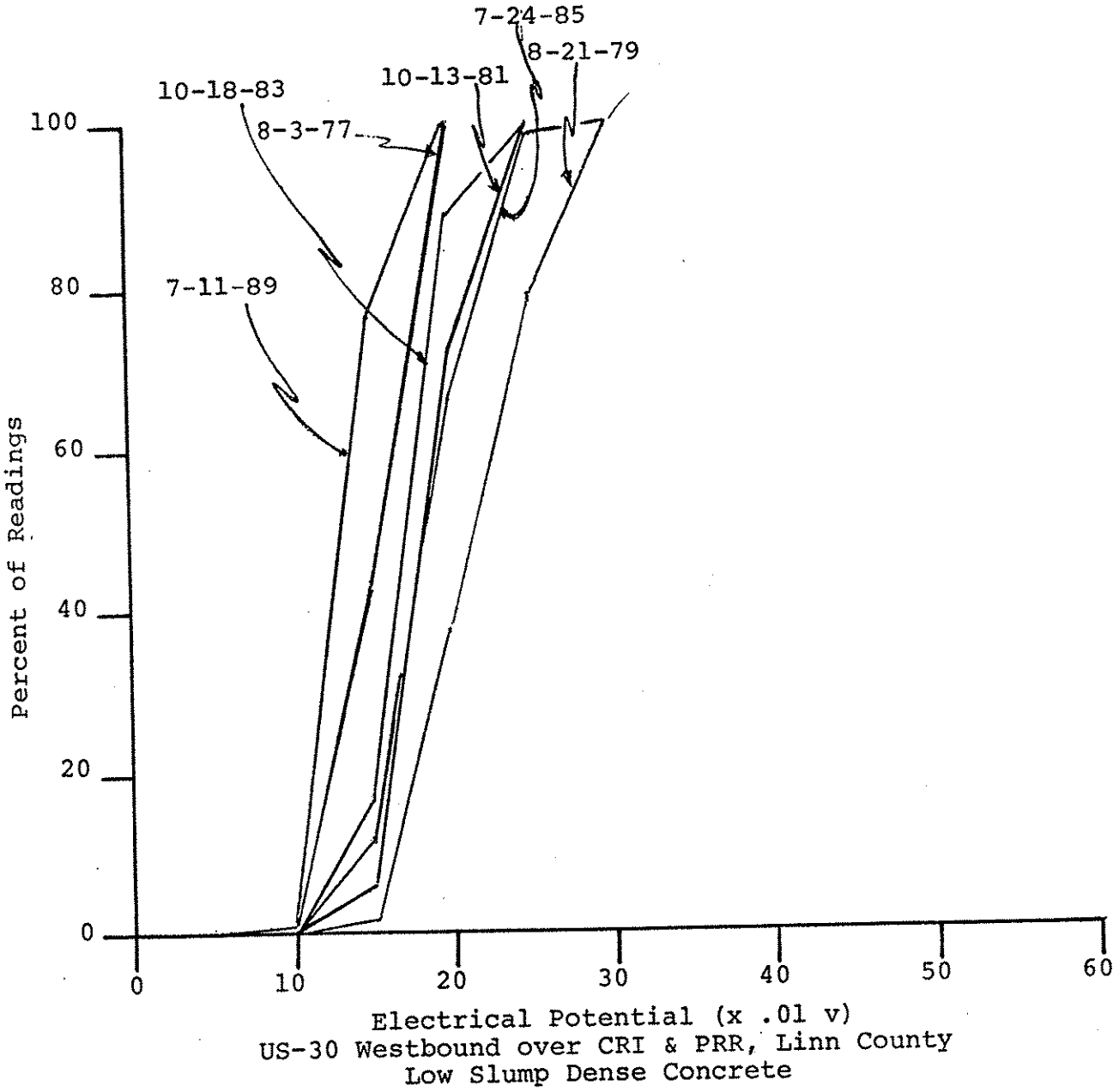
Appendix C
US 30 Westbound Over CRI & PRR

US-30 Westbound over CRI&PRR

Linn County
Project No. F-U-UG-30-7(29)--27-57 Design 473

Deck Thickness: 8"
Open to Traffic: 1976
1976 ADT: 5430




7-24-85
8-21-79
10-13-81
10-18-83
8-3-77
7-11-89
100
80
60
40
20
0
Percent of Readings
0
10
20
30
40
50
60
Electrical Potential (x .01 v)
US-30 Westbound over CRI & PRR, Linn County
Low Slump Dense Concrete

Bridge: US-30 Westbound over CRI & PRR - Linn County

Constructed 1975 - Iowa Method Surface

CHLORIDE CONTENT - LBS/CU. YD.

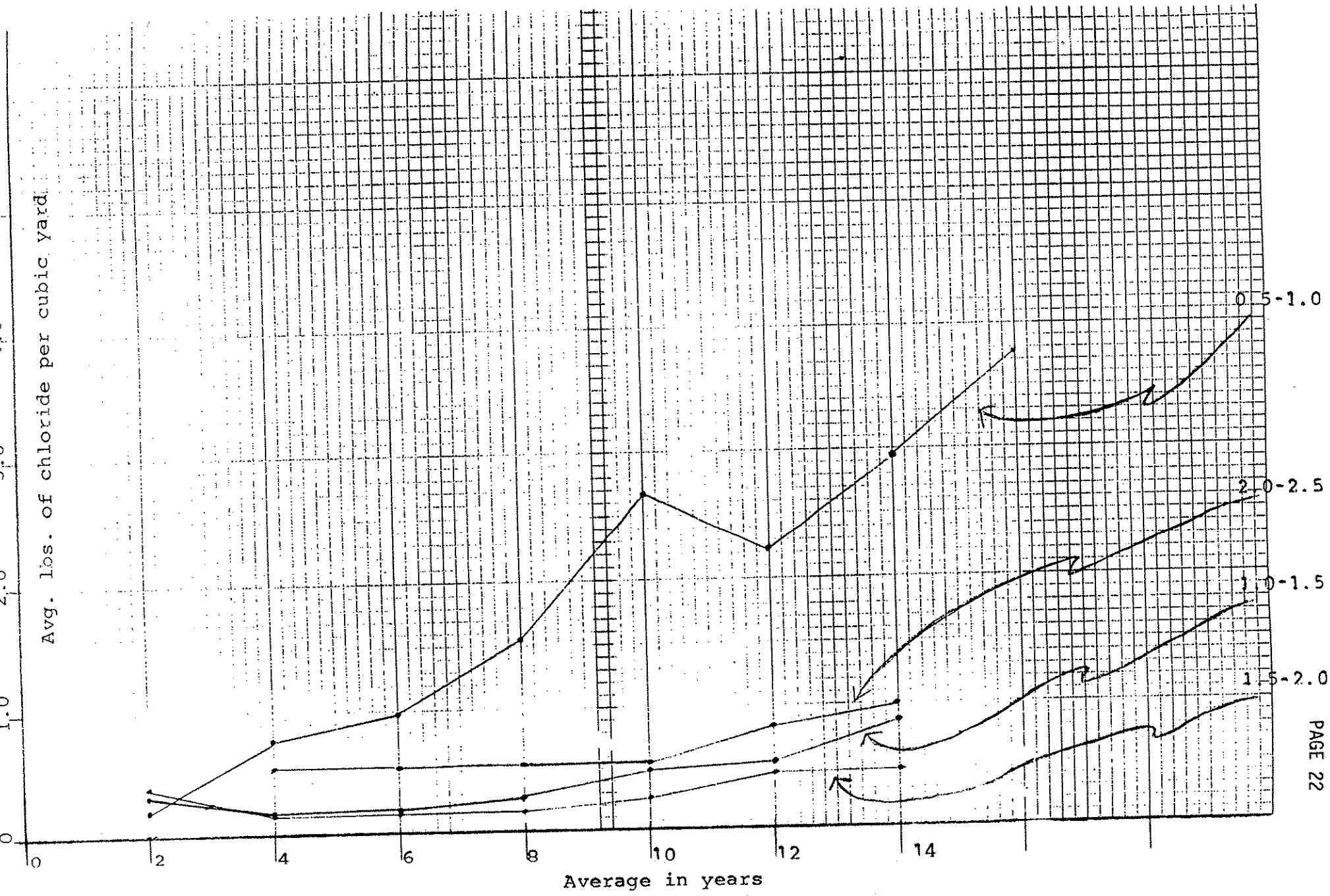
Year Sampled	Sample Depth (Inches) 0 - 0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5
1977	0.83				
	0.35				
	0.56				
	0.83				
	0.07				
	0.34				
	1.11				
	0.97				
	1.45				
	1.04				
1979	1.63	0.23	0.15	0.08	0.23
	3.55	0.34	0.11	0.11	0.30
	3.74	0.30	0.11	0.08	0.34
	2.15	0.11	0.11	0.15	0.42
	4.23	0.08	0.11	0.15	0.34
	2.04	0.08	0.04	0.04	0.23
1981	2.27	0.26	0.08	0.08	0.38
	2.87	0.19	0.11	0.08	0.60
	2.15	0.11	0.11	0.08	0.57
	4.31	0.38	0.08	0.04	0.34
	1.81	0.23	0.08	0.08	0.30
	2.61	0.11	0.11	0.15	0.34
1983	9.15	1.40	0.08	0.08	0.26
	7.14	0.08	0.04	0.04	0.45
	1.25	0.11	0.08	0.08	0.42
	1.85	0.26	0.08	0.04	0.11
	4.20	0.08	0.04	0	0.42
	6.05	0.26	0.04	0.04	0.19

Bridge: US 30 Westbound over CRI & PRR - Linn County

CHLORIDE CONTENT - LBS/CU. YD.

Year Sampled	Sample Depth (Inches) 0 - 0.5	0.5 - 1	1 - 1.5	1.5 - 2	2 - 2.5
1985	3.14	0.30	0.26	0.04	0.38
	0.53	0.19	0.04	0.19	0.42
	4.61	0.72	0.15	0.30	0.34
	3.63	1.29	0.23	0.04	0.45
	7.18	0.60	0.19	0.19	0.15
	7.48	1.55	0.08	0.15	0.64
1987	6.01	0.49	0.08	0.19	0.38
	5.37	0.57	0.30	0.08	0.60
	2.27	0.19	0.26	0.08	0.68
	4.61	0.57	0.15	0.23	0.08
	6.09	0.26	0.00	0.04	0.45
	3.78	0.00	0.19	0.19	0.26
1989	8.43	1.63	0.64	0.26	0.87
	3.14	0.76	0.49	0.38	1.02
	5.41	1.40	0.76	0.38	1.02
	8.69	1.89	0.49	0.38	0.64
	9.56	2.38	0.76	0.38	0.26
	5.03	1.02	0.38	0.49	0.49

Appendix D
Average Chloride Content of 3 Bridges



Average chloride content at different levels in the three bridges associated with Project HR-502