LABORATORY EVALUATION OF NORLITE AND SOLITE LIGHTWEIGHT AGGREGATE CONCRETE MIXTURES

REPORT 81-8
DECEMBER 1981

Reporting on Work Plans 78-C&R-21
and 78-C&R-34

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

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Materials & Research Engineer

Date: Sept. 9, 1982

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ABSTRACT

Two lightweight coarse aggregates were examined and compared with a normal weight dolomite coarse aggregate. Concrete mixes were prepared and tests performed in the laboratory to provide information for design, specification and construction purposes.

INTRODUCTION

Concrete bridge barrier curbs were planned for use on the Milton - Colchester F028-1(3) project. Structural lightweight concrete was proposed for these curbs to reduce the dead load carried by the exterior beams of the bridge. This investigation of lightweight aggregate was initiated at the request of the Structures Division to provide information for design, specification and construction purposes.

Samples of structural lightweight aggregate were obtained from two manufacturers. The aggregates were tested for compliance with the Standard Specifications for Highway and Bridge Construction and concrete mixes were designed and prepared in the laboratory.

Results of tests performed on concretes containing the lightweight aggregates were compared with results obtained using a dolomite normal weight aggregate. Freeze-thaw durability, compressive and bond strengths, resistance to chloride intrusion and unit weight were examined for all concretes. Sample sections of curb were cast, using the lightweight concretes to determine how variations in slump would affect the surface texture of the finished product.

MATERIALS

Following are listed the materials used in this investigation and their sources: (See Table 1 and Table 2 for aggregate test data.)

COARSE AGGREGATES:

Reference Aggregate:

3/4" Crushed Dolomite

F. W. Whitcomb

Winooski, Vermont

Lightweight Aggregates:

3/4" Expanded Shale (Norlite)

Norlite Corporation

Cohoes, New York

3/4" Expanded Slate (Solite)

Hudson Valley Lightweight Aggregate Corp.

West New York, New Jersey

FINE AGGREGATE:

S. T. Griswold

Williston, Vermont

CEMENT:

Type II

Glens Falls Portland Cement Co.

Glens Falls, New York

AIR ENTRAINING ADMIXTURE:

Darex AEA

W. R. Grace & Co.

Cambridge, Mass.

RETARDING ADMIXTURE:

Daratard H C

W. R. Grace & Co.

Cambridge, Mass.

TABLE 1
COARSE AGGREGATE TEST DATA

	3/4" Norlite	3/4" Solite	3/4" Dolomite	Specification Requirements
Sieve Size	% passing	% passing	% passing	% passing
1"	100	100	100	100
3/4"	100	94	100	90-100
3/8"	25	15*	36	20- 55
#4	2	3	3	0- 10
#8	1	2	2	0- 5
Thin and/or elongated particles (%)	1	0.6	8	10 Max.
L.A. Abrasion (T96)(% loss)				
Reference Aggregate			14	30 Max.
Lightweight Aggregate	30	26		50 Max.
Specific Gravity				
Bulk (Dry)	1.25**	1.49	2.69	NA
Bulk (SSD)	-	1.69	2.70	NA
Apparent	-	1.86	2.72	NA
Absorption (%)				
24 hours	13.3	13.0	0.5	NA
30 minutes	5.3	5.7	-	NA
Soundness (% loss)	0.27	2.38	0.15	8 Max.
Weight per cubic foot (lbs.)				
Dry Loose	40.51	49.38	-	55 Max.
Dry Rodded	45.00	54.07	95.63	NA

* This material did not have the required minimum 20 percent passing the 3/8" sieve. The material was used, as received, and was not processed to meet requirements.

** From Manufacturer's Data Sheet.

TABLE 2
FINE AGGREGATE TEST DATA

	Fine Aggregate	Specification Requirements
Sieve Size	% passing	% passing
3/8"	100	100
#4	99	95 -100
#8	85	NA
#16	68	50 - 80
#30	48	25 - 60
#50	23	10 - 30
#100	3	2 - 10
Fineness Modulus	2.69	2.60 - 3.10
Organic Impurities (Color)	-1	2 Max.
Specific Gravity		
Bulk (Dry)	2.60	NA
Bulk (SSD)	2.63	NA
Apparent	2.68	NA
Absorption (%) 24 hours	1.1	NA
Soundness (% loss)	2.03	8 Max.

CONCRETE MIXES

CONCRETE MIXING AND PROPORTIONS

ACI Standard 211.1 Recommended Practice for Selecting Proportions for Normal Weight Concrete was used for establishing mix proportions for the reference concrete and lightweight concrete.

All concrete mixes were prepared in the laboratory using a Lancaster pan type mixer. Prior to mixing the lightweight concrete, the lightweight coarse aggregate was placed in the mixer with part of the mixing water. The aggregate was allowed to soak for 30 minutes before adding the remainder of the ingredients.

Table 2 presents the mix proportions used.

Table 2

MIX PROPORTIONS, POUNDS PER C.Y.

Concrete	Coarse Aggregate (dry)	Fine Aggregate (dry)	Cement	Net Water
Reference	1651	1260	660	273
Norlite	776	1242	660	292
Solite	920	1208	660	295

FRESH CONCRETE TESTS

Slump, air content, and unit weight tests were performed in accordance with AASHTO T119, T152 (Reference Concrete), T196 (Lightweight concrete) and T121 respectively. Table 3 presents the results of these tests.

Table 3

FRESH CONCRETE TESTS

Concrete	Slump Inches	Air Content Percent	Unit Weight Lbs/Ft^3
Reference	3	6.9	143.0
Norlite	3 1/4	7.3	109.4
Solite	3 1/4	6.6	117.9

UNIT WEIGHT - HARDENED CONCRETE

The unit weight of hardened concrete was obtained by weighing test cylinders in a saturated surface-dry (SSD) condition and by determining the air-dry unit weight of lightweight concrete in accordance with ASTM C567. Table 4 presents the results of these tests.

Table 4

UNIT WEIGHT-HARDENED CONCRETE

Concrete	SSD Weight Lbs/Ft^3	Air Dry Weight Lbs/Ft^3
Reference	144.7	--
Norlite	112.9	109.5
Solite	122.0	118.1

COMPRESSIVE STRENGTH

The compressive strengths of the various concretes were determined using 6 by 12 inch cylinders in accordance with AASHTO T22. Specimens were cured in the moist room until time of testing. All concretes had 28 day compressive strengths in excess of 4000 psi. Table 5 presents the results of compressive strength tests.

Table 5

AVERAGE COMPRESSIVE STRENGTH, psi.

Concrete	7 days	14 days	28 days
Reference	3457	4229	4485
Norlite	3534	4170	4542
Solite	3457	4076	4861

BOND STRENGTH

The bond strengths of all concretes were tested at 10 days, in accordance with Vt. Agency of Transportation - MRD-3-77. Table 6 presents the bond strength test results.

Table 6

BOND STRENGTH

Concrete	Average Bond Strength, psi
Reference	278
Norlite	473
Solite	653

FREEZE-THAW DURABILITY

The resistance of the concretes to freeze-thaw damage was examined, following procedures described in Vt. Agency of Transportation-MRD-4-77.

The results indicated the performance of Norlite concrete was approximately equal to the Reference concrete at the 28 day and 60 day curing periods. After 90 days of curing, the Norlite concrete performed slightly better than the Reference concrete.

Solite concrete exhibited less weight loss for all curing ages than either the Norlite or Reference concretes. The results of freeze-thaw testing are shown in Table 7.

Table 7

FREEZE-THAW DURABILITY

Cure Time Prior to Testing and Concrete Type	Percent Weight Loss After 25 cycles	50 cycles	75 cycles	100 cycles
#1 Cured 28 days				
Reference	16	20	*	
Norlite	14	20	*	
Solite	6	7	8	8
#2 Cured 60 days				
Reference	10	16	18	*
Norlite	11	17	20	*
Solite	6	6	6	6
#3 Cured 90 days				
Reference	8	8	*	
Norlite	2	2	2	**
Solite	0	0	0	0

* Testing discontinued due to excessive deterioration of samples.

** Identification marks on these samples were destroyed and testing was discontinued.

CHLORIDE PERMEABILITY

Chloride permeability of the various concretes was determined using the Vermont Agency of Transportation-MRD 20-77 procedure. Chloride contents were determined at three depths in the concrete; 1/2 - 1 inch, 1 - 1 1/2 inch, and 1 1/2 - 2 inches.

The corrosion threshold range is currently thought to be between 300 and 400 ppm of chloride at the rebar level. After 200 days of continuous ponding with a 3% NaCL solution, none of the concretes contained an amount of chloride at the 1 1/2 - 2 inch depth which would be considered harmful. The Solite concrete did allow slightly more chloride ingress at the 1/2 - 1 1/2 inch levels after 200 days of ponding than either the Reference or Norlite concretes. Table 8 presents the results of the chloride permeability tests.

Table 8

CHLORIDE PERMEABILITY

Concrete	Sampling Depth, inches	Total Chloride, PPM/lbs per CY Ponding For 100 days	200 days
Reference	1/2 - 1	602/2.4	83/0.3
	1 - 1 1/2	65/0.3	69/0.3
	1 1/2 - 2	43/0.2	60/0.2
Norlite	1/2 - 1	72/0.3	69/0.3
	1 - 1 1/2	50/0.2	52/0.2
	1 1/2 - 2	42/0.2	42/0.2
Solite	1/2 - 1	95/0.4	243/1.0
	1 - 1 1/2	68/0.3	104/0.4
	1 1/2 - 2	60/0.2	66/0.3

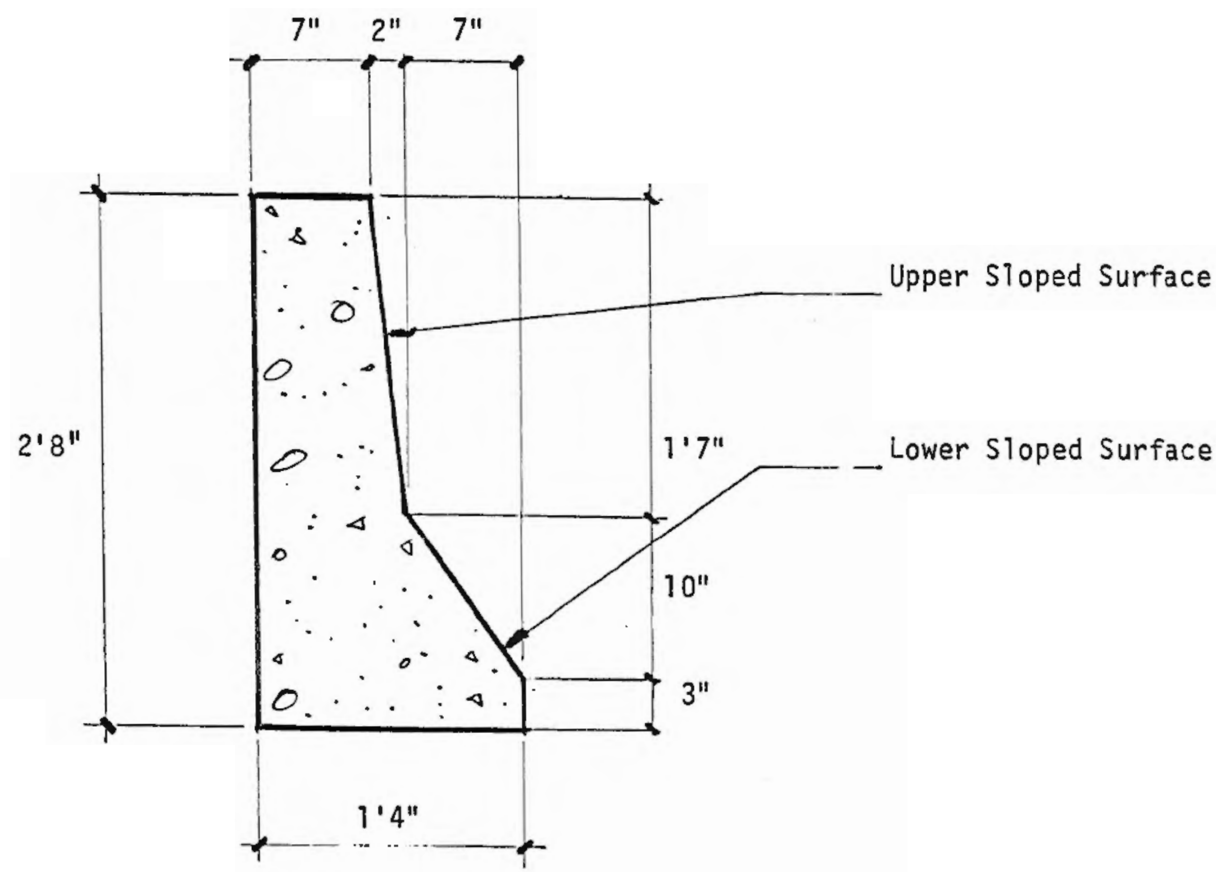
SAMPLE BRIDGE BARRIER CURBS

Sample sections of bridge barrier curbs were cast using the Norlite and Solite concretes to examine the type of surface texture which might be encountered on the sloped surfaces of the curbs.

Two samples were cast for each of the concretes; one using a low slump (1 1/2 - 2 inches), the other using a higher slump (4-4 1/2 inches). The samples were cast in an upright position using plywood forms. Horizontal joints in the forms were sealed with reinforced tape. Consolidation of the concrete was achieved with an internal vibrator.

An examination of the samples indicated that a better surface texture, i.e., less "bug holes" and other defects, will be obtained using low slump concrete.

Figure I shows the typical section of the sample curbs. Photographs showing some of the surface textures are displayed on pages 13 through 16.



Typical Section
(1" = 1' - 0")

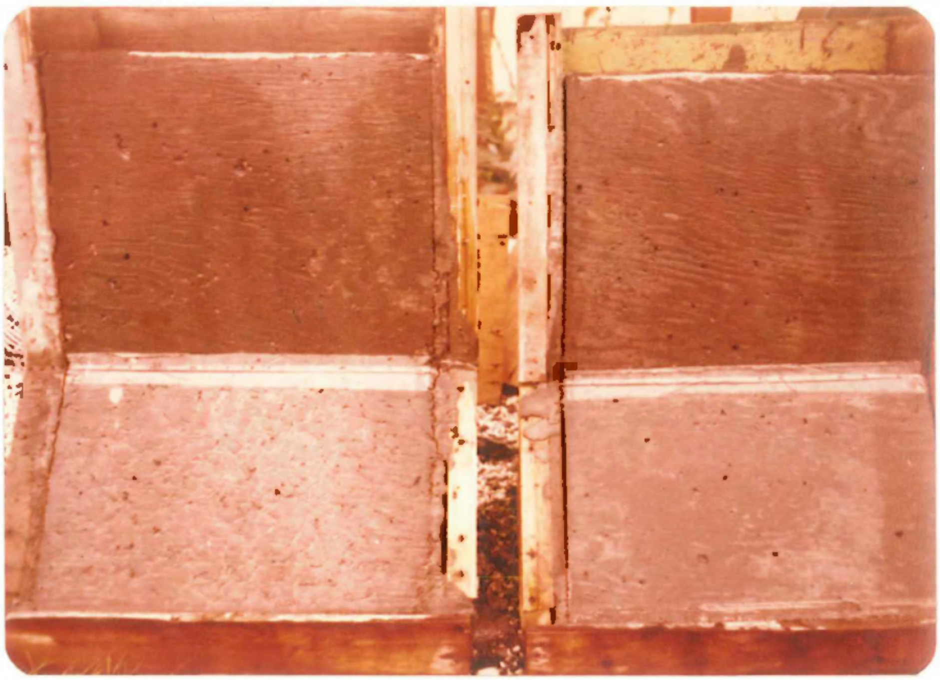
CONCRETE BRIDGE BARRIER CURB - TYPICAL SECTION

FIGURE I

SOLITE CONCRETE

4 ½" Slump

1 ½" Slump

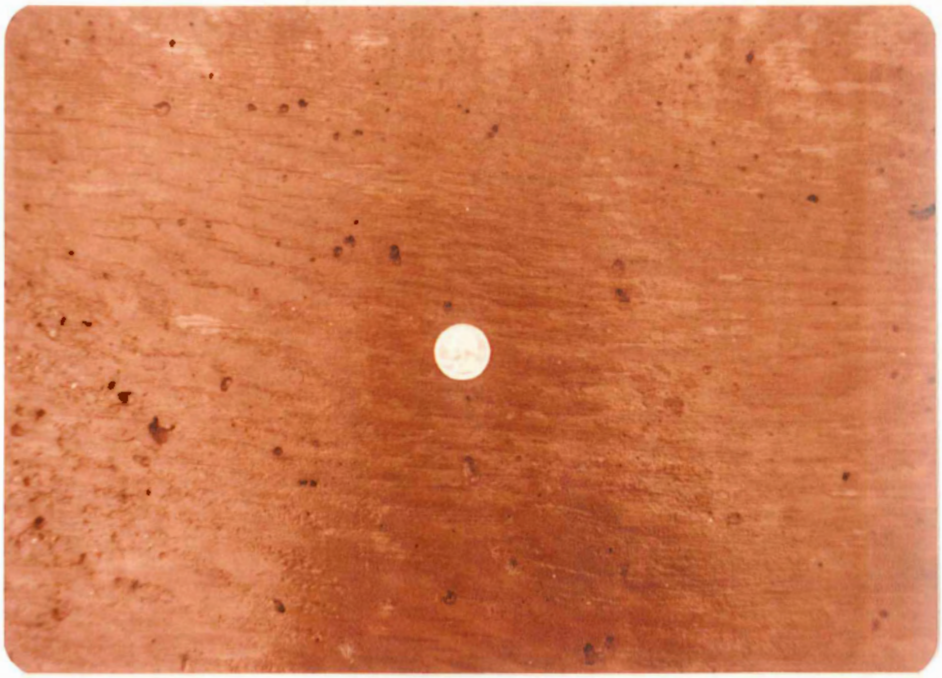


Upper Sloped Surface

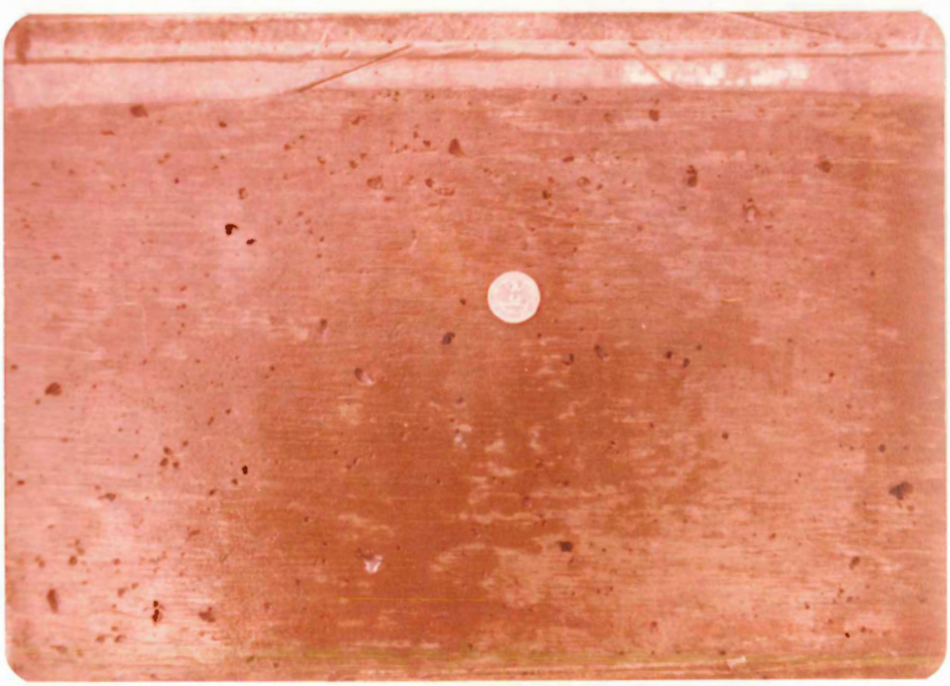
Lower Sloped Surface

SOLITE CONCRETE

1½" Slump



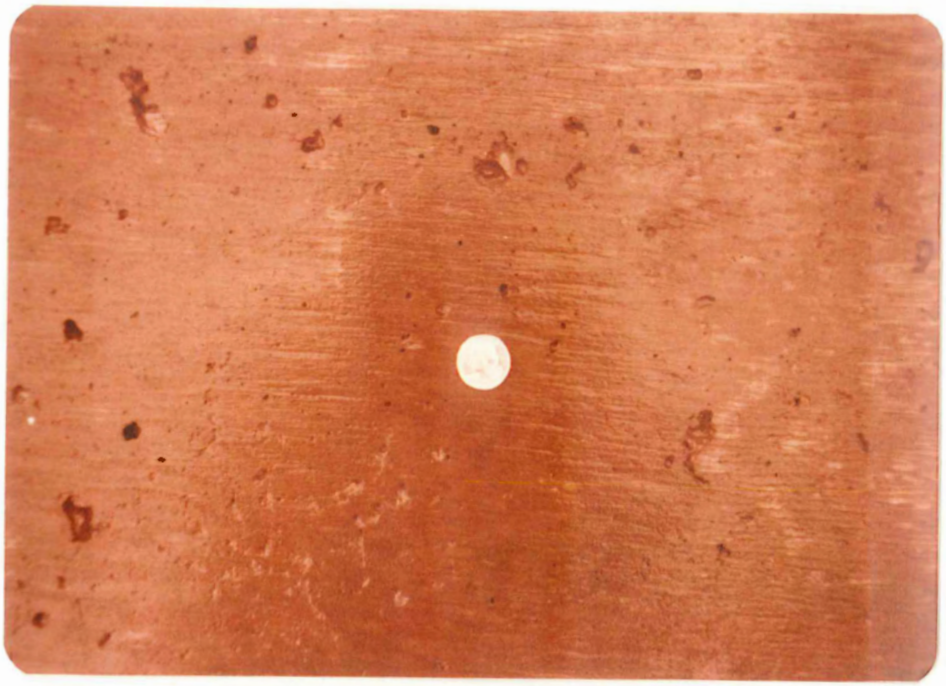
Upper Sloped Surface



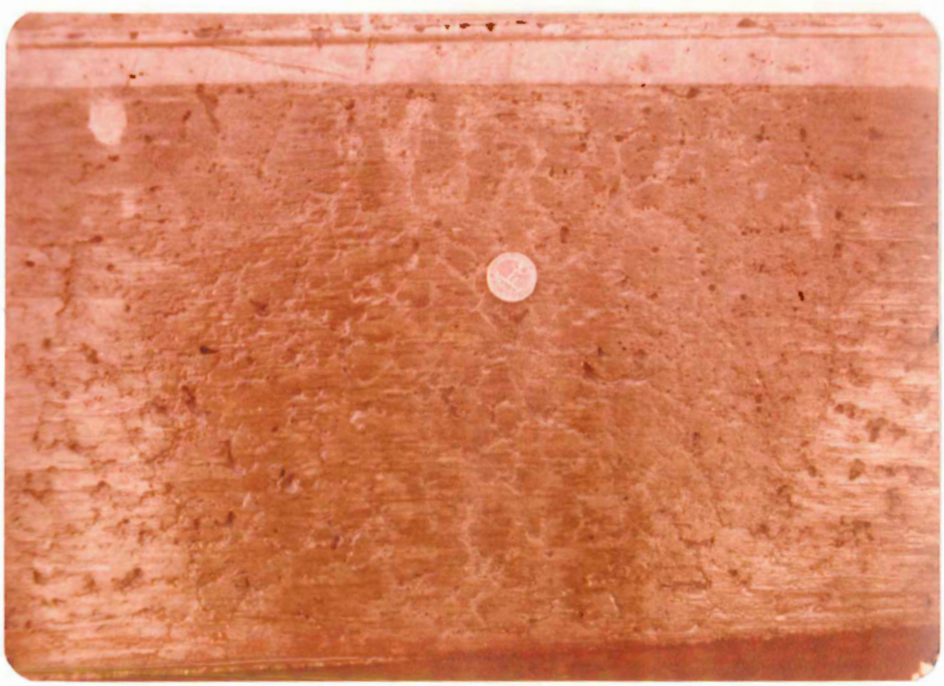
Lower Sloped Surface

SOLITE CONCRETE

4½" Slump



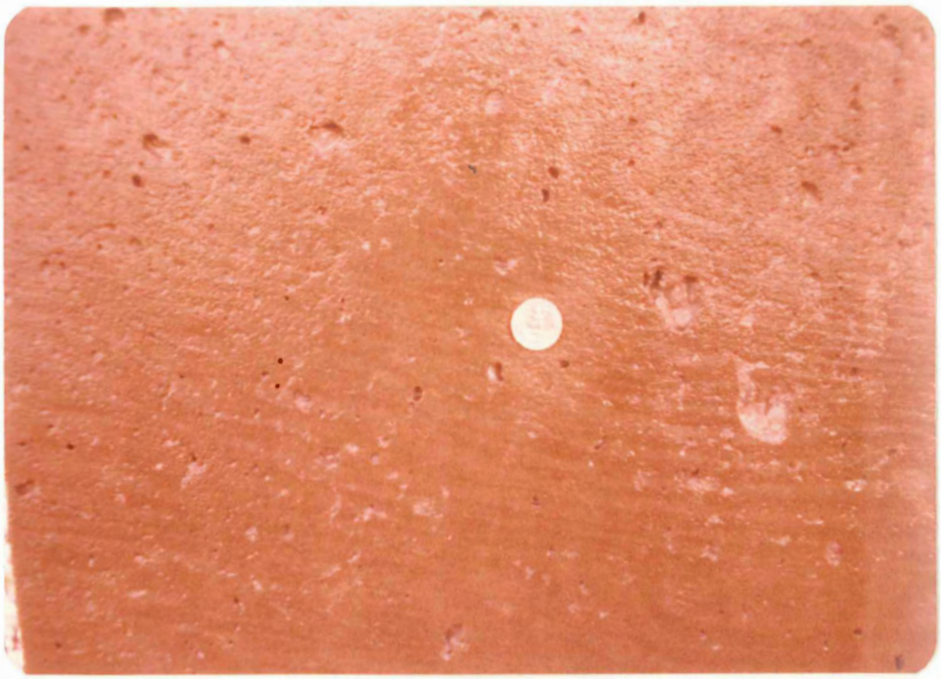
Upper Sloped Surface



Lower Sloped Surface

NORLITE CONCRETE

4½" Slump



Upper Sloped Surface

Lower Sloped Surface

SUMMARY

A. All concretes exhibited average 28 day compressive strengths greater than 4000 psi.

B. Air contents of the lightweight and reference concretes were within the ranges recommended by the American Concrete Institute.

C. When subjected to freeze-thaw testing, the concrete containing Solite coarse aggregate exhibited less weight loss than the concrete containing the Norlite coarse aggregate and the concrete containing the Reference coarse aggregate.

D. After 200 days of continuous ponding with a 3% NaCL solution, none of the concretes examined contained an amount of chloride at the 1½ - 2 inch depth which would be considered harmful.

E. The lightweight concrete containing Norlite coarse aggregate weighed approximately 8½ lbs/ft^3 less than the concrete containing the Solite coarse aggregate.

F. Lightweight concrete of stiff consistency (low slump) produced a better finish on the sloped surfaces of the sample curbs than the higher slump concrete.

IMPLEMENTATION

Information obtained, as a result of this investigation, was used in the preparation of specifications for lightweight coarse aggregates and lightweight concrete. The experience gained was beneficial to Structural Concrete Subdivision personnel who provided assistance with the testing of lightweight concrete on several Agency projects and on the Barre Courthouse project.

Prepared By: W. Meyer WJM
Date: July 19, 1978
Sheet 1 of 1

Appendix A

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS DIVISION - RESEARCH & DEVELOPMENT SUBDIVISION

RESEARCH INVESTIGATION

Work Plan No. 78-C&R-21

Subject: Investigation of the durability of lightweight concrete (Norlite)

Investigation Requested By: Wendell Smith, Structures Engineer Date: May 17, 1978

Date Information Required: April, 1979

Purpose of Investigation: To compare freeze thaw durability; compressive and bond strengths; resistance to chloride intrusion; base level chloride content; w/c ratio; unit weight; and percentage of air of a Class A concrete using Norlite coarse aggregate to a Class A Reference Mix using a Dolomite normal weight aggregate.

Proposed Tests or Evaluation Procedure

1. Aggregates will be tested for compliance with Item 704.01 and Item 704.02.
2. Compressive strengths 7 days, 14 days, 28 days.
3. Bond test 10 days.
4. Sample curbs will be poured to determine the best procedure to obtain the desired finish in the field.
5. Freeze thaw durability (wgt. loss @ 25 cycle intervals). The specimens will be cured for the various ages of 3, 14, 28, and 50 days before the cycling begins.
6. Chloride Intrusion 50 day intervals after 28 day cure.
7. Chloride content analysis.

Proposal Discussed With: R. Haupt, R. Frascoia

Projected Manpower Requirements: Preparation & Testing 7 man days, report - 3 man days

Investigation To Be Conducted By: Structural Concrete and Research & Development

Proposed Starting Date: July, 1978 Estimated Completion Date: March, 1979

Approval/Disapproval by Materials Engineer: R. F. Nicholson 7/21/78

Comments by Materials Engineer:

Materials Division
Agency of Transportation

Prepared By: W. Meyer WJM
Date: 7/19/78
Sheet 1 of 1

Appendix B

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS DIVISION - RESEARCH & DEVELOPMENT SUBDIVISION

RESEARCH INVESTIGATION

Work Plan No. 78-C&R-34

Subject: Investigation of the durability of lightweight concrete (Solite)

Investigation Requested By: Wendell Smith, Structures Engineer Date: May 17, 1978

Date Information Required: April, 1979

Purpose of Investigation: To compare freeze thaw durability; compressive and bond strengths; resistance to chloride intrusion; base level chloride content; w/c ratio; unit weight; and percentage of air of a Class A concrete using Solite coarse aggregate to a Class A Reference Mix using a Dolomite normal weight aggregate.

Proposed Tests or Evaluation Procedure

1. Aggregates will be tested for compliance with Item 704.01 and Item 704.02.
2. Compressive strengths 7 days, 14 days, 28 days.
3. Bond test 10 days.
4. Sample curbs will be poured to determine the best procedure to obtain the desired finish in the field.
5. Freeze thaw durability (wgt. loss @ 25 cycle intervals). The specimens will be cured for the various ages of 3, 14, 28, and 50 days before the cycling begins.
6. Chloride Intrusion 50 day intervals after 28 day cure.
7. Chloride content analysis.

Proposal Discussed With: R. Haupt, R. Frascoia

Projected Manpower Requirements: Preparation & Testing 7 man days, report - 3 man days

Investigation To Be Conducted By: Structural Concrete and Research & Development

Proposed Starting Date: July, 1978 Estimated Completion Date: March, 1979

Approval/Disapproval by Materials Engineer: R. F. Nicholson 7/21/78

Comments by Materials Engineer:

Materials Division
Agency of Transportation

AGENCY OF TRANSPORTATION
~~HIGHWAY DEPARTMENT~~

Appendix C

OFFICE MEMORANDUM

TO: R. Haupt, P.E. via W. Smith, P.E., Structures Engineer

FROM: E. R. Waibel, P.E., Structural Concrete Eng. via R. F. Nicholson, P.E., Materials and Research Engineer

Ervin R. Waibel

DATE: January 12, 1979

SUBJECT: Proposed Specifications for Structural Lightweight Concrete and Lightweight Coarse Aggregate for Structural Concrete

Per your request we have drawn up the enclosed specification to permit the use of lightweight concrete for bridge construction.

The enclosed specifications are for your review and comments.

RFN/ERW/msd
cc: RFN/Lab File
HHH/Structural Concrete Chrono file
E. Englehardt
E. Waibel
Central Files

HD 296 50M 12-75

501.02 MATERIALS, is hereby modified by adding the following subsection of Division 700 - Materials:

Lightweight Coarse Aggregate For Structural Concrete 704.22

501.03, CLASSIFICATION AND PROPORTIONING. Table 501.03A is hereby modified by adding the classification of structural lightweight concrete (LW) as follows:

TABLE 501.03A

Class	Minimum Cement Lbs/Cy	Maximum Net Water Content Gal per Sack (94#) of Cement	Maximum Water Cement Ratio	Range In Slump Inches	Air Content Percent	Coarse Aggregate Gradation Table	28 Day** Compressive Strength P.S.I.
LW	660	5.0	.44	1-3	6.±1	704.02B	4000

Unit Weight of Concrete

Plastic max. lb. per cu. ft.	Dry max. lb. per cu. ft.
120.	115

**The listed 28 day compressive strengths will serve as the basis of designing or approving the concrete mix.

704.22 LIGHWEIGHT COARSE AGGREGATE FOR STRUCTURAL CONCRETE
Lightweight coarse aggregate for structural concrete shall be clean, hard and uniformly graded. It shall be reasonably free from dirt, deleterious material, pieces which are structurally weak and shall meet the following requirements.

(a) General Characteristics. Two general types of lightweight aggregates may be used.

1. Aggregates prepared by expanding, calcining, or sintering products such as blast furnace slag, clay, shale or slate. Other raw materials may be used if the aggregates prepared meet the requirements of this specification.

2. Aggregates prepared by crushing, screening, and cleaning natural lightweight materials such as pumice, scoria, or tuff.

(b) Grading. The grading shall conform to the requirements given in Table 704.02B.

(c) Percent of Wear. The percent of wear shall not be more than 50 when tested in accordance with AASHTO T96.

(d) Thin and Elongated Pieces. The thin and elongated pieces shall conform to the requirements of subsection 704.02(d).

(e) Soundness. The soundness shall conform to the requirements of subsection 704.02(e).

(f) Unit Weight. The maximum dry loose weight of the lightweight coarse aggregate shall not exceed 55 lbs/cu. ft. when tested in accordance with AASHTO T19.