PROTECTION OF STRUCTURAL CONCRETE SUBSTRUCTURES

IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-220

FEBRUARY 27, 1981

CONSTRUCTION REPORT

by

JOHN E. WHITING JOHN G. RISCH

Highway Division
Iowa Department of Transportation
Ames, Iowa 50010

TABLE OF CONTENTS

RESEARCH OBJECTIVES

It is the objective of this project to determine, via field tests, the long term effectiveness of several available systems as their ability to protect concrete surfaces against the intrusion of chloride ions.

PRELIMINARY PLANNING

Early concepts of this project included utilizing personnel from several offices within the Highway Division of the Iowa Department of Transportation. Cooperation and coordination with regularly scheduled activities were considered imperative. A meeting for this purpose was held on April 16, 1980. This meeting was attended by the investigators, Mr. Bernard C. Brown, Office of Materials, Mr. Richard Merritt, District 6 Materials Engineer, Mr. John Saunders, District 6 Maintenance Engineer, and Mr. James Phinney, Resident Maintenance Engineer.

The following topics were discussed.

(1) Project scope. Initial construction work (sealer application) is scheduled for completion during the 1980 construction season. Laboratory product testing requires a considerable period of time. It was decided, therefore, that field evaluation would be limited to those products previously tested in the laboratory and approved for use and additional products for which test reports from other user agencies indicated a significant promise of success.

(2) Project site. A project site was selected in the I-380 corridor. The median piers supporting each of two grade separation bridges provides five columns to serve as individual candidates. Two columns are beneath the 27th Avenue Southwest crossing. Three columns are beneath the Wilson Avenue Southwest crossing. These pier columns are equidistant from the adjacent traffic lanes and are reasonably accessible. They have been exposed to essentially the same traffic and climatic conditions and should provide comparable results. The piers selected were constructed in 1972. This segment of I-380 was opened to local traffic in December 1975 and to general traffic in June 1976.

(3) All substructure concrete in the I-380 corridor was coated during original construction with an acrylic coating for aesthetic purposes. It was decided to remove this coating from the candidate pier columns to provide test surfaces free of any possible protective effect from material other than the ones being tested. It was further agreed that this removal would be accomplished by lightly sandblasting the surfaces. Local maintenance forces would do this work as soon as their schedule permitted.

(4) Core samples would be obtained prior to the application of test systems. Test results of these cores would be used to establish the "before" chloride levels for comparison with later tests. It was agreed that cores would be obtained by personnel from the District 6 Materials staff.

(5) A special core drilling machine would be needed. This machine should be as light weight as possible and should be capable of being attached rigidly to a pier column while drilling horizontally. It was agreed that a standard core drilling machine would be purchased and modified for this project. Modifications would be developed and implemented by the Central Office of Materials.

(6) Structures in the I-380 corridor are relatively new (about five years' service). Structures in the I-235 corridor (Des Moines Freeway) are much older; the oldest section has been in service eighteen years. It was decided to obtain and test cores from representative structures in the I-235 corridor for information purposes. The concentrations of chloride content might provide some indication of the zones within which chloride contamination occurs to a significant degree and thus provide guidance on the extent of sampling needed for the project in the I-380 corridor.

PRECONSTRUCTION EVALUATION

The core drill modifications were developed and implemented by Karman Kellogg, Office of Materials.

Representative pier columns were selected within the oldest section of the Des Moines Freeway (I-235) for sampling and testing chloride content. The east column of the median pier at 6th Avenue (5.75 feet from the adjacent lane), the east column of the north pier at 19th Street (11.67 feet from the adjacent lane) and the east column of the median pier at 19th Street (18.5 feet from the adjacent lane) were chosen. Core samples were obtained May 1 and 2, 1980 from each of these columns. A core was obtained from the face nearest west bound traffic and at the lowest elevation physically possible. Additional cores were obtained at one foot intervals upward to the bottom of pier cap. A number of pier columns in this section of I-235 exhibit spalling. Cores were obtained, however, from columns which are still sound in order to avoid chloride concentrations resulting from channelized flow through cracks.

This coring operation also provided a field trial of the recently modified core drill machine.

Concrete cores were cut into samples, each representing one-half inch of depth of the concrete from which the core was extracted. Chloride determinations, thus, are representative of conditions at successive depths from the surface.

Chloride determination procedures used were in accordance with "Standard Method of Sampling and Testing for Total Chloride Ion in Concrete" as described in Federal Highway Administration Report No. FHWA RD-77-85.

Chloride contents were not determined from all of the cores obtained from pier columns in the I-235 corridor. Tests were conducted on cores from the lowest elevation available at each column and at a three foot interval above the lowest core obtained. A tabulation of chloride test results is provided in Table 1, Appendix A.

Concrete cores were obtained June 17 and 18, 1980 from the candidate pier columns in the I-380 corridor. The location and identification of the columns involved in this project are shown in the sketch "Site Location" (Figure 2, Appendix B). The "Core Sampling Plan" (Figure 3, Appendix B) indicates the locations from which cores were extracted from each pier column and the planned locations for core extractions in subsequent years.

An acrylic surface coating was applied to substructure concrete in the I-380 corridor during original construction to provide an aesthetic finish. This coating was removed on August 11 and 12, 1980 from those pier columns intended as candidates for this project. Light sandblasting under the direction of Francis Clabaugh, District Bridge Crew Foreman, provided a slightly textured surface on dense concrete with occasional small surface pock marks, hemispherical in shape with diameters up to about three-eighths inch.

The Office of Materials performed the testing for chloride content in the concrete cores obtained from the I-380 pier columns. Acrylic coating of the core tops was removed. The cores were sectioned into one-half inch layers as described earlier for cores from the I-235 corridor. Test results (Table 2, Appendix B), reported October 6, 1980, will serve to establish initial chloride ion content of the concrete. Future tests will be compared with these results.

CONSTRUCTION

Candidate pier columns were assigned numbers 1 through 5 from south to north ie: Numbers 1 and 2 at 27th Avenue Southwest, Numbers 3, 4 and 5 at Wilson Avenue Southwest (Figure 2, Appendix B).

Application of the protective systems was achieved on September 16 and 17, 1980 by the District Bridge Crew. Overall direction for this work was provided jointly by the investigators.

Column No. 1 received one coat of PE50 penetrating epoxy sealer, manufactured by Steelcote Manufacturing Company.

Column No. 2 received two coats of TE3008 penetrating epoxy sealer, manufactured by Technical Sealants and Adhesives, Inc.

Column No. 3 received one coat of Niklepoxy penetrating epoxy sealer, manufactured by Rocky Mountain Chemical Company.

Column No. 4 received no treatment. This column was selected as comparison control.

Column No. 5 received one coat of Chem Trete Silane, a product imported from Germany and distributed by Dynamit Nobel of America, Inc.

A detailed description of construction procedures is included in Appendix C.

EVALUATIONS

Evaluation of the principal objective, that of protection durability, cannot, of course, be made at this time.

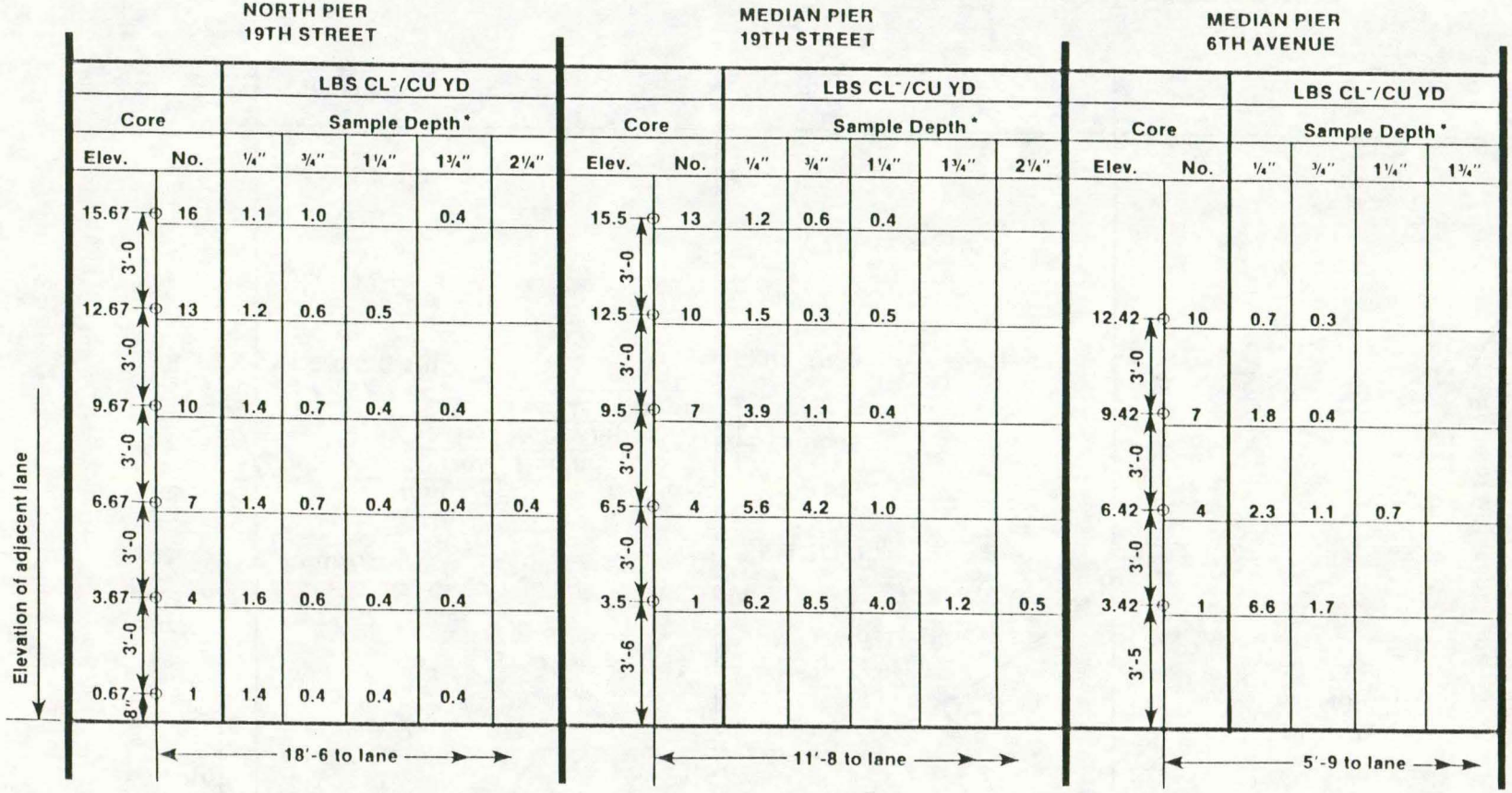
Field confirmation of laboratory tests on acrylic coatings as a protective sealer can be offered. Chloride contents of concrete in the 0 to 1/2" depth from the surface (nominal 1/4 inch) are significant, approximately one half of the concentrations found in a column in the I-235 corridor at a similar distance from exposure source after 18 years of such exposure. Thus, it would appear that acrylic coatings provide little, if any, protection.

From the tests of core samples taken in the I-235 corridor, there is an indication that chloride intrusion, adequate to provide an electrolyte, is not likely beyond a zone which extends to a height of approximately twelve feet above the traffic lane and horizontally to a lateral distance of approximately twenty two feet from the edge of the traffic lane. There has been insufficient testing to date to support this as a firm conclusion (Table 1 and Figure 1, Appendix A).

Additional core sampling and testing will be conducted annually. A progress report will be made early in 1983.

SUMMARY

The primary objective of this project is to determine, via field tests, the long term effectiveness of several products or procedures in protecting concrete surfaces against the intrusion of chloride ions. Five separate structural elements (pier columns), constructed under identical construction standards and subject to very similar exposure conditions in both the past and future, were selected as a candidate site. Each of four structural elements were coated with a separate protective system. The fifth was untreated for control comparison. Prior to the application of protective systems, two inch diameter core samples were obtained from each pier column. These core samples were tested to establish chloride content level for comparison with later samples.



*Sample Depth is mid-depth of one-half inch sample

TABLE 1 - CHLORIDE CONTENT
I-235 PIER COLUMNS

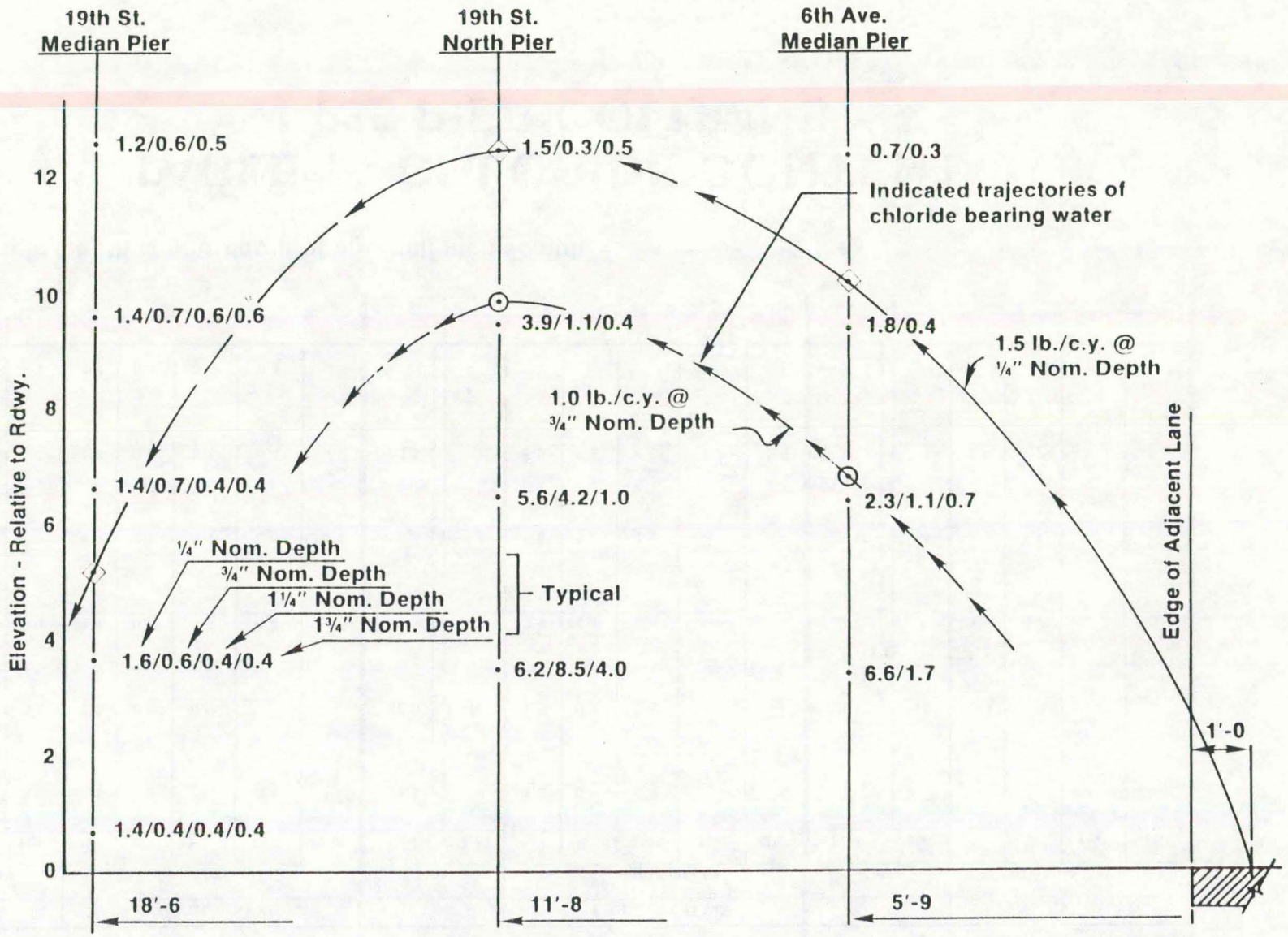


FIGURE 1 - CHLORIDE CONTENTS
I-235 PIER COLUMNS

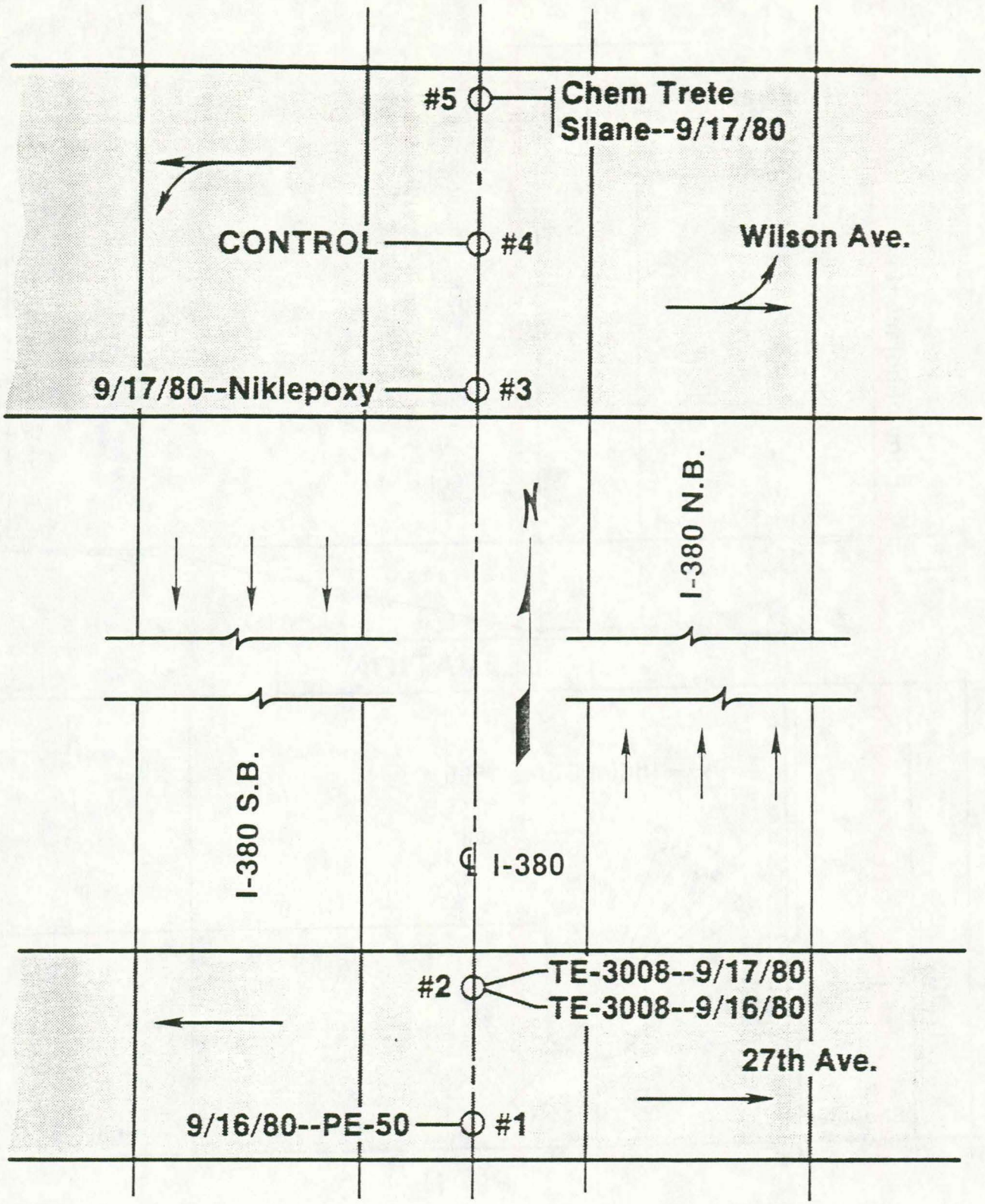


FIGURE 2 - SITE LOCATION COLUMN IDENTIFICATION

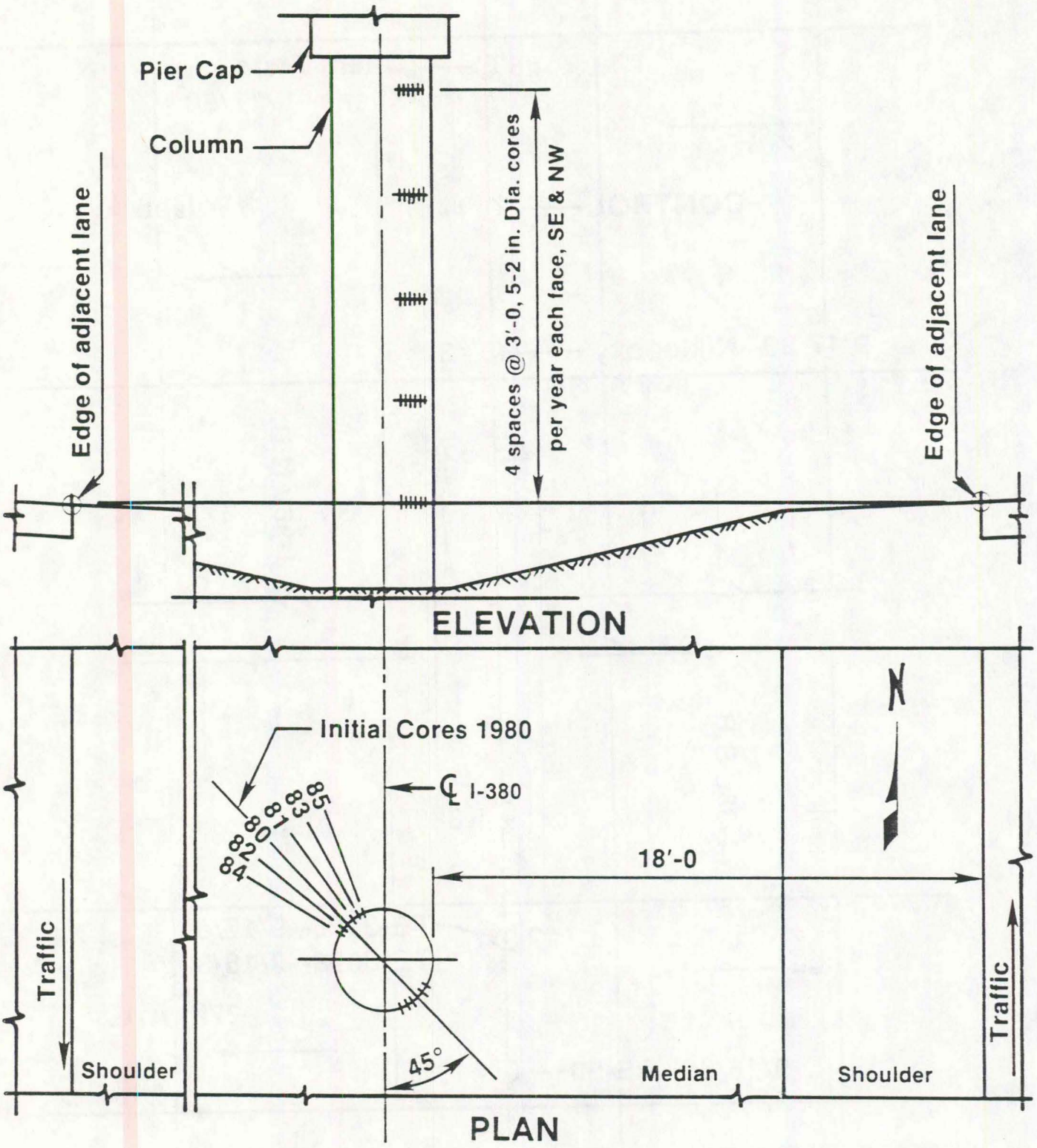


FIGURE 3 - I-380 CORE SAMPLING PLAN

Column	CHLORIDE - POUNDS PER CUBIC YARD								
	N.W. Face - Sample Depth, in.*				Elev. Above Lane, ft.	S.E. Face - Sample Depth, in.*			
	1/4	3/4	1 1/4	1 3/4		1/4	3/4	1 1/4	1 3/4
#5 Wilson Ave. N. Col.	0.7	0.5	0.7	0.5	12	0.8	0.5	0.7	-
	0.6	0.5	0.4	0.8	9	0.5	0.7	0.6	0.5
	1.0	0.7	0.5	0.5	6	0.7	0.6	0.5	0.5
	0.9	0.8	0.5	0.5	3	1.2	0.5	0.4	0.4
	0.7	0.6	0.6	0.3	0	1.1	0.7	0.4	0.6
#4 Wilson Ave. CTR. Col.	0.7	0.5	0.5	0.7	12	0.6	0.7	0.8	0.6
	0.6	0.5	0.6	0.7	9	0.9	0.5	0.5	0.5
	0.7	0.5	0.5	0.4	6	1.1	0.8	0.5	0.6
	0.9	0.4	0.7	0.6	3	1.1	0.5	0.5	0.5
	1.0	0.5	0.6	0.5	0	0.9	0.6	0.7	0.7
#3 Wilson Ave. S. Col.	0.6	0.5	0.6	-	12	0.7	0.7	0.4	-
	0.7	0.8	0.6	-	9	1.0	0.7	0.5	0.5
	1.1	0.4	0.2	-	6	1.1	0.7	0.6	0.6
	1.1	0.5	-	-	3	0.9	0.6	0.5	0.8
	1.1	0.4	1.0	0.6	0	1.1	0.9	0.5	0.7
#2 27th Ave. N. Col.	1.0	0.6	0.7	0.9	12	0.6	0.7	0.6	0.5
	0.9	0.5	0.5	0.7	9	0.9	1.0	0.5	0.4
	1.2	0.7	0.5	0.5	6	0.9	0.5	0.5	0.4
	0.9	0.9	0.6	0.8	3	0.8	0.6	0.7	0.5
	1.4	0.5	0.5	0.4	0	1.1	0.5	0.8	0.6
#1 27th Ave. S. Col.	0.9	0.7	0.5	0.6	12	0.8	0.5	0.7	0.5
	0.9	0.7	0.7	0.6	9	0.7	0.5	0.5	0.6
	1.2	0.5	0.4	0.5	6	0.8	0.6	0.5	0.4
	1.4	0.5	0.7	0.4	3	0.8	0.6	0.5	0.7
	1.4	0.7	0.5	0.5	0	0.9	0.7	0.9	0.4

*Sample Depth is mid-depth of one-half inch sample

TABLE 2. INITIAL CHLORIDE CONTENT I-380 PIER COLUMNS

Construction Details

Column Number 1

System - PE-50 penetrating epoxy.

Date Applied - September 16, 1980, P.M.

Weather - Cloudy, windy, temperature 65° F. Humidity, high.

(Note: Light rain fell during the forenoon. The column was surface dry approximately one hour prior to application of PE-50.

Mix - Part A, 6 cups; Part B, 6 cups.

Stirred with electric drill mixer at low speed, 4 minutes.

Induction time - 40 minutes.

Remixed and applied.

Application made with 6" wide paint roller, with emphasis on full coverage including interior of small pock marks. Worked with full roller, maintaining a surplus of material in the roller.

Material Used - Ten cups of mixed material, 5/8 gallon.

Coverage - 137 ft^2 -- .625 = 219 ft^2/gal.

Recommended Rate - 150 ft^2/gal.

Observation - It would be necessary to use two coats in order to increase application rate. Viscosity of material is quite low. Concrete is quite dense with tight surface texture.

Column Number 2

System - TE-3008 penetrating epoxy.

Date Applied - First coat, September 16, 1980, P.M.
Second coat, September 17, 1980, A.M.

Weather - 9-16-80 Cloudy, windy, temperature 65° F. Humidity, high.

(Note: Light rain fell during the forenoon. The column was surface dry approximately two hours prior to application of TE-3008, first coat.

9-17-80 Clear, near calm, temperature 70° F. Humidity somewhat lower than on 9-16-80.

Mix - Part A, 6 cups; Part B, 6 cups.

Stirred with electric drill at low speed, 4 minutes.

Induction Time - 90 minutes.

Remixed and applied.

Application made with 6" wide paint roller, with emphasis on full coverage including interior of small pock marks. Worked with full roller, maintaining a surplus of material in the roller.

Material Used - Eight cups of mixed material, first coat.
Seven cups of mixed material, second coat.

Coverage - 137 ft^2 -- .5 = 274 ft^2/gal., first coat.
137 ft^2 -- .438 = 313 ft^2/gal., second coat.

Recommended Rate - 300 ft^2/gal., 2 coats = 150 ft^2/gal.

Column Number 3

System - Niklepoxy penetrating epoxy.

Date Applied - September 17, 1980, A.M.

Weather - Clear, near calm, temperature 70° F. Humidity, somewhat lower that 9-16-80.

Mix - Part A, 17 cups; Part B, 3 cups (85/15).

Stirred with electric drill at low speed, 4 minutes.

Induction Time - None required, but application was delayed approximately 20 minutes.

Remixed and applied.

Application made with 6" wide paint roller, with emphasis on full coverage including interior of small pock marks. Worked with full roller, maintaining a surplus of material in the roller.

Material Used - Twelve cups of mixed material.

Coverage - 137 -- .75 = 183 ft^2/gal.

Recommended Rate - 90 ft^2/gal.

Observation - It would be necessary to use two coats in order to increase application rate. Viscosity of material is quite low. Concrete is quite dense with tight surface texture.

Column Number 4

This column was selected for comparison control.

The acrylic surface coating was removed by sandblasting as were all candidate columns. No treatment was applied to the bare concrete.

Cores were obtained and tested for chloride content. Further cores will be obtained and tested when sampling of treated columns is performed.

Column Number 5

System - Chem Trete Silane coating.

Date Applied - September 17, 1980, P.M.

Weather - Clear, near calm, temperature 70° F. Humidity, somewhat lower than 9-16-80.

Mix - No mixing required, use as supplied.

Application made with a Hudson airless sprayer in accordance with recommended procedure - "Proper quantities are being applied when excess solution runs six to eight inches below the spray pattern before penetrating the surface."

Material Used - Two gallons of solution.

Coverage - 137 -- 2 = 68 ft^2/gal.

Recommended Rate - 100 to 400 ft^2/gal.

Observation - It would not be possible to reduce the application rate to the recommended range and still obtain full coverage in accordance with the recommended procedure.