EVALUATION OF THE DURABILITY OF MORTARS TYPE I AND TYPE II

REPORT 93-1
MARCH 1993

REPORTING ON WORK PLAN 89-C-2

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS AND RESEARCH DIVISION

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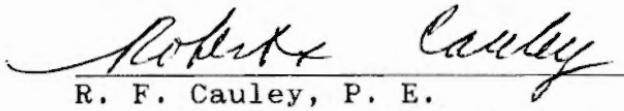

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Date: MAR 1 5 1993

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ABSTRACT

This program was adopted to evaluate each of the constituents which go into masonry construction used on Vermont Agency of Transportation projects. Concrete and clay bricks, three types of cement, two aggregates and two types of mortar were examined. Also studied, were the effects of hand vs machine mixing and remixing of mortar batches, one hour after initial mixing had begun.

As important data was collected, specification changes were implemented without delay. The use of concrete bricks is no longer permitted on Agency projects. When air-entraining cement is required, Type IA is now specified, as Type IIA is no longer available.

This report further recommends allowing Fine Aggregate for Concrete as an aggregate in masonry construction.

INTRODUCTION

Transportation maintenance personnel are faced with a multitude of challenges while endeavoring to maintain the highway infrastructure in a safe, passable condition. One area of growing concern in this effort has been the deterioration of masonry construction. Catch basins, drop inlets, and other areas of masonry construction subjected to cycles of freezing and thawing in the presence of deicing salts often deteriorate prematurely, resulting in expensive and time consuming repairs.

To address this problem, tests were proposed and programs adopted to examine each of the constituents which go into masonry construction used on Vermont Agency of Transportation projects.

During developmental stages of the investigation, concrete and clay bricks were subjected to rapid freezing and thawing tests with interesting results. Clay sewer bricks, AASHTO M91, Grade SM, completed 300 cycles of freezing and thawing in a 3% sodium chloride solution with no evidence of deterioration. Concrete bricks, ASTM C55, Grade N, Type I and II, on the other hand, disintegrated completely in less than 50 cycles in the same environment. This discovery led to an immediate prohibition on the use of concrete bricks on Agency projects.

About the same time the bricks were being investigated, a broad program was being organized to examine the cementing matrix of mortars used in masonry construction.

During the preliminary stages of our evaluation, several cement manufacturers were canvassed regarding availability of their products. At that time, it was discovered Type IIA, Air-entraining Portland Cement is no longer available in this region of the country. A limited number of manufacturers, however, still produce a Type IA, Air-entrained Portland Cement. Changes were initiated and specifications now require the use of Type IA cement in masonry work.

Many grouting situations require large quantities of materials. When this occurs, Fine Aggregate for Concrete is often substituted for the Sand for Cement Mortar with the materials batched at a ready mixed concrete plant and delivered to the project in transit mixers.

Vermont Agency of Transportation specifications currently require a blend of Type IA, Air-entraining Portland Cement and Sand for Cement Mortar, consisting of one part cement and one part sand, or one part cement and two parts sand, depending on the use for which the mortar is employed. The cement and sand are blended with sufficient water to provide a mixture of the required consistency.

To obtain the greatest information on current practices and to assist with the development of possible future specifications, a complex program was established. Three types of cement were used in the investigation: Type IA, Air-entrained Portland Cement, Type II, Portland Cement, and Type S, Masonry Cement. Each cement was blended with Sand for Cement Mortar and Fine Aggregate for Concrete, using the proportions noted above. Mixing was accomplished using a Sears 1.5 cubic foot concrete mixer for machine mixed mortar and by using a wheelbarrow and hoe for hand mixed mortar.

All mixtures were blended to a plastic consistency, as determined with a flow table. Air content, temperature, compressive strength and freeze-thaw durability were determined for each batch of material. Effects of retempering were examined by remixing the remaining materials, with and without additional water, one hour after initial mixing then repeating all tests.

MATERIALS

The materials used in this investigation are as follows:

Cements

Type IA, Air Entraining Portland Cement

Glens Falls Portland Cement Co.
Glens Falls, NY

Type II, Portland Cement

Glens Falls Portland Cement Co.
Glens Falls, NY

Type S, Masonry Cement

Glens Falls Portland Cement Co.
Glens Falls, NY

Sand for Cement Mortar

Albert S. Nadeau
Johnson, VT

Fine Aggregate for Concrete

A.G. Anderson Company, Inc.
Highgate, VT

PROCEDURES

The Type IA and Type II cements used in this evaluation were subjected to physical testing in accordance with: Air Content of Hydraulic Cement Mortar (AASHTO T137-87I), Fineness of Portland Cement by Air Permeability Apparatus (AASHTO T153-86), Autoclave Expansion of Portland Cement (AASHTO T107-86), Normal Consistency of Hydraulic Cement (AASHTO T129-88I), Time of Setting of Hydraulic Cement by Gillmore Needles (AASHTO T154-89I) and Compressive Strength of Hydraulic Cement Mortar (AASHTO T106-88I). The Type S Masonry Cement, was tested in a similar manner, but using Fineness of Hydraulic Cement determined by means of the No. 325 sieve, AASHTO T192-86. Additional test procedures for the Type S Masonry Cement are as shown in the Standard Specification for Masonry Cement (ASTM C91-89).

The Sand for Cement Mortar and Fine Aggregate for Concrete were tested in accordance with procedures outlined in Sieve Analysis of Fine and Coarse Aggregates (AASHTO T27-88I), and Organic Impurities in Sands for Concrete (AASHTO T21-87I).

The Vermont Agency of Transportation Standard Specifications for Construction (1990) outline requirements for Type I and Type II mortars as follows:

> 707.01 MORTAR, TYPE I. Mortar, Type I, is generally used as a joint filler between curb stones, stone slope edging and for the grouting of dowels. It shall be used in small quantities as needed and shall not be retempered or used after it has begun to set.
>
> The mortar shall be composed of one part cement and one part sand and mixed with sufficient water to form a plastic composition. For grouting, sufficient water shall be added to provide the required consistency.
>
> The cement, sand and water shall meet the following requirements:
>
> (a) Cement. Cement shall conform to the requirements of Air-Entraining Portland Cement, subsection 701.03.
>
> (b) Sand. Sand shall conform to the requirements of Sand for Cement Mortar, subsection 704.13.
>
> (c) Water. Water shall conform to the requirements of Water, subsection 745.01.
>
> 707.02 MORTAR, TYPE II. Mortar, Type II, is generally used as a joint filler for concrete and clay pipes, stone and brick masonry, and for repointing. It shall be used in small quantities as needed and shall not be retempered or used after is has begun to set.

The mortar shall be composed of one part cement and two parts sand and mixed with sufficient water to form a plastic composition.

The cement, sand and water shall meet the requirements specified in subsection 707.01.

After mixing, the flow of each batch was determined using procedures outlined in Compressive Strength of Hydraulic Cement Mortar (AASHTO T106-86). Every effort was made to maintain the flow in the range of 110 ±5. Each batch was also tested for Air Content of Freshly Mixed Concrete By The Volumetric Method (AASHTO T196-80), and Temperature Of Freshly Mixed Portland Cement Concrete (ASTM C1064-86). The water/cement ratio was determined for each batch of material used.

Compressive strength was determined using 2 inch cube specimens prepared and tested in accordance with AASHTO T106-86. Compressive strengths were determined at 24 hours, 7 days, and 28 days.

Two freeze-thaw specimens (3"x3"x16") were prepared in accordance with Making And Curing Concrete Test Specimens In The Laboratory (AASHTO T126-86). Specimens were subjected to freeze-thaw testing at an age of 14 days, in accordance with Resistance Of Concrete To Rapid Freezing And Thawing (AASHTO T161-86), Procedure A, modified by using a 3% sodium chloride solution. Testing was continued until severe deterioration of the specimens occurred or until a maximum of 300 cycles was obtained.

The compressive strength and freeze-thaw test specimens were cured by storing them in a dry condition, at room temperature, in the laboratory.

To obtain information on the effects of retempering and remixing of the material, the remaining mortar was allowed to stand for a period of 1 hour following initial introduction of water. The material was then remixed, with and without additional water, to again attain a flow of 110 ±5. Air content and temperature were again determined and a duplicate set of compressive strength and freeze-thaw specimens was prepared. All test conditions, including ages of test, were the same as with the initial specimens.

Batches of Type I mortar were prepared initially by measuring one part cement and one part Sand for Cement Mortar or Fine Aggregate for Concrete, by volume, then determining the weight obtained with the initial batch. Type II mortar was prepared in a similar manner, except that one part cement and two parts Sand for Cement Mortar or Fine Aggregate for Concrete were used. Sufficient water was added to obtain a plastic consistency, as determined with the flow table.

Machine mixed mortar used in this evaluation was blended in a Sears 1.5 cubic ft. rotary drum concrete mixer. Hand mixed mortar was blended in a steel "contractors" wheelbarrow using a common garden hoe. The Sand for Cement Mortar and Fine Aggregate for Concrete were air-dried prior to the start of mixing operations.

Duplicate batches of mortar were prepared for all combinations of materials as shown in Table 1 and Table 2, in Appendix B.

RESULTS

Results of physical testing of Type IA, Air-entraining Portland Cement; Type II, Portland Cement; and Type S, Masonry Cement are shown in Table 3, Table 4, and Table 5 respectively, in Appendix B. Test results of Sand for Cement Mortar and Fine Aggregate for Concrete are shown in Table 6 and Table 7 respectively, in Appendix B. Results of tests performed on the freshly mixed and hardened mortar are illustrated in Table 8 through Table 31, in Appendix B.

> NOTE: This report will not contain information for the following batch numbers: 3, 26, 27, 28, 29 and 30. Results of Batch Number 3 were omitted due to the material having an initial flow substantially higher than that desired for testing. There was an intentional "skip" from Batch Number 25 to Batch Number 31 for the purpose of separating two sections of our laboratory evaluation.

SUMMARY/DISCUSSION

RESISTANCE TO RAPID FREEZING AND THAWING

1. The Type IA, Air Entraining Portland Cement, provided greater overall resistance to rapid freezing and thawing than both Type II and Type S cements. Performance of mixtures containing Type S cement was somewhat better than those with Type II cement; however, results with both of these products were more erratic than those obtained with the Type IA.

2. Machine mixed mortars demonstrated better resistance to freezing and thawing than hand mixed mortars when the Type IA and Type S cements were used. No clear advantage with either type of mixing was observed with the Type II cement.

3. A comparison of mixtures containing Sand for Cement Mortar or Fine Aggregate for Concrete showed the Sand for Cement Mortar performing somewhat better when used with Type IA and Type S cements. With Type II cement, the fine aggregate yielded slightly better results.

4. Remixing the batches, one hour after initial mixing, did not appear to have a significant effect on the results. In many cases, resistance to freezing and thawing was unchanged when the materials were remixed and a small amount of water added to the batch.

5. Type I Mortar and Type II Mortar exhibited erratic yet similar performance in all batches, regardless of the type of cement or aggregate used. Neither type of mortar appeared to provide consistently better results in freeze-thaw testing than the other.

COMPRESSIVE STRENGTH

1. A comparison of the three cements examined indicates Type S, Masonry Cement, yielded the lowest compressive strength at all ages of the test.

2. Type IA cement demonstrated a clear advantage in compressive strength at 24 hours, while Type II, as anticipated, achieved the greatest overall strength at 28 days.

3. An examination of 28 day compressive strengths of initial mixes indicates that with Type S cement there is an advantage when the mortar is mixed by hand. Type IA and Type II cements showed no benefit attributable to either hand or machine mixing.

4. Two thirds of initially mixed batches achieved greater compressive strength when Fine Aggregate for Concrete was used, when compared with batches containing Sand for Cement Mortar. In those instances when results were higher with Sand for Cement Mortar they were attained in Type I Mortar.

REMIXING

1. As noted earlier in this report, remixing the mortar, with the addition of a small amount of water, did not appear to have a pronounced effect on either strength or durability.

2. Minor quantities of water were required to maintain the flow in the desired range at one hour after initial mixing. Average increases in water-cement ratio for the different types of cement were as follows:

Cement Type	W/C Ratio Increase
Type IA	0.008
Type S	0.020
Type II	0.010

3. A small reduction in the air contents of the various mortars was experienced during the one hour delay and remixing period. Average reductions in air content for the three types of cement were as follows:

Cement Type	Air Content Reduction (%)
Type IA	0.17
Type S	0.56
Type II	0.13

MISCELLANEOUS

1. Machine mixing of mortars, in most cases, produced slightly higher air content than hand mixing.

2. Air content of mortars was generally highest using Type IA cement, with Type S cement yielding results close to the Type IA. The mixtures using Type II cement, however, were usually not more than 1.0% lower than those obtained with the Type IA and Type S.

3. Mixtures containing Sand for Cement Mortar produced air contents which typically ranged 1.0% to 2.0% higher than those realized with the Fine Aggregate for Concrete.

4. The selected flow, 110 $\pm$5, provided adequate workability and plasticity in the various mortars examined in this investigation.

CONCLUSIONS AND RECOMMENDATIONS

1. During the developmental stages of this program, freeze-thaw tests of concrete bricks led to their prohibition on Agency projects. No further work has been done with these products and the prohibition remains in effect at this time.

2. It was also discovered, early in the program, that Type IIA cement is no longer available in this region of the country. In order to provide air entrainment in masonry work, specification changes were initiated to require the use of Type IA cement. Results obtained in this evaluation indicate mortars containing air entrained cement will provide greater resistance to freezing and thawing than mortars containing either non air entrained cement or masonry cement. It is recommended that Type IA, Air-entrained cement continue to be specified for use in Agency of Transportation masonry work.

3. Although mortars containing Sand for Cement Mortar provided somewhat better resistance to freezing and thawing than mortars containing Fine Aggregate for Concrete, the latter should be considered as an acceptable substitute. It is recommended that the 1990 Standard Specifications For Construction, Section 707.01 MORTAR, TYPE I, subsection (b), be rewritten as follows:

> (b) Sand. Sand shall conform to the requirements of Sand for Cement Mortar, subsection 704.13, or Fine Aggregate for Concrete, subsection 704.01.

4. Inspection personnel and contractors should be reminded of specification changes and current requirements to insure only acceptable materials are introduced into the project. Many local hardware stores and other suppliers do not presently stock Type IA cement. As the demand increases, the supply should become more readily available.

TA 565 Rev. 4/79

Prepared By: W. Meyer WJM
Date: 02/22/89
Sheet 1 of 2

APPENDIX "A"

STATE OF VERMONT
AGENCY OF TRANSPORTATION
MATERIALS & RESEARCH DIVISION

RESEARCH INVESTIGATION

Work Plan No. 89-C-2

Subject Evaluation of the Durability of Mortars, Type I and Type II

Investigation Requested By M. W. Lawson Date February, 1989

Date Information Required ASAP

Purpose of Investigation To evaluate the freeze-thaw durability of Type I & Type II mortars employed by the Agency of Transportation for grouting, joint filling and masonry work.

Proposed Tests or Evaluation Procedure Mortar Type I and Mortar Type II will be evaluated, using Type II Portland Cement, Type II-A, Air Entraining Portland Cement and a commercial masonry cement.

Evaluations will be conducted using Fine Aggregate For Concrete, Item 704.01 and Sand for Cement Mortar, Item 704.13.

Mixing procedures will be varied to include hand mixing, using a wheelbarrow and hoe, and mechanical mixing, using a Sears 1½ cf mixer.

The effects of retempering at 30 minutes after initial mixing will also be evaluated.

(SEE PAGE 2)

Proposal Discussed With R. Frascoia, C. Benda Projected Manpower Requirements 85 man days

Investigation To Be Conducted By Structural Concrete Subdivision

Proposed Starting Date ASAP Estimated Completion Date June 1990

Approval/Disapproval by Materials & Research Engineer [signature]

Comments by Materials & Research Engineer PROGRESS REPORTS SHOULD BE MADE AT EVERY PHASE, PARTICULARLY WHEN INFO CAN BE MADE AVAILABLE.

Materials & Research Division
Agency of Transportation
Date Typed:
March 2, 1989

The following tests will be conducted:

1. Mortars

   a. Compressive Strength - AASHTO T106-86, modified, using 2" cubes. Tests will be conducted at ages of 1 day, 7 days and 28 days. Following mixing, specimens will be air-dried until tested.

   b. Resistance to Rapid Freezing and Thawing - AASHTO T161-86, Procedure A, modified for use of a 3% sodium chloride solution. Following mixing, specimens will be air-dried until freeze-thaw cycling begins at 14 days.

   c. Consistency Using Flow Table - AASHTO T106-86. Consistency will be determined to insure uniformity of the various mixes examined.

   d. Air Content - AASHTO T196-80. Air contents will be measured to determine variation caused by mixing procedures.

2. **Fine Aggregate For Concrete and Sand For Cement Mortar**

   a. Gradation - AASHTO T27-84.

   b. Organic Impurities - AASHTO T21-81.

3. **Type II, Portland Cement, Type II-A, Air Entraining Portland Cement and Masonry Cement**

   a. All Physical tests normally conducted in the Materials and Reseach Division, Cement Laboratory.

TABLE 3
CEMENT TEST DATA

	Glens Falls-Type IA Date Sampled 06/26/89	12/20/89	Type IA AASHTO M85-89I Specification Requirements
Air Content of Mortar, percent by volume	16.0	13.4	16 minimum 20 maximum
Fineness-Specific Surface, sq. meters per kg	390	356	280 minimum 400 maximum
Soundness-Autoclave Expansion, percent	0.06	0.07	0.80 maximum
Normal Consistency-Vicat Needle	26.5	26.5	-----
Time of Setting-Gillmore Needle			
Initial- hours:minutes	1:55	2:20	1:00 minimum
Final- hours:minutes	3:35	4:40	10:00 maximum
Compressive Strength, psi			
3 days - cube no. 1	3240	2530	
cube no. 2	3440	2630	
cube no. 3	3530	2590	
average	3400	2580	1450 minimum
7 days - cube no. 1	3810	3650	
cube no. 2	3680	3780	
cube no. 3	3770	3700	
average	3750	3710	2250 minimum

TABLE 4
CEMENT TEST DATA

	Glens Falls-Type II Date Sampled 06/26/89	12/20/89	Type II AASHTO M85-89I Specification Requirements
Air Content of Mortar, percent by volume	9.0	9.0	12 maximum
Fineness-Specific Surface, sq. meters per kg	320	342	280 minimum 400 maximum
Soundness-Autoclave Expansion, percent	-0.03	0.00	0.80 maximum
Normal Consistency-Vicat Needle	24.5	24.5	-------
Time of Setting-Gillmore Needle			
Initial - hours:minutes	2:55	2:10	1:00 minimum
Final - hours:minutes	4:40	4:45	10:00 maximum
Compressive Strength, psi			
3 days - cube no. 1	2590	2410	
cube no. 2	2470	2560	
cube no. 3	2580	2470	
average	2550	2480	1500 minimum
7 days - cube no. 1	3010	3750	
cube no. 2	3110	3550	
cube no. 3	3080	3520	
average	3070	3610	2500 minimum

TABLE 6

SAND FOR CEMENT MORTAR TEST DATA

	A. S. Nadeau Johnson, VT	VAOT Specification Requirements
Sieve Size	% Passing	% Passing
# 8	100	100
# 16	97	-
# 30	73	-
# 50	33	15-40
#100	8	0-10
#200	1	0-5
Fineness Modulus	1.89	N/A
Color	1	2 Max.

TABLE 7

FINE AGGREGATE FOR CONCRETE TEST DATA

	A. G. Anderson Highgate, VT	VAOT Specification Requirements
Sieve Size	% Passing	% Passing
3/8"	100	100
# 4	99	95-100
# 8	86	-
# 16	66	50-80
# 30	41	25-60
# 50	16	10-30
#100	4	2-10
Fineness Modulus	2.88	2.60-3.10
Color	<1	2 Max.

TABLE 8

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
INITIAL MIX-Type IA Cement & Sand For Cement Mortar

Batch Number Type of Mixing	1I Machine	2I Machine	6I Hand	7I Hand
Flow	112.5	110.0	106.5	105.0
Air Content, %	4.8	4.4	4.6	---
Temperature, ^{o}F	76	78	75	73
W/C Ratio	0.371	0.398	0.392	0.385
Comp. Strength, psi				
24 hours-Cube 1	4973	3990	4365	4627
Cube 2	4741	4227	4425	4805
Cube 3	4899	4183	4553	4810
Average	4871	4133	4448	4747
7 days-Cube 1	6565	5918	6046	6249
Cube 2	6719	5800	6308	5196
Cube 3	5596	6066	6308	6135
Average	6293	5928	6221	5860
28 days-Cube 1	6725	6400	7263	6708
Cube 2	7113	6538	7100	6743
Cube 3	6975	6488	7088	7200
Average	6938	6475	7150	6884
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.2	-3.9	+0.6	+1.0
Specimen B	-1.3	-3.0	+0.5	+0.9
100 Cycles-Specimen A	-1.4	-6.8	+0.7	+1.0
Specimen B	-1.6	-5.4	+0.2	+1.0
150 Cycles-Specimen A	-1.3	-7.6	+0.8	+0.9
Specimen B	-1.5	-6.1	+0.1	+0.9
200 Cycles-Specimen A	-1.3	-8.0	+0.9	+0.8
Specimen B	-1.5	-6.4	-0.1	+0.9
250 Cycles-Specimen A	-1.3	-8.2	+0.9	+0.7
Specimen B	-1.6	-6.8	-0.3	+0.7
300 Cycles-Specimen A	-1.4	-8.4	+0.9	+0.4
Specimen B	-1.8	-7.1	-0.4	+0.5

TABLE 9

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
RETEMPERED MIX-Type IA Cement & Sand For Cement Mortar

Batch Number Type of Mixing	1R Machine	2R Machine	6R Hand	7R Hand
Flow	112.0	110.0	109.5	105.5
Air Content, %	4.6	3.8	4.5	4.7
Temperature, ^{o}F	77	79	75	75
W/C Ratio	0.376	0.408	0.398	0.395
Comp. Strength, psi				
24 hours-Cube 1	4316	4267	4865	4138
Cube 2	4529	4099	4316	4385
Cube 3	4499	4262	4573	4578
Average	4448	4209	4585	4367
7 days-Cube 1	7589	5715	6274	6002
Cube 2	6570	5814	5553	5992
Cube 3	7015	6551	6002	5953
Average	7058	6027	5943	5982
28 days-Cube 1	7300	6488	6775	7388
Cube 2	7150	6525	7350	7338
Cube 3	7438	6688	6975	7065
Average	7296	6567	7033	7264
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-0.4	-2.8	+0.5	+1.0
Specimen B	-0.9	-3.2	+1.0	+1.4
100 Cycles-Specimen A	-0.8	-4.9	+0.4	+1.0
Specimen B	-1.2	-5.7	+0.9	+1.2
150 Cycles-Specimen A	-0.8	-5.5	+0.4	+0.9
Specimen B	-1.2	-6.3	+0.6	+0.9
200 Cycles-Specimen A	-0.8	-5.8	+0.4	+0.9
Specimen B	-1.3	-6.6	+0.4	+0.8
250 Cycles-Specimen A	-0.8	-6.1	+0.2	+0.8
Specimen B	-1.4	-6.8	+0.2	+0.6
300 Cycles-Specimen A	-0.9	-6.4	+0.1	+0.5
Specimen B	-1.6	-7.2	+0.1	+0.5

TABLE 10

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
INITIAL MIX-Type IA Cement & Sand For Cement Mortar

Batch Number Type of Mixing	4I Machine	5I Machine	8I Hand	9I Hand
Flow	105.0	106.0	105.5	115.0
Air Content, %	6.8	6.8	6.6	6.8
Temperature, ^{o}F	80	76	77	76
W/C Ratio	0.473	0.462	0.493	0.482
Comp. Strength, psi				
24 hours-Cube 1	3036	3335	2899	2838
Cube 2	2932	3243	2830	3042
Cube 3	2966	3579	2855	2881
Average	2978	3386	2861	2920
7 days-Cube 1	4983	5092	4400	4700
Cube 2	4791	4924	4338	4688
Cube 3	4726	5023	4675	4588
Average	4833	5013	4471	4659
28 days-Cube 1	5175	5763	4900	5375
Cube 2	5275	5100	4938	5425
Cube 3	5050	5425	5025	5438
Average	5167	5429	4954	5413
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-2.7	+0.3	-0.7	-1.0
Specimen B	-1.7	+0.4	-0.9	-0.4
100 Cycles-Specimen A	-7.5	0.0	-1.5	-2.2
Specimen B	-2.4	-0.1	-2.4	-1.8
150 Cycles-Specimen A	-10.2	-0.4	-1.8	-2.7
Specimen B	-2.6	-0.5	-3.5	-2.6
200 Cycles-Specimen A	-11.5	-0.6	-2.5	-3.2
Specimen B	-3.3	-0.5	-4.4	-3.2
250 Cycles-Specimen A	-12.7	-0.7	-3.0	-4.1
Specimen B	-3.6	-0.7	-5.4	-3.8
300 Cycles-Specimen A	-13.5	-1.0	-3.5	-4.8
Specimen B	-4.0	-1.1	-6.1	-4.6

TABLE 11

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
RETEMPERED MIX-Type IA Cement & Sand For Cement Mortar

Batch Number Type of Mixing	4R Machine	5R Machine	8R Hand	9R Hand
Flow	105.5	112.0	107.0	106.5
Air Content, %	6.5	6.8	6.6	6.3
Temperature, ^{o}F	74	75	76	76
W/C Ratio	0.487	0.481	0.499	0.482
Comp. Strength, psi				
24 hours-Cube 1	2788	3120	2788	2937
Cube 2	2719	3006	2847	3007
Cube 3	2897	3174	2857	3021
Average	2801	3100	2831	2988
7 days-Cube 1	4662	4761	4363	4213
Cube 2	4682	4647	4263	4688
Cube 3	4529	4692	4525	4650
Average	4624	4700	4384	4517
28 days-Cube 1	5363	5463	4813	5088
Cube 2	5325	5600	4963	5188
Cube 3	5038	5000	5088	5300
Average	5242	5354	4955	5192
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.4	0.0	-0.9	-0.5
Specimen B	+0.2	+0.3	-0.7	-0.7
100 Cycles-Specimen A	-1.6	-0.3	-2.3	-1.6
Specimen B	-0.1	0.0	-2.3	-1.7
150 Cycles-Specimen A	-1.5	-0.6	-2.5	-2.4
Specimen B	-0.4	-0.4	-3.2	-2.8
200 Cycles-Specimen A	-1.8	-0.8	-3.0	-3.2
Specimen B	-0.7	-0.7	-4.1	-3.4
250 Cycles-Specimen A	-2.3	-1.0	-3.5	-3.8
Specimen B	-1.1	-1.0	-5.0	-3.8
300 Cycles-Specimen A	-2.6	-1.2	-3.7	-4.5
Specimen B	-1.3	-1.3	-5.6	-4.4

TABLE 12

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
INITIAL MIX-Type S-Masonry Cement & Sand For Cement Mortar

Batch Number	10I	11I	14I	15I
Type of Mixing	Machine	Machine	Hand	Hand
Flow	109.0	106.5	114.0	115.0
Air Content, %	3.5	4.0	4.2	3.7
Temperature, ^{o}F	76	76	75	74
W/C Ratio	0.361	0.354	0.345	0.346
Comp. Strength, psi				
24 hours-Cube 1	2863	2213	2713	2218
Cube 2	2975	2300	2638	2155
Cube 3	2938	2225	2550	2103
Average	2925	2246	2634	2159
7 days-Cube 1	5088	4800	5260	4913
Cube 2	4625	5475	4923	4975
Cube 3	5325	5250	4855	5088
Average	5013	5175	5013	4992
28 days-Cube 1	5500	5375	5363	5298
Cube 2	5800	5350	5590	5848
Cube 3	5238	4825	5593	5258
Average	5513	5138	5515	5468
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.4	-1.7	-2.1	-4.4
Specimen B	-0.8	-1.8	-0.8	-3.2
100 Cycles-Specimen A	-4.1	-6.2	-9.5	-9.7
Specimen B	-3.4	-5.8	-8.4	-9.1
150 Cycles-Specimen A	-7.4	-10.2	-15.1	-16.6
Specimen B	-5.0	-10.1	-15.2	-14.9
200 Cycles-Specimen A	-10.2	-13.3	-19.2	-21.2
Specimen B	-7.0	-14.6	-20.1	-18.6
250 Cycles-Specimen A	-12.3	-14.9	-22.5	*****
Specimen B	-9.0	-16.5	-22.7	-24.9
300 Cycles-Specimen A	-14.4	-16.5	*****	*****
Specimen B	-11.2	-19.1	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 13

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
RETEMPERED MIX-Type S-Masonry Cement & Sand For Cement Mortar

Batch Number Type of Mixing	10R Machine	11R Machine	14R Hand	15R Hand
Flow	108.0	106.5	109.0	105.0
Air Content, %	2.6	3.0	3.7	3.6
Temperature, ^{o}F	76	78	78	76
W/C Ratio	0.383	0.372	0.366	0.346
Comp. Strength, psi				
24 hours-Cube 1	2775	2288	2800	2245
Cube 2	2850	2338	2763	2310
Cube 3	2825	2475	2763	2155
Average	2817	2367	2775	2237
7 days-Cube 1	4688	4888	5125	5125
Cube 2	4725	5275	4963	5338
Cube 3	5145	5125	5105	5163
Average	4853	5096	5064	5209
28 days-Cube 1	6025	4788	5808	5540
Cube 2	5600	4988	5745	5528
Cube 3	5725	5600	6123	5585
Average	5783	5125	5892	5551
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.5	-0.3	-6.3	-5.8
Specimen B	-2.3	-0.8	-5.0	-6.9
100 Cycles-Specimen A	-4.4	-2.3	-14.0	-14.0
Specimen B	-5.8	-4.1	-12.3	-24.4
150 Cycles-Specimen A	-7.2	-4.0	-21.8	-23.6
Specimen B	-8.5	-6.2	-19.4	*****
200 Cycles-Specimen A	-9.2	-5.5	-27.4	*****
Specimen B	-10.4	-9.6	-25.0	*****
250 Cycles-Specimen A	-10.7	-6.4	*****	*****
Specimen B	-12.0	-11.5	*****	*****
300 Cycles-Specimen A	-12.1	-8.3	*****	*****
Specimen B	-14.2	-13.4	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 14

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
INITIAL MIX-Type S-Masonry Cement & Sand For Cement Mortar

Batch Number Type of Mixing	12I Machine	13I Machine	16I Hand	17I Hand
Flow	109.5	114.5	105.5	110.5
Air Content, %	6.5	7.5	6.6	6.6
Temperature, ^{o}F	79	77	73	71
W/C Ratio	0.445	0.448	0.420	0.421
Comp. Strength, psi				
24 hours-Cube 1	1463	1313	1420	1378
Cube 2	1550	1350	1465	1393
Cube 3	1450	1425	1480	1373
Average	1488	1363	1455	1381
7 days-Cube 1	3263	3078	3900	3700
Cube 2	3588	3048	3788	3713
Cube 3	3638	3313	3675	3800
Average	3496	3146	3788	3738
28 days-Cube 1	3450	3190	4493	4285
Cube 2	3575	3533	4013	4153
Cube 3	3300	3048	4445	3703
Average	3442	3257	4317	4047
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-0.2	+0.3	-4.6	-3.9
Specimen B	-0.4	-1.4	-4.4	-5.4
100 Cycles-Specimen A	-1.3	-1.7	-8.0	-7.0
Specimen B	-1.7	-5.0	-9.0	-9.6
150 Cycles-Specimen A	-2.1	-2.7	-11.0	-10.3
Specimen B	-2.9	-8.2	-12.7	-14.0
200 Cycles-Specimen A	-3.3	-4.1	-13.3	-13.5
Specimen B	-4.3	-11.2	-16.0	-18.3
250 Cycles-Specimen A	-4.4	-5.4	-16.4	-16.1
Specimen B	-5.5	-14.2	-20.0	-22.5
300 Cycles-Specimen A	-5.6	-6.7	-19.6	-18.7
Specimen B	-7.1	-16.4	*****	-25.6

***** - Indicates specimens removed due to severe deterioration.

TABLE 15

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
RETEMPERED MIX-Type S-Masonry Cement & Sand For Cement Mortar

Batch Number Type of Mixing	12R Machine	13R Machine	16R Hand	17R Hand
Flow	106.5	106.5	106.5	108.5
Air Content, %	6.0	6.0	6.3	6.4
Temperature, ^{o}F	79	73	75	74
W/C Ratio	0.461	0.466	0.442	0.447
Comp. Strength, psi				
24 hours-Cube 1	1563	1488	1343	1253
Cube 2	1788	1563	1383	1253
Cube 3	1613	1588	1443	1170
Average	1655	1546	1390	1225
7 days-Cube 1	3450	3130	3525	3350
Cube 2	3550	3040	3638	3375
Cube 3	3463	3300	3638	3488
Average	3488	3157	3600	3404
28 days-Cube 1	3625	3643	3983	3878
Cube 2	3513	3745	4048	3963
Cube 3	3438	3748	3840	3593
Average	3525	3712	3957	3811
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.2	-0.2	-6.5	-4.4
Specimen B	-1.9	-0.6	-4.5	-4.2
100 Cycles-Specimen A	-1.8	-1.5	-11.4	-6.9
Specimen B	-3.3	-2.1	-13.9	-8.8
150 Cycles-Specimen A	-2.8	-2.3	-20.4	-9.8
Specimen B	-4.6	-3.2	-21.1	-14.6
200 Cycles-Specimen A	-3.9	-4.0	*****	-12.0
Specimen B	-6.5	-4.7	*****	-18.1
250 Cycles-Specimen A	-4.8	-5.4	*****	-14.4
Specimen B	-7.3	-5.5	*****	-22.1
300 Cycles-Specimen A	-5.6	-6.8	*****	-16.3
Specimen B	-8.2	-6.8	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 16

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
INITIAL MIX-Type II Cement & Sand For Cement Mortar

Batch Number	18I	19I	22I	23I
Type of Mixing	Machine	Machine	Hand	Hand
Flow	113.5	115.5	107.0	113.0
Air Content, %	3.5	3.8	3.3	3.3
Temperature, ^{o}F	76	78	73	72
W/C Ratio	0.338	0.334	0.330	0.338
Comp. Strength, psi				
24 hours-Cube 1	3978	4738	4338	3988
Cube 2	3745	4663	4263	3938
Cube 3	3770	4700	4138	4100
Average	3831	4700	4246	4009
7 days-Cube 1	6975	8125	7348	7525
Cube 2	7625	7625	7290	7328
Cube 3	7375	7625	7115	7578
Average	7325	7792	7251	7477
28 days-Cube 1	7413	8300	7293	8230
Cube 2	8458	8258	7528	8230
Cube 3	7748	8025	7923	8415
Average	7873	8194	7581	8292
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.9	-1.3	-0.6	-1.9
Specimen B	-3.0	-2.4	-0.5	-0.7
100 Cycles-Specimen A	-7.0	-7.5	-8.1	-8.9
Specimen B	-7.4	-9.1	-9.3	-12.2
150 Cycles-Specimen A	-11.4	-11.1	-13.0	-16.8
Specimen B	-11.0	-13.7	-15.4	-28.2
200 Cycles-Specimen A	-13.7	-13.4	-16.9	-23.0
Specimen B	-13.1	-16.5	-20.6	*****
250 Cycles-Specimen A	-15.5	-15.5	-19.8	*****
Specimen B	-15.2	-18.7	*****	*****
300 Cycles-Specimen A	-17.0	-17.3	*****	*****
Specimen B	-16.9	*****	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 17

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
RETEMPERED MIX-Type II Cement & Sand For Cement Mortar

Batch Number Type of Mixing	18R Machine	19R Machine	22R Hand	23R Hand
Flow	112.0	115.0	107.0	109.0
Air Content, %	2.8	2.9	3.0	3.4
Temperature, ^{o}F	75	77	71	70
W/C Ratio	0.343	0.345	0.339	0.345
Comp. Strength, psi				
24 hours-Cube 1	3865	4425	4325	4213
Cube 2	4080	4513	4300	4588
Cube 3	4280	4313	4338	4350
Average	4075	4417	4321	4384
7 days-Cube 1	7125	7625	7093	7733
Cube 2	7250	7875	6970	7255
Cube 3	7875	7250	6870	7503
Average	7417	7583	6978	7497
28 days-Cube 1	7325	8523	7665	8080
Cube 2	7148	7755	7245	7883
Cube 3	7163	7755	7435	8345
Average	7212	8011	7448	8103
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-3.4	-1.7	0.0	-0.8
Specimen B	-1.0	-0.4	-0.8	-0.8
100 Cycles-Specimen A	-10.3	-6.2	-7.7	-8.5
Specimen B	-4.9	-2.6	-12.5	-6.8
150 Cycles-Specimen A	-15.8	-8.6	-12.8	-13.6
Specimen B	-8.2	-4.5	-18.2	-13.6
200 Cycles-Specimen A	-19.5	-9.9	-----	-18.6
Specimen B	-10.0	-5.8	*****	-17.1
250 Cycles-Specimen A	-22.2	-11.2	-19.2	-24.0
Specimen B	-11.6	-6.7	*****	-20.5
300 Cycles-Specimen A	*****	-12.0	-21.0	*****
Specimen B	-12.9	-7.7	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 18

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
INITIAL MIX-Type II Cement & Sand For Cement Mortar

Batch Number Type of Mixing	20I Machine	21I Machine	24I Hand	25I Hand
Flow	113.0	108.5	109.0	111.5
Air Content, %	6.0	6.3	5.9	6.0
Temperature, °F	78	77	72	74
W/C Ratio	0.384	0.423	0.426	0.423
Comp. Strength, psi				
24 hours-Cube 1	2838	2950	2138	2353
Cube 2	3033	2888	2213	2315
Cube 3	3000	2775	2150	2383
Average	2959	2871	2167	2350
7 days-Cube 1	5325	4788	4670	5138
Cube 2	5300	5238	4500	5188
Cube 3	5375	5150	4485	5338
Average	5333	5059	4552	5221
28 days-Cube 1	5930	5693	5133	5475
Cube 2	5880	5900	5250	5325
Cube 3	5778	5450	5275	5200
Average	5863	5681	5219	5333
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-8.1	-2.7	-1.6	-3.0
Specimen B	-6.6	-2.7	-3.9	-3.5
100 Cycles-Specimen A	-19.4	-9.9	-9.8	-4.6
Specimen B	-19.9	-9.3	-11.9	-4.3
150 Cycles-Specimen A	*****	-16.1	-17.4	-9.9
Specimen B	*****	-17.3	-17.9	-9.9
200 Cycles-Specimen A	*****	-19.7	-31.6	-16.1
Specimen B	*****	-21.2	-24.7	-16.3
250 Cycles-Specimen A	*****	-23.2	*****	-21.2
Specimen B	*****	*****	*****	-21.8
300 Cycles-Specimen A	*****	*****	*****	*****
Specimen B	*****	*****	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 19

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
RETEMPERED MIX-Type II Cement & Sand For Cement Mortar

Batch Number Type of Mixing	20R Machine	21R Machine	24R Hand	25R Hand
Flow	109.5	106.5	106.0	106.0
Air Content, %	5.5	6.2	6.4	6.3
Temperature, ^{o}F	80	78	70	73
W/C Ratio	0.400	0.440	0.436	0.434
Comp. Strength, psi				
24 hours-Cube 1	2650	2863	2250	2375
Cube 2	2863	2725	2225	2273
Cube 3	2575	2850	2263	2355
Average	2696	2813	2246	2334
7 days-Cube 1	5000	4800	4540	4863
Cube 2	4988	4663	4443	4988
Cube 3	5088	4700	4660	4415
Average	5025	4721	4548	4755
28 days-Cube 1	5340	5303	5310	5250
Cube 2	5360	5443	4995	5455
Cube 3	5083	5205	5293	5355
Average	5261	5317	5199	5353
Resistance To Rapid Freezing And Thawing % weight change				
50 Cycles-Specimen A	-5.0	-3.4	-2.8	+0.5
Specimen B	-4.1	-2.3	-3.5	+0.3
100 Cycles-Specimen A	-12.0	-8.7	-10.5	-0.5
Specimen B	-11.9	-6.0	-8.5	-1.1
150 Cycles-Specimen A	-16.9	-13.7	-19.2	-2.1
Specimen B	-20.2	-10.1	-15.0	-3.3
200 Cycles-Specimen A	-20.6	-15.7	-26.1	-5.7
Specimen B	-24.8	-12.3	-19.4	-8.9
250 Cycles-Specimen A	*****	-16.7	*****	-8.0
Specimen B	*****	-14.6	-23.9	-11.1
300 Cycles-Specimen A	*****	-20.4	*****	-7.7
Specimen B	*****	-16.5	*****	-13.6

***** - Indicates specimens removed due to severe deterioration.

TABLE 20

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
INITIAL MIX-Type IA Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	31I Machine	32I Machine	35I Hand	36I Hand
Flow	105.5	114.5	108.0	110.0
Air Content, %	3.3	3.5	3.2	3.6
Temperature, ^{o}F	77	75	74	77
W/C Ratio	0.341	0.339	0.356	0.381
Comp. Strength, psi				
24 hours-Cube 1	6100	5775	5710	5122
Cube 2	5825	6475	5545	5102
Cube 3	6625	5750	6235	5140
Average	6183	6000	5830	5121
7 days-Cube 1	7798	8115	6890	6935
Cube 2	7608	7933	6910	6250
Cube 3	7603	7725	6778	5943
Average	7670	7924	6859	6376
28 days-Cube 1	7735	7298	7673	6762
Cube 2	8298	7920	7263	6550
Cube 3	8480	7068	6820	6527
Average	8171	7429	7252	6613
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.4	-0.5	-3.7	-0.5
Specimen B	-1.2	-0.8	-3.5	-0.8
100 Cycles-Specimen A	-2.7	-2.7	-5.3	-2.8
Specimen B	-2.6	-2.9	-5.0	-4.0
150 Cycles-Specimen A	-3.3	-2.5	-6.5	-4.5
Specimen B	-3.6	-3.4	-5.9	-5.9
200 Cycles-Specimen A	-5.2	-1.4	-7.6	-5.5
Specimen B	-5.6	-2.4	-6.8	-7.3
250 Cycles-Specimen A	-5.7	-1.8	-7.7	-6.3
Specimen B	-6.0	-2.8	-7.5	-8.4
300 Cycles-Specimen A	-6.3	-2.4	-8.6	-7.1
Specimen B	-6.6	-3.5	-8.5	-9.4

TABLE 21

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
RETEMPERED MIX-Type IA Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	31R Machine	32R Machine	35R Hand	36R Hand
Flow	107.5	109.0	108.5	106.0
Air Content, %	3.1	3.1	3.3	3.7
Temperature, ^{o}F	79	77	73	77
W/C Ratio	0.353	0.347	0.363	0.385
Comp. Strength, psi				
24 hours-Cube 1	5900	5425	5580	5025
Cube 2	5650	5500	6000	5132
Cube 3	5975	5500	5935	5025
Average	5842	5475	5838	5061
7 days-Cube 1	7375	6958	6850	6748
Cube 2	7288	7243	6855	6355
Cube 3	7420	7345	6440	6800
Average	7361	7182	6715	6634
28 days-Cube 1	7868	7848	7268	6228
Cube 2	7380	7228	7020	6735
Cube 3	6983	7615	7218	6549
Average	7410	7564	7169	6504
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.0	-0.3	-3.8	0.0
Specimen B	-0.6	-1.5	-3.8	+0.7
100 Cycles-Specimen A	-2.3	-2.1	-5.2	-1.5
Specimen B	-1.5	-2.5	-5.5	-1.0
150 Cycles-Specimen A	-2.9	-2.9	-6.3	-2.4
Specimen B	-1.9	-3.0	-6.7	-2.3
200 Cycles-Specimen A	-4.7	-5.0	-7.3	-3.6
Specimen B	-3.8	-4.9	-7.8	-3.3
250 Cycles-Specimen A	-5.1	-5.7	-8.2	-4.5
Specimen B	-4.1	-5.4	-8.7	-4.5
300 Cycles-Specimen A	-5.7	-6.6	-9.3	-5.4
Specimen B	-4.8	-6.3	-9.9	-5.1

TABLE 22

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
INITIAL MIX-Type IA Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	33I Machine	34I Machine	37I Hand	38I Hand
Flow	110.5	109.0	115.8	112.0
Air Content, %	5.3	5.5	4.7	4.6
Temperature, ^{o}F	76	70	79	77
W/C Ratio	0.485	0.403	0.432	0.450
Comp. Strength, psi				
24 hours-Cube 1	4098	4190	4092	4488
Cube 2	4025	3968	4258	4325
Cube 3	4103	4218	4068	4380
Average	4075	4125	4139	4398
7 days-Cube 1	5738	5920	5575	5835
Cube 2	6038	6230	5900	5608
Cube 3	5588	6258	5728	5703
Average	5788	6136	5734	5715
28 days-Cube 1	6600	6530	5920	6058
Cube 2	6685	6178	6128	6470
Cube 3	6618	6373	6098	6313
Average	6634	6360	6048	6280
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.9	-1.1	-1.3	-1.7
Specimen B	+0.4	-3.0	-0.7	-0.2
100 Cycles-Specimen A	-2.6	-1.0	-5.5	-6.0
Specimen B	+1.1	-2.9	-5.4	-2.6
150 Cycles-Specimen A	-1.7	-2.7	-10.1	-8.7
Specimen B	+0.3	-5.2	-10.4	-3.8
200 Cycles-Specimen A	-2.3	-3.6	-15.2	-10.3
Specimen B	-0.2	-6.5	-15.3	-5.7
250 Cycles-Specimen A	-2.7	-4.9	-18.3	-11.6
Specimen B	-0.5	-8.3	-18.7	-7.2
300 Cycles-Specimen A	-3.2	-6.1	-21.0	-14.1
Specimen B	-0.9	-9.4	-21.5	-8.9

TABLE 23

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
RETEMPERED MIX-Type IA Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	33R Machine	34R Machine	37R Hand	38R Hand
Flow	106.5	105.0	106.5	106.0
Air Content, %	5.2	5.0	4.6	4.9
Temperature, ^{O}F	72	69	79	77
W/C Ratio	0.494	0.416	0.439	0.448
Comp. Strength, psi				
24 hours-Cube 1	3940	4428	4068	4460
Cube 2	3900	4533	4395	4275
Cube 3	3983	4260	4112	4228
Average	3941	4407	4192	4321
7 days-Cube 1	5850	6288	5332	6100
Cube 2	5710	6255	5725	5900
Cube 3	5720	6310	5765	6228
Average	5760	6284	5607	6076
28 days-Cube 1	6243	5803	6125	5817
Cube 2	6253	6183	6228	5970
Cube 3	6600	6120	6443	5945
Average	6365	6035	6265	5911
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-0.1	-0.9	-1.8	-1.7
Specimen B	-1.8	-1.0	-1.2	-0.8
100 Cycles-Specimen A	-1.2	-1.6	-5.2	-5.0
Specimen B	-2.5	-1.5	-3.9	-4.3
150 Cycles-Specimen A	-1.8	-2.2	-7.5	-6.9
Specimen B	-1.4	-2.9	-5.5	-6.0
200 Cycles-Specimen A	-0.8	-2.8	-8.9	-8.5
Specimen B	-1.7	-3.0	-6.8	-7.0
250 Cycles-Specimen A	-1.2	-3.0	-10.5	-10.1
Specimen B	-2.2	-3.0	-8.5	-8.3
300 Cycles-Specimen A	-1.8	-3.7	-12.5	-12.0
Specimen B	-2.7	-3.6	-10.4	-9.9

TABLE 24

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
INITIAL MIX-Type S-Masonry Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	39I Machine	40I Machine	43I Hand	44I Hand
Flow	106.5	112.0	105.5	114.5
Air Content, %	2.6	2.8	3.1	2.9
Temperature, ^{o}F	79	79	77	77
W/C Ratio	0.351	0.353	0.348	0.350
Comp. Strength, psi				
24 hours-Cube 1	3170	2745	2645	2095
Cube 2	3395	2733	2523	2123
Cube 3	3195	2495	2533	2235
Average	3253	2658	2567	2151
7 days-Cube 1	4780	4600	5213	5113
Cube 2	4840	4545	4948	4710
Cube 3	4960	4533	5003	4603
Average	4860	4559	5055	4809
28 days-Cube 1	5320	4973	6410	5573
Cube 2	5148	4835	6213	5098
Cube 3	5570	4620	6483	5095
Average	5346	4809	6369	5255
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-3.1	-1.8	-7.1	-7.4
Specimen B	-2.3	-1.6	-7.6	-10.0
100 Cycles-Specimen A	-7.9	-9.3	-18.6	-12.3
Specimen B	-6.5	-10.4	-12.4	-15.7
150 Cycles-Specimen A	-10.3	-16.7	-23.2	-18.4
Specimen B	-9.4	-17.1	-14.4	-23.6
200 Cycles-Specimen A	-12.4	-21.2	*****	-29.2
Specimen B	-11.5	-21.2	-17.8	-27.0
250 Cycles-Specimen A	-13.4	-24.7	*****	*****
Specimen B	-14.1	-25.0	-20.1	*****
300 Cycles-Specimen A	-16.9	-28.8	*****	*****
Specimen B	-16.1	-28.0	-26.0	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 25

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
RETEMPERED MIX-Type S-Masonry Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	39R Machine	40R Machine	43R Hand	44R Hand
Flow	107.5	111.5	106.0	106.0
Air Content, %	1.8	2.4	2.6	2.6
Temperature, °F	84	80	76	76
W/C Ratio	0.378	0.378	0.365	0.362
Comp. Strength, psi				
24 hours-Cube 1	3050	2643	2473	2093
Cube 2	3008	2408	2395	2045
Cube 3	2868	2668	2455	2153
Average	2975	2573	2441	2097
7 days-Cube 1	4625	4433	4815	4530
Cube 2	4593	4483	4918	4453
Cube 3	4663	4380	4793	4235
Average	4627	4432	4842	4406
28 days-Cube 1	4680	4545	5285	5440
Cube 2	4683	4423	5635	5310
Cube 3	4530	4800	5765	4870
Average	4631	4589	5562	5207
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-2.4	-19.0	-7.0	-10.5
Specimen B	-2.8	-21.5	-11.4	-7.4
100 Cycles-Specimen A	-7.4	-33.8	-11.8	-17.4
Specimen B	-7.7	-37.3	-21.9	-14.5
150 Cycles-Specimen A	-12.3	*****	-14.3	-23.2
Specimen B	-13.4	*****	-24.7	-21.8
200 Cycles-Specimen A	-15.2	*****	-17.4	-25.7
Specimen B	-16.8	*****	-29.4	-24.9
250 Cycles-Specimen A	-17.9	*****	-19.4	*****
Specimen B	-19.4	*****	*****	*****
300 Cycles-Specimen A	-20.0	*****	-21.9	*****
Specimen B	-21.7	*****	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 26

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
INITIAL MIX-Type S-Masonry Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	41I Machine	42I Machine	45I Hand	46I Hand
Flow	112.5	113.5	106.5	105.5
Air Content, %	6.3	6.0	4.9	5.0
Temperature, ^{O}F	74	78	77	77
W/C Ratio	0.420	0.418	0.391	0.412
Comp. Strength, psi				
24 hours-Cube 1	1555	1495	1845	1773
Cube 2	1563	1450	1985	1718
Cube 3	1560	1538	1933	1810
Average	1559	1494	1921	1767
7 days-Cube 1	3023	3148	3795	3230
Cube 2	2820	3068	3818	3383
Cube 3	3003	3293	3645	3413
Average	2949	3170	3753	3342
28 days-Cube 1	3915	4005	5028	3993
Cube 2	3435	3780	4500	4368
Cube 3	3728	3590	5095	4378
Average	3693	3792	4874	4246
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-2.7	-3.0	-8.3	-7.8
Specimen B	-1.2	-2.4	-9.1	-6.9
100 Cycles-Specimen A	-4.6	-5.9	-16.4	-15.5
Specimen B	-4.2	-6.2	-17.1	-17.0
150 Cycles-Specimen A	-6.0	-9.6	-23.7	-26.8
Specimen B	-6.9	-9.8	-25.2	-24.7
200 Cycles-Specimen A	-7.4	-11.0	-30.3	*****
Specimen B	-9.5	-11.5	-34.6	*****
250 Cycles-Specimen A	-9.0	-13.3	*****	*****
Specimen B	-11.7	-13.9	*****	*****
300 Cycles-Specimen A	-9.9	-15.1	*****	*****
Specimen B	-13.5	-15.9	*****	*****

***** - Indicates specimens removed due to severe deterioration.

TABLE 27

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
RETEMPERED MIX-Type S-Masonry Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	41R Machine	42R Machine	45R Hand	46R Hand
Flow	106.0	*116.5	106.5	105.0
Air Content, %	5.8	5.4	4.1	4.9
Temperature, °F	73	78	75	78
W/C Ratio	0.439	0.455	0.422	0.417
Comp. Strength, psi				
24 hours-Cube 1	1675	1348	1620	1748
Cube 2	1663	1430	1670	1785
Cube 3	1675	1383	1613	1695
Average	1671	1387	1634	1743
7 days-Cube 1	3035	2615	3865	3335
Cube 2	3010	2863	3650	3300
Cube 3	3228	2715	3355	3348
Average	3091	2731	3623	3328
28 days-Cube 1	3395	3313	4465	4073
Cube 2	3375	3053	4508	4298
Cube 3	3385	3185	4223	4230
Average	3385	3184	4399	4200
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.8	-2.6	-11.9	-7.2
Specimen B	-2.5	-5.0	-10.2	-6.4
100 Cycles-Specimen A	-4.6	-6.3	-23.7	-13.6
Specimen B	-4.1	-10.6	-21.4	-11.9
150 Cycles-Specimen A	-7.3	-10.0	-32.3	-19.9
Specimen B	-6.2	-14.3	-29.1	-17.0
200 Cycles-Specimen A	-9.7	-11.8	*****	-26.0
Specimen B	-7.8	-18.4	*****	-21.9
250 Cycles-Specimen A	-12.0	-14.6	*****	-32.0
Specimen B	-9.5	-20.6	*****	-26.4
300 Cycles-Specimen A	-13.8	-17.0	*****	*****
Specimen B	-10.5	-22.6	*****	*****

* - First Flow test 120+ - retest 116.5
***** - Indicates specimens removed due to severe deterioration.

TABLE 28

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
INITIAL MIX-Type II Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	47I Machine	48I Machine	51I Hand	52I Hand
Flow	114.5	113.0	111.5	110.0
Air Content, %	3.2	3.4	3.3	3.1
Temperature, ^{o}F	77	70	66	68
W/C Ratio	0.336	0.344	0.337	0.324
Comp. Strength, psi				
24 hours-Cube 1	5240	4655	3478	4488
Cube 2	4928	4948	3458	4415
Cube 3	5152	4785	3500	4598
Average	5107	4796	3479	4500
7 days-Cube 1	6750	8055	*7943	7683
Cube 2	6973	8120	*7825	7950
Cube 3	6333	8148	*7873	7973
Average	6685	8108	*7880	7870
28 days-Cube 1	7405	7913	7573	7545
Cube 2	7493	7850	7590	7415
Cube 3	7303	7780	8223	7650
Average	7400	7840	7795	7537
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-2.7	-1.3	+0.4	+0.2
Specimen B	-2.7	-1.7	+0.2	+0.6
100 Cycles-Specimen A	-5.7	-4.5	-0.4	-0.5
Specimen B	-5.5	-5.8	-0.8	0.0
150 Cycles-Specimen A	-10.0	-6.4	-0.9	-1.7
Specimen B	-10.2	-7.8	-1.3	-0.3
200 Cycles-Specimen A	-12.3	-7.3	-1.0	-2.2
Specimen B	-13.2	-8.8	-1.5	-0.7
250 Cycles-Specimen A	-14.2	-8.4	-1.3	-2.6
Specimen B	-15.0	-9.7	-1.9	-1.0
300 Cycles-Specimen A	-16.1	-11.3	-1.5	-3.0
Specimen B	-17.4	-10.8	-2.0	-1.2

* - These cubes were tested at 8 days.

TABLE 29

TEST RESULTS-TYPE I MORTAR(one part cement/one part sand)
RETEMPERED MIX-Type II Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	47R Machine	48R Machine	51R Hand	52R Hand
Flow	106.0	106.0	108.0	109.0
Air Content, %	2.7	2.9	3.3	3.0
Temperature, ^{o}F	74	69	64	66
W/C Ratio	0.336	0.350	0.343	0.332
Comp. Strength, psi				
24 hours-Cube 1	5015	4248	3493	4610
Cube 2	5375	4090	3520	4560
Cube 3	5255	4095	3445	4618
Average	5215	4144	3486	4596
7 days-Cube 1	7238	7773	*7645	7548
Cube 2	7280	8023	*7078	7333
Cube 3	7110	7135	*7703	7255
Average	7209	7644	*7475	7379
28 days-Cube 1	8340	8185	7420	7770
Cube 2	7908	7513	7563	7468
Cube 3	7668	7250	7463	8128
Average	7972	7649	7481	7789
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-2.7	-2.2	-0.1	+0.4
Specimen B	-1.0	-4.0	+0.1	+0.2
100 Cycles-Specimen A	-3.4	-4.2	-0.7	-0.3
Specimen B	-4.3	-5.9	-1.5	-0.2
150 Cycles-Specimen A	-5.8	-4.9	-1.5	-0.7
Specimen B	-7.8	-7.1	-3.3	-0.6
200 Cycles-Specimen A	-8.2	-5.5	-1.8	-0.9
Specimen B	-10.7	-8.0	-4.2	-0.8
250 Cycles-Specimen A	-9.6	-6.2	-2.2	-1.2
Specimen B	-12.3	-8.8	-5.1	-1.1
300 Cycles-Specimen A	-11.6	-7.5	-2.6	-1.3
Specimen B	-14.4	-9.5	-5.8	-0.9

* - These cubes were tested at 8 days.

TABLE 30

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
INITIAL MIX-Type II Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	49I Machine	50I Machine	53I Hand	54I Hand
Flow	107.0	108.0	113.5	110.5
Air Content, %	4.2	4.4	4.5	4.3
Temperature, °F	68	66	70	66
W/C Ratio	0.373	0.386	0.398	0.388
Comp. Strength, psi				
24 hours-Cube 1	2715	2838	2173	2823
Cube 2	2738	2838	2158	2780
Cube 3	2690	2890	2188	2880
Average	2714	2855	2173	2828
7 days-Cube 1	5815	5708	6215	5625
Cube 2	5885	6513	6313	6620
Cube 3	5498	6405	6350	6970
Average	5733	6209	6293	6405
28 days-Cube 1	6653	6458	6875	6433
Cube 2	6513	6380	6998	6360
Cube 3	6795	6463	6795	6530
Average	6653	6434	6889	6441
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-4.0	-0.6	-0.8	+0.3
Specimen B	-3.1	-4.8	0.0	-0.1
100 Cycles-Specimen A	-13.2	-3.8	-5.2	-0.7
Specimen B	-7.6	-4.9	-3.0	-1.8
150 Cycles-Specimen A	-19.2	-9.5	-11.3	-1.7
Specimen B	-16.9	-10.7	-6.5	-2.0
200 Cycles-Specimen A	*****	-11.5	-15.1	-3.1
Specimen B	-21.7	-12.7	-9.6	-2.3
250 Cycles-Specimen A	*****	-13.8	-18.0	-4.5
Specimen B	-25.4	-17.0	-12.3	-2.5
300 Cycles-Specimen A	*****	-15.4	-20.2	-5.9
Specimen B	-28.8	-17.9	-14.4	-3.0

***** - Indicates specimens removed due to severe deterioration.

TABLE 31

TEST RESULTS-TYPE II MORTAR(one part cement/two parts sand)
RETEMPERED MIX-Type II Cement & Fine Aggregate For Concrete

Batch Number Type of Mixing	49R Machine	50R Machine	53R Hand	54R Hand
Flow	113.0	106.0	107.0	106.5
Air Content, %	4.2	4.2	4.5	4.9
Temperature, ^{o}F	64	62	70	67
W/C Ratio	0.397	0.396	0.403	0.398
Comp. Strength, psi				
24 hours-Cube 1	2648	2903	2510	4045
Cube 2	2735	2980	2740	4030
Cube 3	2778	3038	2768	4033
Average	2720	2974	2673	4036
7 days-Cube 1	6103	5890	5858	6550
Cube 2	5953	6460	5863	5810
Cube 3	6145	6058	6145	6315
Average	6068	6136	5955	6225
28 days-Cube 1	6170	6250	6258	5928
Cube 2	6355	6175	6090	6425
Cube 3	6115	6115	6228	6020
Average	6213	6180	6192	6124
Resistance To Rapid Freezing And Thawing, % weight change				
50 Cycles-Specimen A	-1.9	-0.9	+0.3	+0.5
Specimen B	-1.5	-1.1	+0.6	+0.2
100 Cycles-Specimen A	-5.0	-5.6	-1.5	-2.2
Specimen B	-6.5	-4.5	-1.0	-1.7
150 Cycles-Specimen A	-10.3	-9.5	-3.3	-3.6
Specimen B	-14.3	-8.9	-2.6	-2.9
200 Cycles-Specimen A	-15.5	-11.2	-5.3	-4.2
Specimen B	-19.9	-10.1	-5.1	-3.6
250 Cycles-Specimen A	-18.7	-13.6	-6.7	-5.2
Specimen B	-22.9	-11.5	-7.2	-4.5
300 Cycles-Specimen A	-21.2	-15.0	-9.3	-6.4
Specimen B	-26.3	-12.5	-9.8	-5.8