PROTECTION OF STRUCTURAL CONCRETE SUBSTRUCTURES

IOWA HIGHWAY RESEARCH BOARD

PROJECT HR-220

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PROGRESS REPORT

by

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RESEARCH OBJECTIVES

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

CONSTRUCTION SUMMARY

The test site chosen for this project consists of the two median piers where 27th Avenue Southwest and Wilson Avenue in Cedar Rapids, Iowa cross I-380.

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).

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 the Construction Report.

PROGRESS TESTING

Sampling and testing were performed in 1981 and 1982 in accord with original plans. Results from these tests indicated no change in chloride concentrations in any of the candidate pier columns including the untreated control column. It was decided to extend the sampling cycle. The sample cores, scheduled for 1983, were extracted and tested in 1984. Test results are tabulated on page B-4 for 1981, B-5 for 1982 and B-6 for 1984.

Tests in 1984 of samples from column 4, the control column, were performed to determine whether any change had occurred in the untreated concrete. Evaluation of these test results indicated possible change only at the two lowest levels of sampling, ie at the elevation of the adjacent roadway and at three feet above the roadway elevation. Furthermore, the indication of change was found only in the surface layer and the second one-half inch layer at these elevations. Additional testing was limited to four tests per column face as tabulated on page B-6 for columns 1,2,3 and 5.

Some of the tests indicate an increase in chloride concentration. Others indicate no change or a reduction. Test results for the four samples from each face of column four were plotted over time in an effort to detect an identifiable trend. It appears that further tests over perhaps a considerable period will be required to establish such a trend.

EVALUATIONS

(1) 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.

(2) 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.

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.

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 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.

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).

The results of subsequent testing tend to confirm the horizontal limits of a zone within which concrete structures are susceptible to chloride intrusion as a result of splash from adjacent roadway traffic.

(3) It appears that the pier columns selected for this project are located near the outer boundary of the zone in which chloride intrusion from splash will occur. The untreated control column is only beginning to exhibit increases in chloride concentrations and only near the bottom of the column. No evaluation of the effectiveness of the sealers under test can be made at this time.

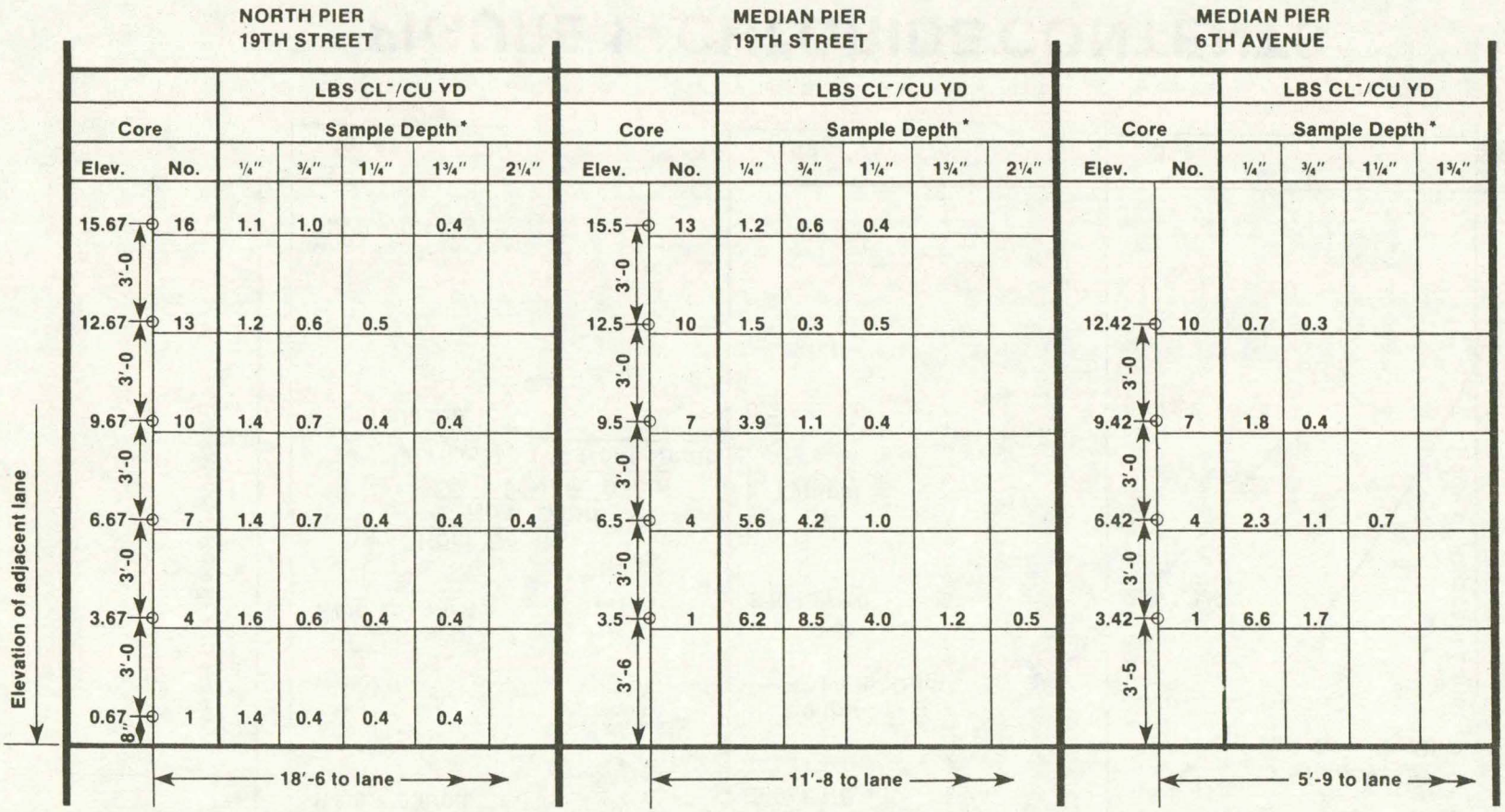
SUMMARY AND RECOMMENDATIONS

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.

The untreated control column has begun to exhibit increases in chloride concentration in 1984. Conclusive trends in protected columns are expected to require a considerable extension beyond the period scheduled for this project.

It is recommended that this project either be discontinued or extended. If extended, it is further recommended that the sampling and testing frequency be extended from the originally scheduled one year to perhaps three years.



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

TABLE 1 - CHLORIDE CONTENT
I-235 PIER COLUMNS

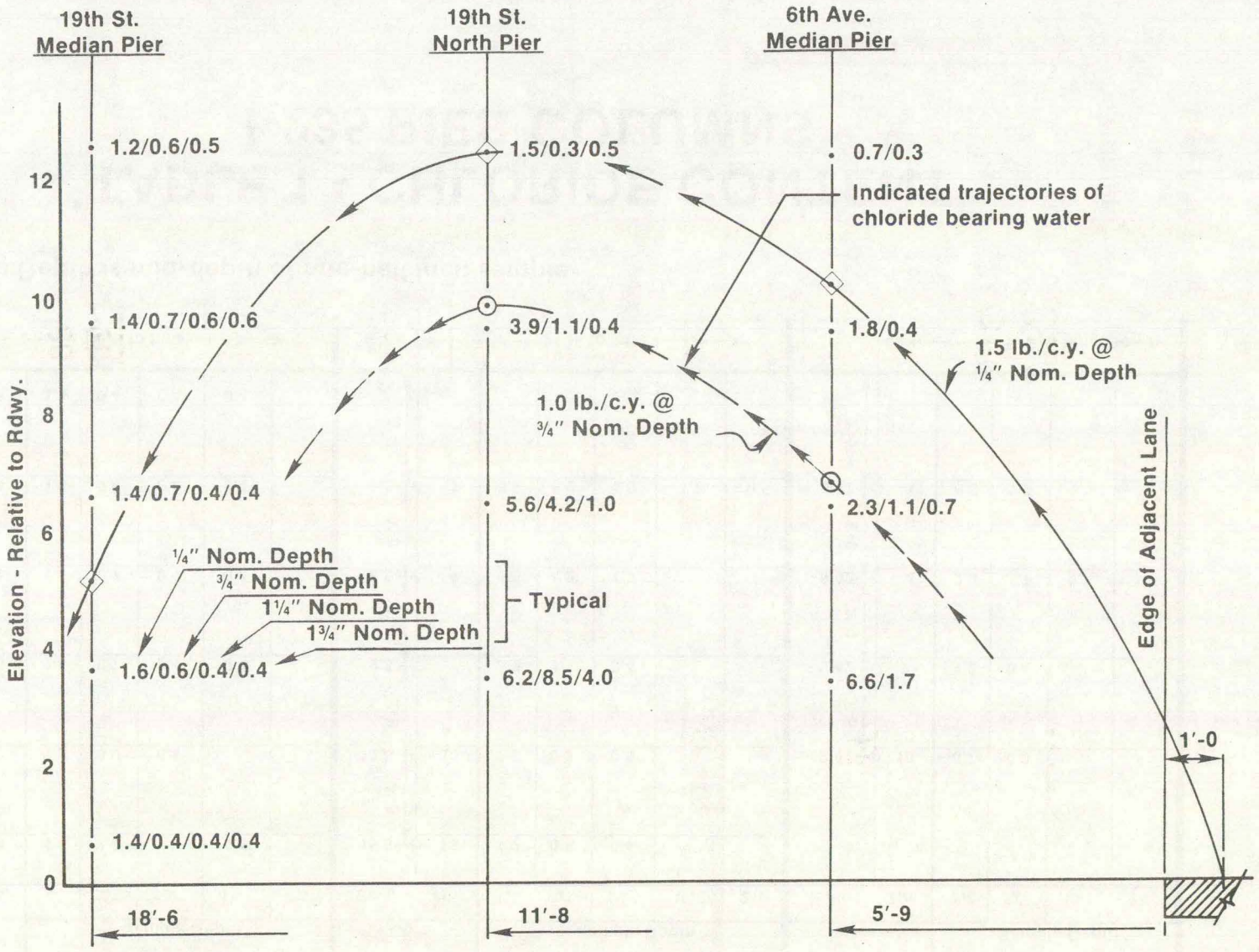


FIGURE 1 - CHLORIDE CONTENTS
I-235 PIER COLUMNS

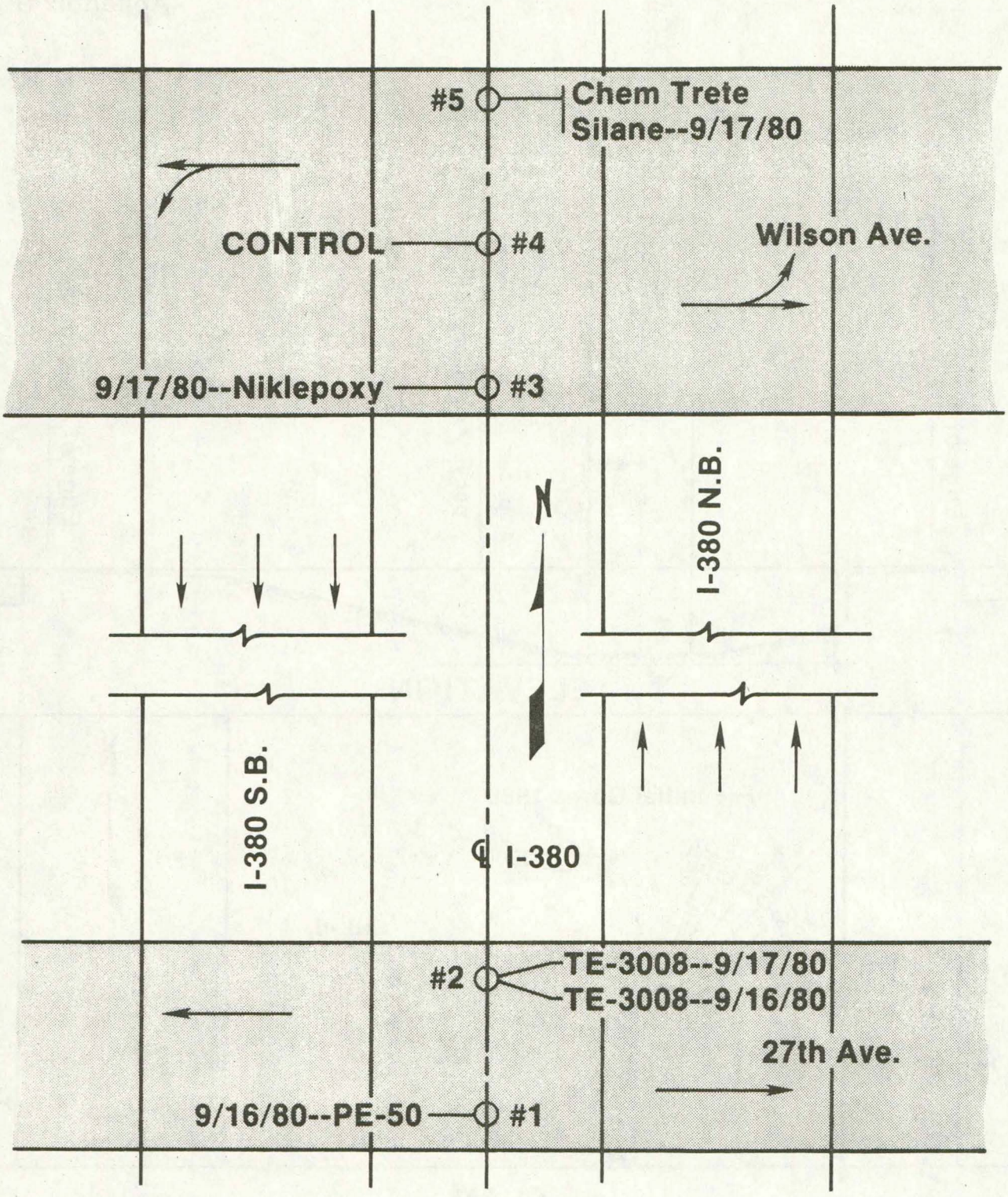


FIGURE 2 - SITE LOCATION COLUMN IDENTIFICATION

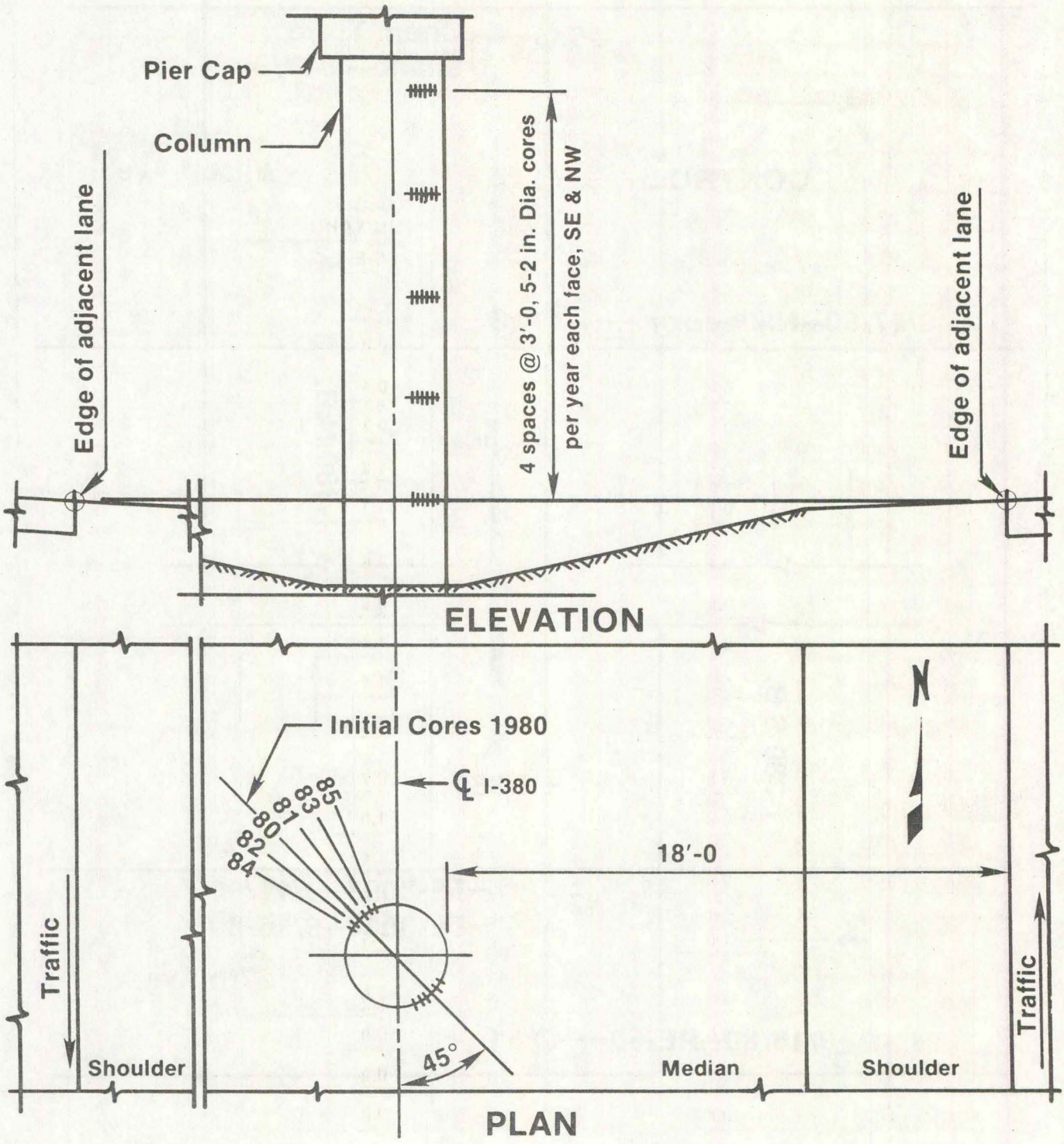


FIGURE 3 - I-380 CORE SAMPLING PLAN

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

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.	0.59	0.59	0.70	0.43	12	0.70	0.31	0.31	0.55
	0.67	0.35	0.43	0.31	9	0.67	0.59	0.70	0.51
	0.74	0.47	0.51	0.47	6	0.55	0.55	0.70	-
	1.06	0.82	0.43	0.47	3	0.90	0.63	0.59	0.63
	0.82	0.47	0.35	0.51	0	2.39	0.90	0.82	0.39
#4 Wilson Ave. Ctr. Col.	0.82	0.70	0.51	0.55	12	0.90	0.59	0.67	0.47
	0.90	0.63	0.59	0.59	9	0.67	0.59	0.51	0.70
	0.98	0.43	0.75	0.59	6	1.14	0.47	0.59	0.59
	1.21	0.59	0.59	0.59	3	0.90	0.35	0.47	0.78
	1.21	0.31	0.23	0.31	0	0.90	0.59	0.55	0.59
#3 Wilson Ave. S. Col.	0.47	0.39	0.35	0.35	12	0.59	0.31	0.43	0.47
	0.55	0.43	0.51	0.35	9	0.82	0.47	0.39	0.63
	0.78	0.43	0.47	0.51	6	0.94	0.67	0.35	0.39
	1.06	0.67	0.47	0.51	3	0.86	0.70	0.35	0.31
	1.49	0.82	0.55	0.70	0	1.06	0.59	0.43	0.47
#2 27th Ave. N. Col.	1.10	0.55	0.47	0.31	12	0.74	0.74	0.70	0.47
	0.82	0.51	0.59	0.63	9	0.74	0.51	0.70	0.51
	2.08	0.67	0.35	0.70	6	0.82	0.43	0.43	0.47
	0.94	0.59	0.47	0.55	3	0.78	0.55	0.20	0.70
	0.94	0.82	0.43	0.59	0	1.02	0.78	0.51	0.55
#1 27th Ave. S. Col.	0.94	0.54	0.70	0.70	12	0.70	0.47	0.47	0.47
	1.10	0.67	0.59	0.51	9	0.74	0.78	0.39	0.55
	1.21	0.59	0.51	0.59	6	0.70	0.70	0.59	-
	1.45	0.63	0.59	0.59	3	0.74	0.70	0.70	-
	1.14	0.74	0.51	0.47	0	0.94	0.59	0.78	0.78

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

TABLE 3. 1981 CHLORIDE CONTENT I-380 PIER COLUMNS

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
Wilson Ave. N. Col. #5	0.45	0.49	0.45	0.68	12	0.57	0.64	0.42	0.57
	0.49	0.64	0.57	0.45	9	0.34	0.42	0.42	0.45
	0.72	0.49	0.60	0.57	6	0.45	0.72	0.76	0.57
	0.87	0.53	0.45	0.42	3	0.98	0.83	0.53	0.49
	0.38	0.34	0.30	0.30	0	0.76	0.49	0.45	-
Wilson Ave. Ctr. Col. #4	0.30	0.30	0.60	0.76	12	0.72	0.64	0.45	0.45
	0.57	0.53	0.57	0.64	9	0.57	0.87	0.64	0.49
	0.76	0.57	0.49	0.42	6	0.87	0.42	0.45	0.42
	1.02	0.53	0.34	0.30	3	0.72	0.68	0.34	0.45
	1.06	0.57	0.64	0.38	0	0.72	0.49	0.45	0.23
Wilson Ave. S. Col. #3	0.45	0.45	0.45	0.19	12	0.76	0.23	0.34	-
	0.53	0.60	0.68	0.49	9	1.06	0.49	0.34	0.42
	0.87	0.45	0.49	0.30	6	1.36	0.72	0.42	0.45
	1.81	0.57	0.64	-	3	0.64	0.45	0.49	0.45
	1.55	0.79	0.68	0.64	0	0.87	0.91	0.89	0.64
27th Ave. N. Col. #2	0.83	0.64	0.68	0.49	12	0.64	0.57	0.42	0.45
	1.17	0.38	0.49	0.57	9	0.68	0.68	0.60	0.53
	0.79	0.76	0.68	0.42	6	0.57	0.42	0.49	0.49
	1.06	0.64	0.68	0.42	3	0.68	0.68	0.45	0.30
	0.79	0.57	0.45	0.57	0	1.06	0.72	0.57	0.68
27th Ave. S. Col. #1	0.53	0.60	0.42	0.53	12	0.68	0.68	0.57	0.45
	0.68	0.57	0.45	0.53	9	0.68	0.49	0.45	0.34
	1.10	0.60	0.53	0.43	6	0.60	0.53	0.38	0.68
	1.21	0.68	0.57	0.64	3	0.79	0.72	0.38	0.53
	1.59	0.64	0.53	0.60	0	0.76	0.76	0.45	0.68

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

TABLE 4. 1982 CHLORIDE CONTENT I-380 PIER COLUMNS

Column	CHLORIDE - lb/yd³								
	N.W. Face - Sample Depth, *				Elev. Above Lane, ft.	S.E. Face - Sample Depth, *			
	1/4"	3/4"	1 1/4"	1 3/4"		1/4"	3/4"	1 1/4"	1 3/4"
Wilson Ave. N. Col. #5					12				
					9				
					6				
	1.21	0.51			3	0.86	2.66		
	1.17	0.59			0	0.98	0.70		
Wilson Ave. Ctr. Col. #4	1.10	0.51	0.59	0.39	12	0.86	0.47	0.47	0.47
	0.98	1.21	0.67	0.63	9	0.82	0.43	0.39	0.47
	1.37	0.59	0.51	0.39	6	0.98	0.59	0.39	0.27
	1.37	0.78	0.27	0.39	3	0.71	0.51	0.51	0.51
	2.62	0.98	0.47	0.43	0	1.10	0.86	0.59	0.27
Wilson Ave. S. Col. #3					12				
					9				
					6				
	0.70	0.43			3	0.51	0.63		
	1.68	0.78			0	1.37	1.21		
27th Ave. N. Col. #2					12				
					9				
					6				
	0.98	0.20			3	1.10	0.59		
	0.98	0.55			0	1.49	0.78		
27th Ave. S. Col. #1					12				
					9				
					6				
	1.80	0.74			3	1.80	0.59		
	2.15	0.94			0	0.39	0.59		

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

TABLE 5. 1984 CHLORIDE CONTENT I-380 PIER COLUMNS