Designation: D5519 – 07

Standard Test Methods for Particle Size Analysis of Natural and Man-Made Riprap Materials[1]

This standard is issued under the fixed designation D5519; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 These test methods cover the particle size and mass analysis of natural and man-made riprap and related materials, including filter stone or coarse bedding materials.

1.2 These test methods are generally intended for riprap and related materials. They are applicable for mixtures of stones screened from natural deposits, blast rock, processed materials from quarried rock, or recycled concrete. They are applicable for sizes 3 in. (75 mm) and above, with the upper size limited only by equipment available for handling and weighing the individual particles.

1.3 Four alternate procedures are provided. There is a wide range in the level of effort and the precision of the test procedures. It is important for specifiers to indicate the test procedure. Test reports should clearly indicate which procedure was used.

NOTE 1—While conducting these test methods, it may be convenient to collect data on other attributes, such as the amount of slab pieces and deleterious materials.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.5 The values stated in inch-pound units are to be regarded as the standard. The metric equivalents of inch-pound units given in parentheses may be approximate.

1.6 *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 safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific precautionary statements are given in Section 7.

2. Referenced Documents

2.1 *ASTM Standards:*[2]
C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates
D422 Test Method for Particle-Size Analysis of Soils
D653 Terminology Relating to Soil, Rock, and Contained Fluids
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
D4992 Practice for Evaluation of Rock to be Used for Erosion Control
D5240 Test Method for Testing Rock Slabs to Evaluate Soundness of Riprap by Use of Sodium Sulfate or Magnesium Sulfate
D5312 Test Method for Evaluation of Durability of Rock for Erosion Control Under Freezing and Thawing Conditions
D5313 Test Method for Evaluation of Durability of Rock for Erosion Control Under Wetting and Drying Conditions
D6026 Practice for Using Significant Digits in Geotechnical Data
D6825 Guide for Placement of Riprap Revetments
E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

3. Terminology

3.1 *Definitions:*

3.1.1 Terminology used within these test methods is in accordance with Terminology D653 with the addition of the following:

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *bedding (riprap)*—an aggregate mixture placed below the riprap. (See D6825 for further information.)

[1] These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.17 on Rock for Erosion Control.

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[2] 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

3.2.2 *slab pieces*—pieces of riprap that exhibit dimensional ratios of the thickness to width or width to length, or both, in excess of a specified ratio. The specified ratios typically range from 1:4 to 1:3 or less.

4. Summary of Test Method

4.1 The following four test methods for evaluating particle size distribution are available: Methods A and B involve weighting the material, Methods C and D involve measuring the sizes. Generally, the precision is highest for Method A, and consecutively lowest for Method D. The advantages to using different methods depend on resources, sampling frequency and quantity, and to some extent the material size uniformity.

4.1.1 *Test Method A*—A sample of the material is obtained, each individual particle is weighted and recorded. Test Method A is the most rigorous. It is most easily implemented for small sized rock that can be handled manually, or for very limited samples of large pieces.

4.1.2 *Test Method B*—A sample of the material is obtained, grouped into weight ranges, and each pile within a weight range is weighted.

4.1.3 *Test Method C*—A sample of the material is obtained, the size of each particle is measured and grouped into size ranges, and the size ranges are converted to mass.

4.1.4 *Test Method D*—A sample of the material is partitioned within a revetment, particle sizes are measured and grouped into size ranges, and the size ranges are converted to mass.

5. Significance and Use

5.1 Riprap is commonly used to prevent erosion of underlying materials due to the effects of rain runoff, wind, flowing water, or wave action. The particle size distribution (mass of particles) is an important physical characteristic of riprap, as discussed in D6825. These test methods provide a gradation of the material graphically represented as percent finer than the particle mass. If a gradation can be established or accepted on the basis of only maximum and minimum particle sizes, then it may not be necessary to establish the complete gradation in accordance with these test methods.

5.2 These test methods can be used during evaluation of a potential source, as a means of product acceptance, or for assessment of existing installations. Method D is not recommended as a means of product acceptance.

5.3 Other characteristics of interest, such as particle shape, particle angularity, or visually evident rock durability characteristics may be determined during the performance of these test methods.

5.4 Interpretation of test results must consider the representativeness of the sample.

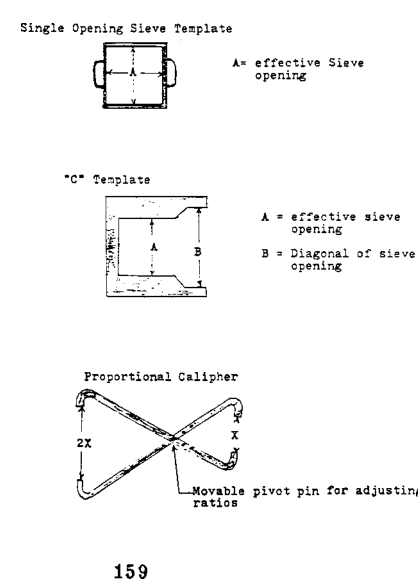
NOTE 2—The agency performing these test methods can be evaluated in accordance with Practice D3740. Not withstanding statements on precision and bias contained in these test methods: The precision of these test methods is dependent on the competence of the personnel performing it and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing. Users of these test methods are cautioned that compliance with Practice D3740 does not in itself ensure reliable testing. Reliable testing depends on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Scales,* of adequate capacity to determine the mass of the sorted riprap pieces either individually or in whole. For Test Method A (or calibrations for Test Methods B and C), the scale will be accurate to 1 % of the indicated mass. Calibrated or certified commercial truck or quarry scales of adequate capacity are typically used. For individual particle measurements using Test Method A, hoist line load cells have been used successfully. For Test Method B, the scale will be accurate to 5% of the indicated mass. If bucket scales are used, they shall be subject to calibration and verification with a certified truck scale.

6.2 *Sieves or Templates,* meeting the requirements of Specification E11 for sizes up to 5 in. (125 mm). For sizes above 5 in., single-opening templates may be fabricated for the required sizes. Templates may be fabricated from steel bar or other sufficiently rigid materials in the sizes required. For templates openings from 5 in. to 16 in. (125 to 400 mm), the openings will be within ±2 % of the size, for templates greater than 16 in., the openings will be within ±0.25 in. (6.35 mm). Sieves and templates should be checked on a regular basis to verify squareness, straightness, and conformance to opening tolerances. Hand grips or handles should be considered for ease of use. For larger sizes, it has been found useful to fabricate templates in the form of a C-shaped caliper representing the sieve opening and the diagonal of the sieve opening (see Fig. 1).

6.3 *Transport Vehicle,* capable of conveying the individual or groups of the individual sorted riprap pieces from the sampling point to the test area, and from the test area to the weighing station. If truck scales are used, the transport vehicle should be tared prior to and after determination of the masses.



NOTE 1—The following figure illustrate typical apparatus that have been fabricated for use in these test methods.

FIG. 1 Single-Opening Sieve Template

6.4 *Handling Equipment,* such as forklifts, loaders, or like equipment for sampling, transporting, assisting in the sorting, loading for transport, weighing, and other tasks involved in the physical performance of the test.

6.5 *Tape Measures* for determining particle size dimensions to estimate mass or determine slab pieces.

6.6 *Test Area,* sufficiently large to allow the placement of the test sample, areas or bins to place the sorted materials, and adequate to allow trucks, loaders, and other required equipment to operate safely. The test area should have a smooth surface, preferably of concrete, to provide a suitable work surface and prevent loss of the fines.

6.7 *Proportional Calipers,* fabricated in a sufficient size or sizes for use in determining if pieces meet or exceed dimensional ratios to be considered slab pieces (see Fig. 1).

6.8 *Miscellaneous Equipment,* such as spray paints to mark pieces, rock hammers, cameras for photo documentation, sample bags, tags or signs, data-recording forms, heavy work gloves, safety goggles or glasses, respirators or dust masks, and steel-toed boots or caps, as required for the work.

7. Hazards

7.1 Performance of these test methods includes the moving, lifting, measurement, and transfer of large pieces of rock. This presents the potential for personnel injury from crushing, dropped or rolling of the riprap pieces. Whenever possible, the sample should be spread to a single layer depth to reduce personnel hazard from rolling or falling pieces.

7.2 Personnel performing these test methods will be in the vicinity of working heavy equipment and precautions should be taken to prevent injury from equipment.

7.3 Working with and around the pieces may subject personnel to dust, flying particles, falling pieces, and excessive noise. Personnel should be adequately equipped and trained in the use of personal protective equipment.

8. Sampling

8.1 The precision and representativeness of these test methods is directly related to the sampling process. The sampling should be carefully planned and executed to achieve optimum representativeness. All parties should be involved in the planning process. The sampling plan should be documented and included as a part of the final report.

8.2 The mass of the total test specimen should be large enough to ensure a representative gradation and should be such that it provides test results to the desired level of accuracy. One analogy is to consider a test specimen size of such size that the addition or loss of the largest expected piece will not change the results by more than a specified percentage.[3]

NOTE 3—Example: For a test specimen size to achieve a 1 % accuracy, assume that the largest individual piece mass is expected to be 150 lb (68 kg). For this piece to represent less than 1 %, the sample mass would be 15 000-lb (6 800-kg) minimum. For this piece to represent less than 5 % accuracy, the sample size would be 3000-lb (1360-kg) minimum.

8.3 Take an adequate amount of sample to ensure that the minimum test specimen mass is available, however sampling will not be to a predetermined exact mass. Composite samples will be allowed only when included in the sample plan.

8.4 Composite samples are not recommended, since it is more difficult to trace the sample source and the product that the sample represents. Composite samples may provide some efficiency for Test Method B; but composite samples provide little advantage in reducing field measurements for Test Methods A and C.

8.5 Sampling from the source material will be in accordance with the sampling plan with the emphasis on obtaining a sample representative of the whole in respect to mass, or size and shape.

8.6 Sample handling should be minimized to avoid unnecessary degradation and breakage. For materials that have been submerged, allow the sample to freely drain. Moisture content of riprap samples is considered inconsequential and the sample will be tested and reported as-found.

8.7 Photographs of the sampling process and related activities should be included in the report.

8.8 Select the selection of sieve or template sizes for size or mass range groupings, or both, in accordance with project needs but should not be less than four sieve sizes or mass range groupings.

8.9 It may be desirable to retain the sample after testing to provide a visual comparison of a known gradation for quality-control purposes at a later date.

NOTE 4—Other characteristics, such as soundness by Test Method D5240, freeze-thaw resistance by Test Method D5312, and wetting and drying resistance by Test Method D5313 are normally determined prior to testing for size and mass. If these tests have not been performed previously, or if confirmation of the results is desirable, the sampling for these tests should be included in the sampling plan.

9. Procedure

9.1 *Test Method A:*

9.1.1 Move the sample to the test location. If truck scales are available, determine the total sample mass and record. For samples that contain large pieces (greater than 12 in. (300 mm) in size), spread the sample in a thin layer.

9.1.2 Determine the mass of each piece by placing the particle on a scale or by use of a hoist-type load cell. Determine the mass of each particle down to the smallest particle mass of importance.

9.1.3 If required, perform secondary sorts and counts of the number of pieces, the number of pieces exhibiting angularity (number of fractured faces), and the number of slab-like shapes.

9.1.4 Take photographs to document shape, color, and any unusual or unique properties of the material under test and include in the report.

9.1.5 Calculate the percentages in accordance with Section 10. Compare and report the total sample mass and the cumulative mass from adding the weight ranges. If the total

[3] Howard, A. K., and Horz, R. C., "Minimum Test Specimen for Gradation Analysis," *Geotechnical Testing Journal*, Vol 11, No. 3, September 1988, pp. 213–217.

sample mass is unavailable, or if the sample storage area is not conducive to gathering the fine material from the sample, then one measurement is acceptable.

9.2 *Test Method B:*

9.2.1 Move the sample to the test location. The test location shall include a clean, hard surface that is free of small pieces that could become mixed with the sample. For samples that contain large pieces (greater than 12 in. (300 mm) in size), spread the sample in a thin layer.

9.2.2 Visually screen the pieces to place them into appropriate piles. All pieces will be separated and placed into a pile before weighing. After separating, the smallest and largest piece in each pile shall be weighed and recorded. The pieces shall be adjusted as necessary so that the weight classes do not overlap. After adjustment is adequate and the weight classes have been established, weigh each pile of pieces.

9.2.3 If required, perform secondary sorts and counts of the number of pieces, the number of pieces exhibiting angularity (number of fractured faces), and the number of slab-like shapes for each of the sorted sizes.

NOTE 5—Slab pieces are those whose minimum to maximum dimensions (thickness to width, or width to length) ratios exceed a specified value, such as 1:4. Slab pieces are often considered detrimental in riprap due to their propensity to break during placement, "raft" with wave action, or to align and slip in use.

9.2.4 Take photographs to document shape, color, and any unusual or unique properties of the material under test and include in the report.

9.2.5 Calculate the percentages in accordance with Section 10.

9.3 *Test Method C:*

9.3.1 Move the sample to a test location.

9.3.2 Place each individual piece on a sieve or template to determine the sizes that the piece will pass and be retained on. Alternately, the template may be placed over the piece to determine the piece sizes. Either place the pieces into separate piles depending on size, or mark the individual pieces using paint or other means. For samples containing large size pieces, it has been found convenient to mark the pieces for size using a color code, rather than sorting and moving them into separate piles. This eliminates the need to move the piece until the mass determination is made.

9.3.3 Convert the piece sizes to mass using Eq A1.4 in Annex A1 or the nomograph on Fig. 2.

9.3.4 If required, perform secondary sorts and counts of the number of pieces, the number of pieces exhibiting angularity (number of fractured faces), and the number of slab-like shapes for each of the sorted sizes.

9.3.5 Take photographs to document shape, color, or any unusual or unique properties of the material under test and include in the report.

9.3.6 Calculate the percentages in accordance with Section 10.

9.4 *Test Method D:*

9.4.1 Either move the sample to a test location, or partition a test plot within a revetment. If evaluating an in-place sample, record the length, width, and thickness.

NOTE 6—For in-place samples, the thickness may be poorly defined. If the riprap is mixed with subgrade, filled with silt, or severely degraded, then it may not be possible to clearly define the sample.

9.4.2 Establish piece sizes by means of templates, calipers, or tape measures. A preliminary sorting by size can often be accomplished visually with only periodic checking with measurements. Piece sizes may be estimated by measuring circumference in conjunction with visual estimation of the mean diameter. For the larger fraction of the sample, each piece size should be recorded. For the smaller fraction of the sample, data may be reduced to the number of particles within a range and the mean piece size.

9.4.3 Convert the piece sizes to mass using Eq A1.4 in Annex A1 or the nomograph on Fig. 2.

9.4.4 If required, perform secondary sorts and counts of the number of pieces, the number of pieces exhibiting angularity (number of fractured faces), and the number of slab-like shapes for each of the sorted sizes.

9.4.5 Take photographs to document shape, color, or any unusual or unique properties of the material under test and include in the report.

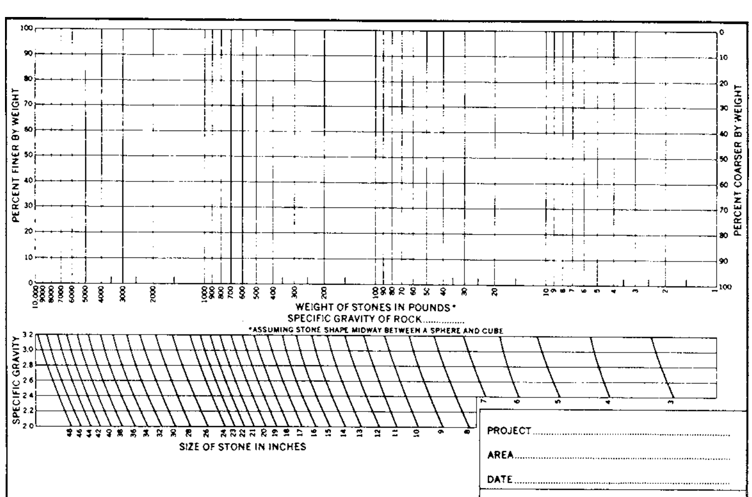


FIG. 2 Typical Grading Graph

9.4.6 Calculate the percentages in accordance with Section 10. If evaluating an in-place sample, compare the cumulative sample mass with the theoretical mass and volume of the sample.

10. Calculation

10.1 Sample worksheets for recording data and calculations are attached. In practice, it is helpful to complete calculations on a spreadsheet.

10.2 Calculate the total percentage passing in various size or weight fractions to the nearest 1 % on the basis of the total weight of the sample. Calculations should follow conventional practice for particle size analysis as commonly employed, such as in Test Methods C136 or D422.

10.3 Plot the results on a graph showing the percentages for each mass range.

11. Report

11.1 Prepare a report including the following for each test performed:

11.1.1 Date test was performed,

11.1.2 Sample identification, source, and source location, including when appropriate, the elevation and coordinates of the sample source,

11.1.3 Test location at which the test was performed,

11.1.4 Location, capacity, accuracy, and last calibration of the scales used to determine the mass,

11.1.5 A copy of the sampling plan used to obtain the test sample, including the calculations of the required sample size, and assumed specific gravities,

11.1.6 Narrative of the actual method for performing the test,

11.1.7 Results of the test, including the specification acceptance limits (if provided), particle counts with accompanying masses or sizes determined, or both. Report cumulative masses or numbers of particles retained on or passing the size or mass ranges of concern. Report any other information obtained, such as the average piece mass on each sieve and the number of pieces retained on each sieve (Test Method A), mass of material not measured (Test Method C). Indicate any values that were determined by calculation,

11.1.8 A graph of the results. When project specifications have been provided, the specification ranges should also be plotted on the graph. Fig. 2 provides an example of a typical graph used for reporting results,

11.1.9 Report the largest particle mass or size encountered, the initial mass of the sample, and the resulting estimated accuracy of the sample representativeness (see 8.2).

11.1.10 Other test information obtained during the test, such as the number of slab pieces per sieve size, angularity, and the like,

11.1.11 Names of the individuals performing the test,

11.1.12 Any other test samples taken and the purpose, such as freeze-thaw, durability, hardness, and the like,

11.1.13 Specifications provided, including the sieve sizes, acceptance percentages, or other acceptance criteria,

11.1.14 Photographs or other illustrative information that may be relevant in evaluating the materials under test, and

11.1.15 Calibration data and frequency on the test sieves, templates, or calipers.

12. Precision and Bias

12.1 The precision of these test methods has not been determined. Limited data are being evaluated to determine the precision of these test methods. Subcommittee D18.17 is seeking pertinent data from users of these test methods.

12.2 The procedure defined in these test methods has no bias because the values of riprap particle size can be defined only in terms of a test method.

12.3 Variation in the results of these test methods is a consequence of the variation in the materials sampled and tested and variation in the application of the test methods.

13. Keywords

13.1 armor stone; filter bedding stone; filter material; gradation; riprap; slab

ANNEX

A1. PIECE SIZE – MASS CONVERSIONS

A1.1 Riprap gradations are commonly specified in terms of mass (weight) or size (diameter). It is commonly necessary to convert between mass and piece size. The conversions used in these test methods are shown below.

For diameter D, the volume of a sphere is

$$V_{sphere} = \frac{\pi}{6} D^3 \quad \text{(A1.1)}$$

For a cube with side length D, the volume of a cube is

$$V_{cube} = D^3 \quad \text{(A1.2)}$$

The dimension D is a characteristic piece size approximately equal to the clear span opening that the piece can pass through.

For the bulk specific gravity G_s, and the unit weight of water γ_{h20}, the weight of a piece is

$$W = G_s \gamma_{h2o} V \quad \text{(A1.3)}$$

Combining (1), (2) and (3), the weight of a piece with shape midway between a sphere and cube is

$$W = \frac{1}{2}\left(1 + \frac{\pi}{6}\right) D^3 G_s \gamma_{h2o} \quad \text{(A1.4)}$$

The nomograph included on Fig. 2 is based on Eq 4. Note that Eq 4 can be expressed with a coefficient A = (1 + π/6)/2 = .76. The coefficient varies from A = 1 for perfect cubes, to A = .52 for perfect spheres. While this may span a wide range, aggregate sources trend toward the midpoint since perfect cubes or spheres do not occur in sources of natural or mined rock, or recycled materials. It may be justified to adjust this coefficient for sub-rounded stones mined from glacial or alluvial deposits, or very blocky rock quarried from massive ledges. However, this is seldom necessary and not recommended unless experience or the intended use of the test shows it to be necessary. If the coefficient is adjusted from the standard of .76, it should be documented in the test report, and Fig. 2 cannot be used.

A1.2 The characteristic piece size D may be estimated from measuring the circumference in place of the diameter. If a characteristic circumference C calculated for the geometric mean of the circumference measured in 3 orthogonal axes (C1, C2, and C3) is valid, then

$$\bar{C} = \sqrt[3]{C_1 C_2 C_3} \tag{A1.5}$$

Again using the assumption of a piece midway between a sphere and cube, the circumference is related to the piece size by

$$\bar{C} = \left(\frac{\pi + 4}{2}\right) D \tag{A1.6}$$

Combining Eqs 5 and 6,

$$D = \left(\frac{2}{\pi + 4}\right) \sqrt[3]{C_1 C_2 C_3} \tag{A1.7}$$

Note that Eq 7 should be used with caution. For slabs with one dimension vanishing with respect to the planar area, the volume approaches zero, but the measured circumferences and therefore the piece size D do not.

APPENDIX

(Nonmandatory Information)

X1. Sample Worksheets

X1.1 Figs. X1.1-X1.3 are sample worksheets.