FREEZE-THAW EVALUATION OF LIGHTWEIGHT CONCRETE 1983 TESTING PROGRAM

REPORT 84-6
JULY 1984

Reporting on Work Plan 83-C-38

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

P. J. GARAHAN, P.E., SECRETARY OF TRANSPORTATION
S. J. GAGE, P.E., DIRECTOR OF ENGINEERING & CONSTRUCTION
R. F. NICHOLSON, P.E., MATERIALS & RESEARCH ENGINEER
C. C. BENDA, P.E., STRUCTURAL CONCRETE ENGINEER

Prepared By:

W. L. Meyer, Technician C
Structural Concrete Subdivision

Reviewed By:

R. F. Nicholson

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

Date: 07-23-84

"The information contained in this report was compiled for the use of the Vermont Agency of Transportation. Conclusions and recommendations contained herein are based upon the research data obtained and the expertise of the researchers, and are not necessarily to be construed as Agency policy. This report does not constitute a standard, specification, or regulation. The Vermont Agency of Transportation assumes no liability for its contents or the use thereof."

TABLE OF CONTENTS

ABSTRACT

During the 1983 construction season, several Agency projects used structural lightweight concrete in either bridge barrier curbs or in bridge deck placements. Structural concrete subdivision personnel assisted with testing of the concrete and preparation of test specimens at the project site.

Freeze-thaw test specimens were prepared and tests performed to provide data on concretes containing Norlite and Solite lightweight aggregates.

This report concludes that additional research is needed to determine possible causes of early deterioration of concrete specimens containing lightweight aggregate as well as an in-depth analysis of the lightweight aggregates.

INTRODUCTION

Currently there are two feasible sources of lightweight coarse aggregate available to ready mix producers supplying concrete to Vermont Agency of Transportation projects. These are "Norlite", an expanded shale produced by Norlite Corporation, Cohoes, N.Y., and "Solite", an expanded slate produced by Northeast Solite Corp. at their Saugerties, N.Y., plant.

Although both aggregates have been examined in structural concrete mixes at the Materials and Research Division laboratory, Norlite was the only lightweight coarse aggregate used on Agency projects prior to 1983. An increase in the number of projects using lightweight concrete during the 1983 construction season saw Solite being used in concrete bridge barrier curb in the Burlington area.

During 1983, six Agency projects used approximately 785 cubic yards of structural lightweight concrete. Two of these projects used the lightweight concrete in bridge barrier curbs while the other four uses were deck placements.

Since concrete used in bridge decks and curbs is subjected to severe conditions of exposure, tests were planned to evaluate the freeze-thaw resistance of lightweight concrete. Specimens were prepared at several project sites and then transported to the Materials and Research Division laboratory for evaluation.

PROJECT DATA

When placement of structural lightweight concrete is scheduled on a project, the Structural Concrete Subdivision assigns an inspector to assist with field testing and preparation of concrete test specimens. Tests are performed to determine Slump (AASHTO T 119-82), Air Content (AASHTO T 196-80) and Unit Weight (AASHTO T 121-82). Test cylinders made in accordance with AASHTO T 23-80, are prepared as necessary to monitor compressive strength.

During the 1983 construction season, inspectors also prepared several freeze-thaw test specimens on projects using lightweight concrete. The 3"d x 3"w x 16"l specimens were made in accordance with AASHTO T 126-76 and cured under standard conditions for 14 days. The specimens were then subjected to freeze-thaw testing in accordance with AASHTO T 161-82. At intervals of 50 cycles, the specimens were examined for fundamental transverse frequency and weight change. The specimens were also examined for visible defects.

Project data, concrete and materials sources and concrete mix designs are as follows:

A. Morristown BRZ 1446(4) - Lightweight concrete deck

Ready mixed concrete supplier: A. G. Anderson Co., Inc., Johnson, Vt.

Cubic yards of lightweight concrete: 92½

	Batch Quantities Per Cubic Yard	Material Sources
3/4" LW Stone, lbs.	770 dry	Norlite Corp., Cohoes, N.Y.
Fine Aggregate, lbs.	1317 dry	A.S. Nadeau, Johnson, Vt.
Type II Cement, lbs.	660	Northeast Cement, St.Constant, P.Q.
Air Entraining Admixture, oz.	7	Darex AEA, W.R. Grace, Cambridge, MA
Water Reducing Admixture, oz.	19.8	WRDA/Hycol W.R. Grace, Cambridge, MA
Retarding Admixture, oz.	6.6	Daratard 17W.R. Grace, Cambridge, MA

(Retarding Admixture used in 24 cubic yards)

B. Burlington - Colchester BRM 5056(1) - Concrete bridge barrier curb.

Ready mixed concrete supplier: S. T. Griswold Co., Inc., Williston, Vt.

Cubic yards of lightweight concrete: 292¼

	Batch Quantities Per Cubic Yard For 171¼ Cubic Yards	Material Sources
3/4" LW Stone, lbs.	770 dry	Norlite Corp., Cohoes, N.Y.
Fine Aggregate, lbs.	1330 dry	Hinesburg S & G, Hinesburg, Vt.
Type II Cement, lbs.	660	Glens Falls Cement, Glens Falls, N.Y.
Air Entraining Admixture, oz.	6 - 8	MBAE 10, Master Builders, Cleveland,OH
Water Reducing Admixture, oz.	19.8	WRDA/Hycol W.R. Grace, Cambridge, MA

	Batch Quantities Per Cubic Yard For 121 Cubic Yards	Material Sources
3/4" LW Stone, lbs.	870 dry	Northeast Solite Corp.,Saugerties,N.Y.
Fine Aggregate, lbs.	1319 dry	Hinesburg S & G, Hinesburg, Vt.
Type II Cement, lbs.	660	Glens Falls Cement, Glens Falls, N.Y.
Air Entraining Admixture, oz.	5 - 8	MBAE 10, Master Builders, Cleveland,OH
Water Reducing Admixture, oz.	19.8	WRDA/Hycol W.R. Grace, Cambridge, MA

C. Pownal RS BRS 0107(4) - Concrete bridge barrier curb

Ready mixed concrete supplier: Wm.E. Dailey, Inc., So. Shaftsbury, Vt.

Cubic yards of lightweight concrete: 81¼

	Batch Quantities Per Cubic Yard	Material Sources
3/4" LW Stone, lbs.	770 dry	Norlite Corp., Cohoes, N.Y.
Fine Aggregate, lbs.	1327 dry	W.E. Dailey, So. Shaftsbury, Vt.
Type II Cement, lbs.	660	Glens Falls Cement, Glens Falls, N.Y.
Air Entraining Admixture, oz.	6	MBAE 10, Master Builders, Cleveland, OH
Water Reducing Admixture, oz.	19.8	WRDA/Hycol, W.R. Grace & Co., Cambridge, MA
Retarding Admxiture, oz.	6.6-19.8	Daratard 17,W.R. Grace & Co., Cambridge, MA

D. Pomfret BRS 0166(3)S - Lightweight concrete deck

Ready mixed concrete supplier: Miller Ready Mix, W. Lebanon, N.H.

Cubic yards of lightweight concrete: 139½

	Batch Quantities Per Cubic Yard	Material Sources
3/4" LW Stone, lbs.	770 dry	Norlite Corp., Cohoes, N.Y.
Fine Aggregate, lbs.	1312 dry	Lebanon Crushed Stone, Inc.,W. Lebanon,N.H.
Type II Cement, lbs.	660	Glens Falls Cement, Glens Falls, N.Y.
Air Entraining Admixture, oz.	6 - 7	Darex AEA, W.R. Grace & Co., Cambridge, MA
Water Reducing Admixture, oz.	19.8	WRDA/Hycol,W.R. Grace & Co., Cambridge, MA
Retarding Admixture, oz.	13.2	Daratard 17, W.R. Grace & Co., Cambridge, MA

(Retarding Admixture used in 131½ cubic yards)

E. Danby BRS 0130(2)S - Lightweight concrete deck

Ready mixed concrete supplier: F.W. Whitcomb Const. Corp., Wallingford, Vt.

Cubic yards of lightweight concrete: 94

	Batch Quantities Per Cubic Yard	Material Sources
3/4" LW Stone, lbs.	770	Norlite Corp., Cohoes, N.Y.
Fine Aggregate. lbs.	1306 - 1332	F.W. Whitcomb Const., Wallingford, Vt.
Type II Cement, lbs.	660	Glens Falls Cement, Glens Falls, N.Y.
Air Entraining Admixture, oz.	11	Darex AEA, W.R. Grace & Co., Cambridge, MA

Danby BRS 0130(2)S (Continued)

Water Reducing Admixture, oz.	19.8	WRDA/Hycol, W.R. Grace & Co.,Cambridge, MA
Retarding Admixture, oz.	13.2	Daratard 17,W.R. Grace & Co., Cambridge,MA

(Retarding Admixture used in 31 cubic yards)

F. Montpelier BRZ 1446(9) - Lightweight concrete deck

Ready mixed concrete supplier: A. G. Anderson Co., Berlin, Vt.

Cubic yards of lightweight concrete: 84 3/4

	Batch Quantities Per Cubic Yard	Material Sources
3/4" LW Stone, lbs.	770	Norlite Corp., Cohoes, N.Y.
Fine Aggregate, lbs.	1301	A. G. Anderson Co., Highgate, Vt.
Type II Cement, lbs.	660	Glens Falls Cement, Glens Falls, N.Y.
Air Entraining Admixture, oz.	7 - 8	Darex AEA, W. R. Grace & Co., Cambridge, MA
Water Reducing Admixture, oz.	19.8	WRDA/Hycol,W. R. Grace & Co., Cambridge, MA

RESULTS

Table 1 through Table 5 contain a listing of the results by project, of all tests performed in conjunction with this evaluation. Fresh concrete test results and compressive strength test results shown represent the same concrete from which freeze-thaw specimens were molded.

A summary of the weight change due to freeze-thaw cycling is shown in Table 6. A summary of the relative dynamic modulus of elasticity for all specimens examined, is shown in Table 7.

TABLE 1

Morristown BRZ 1446(4)

SUMMARY OF TEST RESULTS

	Specimen Identification			
	LW 1A	LW 1B	LW 2A	LW 2B
Slump, inches	2 3/4	2 3/4	3 1/4	3 1/4
Air Content, percent	5.3	5.3	6.4	6.4
Unit Weight, lbs/ft^3	118.75	118.75	117.60	117.60
Concrete Temperature, °F	75	75	75	75
Compressive Strength, psi				
7 days	3263	3263		
8 days			3121	3121
28 days	4448	4448	4713	4713

*Resistance to Freezing and Thawing

(Weight change, percent/Relative Dynamic Modulus of Elasticity)

Number of Cycles					
	50	-1/100.0	0/100.0	-1/100.0	0/100.0
	100	-1/98.5	0/97.0	-1/90.1	0/95.5
	150	-1/96.2	-1/90.4	-10/57.3	-2/89.7
	200	-4/85.2	-3/78.6		-3/72.6
	250		-4/63.9		-4/62.7
	300		-10/ -		-24/ -

Testing discontinued due to breakage of specimen LW 1A and deterioration of other specimens.

*Specimens subjected to freezing and thawing in a 3% NaCl solution.

TABLE 2

Burlington-Colchester BRM 5056(1) (Using Solite Lightweight Aggregate)

SUMMARY OF TEST RESULTS

	Specimen Identification			
	SLW 1	SLW 2	SLW 8-30-1	SLW 8-30-2
Slump, inches	5	5	2	2
Air Content, percent	8.5	8.5	7.5	7.5
Unit Weight, lbs/ft^3	117.71	117.71	117.15	117.15
Concrete Temperature, °F	74	74	73	73
Compressive Strength, psi				
28 days	Not tested	Not tested	5036	5036

*Resistance to Freezing and Thawing
(Weight Change, percent/Relative Dynamic Modulus of Elasticity)

Number of Cycles				
50	+1/100.8	+1/100.8	0/100.0	0/100.0
100	+2/102.4	+2/102.4	-2/76.8	-1/77.9
150	+1/101.6	+1/102.4	-3/64.5	-4/76.4
200	+1/101.6	+1/102.4	-29/ -	
250	+1/102.4	+1/101.6		
300	+1/102.4	+1/102.4		
350	+1/103.2	+1/100.0		
400	0/101.6	+1/101.6		
450	0/99.2	+1/93.8		
500	-1/96.9	+1/95.3		
550	-2/97.7	0/93.0		
600	- / -	- / -		
650	-2/97.7	0/92.3		
700	-2/93.1	0/89.3		
750	-4/92.3	-1/87.1		
800	-5/90.1	-2/84.1		
850	-6/86.4	-3/86.3		
900	-6/86.4	-3/80.6		
950	-7/84.9	-5/75.7		
1000	-7/81.4	-6/69.0		

Testing discontinued at 1000 cycles for specimens SLW 1 and SLW 2. Testing discontinued due to breakage of specimen SLW 8-30-1 and disintegration of specimen SLW 8-30-2.

*Specimens subjected to freezing and thawing in a 3% NaCl solution.

TABLE 3

Pomfret BRS 0166(3)S

SUMMARY OF TEST RESULTS

	Specimen Identification			
	NPR 1	NPR 2	NPNS 1	NPNS 2
Slump, inches	3	3	3	3
Air Content, percent	7.0	7.0	7.0	7.0
Unit Weight, lbs/ft^3	116.66	116.66	116.66	116.66
Concrete Temperature, °F	79	79	79	79
Compressive Strength, psi 28 days	4683	4683	4683	4683

*Resistance to Freezing and Thawing
(Weight Change, percent/Relative Dynamic Modulus of Elasticity)

Number of Cycles				
50	-1/100.0	0/99.3	+1/100.0	+1/101.5
100	-3/100.0	-1/99.3	+1/100.7	+1/101.5
150	-5/100.0	-3/98.5	+1/100.7	+1/100.7
200	-8/99.3	-6/95.6	+1/100.7	+1/101.5
250	-9/97.8	-7/96.3	+1/100.7	+1/101.5
300	-11/98.5	-8/95.6	+2/100.0	+1/99.3
350	-14/94.1	-11/92.7	+1/95.6	+1/98.5
400	-17/88.4	-13/83.7	+1/88.4	+1/95.6
450	-20/76.2	-14/71.9	+1/76.9	+2/92.0
500	-23/69.9	-17/59.9	-1/68.0	+2/86.4
550		-23/ -	-2/63.8	+2/59.2
600			-4/61.4	+1/58.6
650				+2/68.7
700				+2/63.9
750				+1/59.2
800				+1/58.6
850				+1/58.1
900				-4/56.4

Testing discontinued due to deterioration of specimens NPR 1 and NPR 2, severe cracking of specimen NPNS 1 and deterioration of one end of specimen NPNS 2.

*Specimens NPR 1 and NPR 2 subjected to freezing and thawing in a 3% NaCl solution. Specimens NPNS 1 and NPNS 2 subjected to freezing and thawing in water.

TABLE 4

Danby BRS 0130(2)S

SUMMARY OF TEST RESULTS

	Specimen Identification	
	9-14-1	9-14-2
Slump, inches	3 1/2	3 1/2
Air Content, percent	6.3	6.3
Unit Weight, lbs/ft^3	116.51	116.51
Concrete Temperature, °F	70	70
Compressive Strength, psi	Not tested	Not tested

*Resistance to Freezing and Thawing
(Weight Change, percent/Relative Dynamic Modulus of Elasticity)

Number of Cycles		
50	0/100.7	0/100.0
100	-1/99.3	0/98.5
150	-3/95.6	-1/95.6
200	-4/92.1	-3/95.6
250	-5/90.0	-3/93.5
300	-7/57.9	-14/87.8
350	-13/72.8	-7/72.7
400	-19/58.5	-10/61.2
450		-13/58.9
500		-17/60.6

Testing discontinued due to deterioration of specimens.

*Specimens subjected to freezing and thawing in a 3% NaCl solution.

TABLE 5

Montpelier BRZ 1446(9)

SUMMARY OF TEST RESULTS

	Specimen Identification	
	LWNM 1	LWNM 2
Slump, inches	2 1/2	2 1/2
Air Content, percent	5.5	5.5
Unit Weight, lbs/ft^3	116.21	116.21
Concrete Temperature, °F	68	68
Compressive Strength, psi		
20 days	5248	5248
28 days	5190	5190
60 days	5738	5738

*Resistance to Freezing and Thawing
(Weight Change, percent/Relative Dynamic Modulus of Elasticity)

Number of Cycles		
50	-3/96.4	-2/96.4
100	-5/95.0	-4/96.4
150	-7/80.7	-6/90.1
200	-9/69.3	-8/84.7
250	-20/ -	-12/63.0
300		-15/56.3
350		-23/ -

Testing discontinued due to deterioration and breakage of specimens.

*Specimens subjected to freezing and thawing in a 3% NaCl solution.

TABLE 6

SUMMARY OF PERCENT WEIGHT CHANGE

Project Name and Number	Morristown BRZ1446(4)				Burlington-Colchester BRM 5056(1)				Pomfret BRS0166(3)S				Danby BRS0130(2)S		Montpelier BRZ 1446(9)	
Specimen Identification	LW 1A	LW 1B	LW 2A	LW 2B	SLW 1	SLW 2	SLW 8-30-1	SLW 8-30-2	NPR 1	NPR 2	NPNS 1	NPNS 2	9-14-1	9-14-2	LWNM 1	LWNM 2
Number of Cycles	Percent Weight Change															
50	-1	0	-1	0	+1	+1	0	0	-1	0	+1	+1	0	0	-3	-2
100	-1	0	-1	0	+2	+2	-2	-1	-3	-1	+1	+1	-1	0	-5	-4
150	-2	-1	-10	-2	+1	+1	-3	-4	-5	-3	+1	+1	-3	-1	-7	-6
200	-4	-3		-3	+1	+1	-29		-8	-6	+1	+1	-4	-3	-9	-8
250		-4		-4	+1	+1			-9	-7	+1	+1	-5	-3	-20	-12
300		-10		-24	+1	+1			-11	-8	+2	+1	-7	-14		-15
350					+1	+1			-14	-11	+1	+1	-13	-7		-23
400					0	+1			-17	-13	+1	+1	-19	-10		
450					0	+1			-20	-14	+1	+2		-13		
500					-1	+1			-23	-17	-1	+2		-17		
550					-2	0				-23	-2	+2				
600					-	-					-4	+1				
650					-2	0						+2				
700					-2	0						+2				
750					-4	-1						+1				
800					-5	-2						+1				
850					-6	-3						+1				
900					-6	-3						-4				
950					-7	-5										
1000					-7	-6										

TABLE 7

SUMMARY OF RELATIVE DYNAMIC MODULUS OF ELASTICITY

Proj.Name & Number	Morristown BRZ 1446(4)				Burlington-Colchester BRM 5056(1)				Pomfret BRS 0166(3)S				Danby BRS 0130(2)S		Montpelier BRZ 1446(9)	
Specimen Ident.	LW 1A	LW 1B	LW 2A	LW 2B	SLW 1	SLW 2	SLW 8-30-1	SLW 8-30-2	NPR 1	NPR 2	NPNS 1	NPNS 2	9-14-1	9-14-2	LWNM 1	LWNM 2
Number of Cycles	Relative Dynamic Modulus of Elasticity															
50	100.0	100.0	100.0	100.0	100.8	100.8	100.0	100.0	100.0	99.3	100.0	101.5	100.7	100.0	96.4	96.4
100	98.5	97.0	90.1	95.5	102.4	102.4	76.8	77.9	100.0	99.3	100.7	101.5	99.3	98.5	95.0	96.4
150	96.2	90.4	57.3	89.7	101.6	102.4	64.5	76.4	100.0	98.5	100.7	100.7	95.6	95.6	80.7	90.1
200	85.2	78.6		72.6	101.6	102.4			99.3	95.6	100.7	101.5	92.1	95.6	69.3	84.7
250		63.9		62.7	102.4	101.6			97.8	96.3	100.7	101.5	90.0	93.5		63.0
300					102.4	102.4			98.5	95.6	100.0	99.3	57.9	87.8		56.3
350					103.2	100.0			94.1	92.7	95.6	98.5	72.8	72.7		
400					101.6	101.6			88.4	83.7	88.4	95.6	58.5	61.2		
450					99.2	93.8			76.2	71.9	76.9	92.0		58.9		
500					96.9	95.3			69.9	59.9	68.0	86.4		60.6		
550					97.7	93.0					63.8	59.2				
600					-	-					61.4	58.6				
650					97.7	92.3						68.7				
700					93.1	89.3						63.9				
750					92.3	87.1						59.2				
800					90.1	84.1						58.6				
850					86.4	86.3						58.1				
900					86.4	80.6						56.4				
950					84.9	75.7										
1000					81.4	69.0										

SUMMARY AND CONCLUSIONS

Freeze-thaw tests produced a wide range of results with both aggregates used. While these results appeared to be influenced in some cases by air content of the concrete, no definite pattern was established.

When Solite aggregate was used, the two specimens which showed deterioration at 150-200 freeze-thaw cycles had an air content of 7.5% while the specimens which showed very little deterioration at 1000 cycles had an air content of 8.5%.

The concrete containing Norlite aggregate performed slightly better with air contents of 6.3% and 7.0% than with air contents of 5.3% and 5.5%. However, specimens LW 2A and LW 2B with an air content of 6.4% performed poorly.

The two specimens from the Pomfret project, tested in a 3% NaCl solution showed excessive deterioration at 500 and 550 cycles. One of the specimens tested in water cracked severely and testing was discontinued at 600 cycles. The other specimen tested in water showed deterioration severe enough to discontinue testing at 900 cycles.

The broad range of results obtained indicates that additional research of lightweight concrete and lightweight aggregate is necessary. Attention should be directed at determining optimum air content of lightweight concrete and the possibility that unburned or underburned particles of material are present in the lightweight aggregate.

TA 565 Rev. 4/79

Prepared By: Meyer & Benda
Date: 10/3/83
Sheet 1 of 1

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

Appendix

RESEARCH INVESTIGATION

Work Plan No. 83-C-38

Subject Freeze-Thaw Evaluation of Lightweight Concrete

Investigation Requested By Structural Concrete Subdivision Date September 3, 1983

Date Information Required As soon as possible

Purpose of Investigation To acquire freeze-thaw data from field prepared lightweight concrete specimens made with Solite and Norlite lightweight aggregate

Proposed Tests or Evaluation Procedure Perform tests of plastic concrete to determine: Slump (AASHTO T119), Air Content (AASHTO T196) and Unit Weight (AASHTO T121).

Mold a minimum of two freeze-thaw test specimens (3"x3"x16"). Cure specimens under standard conditions for 14 days. After 14 days of curing, specimens will be subjected to freeze-thaw testing in a 3% NaCl solution. After curing, additional pairs of specimens will be allowed to dry out before freeze-thaw testing. In addition to the 3% NaCl solution, at least one pair of specimens will be freeze-thaw tested in water without N aCl.

Testing of plastic concrete and preparation of freeze-thaw specimens to be performed in conjunction with five projects having lightweight concrete items during the 1983 calendar year.

Proposal Discussed With R. Frascoia, N. Danforth Projected Manpower Requirements 15 man days

Investigation To Be Conducted By Structural Concrete Subdivision

Proposed Starting Date July 14, 1983 Estimated Completion Date March 1, 1984

Approval/Disapproval by Materials Engineer R. F. Nicholson 10-11-83

Comments by Materials Engineer

10-3-83