

Hydraulic Cement Grout Testing

**Final Report
for
MLR-89-14**

August 1990

Highway Division



HYDRAULIC CEMENT GROUT TESTING

Final Report
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Disclaimer

The contents of this report reflect the views of the author and do not necessarily reflect the official view of the Iowa Department of Transportation. This report does not constitute a standard, specification or regulation.

ABSTRACT

Currently, hydraulic cement grouts are approved for Iowa Department of Transportation projects on the basis of a pullout test. However, other properties of the grouts should be evaluated. Therefore, this research was initiated to develop criteria to better evaluate hydraulic cement grouts.

Fourteen grouts were tested for compressive strength, time of set, durability, consistency and shrinkage. Tested grouts all yielded compressive strengths higher than 3000 psi at 7 days and durability factors were well above 70. Time of set and consistency was adequate. The testing showed most grouts tested shrank, even though tested grouts were labeled non-shrink grouts. For many applications of grouts such as setting in anchor bolts and as a filler, minor shrinkage is not a problem. However, for some critical applications, shrinkage cannot be tolerated. The proposed Instructional Memorandum will identify those grouts which do not excessively shrink or expand in the tests used.

Based on test results, criteria for evaluation of hydraulic cement grouts have been recommended. Evaluation consists of tests for compressive strength, time of set, durability, consistency, shrinkage and pullout test.

INTRODUCTION

Hydraulic cement grouts are currently being approved for Iowa Department of Transportation projects on the basis of a pullout test as per Instructional Memorandum 491.13. The pullout test consists of bonding a No. 6 reinforcing bar in a 4" deep, 2" diameter hole in concrete. A minimum pullout load of 9000 lbs. is required after 7 days of cure.

Grouts are currently being used for setting in anchor bolts, filling voids under base plates on sign posts and as a filler around light poles. However, if grouts on the approved list are evaluated for other properties, then they can be used for other applications such as repairing damaged light pole bases, patching structural members, high strength leveling, post tensioning of precast deck panels on segmented bridge construction and for retrofitting concrete rails.

Since Instructional Memorandum 491.13, "Inspection and Acceptance of Hydraulic Cement Grouts" is no longer being used in the manner intended when it was first developed, MLR-89-14 was initiated to revise it to better reflect current uses.

OBJECTIVE

The objective of the study was to develop new criteria to better evaluate the properties of non-shrink grouts for I.M. 491.13.

TESTING

Fourteen hydraulic cement grouts were tested for compressive strength, time of set, durability, consistency and shrinkage.

These tests were performed as follows:

- Compressive strength at plastic and high flow state as per ASTM C-109 at 6 hrs., 1 day, 3 days and 7 days.
- Time of set as per ASTM C-266.
- Durability as per ASTM C-666 part B modified. Modification is the 7 days moist cure, 100 cycles of freeze and thaw and 4"x4"x18" beams.
- Consistency test as per ASTM C-109 at plastic state and as per I.M. 375 at high flow state.
- Shrinkage at plastic state as per ASTM C-827 and at hardened state as per ASTM C-157.

Plastic or high flow states were determined by the mix consistency. Consistency was determined by the flow table or by flow cone. Mixtures with a flow between 100% to 125% on the flow table are considered to be plastic and mixtures with a flow of 10 to 30 sec. in the flow cone are considered to be high flow (fluid).

Grout mixes for each product were prepared by first placing the water in the dry bowl then grout material was added and mixed for 1 minute. After mixing, the mix was tested for flow. If the desired flow was not achieved then, additional water was added to the mix, and remixed and then were retested for flow. These

steps were repeated until the proper consistency was achieved for each grout mix. This consistency was then used for all the tests except for the durability test. The manufacturer's recommended consistency was used for the durability test.

RESULTS

The summary of results is in Table 1. All products yielded compressive strengths at plastic state well above 5000 psi at 7 days and at high flow state above 3000 psi at 7 days. Durability factors of all the products were well above 70. With the exception of Garonite, all the products yielded durability factors above 90. Shrinkage was observed on all products at hardened state. At plastic state, all products except for three (Bonsal, Sika Grout 212 and Five Star) shrank. Garonite and Quik-Rok yielded highest early strengths and fastest setting times. However, the strength gain was low for Garonite at both the plastic state and the high flow state. Strengths at 7 days were actually less than initial strengths for Garonite and Quik-Rok. Due to fast setting times, plastic shrinkage was not tested for these two products.

TABLE 1
SUMMARY OF RESULTS

TESTS		PRODUCTS													
		Crystex	Bonsal	Sika Grout 212	Euco	Dura Grout	Sure Grip	Seal Tight 588	Five Star	Comb- extra S	Comb- extra HF	Garonite	Quik- Rok	Sure Grip Utility	Halco
<u>Comp. Strength (PSI)</u>															
Plastic State	6 Hrs.	1580	60	80	840	150	180	610	70	4900	420	5460	6500	200	210
	24 Hrs.	7340	4140	5350	5450	5920	7410	6310	5080	7180	7710	5520	6760	4980	8100
	3 Days	9320	7140	6380	8870	8850	8670	8250	6620	9350	9540	5250	7370	6720	10290
	7 Days	10830	8510	7030	11050	9630	8380	9130	7450	9550	10330	5370	8010	7970	11770
High Flow State	6 Hrs.	140	Not Set	Not Set	50	Not Set	30	Not Set	Not Set	750	50	4470	6570	20	10
	24 Hrs.	1830	950	1320	1250	1150	2420	1200	920	3280	2330	4290	5990	2220	3440
	3 Days	4490	3160	3210	3780	2750	4500	3470	2470	4970	3990	3650	5690	3610	6700
	7 Days	5530	3990	4370	5010	3180	4000	4780	3560	6130	5630	3490	5360	3830	7690
<u>Time of Set</u>															
Initial Final	6 Hrs.	35 Min.	35 Min.	31 Min.	29 Min.	26 Min.	26 Min.	22 Min.	26 Min.	15 Min.	22 Min.	3 Min.	3 Min.	14 Min.	9 Min.
	1 Hr.	1 Hr.	2 Hrs.	3 Hrs.	1 Hr.	37 Min.	1 Hr.	1 Hr.	4 Hrs.	1 Hr.	2 Hrs.	6 Min.	5 Min.	3 Hrs.	48 Min.
	13 Min.	28 Min.	55 Min.	15 Min.				7 Min.	6 Min.					15 Min.	
<u>Durability Factor</u>		97	100	100	100	100	99	90	94	100	99	73	98	100	94
<u>Flow Test</u>															
Plastic State		115%	110%	112.5%	115%	112.5%	110%	112.5%	107.5%	110%	110%	107.5%	110%	112.5%	115%
High Flow State		16 Sec.	16 Sec.	15 Sec.	16 Sec.	18 Sec.	16 Sec.	14 Sec.	14 Sec.	16 Sec.	17 Sec.	20 Sec.	20 Sec.	20 Sec.	16 Sec.
<u>*Shrinkage</u>															
Plastic State		-.27%	.31%	2.88%	-.42%	-.16%	-.19%	-.31%	.66%	-.31%	-.06%	--	--	-.16%	-.06%
Hardened State		-.203%	-.174%	-.183%	-.165%	-.137%	-.193%	-.096%	-.164%	-.091%	-.137%	-.038%	-.055%	-.189%	-.158%

* NOTE: A negative sign on shrinkage value indicates shrinkage and a positive sign on shrinkage value indicates expansion.

ESTABLISHMENT OF CRITERIA

Tests were performed on the hydraulic cement grouts so that criteria could be established to better evaluate grouts. The acceptance criteria for grouts are given in Table 2. Criteria for each test were determined as follows:

Compressive Strength - Compressive strength criteria are based upon current specifications. Iowa Department of Transportation Specifications and Special Provisions on projects where grouts are used currently specify 3000 psi at 7 days and 5000 psi at 28 days as minimum compressive strengths based on ASTM C-109. The requirements established for compressive strength are well above the specified compressive strengths.

Time of Set - Time of set criterion is based primarily on relative comparison between products.

Durability - A 90 minimum durability factor was established to ensure performance in applications subjected to water and freezing.

Shrinkage - Minor shrinkage is acceptable for many applications. However, for critical applications such as filler for pre-stressing tendons, non-shrink grout is required and only 2.0% expansion is acceptable by judgement at plastic state. At hardened state a maximum of .20% shrinkage was selected.

TABLE 2
ACCEPTANCE CRITERIA

Test		Appendix A & B
<u>Compressive Strength</u>		
Plastic State	1 day	3000 psi
	7 days	5000 psi
High Flow State	1 day	800 psi
	7 days	3000 psi
<u>Time of Set</u>		
Initial		1 hr. (Max.)
Final		30 min. (Min.)
<u>Durability Factor</u>		90 (Min.)
<u>Shrinkage</u>		
Plastic State		Non-Shrink grout and 2.0% Max. expansion for critical application
Hardened State		.20% Max.

CONCLUSION

All hydraulic cement grouts at plastic and at high flow state yielded strengths much greater than 3000 psi compressive strength at 7 days. A minimum strength of 5000 psi has been used in the Iowa Department of Transportation Special Provisions on projects where grouts are used for critical applications such as filler for voids within stay cable system and post-tensioned tendons. Consistency, time of set and durability were adequate for plastic state. The manufacturer's literature stated non-shrink, however, the tests used in this study produced shrinkage in both hardened and plastic state for most products. For many applications, such as setting in anchor bolts, and as filler around light poles minor shrinkage is not a problem. However, for critical applications such as filler for voids in stay cable system, non-shrink grouts are required.

RECOMMENDATIONS:

Revise the acceptance section of I.M. 491.13 to read as follows:

ACCEPTANCE

Prior to being placed on the list of approved brands, one or more product per manufacturer will be evaluated by the Office of Materials. The evaluation will consist of testing the grout for strength, time of set, durability, consistency and shrinkage. Approval of products shall consist of the following:

		Appendix A & B
<u>Compressive Strength</u>	ASTM C-109	
Plastic State	1 day	3000 psi
	7 days	5000 psi
High Flow State	1 day	800 psi
	7 days	3000 psi
<u>Time of Set</u>	ASTM C-266	
Initial		1 hr. (Max.)
Final		30 min. (Min.)
<u>Durability Factor</u>	ASTM C-666 Part B Modified	
7 days moist cure & 100 cycles freeze & thaw		90 (Min.)
<u>Shrinkage</u>		
Plastic State	ASTM C-827	Non-Shrink grout and 2.0% Max. expansion for critical application
Hardened State	ASTM C-157	.20% Max.
<u>Pull-Out Test</u>		
Bond No. 6 reinforcing bar in a 4" deep, 2" diameter hole in concrete. A 9000 lb. minimum load is required after the grouting material has cured 7 days.		
<u>Consistency</u>		
Plastic State	ASTM C-109	110 \pm 5%
High Flow State	I.M. 375	20 \pm 5 Sec.

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Appendix A

APPENDIX A

Approved Sources - Hydraulic Cement Grouts

<u>Manufacturer</u>	<u>Brand Name</u>
Dayton Superior Corp.	Sure-Grip Grout
Dayton Superior Corp.	Sure-Grip Utility Grout
Euclid Chemical Company	Euco Non-Shrink Grout
Fosroc, Inc.	Conbextra HF
Fosroc, Inc.	Conbextra S
L & M Construction Chemicals, Inc.	Crystex
L & M Construction Chemicals, Inc.	Duragrout
Minwax Construction Products Div.	Halco Grout
Sika	Sikagrout 212
W. R. Meadows, Inc.	Sealtight 588 Non-Shrink, Non-Metallic Grout

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Appendix B

APPENDIX B

Approved Sources - Hydraulic Cement Grouts
Non-Shrink

Manufacturer

Brand Name

Five Star Products

Five Star Grout

United Products

Bonsal Construction Grout

APPENDIX

PLASTIC SHRINKAGE RESULTS

PLASTIC SHRINKAGE RESULTS

PRODUCTS

Minutes	Crystex		Bonsal		Sika Grout 212		Euco		Dura Grout		Sure Grip		Seal Tight 588		Five Star		Comb-extra S		Comb-extra HF		Sure Grip Utility		Halco	
	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	% Growth ^o		#1	#2	#1	#2	#1	#2	#1	#2	#1	#2	#1	#2
5	-.06	-.06	.06	.09	.06	.06	-.05	-.05	-.16	-.09	-.13	-.13	-.13	-.06	.31	.56	-.31	-.19	0	0	0	0	-.06	-.06
10	-.13	-.09	.09	.16	.34	.22	-.09	-.13	-.16	-.09	-.16	-.16	-.25	-.13	.38	.66	-.31	-.19	0	0	0	0	-.06	-.06
15	-.13	-.09	.13	.31	.97	.91	-.13	-.19	-.16	-.09	-.16	-.16	-.31	-.19	.38	.66	-.31	-.19	0	0	0	0	-.06	-.06
20	-.19	-.09	.13	.31	1.22	1.09	-.14	-.23	-.16	-.09	-.17	-.16	-.31	-.19	.38	.66	-.31	-.19	0	0	-.06	-.06	-.06	-.06
25	-.25	-.09	.13	.31	1.72	1.69	-.16	-.27	-.16	-.09	-.17	-.16	-.31	-.19	.41	.66	-.31	-.19	-.03	-.03	-.06	-.06	-.06	-.06
30	-.25	-.09	.13	.31	2.06	2.00	-.16	-.30	-.16	-.09	-.17	-.19	-.31	-.19	.41	.66	-.31	-.19	-.03	-.03	-.06	-.06	-.06	-.06
35	-.27	.09	.13	.31	2.22	2.13	-.16	-.33	-.16	-.09	-.17	-.19	-.31	-.19	.41	.66	-.31	-.19	-.03	-.03	-.06	-.06	-.06	-.06
40	-.27	-.11	.13	.31	2.25	2.22	-.17	-.36	0	0	-.17	-.19	-.31	-.19	.41	.66	-.31	-.19	-.03	-.03	-.06	-.06	-.06	-.06
45	-.27	-.11	.13	.31	2.34	2.31	-.17	-.36	0	0	-.17	-.19	-.31	-.19	.41	.66	-.31	-.19	-.03	-.03	-.06	-.06	-.06	-.06
50	-.27	-.11	.13	.31	2.34	2.44	-.17	-.38	0	0	-.17	-.19	-.31	-.19	.41	.66	-.31	-.19	-.06	-.03	-.06	-.06	0	0
55	-.27	-.11	.13	.31	2.34	2.50	-.19	-.39	0	0	-.17	-.19	-.31	-.19	.41	.66	-.31	-.19	-.06	-.06	-.06	-.06	0	0
60	-.27	-.11	.13	.31	2.53	2.72	-.22	-.42	0	0	-.17	0	-.31	-.19	.41	.66	-.31	-.19	-.06	-.06	-.06	-.06	0	0
65	-.27	-.11	.13	.31	2.63	2.72	-.22	-.42	0	0	0	0	-.31	-.19	.34	.66	0	0	-.06	-.06	-.16	-.06	0	0
70	-.27	-.11	.13	.31	2.63	2.72	-.22	-.42	0	0	0	0	-.31	-.19	.13	.56	0	0	-.06	-.06	-.16	-.06	0	0
75	-.27	-.11	.13	.31	2.66	2.75	0	0	0	0	0	0	0	0	.13	.56	0	0	-.06	-.06	-.16	-.06	0	0
80	0	0	.13	.31	2.66	2.81	0	0	0	0	0	0	0	0	.13	.47	0	0	-.06	-.06	-.16	-.06	0	0
85	0	0	.13	.31	2.69	2.88	0	0	0	0	0	0	0	0	.06	.47	0	0	-.06	-.06	-.16	-.06	0	0
90	0	0	.13	.31	2.69	2.88	0	0	0	0	0	0	0	0	.06	.47	0	0	-.06	-.06	-.16	-.06	0	0
100	0	0	0	0	2.69	2.88	0	0	0	0	0	0	0	0	-.06	.41	0	0	-.06	-.06	-.16	-.06	0	0
110	0	0	0	0	2.69	2.88	0	0	0	0	0	0	0	0	-.06	.31	0	0	-.06	-.06	-.16	-.06	0	0
120	0	0	0	0	2.69	2.88	0	0	0	0	0	0	0	0	-.19	.28	0	0	-.06	-.06	-.16	-.06	0	0
130	0	0	0	0	2.69	2.88	0	0	0	0	0	0	0	0	-.19	.28	0	0	0	0	0	0	0	0
140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-.19	.28	0	0	0	0	0	0	0	0

NOTE: A negative sign on shrinkage value indicates shrinkage and a positive sign on shrinkage value indicates expansion.