EVALUATION OF FINE AGGREGATE FROM VERMONT SAND & STONE, INC., WORCESTER, VT. FOR USE IN STRUCTURAL CONCRETE

REPORT 85-3

FEBRUARY 1985

REPORTING ON WORK PLAN 84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

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Date: 02-21-85

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TABLE OF CONTENTS

ABSTRACT

As aggregate sources are developed, tests must be conducted to assure that the materials meet specifications and perform satisfactorily when used in concrete mixtures.

This report documents results of tests performed on a proposed new source of fine aggregate for structural concrete. The material tested was a fine aggregate produced at the Vermont Sand and Stone, Inc. facilities in Worcester, Vermont.

Results indicate that the material performs satisfactorily.

INTRODUCTION

As new aggregate sources are developed for use in structural concrete, they must be evaluated not only to determine their compliance with materials specifications, but to examine their performance in concrete mixtures. A procedure has been developed whereby proposed new aggregate sources are evaluated by comparing results of tests performed on concrete using the new aggregate, with results obtained from concrete containing a reference aggregate. See Appendix A for evaluation procedures.

A request was received from Robert C. Dowdell, Jr., President, Vermont Sand and Stone, Inc., to evaluate fine aggregate being produced at his facility in Worcester, Vermont. Mr. Dowdell indicated the fine aggregate will be sold to S. T. Griswold for use in structural concrete.

Samples of the fine aggregate were obtained by Materials and Research Division representatives and evaluated for compliance with the requirements of Section 704.01 of the Standard Specifications. Materials were obtained and the performance-in-concrete phase of the evaluation was conducted in the Central Laboratory of the Materials and Research Division.

PROCEDURES

PHASE I - SECTION 704.01 and SECTION 704.02 TESTS

The proposed new fine aggregate was sampled, by representatives of the Materials and Research Division, from a stockpile at the Vermont Sand and Stone, Inc. facility in Worcester. The material was examined for gradation, organic impurities, compressive strength of mortar and soundness. It was found to comply with Section 704.01 requirements. The reference fine aggregate and the coarse aggregate were sampled from stockpiles at the S. T. Griswold Ready Mixed Concrete Plant in Montpelier Jct., Vt. The reference fine aggregate was examined for gradation and organic impurities. The coarse aggregate was examined for gradation, percent of wear, thin and elongated pieces and fractured faces. The reference fine aggregate and coarse aggregate were found to comply respectively with Section 704.01 and Section 704.02 requirements. Fine aggregate test results are shown in Table 1. Coarse aggregate test results are shown in Table 2. Aggregate test results are also shown on Laboratory Report Nos. G84 0785, G84 0786, A84 1324, C84 1256, G84 0813, G84 0841 and G84 0842 in Appendix B.

TABLE 1
FINE AGGREGATE TEST DATA

	Proposed New Aggregate Vermont Sand & Stone, Inc., Worcester, VT				Reference Aggregate Nadeau, Johnson, VT	V.A.O.T. Specification Requirements
	Dates Sampled				Date Sampled	
	9-27-84	9-27-84	9-27-84	10-16-84	10-16-84	
Sieve Size	% Passing	% Passing	% Passing	% Passing	% Passing	% Passing
3/8"	100	100	100	100	100	100
#4	99	100	98	99	98	95-100
#8	83	84	83	81	81	-
#16	65	66	64	62	62	60-80
#30	47	48	46	44	39	25-60
#50	24	24	20	22	19	10-30
#100	5	5	3	5	8	2-10
#200	1	1	1	-	-	-
Fineness Modulus	2.77	2.73	2.86	2.87	2.93	2.60-3.10
Organic Impurities, Color	1	1	1	1.5	1	2 maximum
Soundness, percent loss	-	-	3.11	-	-	8 maximum
Compressive Strength of Mortar, percent of Ottawa Sand						
3 days	-	-	137	-	-	100 minimum
7 days	-	-	129	-	-	100 minimum

TABLE 2

COARSE AGGREGATE TEST DATA

	3/4 inch Crushed Igneous Stone Cooley, Websterville, VT Date Sampled 10-16-84	V.A.O.T. Specification Requirements
Sieve Size	% Passing	% Passing
1"	100	100
3/4"	96	90-100
3/8"	31	20-55
#4	5	0-10
#8	3	0- 5
L. A. Abrasion, percent loss "B" Grading	33	50 maximum
Thin and Elongated Pieces, percent	1.1	10 maximum
Fractured Faces, percent	100	-

PHASE II - PERFORMANCE-IN-CONCRETE TESTS

The performance-in-concrete tests were conducted on concrete prepared in the Central Laboratory. Mixtures were designed by Structural Concrete Subdivision personnel for Class A and Class B concrete, using the following materials:

Coarse Aggregate

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

Fine Aggregate

A. Proposed New Aggregate

Vermont Sand and Stone, Inc., Worcester, Vermont

B. Reference Aggregate

Nadeau, Johnson, Vermont

Cement

Type II
Glens Falls Portland Cement Co., Glens Falls, New York

Air Entraining Admixture

MBAE 10
Master Builders, Cleveland, Ohio

Water Reducing Admixture

WRDA with Hycol
W. R. Grace & Co., Cambridge, MA

Aggregate properties used for preparing mix designs are shown in Table 3 and Table 4.

TABLE 3

COARSE AGGREGATE PROPERTIES

	Bulk Specific Gravity	Absorp., Percent	Dry Rodded Unit Weight, lbs/ft^3
Reference Aggregate Cooley, Websterville, Vermont	2.62	0.7	95.71

TABLE 4

FINE AGGREGATE PROPERTIES

	Bulk Specific Gravity	Absorp., Percent	Fineness Modulus
New Aggregate Vermont Sand & Stone, Inc.,Worcester, VT	2.70	1.2	2.75
Reference Aggregate Nadeau, Johnson, Vermont	2.63	1.3	3.00

The concrete used in this evaluation was mixed in a Sears rotary drum mixer with batch size being 1.8 cubic feet. Aggregates were dried prior to the start of mixing operations.

Two batches each of the Class A and Class B concrete containing the new fine aggregate were prepared as well as two batches each of the Class A and Class B concrete containing the reference fine aggregate.

The mix proportions used are shown in Table 5 and Table 6.

TABLE 5

NEW AGGREGATE MIX DESIGN
BATCH QUANTITIES PER C.Y.

	Class A		Class B	
	Batch 1	Batch 2	Batch 3	Batch 4
*Coarse Aggregate, lbs.	1639	1639	1639	1639
*Vt. Sand & Stone Fine Aggregate, lbs.	1264	1264	1412	1412
Cement, lbs.	660	660	611	611
Air Entraining Admixture, oz.	6	6	3	3
Water Reducing Admixture, oz.	19.8	19.8	18.3	18.3
Net Water, gal.	31.5	31.3	32.5	32.0

*Weights converted to saturated surface-dry condition

TABLE 6

REFERENCE AGGREGATE MIX DESIGN
BATCH QUANTITIES PER C.Y.

	Class A		Class B	
	Batch 5	Batch 6	Batch 7	Batch 8
*Coarse Aggregate, lbs.	1561	1561	1561	1561
*Nadeau Fine Aggregate, lbs.	1312	1312	1456	1456
Cement, lbs.	660	660	611	611
Air Entraining Admixture, oz.	5	6	4	3
Water Reducing Admixture, oz.	19.8	19.8	18.3	18.3
Net Water, gal.	31.4	31.3	32.7	31.8

*Weights converted to saturated surface-dry condition

Tests were performed on the fresh concrete to determine Slump (AASHTO T 119-82), Air Content (AASHTO T 152-84I) and Unit Weight (AASHTO T 121-82). Six 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 (AASHTO T 22-84I), two each at ages 7, 14 and 31 days. The freeze-thaw specimens were moist cured for 14 days, after which they were subjected to freezing and thawing (AASHTO T 161-83I) in a 3% NaCl solution.

RESULTS

Results of tests on the fresh concrete and compressive strength test results are shown in Table 7 and Table 8.

TABLE 7

PERFORMANCE TEST RESULTS
NEW AGGREGATE

	Class A		Class B	
	Batch 1	Batch 2	Batch 3	Batch 4
Slump, inches	3	2 1/2	3	2 3/4
Air Content, percent	6.0	5.5	5.0	4.8
Unit Weight, lbs/ft^3	145.30	145.98	146.74	147.18
Compressive Strength, psi				
7 days	3847	3814	3678	3714
14 days	4077	4090	4108	4098
31 days	5036	5085	4885	5173
(Design Compressive Strength, psi)	(4000)		(3500)	

TABLE 8

PERFORMANCE TEST RESULTS
REFERENCE AGGREGATE

	Class A		Class B	
	Batch 5	Batch 6	Batch 7	Batch 8
Slump, inches	2 3/4	3 1/2	4 1/2	3
Air Content, percent	4.7	6.7	6.8	4.9
Unit Weight, lbs/ft^3	146.60	143.62	142.56	146.02
Compressive Strength, psi				
7 days	4077	3864	3475	3802
14 days	4443	4351	3687	4010
31 days	5425	5217	4687	5173
(Design Compressive Strength, psi)	(4000)		(3500)	

The results of compressive strength tests are also shown on Laboratory Reports Nos. C84-1126 through C84-1133 in Appendix C. Strength age plots illustrating average compressive strengths are shown in Figure I and Figure II.

The results of dynamic testing of freeze-thaw specimens are shown in Table 9. The percent weight loss resulting from freezing and thawing of specimens is shown in Table 10. Freeze-thaw test results are also summarized in Figure III and Figure IV. These figures show a comparison of results obtained with the reference aggregate and the new aggregate after 300 cycles of freezing and thawing.

TABLE 9

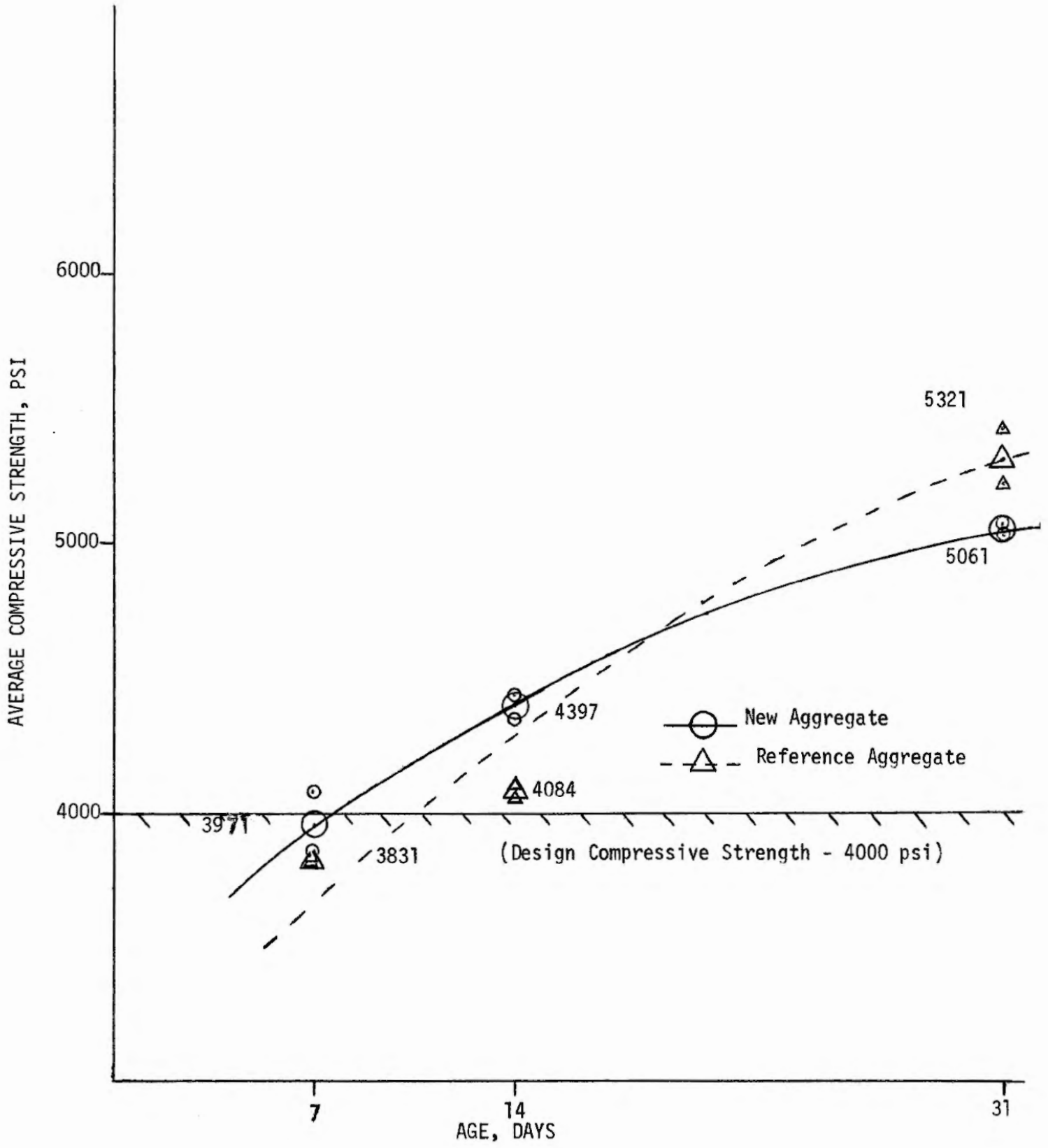
FREEZE-THAW TEST RESULTS - DURABILITY FACTOR

		New Aggregate				Reference Aggregate			
		Class A		Class B		Class A		Class B	
		Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8
		Durability Factor							
Number of Cycles	50	95.7	97.1	96.4	94.3	98.6	98.6	97.8	97.9
	100	99.3	97.1	95.7	95.0	99.3	99.3	97.8	97.1
	150	99.3	96.4	95.7	95.0	99.3	100.7	98.6	97.9
	200	99.3	96.4	95.7	95.7	100.0	102.2	98.6	98.6
	250	99.3	96.4	92.9	94.3	100.0	102.2	99.3	95.0
	300	99.3	97.1	94.3	94.3	99.3	102.2	99.3	95.0

TABLE 10

FREEZE-THAW TEST RESULTS - DURABILITY FACTOR

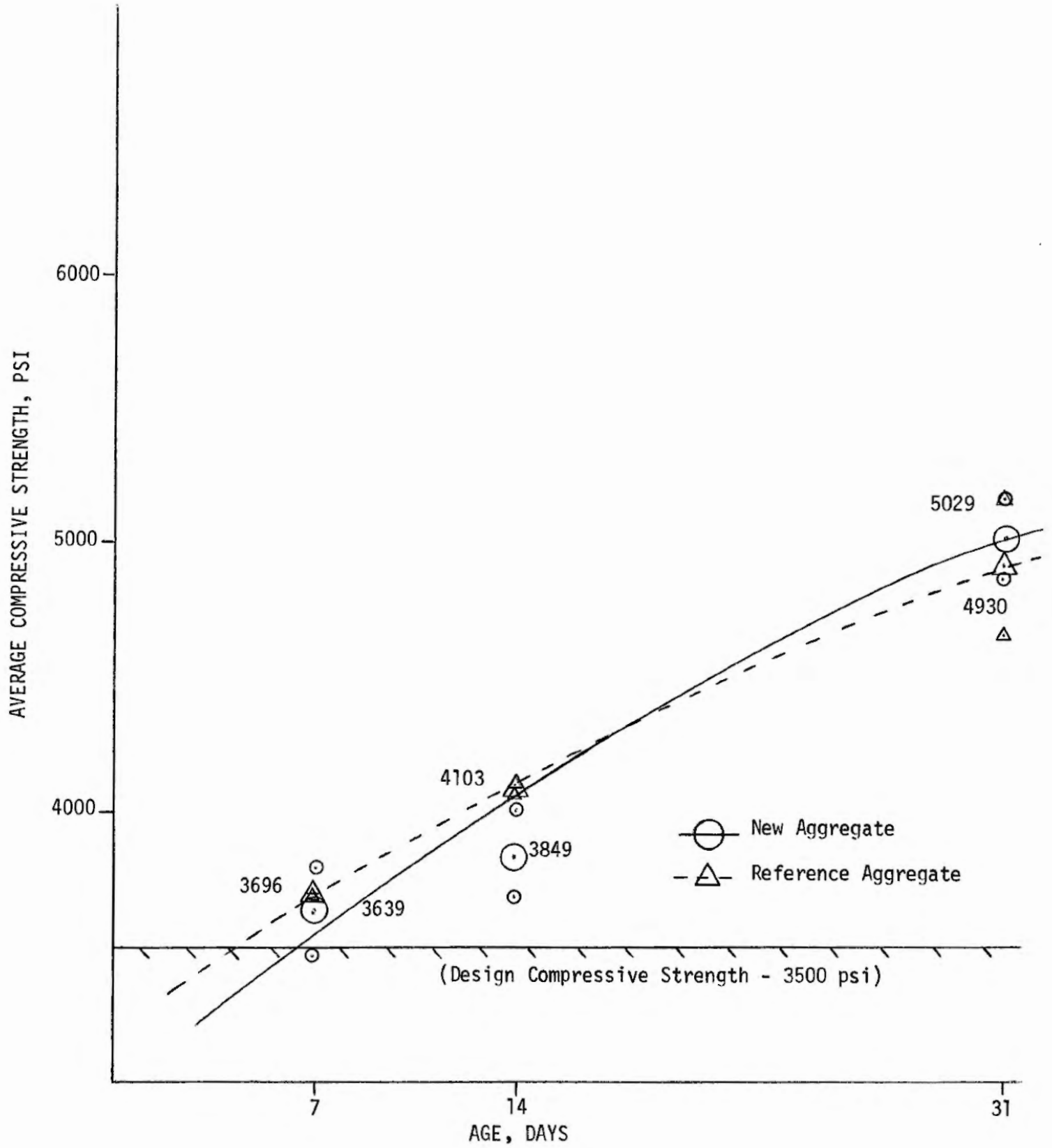
		New Aggregate				Reference Aggregate			
		Class A		Class B		Class A		Class B	
		Batch 1	Batch 2	Batch 3	Batch 4	Batch 5	Batch 6	Batch 7	Batch 8
		Percent Weight Loss							
Number of Cycles	50	0.9	1.0	1.9	2.1	0.6	0.2	1.1	1.1
	100	1.4	1.9	4.2	4.1	0.7	0.2	1.5	1.7
	150	2.2	2.7	5.4	5.5	1.0	0.2	1.3	2.2
	200	2.3	3.1	6.5	6.6	1.1	0.1	1.3	2.5
	250	2.7	3.7	7.4	8.1	1.3	0.2	1.3	3.5
	300	3.4	4.4	9.3	9.6	1.6	0.2	1.5	4.5



AVERAGE COMPRESSIVE STRENGTH VS AGE

CLASS A

FIGURE I



AVERAGE COMPRESSIVE STRENGTH VS AGE

CLASS B

FIGURE II

Batch Number	No. Cycles	Weight lbs.	Percent Weight Loss	Fundamental Transverse Frequency "N"	"N"^{2}	Individual Durability Factor DF	Average DF	Relative Durability Factor RDF
Reference Aggregate								
5	0	12.28	1.6	1380	1904400	99.3		
5	300	12.08		1375	1890625		100.8	
6	0	12.12	0.2	1375	1890625	102.2		
6	300	12.09		1390	1932100			
New Aggregate								97.4
1	0	12.42	3.4	1365	1863225	99.3		
1	300	12.00		1360	1849600		98.2	
2	0	12.43	4.4	1370	1876900	97.1		
2	300	11.88		1350	1822500			

SUMMARY OF FREEZE-THAW TEST RESULTS
CLASS A

FIGURE III

Batch Number	No. Cycles	Weight lbs.	Percent Weight Loss	Fundamental Transverse Frequency "N"	"N"^{2}	Individual Durability Factor DF	Average DF	Relative Durability Factor RDF
Reference Aggregate								
7	0	12.00	1.5	1375	1890625	99.3		
7	300	11.82		1370	1876900		97.2	
8	0	12.38	4.5	1390	1932100	95.0		
8	300	11.82		1355	1836025			
New Aggregate								97.0
3	0	12.52	9.3	1375	1890625	94.3		
3	300	11.35		1335	1782225		94.3	
4	0	12.54	9.6	1380	1904400	94.3		
4	300	11.33		1340	1795600			

SUMMARY OF FREEZE-THAW TEST RESULTS

CLASS B

FIGURE IV

SUMMARY AND CONCLUSIONS

1. The fine aggregate from the Vermont Sand and Stone, Inc. facility in Worcester, Vermont complied with all requirements of Section 704.01 when tested in conjunction with this evaluation.

2. The compressive strengths of concretes containing the Worcester fine aggregate were approximately equal to the strengths of concretes containing the reference aggregate. The Class A concrete containing the reference aggregate had an average compressive strength at 31 days which was 260 psi higher than the Class A concrete containing the Worcester aggregate. However, the average compressive strength of Class B concrete containing the Worcester aggregate was approximately 100 psi higher at 31 days than the Class B concrete with the reference aggregate.

3. Concrete containing the new aggregate did not perform as well in freeze-thaw testing as the concrete containing the reference aggregate. Results of sonic testing showed slightly reduced performance of concrete containing the new aggregate when compared to concrete containing the reference aggregate, with relative durability factors of 97.4 for Class A concrete and 97.0 for Class B concrete. Average weight loss results for the Class A and Class B concrete mixed with the reference aggregate were respectively 3 percent and 6.5 percent less than the weight loss results of Class A and Class B concrete containing the new aggregate. Although concrete containing the Worcester fine aggregate did not perform as well in freeze-thaw testing as the concrete containing the reference aggregate, its performance is considered acceptable.

RECOMMENDATIONS

1. It is recommended that the present Vermont Sand and Stone, Inc. facility in Worcester, Vermont, be approved as a source of fine aggregate for use in structural concrete.

2. During the initial uses of concrete containing this aggregate on Agency projects, Materials and Research Division representatives shall conduct tests necessary to determine the performance of this aggregate in concrete under field conditions.

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

Appendix A

VERMONT PROCEDURE FOR EVALUATING A NEW SOURCE OF STRUCTURAL CONCRETE AGGREGATE

VT-AOT-MRD 9-82

1. SCOPE

A procedure for evaluating new structural concrete aggregate sources by testing proposed new aggregates for compliance with Section 700 requirements and by comparing results of tests performed on concrete using the new aggregate with results obtained from concrete containing a reference aggregate.

2. PROCEDURE

General

The evaluation of a new structural concrete aggregate source (i.e., one on which the Materials and Research Division has no service-in-concrete data) shall be divided into two sections called:

Phase I Section 700 and related tests, and Phase II Performance-in-Concrete tests.

All requests for evaluation of new structural concrete aggregate sources shall be made, in writing, to the Materials and Research Engineer. Requests shall describe the type of material proposed for use as well as the location and quantity of available stockpiles.

Materials and Research Division personnel shall perform all work necessary for both the Phase I and Phase II sections of this evaluation process. The work will be performed in an expeditious manner consistent with availability of manpower. Evaluations may require 60 calendar days or more from the date the aggregate is available for testing (controlled by the availability of personnel to perform testing). Delays beyond the control of the Materials and Research Division shall be documented and notification given of the consequent extension of time required to complete the evaluation.

Test results shall be the basis for determining acceptance, further testing, or rejection of the proposed new material. Failure of the material to comply with all applicable requirements, during any phase of testing, may necessitate rescheduling or termination of the evaluation.

The cost of materials necessary to complete the evaluation will be borne by the requesting party.

A report shall be prepared documenting the Materials and Research Division's involvement in the evaluation. A copy of the report shall be forwarded with a cover letter, informing the requesting party of the acceptability or nonacceptability of the aggregate.

Phase I

1. Following receipt of the written request, the Structural Concrete Engineer will schedule a field petrographic examination of the proposed new aggregate source by the Vermont A.O.T. Chief Geologist.

2. The Structural Concrete Engineer or his representative will visit the site and determine:

   (a) Does a stockpile of at least 50 cubic yards of processed material exist?

   (b) Can samples be obtained in the standard manner from the stockpiles?

3. If 2(a) and 2(b) are yes, the Structural Concrete Engineer shall make necessary arrangements for obtaining samples from the designated stockpile.

4. The material shall be tested at the Central Laboratory using the Structural Concrete Subdivision Annual Aggregate Testing Program procedure.

5. Report the results (as an Evaluation Sample) on the Standard Materials and Research Division forms.

Phase II

1. The performance-in-concrete tests shall be performed on concrete prepared at the Central Laboratory. The proposed new aggregate will be evaluated by comparing results of tests performed on concrete using the new aggregate with results obtained from concrete containing a reference aggregate. Cement, admixtures, and aggregates, other than the proposed new aggregate, will be selected by the Structural Concrete Engineer. Normally, these materials will be the same as the materials currently in use at the Ready-mix plant where the proposed new aggregate will be used.

2. Mix proportions for each class of concrete required shall be designed or approved by the Materials and Research Division and shall conform to Table 501.03A of the Vermont Standard Specifications for Highway and Bridge Construction, current edition.

3. Test cylinders shall be fabricated and cured in accordance with AASHTO T23. They shall be tested for compressive strength at ages 7, 14, and 28 days in accordance with AASHTO T22.

4. Tests of Slump, Air Content, and Unit Weight shall be in accordance with AASHTO T119, AASHTO T152, and AASHTO T121, respectively.

A 182F Rev. 2M 3/82
Rev. 2M 4/83
2M 6/84

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MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

REPORT ON SAMPLE OF AGGREGATE

Report 10-24, 19 84

Laboratory No. A84 1324 Tested By Lavin

Name Fine Aggregate for Concrete 501

Identification Marks Evaluation sample

Submitted by Meyer Title PFP Address

Sampled 9-27, 19 84 Received 9-27, 1984 Testing Completed 10-24, 19 84

Sample from Stockpile @ Vermont Sand & Stone, Inc. - Worcester

Quantity Represented

Source of Material Vermont Sand & Stone, Inc. - Worcester

Project Name & Number Workplan 84-C-15

Examined for Item 704.01

TEST RESULTS

Total Sample Sieve Size	% Passing	Sand Portion
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	98	
No. 8	83	
No. 10		
No. 16	64	
No. 30	46	
No. 50	20	
No. 100	3	
No. 200	1	

Fineness Modulus
% Coarser Than

No. 100	97
No. 50	80
No. 30	54
No. 16	36
No. 8	17
No. 4	2

Fineness Modulus = 2.86

Color = 1

Comments:
This material was tested for gradation, color and soundness. The results are as indicated.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96
Grading
Fractured Faces, %
Thin & Elongated Pieces, %
Soundness, % Loss 3.11

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

By: R. F. Nicholson 10/24/84
R. F. Nicholson, P.E., Materials & Research Engineer

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Appendix B

TA 183 Rev. 1M 7/80

Benda

STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

REPORT ON MISCELLANEOUS SAMPLE

Report 12-11, 19 84

Laboratory No. C84 1256 Tested by Reed

Name Fine Aggregate for Concrete

Identification Marks Evaluation Sample

Submitted by Meyer Title PEP Address

Sampled 9-27, 19 84 Received 9-27, 19 84

Sample from Stockpile @ Vermont Sand & Stone - Worcester

Quantity Represented

Source of Material Vermont Sand & Stone, Worcester

Location used or to be used Work Plan 84-C-15

Examined for Item 704.01

TEST RESULTS

	Ottwa Sand	Mortar Sand
3 day		
	Cube # 1 - 2900	Cube # 1 - 3838
	# 2 - 2775	# 2 - 3913
	# 3 - 2775	# 3 - -
	Avg - 2820	Avg - 3875
7 day		
	Cube # 1 - 3675	Cube # 1 - 4913
	# 2 - 3838	# 2 - 4363
	# 3 - 3750	# 3 - 5213
	Avg - 3750	Avg - 4830

This material was examined for mortar strength. The results are as indicated.

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

By: R. F. Nicholson 10/17

R. F. Nicholson, P.E., Materials & Research Engineer

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TA 182F Rev. 2M 3/82
Rev. 2M 4/83
2M 6/84

Appendix B

STATE OF VERMONT
AGENCY OF TRANSPORTATION

MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

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REPORT ON SAMPLE OF AGGREGATE

Report 11-29, 19 84

Laboratory No. G84 0785 Tested By Gates

Name Fine Aggregate for Concrete Item 501

Identification Marks Evaluation Sample (Front of pile)

Submitted by Meyer Title PFP Address

Sampled 9-27, 19 84 Received 9-27, 19 84 Testing Completed 9-28, 19 84

Sample from Stockpile @ Vermont Sand & Stone - Worcester

Quantity Represented

Source of Material Vt. S & S. Worcester

Project Name & Number Possible Future Use

Examined for 704.01

TEST RESULTS

Total Sample Sieve Size	% Passing	Sand Portion
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	83	
No. 10		
No. 16	65	
No. 30	47	
No. 50	24	
No. 100	5	
No. 200 dry	1	

Fineness Modulus
% Coarser Than

No. 100	95
No. 50	76
No. 30	53
No. 16	35
No. 8	17
No. 4	1

Fineness Modulus = 2.77

Color = <1

Comments:

This material was examined for gradation and organic impurities and the results are as indicated.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96
Grading
Fractured Faces, %

Thin & Elongated Pieces, %

Soundness, % Loss

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

By: R. F. Nicholson 10/97
R. F. Nicholson, P.E., Materials & Research Engineer

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Appendix B

TA 182F Rev. 2M 3/82
Rev. 2M 4/83
2M 6/84

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MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

REPORT ON SAMPLE OF AGGREGATE

Report 11-29, 19 84

Laboratory No. G84 0786 Tested By Gates

Name Fine Aggregate for Concrete Item 501

Identification Marks Evaluation Sample (Back of pile)

Submitted by Meyer Title PFP Address

Sampled 9-27, 19 84 Received 9-27, 19 84 Testing Completed 9-28, 19 84

Sample from Stockpile @ Vermont Sand & Stone - Worcester

Quantity Represented

Source of Material Vt. S & S. Worcester

Project Name & Number Possible Future Use

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"	
No. 4	100
No. 8	84
No. 10	
No. 16	66
No. 30	48
No. 50	24
No. 100	5
No. 200 dry	1

Sand Portion

Fineness Modulus % Coarser Than

No. 100	95
No. 50	76
No. 30	52
No. 16	34
No. 8	16
No. 4	0

Fineness Modulus = 2.73

Color = <1

Comments:

This material was examined for gradation and organic impurities and the results are as indicated.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96
Grading
Fractured Faces, %
Thin & Elongated Pieces, %
Soundness, % Loss

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

By: R. F. Nicholson 1/87

R. F. Nicholson, P.E., Materials & Research Engineer

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Appendix B

TA 182F Rev. 2M 3/82
Rev. 2M 4/83
2M 6/84

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MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

REPORT ON SAMPLE OF AGGREGATE

Report 12-4, 19 84

Laboratory No. G84 0813 Tested By Gates

Name Fine Aggregate for Concrete Item 501

Identification Marks Preliminary Sample

Submitted by Gates Title PFP Address

Sampled 10-16, 19 84 Received 10-16, 19 84 Testing Completed 10-18, 19 84

Sample from Stockpile @ Vt. Sand & Stone - Worcester

Quantity Represented

Source of Material Vt. Sand & Stone

Project Name & Number Work Plan 84-C-15

Examined for 704.01

TEST RESULTS

Total Sample Sieve Size	% Passing	Sand Portion
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	81	
No. 10		
No. 16	62	
No. 30	44	
No. 50	22	
No. 100	5	
No. 200		

Fineness Modulus
% Coarser Than

No. 100	95
No. 50	78
No. 30	56
No. 16	38
No. 8	19
No. 4	1

Fineness Modulus = 2.87

Color = 1.5

Comments:

This material was examined for gradation, fineness modulus, and organic impurities. The results are as indicated.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96
Grading
Fractured Faces, %

Thin & Elongated Pieces, %

Soundness, % Loss

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

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

mlm

TA 182F Rev. 2M 3/82
Rev. 2M 4/83
2M 6/84

STATE OF VERMONT
AGENCY OF TRANSPORTATION

Appendix B

MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

REPORT ON SAMPLE OF AGGREGATE

Report 12-4, 19 84

Laboratory No. G84 0841 Tested By Gates

Name Fine Aggregate for Concrete Item 501

Identification Marks Preliminary Sample

Submitted by Gates Title PFP Address

Sampled 10-16, 19 84 Received 10-16, 19 84 Testing Completed 10-18, 19 84

Sample from Stockpile @ Griswold -Montpelier Jct.

Quantity Represented

Source of Material Nadeau -Johnson

Project Name & Number Work Plan No. 84-C-15

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	98
No. 8	81
No. 10	
No. 16	62
No. 30	39
No. 50	19
No. 100	8
No. 200	

Sand Portion

Fineness Modulus % Coarser Than

No. 100	92
No. 50	81
No. 30	61
No. 16	38
No. 8	19
No. 4	2

Fineness Modulus = 2.93

Color = <1

Comments:

This material meets requirements for the tests indicated for item 704.01.

Percent of Wear

AASHTO T3
AASHTO T4
AASHTO T96
Grading
Fractured Faces, %
Thin & Elongated Pieces, %
Soundness, % Loss

ACCEPTED
S. J. Gage, P.E., Chief Engineer
By: R. F. Nicholson 10/87
R. F. Nicholson, P.E., Materials & Research Engineer

mlm

Appendix B

TA 182F Rev. 2M 3/82
Rev. 2M 4/83
2M 6/84

STATE OF VERMONT
AGENCY OF TRANSPORTATION

Benda

MATERIALS & RESEARCH DIVISION
Montpelier, Vermont 05602

REPORT ON SAMPLE OF AGGREGATE

Report 12-4, 1984

Laboratory No. G84 0842 Tested By Gates

Name Coarse Aggregate forConcrete Item 501

Identification Marks Preliminary Sample 3/4" Crushed Igneous Stone

Submitted by Gates Title PFP Address

Sampled 10-16, 19 84 Received 10-16, 19 84 Testing Completed 10-18, 19 84

Sample from Stockpile @ Griswold - Montpelier Jct.

Quantity Represented

Source of Material Cooley - Websterville

Project Name & Number Work Plan No. 84-C-15

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"	96
5/8"	
1/2"	
3/8"	31
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 33
B Grading
Fractured Faces, % 100

Thin & Elongated Pieces, % 1.1

Soundness, % Loss

ACCEPTED
S. J. Gage, P.E., Chief Engineer
By: R. F. Nicholson 10/17
R. F. Nicholson, P.E., Materials & Research Engineer

mlm

Project Name
Work Plan
Project Number
84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1126 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PFP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft.^{3}

Coarse Aggregate Cooley - Websterville Fine Aggregate Vermont Sand & Stone, Worcester

Cement Brand Glens Falls Type II Lbs. 660

Air Entraining Admixture MBAE 10 Dosage 6 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 2877

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Test Mix Batch #1

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

Unit Weight Fresh Concrete 145.40 Air: Pressure 6.0 Chace

Total Water, Gal/Cy Used 31.5 Slump 3 Temperature, Concrete 73 Ambient

Specimen No.	Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
DA-1 1	147	10-26	11-2	7	7	S	3873	3820	3847		
2	147										
3	146	10-26	11-9	14	14	S	3979	4174	4077		
4	146										
5	147	10-26	11-26	28	31	S	5084	4987	5036		
6	147										

*S = Standard Cured; F = Field Cured

Types of Breaks:

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

By: R. F. Nicholson 10/97
R. F. Nicholson, P.E., Materials & Research Engineer

mlm
Comments:
TA 183H Rev.
2M 4/81
2M 8/83

Appendix C

Project Name: Work Plan
Project Number: 84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

CORRECTED COPY
12-4-84

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1127 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PFP Address

Source of Material Mat. & Res. Lab Quantity Represented 1.8 ft^3

Coarse Aggregate Cooley - Websterville Fine Aggregate Vt. Sand & Stone - Worcester

Cement Brand Glens Falls Type II Lbs. 660

Air Entraining Admixture MBAE 10 Dosage 6 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 2877

Field Tested by Structural Conc. Div. Lab. Tested by Stevens

Sampled from Sears mixer @ lab Date Sampled: 10-26-84

Location Used or to be Used test mix batch #2

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

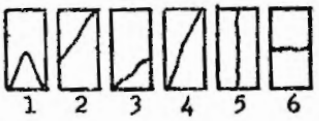
Unit Weight Fresh Concrete 145.98 Air: Pressure 5.5 Chace

Total Water, Gal/Cy Used 31.3 Slump 2½ Temperature, Concrete 72 Ambient

Specimen No.		Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
DA-2	1	147	10-26	11-2	7	7	S	3667	3961	3814		
	2	147										
	3	147	10-26	11-9	14	14	S	3988	4191	4090		
	4	147										
	5	147	10-26	11-26	28	31	S	5226	4943	5085		
	6	147										

*S = Standard Cured; F = Field Cured

Types of Breaks:



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

By: R. F. Nicholson 12/7

R. F. Nicholson, P.E., Materials & Research Engineer

mlm

Comments:
TA 183H Rev.
2M 4/81
2M 8/83

Project Name
Work Plan
Project Number
84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1128 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PEP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft.^{3}

Coarse Aggregate Cooley - Websterville Fine Aggregate Vt. Sand & Stone, Worcester

Cement Brand Glens Falls Type II Lbs. 611

Air Entraining Admixture MBAE 10 Dosage 3 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 3023

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Test Mix Batch #3

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

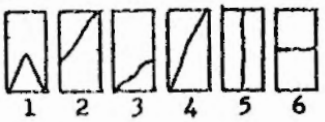
Unit Weight Fresh Concrete 146.74 Air: Pressure 5.0 Chace

Total Water, Gal/Cy Used 32.5 Slump 3 Temperature, Concrete 72 Ambient

Specimen No.		Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
DB-1	1	148	10-26	11-2	7	7	S	3625	3731	3678		
	2	149										
	3	148	10-26	11-9	14	14	S	4041	4174	4108		
	4	148										
	5	148	10-26	11-26	28	31	S	4748	5022	4885		
	6	148										

*S = Standard Cured; F = Field Cured

Types of Breaks:



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

By: R. F. Nicholson 11/29/84
R. F. Nicholson, P.E., Materials & Research Engineer

mlm
Comments:
TA 193H Rev.
2M 4/81
2M 8/83

Appendix C

Project Name Work Plan

Project Number 84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1129 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PFP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft.^{3}

Coarse Aggregate Cooley - Websterville Fine Aggregate Vt. Sand & Stone, Worcester

Cement Brand Glens Falls Type II Lbs. 611

Air Entraining Admixture MBAE 10 Dosage 3 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 3023

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Test Mix Batch #4

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

Unit Weight Fresh Concrete 147.18 Air: Pressure 4.8 Chace

Total Water, Gal/Cy Used 32.0 Slump 2 3/4 Temperature, Concrete 71 Ambient

Specimen No.	Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
DB-2 1	148	10-26	11-2	7	7	S	3785	3643	3714		
2	148										
3	149	10-26	11-9	14	17	S	4359	3837	4098		
4	149										
5	149	10-26	11-26	28	31	S	5270	5075	5173		
6	149										

*S = Standard Cured; F = Field Cured

Types of Breaks:

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

By: R. K. Nicholson 1987
R. F. Nicholson, P.E., Materials & Research Engineer

mlm
Comments:
TA 1931 Rev.
2/84/21
2/ 9/83

Appendix C

Project Name: Work Plan
Project Number: 84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1130 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PFP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft^3

Coarse Aggregate Cooley - Websterville Fine Aggregate Nadeau - Johnson

Cement Brand Glens Falls Type II Lbs. 660

Air Entraining Admixture MBAE 10 Dosage 5 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 2845

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Reference Mix Batch #5

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

Unit Weight Fresh Concrete 146.60 Air: Pressure 4.7 Chace

Total Water, Gal/Cy Used 31.4 Slump 2 3/4 Temperature, Concrete 72 Ambient

Specimen No.		Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
GA-1	1	147	10-26	11-2	7	7	S	4192	3962	4077		
	2	147										
	3	147	10-26	11-9	14	14	S	4350	4536	4443		
	4	147										
	5	147	10-26	11-26	28	31	S	5394	5456	5425		
	6	147										

*S = Standard Cured; F = Field Cured

Types of Breaks:

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

By: R. F. Nicholson 12/27

R. F. Nicholson, P.E., Materials & Research Engineer

mlm
Comments:
TA 183H Rev.
2M 4/81
2M 8/83

Appendix C

Project Name
Work Plan
Project Number
84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1131 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PFP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft.^{3}

Coarse Aggregate Cooley - Websterville Fine Aggregate Nadeau - Johnson

Cement Brand Glens Falls Type II Lbs. 660

Air Entraining Admixture MBAE 10 Dosage 6 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 2845

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Reference Mix Batch #6

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

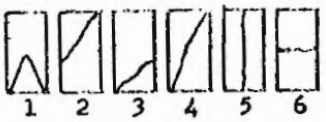
Unit Weight Fresh Concrete 143.62 Air: Pressure 6.7 Chace

Total Water, Gal/Cy Used 31.3 Slump 3 1/2 Temperature, Concrete 74 Ambient

Specimen No.	Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
GA-2 1	145	10-26	11-2	7	7	S	3802	3926	3864	•	
2	145										
3	145	10-26	11-9	14	14	S	4165	4536	4351		
4	145										
5	144	10-26	11-26	28	31	S	5261	5173	5217		
6	144										

*S = Standard Cured; F = Field Cured

Types of Breaks:



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

By: R. F. Nicholson 10/87
R. F. Nicholson, P.E., Materials & Research Engineer

mlm
Comments:
TA 183H Rev.
2/4/81

Project Name
Work Plan
Project Number
84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1132 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PFP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft^3

Coarse Aggregate Cooley - Websterville Fine Aggregate Nadeau - Johnson

Cement Brand Glens Falls Type II Lbs. 611

Air Entraining Admixture MBAE 10 Dosage 4 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 2987

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Reference Mix Batch #7

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

Unit Weight Fresh Concrete 142.56 Air: Pressure 6.8 Chace

Total Water, Gal/Cy Used 32.7 Slump 4 1/2 Temperature, Concrete 74 Ambient

Specimen No.		Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
GB-1	1	144										
	2	144	10-26	11-2	7	7	S	3519	3431	3475		
	3	144										
	4	144	10-26	11-9	14	14	S	3731	3643	3687		
	5	144										
	6	144	10-26	11-26	28	31	S	4642	4731	4687		

*S = Standard Cured; F = Field Cured

Types of Breaks:

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

By: R. F. Nicholson 10/87
R. F. Nicholson, P.E., Materials & Research Engineer

mlm
Comments:
TA 183H Rev.
2M 4/81
2M 8/83

Appendix C

Project Name
Work Plan
Project Number
84-C-15

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION
Montpelier, Vermont 05602

Benda

Report on Concrete Test Beam or Cylinders

Laboratory No. C84 1133 (28) Report of 28 Day Breaks Date typed 11-29-84

Pay Item Performance in Concrete Type of Sample Evaluation

Submitted by Meyer Title PEP Address

Source of Material Mat. & Res. Laboratory Quantity Represented 1.8 ft.^{3}

Coarse Aggregate Cooley - Websterville Fine Aggregate Nadeau - Johnson

Cement Brand Glens Falls Type II Lbs. 611

Air Entraining Admixture MBAE 10 Dosage 3 oz/cy Admixture WRDA Hycol Dosage 3 oz/cwt

Maximum allowable water content, Gal/Cy Total Aggregate, Dry Wgt. 2987

Field Tested by Structural Concrete Subdivision Lab. Tested by Stevens

Sampled from Sears Mixer @ Lab Date Sampled: 10-26-84

Location Used or to be Used Reference Mix Batch #8

Examined for Mod. of Rupture Compressive Strength

TEST RESULTS

Unit Weight Fresh Concrete 146.02 Air: Pressure 4.9 Chace

Total Water, Gal/Cy Used 31.8 Slump 3 Temperature, Concrete 73 Ambient

Specimen No.	Cyl. Unit Wgt. P.C.F.	Date Rec'd	Date Broken	Desired age at break	Age at Break	Type* S - F	Break 1 P.S.I.	Break 2 P.S.I.	Ave. P.S.I.	Break Type 1	Break Type 2
GB-2 1	148										
2	147	10-26	11-2	7	7	S	3785	3820	3802		
3	148										
4	148	10-26	11-9	14	14	S	3802	4218	4010		
5	148										
6	148	10-26	11-26	28	31	S	5155	5190	5173		

*S = Standard Cured; F = Field Cured

Types of Breaks:

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

By: R. F. Nicholson 12/17

R. F. Nicholson, P.E., Materials & Research Engineer

mlm

Comments:
TA 1830 Rev.
2[illegible]4/81
2[illegible]8/83

TA 565 Rev. 4/79

Prepared By: W. L. Meyer
Date: 9/27/84
Sheet 1 of 1

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

Appendix D

RESEARCH INVESTIGATION

Work Plan No. 84-C-15

Subject Evaluation of Fine Aggregate, Vermont Sand & Stone, Inc., Worcester, VT.

Investigation Requested By Robert Dowdell Date Received 9/24/84

Date Information Required As soon as possible

Purpose of Investigation To evaluate the fine aggregate from Vermont Sand & Stone, Inc., proposed for use as a structural concrete aggregate

Proposed Tests or Evaluation Procedure

See Vermont Procedure for Evaluating a New Source of Structural Concrete Aggregate, VT. A.O.T. -MRD 9-82

1. Performance-in-concrete tests will be performed using two batches each of Class A and Class B concrete containing the proposed new aggregate, and two batches each of Class A and Class B concrete containing a reference aggregate.

2. Prepare specimens from each batch of concrete to determine resistance to freezing and thawing.

Proposal Discussed With C. Benda, D. Brown R. Frascoia Projected Manpower Requirements 25 man days

Investigation To Be Conducted By Structural Concrete Subdivision

Proposed Starting Date September 27, 1984 Estimated Completion Date December 21, 1984, including report

Approval/Disapproval by Materials Engineer R. F. Nicholson 10-03-'84

Comments by Materials Engineer

Materials & Research Division
Agency of Transportation
Date: October 2, 1984