Rapid Freezing and Thawing Test for Aggregate

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This report describes a freezing and thawing procedure which requires about the same test period as the sulfate soundness test. The accelerated action of this test resulted from the use of a water-alcohol solution as the freezing medium rather than water. A home-type freezer was found to be suitable for conducting such a freezing and thawing procedure. The results of freezing and thawing 27 different materials by the water-alcohol method showed that 16 cycles of the method are equal in severity to 5 cycles of the sulfate soundness tests and are much more severe than 50 cycles of freezing and thawing in water. Freezing and thawing in the water-alcohol solution, however, resulted in a different order of soundness being indicated for the various materials than when water was used. The results of the sulfate soundness test did not correlate closely with any of the freezing and thawing procedures.

●THE RESISTANCE of aggregates to natural freezing and thawing is a property which is difficult to evaluate properly in the laboratory. The test most frequently applied to aggregates for this purpose is an accelerated soundness test in which the crystallization of sodium or magnesium sulfate is used to simulate the action of ice formation in aggregate pore spaces. Although the results of this test show a general correlation with the performance of aggregates in service, numerous instances of disagreement with known service records have resulted in considerable loss of confidence in the method. The sulfate soundness test, however, continues to be used extensively because of the short test period and the inexpensive equipment required as compared to most laboratory freezing and thawing procedures.

Further justification for using the sulfate soundness test is frequently based on the fact that laboratory freezing and thawing, per se, does not guarantee a correct evaluation of the durability of an aggregate. Freezing and thawing in the laboratory is generally designed to be more severe than that occurring in nature in order to obtain results in a reasonable length of time. The greater severity of laboratory freezing and thawing not only hastens disintegration, but for some aggregates may cause disintegration which would not occur under most service conditions. At the present time there is no single freezing and thawing procedure which is generally recognized as being suitable for evaluating all aggregates for use under all conditions of exposure. The current AASHO method for freezing and thawing of aggregates, T 103, is specified by only three of the seven state highway departments which include such a test for aggregates in their standard specifications. The remaining four states have developed other procedures which presumably provide more satisfactory results for the aggregates in their particular areas.

PURPOSE OF STUDY

Although there is often difficulty in interpreting the results of a freezing and thawing test, such results usually command greater confidence than those obtained by the sulfate soundness test. Some specifications, for example, permit the use of an aggregate failing the sulfate soundness test provided it passes a freezing and thawing test. In such instances, it is evident that the sulfate soundness test would not be specified at all if a freezing and thawing procedure was available which could be performed as easily and quickly and did not require expensive refrigeration equipment. The primary purpose of this investigation was to study the feasibility of using a procedure and equipment which meet these requirements.

The Standard Specifications of the Iowa State Highway Commission contain a requirement regarding the soundness of concrete aggregates which is based on 16 cycles of freezing and thawing in water containing 0. 5 percent alcohol. In most other procedures

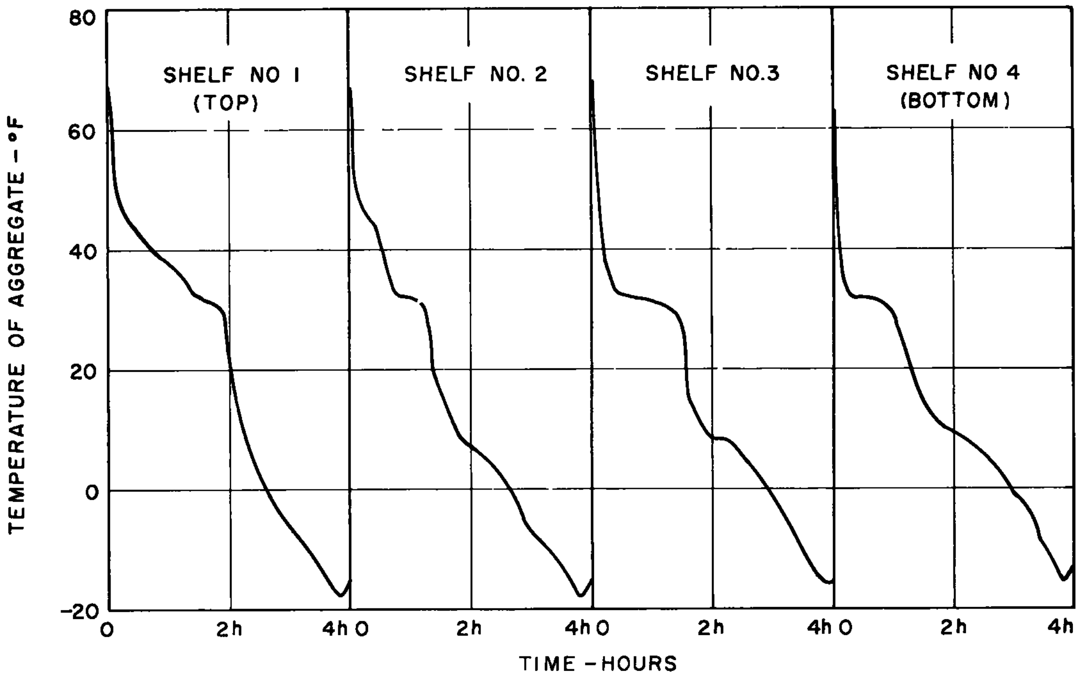

Figure 1. Cooling rate of 25-cu ft home freezer. Freezer loaded with 24 pans containing 1,000 gm samples in $\frac{1}{4}$ in. of water.

TABLE 1

ABSORPTION AND SULFATE SOUNDNESS LOSS OF AGGREGATES

BPR Lab. No.	Type of Rock	Absorption: 24 Hours (%)	Absorption: Vacuum Saturated for 15 min (%)	Loss of 1- to ¾-in. Material After 5 Cycles of Sodium Sulfate Soundness Test: Through ¾-in. sieve (%)	Loss of 1- to ¾-in. Material After 5 Cycles of Sodium Sulfate Soundness Test: Through ⅜-in. sieve (%)
70124	Limestone	0.6	0.4	4.7	1.3
78266	do	2.4	2.6	36 1	12.4
79826	Sandstone	2.2	2.6	33.7	26.6
81967	do	5.9	8.3	90.1	74.5
83888	Peridotite	0.6	0.5	13.7	5.2
89805	Limestone	2.5	3.9	28.9	14.0
89812	do	0.9	1 1	13.2	4.2
89813	do	1.3	1 6	17.9	6.4
89918	do	1.7	2.0	19.1	11.8
89889	Dunite	0.3	0.2	1.7	0.3
89892	Limestone	1.9	2.4	16.5	4.6
89988	do	0.9	0.9	49.0	20.4
Stock	Dolomite	0.2	0.3	4.1	0.5
94544	Limestone	0.5	0.4	11.5	6.1
N-74	Light Limestone	7.4	9.2	66.8	28.9
N-74	Dark Limestone	5.7	6.2	71.5	38.4
N-92	Limestone	1.8	2.9	2.5	1.0
N-127	Serpentine Diopside Garnet	1.3	1.1	4.9	1.4
N-162	Dolomite	3.3	3.6	11.1	8.5
N-163	do	3.7	4.0	25.6	11.1
N-164	Limestone	3.8	4.1	25.8	8.8
N-165	do	1.3	1.1	44.1	9.9
N-166	do	2.2	1.8	55.2	20.5
N-167	do	0.7	0.7	15.5	3.9
N-168	do	0.4	0.4	2.1	1.8
N-169	Dolomite	0.9	1.0	9.3	1.4
N-419	Gneiss Granite Schist	0.4	0.5	1.8	0.6

TABLE 2

FREEZING AND THAWING OF AGGREGATES BY METHOD A[1]
(Samples arranged in order of increasing loss on the 3/8 - inch sieve after 50 cycles)

BPR No.	Type of Rock	Loss of 1-in. to 3/4-in. Material (%)								
		3/4-in. Sieve			3/8-in. Sieve			No. 8 Sieve		
		16 Cycles	25 Cycles	50 Cycles	16 Cycles	25 Cycles	50 Cycles	16 Cycles	25 Cycles	50 Cycles
Stock	Dolomite	1.8	5.0	5.0	0.0	0.0	0.1	0.0	0.0	0.1
N-419	Gneiss Schist Granite	1.0	1.0	1.6	0.1	0.2	0.2	0.1	0.2	0.2
N-169	Dolomite	2.9	2.9	2.9	0.1	0.3	0.5	0.1	0.2	0.4
89812	Limestone	2.7	5.4	5.5	0.0	0.3	0.5	0.0	0.2	0.3
89892	do	0.6	1.5	3.0	0.1	0.3	0.6	0.0	0.3	0.5
N-92	do	2.8	5.6	6.8	0.0	0.4	0.6	0.0	0.1	0.3
N-168	do	0.2	0.4	1.3	0.2	0.4	0.6	0.2	0.4	0.6
83888	Peridotite	2.3	2.3	2.7	0.1	0.4	0.7	0.0	0.4	0.7
70124	Limestone	5.0	7.6	9.3	0.0	0.4	0.8	0.0	0.2	0.4
N-127	Serpentine Diopside Garnet	3.1	4.3	6.7	0.1	0.5	0.9	0.0	0.3	0.5
N-163	Dolomite	1.2	5.5	5.6	0.2	0.6	1.0	0.0	0.3	0.5
89889	Dunite	5.3	6.5	9.0	0.4	0.7	1.0	0.3	0.4	0.7
N-167	Limestone	0.4	0.4	1.2	0.1	0.4	1.2	0.0	0.1	0.3
N-165	do	2.1	4.3	7.2	0.2	0.8	1.7	0.0	0.3	0.7
79826	Sandstone	3.2	3.6	3.6	0.7	1.3	1.7	0.5	1.1	1.5
89805	Limestone	3.9	3.9	7.3	0.3	1.0	1.8	0.2	0.6	1.0
N-162	Dolomite	0.4	2.7	7.0	0.1	0.7	1.9	0.0	0.4	0.8
89813	Limestone	2.2	5.8	10.2	0.6	1.5	2.7	0.1	0.7	1.1
78266	do	6.2	11.9	22.9	0.3	1.2	3.1	0.0	0.6	1.0
94544	do	1.9	3.1	12.2	0.5	1.0	3.2	0.0	0.5	1.8
N-164	do	5.1	10.6	21.7	0.6	2.3	4.3	0.0	1.0	1.6
89988	do	1.5	3.9	20.6	0.5	1.5	6.9	0.1	1.0	3.7
N-166	do	1.2	4.2	11.2	0.2	1.3	10.8	0.0	0.7	1.2
89918	do	7.2	13.5	27.4	2.8	5.6	12.4	0.9	2.1	4.4
81967	Sandstone	5.7	16.9	38.4	2.0	9.0	18.8	1.6	7.3	18.5
N-74	Light Limestone	30.8	43.5	65.7	13.1	21.5	36.9	6.3	9.3	13.7
N-74	Dark Limestone	45.8	76.2	89.5	15.7	41.0	67.9	3.8	11 4	22.7

[1] Samples were vacuum saturated before test for 15 minutes, frozen in 1/4 in. of water at a temperature between -10 to 20 F, and thawed in water at 70±5 F.

where plain water is used, at least 50 cycles of freezing and thawing are considered necessary to permit positive identification of sound materials. A test requiring only 16 cycles and conducted with freezing equipment capable of obtaining at least 3 cycles per day, requires about the same testing time as that necessary to perform 5 cycles of the sulfate soundness test. In this study, freezing equipment capable of completing 3 cycles per day was used to test 27 different materials by the Iowa alcohol-water method and two other freezing and thawing procedures, thus providing comparative data by which the relative severity of the three methods can be determined. The accelerated soundness test using sodium sulfate was also performed on these same materials.

REFRIGERATION EQUIPMENT

The refrigeration equipment used for these tests was a 25-cu ft vertical-type home freezer. The freezer had four shelves, each containing cooling coils, and readily accessible through a door at the front of the unit. Temperature was controlled by a thermostat having seven settings. The temperatures corresponding to these settings ranged from a high of 10 F to a low of about -15 F. Using the coldest setting, the time required to cool samples of aggregate from 70 F to -15 F is shown in Figure 1. The temperatures plotted were measured by means of thermocouples placed at the

TABLE 3

FREEZING AND THAWING OF AGGREGATES BY METHOD B[1]
(Samples arranged in order of increasing loss on the ⅜-inch sieve after 16 cycles)

BPR No	Type of Rock	Loss of 1-in. to ¾-in. Material (%)								
		¾-in. Sieve			⅜-in. Sieve			No. 8 Sieve		
		16 Cycles	25 Cycles	50 Cycles	16 Cycles	25 Cycles	50 Cycles	16 Cycles	25 Cycles	50 Cycles
N-419	Gneiss Granite Schist	0.0	2.3	2.3	0.0	0.2	0.2	0.0	0.2	0.2
N-168	Limestone	0.9	0.9	2.8	0.3	0.9	1.4	0.3	0.9	1.3
Stock	Dolomite	3.2	5.1	7.1	0.3	0.3	1.2	0.2	0.2	0.4
89892	Limestone	0.4	0.4	0.7	0.3	0.4	0.7	0.3	0.4	0.6
89889	Dunite	0.6	0.9	4.9	0.6	0.9	1.1	0.6	0.9	1.1
83888	Peridotite	10.6	10.8	10.9	0.7	0.7	1.6	0.5	1.0	1.5
N-92	Limestone	3.1	4.3	8.5	0.9	1.7	3.8	0.5	1.1	2.9
79826	Sandstone	2.6	6.5	18.5	1.0	3.0	7.5	1.0	2.9	7.2
N-169	Dolomite	3.2	3.2	8.2	1.5	1.9	2.5	0.6	1.0	1.6
70124	Limestone	6.6	6.6	26.4	2.4	3.6	8.6	2.1	3.3	7.2
N-127	Serpentine Diopside Garnet	8.8	8.8	15.7	2.6	5.6	10.3	2.0	4.1	8.8
94544	Limestone	4.4	7.1	13.7	3.5	4.5	6.9	2.7	3.9	6.4
81967	Sandstone	15.6	32.1	61.5	5.6	17.7	45.4	5.3	16.6	44.2
89813	Limestone	16.4	21.7	34.8	5.7	8.4	15.2	3.9	5.3	9.1
89805	do	7.6	10.2	17.9	6.9	8.4	10.5	5.3	6.6	8.2
N-167	do	14.6	29.3	54.8	7.5	14.0	34.1	3.7	8.4	26.2
N-167	Dolomite	26.7	40.8	59.2	8.5	15.9	39.2	5.8	12.8	35.2
89812	Limestone	18.2	21.8	31.9	8.6	9.9	17.2	5.6	6.9	11.2
89988	do	16.0	24.6	49.2	10.0	14.0	30.4	8.6	12.1	25.4
N-165	do	38.6	58.5	88.9	16.1	27.7	59.8	9.9	17.9	44.1
89918	do	40.5	45.9	52.1	17.5	21.6	32.6	12.0	14.1	21.6
78266	do	33.7	50.7	76.2	17.6	23.8	41.8	13.1	17.3	32.8
N-166	do	29.7	55.1	88.4	18.4	33.0	66.8	14.7	28.1	61.9
N-162	Dolomite	42.1	59.1	91.5	24.8	41.4	75.9	22.3	38.7	74.2
N-74	Light Limestone	59.1	77.5	94.9	30.5	48.3	83.2	22.5	34.4	67.3
N-164	do	66.1	81.8	100.0	31.3	48.8	89.9	20.3	38.5	85.9
N-74	Dark Limestone	82.4	89.1	96.7	64.4	74.1	89.1	43.7	60.8	83.2

[1] Samples were vacuum saturated before test for 15 minutes, frozen in ¼ in. of a 0.5 percent alcohol solution at a temperature between -10 and -20 F, and thawed in the same solution at 70±5 F.

center of 1- to ¾-in. particles stored in ¼ in. of water. The freezer was initially at -15 F and was fully loaded with 24 pans each containing 1,000 gm of material at room temperature. Under these conditions, the temperature of the particles was reduced to below 0 F after 3 hours, but between 3½ and 4 hours was necessary to cool the samples to -15 F.

TESTING PROCEDURES

In the tests reported here under methods A, B, and C, only two cycles of freezing and thawing were obtained each 24 hours because of limited personnel. Samples remained in the freezer for 6 hours during the working day and 16 hours overnight. The thawing period was about 1 hour. It was demonstrated in later tests that it was practical to obtain 3 cycles of freezing and thawing in 24 hours by using two 3½-hour freezing and three ½-hour thawing periods during the working day. All samples consisted of approximately 1,000 gm of 1- to ¾-in. material which had been originally ovendried. All freezing was done at -15±5 F and all thawing at 70±5 F in a circulating bath. Otherwise, the three procedures covered by this report had the following distinguishing features:

Method A. Samples were saturated with water before test by first being subjected

TABLE 4

FREEZING AND THAWING OF AGGREGATES BY METHOD C[1]
(Samples arranged in order of increasing loss on the ⅜-inch sieve after 50 cycles)

BPR No.	Type of Rock	Loss of 1-in to ¾-in. Material (%) ¾-in. Sieve 16 Cycles	¾-in. Sieve 25 Cycles	¾-in. Sieve 50 Cycles	⅜-in. Sieve 16 Cycles	⅜-in. Sieve 25 Cycles	⅜-in. Sieve 50 Cycles	No. 8 Sieve 16 Cycles	No. 8 Sieve 25 Cycles	No. 8 Sieve 50 Cycles
N-127	Serpentine Diopside Garnet	2.2	2.2	2.4	0.0	0.0	0.2	0.0	0.0	0.1
N-419	Gneiss Granite Schist	0.0	0 1	1.2	0.0	0.1	0.2	0 0	0.1	0.2
Stock	Dolomite	3.1	3 9	3.9	0.1	0 1	0.2	0.1	0.1	0.1
N-92	Limestone	1.2	1.4	1.6	0.1	0.2	0.3	0.1	0 2	0 3
N-163	Dolomite	1.9	3.9	4 8	0.1	0.3	0.3	0.0	0 1	0.1
70124	Limestone	3.3	3.7	3.7	0.3	0.3	0.3	0.1	0.1	0.1
N-168	do	0.0	0.2	1 3	0.0	0.2	0.4	0.0	0.2	0.4
89892	do	0.0	0.3	1.6	0.0	0.3	0.4	0.0	0.2	0.4
89805	do	0.0	0.3	2.1	0.0	0.3	0.4	0.0	0.3	0.4
N-162	Dolomite	1.3	2.9	7.6	0.1	0.3	0.4	0.0	0.2	0.2
N-169	do	0.2	1.2	1.2	0.2	0.3	0.4	0.2	0 2	0.4
N-167	Limestone	3.0	3.1	9.9	0.1	0.3	0.5	0.0	0.1	0.2
89812	do	1 1	1.2	1.3	0.3	0.3	0.5	0.3	0.3	0.5
89889	Dunite	1.5	2.9	3.7	0.4	0.5	0.7	0.3	0 4	0.6
79826	Sandstone	1.3	1 3	3.0	0.5	0.5	0.9	0.3	0.4	0.8
N-164	Limestone	3.1	3.1	4.1	0.0	0.9	1.1	0.0	0 6	0.6
N-166	do	1.7	4 8	6.1	0.4	0.7	1.4	0.2	0.4	0.6
N-165	do	0.2	0.7	4.1	0.2	0.7	1.6	0.0	0.4	0.6
78266	do	4.9	6.9	10.6	0.2	0.7	1.6	0.1	0.4	0.7
83888	Peridotite	0.6	1.1	1.7	0.6	0 9	1.6	0.6	0.9	1.6
89813	Limestone	3.8	5.2	8 5	2.2	2.2	2.7	0 1	1.5	2.0
94544	do	8.2	8 6	10.0	1.6	2.1	3.1	0.7	1.0	1.9
89918	do	1.9	4.5	5.3	1.1	1.9	3.6	0.7	1.1	2.1
81967	Sandstone	6.7	8.8	9 6	0.9	2.7	4.5	0.7	2.6	4.4
89988	Limestone	2.7	4.1	10.8	0.7	1.1	5.4	0.4	0.9	3.2
N-74	Light Limestone	5.9	9.6	16.6	2 3	4.3	7.9	1.0	2.8	5.2
N-74	Dark Limestone	6.0	12.1	31.1	3 3	5.7	13.6	1.9	3.4	6.7

[1] Samples were saturated for 24 hours before test, frozen in air at a temperature between -10 and -20 F and thawed in water at 70±5 F.

to an air pressure reduced to about 1 in. of mercury and then submerged in water for 15 minutes while the vacuum was maintained. Samples were frozen in 8- by 12-in. pans containing ¼ in. of water. Thawing was done in water.

Method B. Samples were vacuum-saturated with water as in method A, but were frozen in 8- by 12-in. pans containing ¼ in. of the alcohol-water mixture (0. 5 percent alcohol). Thawing was done in this same alcohol-water mixture.

Method C. Samples were saturated before test by being submerged in water at atmospheric pressure for 24 hours. Samples were frozen in air using sieves as containers and were thawed in water.

DISCUSSION OF RESULTS

Table 1 shows the absorption and sodium sulfate soundness losses for each of the materials used in this study. Their resistance to freezing and thawing was determined after 16, 25, and 50 cycles by measuring losses through the ¾-in., ⅜-in., and No. 8 sieves. These losses by methods A, B, and C are shown in Tables 2, 3, and 4 respectively.

Although each of the freezing methods used in this study is patterned after a procedure followed by a state highway laboratory, the specification limit prescribed by

TABLE 5

RELATIVE SEVERITY OF THREE METHODS OF FREEZING AND THAWING

BPR No.	Type of Rock	Loss on $^3/_8$-in. Sieve After 50 Cycles of Method C	Number of Cycles Equivalent to 50 Cycles of Method C[1] Method A	Method B
N-92	Limestone	0.3	22	5
70124	do	0.3	22	3
N-168	do	0.4	25	17
89892	do	0.4	33	25
89805	do	0 4	17	1
N-167	do	0.5	28	1
89812	do	0.5	50	1
N-164	do	1.1	19	1
N-166	do	1.4	26	1
N-165	do	1.6	48	2
78266	do	1.6	30	2
89813	do	2.7	50	8
94544	do	3.1	48	14
89918	do	3.6	19	3
89988	do	5.4	45	9
N-74Light	do	7.9	9	4
N-74 Dark	do	13.6	6	3
Stock	Dolomite	0 2	100	10
N-163	do	0.3	18	1
N-162	do	0.4	17	1
N-169	do	0.4	37	4
Average (21 carbonate-type rocks)			32	6
N-127	Serpentine Diopside Garnet	0.2	18	2
N-419	Gneiss Granite Schist	0.2	25	25
83888	Peridotite	1.6	100+	50
89889	Dunite	0.7	25	19
79826	Sandstone	0.9	19	14
81967	do	4.5	19	13
Average (6 miscellaneous-type rocks)			34	20
Average (27 samples)			32	9

[1] This value is the number of cycles required to produce the same loss on the $^3/_8$-in. sieve as 50 cycles by method C, as estimated by consideration of the losses obtained at 16, 25, and 50 cycles.

that state is not necessarily applicable to the results obtained here. For example, in the case of method B, the Iowa specifications make provision for testing a sample graded down to the No. 4 sieve with the loss to be determined on a No. 8 sieve. The loss on a No. 8 sieve will tend to be greater for such a graded sample than for 1-in. to $^3/_4$-in. material of the same quality such as used in this study because many of the particles in the graded test sample will be closer in size to the sieve used for determining the loss. However, these results do provide a means of directly comparing the severity of each of the three freezing and thawing procedures. In Table 5, this comparison is made in terms of the equivalent number of cycles of methods A and B which would produce the same destructive effect as 50 cycles of method C. Considering the entire group of 27 samples, method A (freezing in water) required about two-thirds and method B (freezing in alcohol-water) about one-fifth the number of cycles required by method C (freezing in air) to produce the same action. The greater severity of method B over methods A and C was more pronounced for the carbonate-type rocks than the miscellaneous types, although the limited number of samples in this latter group precludes drawing a general conclusion to that effect. Comparisons for individual samples also indicate that the relative severity of the three methods varies considerably for different materials.

Since the rates of freezing and thawing were the same for the three procedures covered by this report, it might be expected that differences in degree of saturation of the particles during freezing would account for differences in destructive effect of the three methods. It is reasonable, for example, to attribute the low losses obtained by method C, where freezing was done in air, to the reduced amount of water in the aggregate as a result of partial drying taking place in the freezer. The greater severity of method B where alcohol was used, as compared to methods A and C, is believed to result from the increased absorption caused by the alcohol. It was determined, for example, that the absorption of aggregates which had been subjected to several cycles of freezing and thawing in the 0. 5 percent water-alcohol mixture was greater than the absorption of similar samples which had been frozen in plain water. Alcohol did not, however, increase the absorption of aggregates when they were simply immersed in the mixture without freezing.

It is of interest to compare the relative order of soundness of the 27 samples as determined by each freezing and thawing procedure. To help visualize this comparison, losses of all materials by the three methods were plotted in Figure 2, the samples being arranged from left to right in order of increasing loss by method A. It is evident that arranging the samples according to their losses by either of the other methods would have produced a different order. The difference in order of soundness found by comparing results obtained by methods A and C could result from sampling variations or the general lack of preciseness which is common to any freezing and thawing method. However, the difference between results obtained by method B compared to method A or C is sufficiently great to preclude an explanation based entirely on such factors. It is possible that the different order of soundness found by method B is related to the relatively advanced state of disintegration of many samples after 16 cycles of this method as compared to 50 cycles of the other methods. Another possibility is

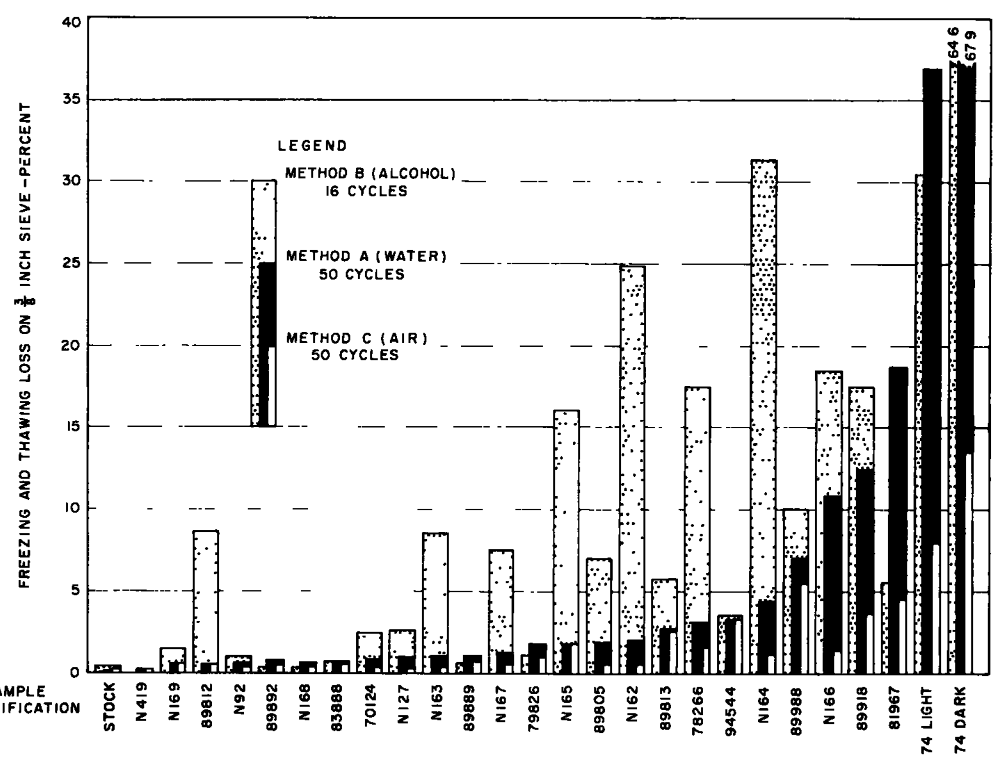

Figure 2. Comparison of freezing and thawing loss by methods A, B and C. Samples arranged from left to right in order of increasing loss by method A.

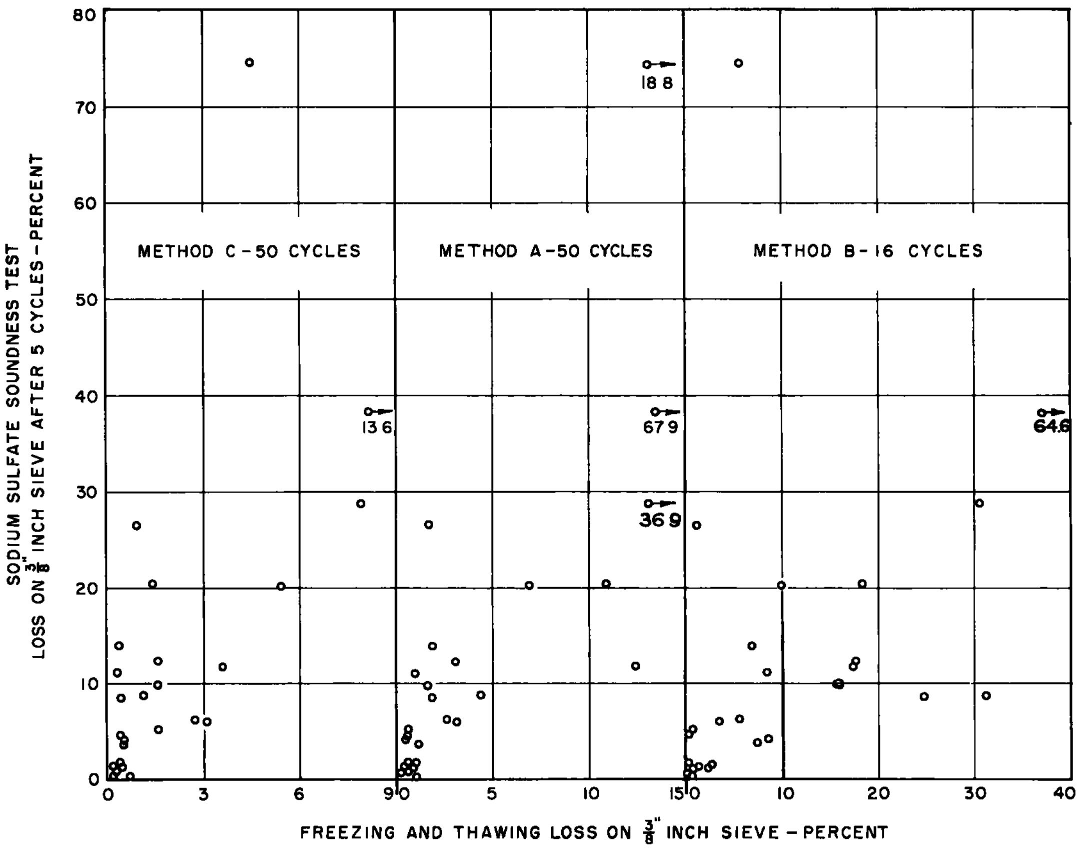

Figure 3. Relation between the losses by the sulfate soundness test and freezing and thawing methods A, B and C.

that the alcohol method may be introducing some destructive process in the freezing and thawing procedure which is inherently different than that involved in methods A and C.

This possibility raises the question of agreement of the findings of the alcohol-water method with the service record of the materials tested. To determine this, the submitters of the samples were asked to furnish information of the behavior of the materials in service. Replies were obtained for 22 of the 27 materials. Of these 22 materials for which dependable service records were obtained, 12 were rated as either unsound or questionable and had losses by method B of 5. 7 percent or more. Of the 10 materials rated as sound, 9 had losses by method B of 3. 5 percent or less and one had a loss of 7. 5 percent. Hence, in all but one instance, a good separation was made between sound and questionable materials.

Although the feasibility of substituting a freezing and thawing procedure for the sulfate soundness test should not hinge on obtaining good correlation between the two types of test, a comparison between results obtained by the sulfate method and those obtained by methods A, B, and C is made in Figure 3. The horizontal scales were adjusted so that except for a few points, the plotted values occupy about the same horizontal distance for each of the three freezing and thawing methods. Losses obtained after 5 cycles of the sulfate test greatly exceeded the losses obtained by methods A and C but were approximately equal in magnitude to those obtained by method B. However, it is apparent from the scattering of points in Figure 3 that the sulfate test does not correlate closely with any of the freezing and thawing methods used in this study.

The results of this study should not be interpreted as a recommendation that the alcohol-water method of freezing and thawing aggregates be blindly substituted for the sulfate soundness test as a method of judging the durability of aggregates. It is sufficient for the purpose of this study that those having the responsibility of selecting sound materials be made aware of the existence of such a procedure as well as the availability of inexpensive equipment for its rapid performance. By thus demonstrating the procedure, it is hoped that others will be moved to investigate the suitability of such a method, or some modification of it, for use with the materials with which they are immediately concerned.

CONCLUSIONS

1. A home-type freezing unit proved satisfactory for rapid freezing and thawing tests of aggregates. Three cycles per day were possible with a minimum freezing temperature between -10 and -15 F.
2. Sixteen cycles of method B, which involved freezing and thawing in a 0.5 percent alcohol-water solution, was equally as effective as 5 cycles of the sodium sulfate test, but was much more destructive than 50 cycles of method A with freezing and thawing in plain water, or method C, with freezing in air and thawing in water.
3. The order of soundness of the materials used in this study was significantly different when determined by method B and either method A or C. However, the losses obtained by method B were in reasonable agreement with the service records of the 22 materials for which such information was available. The results of the sulfate soundness test did not correlate closely with the results obtained by any of the freezing and thawing procedures.

HRB:OR-201