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Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis[1]

This standard is issued under the fixed designation D6913; 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.

ε[1] NOTE—Editorially corrected Eq 1 in July 2014.

INTRODUCTION

Although this test method has been used for many years, there are vast testing variations required due to soil types and conditions. The test is more complicated and complex than would be expected. Multiple procedures are being presented along with new terminology. Although these procedures are not new, they will now be defined and explained. Some examples of these new terms are composite sieving, designated separating sieve and subspecimen. This test method outlines the majority of conditions and procedures but does not cover every conceivable variation or contingency. The table of contents in the Scope section is added to enable the user to easily find a specific topic or requirement. Only sections/subsections with titles are presented. Therefore, numbered subsections will not be continuous in some cases, as indicated in the Scope section.

1. Scope

1.1 Soils consist of particles with various shapes and sizes. This test method is used to separate particles into size ranges and to determine quantitatively the mass of particles in each range. These data are combined to determine the particle-size distribution (gradation). This test method uses a square opening sieve criterion in determining the gradation of soil between the 3-in. (75-mm) and No. 200 (75-μm) sieves.

1.2 The terms, soils and material, are used interchangeably throughout the standard.

1.3 In cases where the gradation of particles larger than 3 in. (75 mm) sieve is required, Test Method D5519 may be used.

1.4 In cases where the gradation of particles smaller than No. 200 (75-μm) sieve is required, Test Method D422[2] may be used.

1.5 Typically, if the maximum particle size is equal to or less than 4.75 mm (No. 4 sieve), then single-set sieving is applicable. Furthermore, if the maximum particle size is greater than 4.75 mm (No. 4 sieve) and equal to or less than 9.5 mm (3⁄8-in sieve), then either single-set sieving or composite sieving is applicable. Finally, if the maximum particle size is equal to or greater than 19.0 mm (3⁄4-in sieve), composite sieving is applicable. For special conditions see 10.3.

1.6 Two test methods are provided in this standard. The methods differ in the significant digits recorded and the size of the specimen (mass) required. The method to be used may be specified by the requesting authority; otherwise Method A shall be performed.

1.6.1 *Method A*—The percentage (by mass) passing each sieve size is recorded to the nearest 1 %. This method must be used when performing composite sieving. For cases of disputes, Method A is the referee method.

1.6.2 *Method B*—The percentage (by mass) passing each sieve size is recorded to the nearest 0.1 %. This method is only applicable for single sieve-set sieving and when the maximum particle size is equal to or less than the No. 4 (4.75-mm) sieve.

1.7 This test method does not cover, in any detail, procurement of the sample. It is assumed that the sample is obtained using appropriate methods and is representative.

1.8 *Sample Processing*—Three procedures (moist, air dry, and oven dry) are provided to process the sample to obtain a specimen. The procedure selected will depend on the type of sample, the maximum particle-size in the sample, the range of particle sizes, the initial conditions of the material, the plasticity of the material, the efficiency, and the need for other testing

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils.

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[2] Currently Subcommittee D18.03 is preparing a new test method (Hydrometer Analysis or Combined Sieve and Hydrometer Analysis) to replace D422.

on the sample. The procedure may be specified by the requesting authority; otherwise the guidance given in Section 10 shall be followed.

1.9 This test method typically requires two or three days to complete, depending on the type and size of the sample and soil type.

1.10 This test method is ***not*** applicable for the following soils:

1.10.1 Soils containing fibrous peat that will change in particle size during the drying, washing, or sieving procedure.

1.10.2 Soils containing extraneous matter, such as organic solvents, oil, asphalt, wood fragments, or similar items. Such extraneous matter can affect the washing and sieving procedures.

1.10.3 Materials that contain cementitious components, such as cement, fly ash, lime, or other stabilization admixtures.

1.11 This test method may not produce consistent test results within and between laboratories for the following soils and the precision statement does not apply to them.

1.11.1 Friable soils in which the sieving processes change the gradation of the soil. Typical examples of these soils are some residual soils, most weathered shales and some weakly cemented soils such as hardpan, caliche or coquina.

1.11.2 Soils that will not readily disperse such as glauconitic clays or some dried plastic clays.

1.11.3 To test these soils, this test method must be adapted, or altered, and these alterations documented. Depending on the design considerations, a specialized gradation-testing program could be performed. The alterations could require the washing and sieving procedures to be standardized such that each specimen would be processed in a similar manner.

1.12 Some materials that are not soils, but are made up of particles may be tested using this method. However, the applicable sections above should be used in applying this standard.

1.13 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026, unless superseded by this test method.

1.13.1 The procedures used to specify how data are collected/recorded and calculated in this standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering design.

1.14 *Units*—The dimensional values stated in either SI units or inch-pound units are to be regarded as standard, such as 200-mm or 8-in. diameter sieve. Except, the sieve designations are typically identified using the "alternative" system in accordance with Practice E11, such as 3 in. and No. 200, instead of the "standard" system of 75 mm and 75 µm, respectively. Only the SI units are used for mass determinations, calculations, and reported results. However, the use of balances or scales recording pounds of mass (lbm) shall not be regarded as nonconformance with this standard.

1.15 A summary of the symbols used in this test method is given in Annex A1.

1.16 *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.*

1.17 *Table of Contents*—All tables and figures appear at the end of this standard.

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C702 Practice for Reducing Samples of Aggregate to Testing Size

D422 Test Method for Particle-Size Analysis of Soils

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12 400 ft-lbf/ft^3 (600 kN-m/m^3))

D1140 Test Methods for Determining the Amount of Material Finer than 75-μm (No. 200) Sieve in Soils by Washing

D1557 Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft^3 (2,700 kN-m/m^3))

D2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D2487 Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

D2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4318 Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils

D4753 Guide for Evaluating, Selecting, and Specifying Balances and Standard Masses for Use in Soil, Rock, and Construction Materials Testing

D5519 Test Methods for Particle Size Analysis of Natural and Man-Made Riprap Materials

D6026 Practice for Using Significant Digits in Geotechnical Data

E11 Specification for Woven Wire Test Sieve Cloth and Test Sieves

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 *General:*

3.1.1 An overview of terms used in the sieving processes is presented in Fig. 1(a) using a tabular format and in Fig. 1(b) using a flowchart format. In addition, Fig. 1(a) includes symbols used in the sieving processes.

3.1.2 There are two types of definitions in the following sections. There are definitions that are general (see 3.2) and others that are specific to this standard (see 3.3). To locate a definition, it may be necessary to review both sections. The definitions are in alphabetical order.

3.2 *Definitions:*

3.2.1 For definitions of general terms used in this test method, refer to Terminology D653.

3.2.2 *composite sieving, v—in sieving*, the process of separating a large specimen on a designated separating sieve to obtain coarser and finer particle-size portions. The coarser portion is sieved using the coarser sieve set. The finer portion is subsampled to obtain a subspecimen of manageable size (mass) and this subspecimen is sieved using the finer sieve set. The results of both sieve sets (coarser and finer) are combined mathematically to determine the gradation of the large specimen.

3.2.2.1 *Discussion*—In some cases the subspecimen may require another separation; i.e., using a 2nd designated separating sieve and resulting in a 2nd coarser portion and 2nd subspecimen obtained from the 2nd finer portion.

3.2.3 *cumulative material retained (cumulative retained material or cumulative mass retained), n—in sieving*, the mass of material retained on an individual sieve plus the masses of material retained on all the coarser sieves in a given stack/set of sieves.

3.2.4 *cumulative percent retained, n— in sieving*, the ratio of cumulative material retained on a given sieve to the mass of the specimen, expressed in percent.

3.2.5 *designated separating sieve, n— in composite sieving*, the sieve selected to separate the specimen into coarser and finer portions for composite sieving.

3.2.5.1 *Discussion*—The designated separating sieve size is a standard sieve size typically ranging from the ¾-in. (19.0-mm) sieve to the No. 10 (2.00-mm) sieve. There can be two designated separating sieves used in composite sieving, that is the 1st subspecimen can be separated on a 2nd designated separating sieve to obtain a 2nd coarser portion and a 2nd subspecimen obtained from the 2nd finer portion.

3.2.6 *fractional cumulative material retained, n—in composite sieving*, when sieving a subspecimen, the mass of material retained on an individual sieve plus the masses of material retained on all the coarser sieves in a given sieve set.

3.2.7 *fractional cumulative percent retained, n—in composite sieving*, the ratio of fractional cumulative material retained on a given sieve to the mass of the subspecimen, expressed in percent.

[3] 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.

Terms [A]	Modifying Adjectives & Symbols
A – Single Sieve-Set Sieving	
<u>specimen</u>	moist (S,M_m), dry or oven-dried (S,M_d), air-dried (S,M_{ad}), washed (S_wM_d)
sieve set	
cumulative material or mass retained on *Nth* sieve	CMR_N
cumulative percent retained on *Nth* sieve	CPR_N
percent passing the *Nth* sieve [B]	PP_N
percent retained on *Nth* sieve [C]	PR_N
B – Composite Sieving: Single Separation, Only One Designated Separating Sieve Used	
<u>specimen</u>	Same as above.
designated separating sieve	
<u>coarser portion</u>	moist (CP,M_m), dry or oven-dried (CP,M_d), air-dried (CP,M_{ad}), washed ($CPwM_d$)
coarser sieve set	
cumulative material or mass retained on *Nth* sieve	CP,CMR_N
cumulative percent retained on *Nth* sieve	CP,CPR_N
percent passing the *Nth* sieve [B]	CP,PP_N
composite sieving correction factor	$CSCF$
<u>finer portion</u>	moist (FP,M_m), dry (FP,M_m), air-dried (FP,M_{ad})
subspecimen	moist ($SubS,M_m$), dry or oven-dried ($SubS,M_d$), air-dried ($SubS,M_{ad}$), washed ($SubS_w,M_d$)
finer sieve set	
fractional cumulative mass retained on *Nth* sieve	$SubS,FCMR_N$
fractional cumulative percent retained on *Nth* sieve	$SubS,FCPR_N$
fractional percent passing the *Nth* sieve	$SubS,FPP_N$
fractional percent retained the first sieve	$SubS,FPR_{first}$
finer portion percent passing the *Nth* sieve	FP,PP_N
percent passing the *Nth* sieve [D]	$SubS,PP_N$
C – Composite Sieving: Double Separation, 1st & 2nd Designated Separating Sieves Used	
<u>specimen</u>	Same as above.
1st designated separating sieve	
<u>1st coarser portion</u>	Same as above.
Same as above, except the prefix 1st is added to all terms	$1^{st}CP,CMR_N$, $1^{st}CP,CPR_N$, $1^{st}CP,PP_N$, $1^{st}CP,PP_N$, $1^{st}CSCF$
<u>1st finer portion</u>	Same as above.
1st subspecimen (used to produce 2nd subspecimen and 2nd coarser portion for sieving)	moist ($1^{st}SubS,M_m$), dry ($1^{st}SubS,M_d$), air-dried ($1^{st}SubS,M_{ad}$)
2nd designated separating sieve	
2nd coarser portion	dry or oven-dried ($2^{nd}CP,M_d$), washed ($2^{nd}CP_w,M_d$)
2nd finer portion	dry or oven-dried ($2^{nd}FP,M_d$)
2nd coarser sieve set	
1st fractional cum. mass retained on *Nth* sieve	$2^{nd}CP,FCMR_N$
1st fractional cum. percent retained on *Nth* sieve	$2^{nd}CP,,FCPR_N$
1st fractional percent passing the *Nth* sieve	$2^{nd}CP,FPP_N$
1st fractional percent retained on first sieve	$2^{nd}CP,FPR_{first}$
percent passing the *Nth* sieve [C]	$2^{nd}CP,PP_N$
finer portion percent passing the *Nth* sieve	FP,PP_N
2nd composite sieving correction factor	$2^{nd}CSCF$
1st finer portion composite sieving correction factor	$1^{st}FP, CSCF$
2nd <u>subspecimen</u> (selected from 2nd finer portion)	moist ($2^{nd}SubS,M_m$), dry ($2^{nd}SubS,M_d$), air-dried ($2^{nd}SubS,M_{ad}$)
finer sieve set	
2nd fractional cum. mass retained on *Nth* sieve	$2^{nd}SubS,FCMR_N$
2nd fractional cum. percent retained on *Nth* sieve	$2^{nd}SubS,FCPR_N$
2nd fractional percent passing the *Nth* sieve	$2^{nd}SubS,FPP_N$
2nd fractional percent retained on the first sieve	$2^{nd}SubS,FPR_{first}$
1st finer portion percent passing the *Nth* sieve	$1^{st}FP,PP_N$
percent passing the *Nth* sieve [D]	$2^{nd}SubS,PP_N$

Notes: [A] The term mass is omitted, since all non-percent terms are in mass (g). Some terms, such as material retained, percent retained (except as required) and fractional material are omitted since only the "cumulative" methodology is presented herein.

[B] Equals 100 minus cumulative percent retained. [C] Only required in precision determination.

[D] Function of the appropriate fractional percent passing and *CSCF*.

FIG. 1 (a) Typical Terminology and Symbols Used in Sieving Processes

3.2.8 *fractional material retained, n— in composite sieving*, when sieving a subspecimen, the mass of material retained on an individual sieve.

3.2.9 *fractional percent passing, n— in composite sieving*, the portion of material by mass in the subspecimen(s) passing a given sieve expressed in percent.

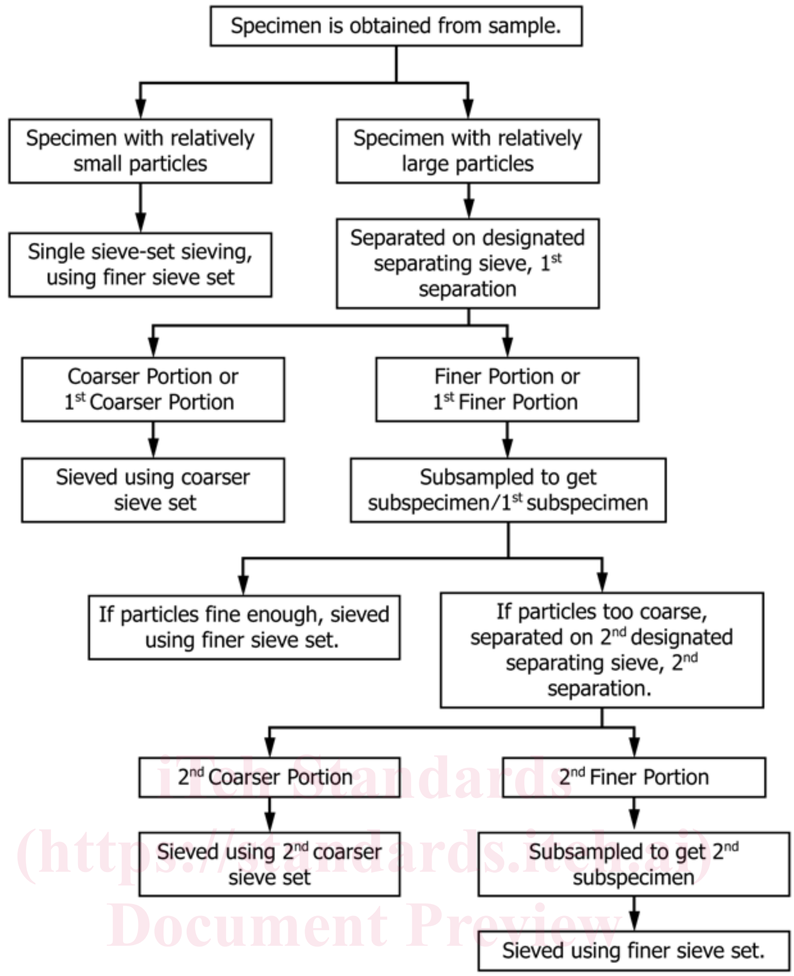

FIG. 1 (b) Terminology Flowchart for Sieving Processes *(continued)*

3.2.9.1 *Discussion*—When two subspecimens are used, there will be a 1st and 2nd fractional percent passing.

3.2.10 *fractional percent retained, n— in composite sieving*, the ratio of fractional material retained on a given sieve to the mass of the subspecimen, expressed in percent.

3.2.11 *gradation, n—in soil*, the proportion by mass of various particle sizes.

3.2.11.1 *Discussion*—This proportion is usually presented in tabular format (sieve size and percent passing) or graphical format (percent passing versus logarithm of the sieve size in mm). The graphical format is referred to as particle-size distribution or gradation curve.

3.2.12 *maximum particle size, n—in sieving*, the smallest sieve size from the standard sieve set on which less than one percent of the sample would be retained.

3.2.12.1 *Discussion*—For practical purposes, estimate the maximum particle size as equal to the smallest sieve size from the standard sieve set in which it appears that all the material being tested would pass through that sieve. The maximum particle size is needed to determine the required mass of the specimen and subspecimen.

3.2.13 *maximum sieve size, n—in sieving*, the smallest sieve size that is larger than any particle in the specimen or subspecimen.

3.2.14 *minimum sieve size, n—in sieving*, the smallest sieve size in a sieve set used in sieving the specimen or subspecimen.

3.2.14.1 *Discussion*—This size is either the size of the designated separating sieve (1st or 2nd) or the No. 200 (75-µm) sieve.

3.2.15 *percent passing, n—in sieving*, the portion of material by mass in the specimen passing a given sieve expressed in percent.

3.2.15.1 *Discussion*—This value is equal to the cumulative material retained in a given sieve set divided by the mass of the specimen, subtracting that ratio from one, and then multiplying by 100. For composite sieving, it would be the fractional percent passing multiplied by the composite sieving correction factor (*CSCF*).

3.2.16 *particle size distribution, n*—see *gradation.*

3.2.17 *percent retained, n—in sieving*, the ratio of the material retained on a given sieve to the mass of the specimen, expressed in percent.

3.2.18 *saturated surface-dry condition, n—in coarse-grained soils*, a state in which the soil particles are basically saturated with water, but there are not visible films of water.

3.2.19 *sieve set, n—in sieving*, a set of standard sized sieves. For single sieve-set sieving, the sieve set will range from the maximum sieve size to the No. 200 (75-µm) sieve. For composite sieving, there will be a coarser sieve set and a finer sieve set. Together, these sets will range from the maximum sieve size to the No. 200 (75-µm) sieve. The designated separating sieve will be used as the minimum size in the coarser set and the maximum size in the finer set.

3.2.20 *sieve size, n—in sieving*, the size of the opening in the wire cloth of a given sieve in mm or µm.

3.2.21 *single sieve-set sieving, v—in sieving*, the process in which only one set of sieves is required to determine the gradation of the specimen from the maximum particle size to the No. 200 (75-µm) sieve.

3.2.21.1 *Discussion*—Typically, this applies to specimens having a maximum particle size of 9.5 mm (3⁄8 in.) or less when using Method A or a maximum particle size of 4.75 mm (No. 4 sieve) or less when using Method B and the distribution of particles less than the No. 200 (75-µm) sieve is not needed.

3.2.22 *splitting, v—in sampling or subsampling*, the process of stockpile sampling, quartering material, or passing material through a splitter or riffle box to obtain a representative portion of that material for testing; i.e., a specimen or subspecimen.

3.2.22.1 *Discussion*—A description of stockpile sampling, and quartering and splitting material is given in Annex A2, A2.1.1 through A2.1.3.

3.2.23 *standard shaking period, n—in sieving*, a time period ranging from 10 to 20 minutes that a mechanical sieve shaker operates during the sieving process and which has been verified to satisfy the requirements for sieving thoroughness.

3.2.24 *standard sieve set, n—in sieving soils*, the group of fourteen specific sieve sizes required to determine the gradation of soils between and including the 3-in. (75-mm) and No. 200 (75-µm) sieves, as listed in Table 1.

3.2.24.1 *Discussion*—Most of these sieve sizes are different than those used in aggregate testing for concrete (Test Method C136), especially for sieves finer than the No. 4 (4.75 mm).

3.2.25 *subspecimen, n—in composite sieving*, a representative portion of the material passing the designated separating sieve; i.e., the finer portion.

3.2.25.1 *Discussion*—When composite sieving requires multiple designated separating sieves, there will be more than one subspecimen. The 1st subspecimen (i.e. the subspecimen from the finer portion) would be separated into a 2nd coarser portion and a 2nd finer portion that would be subsampled to obtain the 2nd subspecimen.

3.3 *Definitions of Terms Specific to This Standard:*

3.3.1 *coarser portion, n—in composite sieving*, the portion of the specimen retained on the designated separating sieve.

3.3.1.1 *Discussion*—When two designated separating sieves are used, there will be a 1st and 2nd coarser portion.

3.3.2 *coarser sieve set, n—in composite sieving*, the sieve set that ranges from the maximum sieve size to the designated separating sieve size.

3.3.2.1 *Discussion*—When two designated separating sieves are used, the 1st coarser sieve set ranges from the maximum sieve size to the 1st designated separating sieve size. The 2nd coarser sieve set would range from the 1st designated separating sieve size to the 2nd designated separating sieve size.

3.3.3 *composite sieving correction factor (CSCF), n—in composite sieving*, a factor used to convert the fractional percent passing determined from sieving the subspecimen to the percent passing for the specimen. The *CSCF* is equal to the percent passing the designated separating sieve size in the coarser portion sieve set (i.e., the last sieve in the coarser portion set). This value shall be calculated to one more digit than required (0.1 %) to reduce rounding errors.

3.3.3.1 *Discussion*—When two designated separating sieves are used, there will be a 1st and 2nd *CSCF*.

3.3.4 *finer portion, n—in composite sieving*, the portion of the specimen passing the designated separating sieve.

3.3.4.1 *Discussion*—When two designated separating sieves are used, the 1st subspecimen obtained from the 1st finer portion will be separated into a 2nd coarser portion and 2nd finer portion, from which the 2nd subspecimen is obtained.

3.3.5 *finer sieve set, n—in composite sieving*, the sieve set that ranges from the last designated separating sieve size to the No. 200 (75-µm) sieve.

3.3.5.1 *Discussion*—When composite sieving requires a 2nd subspecimen, the finer sieve sets ranges from the 2nd separating sieve size to the No. 200 (75-µm) sieve.

TABLE 1 Standard Sieve Set[A]

Sieve Designation in Accordance with E11			
Alternative	Standard	Alternative	Standard
Lid		No. 10	2.00 mm
3 in.	75 mm	No. 20	850 µm
2 in.	50 mm	No. 40	425 µm
1-½ in.	37.5 mm	No. 60	250 µm
1 in.	25.0 mm	No. 100	150 µm
¾ in.	19.0 mm	No. 140	106 µm
⅜ in.	9.5 mm	No. 200	75 µm
No. 4	4.75 mm	Pan	

[A] A lid is typically not used or required when using rectangular coarser sieves having dimensions greater than 200 mm or 8 in.

3.3.6 *insignificant sieve, n—in precision of test results*, any sieve which has 1 % or less cumulative material retained during the sieve analysis.

3.3.7 *separating, v—in composite sieving*, the process of dividing a specimen or subspecimen into two portions, the coarser (retained) and finer (passing) portions, using a designated separating sieve.

3.3.7.1 *Discussion*—When composite sieving requires two designated sieves, there will be a 1st and 2nd coarser portion, finer portion and subspecimen.

3.3.8 *significant sieve, n—in precision of test results*, any sieve which has more than 1 % of cumulative material retained during the sieve analysis.

4. Summary of Test Method

4.1 This test method is used to determine the particle-size distribution (gradation) of a soil sample. A representative specimen must be obtained from the sample by one of three procedures (moist, air-dried or oven-dried). For specimens containing relatively small particles, the specimen is sieved in its entirety, using single sieve-set sieving. However, the specimen may contain a wide range of particle sizes and may require separating the soil into two, or three size ranges for more efficient sieving, using one or two designated separating sieve(s). This process is termed composite sieving. For a single separation (two portions), the coarser portion is sieved in its entirety, while the finer portion is split into a smaller subspecimen for sieving. These results are mathematically combined. For specimens containing very large particles, the specimen may require two separations; i.e., three portions (1st and 2nd coarser portions and 2nd finer portion), see Fig. 1(a) and Fig. 1(b). Prior to sieving, as applicable, the material will be washed to remove fine particles and oven dried. The material to be sieved will be placed on the coarsest sieve size of each sieve set and mechanically shaken. The mass of particles retained on each sieve will be determined. The results will produce a tabulation of sieve sizes versus percent passing that can be graphically presented as a gradation curve (a plot of the percent passing versus the log of the particle size in mm.).

4.2 Flowcharts outlining the requirements of the various sieving processes covered above are presented below in four figures, Fig. 2 through Fig. 4(b).

5. Significance and Use

5.1 The gradation of the soil is used for classification in accordance with Practice D2487.

5.2 The gradation (particle-size distribution) curve is used to calculate the coefficient of uniformity and the coefficient of curvature.

5.3 Selection and acceptance of fill materials are often based on gradation. For example, highway embankments, backfills, and earthen dams may have gradation requirements.

5.4 The gradation of the soil often controls the design and quality control of drainage filters, and groundwater drainage.

5.5 Selection of options for dynamic compaction and grouting is related to gradation of the soil.

5.6 The gradation of a soil is an indicator of engineering properties. Hydraulic conductivity, compressibility, and shear strength are related to the gradation of the soil. However, engineering behavior is dependent upon many factors (such as effective stress, stress history, mineral type, structure, plasticity, and geologic origins) and cannot be based solely upon gradation.

NOTE 1—The quality of the result produced by 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/sampling/inspection/etc. Users of these test methods are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Sieves*—Each sieve shall conform to the requirements of Specification E11. Generally, these sieve frames are circular and 200 mm or 8 in. in diameter, and either full (50 mm or 2 in.) or half height (25 mm or 1 in.). The sieve height generally depends upon the number of sieves typically required in the sieve set, the particle sizes being sieved, and the size and type of the sieve shaker. Particles having dimensions exceeding or relatively close to the sieve heights cannot be sieved in the sieve stack, but individually. Therefore, in a stack of sieves, the ratio of sieve height or spacing between rectangular sieves to sieve cloth opening shall exceed 2. Larger frames that conform to Specification E11 are acceptable but require special considerations for reinforcement.

6.1.1 *Standard Sieve Set*—This set consists of all the sieve sizes listed in Table 1. Additional sieves sizes may be added if requested or required to reduce sieve overloading. In addition, some larger sieve sizes may be omitted during the sieve analysis depending on the maximum particle size; however, at least one sieve in the sieving process shall have 100 percent passing.

6.1.2 *Washing Sieve, No. 200 (75-μm)*—A No. 200 (75-μm) sieve with a minimum height above the screen of 50 mm or 2 in. to prevent loss of retained material while washing. Stainless steel sieve cloth is preferred because it is more durable, and less prone to damage or wear. The sieve may be reinforced with a larger mesh underneath the 75-μm cloth. The reinforcement wire cloth (backing) should not have a mesh coarser than the No. 20 (850-μm) wire cloth. The reinforcement wire cloth should be bonded to the sieve frame along with the No. 200 (75-μm) wire cloth, not bonded to the sieve frame below where the No. 200 (75-μm) wire cloth was attached. In addition, it is good practice to use a flattened backing cloth (rolled or calendered backing cloth), so it is less abrasive to the No. 200 (75-μm) wire cloth.

6.1.3 *Designated Separating Sieve*—A sieve used to separate the specimen into two portions (coarser and finer portion) in composite sieving. The designated separating sieve shall conform to Specification E11. It may be necessary to have various sizes of sieves to use as designated separating sieves. Normally, these are not the same sieves that are used in the stack of sieves (sieve set) placed in the sieve shaker. Typically, the 1st designated separating sieve is rectangular and quite

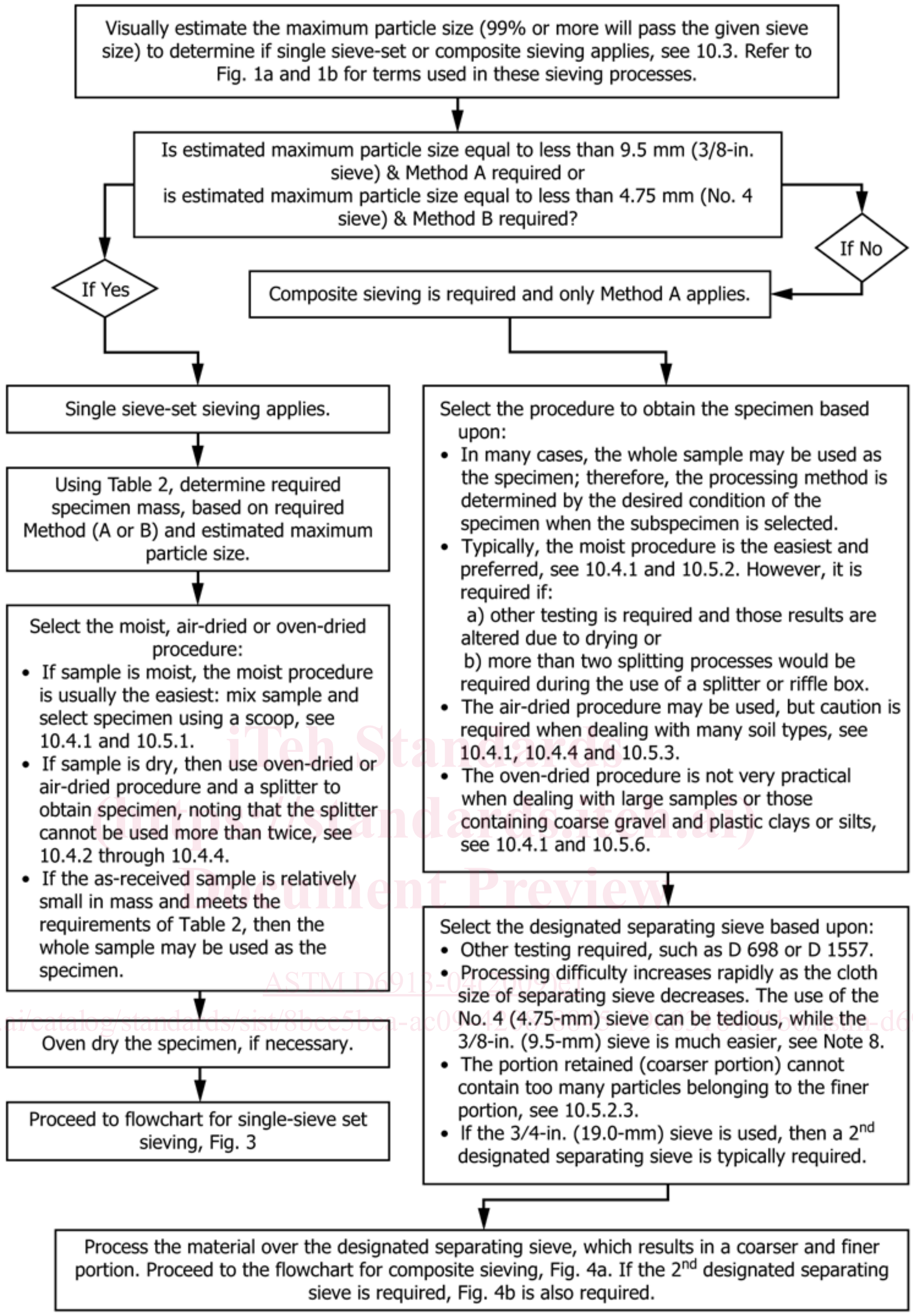

FIG. 2 Decision Flowchart for Sieving Processes

large, while the 2nd designated separating sieve is either 200-mm or 8-in. in diameter.

6.2 *Washing Sink with Spray Nozzle*—A sink having a spray nozzle attached to a flexible line to facilitate the washing and material transferring processes without spillage. In addition, the spray nozzle shall be such that the rate of water flow can be easily controlled. The temperature of the water shall be relatively close to room temperature to prevent changing the dimensions of the sieve cloth and health and safety concerns.

6.3 *Mechanical Sieve Shaker*—A device that holds a stack of sieves while imparting sufficient motion to the sieves to meet the sieving thoroughness requirements covered in 8.2. The "Standard Shaking Period" must be from 10 to 20 minutes. The shaker shall have a timing device or a timing device shall be used in conjunction with the shaker.

NOTE 2—Shakers imparting a motion that causes the particles on the sieves to bounce and turn so that all particles have ample opportunity in various orientations to the sieve openings will typically meet this sieving

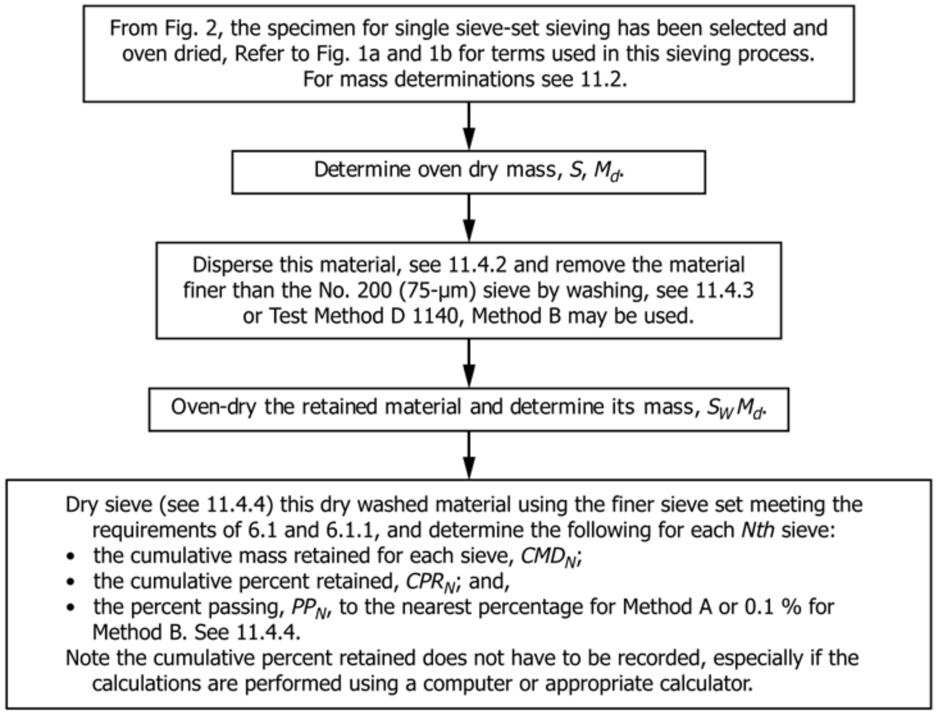

FIG. 3 Flowchart for Single Sieve-Set Sieving

thoroughness requirement. A sieve shaker that has a smooth horizontal and/or vertical gyratory/orbital motion will typically ***not*** meet this sieving thoroughness requirement, since the particles will not be bouncing and turning.

6.4 *Balances*—For single sieve-set sieving, one balance will be used. For composite sieving, more than one balance may be required. Balances must conform to the requirements of Specification D4753; i.e., having a readability (with no estimation) to determine the mass of the specimen or subspecimen to a minimum of three significant digits for Method A or a minimum four significant digits for Method B. The mass of the specimen can be determined in parts (multiple mass determinations). The balance used to determine the cumulative material retained or the fractional cumulative material retained on any given sieve has to have a readability equal to or better than that used to determine the mass of the specimen/subspecimen.

NOTE 3—Preferably the balance should have a taring capability so that the mass of material can be directly determined without subtracting the mass of the container. This feature is extremely useful during the sieving process to determine the mass of the cumulative material retained or when making multiple mass determinations to determine specimen's mass.

6.5 *Drying Oven*—Thermostatically controlled oven, capable of maintaining a uniform temperature of 110 ± 5°C throughout the drying chamber. These requirements typically require the use of a forced-draft oven.

6.6 *Sieving Containers*—The containers used to: *(a)* contain the sieving specimen or material which will be sieved, such as coarser portion; *(b)* remove the retained material from the sieve(s); *(c)* collect and transfer that material; and, *(d)* contain the cumulative material retained.

6.6.1 *Specimen Containers*—Smooth walled containers, without tight corners to trap material, made of material resistant to corrosion and change in mass upon repeated heating, cooling, specimen soaking, and cleaning. The containers should be large enough to enable soaking of the specimen. The container should facilitate the transfer of the specimen from the container to the washing sieve (No. 200 (75 µm) or designated separating sieve) and back by a rinsing/washing operation, and allow for decanting the clear wash water from the container.

6.6.2 *Collection/Transfer Container*—This container is used to collect the material retained on a given sieve and to transfer it to the container holding the cumulative retained material during the sieving process. The container must be larger in diameter than the sieve. A smoothsurface 230-mm (9-in.) pie pan may be used along with a 25-mm (1-in.) paintbrush to assist in transferring all the material. The color of this container shall enhance the observation that all material has been transferred.

6.6.3 *Cumulative Mass Container*—This container shall be large enough to receive the retained material contained in the collection/transfer device without any loss. The mass should be less than the taring capacity of the balance so that the cumulative mass retained can be determined directly (see Note 3). In most cases, the specimen/subspecimen container can be used. This test method assumes that the mass of the cumulative retained material is determined directly. This approach is easier than determining the mass of retained material on each sieve.

6.7 *Sieve Brushes*—Brushes to assist in the removal of the material retained on the smaller (≤ 200-mm or 8-in.) diameter and finer sieve sizes (≤ ¾-in. (19.0-mm)). The brushes shall have the following characteristics:

6.7.1 The bristles shall be firmly attached to the brush handle so that the bristles do not become part of the retained material.

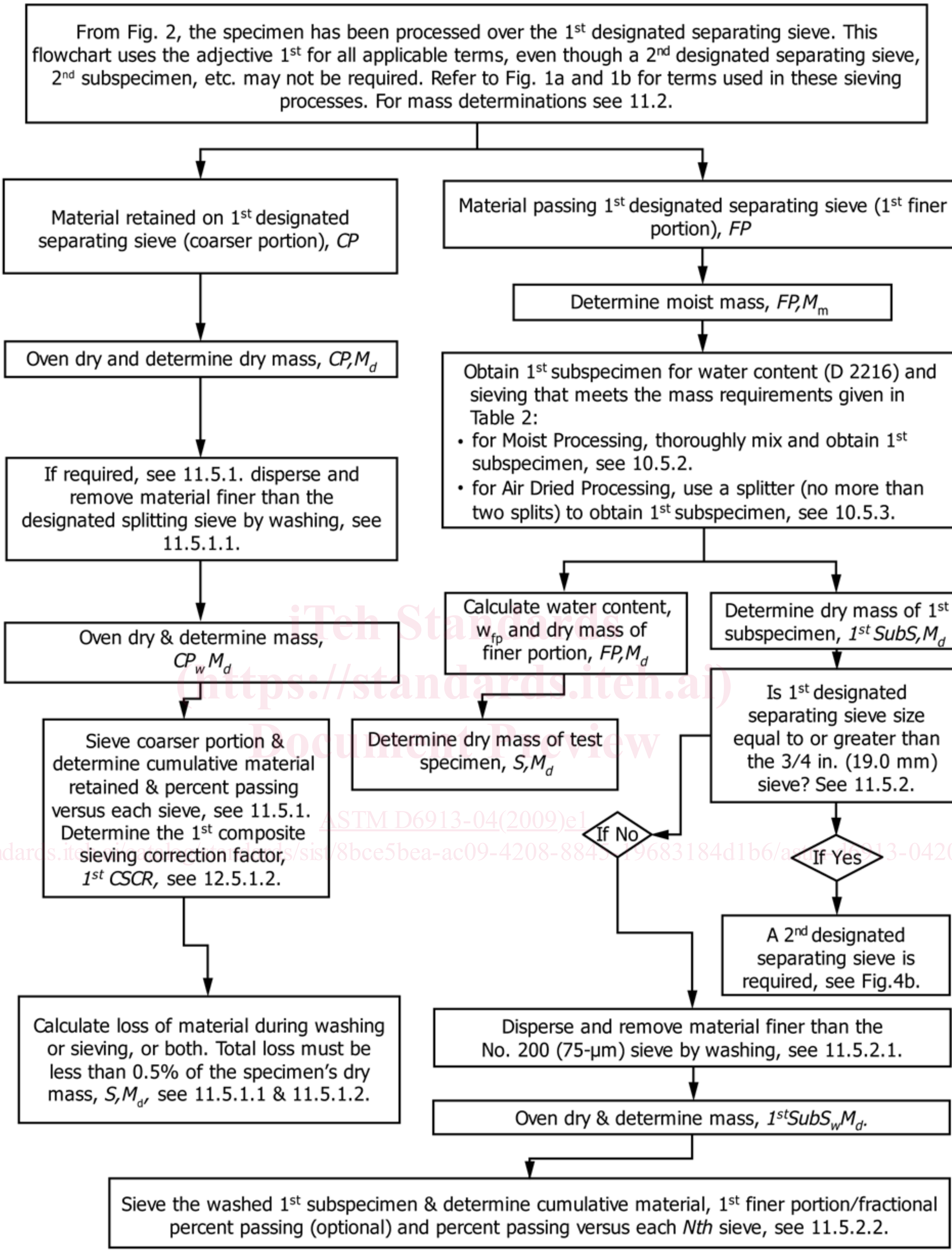

FIG. 4 (a) Flowchart for Composite Sieving—Single Separation