BRIDGE SLAB CONSTRUCTION USING SUPER WATER REDUCERS

DHT-16

DEPARTMENTAL
INFORMATION
EXCHANGE

STATE DEPARTMENT OF HIGHWAYS
AND
PUBLIC TRANSPORTATION

RESEARCH SECTION, FILE D10-R, P.O. BOX 5051 AUSTIN, TX 78763-5051, 512-465-7403, STS 241-7403

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
DHT-16		

4. Title and Subtitle	5. Report Date
Bridge Slab Construction Using Super Water Reducers	September, 1988
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
H. D. Butler, P.E.	DHT-16
9. Performing Organization Name and Address	10. Work Unit No.
Texas State Department of Highways and Public Transportation – Bridge Division Austin, Texas	11. Contract or Grant No.
12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
Texas State Department of Highways and Public Transportation – Bridge Division Austin, Texas	Final Oct. 1980-Sept. 1988
	14. Sponsoring Agency Code

15. Supplementary Notes

Work done in cooperation with the Federal Highway Administration Experimental Project 78-06

16. Abstract

A bridge deck slab was constructed using a super water reducer to reduce the amount of mixing water and to increase the compressive strength of the concrete. No significant problems were encountered during mixing, placing or finishing the concrete. The only cracking that has occurred is over the interior bents. This type of cracking is typical of slabs placed continuously on simple span beams. Laboratory tests indicated that the super plasticized concrete has a high durability factor and a good resistance to chloride penetration.

17. Key Words	18. Distribution Statement
Super Water Reducers Bridge Deck Exp. Proj. 78-06 High-Range Water Reducer Durability Chloride Penetration	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of pages	22. Price
Unclassified	Unclassified	23	

Form DOT F 1700.7 (8-69)

Bridge Slab Construction Using Super Water Reducers
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Work done in Cooperation with
U.S. Department of Transportation
Federal Highway Administration

FHWA Experimental Project
No. 78-06

"Bridge Slab Construction Using
Super Water Reducers"

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or policies of the Federal Highway Administration. This report does not constitute a standard, specification or regulation.

The material contained in this report is experimental in nature and is published for informational purposes only. Any discrepancies with official views or policies of the State Department of Highways and Public Transportation should be discussed with the appropriate Austin Division prior to implementation of the procedures or results.

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Bridge Slab Construction Using Super Water Reducers

Chloride-induced corrosion of the top mat of reinforcing steel, with the resultant cracking and spalling of surface concrete, is generally considered to be one of the major causes of premature deterioration of bridge decks. Experience has shown that a dense, low water cement ratio concrete will significantly retard the intrusion of deicing chemicals and other corrosive compounds into concrete. Super water reducing additives can be used to produce a low water/cement ratio concrete that is easily placed and offers the potential for increasing the concrete's impermeability to the destructive deicing chemicals.

Objectives

The objectives of this experimental project were to construct a bridge deck using a super water reducing admixture to produce a concrete with a low water/cement ratio (4.2 gal/sk), to identify any problems that might result from the use of super water reducers, and to evaluate the performance of the deck slab under service conditions.

Description of Test Bridge

The experimental bridge is located approximately five miles east of Monahans, Texas, and carries the eastbound lanes of Interstate Highway 20 over Texas Park Road 41. The average daily traffic is approximately 4250 vehicles per day with about 19% trucks.

The bridge is 160'-0" long with three prestressed concrete girder spans (40'-80'-40') and a 7.5 inch thick deck slab. The girders are simply supported and the slab is continuous over the interior bents. The overall width of the bridge is 44.0 feet and the clear roadway width is 42.0 feet.

Construction

Prior to placing any bridge deck concrete, a 6'-0" x 8'-0" x 8" test slab was cast by the contractor. This test slab was used to evaluate the mix design and construction procedures. The concrete and admixture specifications for this project are contained in Appendix A.

The concrete was mixed in seven cubic-yard batches at a portable batch plant located approximately five miles from the bridge site. All dry materials were moved up into an elevated hopper by conveyor belt then dumped into a transit-mix truck. Water was added to the dry mix and the concrete mixed with 70 revolutions of the drum at the plant and 25 to 40 revolutions at the bridge. Ten to fifteen gallons of water and 343 ounces (7 oz/100 lb. cement) of Mighty 150 water reducer were added to four of the first five trucks at the bridge site. This resulted in a soupy mix that was difficult to finish and produced an excessive amount of surface water that had to be removed. The water was then reduced to 21 gal/cu yd and the water reducer to 5 oz/100 lb cement. This produced a good workable concrete with a slump of 6"-6 1/2".

After the mix was adjusted, no significant problems were encountered during mixing and placing the super-plasticized concrete. Placement of the deck slab began about 9:00 in the morning and was completed about 3:00 in the afternoon. The concrete was placed on the deck with a crane and dumping bucket, then finished with a transverse finishing machine. No problems were encountered during finishing and texturing the concrete and a good riding surface was obtained.

Tests and Observations

Minimum compressive strength for the super water reduced concrete was specified to be 4500 psi at seven days and 5500 psi at 28 days. Compression tests were performed on cylinders made from the bridge deck concrete to verify the required strength. At seven days the compressive strength varied from 6250 psi to 6784 psi with an average of 6573 psi. Since the 7-day strength exceeded the required 28-day strength, no further compression tests were conducted.

Dye penetration, freeze-thaw durability, and chloride penetration tests were made on cores taken from the bridge deck. The dye penetration test was inffectual in showing penetration of the dye solution into the concrete. No penetration was observed. After 300 freeze-thaw cycles the cores had a durability factor of 76.3% (ASTM C666) and showed no signs of spalling or cracking. Appendix B contains the test data and results of the chloride penetration tests. These test results show a significant decrease of chloride ion content with depth. At 1"-1 1/2" depth the chloride content was below the corrosion threshold of 1.5 lb/cy and below 1.0 lb/cy in all cores except one.

The deck slab has been visually inspected on numerous occasions since it was opened to traffic in 1980. The only cracking that has occurred is over the interior bents. These cracks are typical for slabs placed continuously over simple span beams. Figure 1 shows a plot of these cracks.

Conclusions

Based upon the results of tests and observations made during and after the construction of this experimental bridge deck slab, it can be concluded that super water reducers can be used to produce low water/cement ratio concrete that is easy to place and finish, has a high durability factor, and has good resistance to chloride penetration.

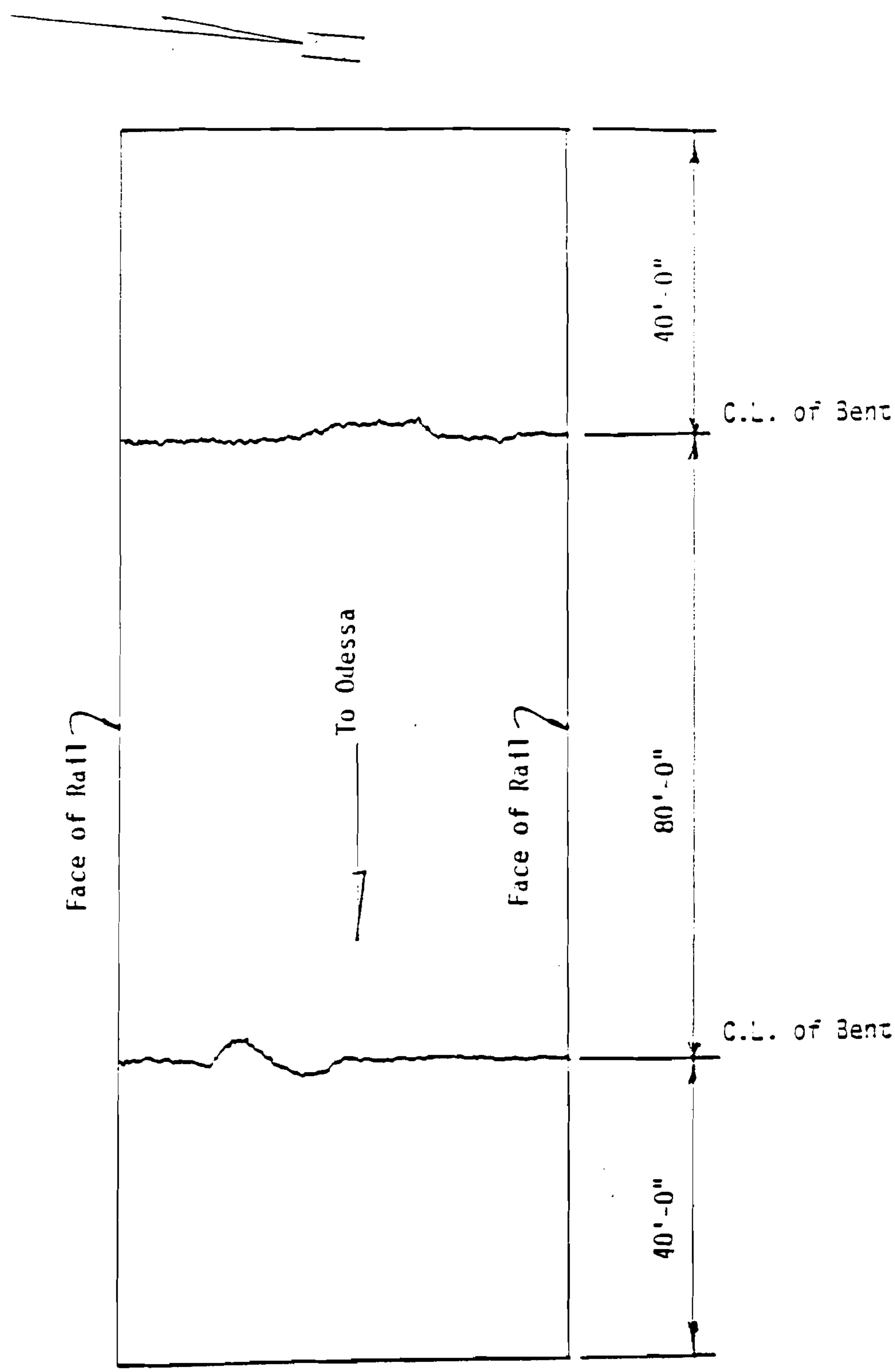


Figure 1. Location of cracks in Super Water Reduced Concrete Deck

Appendix A

Specifications

State Department of Highways and Public Transportation

Special Provision

To

Item 421

Concrete for Structures

For this project, the Item, "Concrete for Structures" is hereby amended with respect to the clauses cited below. No other clauses or requirements are waived or changed hereby.

Article 421.2. Materials. (1) Cement. The first paragraph of this Subarticle is hereby supplemented by the following:

When the cement is to be used in concrete with aggregates that may be deleteriously reactive, the alkali content ($Na_2O + 0.658K_2O$) of the cement shall not exceed 0.60 percent.

The fourth paragraph of this Subarticle is hereby voided and replaced by the following:

All cement used in a monolithic placement shall be of the same type.

Article 421.2. Materials. Subarticle (3) Coarse Aggregate. The second paragraph of this Article is hereby voided and replaced by the following:

Unless otherwise specified on the plans, coarse aggregate will be subjected to five cycles of both the sodium sulfate and the magnesium sulfate soundness test in accordance with Test Method Tex-411-A. When the loss is greater than 12 percent with sodium sulfate and/or 18 percent with magnesium sulfate, further testing will be required prior to acceptance or rejection of the material. A satisfactory record under similar conditions of service and exposure will be considered in the evaluation of the material failing to meet these requirements.

The fifth paragraph of this Article is hereby supplemented by the following:

In the case of aggregates made primarily from the crushing of stone, if the material finer than the 200 sieve is definitely established to be the dust of fracture, essentially free from clay or shale, as established by Part III of Test Method Tex-406-A, the percent may be increased to 1.5.

Article 421.2. Materials. (4) Fine Aggregate. The third paragraph of this Subarticle and Table 2, Fine Aggregate Graduation Chart are hereby voided and replaced by the following:

Unless otherwise shown on plans, the acid insoluble residue of fine aggregate used in slab concrete subject to direct traffic shall be not less than 28 percent by weight when tested in accordance with Test Method Tex-612-J.

Percent Retained on Each Sieve								
Aggregate Grade No.	3/8 in.	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	No. 200
1	0	0 to 5	0 to 20	15 to 50	35 to 75	65 to 90	90 to 100	97 to 100

NOTE 1: Where manufactured sand is used in lieu of natural sand the percent retained on the No. 200 sieve shall be 94 to 100.

NOTE 2: Where the sand equivalent value is greater than 85, the retainage on the No. 50 sieve may be 65 to 94 percent.

Table 2
Fine Aggregate Gradation Chart

Article 421.2. Materials. (7) Admixtures. This Subarticle is hereby supplemented by the following:

Where a water reducing plasticizer is used it shall conform to the requirements of the Item, "Concrete Admixtures".

Article 421.7. Classification and Mix Design. The first sentence of the fourth paragraph of this Article is hereby voided and replaced with the following:

Trial batches will be made and tested using all the proposed ingredients prior to the placing of concrete, and when the aggregate, and/or type, brand or source of cement, or admixture is changed. When the brand and/or source of cement only is changed the Engineer may waive trial batches only if a prior record of satisfactory performance of the cement has been established.

The seventh paragraph of this Article is hereby voided and not replaced.

The first sentence of the ninth paragraph of this Article is hereby voided and replaced by the following:

When a retarding admixture is required for hot weather concreting, as specified in Article 420.13., the amount to be used will be as required in the Item, "Concrete Admixtures", subject to change by the Engineer when required.

Article 421.8. Consistency. The first paragraph and the last sentence of the second paragraph are hereby voided and not replaced.

Article 421.9. Quality of Concrete, General. The first, second and fourth paragraphs of this Article are hereby voided and replaced by the following:

The concrete shall be uniform, workable and of a consistency acceptable to the Engineer. The cement content, maximum allowable water/cement ratio, the desired and maximum slump, and the strength requirements for all classes of concrete shall conform to the requirements of these specifications. It shall be the responsibility of the Contractor to provide concrete meeting these requirements.

During the progress of the work, the Engineer will cast test cylinders or beams, perform slump and entrained air tests and temperature checks, as required, to insure compliance with the specifications. If the required strength or consistency of the class of concrete being produced cannot be secured with the minimum cement specified or without exceeding the maximum water/cement ratio, the Contractor will be required to furnish different aggregates, use a different water reducing plasticizer or furnish additional cement in order to provide concrete meeting these specifications.

When a water reducing plasticizer is used to produce a low water/cement ratio concrete, the slump to be used on the job shall be as specified by the Engineer from the results of trial batches. Once this slump has been established, all concrete shall be delivered to the forms with a consistency of ± 1.5 inches from that designated. If during the placement of concrete an appreciable slump loss is noted, additional water reducing plasticizer will be required to bring the concrete back to the desired consistency. The addition of water other than that in the plasticizer will not be permitted at the job site.

The Engineer reserves the right to reduce the quantity of concrete mixed in any mixer to less than the maximum rated capacity, if deemed necessary to produce adequately mixed concrete.

Table 4 – Classes of Concrete is hereby voided and replaced by the following:

Class of Conc.	Sx. Cement per C.Y. Min.	Min. Comp. Strength (f'_c) 28 Day psi	Min. Beam Strength 7 Day psi	Max. Water Cement Ratio	Coarse Aggr. No.
A*	5.0	3000	#500	6.5	**1-2-3-4^x
B	4.0	2000	330	8.0	2-3-4^x
C*	6.0	3600	#600	6.0	**1-2-3
C*^{Y}	6.0 Min.	3600	#600	5.5	2-3
C*-C^Y ###	7.0 Min.	5500 (7 day-4500)	N.A.	4.2	2-3
D	3.0	1500	250	11.0	2-3-4^x
E	6.0	3000	500	7.0	2-3
F*	6.0 to 8.0	As Specified on Plans	$\frac{f'_c}{6}$	5.5	2-3
H***	6.0 to 8.0	As Specified on Plans	N.A.	5.5	3

* Entrained Air (slab, pier and bent concrete).

** Grade 1 Coarse Aggregate may be used in foundations only (except cased drilled shafts).

*** Entrained Air for slab concrete.

\# When Type II Cement is used with Class C Concrete, the 7 day beam break requirement will be 550 psi; with Class A, 460 psi min.

x The use of grade 4 aggregate must have prior approval of the Engineer.

Y For bridge slabs and slabs of direct traffic culverts.

\### A water reducing plasticizer will be required with this class of concrete.

Table 4
Classes of Concrete

Ward County
I 20-1(86)082
Control 4-4-46, etc.

State Department of Highways and Public Transportation

Special Provision

To

Item 437

Concrete Admixtures

For this project the Item, "Concrete Admixtures", is hereby amended with respect to the clauses cited below. No other clauses or requirements are waived or changed hereby.

Article 437.2. General. This Article is hereby supplemented by the following:

A "water reducing plasticizer" is defined as a material which when added to a concrete mix in the correct quantity will produce the results required in Article 437.3. herein.

Article 437.3. Retarding and Water Reducing Admixtures is hereby supplemented by the following:

When required by the plans and/or specifications a water reducing plasticizer shall be used which, when compared to a standard mix design in accordance with ASTM C-494, shall produce the following results:

1. It shall reduce the required water by a minimum of 15%.
2. It shall not increase shrinkage when tested in accordance with ASTM C-494.
3. It shall increase the seven day compressive strength of the concrete by a minimum of 25%.
4. It shall not retard the initial set of concrete by more than one hour when tested in accordance with ASTM C-403.
5. It shall contain no chlorides, air entraining agents or urea.

Article 437.5. Approval of Admixtures is hereby supplemented by the following:
Any of the following water reducing plasticizers may be used if they meet the requirements specified herein:

FX-32, Sikament, Melment, Lomar-D, Mighty-150 or WRDA-19.

Article 437.6. Construction Use of Admixtures is hereby supplemented by the following:

The water reducing plasticizer shall be incorporated into the mix in liquid form. The amount to be used shall be in accordance with the manufacturer's recommended range, based upon adequate trial batches and as approved by the Engineer. The volume of water in the plasticizer shall be taken into account in determining the water/cement ratio of the mix.

The water reducing plasticizer may be introduced into the mix entirely at the plant, a portion thereof introduced at the plant with the balance added at the job site, or all of the required amount introduced at the job site as determined by adequate trial batches, and approved by the Engineer.

If, during the placement of concrete, an appreciable slump loss is noted, additional water reducing plasticizer will be required to bring the concrete back to the desired consistency. The addition of water other than that in the plasticizer will not be permitted at the job site.

A retarder may be used if approved by the Engineer when the temperature of the concrete is approaching the maximum limit of 85F. When a retarding agent is required herein or by Article 420.11 or 420.13, a separate retarding agent will be used. The retarder must be compatible with the water reducing plasticizer.

Appendix B

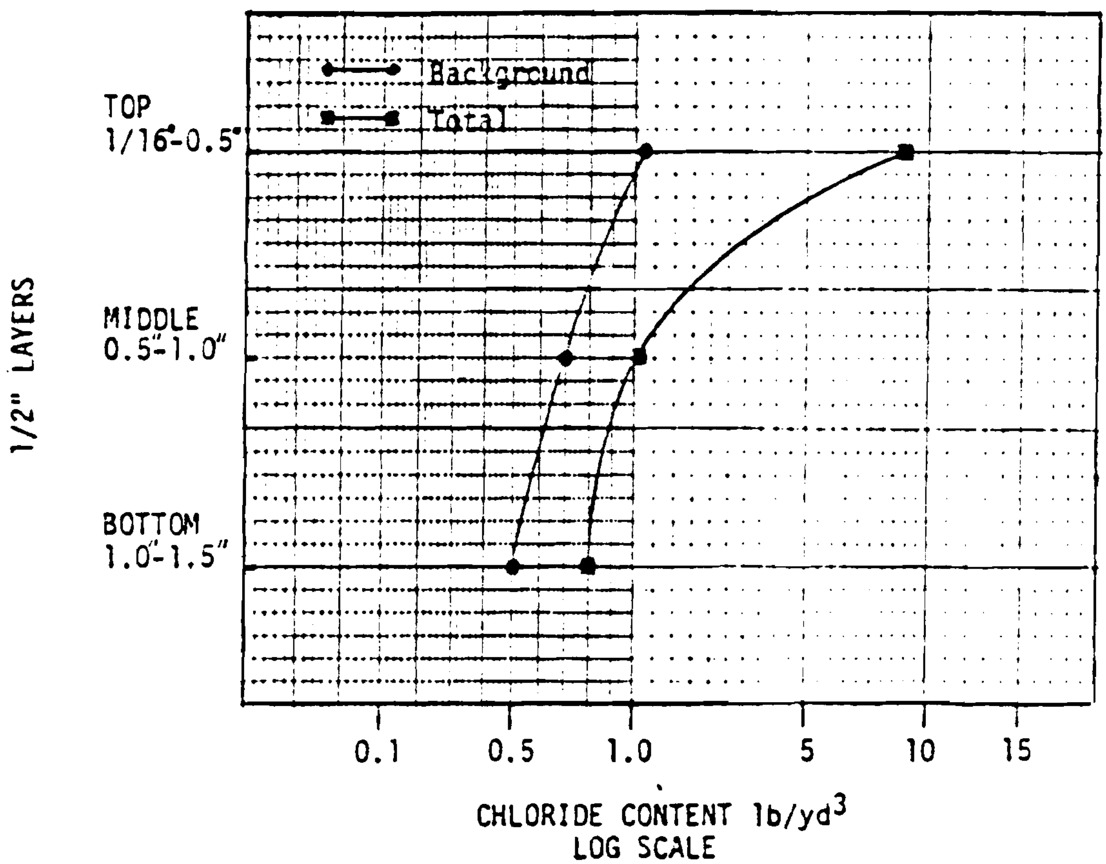
Chloride Analysis – Test Results

Test Results
Chloride Analysis

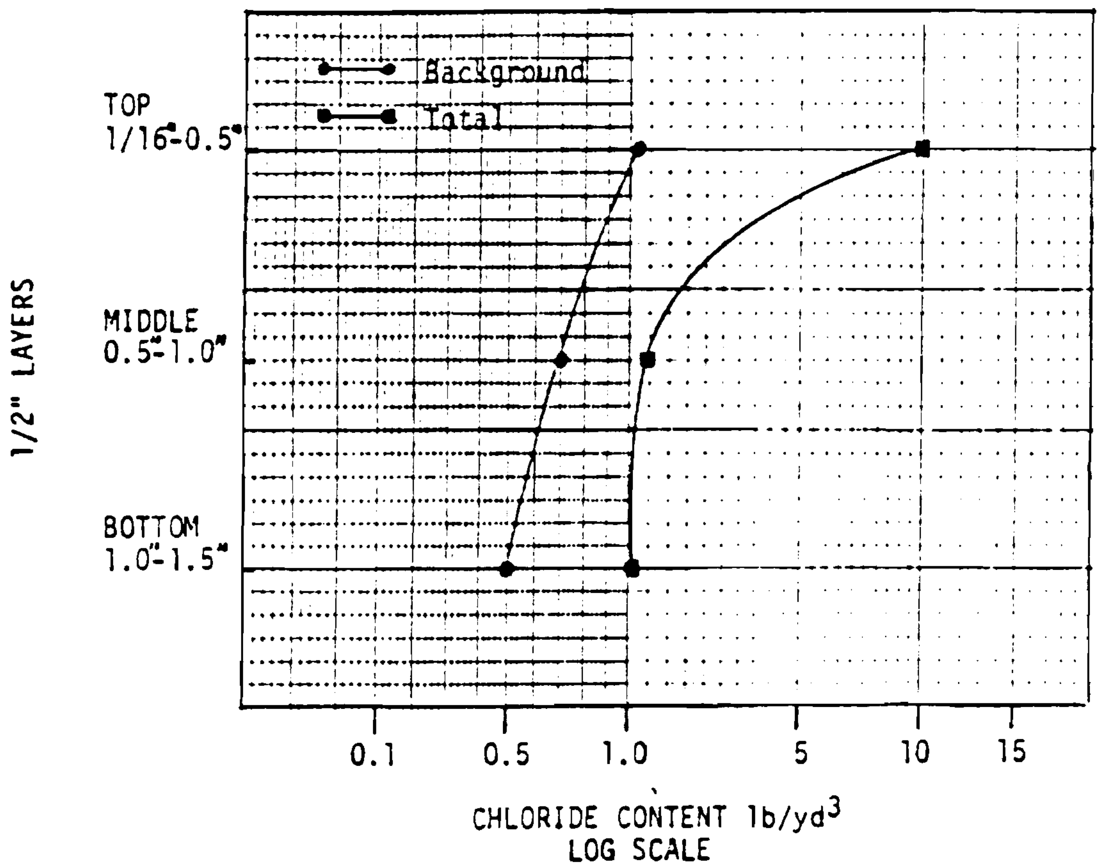
Low Water-Cement Ratio Concrete (With Super-Water Reducer)

Core	Concrete Depth	Test No.	%	Chloride Ion Content PPM	Chloride Ion Content Lb/cu yd
1-SWR Dense	1/16" to 1/2"	1	0.22	2227	8.9
		2	0.22	2227	8.9
	1/2" to 1"	1	0.03	283	1.1
		2	0.03	283	1.1
	1" to 1-1/2"	1	0.02	209	0.8
		2	0.02	209	0.8
2-SWR Dense	1/16" to 1/2"	1	0.25	2461	9.8
		2	0.25	2461	9.8
	1/2" to 1"	1	0.04	356	1.4
		2	0.04	356	1.4
	1" to 1-1/2"	1	0.03	356	1.2
		2	0.03	283	1.1
3-SWR Dense	1/16" to 1/2"	1	0.29	2931	11.7
		2	0.29	2931	11.7
	1/2" to 1"	1	0.04	352	1.4
		2	0.04	410	1.6
	1" to 1-1/2"	1	0.02	221	0.9
		2	0.02	221	0.9
4-SWR Dense	1/16" to 1/2"	1	0.03	307	1.2
		2	0.03	307	1.2
	1/2" to 1"	1	0.02	184	0.7
		2	0.02	184	0.7
	1" to 1-1/2"	1	0.01	135	0.5
		2	0.01	135	0.5

Low Water/Cement Ratio Concrete (With Super-Water Reducer)
Core #1



Low Water/Cement Ratio Concrete (With Super-Water Reducer)
Core #2



Low Water/Cement Ratio Concrete (With Super-Water Reducer)
Core #3