LABORATORY EVALUATION OF HIGH RANGE WATER REDUCING ADMIXTURES

Report 84-8
October, 1984

Reporting on Work Plan 83-C-39

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

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Date: 10-15-'84

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ABSTRACT

This evaluation was initiated to examine three high range water reducing admixtures for compliance with AASHTO M 194-82, Type F, Chemical Admixtures for Concrete, and for their ability to produce flowable concrete. Tests were conducted to study compressive strength, time of setting, water content, resistance to freezing and thawing, and for the flowable concrete, rate of slump loss. Two of the products examined complied with applicable requirements.

This report recommends that trial use of WRDA 19 and Eucon 37 be permitted in prestressed concrete members or other precast applications where their use can be closely monitored.

INTRODUCTION

High range water reducing admixtures, known also as super plasticizers, are used to:

(a) provide flowable concrete while maintaining a normal water/cement ratio

(b) provide normal slump concrete with a greatly reduced water/cement ratio

(c) provide concrete with a combination of the above properties.

Tests conducted at the Materials and Research Division several years ago examined the ability of products available at that time to appreciably reduce the water/cement ratio or increase the slump of concrete. However, problems were encountered achieving proper air content of the concrete and with rapid loss of slump.

Manufacturers have since modified many of the earlier products and are now able to better control the rate of slump loss. The use of vinsol resin air entraining admixtures also enables ready mixed concrete producers to provide concrete with more uniform air contents.

The Structural Concrete Subdivision initiated this evaluation to examine high range water reducing admixtures for compliance with AASHTO requirements and to gain further information and experience relative to the performance of these materials. Three products were examined for compliance with AASHTO M 194-82,

Chemical Admixtures for Concrete, and for their ability to produce flowable concrete. Compressive strength, time of setting, water content and resistance to freezing and thawing were studied for all mixes. For the flowable concrete mixes, the rate of slump loss was also studied.

MATERIALS

The materials used in this evaluation are as follows:

A. Aggregates

1. Coarse Aggregate

   3/4 inch Crushed Igneous Stone
   Cooley, Websterville, Vermont

2. Fine Aggregate

   A. G. Anderson, Highgate, Vermont

B. Cement

Type II
Glens Falls Portland Cement Co., Glens Falls, N.Y.

C. Air Entraining Admixture

MBAE 10
Master Builders, Cleveland, Ohio

D. High Range Water Reducing Admixtures

1. Pozzolith 400-N
   Master Builders, Cleveland, Ohio

2. WRDA 19
   W. R. Grace & Co., Cambridge, Massachusetts

3. Eucon-37
   Euclid Chemical Co., Cleveland Ohio

PROCEDURES

The fine aggregate used in this investigation was examined for gradation and organic impurities. The coarse aggregate was examined for gradation, fractured faces, thin and elongated pieces and wear.

The Class B concrete used in this investigation was prepared in the laboratory in a Sears 3½ cu. ft. mixer. To determine compliance with AASHTO M 194-82, Type F - Water Reducing High Range Admixtures, three reference batches were prepared as well as three batches for each admixture investigated. The size of the batches used to determine specification compliance was 1.8 cu. ft.

Tests were performed on the fresh concrete to determine Slump (AASHTO T 119-82), Air Content (AASHTO T 152-82), Unit Weight (AASHTO T 121-82), and Time of Setting (AASHTO T 197-82). Four test cylinders (6"x12") and one 3"w x 3"d x 16" l freeze-thaw specimen were cast from each batch. The cylinders were tested for compressive strength (AASHTO T 22-82) one from each batch at ages 1, 3, 7, and 28 days. The freeze thaw specimens were moist cured for 14 days, after which they were

subjected to freezing and thawing in a 3% NaCl solution for 300 cycles.

The batches used to examine flowable concrete and rate of slump loss were prepared in the same mixer with the size of the batch being 3.0 cu.ft. This concrete was mixed to approximately the same slump as the reference batches, then tested for slump, air content and unit weight prior to addition of the high range water reducing admixtures.

After adding the high range water reducers, the concrete was tested for slump, air content, unit weight and time of setting. Eight test cylinders (6" X 12") and one 3"w X 3"d X 16" l freeze-thaw specimen were cast from each batch. The cylinders were tested for compressive strength, two from each batch at ages 1, 3, 7 and 28 days. The freeze-thaw specimens were cured and tested in the same manner as the specification compliance batches.

Rate of slump loss was determined by conducting a second slump test 30 minutes after the addition of the high range water reducers, then repeating the test at 15 minute intervals until the original slump was attained.

Mix design quantities for the batches used to determine specification compliance are shown in Table 1. Flowable concrete mix designs are shown in Table 2.

TABLE 1

CLASS B CONCRETE MIX DESIGNS - SPECIFICATION COMPLIANCE CONCRETE

BATCH QUANTITIES PER CUBIC YARD

		Test Concrete		
	Reference Concrete	Pozzolith 400N	WRDA 19	Eucon 37
*Coarse Aggregate, lbs	1587	1587	1587	1587
*Fine Aggregate, lbs	1417	1558	1558	1558
Cement, lbs	611	611	611	611
Air Entraining Admixture, oz	4-6½	3	4	3½
High Range Water Reducing Admixture, oz	-	92	67	61

*Weights converted to saturated surface-dry condition.

TABLE 2

CLASS B CONCRETE MIX DESIGNS - FLOWABLE CONCRETE

BATCH QUANTITIES PER CUBIC YARD

		Flowable Concrete		
	Reference Concrete	Pozzolith 400N	WRDA 19	Eucon 37
*Coarse Aggregate, lbs	1587	1587	1587	1587
*Fine Aggregate, lbs	1417	1417	1417	1417
Cement, lbs	611	611	611	611
Air Entraining Admixture, oz	4-6½	5	6½	5½
High Range Water Reducing Admixture, oz	-	92	67	61

*Weights converted to saturated surface-dry condition.

RESULTS

The results of tests on the coarse and fine aggregates are shown in Appendix A.

Following are test results from the batches used to determine specification compliance of the three materials examined.

	Reference Concrete	Test Concrete			AASHTO M 194-82 & VAOT Requirements
		Pozzolith 400N	WRDA 19	Eucon 37	
Slump, inches					
Batch 1	3 1/2	4 1/2	3	3 1/2	
Batch 2	2 1/2	2 1/2	2 1/2	2 3/4	
Batch 3	2 3/4	1 3/4	2 3/4	3	
Average	3	3	2 3/4	3	2-4(1)
Air Content, percent					
Batch 1	4.2	7.1	5.9	8.1	
Batch 2	4.3	4.9	5.4	5.5	
Batch 3	4.5	4.7	6.2	6.2	
Average	4.3	5.6	5.8	6.6	4-6(2)
Unit Weight, lbs/ft^3					
Batch 1	146.36	144.63	145.84	142.32	
Batch 2	146.56	148.77	146.46	146.60	
Batch 3	146.32	148.67	145.45	145.55	
Average	146.41	147.36	145.92	144.82	

(1) VAOT requirement for Class B concrete, AASHTO M 194-82 requires a slump of 2 1/2 ± 1/2 inches.

(2) VAOT requirement for Class B concrete, AASHTO M 194-82 requires that for tests for resistance to freezing and thawing, the range shall be 5% to 7%. It also requires the difference between the air content of the reference concrete and that of the concrete containing the admixture under test shall not exceed 0.5 percent.

	Reference Concrete	Test Concrete Pozzolith 400N	WRDA 19	Eucon 37	AASHTO M 194-82 & VAOT Requirements
Concrete Temp., °F					
Batch 1	74	72	68	68	
Batch 2	72	72	70	70	
Batch 3	69	74	70	71	
Average	72	73	69	70	73 ± 3
Water Content, lbs/yd^3					
Batch 1	276	214	226	224	
Batch 2	262	210	226	229	
Batch 3	261	210	225	231	
Average	266	211	226	228	
Percent of Reference		79	85	86	88 Maximum
Time of Setting, Hrs:Min					
Initial Set					
Batch 1	6:15	5:54	5:24	6:15	
Batch 2	5:45	5:20	5:10	5:56	
Batch 3	5:45	5:18	5:06	5:40	
Average	5:55	5:31	5:13	5:57	
Deviation from Reference		0:24 (earlier)	0:42 (earlier)	0:02 (later)	Not more than 1:00 earlier nor 1:30 later
Final Set					
Batch 1	8:18	7:40	7:22	8:12	
Batch 2	7:36	7:10	7:31	7:28	
Batch 3	7:54	7:15	7:18	7:38	
Average	7:56	7:22	7:24	7:46	
Deviation from Reference		0:34 (earlier)	0:32 (earlier)	0:10 (earlier)	Not more than 1:00 earlier nor 1:30 later
Compressive Strength, psi - 1 day					
Batch 1	1688	2838	2458	2520	
Batch 2	1804	3104	2556	2688	
Batch 3	1716	3059	2458	2511	
Average	1736	3000	2491	2573	
Percent of Reference		173	143	148	140 Minimum

	Reference Concrete	Test Concrete Pozzolith 400N	WRDA 19	Eucon 37	AASHTO M 194-82 & VAOT Requirements
Compressive Strength, psi - 3 days					
Batch 1	2848	3979	3979	3520	
Batch 2	2865	4519	4050	3891	
Batch 3	2830	4519	4156	3272	
Average	2848	4339	4062	3561	
Percent of Reference		152	143	125	125 Minimum
Compressive Strength, psi - 7 days					
Batch 1	4023	5243	4969	5040	
Batch 2	4536	5836	5217	5261	
Batch 3	4174	5252	5226	5305	
Average	4244	5444	5137	5202	
Percent of Reference		128	121	123	115 Minimum
Compressive Strength, psi - 28 days					
Batch 1	6225	6989	6888	6826	
Batch 2	5677	7612	6632	7073	
Batch 3	6278	7644	6968	6985	
Average	6060	7415	6829	6961	
Percent of Reference		122	113	115	110 Minimum
Resistance to Freezing & Thawing - 300 cycles					
Durability Factor					
Batch 1	90.3	97.2	98.6	99.3	
Batch 2	100.0	57.7	99.3	94.3	
Batch 3	100.0	56.3	98.6	99.3	
Average	96.8	70.4	98.8	97.6	
Relative Durability Factor		72.7	102.1	100.8	80 Minimum
Weight Loss, Percent					
Batch 1	11.4	7.5	4.3	2.9	
Batch 2	7.1	7.6	6.5	9.3	
Batch 3	4.6	11.6	5.8	5.5	
Average	7.7	8.9	5.5	5.9	

Following are listed the results of tests performed on the flowable concrete batches:

	Reference Concrete	Flowable Concrete					
		Pozzolith 400N		WRDA 19		Eucon 37	
		Before(3)	After(4)	Before(3)	After(4)	Before(3)	After(4)
Slump, inches	3	2 3/4	10	2	9 1/2	3 1/4	10+
Air Content, percent	4.3	4.4	2.3	4.3	5.8	4.2	3.9
Unit Weight, lbs/ft^3	146.41	146.94	147.18	147.71	143.38	146.89	143.86
Concrete Temp., °F.	72	70	70	70	70	68	68
Water Content, lbs/yd^3	266	266	266	253	253	273	273
Time of Setting, Hrs:Min							
Initial Set	5:55		6:24		5:55		7:18
Deviation from Reference			0:29 later		None		1:23 later
Final Set	8:05		8:05		7:54		8:48
Deviation from Reference			None		0:11 earlier		0:43 later
Compressive Strength, psi - 1 day							
Cylinder 1			2076		2052		1928
Cylinder 2			1972		2105		1875
Average	1736		2024		2079		1902
Percent of Reference			117		120		110
Compressive Strength, psi - 3 days							
Cylinder 1			3237		3405		3148
Cylinder 2			3316		3458		3060
Average	2848		3277		3432		3104
Percent of Reference			115		121		109

(3) Before application of high range water reducer.

(4) After application of high range water reducer.

	Reference Concrete	Flowable Concrete					
		Pozzolith 400N		WRDA 19		Eucon 37	
		Before[3]	After[4]	Before[3]	After[4]	Before[3]	After[4]
Compressive Strength, psi - 7 days							
Cylinder 1		4571		4111		4456	
Cylinder 2		4456		4421		4580	
Average	4244	4514		4266		4518	
Percent of Reference		106		101		106	
Compressive Strength, psi - 28 days							
Cylinder 1		6172		6322		6455	
Cylinder 2		6270		6437		6366	
Average	6060	6221		6380		6411	
Percent of Reference		103		105		106	
Resistance to Freezing & Thawing - 300 cycles							
Durability Factor	96.8 average	59.0		87.3		86.7	
Relative Durability Factor		61.0		90.2		89.6	
Weight Loss, percent	7.7 average	15.3		15.8		18.0	

(3) Before application of high range water reducer.

(4) After application of high range water reducer.

The results of tests to determine rate of slump loss are as follows:

Rate of Slump Loss

	Pozzolith 400N	WRDA 19	Eucon 37
	Slump, inches	Slump, inches	Slump, inches
Prior to addition of High Range Water Reducer	2 3/4	2	3 1/4
Immediately following addition of High Range Water Reducer	10	9 1/2	10+
Time following addition of High Range Water Reducer, Hrs:Min			
0:30	7 1/2	8	9 1/4
0:45	6	6 3/4	- (5)
1:00	3 1/2	5 3/4	
1:15	2 1/4	4	
1:30		2 3/4	
1:45		2	

(5) Insufficient concrete to continue tests.

SUMMARY

A. SPECIFICATION COMPLIANCE BATCHES

1) Average slumps were within the ranges required for VAOT Class B concrete and AASHTO M 194-82. Individual slumps not within those ranges did not appear to adversely affect other test results.

2) Air contents of the test concretes varied considerably and were not generally within 0.5 percent of the reference concrete as required. However, all of the test concrete batches had air contents which were higher than the reference batches.

3) The maximum water content, expressed as a percent of the reference batches, was in compliance with requirements for all three products examined.

4) The use of Pozzolith 400N and WRDA 19 produced concrete having earlier initial and final setting times when compared to the reference concrete. Setting times of concrete containing Eucon 37 were approximately equal to setting times of the reference concrete. All three products complied with requirements for initial and final time of setting.

5) Compressive strengths, expressed as a percent of reference, complied with requirements at all ages of test, for the three products examined.

6) When tested for resistance to freezing and thawing, concretes containing WRDA 19 and Eucon 37 performed slightly better than the reference concrete and results after 300 freeze-thaw cycles were in compliance with requirements. Concrete containing Pozzolith 400N failed to comply

with requirements after 300 freeze-thaw cycles. Batch No. 1 of the Pozzolith 400N concrete with an air content of 7.1% showed good performance while Batch No. 2 and Batch No. 3 with air contents of 4.9% and 4.7% respectively exhibited poor performance.

B. FLOWABLE CONCRETE BATCHES

1) Adding the high range water reducers after achieving mixes similar to the reference concrete produced concretes with slumps of 9 1/2 inches or greater. All concretes exhibited segregation at the measured slumps.

2) Each of the three high range water reducers appeared to have a different effect on the air content of the concrete mixes. The Pozzolith 400N reduced the air content from 4.4% to 2.3% when the flowable concrete was produced. The WRDA 19 increased the air content from 4.3% to 5.8% and the Eucon 37 reduced the air content slightly, from 4.2% to 3.9%.

3) When used in flowable concrete, the Eucon 37 produced concrete with an initial setting time 1 hour 23 minutes later than the reference concrete and a final setting time 43 minutes later than the reference concrete. The only other notable change using high range water reducers was a 29 minutes later initial set obtained with Pozzolith 400N.

4) The use of all three products resulted in an increase in compressive strength at all ages of test when compared to the reference concrete. As expected, the increases experienced with the flowable concretes were not as great as the increases noted with the specification compliance concretes.

5) Producing flowable concrete with all three admixtures resulted in decreased resistance to freezing and thawing. When compared to the specification compliance concrete, a reduction in the relative durability factor was experienced as well as an increase in the percent of weight loss.

6) Although data for rate of slump loss was incomplete for the concrete mixed with Eucon 37, slump loss was examined and recorded for concretes mixed with WRDA 19 and Pozzolith 400N. Reduction in slump was approximately 1 inch for each 9.4 minutes of elapsed time for the concrete mixed with Pozzolith 400N and 1 inch for each 13.2 minutes of elapsed time for the concrete mixed with WRDA 19. Alternately, the rate of slump loss with Pozzolith 400N was 0.11 inch per minute while that with WRDA 19 was 0.08 inch per minute or the equivalent of 1.8 inches per hour less slump loss with WRDA 19 than with Pozzolith 400N.

CONCLUSIONS AND RECOMMENDATIONS

1) WRDA 19 and Eucon 37 complied with the requirements of AASHTO M194-82, Type F, for 1, 3, 7 and 28 days compressive strengths, time of setting, water content and resistance to freezing and thawing. These products, WRDA 19 and Eucon 37, are recommended for trial use in either prestressed concrete members or other precast applications where their use can be closely monitored. Pozzolith 400N complied with requirements for compressive strength, time of setting, and water content, but failed to comply with requirements for resistance to freezing and thawing. Recommendation for trial use of Pozzolith 400N is being withheld due to the questionable durability of concrete produced using this material.

2) Slumps experienced in the flowable concrete part of this evaluation would generally be considered excessively high and unnecessary for normal construction purposes. However, control of the slump can be maintained by reducing the initial quantity of water added to the mix or by adjusting the addition rate of the high range water reducer. It is recommended

that a maximum slump of 6 inches be established when high range water reducing admixtures are used to avoid possible segregation of the concrete.

3) Due to the rate of slump loss experienced with these materials, caution should be excerised to insure that forms are ready prior to the start of work and other delays are avoided during concrete placing operations.

4) Use of high range water reducing admixtures should be under the direction of the Materials and Research Division and their use employed only with the approval of the Structural Concrete Engineer.

TA 182F Rev. 2M 3/82
Rev. 2M 4/83

Benda
CF

STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

REPORT ON SAMPLE OF AGGREGATE

Report 11-30, 1983

Laboratory No. G83 0742 Tested By Morissette

Name Fine Aggregate for concrete Item 501.25

Identification Marks Preliminary Sample

Submitted by Morissette Title PFP Address

Sampled 11-28, 19 83 Received 11-28, 19 83 Testing Completed 11-29, 19 83

Sample from Stockpile @ Anderson - Berlin

Quantity Represented

Source of Material Anderson - Highgate

Project Name & Number Laboratory Evaluation of Super Plasticizers, W.P. #83-C-39

Examined for 704.01-

TEST RESULTS

Total Sample Sieve Size	% Passing
4 1/2"	
4"	
3 1/2"	
3"	
2 1/2"	
2"	
1 3/4"	
1 1/2"	
1"	
3/4"	
5/8"	
1/2"	
3/8"	100
No. 4	99
No. 8	87
No. 10	
No. 16	68
No. 30	43
No. 50	18
No. 100	4
No. 200 dry	1.4

Sand Portion

Fineness Modulus % Coarser Than	
No. 100	96
No. 50	82
No. 30	57
No. 16	32
No. 8	13
No. 4	1

Fineness Modulus = 2.81

Color = -1

Comments:

This material meets requirements for the tests indicated for 704.01.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96

Fractured Faces, %

Thin & Elongated Pieces, %

Soundness, % Loss

ACCEPTED
S. J. Gage, P.E., Chief Engineer

By: R. F. Nicholson 10/07
R. F. Nicholson, P.E., Materials & Research Engineer

TA 182F Rev. 2M 3/82
Rev. 2M 4/83

CF
Benda

STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

REPORT ON SAMPLE OF AGGREGATE

Report 12-6, 19 83

Laboratory No. G83 0758 Tested By Reed

Name Coarse Aggregate for Concrete Item 501

Identification Marks Preliminary Sample 3/4" Crushed Stone

Submitted by Reed Title PFP Address

Sampled 11-30 19 83 Received 11-30, 19 83 Testing Completed 11-30, 19 83

Sample from Stockpile @ Anderson - Berlin

Quantity Represented

Source of Material Cooley - Websterville

Project Name & Number Possible Future Use - Work Plan 83-C-39

Examined for 704.02

TEST RESULTS

Total Sample Sieve Size	% Passing
4 1/2"	
4"	
3 1/2"	
3"	
2 1/2"	
2"	
1 3/4"	
1 1/2"	
1"	100
3/4"	99
5/8"	
1/2"	
3/8"	33
No. 4	5
No. 8	3
No. 10	
No. 16	
No. 30	
No. 50	
No. 100	
No. 200	

Sand Portion

Fineness Modulus
% Coarser Than

No. 100	
No. 50	
No. 30	
No. 16	
No. 8	
No. 4	

Fineness Modulus =

Color =

Comments:

This material meets requirements for the tests indicated for item 704.02.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96 34.9
B Grading
Fractured Faces, % 100
Thin & Elongated Pieces, % 1.3
Soundness, % Loss

ACCEPTED
S. J. Gage, P.E., Chief Engineer

By: R. F. Nicholson 12/27
R. F. Nicholson, P.E., Materials & Research Engineer

TA 565 Rev. 4/79

Prepared By: M. Morissette mlsm
Date: 10/25/83
Sheet 1 of 2

Appendix B

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

RESEARCH INVESTIGATION

Work Plan No. 83-C-39

Subject Laboratory Evaluation of Superplasticizers

Investigation Requested By Structural Concrete Subdivision Date 10/25/83

Date Information Required March 1984

Purpose of Investigation To conduct a laboratory evaluation of three high range water reducing admixtures: (1) WRDA 19; W. R. Grace & Co., Cambridge, Massachusetts; (2) EUCON-37; Euclid Chemical Co., Cleveland, Ohio (3) Pozzolith 400-N; Master Builders, Cleveland, Ohio

Proposed Tests or Evaluation Procedure (SEE ATTACHED SHEET)

Proposal Discussed With CCB; WLM; NRD; DCB Projected Manpower Requirements 40 man days

Investigation To Be Conducted By Structural Concrete Subdivision

Proposed Starting Date November 1, 1983 Estimated Completion Date March 31, 1984 (Including Report)

Approval/Disapproval by Materials & Research Engineer R F Nielson 11-9-83

Comments by Materials & Research Engineer

Materials & Research Division
Agency of Transportation
Date Typed: October 27, 1983

10-31-83

V.A.O.T.
Materials & Research Div.

PROPOSED TESTS OR EVALUATION PROCEDURE:

To perform fresh concrete tests on a minimum of four 1½ c.f. mixes of Class B concrete for each product, in addition to three reference mixes. The fresh concrete tests will be conducted both before and after the addition of the high range water reducer. Tests will include, but not be limited to,:

(a) Slump (AASHTO T 119),

(b) Air content (AASHTO T 152 and/or VT. AOT-MD28),

(c) Unit weight (AASHTO T 121)

Three of the mixes will be used to determine compliance with AASHTO M 194, Type F.

(a) Compressive strength 3, 7, 28 days (AASHTO T 22)

(b) Resistance to freezing & thawing (AASHTO T 161)

(c) Time of set (AASHTO T 197)

(d) Water content

The fourth mix will be used to determine the time required for the concrete mixture to revert to its original slump after the addition of the high range water reducer.