STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS DIVISION

RESULTS OF TRIAL MIXES FOR CLASS A, B, C, AND D CONCRETE USING COLD RIVER SAND & GRAVEL. NORTH WALPOLE, N.H. PROPOSED CRUSHED STONE COARSE AGGREGATE.

REPORT 78-4
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REPORTING ON WORK PLAN NO. 77-C-31

R.E.W. Crisman, Secretary of Transportation
S.J. Gage, P.E., Director of Engineering & Construction
R.F. Nicholson, P.E., Materials Engineer

Prepared By

J.L. Talbot, Structural Concrete Engineer
Structural Concrete Subdivision

Agency of Transportation
Materials Division
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Reviewed By:

R.F. Nicholson

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

Date: July 13/'78

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ABSTRACT

Occasionally new sources of materials are proposed for the production of concrete. As new sources are developed, tests are conducted on the materials to assure that the materials will meet specifications and perform satisfactorily.

Cold River Sand and Gravel, Inc., whose quarry is located at their plant in N. Walpole, N.H., has submitted samples of a new coarse aggregate material. The material is described as a crushed stone manufactured from a metamorphic, medium grained biolite gneiss, strongly to weakly foliated, and known as Bethlehem Gneiss.

This report documents the results of the tests performed on this material. The results indicate that concrete mix designs, using this material, can produce compressive strength in excess of 4900 P.S.I. Results also indicate that the coarse aggregate is structurally weak and therefore is not recommended as a material to be used in the production of structural concrete for projects contracted by the State of Vermont, Agency of Transportation.

INTRODUCTION

Crushed gravel for use in structural concrete is becoming a scarce item. As construction projects deplete existing sources, the use of a quarried crushed stone as a coarse aggregate in the production of structural concrete will become necessary. It is important that we investigate new proposed sources and determine if the material is acceptable for use on projects contracted by the State of Vermont, Agency of Transportation.

Frank W. Whitcomb Construction Corporation, N. Walpole, N.H. formerly Cold River Sand and Gravel, Inc., has developed a new coarse aggregate source. They have notified the Materials Division of their desire to market this product if it is acceptable for State work. Should this material be acceptable, it would become a product available to Charlestown Ready-Mix, Inc., Charlestown, N.H.

Samples of the proposed new source have been obtained. Three series of tests have been performed on the aggregates. Each test series consisted of preparing volumetric mix designs, manufacturing cylinders under laboratory control, and breaking these cylinders to determine the results of the mix design and the performance of the coarse aggregate.

The results of our test series indicate that concrete having compressive strengths in excess of 4900 P.S.I. can be obtained.

However, the tests also indicate that the coarse aggregate is weak and should not be used in the production of concrete for projects contracted by the State of Vermont, Agency of Transportation.

MATERIALS

Following are listed the materials used in this investigation:

Parent Material:

F.W. Whitcomb Construction Corporation, N. Walpole, N.H.

Coarse Aggregate:

1 1/2" Stone - F.W. Whitcomb Construction Corporation, N. Walpole, N.H.

Coarse Aggregate:

3/4" Stone - F.W. Whitcomb Construction Corporation, N. Walpole, N.H.

Fine Aggregate:

Sand - F.W. Whitcomb Construction Corporation, N. Walpole, N.H.

Cement:

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

Admixtures:

Air Entraining:
Darex AEA - W.R. Grace & Co., Cambridge, Mass.

Water Reducing:
WRDA Hycol - W.R. Grace & Co., Cambridge, Mass.

Retarding:
Daratard 17 - W.R. Grace & Co., Cambridge, Mass.
Daratard HC - W.R. Grace & Co., Cambridge, Mass.

PROCEDURES

Samples of the new coarse aggregate and samples of the fine aggregate were obtained and tested in the laboratory. All aggregate samples were tested for compliance with the "State of Vermont Department of Highways Standard Specification for Highway and Bridge Construction," dated 1976, Item 704.01 Fine Aggregate for Concrete and Item 704.02 Coarse Aggregate for Concrete.

Mix designs were established for Class A and Class B concrete. The volumetric designs were based upon material characteristics and the application of the principles of A.C.I. 214. The laboratory design strength for each concrete class was determined by using its specified strength and a coefficient of variation of 14. The laboratory design strengths of 4875 P.S.I. for Class A and 4275 P.S.I. for Class B concrete were established.

Two Class A and one Class B mixes were prepared in the laboratory. Each mix was tested in the plastic state and cylinders were prepared for breaking at ages of 14, 28, and 42 days. After receiving a standard cure for the prescribed age, the cylinders were broken. Compressive strengths were recorded and observations of the fractured aggregate were noted.

Because neither mix design obtained the desired laboratory design strength, and because the cylinders exhibited an abnormally high amount of coarse aggregate failure, it was decided to institute another test series.

A work plan investigating mix designs for Class A, Class B, Class C, and Class D concrete was initiated. The same principles of A.C.I. 214 used in establishing the laboratory design strengths for Class A and Class B in our first test series were now expanded to include Class C and Class D concrete. The laboratory design strengths of 3650 P.S.I. and 3050 P.S.I. were established for Class C and Class D concrete, respectively.

Aggregates were tested and trial batches prepared for our second test series. Tests were performed on the plastic concrete and cylinders were prepared for breaking at the ages of 7, 14, and 28 days. After receiving a standard cure for the prescribed age, the cylinders were broken. Compressive strengths were recorded and observations of the fractured aggregate were noted.

The Class A and Class C mix designs obtained 28 day strengths very close to those desired. The Class B and Class D mix designs failed to obtain their desired 28 day strengths. Inspection of the broken cylinders again revealed an abnormally high amount of coarse aggregate failure.

Because the Class A mix had obtained a compressive strength in excess of 4900 P.S.I., we decided to institute a third test series to complete the objective of the work plan.

Class B and Class D mixes were again prepared following the testing of aggregates and redesigning the mixes. Laboratory tests were performed on the plastic concrete and cylinders were again tested and inspected as previously outlined.

RESULTS

Results of the First Test Series
Aggregates

Sampled October 1, 1976 from stockpile at Cold River Sand and Gravel, Inc., N. Walpole, N.H. by Earl Chaffee.

Laboratory Number Identification (Sieve Size)	A 76-1739 1 1/2" Stone (% Passing)	A 76-1704 3/4" Stone (% Passing)	A 76-1647 Fine Aggregate (% Passing)
1 3/4	-	-	-
1 1/2	100	-	-
1	42	100	-
3/4	9	94	-
3/8	1	10	100
No. 4	-	2	98
No. 8	-	1	88
No. 16	-	-	76
No. 30	-	-	51
No. 50	-	-	15
No. 100	-	-	3
No. 200	1.1	0.5	1
Fineness Modulus	-	-	2.69
% of Wear AASHTO T3	-	-	-
% of Wear AASHTO T96	27.2	27.2	-
Thin and Elongated Pieces %	3	16	-
Soundness	3.11	3.11	2.50
Specific Gravity (Bulk Dry)	2.81	2.80	2.62
Dry Rodded Unit Weight	-	-	-
Absorption	0.5	0.9	1.3

The tests on the 3/4" Stone used in the first test series revealed 16% thin and elongated pieces; the maximum allowed is 10%. It also had 10% passing the 3/8" sieve; the minimum allowed is 20%. The 1 1/2" Stone and Fine Aggregate meet specifications.

Because the producer only had a limited stockpile of material and knowing that gradation could be corrected, we continued with the use of these materials in our first test series.

Results of the First Test Series (con't)
Mix Designs and Results

Mix Design No.	Class A (1)	Class A (2)	Class B (1)
1 1/2" Stone (lbs/c.y.)(dry)	-	-	949
3/4" Stone (lbs/c.y.)(dry)	1633	1633	953
Fine Aggregate (lbs/c.y.)(dry)	1363	1363	1195
Cement Type II (lbs/c.y.)	660	660	610
Darex AEA (oz/c.y.)	5	4	5
WRDA Hycol (oz/c.w.t.)	-	-	-
Daratard HC (oz/sack)	3	3	
Slump (inches)	3	3	2 3/4
Air Content (percent)	8	6	5
Density (lbs/cubic feet)	142.51	143.32	149.48
Yield (cubic feet)	27.92	27.77	26.96
Laboratory Design Strength P.S.I.	4875	4875	4275
7 Day Breaks - Ave. of 2 Cylinders	-	-	-
14 Day Breaks - Ave. of 2 Cylinders	3510	3670	3413
28 Day Breaks - Ave. of 2 Cylinders	4129	4125	4041
42 Day Breaks - Ave. of 2 Cylinders	4448	4342	4386

Comments: The laboratory design strengths were not obtained on the standard cured cylinder for either class of concrete at 28 days. Extensive coarse aggregate failure was observed in all cylinders broken.

Results of the Second Test Series
Aggregates

Samples of the 1 1/2" stone and 3/4" stone were obtained on April 18, 1977 from stockpiles at Cold River Sand and Gravel, Inc., N. Walpole, N.H. by E. Blodgett. Fine Aggregate samples were obtained April 12, 1977 by L. Wheeler from Charlestown Ready-Mix, Charlestown, N.H.

Laboratory Number Identification (Sieve Size)	G 77-0067 1 1/2" Stone (% Passing)	G 77-0068 3/4" Stone (% Passing)	G 77-0077 Fine Aggregate (% Passing)
1 3/4	-	-	-
1 1/2	100	-	-
1	45	100	-
3/4	9	97	-
3/8	1	36	100
No. 4	-	6	97
No. 8	-	3	84
No. 16	-	-	68
No. 30	-	-	43
No. 50	-	-	17
No. 100	-	-	5
No. 200	-	-	1.0
Fineness Modulus	-	-	2.86
% Wear AASHTO T3	-	-	-
% Wear AASHTO T96	-	-	-
Thin and Elongated Pieces %	5.2	9.9	-
Soundness	-	-	-
Specific Gravity (Bulk Dry)	2.78	2.78	2.62
Dry Rodded Unit Weight	98.74	97.94	-
Absorption	0.5	1.0	1.4

The aggregate tested met specifications. The 3/4" stone had 9.9% thin and elongated pieces; the maximum allowed is 10%.

Results of the Second Test Series (con't)
Mix Designs and Results

Mix Design No.	Class A (3)	Class B (2)	Class C (1)	Class D (1)
1 1/2" Stone (lbs/c.y.)(dry)	-	933	933	933
3/4" Stone (lbs/c.y.)(dry)	1613	933	933	933
Fine Aggregate (lbs/c.y.)(dry)	1315	1234	1273	1362
Cement Type II (lbs/c.y.)	660	610	564	470
Darex AEA (oz/c.y.)	4	5	4	4
WRDA Hycol (oz/c.w.t.)	-	-	-	-
Daratard RC (oz/c.w.t.)	-	-	-	-
Daratard 17 (oz/c.w.t.)	3	-	-	-
Slump (inches)	2 1/4	2 1/2	2 1/4	2 1/4
Air Content (percent)	5.8	5.8	5.5	6.8
Density (lbs/cubic feet)	145.53	147.30	147.71	145.33
Yield (cubic feet)	26.93	27.30	27.20	27.63
Laboratory Design Strength P.S.I.	4875	4275	3650	3050
7 Day Breaks - Ave. of 2 Cylinders	3413	2591	2401	1433
14 Day Breaks - Ave. of 2 Cylinders	4404	3305	3095	1941
28 Day Breaks - Ave. of 2 Cylinders	4974	3877	3630	2613

Comments: The Class A mix produced adequate compressive strengths. The Class C mix compressive strengths are considered to be acceptable. Extensive coarse aggregate failure was observed in all cylinders broken.

RESULTS (con't)

Results of the Third Test Series
Aggregates

Sampled February 16, 1978 from F. W. Whitcomb Construction Corporation, N. Walpole, N.H., formerly Cold River Sand and Gravel, Inc., by J. Talbot.

Laboratory Number Identification (Sieve Size)	A 78-0276 Parent Material	A 78-0300 1 1/2" Stone (% Passing)	A 78-0299 3/4" Stone (% Passing)	A 78-0298 Fine Aggregate (% Passing)
1 3/4	-	100	-	-
1 1/2	-	100	-	-
1	-	36	100	-
3/4	-	4	95	-
3/8	-	1	20	100
No. 4	-	-	2	97
No. 8	-	-	1	87
No. 16	-	-	-	72
No. 30	-	-	-	47
No. 50	-	-	-	22
No. 100	-	-	-	6
No. 200	-	-	-	-
Fineness Modulus	-	-	-	2.66
% Wear AASHTO T3	7.5	-	-	-
% Wear AASHTO T96	27.8	-	-	-
Thin and Elongated Pieces %	-	6.7	10.8	-
Soundness	0.92	-	-	-
Specific Gravity (Bulk Dry)	-	2.78	2.78	2.62
Dry Rodded Unit Weight	-	98.74	97.94	-
Absorption	-	0.5	1.0	1.4

The tests on the 3/4" coarse aggregate used in the third test series revealed 10.8% thin and elongated pieces; the maximum allowed is 10%. The 1 1/2" coarse aggregate and fine aggregate met specifications.

Results of the Third Test Series (con't)
Mix Designs and Results

Mix Design No.	Class B (3)	Class B (4)	Class D (2)
1 1/2" Stone (lbs/c.y.)(dry)	-	-	960
3/4" Stone (lbs/c.y.)(dry)	1666	1666	960
Fine Aggregate (lbs/c.y.)(dry)	1417	1364	1311
Cement Type II (lbs/c.y.)	610	634	470
Darex AEA (oz/c.y.)	4	3	2
WRDA Hycol (oz/c.w.t.)	-	5	-
Daratard HC (oz/c.w.t.)	-	-	-
Daratard 17 (oz/c.w.t.)	-	-	-
Slump (inches)	2 1/2	2 1/4	2 1/4
Air Content (percent)	5.7	4.4	4.0
Density (lbs/cubic feet)	146.73	148.70	151.35
Yield (cubic feet)	27.47	26.84	26.46
Laboratory Design Strength P.S.I.	4275	4275	3050
7 Day Breaks - Ave. of 2 Cylinders	2392	3391	2171
14 Day Breaks - Ave. of 2 Cylinders	3183	4297	2838
28 Day Breaks - Ave. of 2 Cylinders	4014	4982	3581

Comments: The Class B mix containing 610 lbs. of cement failed to obtain the laboratory design strength. The Class B mix containing 634 lbs. of cement and WRDA Hycol and the Class D mix did obtain the desired compressive strength.

The degree of coarse aggregate failure increased as the compressive strengths increased. At an age of 7 days, the D (2) mix design exhibited low coarse aggregate failure, the B (3) moderate coarse aggregate failure, and the B (4) mix extensive coarse aggregate failure. All cylinders broken at ages 14 and 28 days exhibited extensive coarse aggregate failure.

CONCLUSIONS

The objective of obtaining mix designs for concrete Class A,B,C, and D that produce the desired laboratory design strengths has been achieved. These mix designs are:

Concrete Class	Mix Design No.	Report Page No.
Class A	Class A (3)	9
Class B	Class B (4)	11
Class C	Class C (1)	9
Class D	Class D (2)	11

The coarse aggregate when tested for gradation failed only one test. This is considered minor as gradation can be controlled during manufacture.

The coarse aggregate tests indicate the 3/4" stone may have a problem of consistantly meeting the specifications for thin and elongated pieces. Of the three tests taken, two failed to meet requirements.

Coarse aggregate, when tested by AASHTO T96 "Resistance to Abraision of Small Size Coarse Aggregate by Use of the Los Angeles Machine," met specifications. The parent failed when tested by AASHTO T3 "Abraision of Stone and Slag by Use of the Deval Machine."

Inspection of the cylinders after being tested for compressive strength indicated that an abnormally high degree of coarse aggregate fracture had occured at compressive strengths below their specified strengths. The degree of failure increased as the compressive strengths of fractured cylinders increased.

Coarse aggregate failure was noted in Mix Design No. Class D (2) at 2171 P.S.I. Moderate coarse aggregate failure was noted in Mix Design No. Class B (3) at 2392 P.S.I. and extensive coarse aggregate failure in Mix Design No. Class B (4) at 3391 P.S.I.

The companion cylinders continued to be cured for breaking at later ages. The results of these breaks showed that the matrix of the mix designs did possess the ability to achieve the laboratory design strengths at 28 days. Because of the amount of coarse aggregate failure observed in all cylinders tested, it is concluded that the coarse aggregate is weak and adds little benefit to the production of concrete.

CONCLUSIONS (con't)

Coarse aggregate may be thought of as a filler material used for economy in the manufacture of concrete. This filler should possess a structural strength greater than the design strength of the concrete desired. Materials that do not demonstrate this characteristic should be considered for use only when and where other materials of acceptable quality cannot be obtained.

RECOMMENDATIONS

The crushed stone manufactured by F. W. Whitcomb Construction Corporation, N. Walpole, N.H., formerly Cold River Sand and Gravel, Inc., is not recommended for use as Item 704.02 Coarse Aggregate for concrete on projects awarded by the State of Vermont, Agency of Transportation.

Mix designs using this material can be developed to achieve satisfactory compressive strengths. However, the use of these materials has demonstrated that the product is structurally weak. Structurally weak aggregate is not permitted for use under Item 704.02 Coarse Aggregate for Concrete.

Prepared by: W. Meyer
Date: May 10, 1977

APPENDIX A

Vermont Department of Highways
Materials Division - Structural Concrete Subdivision

PRODUCT EVALUATION WORK PLAN

Number WP 77-C-31

Product Trial mixes for new coarse aggregate source - Cold River S&G, crushed stone

Manufacturer Cold River Sand & Gravel
No. Walpole, N.H.

Distributor or Representative

Evaluation Requested By In House Date NA

Date Information Required NA

Date Product Data & Application Instructions Received NA

Date Samples Received April 15, 1977

Sample Quantity NA Were sufficient samples received Yes

Purpose of Evaluation
Investigative. To evaluate our mix designs for Class A, Class B, Class C, and Class D concretes when used with the new aggregate source to determine if concrete of the desired quality can be produced. Class A - 4875 psi Class C - 3650
Class B - 4275 psi Class D - 3050

Proposed Tests (Attach extra sheet if necessary)

1. One batch for each class of concrete.
   Air Content
   Slump
   Temperature
   Unit Weight and Yield
   7, 14, and 28 day compressive strength using 6"x12" cylinders

   Aggregate tested for
   Gradation
   Specific Gravity and Absorption
   Dry Rodded Unit Weight
   Thin and Elongated Pieces
   Wear

Proposal Discussed with following Sub-divisions Research & Development, Compliance Testing

Projected Manpower Requirements 11 man days including report

Evaluation to be Conducted by Structural Concrete Subdivision

Proposed Starting Date May 16, 1977 Estimated Completion Date June 30, 1977

Approval/Disapproval by Materials Engineer R. F. Nicholson 5/13/77

Comments by Materials Engineer