SIGNIFICANCE OF SOUNDNESS TESTS OF AGGREGATES

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SYNOPSIS

Laboratory tests of soundness of aggregates by means of sodium sulphate and magnesium solutions have been found to correlate with field service with some aggregates and not with others. After 20 years of study the Kansas Road Materials Testing Laboratory has concluded that freezing and thawing tests are a much better measure of the behavior of aggregates in service.

A method of test by freezing and thawing and evaluation of results is proposed which differs from that of the American Society for Testing Materials principally in that the result is based upon cumulative percentages retained on the series of sieves instead of upon separation into a number of sizes by the passed and retained system. This makes it possible to evaluate correctly those pieces which are cracked in crushing and separate in one cycle of freezing and thawing and do not show real signs of disintegration.

The result of the test is expressed as the ratio of the sum of the cumulative percentages retained on each of the sieves after freezing and thawing to the sum of the cumulative percentages before the test.

It is recommended that the test be made upon samples of the processed aggregate as it is believed that tests of samples of ledge rock are not indicative of the quality of material to be produced at a quarry.

The testing of aggregates for soundness by sodium sulphate, magnesium sulphate or by freezing and thawing is a timely subject. Correlation of laboratory tests with the performance of aggregates in service requires years of experience and study. For over 20 years a study dealing with the soundness of aggregates has been in progress at the Road Materials Testing Laboratory located at Kansas State College. The aggregates which have been used in Kansas construction can be classified as limestones, sandstones, chert gravels, flint gravel, flint sand and siliceous sand and gravel.

The first laboratory soundness tests were made using chemical salt solutions which produced expansion when the aggregate was saturated with the salt solution and then dried. These soundness tests on aggregates correlated with field service when the aggregates were soft and contained shales, but did not prove satisfactory on some types of cherts and flints.

By 1928 the studies of laboratory soundness tests by freezing and thawing made at Kansas State College in co-operation with the Highway Department of Kansas indicated that the freezing and thawing method was a much better measure of the behavior of aggregates in actual service. Field service tests, field surveys, laboratory soundness tests with the aggregates made into concrete, and laboratory soundness tests of the aggregates alone, have been conducted since 1928 and a large volume of valuable data has been collected.

In the course of highway construction in Kansas, concrete pavement aggregates have been used which have had from zero to 35 per cent loss in weight at 25 cycles of freezing and thawing.

The pavement constructed with aggregate which had a loss of 35 per cent at 25 cycles of freezing and thawing had to be resurfaced 13 years after completion with a bituminous macadam. This pavement disintegrated more rapidly than any other pavement on the Kansas state highway system. The 35 per cent loss was the average on ledge samples from the quarry.

I should like to call your attention to the use of ledge stone samples. Laboratory test results on samples of ledge stone should be used only as a guide in materials surveys and should not be used as a method of qualifying a quarry. In the 14 years that I have been testing aggregates I have never yet received a sample of shale to be tested for use as a coarse aggregate in concrete; yet, in the operation of many quarries, tons of rock, shale and clay are shot down at one time, picked up with a power shovel, loaded on a truck and delivered to the crusher. In nearly all cases the ledge samples of stone represent the type of stone that could be produced, if all the shale, clay and friable stone could be removed in the crushing and screening operation. To qualify a source of aggregate I prefer testing the aggregates after they have been crushed, screened and placed in the stock pile. The testing of ledge samples of stone and making qualification on these test results is about the same as testing the ingredients used in making a chassis grease before the grease is compounded and qualifying the grease on the basis that the ingredients were of good quality.

The American Society of Testing Materials has outlined testing procedures for determining the soundness of aggregates under designations C88-39T and C137-38T. These methods require that the sample be separated into a number of sizes (using the passed and retained system), and each separated size placed in a container, thereby requiring a large number of containers. Another objection to the A.S.T.M. methods is that one must view the sample in order to tell the type of break-down. A person not viewing the sample of aggregate but seeing only the test report can not tell if the aggregate failed by separating only once or into many pieces.

The method of test and evaluation outlined in this paper takes cognizance of those pieces of aggregate which are not unsound but are retained on a sieve by a projection which may become broken off in the soundness test because of a small crack produced in the crushing operation. The A.S.T.M. methods would classify these pieces of aggregate as unsound, but the cumulative method retains the pieces of aggregate on the next sieve and to some extent corrects this error.

We have tested a large number of samples following the A.S.T.M. procedure, but a method which I feel is more practical regarding testing procedure and evaluating of the results is as follows:

SOUNDNESS TEST OF COARSE AGGREGATE

The sample to be used in the freezing and thawing test shall consist of approximately 5,000 g. having 100 per cent retained on the No. 4 mesh sieve. The sample shall be representative of the aggregate to be tested.

The sample may weigh less than 5,000 g. when the material submitted for test has less than 15 per cent retained on the ¾-in. sieve.

If any sample is submitted which has material retained on the 2½-in. sieve, this oversize material shall be crushed to pass the 2½-in. sieve and incorporated in the sample to be tested.

The sample shall be cleaned, dried at approximately 215° F., and sieved over the 2½-in., 1½-in., ¾-in., ⅜-in., and No. 4 sieves.

The cumulative percentages retained on each of these sieves shall be determined before freezing and thawing.

The sample shall be placed in an open top container, covered with a 16 mesh screen and submerged in tap water for not less than 24 hr. at a temperature of from 70° F. to 80° F. before freezing and thawing tests are started.

The sample shall be frozen in a water-saturated condition at a temperature between 0° F. and −20° F. and thawed by submerging in tap water at 70° F. to 80° F. One freezing and one thawing constitutes one cycle.

After the sample has been subjected to 25 cycles of freezing and thawing it shall be dried to constant weight at a temperature of approximately 215° F., and then sieved over the 1½-in., ¾-in., and No. 4 sieves, thus determining the cumulative percentages retained on each of these sieves on the basis of the dry weight of the sample before freezing and thawing.

The sum of the cumulative percentages retained on each of these sieves after 25 cycles of freezing and thawing shall not be less than ——— (—) per cent of the sum of the cumulative percentages retained on these same sieves before freezing and thawing.

Table 1 gives data on a sample of Altamont limestone which has been subjected to 25 cycles of freezing and thawing. Figure 1 gives a pictorial story of the behavior of this stone in the test. I consider this limestone unsound for use in concrete pavement.

Table 2 gives data on a sample of Deercreek limestone which has been subjected to 25 cycles of freezing and thawing. Figure 2 gives the pictorial story of the behavior of this stone in the test. I consider this stone sound for use as an aggregate in concrete pavement.

The soundness results of the stone shown in Table 3 is average for the stone that was used in the concrete paving on Highway No. 4 between Nortonville and Atchison in Atchison County, Kansas. However, the sieve analysis shown in Table 3 is not the same as that of the stone that was used in the Nortonville-Atchison pavement constructed in 1924. The condition of the pavement of this road is shown in Figures 3, 4, 5 and 6.

The test procedure and method of evaluation outlined here can be applied to

TABLE 1

Cumulative grading before freezing and thawing		Cumulative grading after 25 cycles of freezing and thawing	
Sieve size	Retained	Sieve size	Retained
	%		%
1½	0	1½	0
¾	50	¾	37
⅜	80	⅜	71
4	100	4	90
Summation	2 30	Summation	1 98

$$\text{Ratio} = \frac{1\ 98}{2.30} = 0\ 86$$

TABLE 2

Cumulative grading before freezing and thawing		Cumulative grading after 25 cycles of freezing and thawing	
Sieve size	Retained	Sieve size	Retained
	%		%
1½	0	1½	0
¾	47	¾	46
⅜	87	⅜	85
4	100	4	99
Summation	2 34	Summation	2 30

$$\text{Ratio} = \frac{2\ 30}{2\ 34} = 0\ 98$$

TABLE 3

Cumulative grading before freezing and thawing		Cumulative grading after 25 cycles of freezing and thawing	
Sieve size	Retained	Sieve size	Retained
	%		%
1½	0	1½	0
¾	11	¾	10
⅜	65	⅜	54
4	100	4	82
Summation	1 76	Summation	1 46

$$\text{Ratio} = \frac{1\ 46}{1.76} = 0\ 83$$

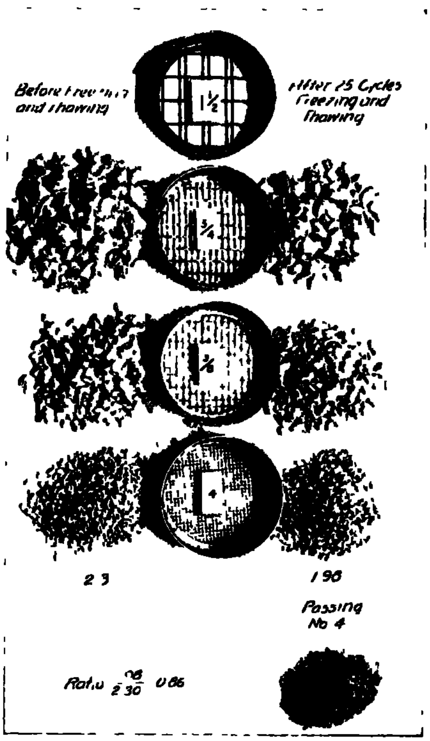

Figure 1

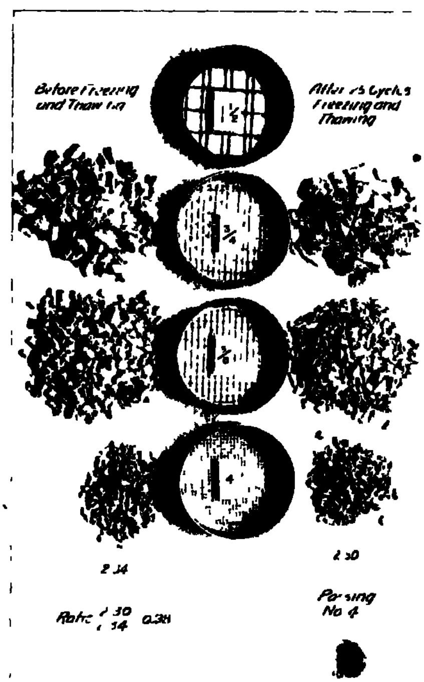

Figure 2

fine aggregates as well as to coarse aggregates. The same is true if the soundness test is made with sodium sulphate, magnesium sulphate, or by freezing and thawing.

It should be remembered that, as yet, no way has been devised by which the aggregates can be passed through a machine and the correct answer on soundness obtained.

Aggregates which are sound for one type of construction, such as concrete pavement, may not be satisfactory for another type, such as decorative concrete

Figure 3

Figure 4

Figure 5

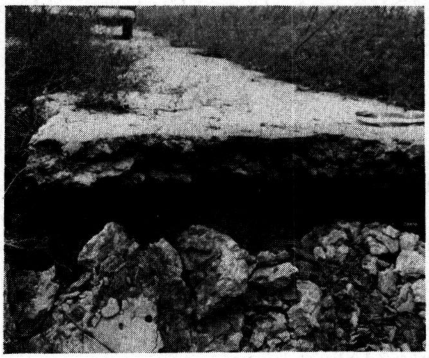

Figure 6

in structures. I have seen concrete pavement made from aggregates which has given satisfactory service for over 25 years—the aggregate contained 3 per cent unsound chert—but when this aggregate was used in concrete handrails, it was unsatisfactory in appearance although it was structurally safe.

It is necessary that the testing engineer use sound judgment in the qualifying of aggregates for the various types of construction in which the aggregates are to be used.