



Designation: C88/C88M – 18

# Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate<sup>1</sup>

This standard is issued under the fixed designation C88/C88M; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the U.S. Department of Defense.*

## 1. Scope\*

1.1 This test method covers the testing of aggregates to estimate their soundness when subjected to weathering action in concrete or other applications. This is accomplished by repeated immersion in saturated solutions of sodium or magnesium sulfate followed by oven drying to partially or completely dehydrate the salt precipitated in permeable pore spaces. The internal expansive force, derived from the rehydration of the salt upon re-immersion, simulates the expansion of water on freezing. This test method furnishes information helpful in judging the soundness of aggregates when adequate information is not available from service records of the material exposed to actual weathering conditions.

1.2 The values stated in SI or inch pound units shall be regarded separately as standard. The inch –pound units are shown in brackets. The values stated are not exact equivalents; therefore each system shall be used independently of the other. Combining values from the two systems may result in nonconformance.

1.3 Some values have only SI units because the inch-pound equivalents are not used in practice.

1.4 If the results obtained from another standard are not reported in the same system of units as used by this test method, it is permitted to convert those results using the conversion factors found in the SI Quick Reference Guide.<sup>2</sup>

NOTE 1—Sieve size is identified by its standard designation in Specification E11. The alternate designation given in parentheses is for information only and does not represent a different standard sieve size.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate*

*appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>3</sup>

C33/C33M Specification for Concrete Aggregates

C125 Terminology Relating to Concrete and Concrete Aggregates

C136/C136M Test Method for Sieve Analysis of Fine and Coarse Aggregates

C670 Practice for Preparing Precision and Bias Statements for Test Methods for Construction Materials

C702/C702M Practice for Reducing Samples of Aggregate to Testing Size

D75/D75M Practice for Sampling Aggregates

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E100 Specification for ASTM Hydrometers

E323 Specification for Perforated-Plate Sieves for Testing Purposes

## 3. Terminology

3.1 For definitions of general terms used in this test method see Terminology C125.

## 4. Significance and Use

4.1 This test method provides a procedure for making a preliminary estimate of the soundness of aggregates for use in concrete and other purposes. The values obtained may be compared with specifications, for example Specification C33/

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.20 on Aggregates.

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<sup>2</sup> Annex A in *Form and Style for ASTM Standards*, www.ASTM.org/COMMIT/Blue\_Book.dpf

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

\*A Summary of Changes section appears at the end of this standard

**C33M**, that are designed to indicate the suitability of aggregate proposed for use. Since the precision of this test method is poor (Section 13), it may not be suitable for outright rejection of aggregates without confirmation from other tests more closely related to the specific service intended.

4.2 Values for the permitted-loss percentage by this test method are usually different for fine and coarse aggregates, and attention is called to the fact that test results by use of the two salts differ considerably and care must be exercised in fixing proper limits in any specifications that include requirements for these tests. The test is usually more severe when magnesium sulfate is used; accordingly, limits for percent loss allowed when magnesium sulfate is used are normally higher than limits when sodium sulfate is used.

NOTE 2—Refer to the appropriate sections in Specification C33/C33M establishing conditions for acceptance of coarse and fine aggregates which fail to meet requirements based on this test.

## 5. Apparatus

5.1 *Sieves*—With square openings of the following sizes conforming to Specifications E11 or E323, for sieving the samples in accordance with Sections 7, 8, and 10:

150 μm (No. 100)	8.0 mm (5/16 in.)
	9.5 mm (3/8 in.)
300 μm (No. 50)	12.5 mm (1/2 in.)
	16.0 mm (5/8 in.)
600 μm (No. 30)	19.0 mm (3/4 in.)
	25.0 mm (1 in.)
1.18 mm (No. 16)	31.5 mm (1 1/4 in.)
2.36 mm (No. 8)	37.5 mm (1 1/2 in.)
	50 mm (2 in.)
4.00 mm (No. 5)	63 mm (2 1/2 in.)
	larger sizes by
4.75 mm (No. 4)	12.5 mm (1/2 in.)
	spread

5.2 *Containers*—Containers for immersing the samples of aggregate in the solution, in accordance with the procedure described in this test method, shall be perforated in such a manner as to permit free access of the solution to the sample and drainage of the solution from the sample without loss of aggregate.

NOTE 3—Baskets made of suitable wire mesh or sieves with suitable openings are satisfactory containers for the samples.

5.3 *Temperature Regulation*—Suitable means for regulating the temperature of the samples during immersion in the sodium sulfate or magnesium sulfate solution shall be provided.

5.4 *Temperature Recorder*—With an accuracy of at least 0.5 °C (1 °F) and capable of recording the temperature of the solution at least once every 15 min for the duration of the test.

5.5 *Balances*—For fine aggregate, a balance or scale accurate within 0.1 g over the range required for this test; for coarse aggregate, a balance or scale accurate within 0.1 % or 1 g, whichever is greater, over the range required for this test.

5.6 *Drying Oven*—The oven shall be capable of being heated continuously at  $110 \pm 5$  °C ( $230 \pm 9$  °F) and the rate of evaporation, at this range of temperature, shall be at least 25 g/h for 4 h, during which period the doors of the oven shall be kept closed. This rate shall be determined by the loss of water from 1-L Griffin low-form beakers, each initially containing

500 g of water at a temperature of  $21 \pm 2$  °C ( $70 \pm 3$  °F), placed at each corner and the center of each shelf of the oven. The evaporation requirement is to apply to all test locations when the oven is empty except for the beakers of water.

5.7 *Specific Gravity Measurement*—Hydrometers conforming to the requirements of Specification E100, or a suitable combination of graduated glassware and balance, capable of measuring the solution specific gravity within  $\pm 0.001$ .

## 6. Special Solutions Required

6.1 Prepare the solution for immersion of test samples from either sodium or magnesium sulfate in accordance with 6.1.1 or 6.1.2 (Note 4). The volume of the solution shall be at least five times the solid volume of all samples immersed at any one time.

NOTE 4—Some aggregates containing carbonates of calcium or magnesium are attacked chemically by fresh sulfate solution, resulting in erroneously high measured losses. If this condition is encountered or is suspected, repeat the test using a filtered solution that has been used previously to test the same type of carbonate rock, provided that the solution meets the requirements of 6.1.1 and 6.1.2 for specific gravity.

6.1.1 *Sodium Sulfate Solution*—Prepare a saturated solution of sodium sulfate by dissolving a USP or equal grade of the salt in water at a temperature of 25 to 30 °C (77 to 86 °F). Add sufficient salt (Note 5), of either the anhydrous ( $\text{Na}_2\text{SO}_4$ ) or the crystalline ( $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$ ) form,<sup>4</sup> to ensure not only saturation but also the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to  $21 \pm 1$  °C ( $70 \pm 2$  °F). Again stir, and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.151 nor more than 1.174. Discard a discolored solution, or filter it and check for specific gravity.

NOTE 5—For the solution, 215 g of anhydrous salt or 700 g of the decahydrate per litre of water are sufficient for saturation at 22 °C (71.6 °F). However, since these salts are not completely stable and since it is desirable that an excess of crystals be present, the use of not less than 350 g of the anhydrous salt or 750 g of the decahydrate salt per litre of water is recommended.

6.1.2 *Magnesium Sulfate Solution*—Prepare a saturated solution of magnesium sulfate by dissolving a USP or equal grade of the salt in water at a temperature of 25 to 30 °C (77 to 86 °F). Add sufficient salt (Note 6), of either the anhydrous ( $\text{MgSO}_4$ ) or the crystalline ( $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ ) (Epsom salt) form, to ensure saturation and the presence of excess crystals when the solution is ready for use in the tests. Thoroughly stir the mixture during the addition of the salt and stir the solution at

<sup>4</sup> Experience with the test method indicates that a grade of sodium sulfate designated by the trade as dried powder, which may be considered as approximately anhydrous, is the most practical for use. That grade is more economically available than the anhydrous form. The decahydrate sodium sulfate presents difficulties in compounding the required solution on account of its cooling effect on the solution.

frequent intervals until used. To reduce evaporation and prevent contamination, keep the solution covered at all times when access is not needed. Allow the solution to cool to  $21 \pm 1$  °C ( $70 \pm 2$  °F). Again stir, and allow the solution to remain at the designated temperature for at least 48 h before use. Prior to each use, break up the salt cake, if any, in the container, stir the solution thoroughly, and determine the specific gravity of the solution. When used, the solution shall have a specific gravity not less than 1.295 nor more than 1.308. Discard a discolored solution, or filter it and check for specific gravity.

NOTE 6—For the solution, 350 g of anhydrous salt or 1230 g of the heptahydrate per litre of water are sufficient for saturation at 23 °C (73.4 °F). However, since these salts are not completely stable, with the hydrous salt being the more stable of the two, and since it is desirable that an excess of crystals be present, it is recommended that the heptahydrate salt be used and in an amount of not less than 1400 g/litre of water.

6.1.3 *Barium Chloride Solution*—Prepare 100 mL of 5 % barium chloride solution by dissolving 5 g of BaCl<sub>2</sub> in 100 mL of distilled water.

## 7. Samples

7.1 The sample shall be obtained in general accordance with Practice **D75/D75M** and reduced to test portion size in accordance with Practice **C702/C702M**.

7.2 *Fine Aggregate*—Fine aggregate for the test shall be passed through a 9.5-mm ( $\frac{3}{8}$ -in.) sieve. The sample shall be of such size that it will yield not less than 100 g of each of the following sizes, which shall be available in amounts of 5 % or more, expressed in terms of the following sieves:

Passing Sieve	Retained on Sieve
600 μm (No. 30)	300 μm (No. 50)
1.18 mm (No. 16)	600 μm (No. 30)
2.36 mm (No. 8)	1.18 mm (No. 16)
4.75 mm (No. 4)	2.36 mm (No. 8)
9.5 mm ( $\frac{3}{8}$ in.)	4.75 mm (No. 4)

7.3 *Coarse Aggregate*—Coarse aggregate for the test shall consist of material from which the sizes finer than the 4.75-mm (No. 4) sieve have been removed. The sample shall be of such a size that it will yield the following amounts of the indicated sizes that are available in amounts of 5 % or more:

Size (Square-Opening Sieves)	Mass, g
9.5 mm ( $\frac{3}{8}$ in.) to 4.75 mm (No. 4)	300 ± 5
19.0 mm ( $\frac{3}{4}$ in.) to 9.5 mm ( $\frac{3}{8}$ in.)	1000 ± 10
Consisting of:	
12.5-mm ( $\frac{1}{2}$ -in.) to 9.5-mm ( $\frac{3}{8}$ -in.) material	330 ± 5
19.0-mm ( $\frac{3}{4}$ -in.) to 12.5-mm ( $\frac{1}{2}$ -in.) material	670 ± 10
37.5 mm (1 $\frac{1}{2}$ in.) to 19.0 mm ( $\frac{3}{4}$ in.)	1500 ± 50
Consisting of:	
25.0-mm (1-in.) to 19.0-mm ( $\frac{3}{4}$ -in.) material	500 ± 30
37.5-mm (1 $\frac{1}{2}$ -in.) to 25.0-mm (1-in.) material	1000 ± 50
63 mm (2 $\frac{1}{2}$ in.) to 37.5 mm (1 $\frac{1}{2}$ in.)	5000 ± 300
Consisting of:	
50-mm (2-in.) to 37.5-mm (1 $\frac{1}{2}$ -in.) material	2000 ± 200
63-mm (2 $\frac{1}{2}$ -in.) to 50-mm (2-in.) material	3000 ± 300
Larger sizes by nominal 12.5-mm ( $\frac{1}{2}$ -in.) spread in sieve size, each fraction	
Consisting of:	
75-mm (3-in.) to 63-mm (2 $\frac{1}{2}$ -in.) material	7000 ± 1000
90-mm (3 $\frac{1}{2}$ -in.) to 75-mm (3-in.) material	7000 ± 1000
100-mm (4-in.) to 90-mm (3 $\frac{1}{2}$ -in.) material	7000 ± 1000

7.4 When an aggregate to be tested contains appreciable amounts of both fine and coarse material, having a grading

with more than 10 % by mass coarser than the 9.5-mm ( $\frac{3}{8}$ -in.) sieve and, also, more than 10 % by mass finer than the 4.75-mm (No. 4) sieve, test separate samples of the minus 4.75-mm (No. 4) fraction and the plus 4.75-mm (No. 4) fraction in accordance with the procedures for fine aggregate and coarse aggregate, respectively. Report the results separately for the fine-aggregate fraction and the coarse-aggregate fraction, giving the percentages of the coarse- and fine-size fractions in the initial grading.

## 8. Preparation of Test Sample

8.1 *Fine Aggregate*—Thoroughly wash the sample of fine aggregate on a 300-μm (No. 50) sieve, dry to constant mass at  $110 \pm 5$  °C ( $230 \pm 9$  °F), and separate into the different sizes by sieving, as follows: Make a rough separation of the graded sample by means of a nest of the standard sieves specified in 7.2. From the fractions obtained in this manner, select samples of sufficient size to yield 100 g after sieving to refusal. (In general, a 110-g sample will be sufficient.) Do not use fine aggregate sticking in the meshes of the sieves in preparing the samples. Weigh samples consisting of  $100 \pm 0.1$  g out of each of the separated fractions after final sieving and place in separate containers for the test.

8.2 *Coarse Aggregate*—Thoroughly wash and dry the sample of coarse aggregate to constant mass at  $110 \pm 5$  °C ( $230 \pm 9$  °F) and separate it into the different sizes shown in 7.3 by sieving to refusal. Weigh out quantities of the different sizes within the tolerances of 7.3 and, where the test portion consists of two sizes, combine them to the designated total mass. Record the mass of the test samples and their fractional components. In the case of sizes larger than 19.0 mm ( $\frac{3}{4}$  in.), record the number of particles in the test samples.

## 9. Procedure

9.1 *Storage of Samples in Solution*—Immerse the samples in the prepared solution of sodium sulfate or magnesium sulfate for not less than 16 h nor more than 18 h in such a manner that the solution covers them to a depth of at least 12.5 mm ( $\frac{1}{2}$  in.) (Note 7). Cover the containers to reduce evaporation and prevent the accidental addition of extraneous substances. Maintain the samples immersed in the solution at a temperature of  $21 \pm 1$  °C ( $70 \pm 2$  °F) for the immersion period.

NOTE 7—Suitably weighted wire grids placed over the sample in the containers will permit this coverage to be achieved with very lightweight aggregates.

9.2 *Drying Samples After Immersion*—After the immersion period, remove the aggregate sample from the solution, permit it to drain for  $15 \pm 5$  min, and place in the drying oven. The temperature of the oven shall have been brought previously to  $110 \pm 5$  °C ( $230 \pm 9$  °F). Dry the samples at the specified temperature until constant mass has been achieved. Establish the time required to attain constant mass as follows: with the oven containing the maximum sample load expected, check the mass losses of test samples by removing and weighing them, without cooling, at intervals of 2 to 4 h; make enough checks to establish required drying time for the least favorable oven location (see 5.6) and sample condition (Note 8). Constant mass will be considered to have been achieved when loss is