Designation: D6913/D6913M – 17

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

This standard is issued under the fixed designation D6913/D6913M; 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.

INTRODUCTION

Although this test method has been used for many years, there are vast testing variations 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 needed, Test Method D5519 may be used.

1.4 In cases where the gradation of particles smaller than No. 200 (75-μm) sieve is needed, Test Method D7928 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 (⅜-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 (¾-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 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] 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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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.

1.18 *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:*[2]

C136 Test Method for Sieve Analysis of Fine and Coarse Aggregates

C702 Practice for Reducing Samples of Aggregate to Testing Size

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

D4220/D4220M Practices for Preserving and Transporting Soil Samples

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

D7928 Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis

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; that is, 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 2ndsubspecimen 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.

[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.

Terms [A]	Modifying Adjectives & Symbols
A – Single Sieve-Set Sieving	
specimen	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	
specimen	Same as above.
designated separating sieve	
coarser portion	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*
finer portion	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	
specimen	Same as above.
1st designated separating sieve	
1st coarser portion	Same as above.
Same as above, except the prefix 1st is added to all terms	$1^{st}CP,CMR_N$, $1^{st}CP,CPR_N$, $1^{st}CP,PP_N$, $1^{st}CP,PP_N$, $1^{st}CSCF$
1st finer portion	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 subspecimen (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

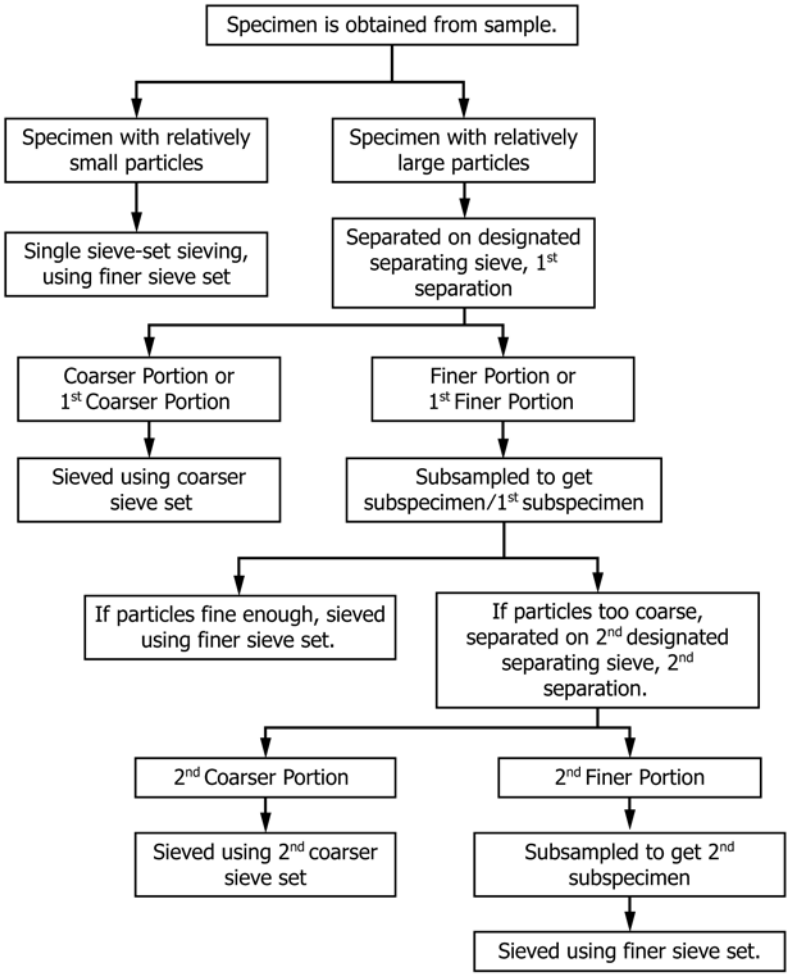

FIG. 1 (b) Terminology Flowchart for Sieving Processes *(continued)*

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.

3.2.8 *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.

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 needed 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 (⅜ 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; that is, 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; that is, 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 (that is, 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 (that is, 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.

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 needed when using rectangular coarser sieves having dimensions greater than 200 mm or 8 in.

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.

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; that is, 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 needed 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.

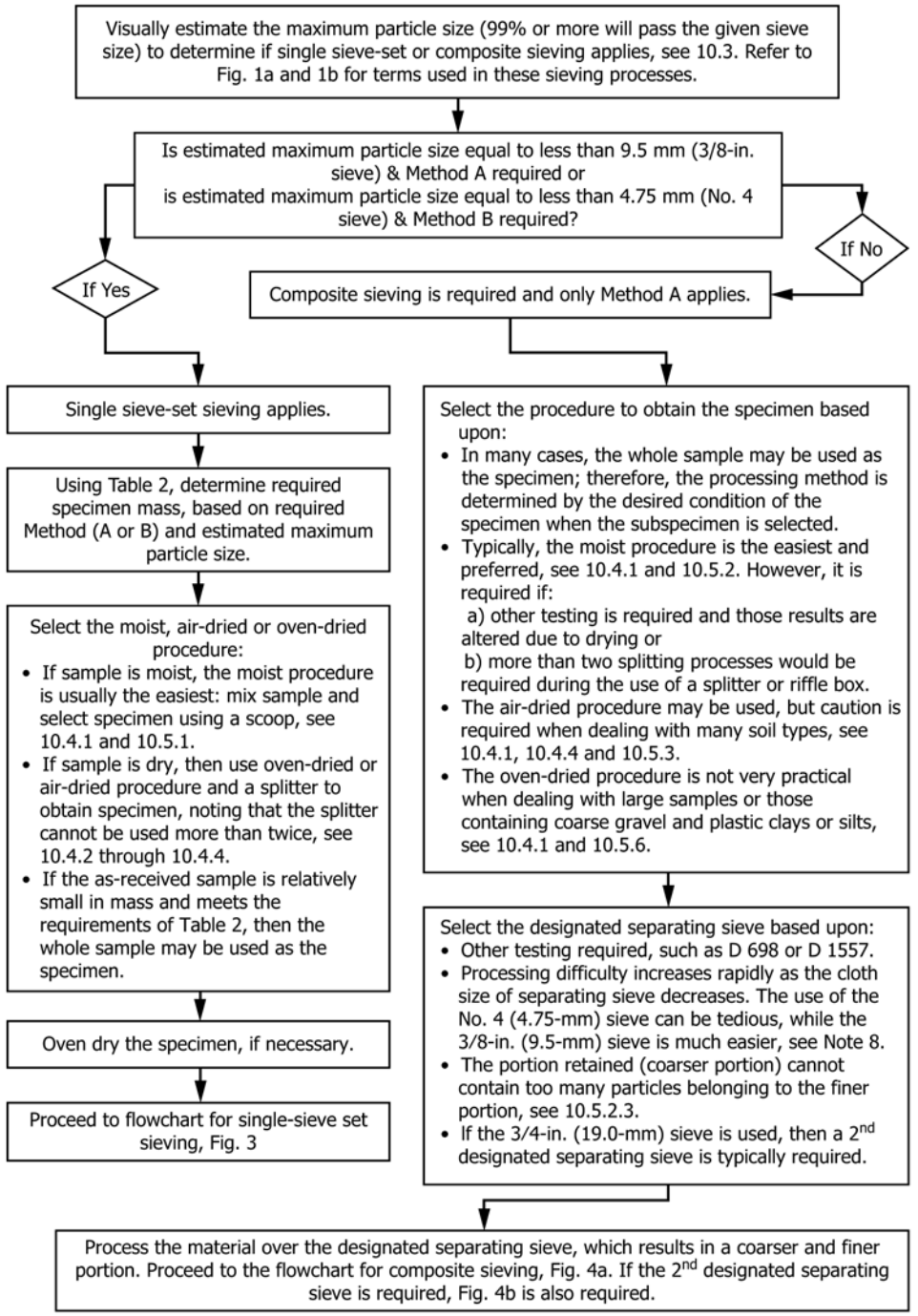

FIG. 2 Decision Flowchart for Sieving Processes

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 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

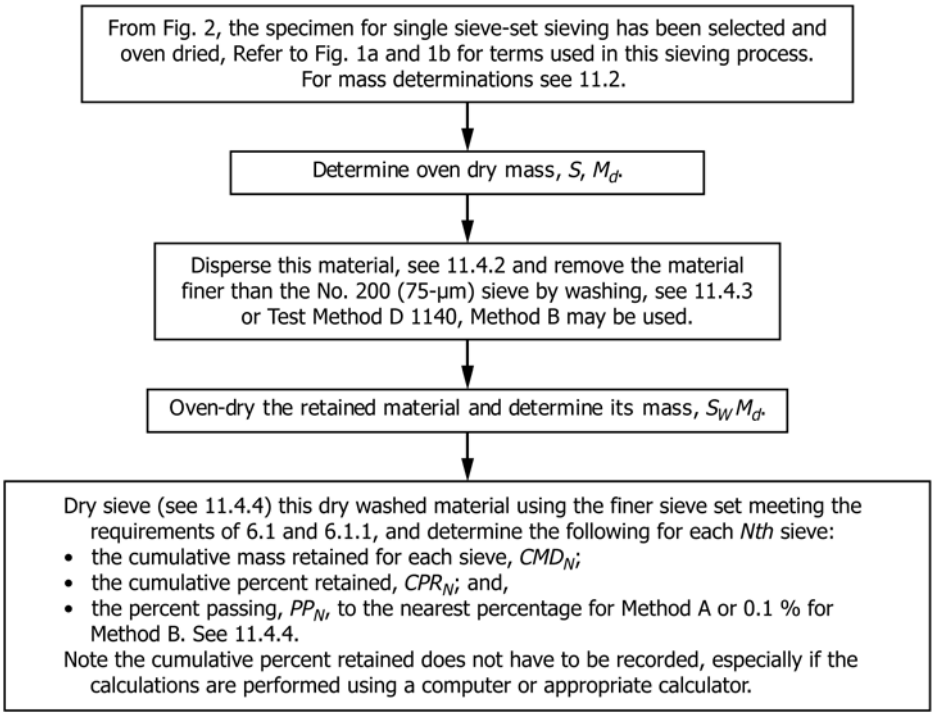

FIG. 3 Flowchart for Single Sieve-Set Sieving

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 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 necessary. Balances must conform to the requirements of Specification D4753; that is, 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 immensely 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

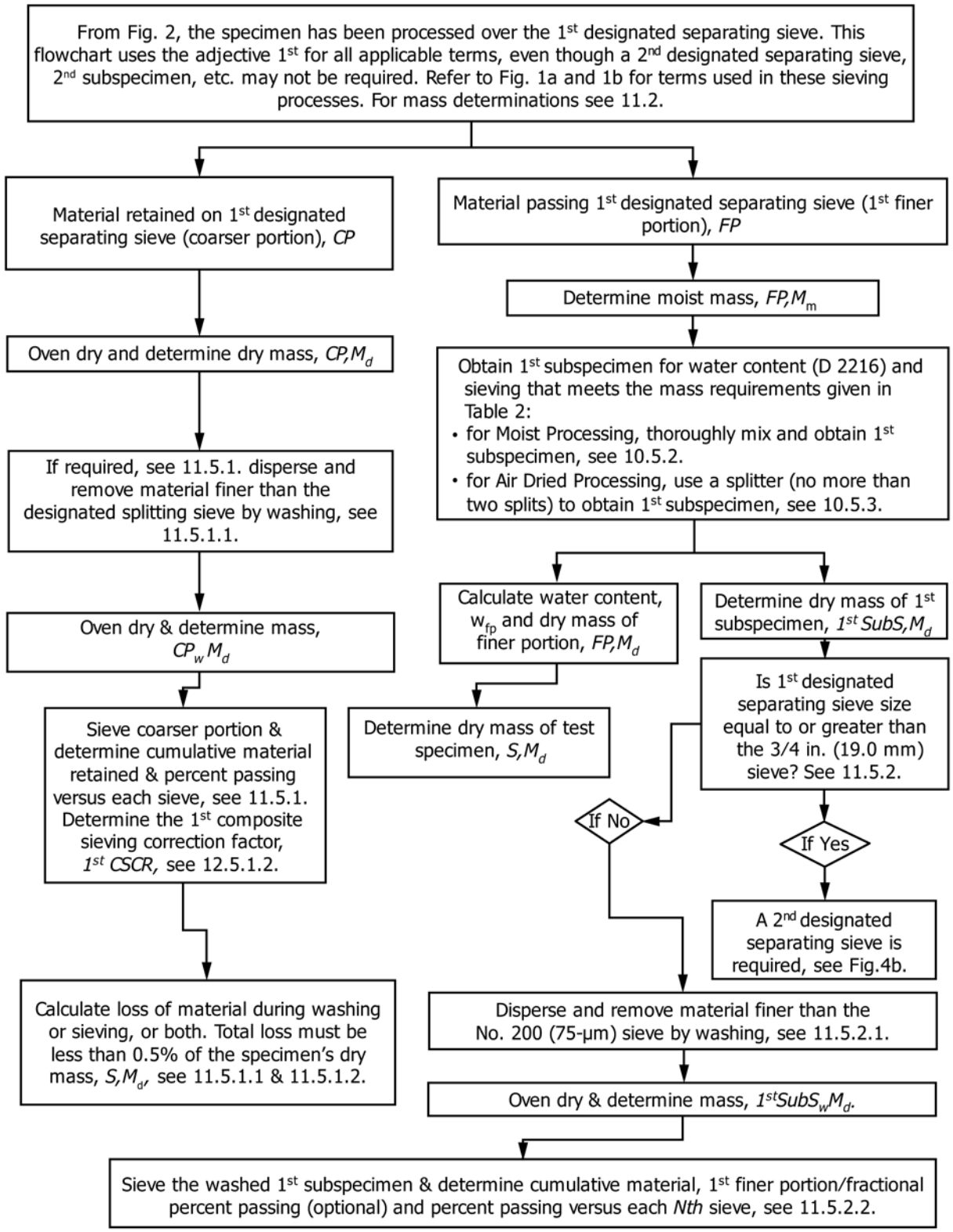

FIG. 4 (a) Flowchart for Composite Sieving—Single Separation

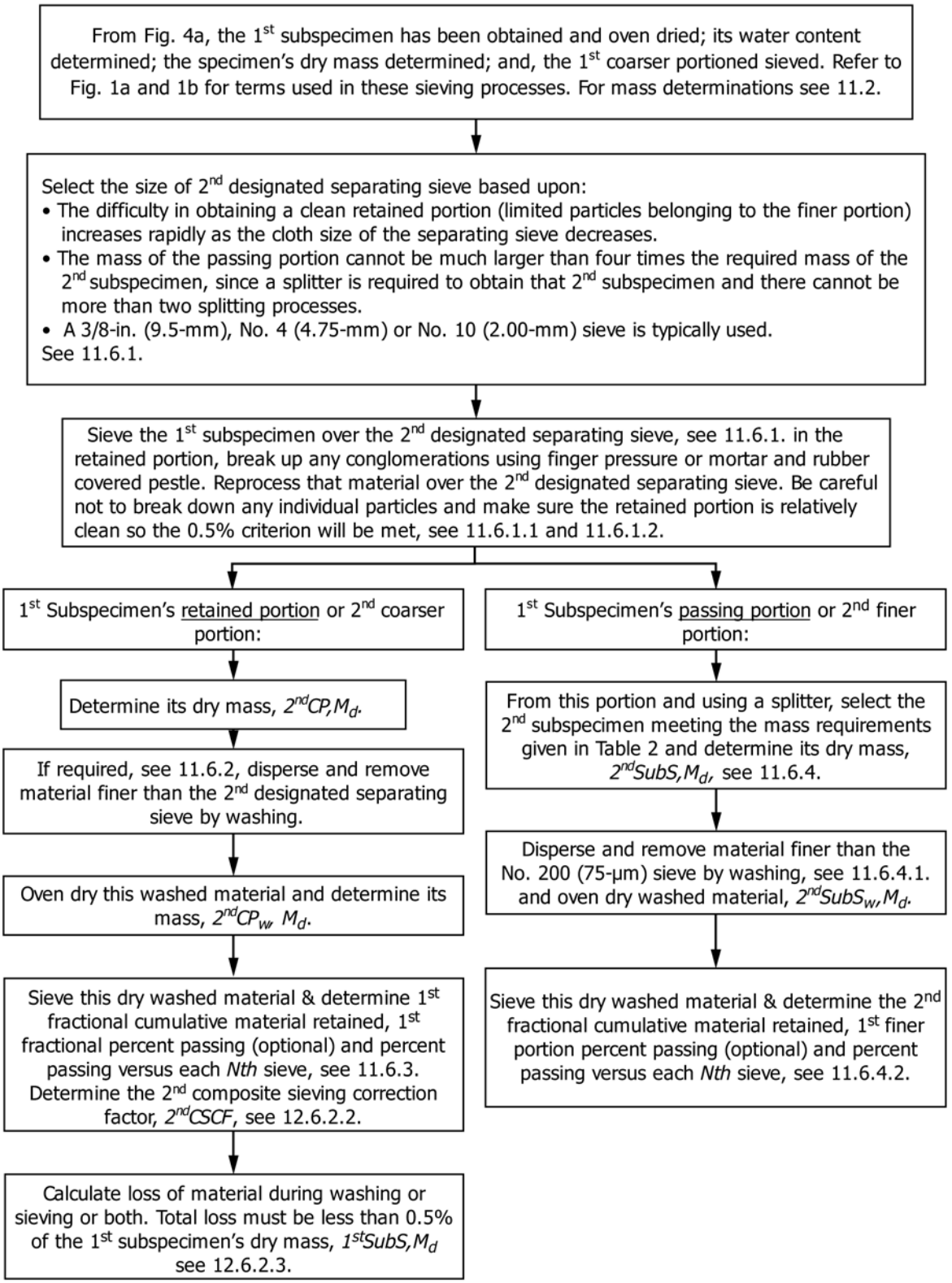

FIG. 4 (b) Flowchart for Composite Sieving—Double Separation *(continued)*

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.

6.7.2 The bristles shall be firm and small enough to readily remove the particles entangled in the sieve openings, but made of a material that will not damage the wire cloth or wear rapidly. Wire bristles, even brass, shall ***not*** be used on wire cloth size finer than No. 20 (850–µm).

6.7.3 The bristles shall be capable of contacting the boundary between the wire cloth and sieve's frame.

6.7.4 The brush's handle shall be such that one's hand can easily control the brushing motion and pressure. An example being, the handle is above the bristles (like a paintbrush) or inclined (30- to 45-degree angle) to the bristle's head (like a vegetable brush or bent toothbrush).

6.7.5 The bristles have to be small in diameter and soft when brushing wire cloth size equal to or less than the No. 100 (150-µm) mesh. Small diameter, soft bristles will remove the particles without any re-alignment of the wire cloth.

6.7.6 Brushes meeting these requirements are relatively small round or rectangular stiff paintbrushes with shortened bristles, soft to hard toothbrushes with bent handles, and vegetable brushes with shortened bristles.

6.8 *Miscellaneous Items*—Miscellaneous items such as wash bottle, spatula, and stirring rod may be useful.

6.9 *Splitter or Riffle Box (optional, but may be needed during composite sieving)*—A device to obtain a representative smaller portion (specimen) from a larger portion (sample). This device has an even number of equal width chutes, but not less than eight, which discharge alternately to each side of the splitter. For dry material having particles coarser than the ⅜-in. (9.5-mm) sieve size, the minimum width of the chutes shall be approximately 1-½ times the largest particle in material being split, but not less than 12.5 mm or ½ in. For dry material finer than or equal to the ⅜-in. (9.5-mm) sieve size, the minimum chute width shall be approximately 1-½ times the largest particle in the material, but not less than approximately 3 mm or ⅛ in. The splitter shall be equipped with two or more receptacles to hold the two halves of the material following splitting. It shall also be equipped with a hopper/feed chute (preferably lever activated or having a cut-off gate) and a straight-edged pan or dustpan that has a width equal to or slightly less than the over-all width of the assembly of chutes, by which the dry material may be fed at a controlled rate to the chutes. The splitter and accessory equipment shall be so designed that the material will flow smoothly without restriction or loss of material.

NOTE 4—Some splitters are designed such that the width of the chutes can be adjusted.

6.10 *Quartering Accessories (optional)*—A hard, clean, level surface, or durable nonporous fabric or plastic sheet approximately 2 by 2.5 m or 6 by 8 ft; a straight-edged scoop, shovel, or trowel; and a broom or brush.

6.11 *Mortar and Rubber-Covered Pestle (optional)*—Apparatus for breaking up aggregations of air-dried or oven-dried soil particles without breaking up any individual particles.

6.12 *Low Temperature Drying Oven (optional)*—Thermostatically controlled oven, capable of maintaining a uniform temperature not to exceed 60°C throughout the drying chamber, for use in air-dried processing.

6.13 *Ultrasonic Water Bath (optional)*—The ultrasonic water bath must be large enough to hold a beaker or flask containing the material to be dispersed prior to washing. The water level in the bath should be equal or higher than the water level in the specimen container.

6.14 *Dispersion Shaker (optional)*—A platform, wrist action or similar type shaker having a gyratory, orbital, reciprocating, or similar motion to assist in the dispersion process by continuously agitating the soaking soil.

7. Reagents

7.1 *Sodium Hexametaphosphate*—Also referred to as sodium metaphosphate, is the dispersion agent used to disperse some fine-grained soils after oven drying and prior to washing. Fine-grained soils requiring the use of a dispersant are those that do not readily slake in water, such as some fat clays and most tropical soils.

7.1.1 For materials needing a chemical dispersant, the dispersant can be added either directly to the soaking material (dry addition) or by adding a dispersant solution to the material, plus water as necessary.

7.1.1.1 *Dry Addition*—Add about 4 grams of sodium hexametaphosphate for each 100 mL of water that has been added to the soaking material and stir to distribute the dispersant throughout the material.

7.1.1.2 *Solution*—Make a solution by using 40 g of sodium hexametaphosphate and 1,000 g distilled, deionized, or demineralized water. Add the solution to the material, plus water if needed and stir to distribute the dispersant throughout the material. The solution must be less than one week old and thoroughly mixed or shaken prior to use. The date of preparation must be indicated on the bottle or in a log.

NOTE 5—Solutions of this salt, if acidic, slowly revert or hydrolyze back to the orthophosphate form with a resultant decrease in dispersive action.

8. Preparation of Apparatus

8.1 *Verification of Sieves*—Prior to ***initial use***, evaluate each sieve for general condition of the wire cloth as specified in Test Method One of Specification E11. That method provides the following evaluation instructions, "view the sieve cloth against a uniformly illuminated background. If apparent deviations, for example, weaving defects, creases, wrinkles, and foreign

matter in the cloth, are found, the wire cloth (sieve) is unacceptable." This evaluation shall be documented. Unacceptable sieves shall be replaced and discarded or returned to the manufacturer for repair (wire cloth).

8.1.1 *Verification Interval*—The same evaluation shall be performed and documented at 6-month intervals on all sieves that are placed in continuous service. However, for sieves that have a limited usage of less than about 1,000 sieve analyses per 6-month interval, then this interval may be increased to 12 months. Sieves that contain excessive soil particles (about 10 % of the sieve openings contain particles) shall be thoroughly cleaned. An ultrasonic water bath may be used to clean the finer sieve sizes, while a stiffer brush or pointed tool can be used to clean the coarser sieves.

8.1.2 During each sieving process, the sieves finer than and including the No. 100 (150-µm) sieve shall be checked for damaged cloth, such as tearing at the frame contact. This check can be done while the retained material is being removed from the sieve during the sieving process. This check does not need to be documented.

8.2 *Verification of Mechanical Sieve Shaker and Standard Shaking Period*—Prior to ***initial use***, the mechanical sieve shaker shall be checked for sieving thoroughness using applicable sieve sets (typically used coarser and finer) and representative material. In addition, the standard shaking period shall be determined for each applicable sieve set. For each size sieve set, follow the guidance given for single sieve-set sieving (see 11.4). Use enough material (specimen) of known mass (g or kg) such that each sieve in the set, except one or two, will have some retained material but no sieve will be overloaded. Shake the sieve set for ten minutes with the mechanical shaker. Upon completion of mechanical shaking, start with the largest sieve size and place the snug-fitting lid on top of the sieve and the pan underneath it. Shake each sieve by hand, for about one minute using the hand shaking procedure (see 8.2.3). For each sieve, determine the mass of material retained on the sieve and in the pan, to the nearest 0.01 g or one part in 1,000, whichever is largest. The ratio of the material mass in the pan to the specimen's mass multiplied by 100 for each sieve shall be less than 0.5 % (see Note 6). If all ratios are less than 0.5 %, the sieve shaker with a 10-minute shaking period is adequate and shall be used as the standard shaking period for that sieve set. If any ratio is equal to or exceeds 0.5 %, repeat the process using a 15-minute shaking period. If this shaking period meets the above criterion, then it shall be used as the standard shaking period for that sieve set, unless a shorted shaking period, like 12 minutes is verified as adequate. If the 15-minute shaking period fails, then try the maximum allowable shaking period of 20 minutes. If the 20-minute shaking period fails, then the mechanical sieve shaker shall be considered inadequate for sieving. It shall either be repaired or discarded. After repair, repeat the instructions given above to determine the standard shaking period.

8.2.1 *Large Mechanical Sieve Shaker*—If a larger mechanical sieve shaker is used to shake large diameter (greater than 200 mm or 8 in.) or rectangular sieve sets and hand shaking is not practicable, then transfer the retained material in appropriate increments to a 200- mm or 8-in. diameter sieve of equal sieve designation, with lid and pan, and shake for one minute. Follow the instructions given above to determine the standard shaking period for each sieve set.

8.2.2 *Verification Interval*—The same verification shall be performed and documented at 12-month intervals for each sieve shaker placed in continuous service. However, for sieve shakers that have a limited usage of less than about 1,000 sieve analyses per 12-month interval, then this interval may be increased to 24 months. Not all sieve set sizes (coarser and finer) have to be re-verified unless the standard shaking time changes for the sieve set being verified. The finer sieve set or the set having the longest standard shaking period shall be used for re-verification.

NOTE 6—For example, after hand shaking the No. 4 (4.75 mm) sieve, the amount of material retained in the pan is 0.20 g. If the specimen mass is 100.00 g, then the ratio is 0.2% = ((0.20/100.00)*100). In this example, if the amount in the pan had been greater than 0.50 g, the ratio would exceed 0.5 % and the verification process would be repeated with a longer time interval.

8.2.3 *Hand Sieve Shaking Procedure*—For 200-mm or 8-in. diameter sieves, hold the individual sieve, with lid and pan, in a slightly inclined (about 15°) position in one hand. Strike the side of the sieve sharply with the heel of the other hand using an upward motion and at a rate of about 150 times per minute, turn the sieve about one sixth of a revolution at intervals of about 25 strokes. Continue for about one minute.

8.2.3.1 For larger diameter or rectangular sieves, transfer the retained material to 200-mm or 8-in. diameter sieves, in appropriate portions to prevent overloading (see 11.3), and follow the above instructions for each portion.

9. Sampling

9.1 *General*—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. However, the testing agency shall preserve all samples in accordance with Practice D4220/D4220M, Group B; except if the as-received sample does not meet those requirements. In that case, the water content of the material does not have to be maintained. The mass of the sample shall meet or exceed the mass requirements for the specimen, as given in Table 2 (see 10.2).

9.2 *Sample Sources*—The sample for a sieve analysis can be from a variety of sources and contain a wide range of particle sizes. Typically, samples for sieve analysis are obtained in the following forms: bulk samples (large bag or bucket samples), small bag or jar samples, tube samples, or specimens from other tests (such as strength, consolidation or hydraulic conductivity). In some cases, (for example, compaction testing) prior testing may cause a reduction of particle sizes. For these cases, the sieve analysis may be required on the initial specimen, or the degraded specimen or both. An overview of how specimens may be selected for various sample types is given below; whereas details for obtaining specimens from samples are in Section 10.

9.2.1 *Bulk Samples*—Generally, bulk samples are obtained because multiple tests are needed or large particles are present, or both. In addition, the bulk sample will usually become the

TABLE 2 Minimum Mass Requirement for Specimen

Maximum Particle Size of Material (99 % or more passes)		Minimum Dry Mass of Specimen, g or kg[A]	
Alternative Sieve Designation	Maximum Particle Size, mm	Method A Results Reported to Nearest 1 %	Method B Results Reported to Nearest 0.1 %
No. 40	0.425	50 g	75 g
No. 10	2.00	50 g	100 g
No. 4	4.75	75 g	200 g[B]
⅜ in.	9.5	165 g[C]	[D]
¾ in.	19.0	1.3 kg[C]	[D]
1 in.	25.4	3 kg[C]	[D]
1-½ in.	38.1	10 kg[C]	[D]
2 in.	50.8	25 kg[C]	[D]
3 in.	76.2	70 kg[E]	[D]

[A] Specimen masses should not significantly exceed (by more than about 50 %) the presented values because excessively large specimens may result in sieve overloading, (see 11.3) and increase the difficulty of specimen processing.
[B] The same as "C," except multiplied by 10.
[C] These values are based on the mass of an individual spherical shaped particle, at the given sieve, multiplied by 100 then 1.2 (factor to account uncertainty) and finally rounded to a convenient number.
[D] Specimens of this size require composite sieving. The sample sizes required for reporting results to 0.1 % are not practical and the possible errors associated with composite sieving causes this sensitivity to be unrealistic for specimens with these larger size particles.
[E] Same as "C," except 1.2 factor is omitted.

specimen and composite sieving will be required. If other testing is needed, these tests should be coordinated with the sieve analysis so that all specimens are obtained efficiently and representatively using moist (preferred) or air-dried procedure. For example, Test Method D698 or D1557 is frequently requested on bulk samples in addition to the sieve analysis. For this test, it is probably most efficient to process the as-received sample, now a specimen, over the designated separating sieve having either the ¾-in. (19.0-mm), ⅜-in. (9.5-mm) or No. 4 (4.75- mm) sieve and obtain the sieve specimens (coarser and finer portions) during this processing. Although oversize particles (coarser portion) are not used in testing with D698 or D1557, the composite sieve analysis should be calculated to represent both the bulk sample and the compaction material (two gradations). Flowcharts presenting an overview of this procedure are presented in Fig. 2 through Fig. 4(b).

9.2.2 *Jar and Small Bag Samples*—Depending on the sample's gradation, it may be necessary to use the entire sample for the specimen. Observe and estimate the maximum particle size. If the amount of material in the sample is less than the minimum mass required (as given in Table 2), note that the specimen is undersized. If the amount (by mass) of sample is much more (by about 50 %) than needed, the sample can be reduced using moist (preferred) or oven-dried procedure. If there is other testing to be obtained from the sample, it may be better to perform the other testing, such as water content and specific gravity and then sieve the used material. Note on the data sheet if prior testing has been performed on the specimen. This approach cannot be used for tests that might alter the gradation of the soil, such as Atterberg Limits.

9.2.3 *Intact Tube Samples*—To obtain a sieve analysis specimen from an intact tube sample, extrude either the entire sample, or a portion. Observe and estimate the maximum particle size. Use moist procedure (see 10.4.1) to obtain the necessary specimen.

9.2.4 *Samples from Prior Testing*—Frequently, after strength, hydraulic conductivity, consolidation or other testing has been completed, that specimen or a portion of it (from water content) is used for a sieve analysis specimen. The entire specimen can be used or split using the most appropriate procedure for specimen selection (moist or oven dried). If the specimen mass is less than required according to Table 2, note that the specimen is undersized on the data sheet. There may be conditions when it is undesirable to test the entire specimen due to the nonhomogeneity of the specimen. If there are layers in the specimen, it may be necessary and more useful to determine the gradation of individual layers.

10. Specimen

10.1 *General*—This section is separated into four parts. The mass requirement for the specimen is given in the first part (*Minimum Mass Requirement*). In the second part on *Selection of Sieving Procedure*, the determination of which sieving procedure applies, single sieve-set or composite sieving, is explained. In the third part on *Specimen Procurement*, an overview of the three applicable procedures (moist, air dried and oven dried) for use in obtaining a specimen from the sample and processing it for sieving is given. Following this overview is a discussion about special considerations relating to soils that readily segregate. In the fourth part on *Specimen Procurement and Processing Requirements*, details are given on how the above moist, air-dried and oven-dried procedures are to be applied to obtain a specimen(s) and prepare it for single sieve-set or composite sieving.

10.2 *Minimum Mass Requirement*—The minimum dry mass needed for a sieve analysis specimen is based on the maximum particle size in the sample and the test method (Method A or B) used to record the data. Based on the estimated maximum particle size, use Table 2 to determine the minimum mass of the specimen in g or kg.

10.3 *Selection of Sieving Procedure*—As shown in Fig. 2, the first decision step in this test method is to estimate the maximum particle size contained in the sample and then determine, based on the assigned Method (A or B), if the single sieve-set sieving or composite sieving procedure is to be used.

10.3.1 *Single Sieve-Set Sieving*—For Method A, this procedure applies to samples having a maximum particle size equal to or less than 9.5 mm (⅜-in. sieve). For Method B, this procedure applies to samples having a maximum particle size equal to or less than 4.75 mm (No. 4 sieve). However, if the material is ***not*** relatively well graded, then these acceptable maximum particle sizes may be smaller. If Method B is assigned and the sample has a maximum particle size larger than 4.75 mm, then this non-conformance should be noted on the data sheet and if necessary, inform the requesting authority. In addition, switch to Method A and if necessary, composite sieving.

10.3.1.1 Single sieve-set sieving ***could*** apply to samples having a maximum particle size up to 19.0 mm (¾-in. sieve) or possibly the 25.4 mm (1-in. sieve); providing Method A applies and the mass of the specimen meets the requirements presented in Table 2. In addition, it depends on the gradation of the sample, the size (diameter) of sieves being used, and if the tester wants to sieve the specimen in portions.

10.3.2 *Composite Sieving*—This procedure applies to samples having a maximum particle size equal to or greater than 19.0 mm (¾-in. sieve), unless 10.3.1.1 applies.

10.4 *Specimen Procurement*—This test method presents three procedures to obtain a representative specimen from the sample (moist, air-dried and oven-dried). In these procedures, the terms moist, air-dried or oven-dried refer to the condition of the material or sample as it is being processed to obtain the specimen. Additional guidance for splitting material to obtain a representative portion (specimen) using a splitter, quartering or moist stockpile sampling (Practice C702, Methods A, B and C, respectively) is given in Annex A2.

10.4.1 *Moist Procedure*—The sample is processed and split using moist stockpile sampling or quartering, if needed, in a moist, as-received state to obtain a representative specimen, unless the material is excessively wet or dry. This procedure is the preferred method for soils that readily segregate in a dry state such as coarse-grained soils with or without fines, or fine-grained soils containing coarse-grained particles, see 10.4.4. In addition, it is the preferred method for any sample containing soil whose properties are altered due to drying, and testing to determine those properties is necessary. These soil types may include most organic soils; many highly plastic fine-grained soils; tropical soils; and soils containing halloysite. Examples of such testing may include compaction, Atterberg Limits, specific gravity, and gradation by sedimentation. For samples requiring composite sieving, the sample typically becomes the specimen and requires additional processing as covered in 10.5.2.

10.4.2 *Air-Dried Procedure*—The sample is air dried, and then processed and split, if needed, using only a splitter to obtain the required specimen. The specimen is oven dried, washed, re-dried and then sieved. For samples requiring composite sieving, the sample typically becomes the specimen and requires additional processing as covered in 10.5.5.

10.4.3 *Oven-Dried Procedure*—The sample is oven dried, and then processed and split using only a splitter, if needed, to obtain the required specimen. The specimen is washed, re-dried, and then sieved. For samples, especially large ones requiring composite sieving and other testing, this procedure is typically not practical and shall not be used for soil types mentioned in 10.4.1.

10.4.4 *Discussion on Segregating Soils*—There are some special considerations relating to soils that readily segregate (such as gravels and sands, with or without fines). Experience gained from the ASTM Reference Soils and Testing Program and obtained at AASHTO Materials Reference Laboratory (AMRL) has clearly demonstrated the following conclusions. When dealing with soils that readily segregate and are in an air-dried or oven-dried state, the splitting processes (Practice C702, Method A) cannot be used more than a few times to obtain a representative specimen. The resulting specimen will have less fine sand and finer particles than the sample. This standard specifies when using a splitter, there cannot be more than two splitting operations (splits) to obtain the specimen. This number is based on judgment. There will be cases when more or less splits would be appropriate; however, use extreme caution in selecting more than two splits. For referee testing two splits cannot be exceeded. The method to obtain representative specimens from these soils requires that the soils be in a moist state. The water content should optimize bulking or be slightly wetter than the saturated surface-dry condition. This water content is to the point that the surface of the soil should look slightly wet but there are no signs of free water exiting the soil. This will reduce the potential for particle segregation and loss. The sample can be mixed and readily scooped/shoveled to obtain representative portions of the material (Practice C702, Method C, see A2.1.3). This procedure is especially useful if the maximum particle size is less than about 19.0 mm (¾-in. sieve).

10.5 *Specimen Procurement and Processing Requirements:*

10.5.1 *Moist Procedure, Single Sieve Set Sieving*—If single sieve-set sieving applies, as determined in 10.3, then either select the whole sample or split the sample after it is mixed in the as-received condition, unless it is too dry or wet for processing to obtain a representative specimen, see 10.5.1.2.

10.5.1.1 If the sample contains standing water or is very wet; then it may be dried back to a moist state, as defined in 10.4.1, 10.4.4, or A2.1.3, by air-drying or oven-drying (60°C). If oven drying is used, the sample is placed in a low temperature, drying oven (not to exceed 60°C) and mixed frequently to avoid excessive drying of any portion of the sample. If the sample is too dry; then water can be added (preferably by spraying) while the sample is being mixed to a moist state.

10.5.1.2 After mixing, obtain a representative specimen having the required mass (Table 2) by taking one or more scoops from the sample. The number of scoops shall increase as the mass of the specimen increases and come from various locations, and each scoop shall have about an equal mass, see A2.1.3. Place all the material in the scoop into the specimen container of known mass (g or kg). In this process, do not attempt to obtain an exact mass or increase the specimen size by adding very small amounts of material. For relatively well-graded coarse-grained soils, especially relatively clean ones containing gravel and coarse sand; do not add material by shaking it off the edge of the scoop. All of these processes could result in altering the gradation of the specimen. Oven dry the specimen (110 ± 5°C), see Notes 7 and 8. Record the identification of the specimen container and the mass (g or kg) of the container on the data sheet. Proceed to Section 11 on *Procedure (Sieving)*.

NOTE 7—For non-referee testing, it is acceptable practice to determine the oven-dried mass of a specimen or subspecimen, based on its moist mass and water content determined to the nearest 1 % for Method A or 0.1 % for Method B.

NOTE 8—This procedure for selecting material from a sample is basically the same as that presented in Practice C702, Method C—Miniature Stockpile Sampling (Damp Fine Aggregate Only) and summarized in A2.1.3.

10.5.2 *Moist Procedure, Composite Sieving*—For composite sieving, typically the whole sample becomes the specimen. If splitting is needed, obtain a representative portion by either the moist stockpile sampling procedure, as described in 10.5.1.2 or quartering (see A2.1.2). For an overview of the composite sieving method, refer to Fig. 2 through Fig. 4(b). In composite sieving, the following information must be obtained:

(a) The oven-dried mass of the coarser portion retained on designated separating sieve, CP,M_d in g or kg,

(b) The moist mass of the finer portion passing the designated separating sieve, FP,M_m in g or kg,

(c) The water content of a subspecimen obtained from the finer portion, w_{fp} in %,

(d) The calculated oven-dry mass of the finer portion, FP,M_d in g or kg, and

(e) The oven-dry mass of the subspecimen obtained from the finer portion for sieving over the finer sieve set, $SubS,M_d$ in g or kg.

10.5.2.1 If necessary, adjust the moisture condition of the material by drying or adding water as described in 10.5.1.1.

10.5.2.2 Select a designated separating sieve following the guidance given in 9.2.1 on *Bulk Samples* and Note 9. Process the specimen over this sieve. Manually or mechanically shake, or wiggle the finer portion through the sieve and collect both the coarser and finer portions. Remove any large conglomerations from the designated separating sieve and break them into individual particles or into conglomerations that are smaller than the openings in the designated separating sieve. Return the soil to the designated separating sieve and continue processing. Do not apply pressure that could damage the sieve. If fines are adhering to the coarser particles, scrape or brush these larger particles and dislodge the fines. If the fines are adhering into large clumps, use knives or spatulas to cut the clumps into chucks that will pass the designated separating sieve.

NOTE 9—Smaller cloth size of the designated separating sieve increases the difficulty in processing the material and having a limited amount of the fines adhering to the retained particles. In addition, selection of the designated separating sieve size may be based on ease of separating the specimen, additional testing to be performed, or convenience. For very plastic, clayey materials, it is easier to select a larger designated separating sieve. For materials that need compaction testing using either D698 or D1557, it is easiest to use the sieve (either No. 4 (4.75 µm), ⅜ in. (9.5 mm) or ¾ in. (19.0 mm)) necessary for the compaction method. Some laboratories are equipped with two sets of mechanical sieve shakers depending on size range, and, hence, the selection would be based on the equipment. There can be more than one designated separating sieve used in composite sieving, because the first subspecimen can be split again to obtain a second subspecimen.

10.5.2.3 *Coarse Portion Acceptable Loss (CP_L)*—It is usually not possible to remove all the fines (particles that would pass the designated separating sieve) adhering to the retained coarser particles. For the finer portion to be representative, the amount adhering to the retained coarser particles has to be less than 0.5 % of the dry mass of the specimen (S,M_d), see Note 9. If it appears that the material adhering to the retained portion will exceed the 0.5 % criterion, then the retained portion must be washed using a minimum amount of water and the washings added to the portion passing the designated separating sieve. The actual value will be determined at the end of the test.

10.5.2.4 Place the coarser portion in a suitable container of known mass (g or kg) and oven dry it (110 ± 5°C). Record the container identification and mass on the data sheet. If the water content of the coarser portion is needed (for example, to report the as received condition), determine it in accordance with Test Method D2216. Record the oven dry mass of the coarser portion, CP,M_d in g or kg.

10.5.2.5 Determine and record the moist mass (g or kg) of finer portion, using a balance meeting the requirements given in 6.4 and 11.2. Depending on the size of this portion, this mass determination can be done in increments as the material is being processed or after it has been processed. Record this moist mass as FP,M_m in g or kg.

10.5.2.6 Mix the moist finer fraction and obtain a representative subspecimen for both a water content determination and sieving using the moist stockpile sampling procedure, see 10.5.1.2. The finer portion subspecimen shall have a mass meeting the requirements given in Table 2. Record the container identification, mass of the container, and mass of the container plus moist material representing the finer portion subspecimen. The balance used shall meet or exceed the requirements of Test Method D2216 for water contents determined to the nearest 1 % or better.

10.5.2.7 Oven-dry the subspecimen in the oven at 110 ± 5°C. Calculate and record the water content, w_{fp}. Determine and record the dry mass of the subspecimen as $SubS,M_d$ in g or kg. If this subspecimen requires a second separation, (see Fig. 4(a) and Fig. 4(b)—composite sieving with double separation) processing the second subspecimen will be performed later (see 11.6).

10.5.2.8 Determine the dry mass of the specimen (coarser portion plus finer portion) in g or kg, see 12.4, and proceed to Section 11 on *Procedure (Sieving)*.

10.5.3 *Air Dried Procedure, General*—This method requires the use of a splitter to obtain a specimen from a sample

that has been air-dried, unless the whole sample is tested. Therefore, this procedure can only be used for smaller samples in which no more than two splitting processes will be necessary, see 10.4.4. Typically, this procedure would only be used for soils coming from an arid region in which the soil will become air-dried and when other testing requires an air-dried condition.

10.5.3.1 Depending on the size of the sample, place the material either on a tray(s)/pan(s), smooth tarp/plastic sheet/etc. or sealed-smooth floor (prevent loss of fines) and air-dry. Alternatively, an oven not exceeding 60°C may be used. Upon the completion of air-drying; place the material into either a container or pile. During this process, break apart any noticeable aggregations of soil particles. This can be done by hand or using a mortar and rubber-covered pestle or similar method that does not break the individual particles.

10.5.4 *Air Dried Procedure, Single Sieve-Set Sieving*—If this applies, as covered in 10.3; then either test the whole sample, noting its mass cannot be too large (Table 2) or after mixing, obtain a representative specimen having the required mass (Table 2) using a splitter and noting the above requirements and those in Annex A2, Sample to Specimen Reduction Methods, A2.1 and A2.1.1.

10.5.4.1 Place the specimen in a container of known mass (g or kg) and oven-dry the material at 110 ± 5°C. Record the identification of the specimen container, and mass of the container on the data sheet. Determine and record the dry mass of the specimen as S,M_d in g or kg. For non-referee testing, this dry mass may be based on an auxiliary water content of similar air-dried material (see Note 7).

10.5.4.2 Proceed to Section 11 on *Procedure (Sieving)*.

10.5.5 *Air Dried Procedure, Composite Sieving*—If composite sieving applies, as determined in 10.3, follow the moist procedure, as outlined in 10.5.2 through 10.5.2.8 to obtain the specimen and process it for composite sieving, except for the following:

(a) The sample is air-dried prior to any processing, see 10.5.4.1.

(b) The moist masses become air-dried masses.

(c) The water content of the coarser portion is not applicable.

(d) To obtain the subspecimen from the finer portion, the applicable guidance given in 10.5.3 shall be followed instead of that given in 10.5.2.6.

10.5.5.1 Proceed to Section 11 on *Procedure Sieving*).

10.5.6 *Oven-Dried Procedure, General*—This method requires the use of a splitter to obtain a specimen from a sample that has been oven-dried, unless the whole sample is tested. Therefore, this procedure can only be used for smaller samples in which no more than two splitting processes will be necessary, see 10.4.2 and 10.4.4. This procedure shall only be used when other testing is not necessary or needed, see 1.8 and 10.4.1. See 10.5.2 for comments on composite sieving.

10.5.6.1 Place the sample on a tray(s)/pan(s) and oven dry at 110 ± 5°C overnight or until thoroughly dry, see Test Method D2216. Upon the completion of drying; place the material into either a container or pile. During this process, break apart any noticeable aggregations of soil particles. This can be done by hand or using a mortar and rubber-covered pestle or similar method that does not break the individual particles.

10.5.7 *Oven Dried Procedure, Single Sieve-Set Sieving*—If this applies, as covered in 10.3; then either test the whole sample, noting its mass cannot be too large (Table 2) or after mixing, obtain a representative specimen having the required mass (Table 2) using a splitter and noting the above requirements and those in Annex A2, Sample to Specimen Reduction Methods, A2.1 and A2.1.1. Record the identification of the specimen container, and mass (g or kg) of the container on the data sheet. Determine and record the dry mass of the specimen as S,M_d in g or kg.

10.5.7.1 Proceed to Section 11 on *Procedure (Sieving)*.

10.5.8 *Oven Dried Procedure, Composite Sieving*—If composite sieving applies, as determined in 10.3, procure the specimen following the applicable guidance given in 10.5.4 through 10.5.4.2. Double check that the specimen's mass and its container has been determined and recorded. Select a designated separating sieve following the guidance given in 9.2.1 and Note 9. Process the specimen over this sieve following the applicable guidance given in 10.5.2.2 and 10.5.2.3.

10.5.8.1 Record the oven-dry mass of the coarser portion, CP,M_d in g or kg.

10.5.8.2 Mix the finer portion and obtain a representative subspecimen having the required mass (Table 2) using a splitter, see requirements given in 10.4.4. Record the container identification, mass of the container, and mass of the container plus dry material representing the finer-portion subspecimen. Calculate and record the dry mass of the subspecimen, $SubS,M_d$ in g or kg.

10.5.8.3 Proceed to Section 11 on *Procedure (Sieving)*.

11. Procedure (Sieving)

11.1 *General*—There are several different ways to determine the percent passing, since there are several different approaches to determine the amount of material retained on each sieve in a given sieve set. As previously stated, the procedure presented in this test method is to determine and record the mass of the cumulative material retained upon any given sieve within any given sieve set, since it is the easiest approach to present. However, this does not mean that other approaches are in nonconformance with this test method. One alternate approach would be to determine the amount of material retained on each sieve within a given sieve set, and then adjust the method of calculation to determine the percent passing.

11.1.1 The sieving process is usually accomplished using a mechanical sieve shaker (see 6.3); however, hand shaking is permissible, especially for the coarser sieves (larger than about the ¾-in. (19.0-mm). For referee testing, a mechanical sieve shaker shall be used for the portion passing the ¾-in. (19.0-mm) sieve.

11.1.2 The proper gradation of a specimen cannot be obtained if one or more sieves are overloaded during the sieving process, see 11.3 on *Sieve Overloading*.

11.2 *Mass Measurements*—The following details supplement the requirements presented in 6.4 on *Balances*. Determine

the mass of the specimens to a minimum of three significant digits for Method A or a minimum of four significant digits for Method B. For subspecimens, only Method A applies. Determine the mass (g or kg) of the cumulative material retained using a balance having the same readability or better as was used to determine the mass of the specimen or subspecimen, see Note 3. This balance does not have to be the same one used to determine the mass of the specimen.

11.3 *Sieve Overloading*—The overloading of a sieve occurs when too many particles are retained on a sieve such that all particles do not have an opportunity to reach a sieve opening a number of times during sieve shaking. To prevent sieve overloading, the quantity of material retained on an individual sieve must be less than or equal to that specified in Table 3.

11.3.1 To avoid overloading, it is often necessary to divide large specimens or subspecimens into several portions. Each portion would be sieved and the amount retained on each sieve would be recorded. Then, the masses retained on a given sieve from all the sieved portions would be added as explained in 11.4.5.2.

11.3.2 If overloading has occurred, the specimen or subspecimen must be re-sieved in several portions or using sieves having a larger area.

11.4 *Single Sieve-Set Sieving*—A summary of terms used in single sieve-set sieving is presented in Fig. 1(a) and Fig. 1(b) while Fig. 3 presents a flowchart of this sieving process.

11.4.1 *Specimen Mass*—Check that the following had been determined and recorded in accordance with Section 10; the dry mass of the specimen, the identification of the specimen container and the procedure used to obtain that specimen (moist, air-dried or oven-dried). Record this mass as S,M_d in g or kg.

11.4.2 *Specimen Dispersion*—Prior to washing the specimen on the No. 200 (75-µm) washing sieve, the specimen shall be dispersed by one of the following procedures. However, in no case shall a mechanical mixer (with metal blade) be used to disperse the soil, since such mixers have a tendency to degrade (breakdown) coarse-grained particles. Wrist action shakers or similar agitating devices are acceptable, see 6.14.

11.4.2.1 *Soaking without a Dispersant*—Cover the specimen (soil) with tap water and allow it to soak for at least 5 minutes. Longer soaking periods are typically needed as the amount of fines or the plasticity of the fines or both increases. During this soaking period, the soil and water can be agitated using a stirring rod, spatula, dispersion shaker or similar device to facilitate the dispersion process or to check that the soil is dispersed. If clumps of particles or clods are detected, then this method of dispersion is not effective (see Note 10) and proceed to 11.4.2.2. A dispersion shaker shall not be used for relatively clean coarse-grained soils (such as: GP, SP, GP-GM, SP-SM, SP-SC).

NOTE 10—It is not easy to evaluate effective dispersion. Use visual or manual means or both to detect clumps of particles that would indicate incomplete or ineffective dispersion.

11.4.2.2 *Soaking with a Dispersant*—In accordance with Section 7, add the sodium hexametaphosphate either directly (dry addition) or in solution. Follow the instructions in 11.4.2.1. If this method of dispersion is not effective, the ultrasonic water bath could be used or additional time allowed for dispersion.

11.4.2.3 *Using an Ultrasonic Water Bath*—This procedure may be used for soils that are difficult to disperse. Place the specimen and container in the ultrasonic water bath following the guidance given in 6.13. The water in the specimen container should contain dispersant. If the size of the specimen container is not appropriate to fit into the ultrasonic water bath, then transfer the specimen to a suitable one, noting that the specimen can be dispersed in portions.

11.4.3 *Washing Specimen*—At the end of the soaking-dispersion period, the fines (minus No. 200 (75-µm) sieve material) are removed by washing using this procedure or by following the applicable portions of Method B given in Test Method D1140. The apparatus used shall meet the requirements given in 6.1.2 and 6.2.

TABLE 3 Overloading Limits for Standard Sieve Set

Alternative Sieve Designation	Standard Sieve Designation	Number of Grain Layers on Given Sieve	Maximum Mass Retained on 200-mm (8-in.) Diameter Sieve, g[A]	Maximum Mass Retained on 305-mm (12-in.) Diameter Sieve, g	Maximum Mass Retained on 370- by 580-mm (14.6- by 22.8-in.) Sieve, g
3 in.	75 mm	0.8	2 700	6 100	18 000
2 in.	50 mm	0.9	2 000	4 500	13 000
1-½-in.	37.5 mm	0.9	1 500	3 400	10 000
1 in.	25 mm	1	1 100	2 500	7 000
¾ in.	19.0 mm	1	900	2 000	6 000
⅜ in.	9.5 mm	1.25	550	1 200	3 600
No. 4	4.75 mm	1.5	325	730	2 000
No. 10	2.00 mm	2	180	410	1 000
No. 20	850 µm	3	115	260	800
No. 40	425 µm	4	75	170	500
No. 60	250 µm	5	60	140	400
No. 100	150 µm	6	40	90	300
No. 140	106 µm	6	30	70	200
No. 200	75 µm	6	20	50	100

[A] For sieve sizes other than those listed above, determine the surface area of the sieve(s) cloth being used in m^2 and divide this number by 0.028 m^2 (the approximate surface area of a 200-mm or 8-in. diameter sieve). Then multiply this area ratio by the masses listed in this column to form a column of acceptable masses for the different sieve area of interest. Round these values, so the significant digits are similar to those presented.

11.4.3.1 *General Precautions*—Washing specimens larger than about 200 g should be done in increments. For masses containing particles coarser than No. 4 (4.75-mm) sieve, all of the material should ***not*** be placed directly on the washing sieve (No. 200 or 75-µm), especially for brass cloth. In this case, a coarser size sieve (No. 40 or larger) shall be inserted above the washing sieve. It is necessary to see through this coarser sieve to check if the washing sieve is clogging (often the No. 40 sieve obscures this view and a No. 20 (850 µm) sieve is a better choice).

11.4.3.2 *Transfer Specimen*—Transfer the dispersed specimen, or a portion of the specimen to the washing sieve or the coarser sieve inserted above the washing sieve by pouring or any means that prevents spillage. During this process, stop pouring if any material loss will occur due to clogging of the washing sieve, and unclog the washing sieve, see Note 11. After emptying the dispersed specimen container, wash any remaining material onto the washing sieve or the coarser sieve inserted above it using the spray nozzle, wash bottle, or similar method.

11.4.3.3 *Washing*—Wash the specimen (material) on the washing sieve by means of a stream of water from the spray nozzle. Continually check to see if the washing sieve has clogged (see Note 11). The velocity of the water shall not cause any splashing of the material out of the sieve. The water temperature shall remain close to room temperature (see 6.2). To facilitate the washing process, the retained material may be lightly manipulated by hand while it is against the side of the sieve or above it, taking care not to lose any retained material. A wash shaker may be used to aid in the washing process. No downward pressure should be exerted on the retained material or sieve cloth to avoid forcing particles through the sieve or causing damage to the sieve. When the coarser sieve is being used, remove it from above the washing sieve as soon as the coarser material is washed and transfer it to the specimen container (see 11.4.3.4). Continue washing the specimen on the No. 200 (75-µm) sieve until the wash water is clear.

NOTE 11—If clogging of the washing sieve occurs, lightly hand tap the side or the bottom of the washing sieve until it is unclogged. Another method to unclog the washing sieve is gently spray a small amount of water up through the bottom of the washing sieve, then use the tapping approach to assist in the drainage of wash water.

11.4.3.4 *Transfer Washed Specimen*—Using a washing process, return the portion retained on the washing sieve and coarser sieve, if used, to its original specimen container or new container of known mass in g or kg. This can be done by washing the retained material to one side of the sieve, by tilting the sieve and allowing the wash water to pass through the sieve. Then, slowly wash this material into the container using as little wash water as possible, such that water will not fill and overflow the container. If the container approaches overflowing, stop the transfer process and decant the clear water from the container. Decant as much water from the container as practical without losing any retained material, and dry to a constant mass in an oven at 110 ± 5°C. This drying period will most likely be shorter than the overnight period suggested in D2216, because the retained material does not contained any fines. After oven drying, allow the container to cool, determine and record the dry mass of the washed material, S_wM_d in g or kg.

11.4.4 *Dry Sieving*—Dry sieving is accomplished by sieving the oven-dried washed material over an appropriate sieve set using a mechanical sieve shaker for a standard shaking period (see 8.2) and in such a manner that prevents the overloading of any given sieve (see 11.3). Then, the cumulative material retained for each sieve within a sieve set by mass or cumulative mass retained is determined. Based on these measurements, the percent passing each sieve is determined. The following procedure assumes that a stack of 200-mm or 8-in. diameter sieves is being used. However, the use of other sieve sizes or configurations is not prohibited providing they meet the requirements given in Sections 6, 8, and this section.

11.4.4.1 *Sieve Set*—Assemble an appropriate stack of sieves from the standard set given in Table 1 and meeting the requirements given in 6.1. The largest sieve size shall be such that 100 % of the washed (sieving) material passes through it. Do not omit any standard sieves sizes between the largest sieve size and the No. 200 (75-µm) sieve, but it is permissible to include additional sieves. Assemble the stack of sieves with the largest sieve size at the top. Add the remaining sieves in descending sieve size. Add the pan on the bottom and the lid on the top on the sieve stack, if appropriate. If there are too many sieves to fit into the sieve shaker, it is permissible to separate this set into a coarser subset and a finer subset. It is also permissible to use "half height" sieves, see 6.1. Some sieves are designed to stack on top of each other, and other sieves are inserted like drawers into the shaker. Either type is acceptable.

11.4.4.2 *Mechanical Shaking*—Pour the dried washed material from its container onto the sieve at the top of the sieve stack. Then brush any material remaining in the container onto that sieve. The container should be close to the sieve to prevent spillage and creation of dust. Cover the stack of sieves with the lid, if applicable, and place the sieve set in the sieve shaker. Shake the sieve set for the standard shaking period established in 8.2 (using a timing device) for that sieve shaker and size sieve set. Avoid overloading the sieves, see 11.3. Upon completion of shaking, remove the sieve set for determination of the cumulative material retained for each sieve, as covered below.

11.4.5 *Cumulative Material/Mass Retained* (Hereafter referred to as cumulative mass retained.)

11.4.5.1 *First Sieve*—Remove the lid from the sieve set, verify that no material was retained on the top (largest size) sieve (record 0.0 g or kg in the cumulative mass retained column, CMR_N). If material is retained on the top sieve, determine and record its mass, CMR_N, in accordance with 11.2 in g or kg. Transfer that retained material to the next larger sieve size in the standard sieve set, see Table 1. Add the pan and lid and hand shake that sieve following the procedure given in 8.2.3 on *Hand Sieve Shaking*. Shake until either the entire retained material has passed that sieve or for about one minute. Verify that no material was retained on that sieve by recording 0.0 g or kg as appropriate. Transfer the contents of the pan to the cumulative mass container (see 6.6.3).

11.4.5.2 *Remaining Sieves*—Remove the next sieve and turn the sieve upside down such that the retained material falls onto

the collection/transfer device (see 6.6.2) without spillage or creating dust. Any material remaining in the sieve may be gently removed using a sieve brush (see 6.7). Take care to avoid distortion or damage of the sieve cloth (see 6.7.1 through 6.7.6). Next transfer this retained material to the container (see 6.6.3) holding the cumulative mass retained, *CMRN*. Determine, in accordance with 11.2 and record the mass (g or kg) contained in this container, CMR_N. Continue in this manner for the remaining *Nth* sieves and pan.

11.4.5.3 When using the cumulative mass retained method, sieve-overloading problems are not immediately apparent, but they shall be checked for during this process, see 11.3. Conversely, when the data sheet lists the overloading masses and the mass on each sieve is recorded, any problems due to overloading will be immediately noticed. If overloading occurred, re-sieve the material in accordance with the instructions provided in 11.3.1. In the case where the sieving process is done in parts, such as to prevent overloading or overloading has occurred, then there is more than one set of partial cumulative mass retained determinations to be recorded and combined to determine the cumulative mass retained, CMR_N. This will require either special or multiple data sheets.

11.4.5.4 Proceed to Section 12 on *Calculations*.

11.5 *Composite Sieving, Single Separation*—Refer to Fig. 1(a) and Fig. 1(b) for the terms used in composite sieving and Fig. 4(a) for a flowchart of these sieving processes. When composite sieving is necessary, the following items requiring sieving were obtained during the processing of the specimen and identified on the data sheet, as covered in Section 10 on *Specimen*. These items are:

(a) The oven-dried mass of the portion retained on designated separating sieve; that is the coarser portion, CP,M_d in g or kg.

(b) The oven-dried mass of the subspecimen obtained from the finer portion, $SubS,M_d$ in g or kg.

11.5.1 *Coarser Portion*—If the coarser portion is clean (free of material finer than the designated separating sieve) or already washed (see 10.5.2.3), and the testing is not used as referee testing, the coarser portion will not need to be washed. It is permissible to consider the coarser portion to be clean if 0.5 % or less of that finer material (based on specimen's dry mass, S,M_d) would be or are removed from the coarser portion while sieving or washing, or both. Washing is not needed under these conditions. For referee testing, the coarser portion shall be washed.

11.5.1.1 *Dispersing and Washing*—Follow the applicable instructions provided in 11.4.2 to disperse the coarser faction and 11.4.3 to wash the coarser portion after dispersion, while noting the following:

(a) Soaking in water, will usually suffice,

(b) Washing is done on either the designated separating sieve used to separate the specimen into a coarser and finer portion, or another sieve of equal size (designation, see Table 1); and,

(c) During washing or the dispersion process fine particles may be brushed off coarser particles.

11.5.1.2 Return the retained washed portion to the same container and oven dry to a constant mass (110 ± 5°C). Determine and record the dry mass (g or kg) of the washed coarser portion, CP_wM_d, following the instructions provided in 11.2. The calculation of the acceptable percent loss during washing or sieving, or both of the coarser portion is covered in Section 12 on *Calculations*, 12.5.1.3. This calculation is performed after the sieving of the coarser portion. If CF_L is greater than 0.5 %, the sieve analysis is in nonconformance (unless the washings were added to the finer portion) and this factor shall be noted on the data sheet.

11.5.1.3 *Dry Sieving Coarser Portion*—Using this clean or washed coarser portion, follow the applicable instructions given in 11.4.4 (*Dry Sieving*) and 11.4.5 (*Cumulative Mass Retained*), while noting the finest sieve size in the coarser sieve set is the size of the designated separating sieve, ***not*** the No. 200 (75-µm) sieve. Determine and record these values of cumulative mass retained in the coarser sieve set and for each *Nth* sieve as CP,CMR_N in g or kg, Determine and record the mass of material contained in the pan, CP,MR_{pan} in g or kg. The calculation of the acceptable percent loss during washing or sieving, or both of the coarser portion is covered in Section 12 on *Calculations*, 12.5.1.3. If CF_L is greater than 0.5 %, the sieve analysis is in nonconformance and this factor shall be noted on the data sheet.

11.5.2 *Subspecimen from Finer Portion*—If the size of the designated separating sieve is equal to or larger than the ¾-in. (19.0-mm) sieve, then this subspecimen will have to be separated again, or washed and sieved in portions, see 10.3.1.1. If separation over a 2nd designated separation sieve is necessary, then additional processing and sieving is needed, as covered in 11.6.3. If a 2nd separation is ***not*** necessary (see Fig. 4(a)), then this subspecimen can be sieved as described below.

11.5.2.1 *Dispersing and Washing Subspecimen*—Wash the subspecimen following the applicable instructions provided in 11.4.2 to disperse the subspecimen and 11.4.3 to wash the subspecimen after dispersion. After oven drying, allow the container to cool, determine and record the dry mass of the washed material, $SubS_wM_d$ in g or kg.

11.5.2.2 *Dry Sieving Subspecimen*—Using the above dry washed subspecimen, dry sieve this material and determine the cumulative masses retained following the applicable instructions given in 11.4.4 through 11.4.5.3 and noting the following changes:

(a) The coarsest sieve size in the finer sieve set is the size of the designated separating sieve.

(b) For these cumulative mass retained values, they are identified as fractional cumulative mass retained on each *Nth* sieve as $SubS,FCMR_N$ in g or kg.

(c) There should not be any material retained on the coarsest sieve in the finer sieve set. Retained material indicates that the specimen was not split properly or there is a difference in openings in the sieve cloth between the designated separating sieve and the one in the finer sieve set. If the mass of material retained on this sieve, $SubS,MR_{first}$, is equal to or less that 2 % of the subspecimen's mass, $SubS,M_d$, then record the mass in g or kg. There might not be an identifiable space provided on the data sheet for this value, especially in composite sieving with double separations. In that case, record the value in the margin next to the appropriate sieve size.

(d) If the mass retained on this sieve exceeds 2 %, then the sieve analysis is in nonconformance and this factor noted on the data sheet, but record that value and determine the remaining $SubS,FCMR_N$ values. If this continually occurs, then the testing laboratory shall first review its splitting methodology for errors, and then verify that the sieve cloth of the sieves involved meet the full requirements of Specification E11, or replace those sieves with new ones.

11.5.2.3 Proceed to Section 12 on *Calculations*.

11.6 *Composite Sieving, Double Separation*—The 1st subspecimen will be processed over a 2nd designated separating sieve for composite sieving with double separation. See Fig. 1(a) and Fig. 1(b) for summary and flowchart of terms used and Fig. 4(a) and Fig. 4(b) for a flowchart of these sieving processes.

11.6.1 *Separating 1st Subspecimen*—Select the size of the 2nd designated separating sieve; usually this sieve size is the ⅜-in. (9.5-mm), No. 4 (4.75 mm), or No. 10 (2.00-mm) sieve. When selecting this sieve, remember that as the size of the designated separating sieve decreases, it is more difficult to obtain a representative 2nd subspecimen and meet the 0.5 % criterion on loss of material during washing and sieving of the 2nd coarser portion (see 11.6.2).

11.6.1.1 Sieve the 1st subspecimen over the 2nd designated separating sieve using the mechanical sieve shaker and appropriate standard shaking period and in increments to prevent sieve overloading. Separately collect the retained and passing portions.

11.6.1.2 Closely check the retained material for material finer than the 2nd designated separating sieve, if noted, they can be broken up by hand or by using a mortar and rubber-covered pestle. Re-sieve that material over the 2nd designated separating sieve by hand sieving (see 8.2.3) and add the retained and passing portions to the appropriate container.

11.6.2 *Dispersing and Washing 2nd Coarser Portion*—Recheck the retained material, if the amount of adhering particles appears to exceed 0.5 % of $1^{st}SubS,M_d$ then wash those fines into the container containing the second 2nd finer portion (that is, the material passing the 2nd designated separating sieve) and oven dry (110 ± 5°C) both portions ($2^{nd}CP_wM_d$ and 2nd finer portion). If the amount of finer material appears to be equal or less that this 0.5 % criterion; then determine and record the dry mass, $2^{nd}CP,M_d$ in g or kg and then sieve the 2nd coarser portion using the 2nd coarser sieve set. In addition, if this 2nd coarser portion is washed and it appears the adhering particles will not exceed 0.5 %, then the washings do not have to be added to the 2nd finer portion. For referee testing, the 2nd coarser portion has to be washed following the applicable instructions given in 11.5.1.1, while noting the following.

11.6.2.1 Determine and record the oven-dry mass (g or kg) of the 2nd coarser portion before and after washing as $2^{nd}CP,M_d$ and $2^{nd}CP_wM_d$, respectively.

11.6.2.2 The calculation of acceptable loss on washing criterion of 0.5 % is now based on the mass (g or kg) of the 1st subspecimen, $1^{st}SubS,M_d$. This calculation is covered in Section 12 on *Calculations*, 12.6.2.3.

11.6.3 *Dry Sieving 2nd Coarser Portion*—Using this clean or washed 2nd coarser portion, follow the applicable instructions given in 11.4.4 (*Dry Sieving*) and 11.4.5 (cumulative mass retained), while noting the following.

11.6.3.1 The coarsest and finest sieve sizes in this 2nd coarser sieve set are the size of the 1st and 2nd designated separating sieve, respectively.

11.6.3.2 The mass (g or kg) of material retained on the coarsest sieve shall not exceed 2 % of the dry mass of the 1st subspecimen; see 11.5.2.2, Items c and d.

11.6.3.3 The mass of the material in the pan, plus loss on washing, if applicable, cannot exceed 0.5 % criterion.

11.6.3.4 The calculations related to the 2nd coarser portion are covered in 12.6.2.1 through 12.6.2.5.

11.6.4 *2nd Subspecimen*—Using a splitter (see 6.9 and 10.4.4), split the 2nd finer portion to obtain the 2nd subspecimen having a mass (g or kg) meeting the requirements given in Table 2. Following the instructions provided in 11.2, determine and record the mass of the 2nd subspecimen as $2^{nd}SubS,M_d$ in g or kg.

11.6.4.1 *Dispersing and Washing 2nd Subspecimen*—Wash the 2nd subspecimen following the applicable instructions provided in 11.5.2.1. After oven drying, allow the container to cool, determine and record the dry mass of the washed material, $2^{nd}SubS_wM_d$ in g or kg.

11.6.4.2 *Dry Sieving 2nd Subspecimen*—Using this oven-dried, washed 2nd subspecimen; dry sieve this material and determine the 2nd fractional cumulative masses (g or kg) retained following the applicable instructions given in 11.5.2.2, while noting the following:

(a) The coarsest sieve size in this finer sieve set is the size of the 2nd designated separating sieve.

(b) For these cumulative masses retained values, they are identified as 2nd fractional cumulative mass retained for each *Nth* sieve as $2^{nd}SubS,CMR_N$ in g or kg.

(c) As stated in 11.5.2.2, Item c and d, there should not be any material retained on the coarsest sieve in this finer sieve set and the same 2 % criterion is applicable, except the mass (g or kg) of the 2nd subspecimen ($2^{nd}SubS,M_d$) is used instead of the 1st subspecimen ($1^{st}SubS,M_d = SubS,M_d$).

11.6.4.3 Proceed to Section 12 on *Calculations*, 12.6.3 through 12.6.4.2.

12. Calculations

12.1 *General*—Refer to Fig. 1(a) and Fig. 1(b) for the typical terms used in sieving and data reduction. The cumulative mass retained (*CMR*) or fractional cumulative mass retained (*FCMR*) recorded for each *Nth* sieve, CMR_N or $FCMR_N$, will be used to calculate a percent passing (*PP*) each *Nth* sieve, PP_N. These results will be tabulated and may be presented graphically. Depending on the assigned/selected method, the results are rounded and presented to either the nearest 1 % (Method A) or 0.1 % (Method B), except for composite sieving, when only Method A applies. The graphical presentation is a plot of percent passing versus log of particle size (mm). The individual points should be connected by a smooth curve.

12.1.1 In the calculations presented below the masses can be in either g or kg. All sieving masses are dry (oven), unless noted otherwise.

12.1.2 In performing calculations needing intermediate values, the data sheet does not have to provide spaces for those values. For example, when calculating the percent finer, the needed intermediate calculation of cumulative percent retained does not have to be recorded.

12.1.3 The equations are given for calculation of percent passing. To calculate the percent retained necessary in determining the precision of this test method, see 14.1.2.1.

12.1.4 A summary of the symbols used below, along with their definition is given in the Annex A1 on Symbols.

12.2 *Sieve Overloading*—The details for determining when a sieve(s) is overloaded during the sieving process is given in 11.3. The only calculation involved is to determine the dry mass of material retained on each *Nth* sieve in g and then compare that value with the maximum allowable value given in Table 3. When the *CMR* sieving process is used, the dry mass retained on the *Nth* sieve, MR_N, is as follows:

$$MR_N = CMR_N - CMR_{N-1} \quad (1)$$

where:

MR_N = mass retained on the *Nth* sieve, g,
CMR_{N-1} = cumulative mass retained on the sieve above the *Nth* sieve, g, and
CMR_N = cumulative mass retained on the *Nth* sieve (in this case the sieve being checked for overloading), g.

12.3 *Single Sieve-Set Sieving, Percent Passing*—For single sieve-set sieving (specimens not requiring composite sieving), calculate the percent passing each *Nth* sieve as follows:

$$PP_N = 100\,(1 - CMR_N/S,M_d) \quad (2)$$

where:

PP_N = percent passing the *Nth* sieve, %,
CMR_N = cumulative mass retained on the *Nth* sieve; that is, the mass of material retained on the *Nth* sieve and those above it, g or kg, and
S,M_d = dry mass of the specimen, g or kg.

12.4 *Composite Sieving, Mass of Specimen*—Calculate the dry mass of the specimen, S,M_d as follows:

$$S,M_d = CP,M_d + \left(\frac{FP,M_m}{1 + \frac{w_{fp}}{100}}\right) \quad (3)$$

where:

S,M_d = dry mass of the specimen, g or kg,
CP,M_d = dry mass of the coarser portion, g or kg,
FP,M_m = moist or air-dried mass of the finer portion, g or kg, and
w_{fp} = water content of the finer portion, %.

12.5 *Composite Sieving, Single Separation*—The percent passing the coarser portion (*CP*) is calculated using the same approach as for single sieve-set sieving. For the subspecimen obtained from the finer portion; a composite sieving correction factor (*CSCF*) is required to convert the subspecimen's fractional percent passing to the specimen's percent passing, since only a portion of the specimen is sieved. Multiple approaches can be used to make this correction and they are in conformance with this test method, provided the calculated results are the same. In the presentation below, the percent passing values are identified related to the portion being dry sieved, such as CP,PP_N and $SubS,PP_N$; however, this distinction is not necessary on the data sheet. This approach is being done to allow the user to easily distinguish which portion is being calculated to determine the percent passing the specimen.

12.5.1 *Composite Sieving, Coarser Portion (CP):*

12.5.1.1 *CP, Percent Passing*—Calculate the percent passing each *Nth* sieve in the coarser sieve set as follows:

$$CP,PP_N = 100\,(1 - (CP,CMR_N/S,M_d)) \quad (4)$$

where:

CP,PP_N = specimen's percent passing the *Nth* sieve in the coarser sieve set while sieving the coarser portion of the specimen, %, and
CP,CMR_N = coarser portion's cumulative mass retained on the *Nth* sieve in the coarser sieve set, g or kg.

12.5.1.2 *CP, Composite Sieving Correction Factor (CSCF)*—The *CSCF* is equal to the percent passing the designated separating sieve size in the coarser sieve set (that is, the last/bottom sieve in that set). This value, CP,PP_{last}, shall be calculated and recorded to at least one more digit than required (nearest 0.1 %) to reduce rounding errors.

12.5.1.3 *CP, Acceptable Loss During Washing and Sieving*—Calculate the percent loss of the coarser portion during washing or sieving, or both as follows:

$$CP_L = 100\,(((CP,M_d - CP_wM_d) + CP,MR_{pan})/S,M_d) \quad (5)$$

where:

CP_L = percent of the coarser portion lost during washing and dry sieving, %,
CP,M_d = dry mass of the coarser portion, g or kg,
CP_wM_d = dry mass of the coarser portion after washing, g or kg, and
P,MR_{pan} = dry mass retained in the pan after dry sieving the coarser portion, g or kg.

The percent loss is acceptable if the value of CP_L is less than or equal to 0.5 %.

12.5.2 *Composite Sieving, Subspecimen (finer portion):*

12.5.2.1 *Percent Passing, Specimen (combined coarser and finer portions)*—In the approach presented, the fractional percent passing the subspecimen is corrected by the *CSCF* so it represents the percent passing the specimen. Calculate the percent passing each *Nth* sieve in the finer sieve set, $SubS,PP_N$ as follows:

$$SubS,PP_N = CSCF \times SubS,FPP_N = CSCF\,(1 - (SubS,FCMR_N/SubS,M_d)) \quad (6)$$

where:

$SubS,PP_N$ = specimen's percent passing the *Nth* sieve in the finer sieve set, %,
$SubS,FPP_N$ = subspecimen's fractional percent passing the *Nth* sieve in the finer sieve set, decimal (*not in* %),

$SubS,FCMR_N$ = subspecimen's fractional cumulative mass retained on the *Nth* sieve in the finer sieve set, g or kg, and
$SubS,M_d$ = dry mass of the subspecimen, g or kg.

12.5.2.2 *Subspecimen, Acceptable Fractional Percent Retained*—As covered in 11.5.2.2, there should not be any material retained on the first/top sieve, same size as the designated separating sieve, in the finer sieve set; however, when there is, the fractional percent retained shall not exceed 2 %. Calculate the fractional percent retained on the first sieve as follows:

$$SubS,FCPR_{first} = 100\,(SubS,FCMR_{first}/SubS,M_d) \quad (7)$$

where:

$SubS,FCPR_{first}$ = fractional cumulative percent retained on the first sieve (sieve size equal to the designated separating sieve) in the finer sieve set, %, and
$SubS,FCMR_{first}$ = fractional cumulative mass retained on the first sieve in the finer sieve set, g or kg. (This mass is actually the mass retained since there is not any sieve above it.)

12.5.2.3 *Percent Passing, Acceptance Criterion*—If material is retained on the designated separating-sieve size in the fine sieve set, then there will be two percent passing values for the same sieve size. If this occurs, the percent passing value from the coarser sieve set shall be the accepted value in determining the gradation of the specimen.

12.5.3 *Finer Portion, Percent Passing (optional)*—As mentioned in 9.2.1, there are cases where the gradation of the finer portion might be necessary, especially when other testing, such as compaction, are performed. In this case, the fractional percent passing the subspecimen, $SubS,FPP_N$ in %, represents the percent passing the finer portion, FP,PP_N. Calculate those values as follows:

$$FP,PP_N = 100\,(1 - (SubS,FCMR_N/SubS,M_d)) \quad (8)$$

where:

FP,PP_N = finer portion's percent passing the *Nth* sieve, %.

12.6 *Composite Sieving, Double Separation*—The methodology for these calculations is similar to that for calculating composite sieving with single separation, the only basic changes are the addition of new terms, see Fig. 1(a) and Fig. 1(b), and one additional set of calculations relating to the 2nd subspecimen. Therefore, review those figures and the comments presented in 12.5.

12.6.1 *1st Coarser Portion*—The percent passing, *CSCF* and acceptable loss calculations are the same as covered above, see Composite Sieving-Coarser Portion, 12.5.1, except the prefix 1st is added to all terms and symbols.

12.6.2 *1stSubspecimen*—In this case, the subspecimen is not sieved in its entirety, but is separated into a coarser and finer portion (2nd coarser portion and 2nd finer portion). The needed calculations associated with sieving the 2nd coarser portion and associated components are given below.

12.6.2.1 *Percent Passing, 2nd Coarser Portion*—Calculate the percent passing each *Nth* sieve in the 2nd coarser sieve set as follows:

$$2^{nd}CP,PP_N = 1^{st}CSCF \times 2^{nd}CP,\ FPP_N = 1^{st}CSCF\,(1 - (2^{nd}CP,CMR_N/SubS,M_d)) \quad (9)$$

where:

$2^{nd}CP,PP_N$ = specimen's percent passing the *Nth* sieve in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %,
$1^{st}CSCF$ = 1st composite sieving correction factor, which is equal to the percent passing the designated separating sieve size in the 1st coarser sieve set while sieving the coarser portion of the specimen, %,
$2^{nd}CP,\ FPP_N$ = 2nd coarser portion's fractional percent passing the *Nth* sieve in the 2nd coarser sieve set, decimal (*not in %*), and
$2^{nd}CP,CMR_N$ = 2nd coarser portion's fractional cumulative mass retained on *Nth* sieve in the 2nd coarser sieve set, g or kg.

12.6.2.2 *2nd Coarser Portion, Composite Sieving Correction Factor (2ndCSCF)*—The $2^{nd}CSCF$ is equal to the percent passing the 2nd designated separating sieve size in the 2nd coarser sieve set (that is, the last/bottom sieve in that set) while sieving the coarser portion of the 1st subspecimen. This value, $2^{nd}CP,PP_{last}$, shall be calculated and recorded to at least one more digit than required (nearest 0.1 %) to reduce rounding errors.

12.6.2.3 *2nd Coarser Portion, Acceptable Loss on Sieving and Washing*—The calculation and acceptance criterion for the 2nd coarser portion are the same as covered above, see 12.5.1.3, except the prefix 2nd is added to the applicable terms and symbols, and the dry mass of the specimen is replaced by the dry mass of the 1st subspecimen, as shown in the following equation:

$$2^{nd}CP_L = 100\,(((2^{nd}CP,M_{,d} - 2^{nd}CP_wM_d) + 2^{nd}CP,MR_{pan})/1^{st}SubS,M_d) \quad (10)$$

where:

$2^{nd}CP_L$ = percent of the 2nd coarser portion lost during washing and dry sieving, %,
$2^{nd}CP,M_{,d}$ = dry mass of the 2nd coarser portion, g or kg,
$2^{nd}CP_wM_d$ = dry mass of the 2nd coarser portion after washing, g or kg, and
$2^{nd}CP,MR_{pan}$ = dry mass retained in the pan after dry sieving the coarser portion, g or kg.

12.6.2.4 *2nd Coarser Portion, Acceptable Fractional Percent Retained*—As covered in 11.6.3.2, there should not be any material retained on the first/top sieve, same size as the designated separating sieve, in the 2nd coarser sieve set; however, when there is, the fractional percent retained shall not exceed 2 % of the dry mass of the 1st subspecimen. Calculate the fractional percent retained on the first sieve as follows:

$$2^{nd}CP,FPR_{first} = 100\,(2^{nd}CP,FCMR_{first}/SubS,M_d) \quad (11)$$

where:

$2^{nd}CP,FPR_{first}$ = 1st fractional percent retained on the first sieve (sieve size equal to the designated separating sieve) in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %, and

$2^{nd}CP,FCMR_{first}$ = 1st fractional cumulative mass retained on the first sieve in the 2nd coarser sieve set, g or kg. (This mass is actually the mass retained since there is not any sieve above it.)

12.6.2.5 *Percent Passing, Acceptance Criterion*—If material is retained on the designated separating-sieve size in the 2nd coarser sieve set, then there will be two percent passing values for the same sieve size. If this occurs, the percent passing value from the 1st coarser sieve set shall be the accepted value in determining the gradation of the specimen.

12.6.3 *2nd Subspecimen*—The needed calculations associated with sieving the 2nd subspecimen are given below.

12.6.3.1 *Percent Passing, 2nd Subspecimen*—Calculate the percent passing each *Nth* sieve in the finer sieve set as follows:

$$2^{nd}SubS,PP_N = 2^{nd}CSCF \times 2^{nd}SubS,FPP_N = 2^{nd}CSCF\left(1 - \left(2^{nd}SubS,FCMR_N/2^{nd}SubS,M_d\right)\right) \quad (12)$$

where:

$2^{nd}SubS,PP_N$ = specimen's percent passing the *Nth* sieve in the finer sieve set while sieving the 2nd subspecimen, %,

$2^{nd}CSCF$ = 2nd composite sieving correction factor, which is equal to the percent passing the 2nd designated separating sieve size in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %,

$2^{nd}SubS,FPP_N$ = 2nd subspecimen's fractional percent passing the *Nth* sieve in the finer sieve set, decimal (not in %),

$2^{nd}SubS,FCMR_N$ = 2nd subspecimen's fractional cumulative mass retained on the *Nth* sieve in the finer sieve set, g or kg, and

$2^{nd}SubS,M_d$ = dry mass of the 2nd subspecimen, g or kg.

12.6.3.2 *2nd Subspecimen, Acceptable Fractional Percent Retained*—As covered in 11.6.2.2, there should not be any material retained on the first/top sieve, same size as the designated separating sieve, in the finer sieve set; however, when there is, the fractional percent retained shall not exceed 2 %. Calculate the fractional percent retained on the first sieve as follows:

$$2^{nd}SubS,FPR_{first} = 100\left(2^{nd}SubS,FCMR_{first}/2^{nd}SubS,M_d\right) \quad (13)$$

where:

$2^{nd}SubS,FPR_{first}$ = 2nd fractional percent retained on the first sieve (sieve size equal to the 2nd designated separating sieve) in the finer sieve set while sieving the 2nd subspecimen, %, and

$2^{nd}SubS,FCMR_{first}$ = 2nd fractional cumulative mass retained on the first sieve in the finer sieve set while sieving the 2nd subspecimen, g or kg. (This mass is actually the mass retained since there is not any sieve above it.)

12.6.3.3 *Percent Passing, Acceptance Criterion*—If material is retained on the 2nd designated separating-sieve size in the finer sieve set while sieving the 2nd subspecimen, then there will be two percent passing values for the same sieve size. If this occurs, the percent passing value from the coarser sieve set shall be the accepted value in determining the gradation of the specimen.

12.6.4 *1st Finer Portion, Percent Passing (optional)*—As mentioned in 9.2.1, there are cases where the gradation of the specimen's 1st finer portion might be necessary, especially when other testing, such as compaction, are performed. In this case, the fractional percent passing the 2nd coarser portion, $2^{nd}CP,FPP_N$ in %, is representative of the percent passing the 1st finer portion, $1^{st}FP,PP_N$, up to the 2nd designated separating sieve size. Calculate those values as follows:

$$1^{st}FP,PP_N = 100\left(1 - \left(2^{nd}CP,FCMR_N/SubS,M_d\right)\right) \quad (14)$$

where:

$1^{st}FP,PP_N$ = 1st finer portion's percent passing the *Nth* sieve in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %.

While the $1^{st}FP,PP_N$ calculations associated with the 2nd finer portion or 2nd subspecimen are given below.

12.6.4.1 *2nd Finer Portion, Composite Sieving Correction Factor (optional)*—When the gradation of the 1st finer portion is needed and the 1st subspecimen is separated, then an additional composite sieving correction factor is necessary to convert the fractional percent passing the 2nd subspecimen to a percent passing which is representative of the 1st finer portion. This *CSCF* is identified as *FP,CSCF* and is equal to either the fractional percent passing the 2nd designated separating sieve size in the 2nd coarser sieve set, or the 1st finer portion's percent passing the last/bottom sieve in the 2nd coarser sieve set, FP,PP_{last}, as calculated above (see 12.6.4) and recorded to at least one more digit than required (nearest 0.1%) to reduce rounding errors.

12.6.4.2 *1st Finer Portion, Percent Passing for 2nd Subspecimen (optional)*—In this case, the 2nd fractional percent passing the finer sieve set, $2^{nd}SubS,FPP_N$ in % has to be corrected by the *FP,CSCF* (see 12.6.4.1) to represent the percent passing the finer portion, $1stFP,PP_N$. Calculate those values as follows:

$$1^{st}FP,PP_N = FP,CSCF\left(1 - \left(2^{nd}SubS,FCMR_N/2^{nd}SubS,M_d\right)\right) \quad (15)$$

where:

FP,CSCF = 1st finer portion's composite sieving correction factor, which is equal to the finer portion's percent passing the last/bottom sieve in 2nd coarser sieve set,%.

13. Report: Test Data Sheets(s)/Form(s)

13.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.13. If the test results (gradation) are reported in tabular or graphical format for other than the laboratory's data records, then those values have to be representative of the method used (Method A or B). The percent passing values must be rounded to the appropriate percentage before tabulating or plotting; that is, the nearest 1 % and 0.1 % for Method A and B, respectively. However, the laboratory's test data sheet(s)/form(s) do not have to meet this requirement, if the method used (Method A or B) is clearly identified.

13.2 Record as a minimum the following information (data):

13.2.1 Identification of the material being tested, such as project identification, boring number, sample number, depth, and test number.

13.2.2 Name or initials of person performing the test and date(s).

13.2.3 Visual classification of the soil being tested (estimate group name and symbol in accordance with Practice D2487).

13.2.4 Test method used (Method A, or B).

13.2.5 The procedure used to obtain the specimen(s) from the sample, such as moist, air dried, or oven dried, see 1.8 and Section 10.

13.2.6 If any soil or material was excluded from the specimen, describe the excluded material. If any problems were encountered, describe the problems.

13.2.7 Indicate if composite sieving was used and the size of the designated separating sieve(s). If material is retained on the designated separating sieve size in the finer sieve set, then document that the percent retained (*PR*) does not exceed the 2 % criterion (see 11.5.2.2, Item c and d; 11.6.3.2 and 11.6.4.2, Item c) on sieving those portion(s)).

13.2.8 Indicate if the ultrasonic bath or shaking apparatus or both were used during the dispersion process.

13.2.9 Any prior testing performed on specimen.

13.2.10 All mass measurements (to the appropriate significant digits or better).

13.2.11 Tabulation of percent passing (PP) for each sieve, preferably to either the nearest 1 % or 0.1 % in accordance with Method A or B, respectively, see 13.1. Note this percentage should have an extra digit associated with designated separating sieve sieves.

13.2.12 *(Optional)*—A graph of the percent passing versus log of particle size in mm.

14. Precision and Bias

14.1 *Precision*—Criteria for judging the acceptability of test results obtained by this test method using single sieve-set sieving on SP soil types are presented in 14.1.3 and 14.1.4. These estimates of precision are based on the results of the interlaboratory program conducted by the ASTM Reference Soils and Testing Program. In this program, the Moist Procedure, Method A (except two extra digits were recorded) and Single Sieve-Set Sieving procedures were used. The oven-dry mass of the specimen ranged between 97.56 g and 120.83 g, with an average value of 109.88 g and less than 30 % of the mass of the specimen was retained on any given sieve. In addition, some laboratories performed three replicate tests on the SP soil sample provided (triplicate test laboratories), while other laboratories performed a single test (single test laboratories). However, the data was processed twice to obtain a precision statement for both Method A and B. A description of the soil tested is given in 14.1.5. Testing precision may vary due to the specimen preparation procedure (moist, air-dried or oven-dried), the soil's gradation, and variations in the testing method used (Method A or B). If sample variability is assumed to be negligible, the analyses of the sieve data obtained in this program and others clearly indicate the following regarding sieving precision:

(a) Sieving precision cannot be accurately defined for an insignificant sieve (sieve in which 99 percent or more of the soil passes);

(b) Sieving precision is mainly a function of the amount of soil retained on a given sieve and the acceptable range in the size of the openings of a given sieve cloth;

(c) Sieving precision is also effected by sieve overloading, particle shape, and the slope of the gradation curve; and

(d) These items are interconnected in some manner, which has not been determined.

Additionally, judgement is necessary when applying these precision estimates to another soil.

14.1.1 *Precision Data Analysis*—Typically, precision statements include one or two variables per test, therefore, statements are presented in tabular format. However, in a sieve analysis, there are multiple variables (that is, a result for each sieve size) per test, therefore, it was determined that a non-tabular format would be appropriate.

14.1.1.1 As covered in Practices E177 and E691 and for most test methods, precision statements consist of two main components for each set of test results: Single-Operator Results (Within-Laboratory Repeatability) and Interlaboratory Results (Between-Laboratory Reproducibility). In addition, repeatability and reproducibility are composed of three key variables, the average value, the standard deviation (*s*) and the acceptable range of two results (*d2s* or 95 % limit). The *d2s* or 95 % limit is calculated as $1.960\times\sqrt{2}\times s$, as defined by Practice E177.

14.1.1.2 Based on the above, equations were developed to determine the repeatability and reproducibility standard deviation (s_r and s_R, respectively) as a function of the average percent retained on a given sieve ($avgPR_N$) for each set of test results (Method A and B). All values of $avgPR_N$ were less than 30 %. The equations developed are based on the upper bound (a straight line on which or below which all of the data points fall) of s_r or s_R versus $avgPR_N$ relationship, except if an unusually high outlier was noted. Then, using the appropriate s_r or s_R value, the repeatability limit (*r*) and reproducibility limit (*R*) can be determined, that is the acceptable range of two results or the *d2s* or 95 % limit.

14.1.2 *Calculation of Precision*—To compare two test results using single sieve-set sieving and either Method A or B, use the following sequence to determine either the repeatability and reproducibility limit for each *Nth* sieve size of interest.

14.1.2.1 For both reported test results, determine the percent retained on a given *Nth* sieve (PR_N) which is a significant sieve

(that is one in which less than 99 % passes or more than 1 % cumulative mass is retained). This PR_N is equal to the percent passing in the previous sieve (PP_{N-1}) less the percent passing for the given *Nth* sieve (PP_N). In this calculation, use the appropriate rounded PP_N value, for Method A to nearest 1 % and for Method B to nearest 0.1 %. This calculation is shown as follows:

$$PR_N = PP_{N-1} - PP_N \quad (16)$$

where:

PR_N = percent retained on *Nth* sieve, using single sieve-set sieving, %,
PP_{N-1} = percent passing the sieve previous to the *Nth* sieve, for Method A to nearest whole % and Method B to nearest 0.1 %, and
PP_N = percent passing the *Nth* sieve, for Method A to nearest whole % and Method B to nearest 0.1 %.

Then average the two values obtained for each *Nth* sieve size, without rounding, to determine the average percent retained for that *Nth* sieve size, $avgPR_N$. This $avgPR_N$ value shall not exceed 30 %. If it does, the precision shall not be determined for any sieve size within that test result (sieve analysis).

14.1.2.2 Use this $avgPR_N$ value and the appropriate precision equation in 14.1.3 or 14.1.4 to determine the repeatability standard deviation (s_r) or reproducibility standard deviation (s_R). Then, multiply this result by $1.960\times\sqrt{2}$ (or 2.772) and round the result as appropriate, for Method A to nearest 1 % and Method B to nearest 0.1 %. This value is either the Repeatability Limit (r) or the Reproducibility Limit (R), depending on the s_r or s_R equation used.

14.1.2.3 Determine the absolute (positive) difference between the two PR_N test values (PR_N) and compare it to the appropriate limit, r or R to see if that difference is acceptable; that is, PR_N is equal to or less than the appropriate r or R value. For significant sieves only, repeat this process for each pair of results. If there is a non-acceptable value, then both sets of test results shall be checked for any calculation and rounding errors and all sieves involved shall be checked for apparent deviations, for example, weaving defects, creases, wrinkles, foreign matter in the cloth, as covered in Specification E11, Test Method One. If other comparisons of test results continue to obtain non-acceptable values, then the determination of the size distribution of wire cloth openings shall be determined for all sieves involved, in accordance with Specification E11, Test Method Three. A set of example calculations is given in Appendix X2.

14.1.2.4 *Acceptance Criteria*—Duplicate test results (sieve analyses) are considered valid if no more than one sieve size has a non-acceptable value, as determined in 14.1.2.3. If a nonacceptable value is obtained for more than one sieve size, then one or both of the sets of test results (sieve analyses) are non-acceptable.

14.1.3 *Triplicate Test Precision Data (TTPD)*—The precision equations given below are based upon three replicate tests performed by each triplicate test laboratory on samples of an SP-type soil and upon information provided in 14.1 through 14.1.1.2. These equations are to be applied in accordance with 14.1.2. These equations apply specifically to the soil that was tested in the interlaboratory testing program.

14.1.3.1 *TTPD-Method A Repeatability*—This repeatability standard deviation for a given *Nth* sieve size ($As_{r,N}$) is equal to 0 % for $avgPR_N$ values equal to or less than 2 %. For $avgPR_N$ values greater than 2 %, calculate $As_{r,N}$ in % using the following equation:

$$As_{r,N} = 0.022 \times avgPR_N + 0.21 \quad (17)$$

14.1.3.2 *TTPD-Method A Reproducibility*—This reproducibility standard deviation for a given *Nth* sieve size ($As_{R,N}$ in %) is calculated using the following equation:

$$As_{R,N} = 0.073 \times avgPR_N + 0.43 \quad (18)$$

14.1.3.3 *TTPD-Method B Repeatability*—This repeatability standard deviation for a given *Nth* sieve size ($Bs_{r,N}$) is equal to the larger of 0.02 % or that using the following equation:

$$Bs_{r,N} = 0.0197 \times avgPR_N + 0.0055 \quad (19)$$

14.1.3.4 *TTPD-Method B Reproducibility*—This reproducibility standard deviation for a given *Nth* sieve size ($Bs_{R,N}$) is equal to the larger of 0.28 % or that using the following equation:

$$Bs_{R,N} = 0.0821 \times avgPR_N + 0.0110 \quad (20)$$

14.1.4 *Single Test Precision Data (STPD)*—In the ASTM Reference Soils and Testing Program, many of the laboratories performed only a single test. This is common practice in the design and construction industry. The equations given below are based upon the first test result from the triplicate test laboratories and the single test result from the other laboratories on samples of an SP-type soil and upon information provided in 14.1 through 14.1.1.2. These equations are to be applied in accordance with 14.1.2. The equations presented apply specifically to the soil that was tested in the interlaboratory testing program.

14.1.4.1 *STPD-Method A Reproducibility*—This reproducibility standard deviation for a given *Nth* sieve size ($As_{R,N}$ in %) is calculated using the following equation:

$$As_{R,N} = 0.038 \times avgPR_N + 0.65 \quad (21)$$

14.1.4.2 *STPD-Method B Reproducibility*—This reproducibility standard deviation for a given *Nth* sieve size ($Bs_{R,N}$) is equal to the larger of 0.382 % or that using the following equation:

$$Bs_{R,N} = 0.0462 \times avgPR_N + 0.357 \quad (22)$$

14.1.5 *Soil Type*—Based on the interlaboratory results, the soil used in the program is described below in accordance with Practice D2487. In addition, the local name of the soil is given: SP—Poorly graded sand, SP, 20 % coarse sand, 48 % medium sand, 30 % fine sand, 2 % fines, yellowish brown. Local name—Frederick sand.

14.1.6 *Discussion on Precision:*

14.1.6.1 The *TTPD* presents a rigorous interpretation of triplicate test data in accordance with Practice E691 from pre-qualified laboratories. *STPD* is derived from test data that would represent common practice.

14.1.6.2 It is quite possible that precision data presented for Method B is not as precise as it should be since a larger specimen should have been tested.

14.1.6.3 The precision data presented cannot be accurately applied to coarse-grained soils containing gravel size particles where more than 1 % gravel is contained in the sample/specimen. This statement is based on the precision data presented in Test Method C136, which demonstrated that the sieving precision decreases substantially when gravel specimens are tested versus sand specimens.

14.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

15. Keywords

15.1 gradation; grain size; particle size; particle-size distribution; sieve analysis; sieving

ANNEXES

(Mandatory Information)

A1. SYMBOLS

$1^{st}CSCF$ = 1st composite sieving correction factor, which is equal to the percent passing the designated separating sieve size in the 1st coarser sieve set while sieving the coarser portion of the specimen, %

$FP,CSCF$ = 1st finer portion's composite sieving correction factor, which is equal to the finer portion's percent passing the last/bottom sieve in 2nd coarser sieve set, %

$1^{st}FP,PP_N$ = 1st finer portion's percent passing the *Nth* sieve in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %

$2^{nd}CP,FCMR_N$ = 2nd coarser portion's fractional cumulative mass retained on *Nth* sieve in the 2nd coarser sieve set, g or kg

$2^{nd}CP,FPP_N$ = 2nd coarser portion's fractional percent passing the *Nth* sieve in the 2nd coarser sieve set, decimal (not in %), or in %

$2^{nd}CP,FPR_{first}$ = 1st fractional percent retained on the first sieve (sieve size equal to the designated separating sieve) in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %

$2^{nd}CP,M_d$ = dry mass of the 2nd coarser portion, g or kg

$2^{nd}CP,MR_{pan}$ = dry mass retained in the pan after dry sieving the coarser portion, g or kg

$2^{nd}CP,PP_N$ = specimen's percent passing the *Nth* sieve in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %

$2^{nd}CP_L$ = percent of the 2ndcoarser portion lost during washing and dry sieving, %

$2^{nd}CP_w,M_d$ = dry mass of the 2nd coarser portion after washing, g or kg

$2^{nd}CSCF$ = 2nd composite sieving correction factor, which is equal to the percent passing the 2nd designated separating sieve size in the 2nd coarser sieve set while sieving the coarser portion of the 1st subspecimen, %

$2^{nd}SubS,FCMR_{first}$ = 2nd fractional cumulative mass retained on the first sieve in the finer sieve set while sieving the 2nd subspecimen, g or kg (This mass is actually the mass retained since there is not any sieve above it.)

$2^{nd}SubS,FCMR_N$ = 2nd subspecimen's fractional cumulative mass retained on the *Nth* sieve in the finer sieve set, g or kg

$2^{nd}SubS,FPP_N$ = 2nd subspecimen's fractional percent passing the *Nth*th sieve in the finer sieve set, decimal (not in %) or in %

$2^{nd}SubS,FPR_{first}$ = 2nd fractional percent retained on the first sieve (sieve size equal to the 2nd designated separating sieve) in the finer sieve set while sieving the 2nd subspecimen, %

$2^{nd}SubS,M_d$ = dry mass of the 2nd subspecimen, g or kg

$2^{nd}SubS,PP_N$ = specimen's percent passing the *Nth* sieve in the finer sieve set while sieving the 2nd subspecimen, %

$AASHTO$ = American Association of State Highway and Transportation Officials

$AMRL$ = AASHTO Materials Reference Laboratory

$As_{r,N}$ = Method A repeatability standard deviation for a given *Nth* sieve

$As_{R,N}$ = Method A reproducibility standard deviation for a given *Nth* sieve

$avgPR_N$ = average of two percent retained values on the *Nth* sieve between two laboratories or within laboratory

$Bs_{r,N}$ = Method B repeatability standard deviation for a given *Nth* sieve

$Bs_{R,N}$ = Method B reproducibility standard deviation for a given *Nth* sieve

CMR_N = cumulative mass retained on the th sieve; that is, the mass of material retained on the *Nth* sieve and those above it, g or kg

CMR_{N-1} = cumulative mass retained on the sieve above the *Nth* sieve, g or kg

CP,CMR_N = coarser portion's cumulative mass retained on the *Nth* sieve in the coarser sieve set, g or kg

CP,M_d = dry mass of the coarser portion, g or kg

CP,MR_{pan} = dry mass retained in the pan after dry sieving the coarser portion, g or kg

CP,PP_N = specimen's percent passing the *Nth* sieve in the coarser sieve set while sieving the coarser portion of the specimen, %

CP_L = percent of the coarser portion lost during washing and dry sieving, %
CP_w,M_d = dry mass of the coarser portion after washing, g or kg
$CSCF$ = composite sieving correction factor
$d2s$ = acceptable range of two results (or 95 % limit) calculated as $1.960\times\sqrt{2}\times s$, as defined by Practice E177
FP,M_m = moist or air-dried mass of the finer portion, g or kg
FP,PP_N = finer portion's percent passing the *Nth* sieve, %
MR_N = mass retained on the *Nth* sieve, g or kg
PP = percent passing, %
PP_N = percent passing the *Nth* sieve, %
PR = percent retained, %
s = standard deviation, units of calculation
S,M_d = dry mass of the specimen, g or kg
s_r = repeatability (within laboratory) standard deviation
s_R = reproducibility (between laboratories) standard deviation
$STPD$ = single test precision data
$SubS,FCMR_{first}$ = fractional cumulative mass retained on the first sieve in the 2nd coarser sieve set, g or kg (This mass is actually the mass retained since there is not any sieve above it.)
$SubS,FCMR_{first}$ = fractional cumulative mass retained on the first sieve in the finer sieve set, g or kg (This mass is actually the mass retained since there is not any sieve above it.)
$SubS,FCMR_N$ = subspecimen's fractional cumulative mass retained on the *Nth* sieve in the finer sieve set, g or kg
$SubS,FCPR_{first}$ = fractional cumulative percent retained on the first sieve (sieve size equal to the designated separating sieve) in the finer sieve set, %
$SubS,FPP_N$ = subspecimen's fractional percent passing the *Nth* sieve in the finer sieve set, decimal (not in %) or in %
$SubS,M_d$ = dry mass of the subspecimen, g or kg
$SubS,PP_N$ = specimen's percent passing the *Nth* sieve in the finer sieve set, %
$TTPD$ = triplicate test precision data
w_{fp} = water content of the finer portion, %
ΔPP_N = absolute (positive) difference between two PR_N test values (within laboratory or between laboratories)

A2. SAMPLE TO SPECIMEN SPLITTING/REDUCTION METHODS

A2.1 *General*—It is possible that bulk samples, jar samples, or specimens from prior testing may be significantly larger than needed for a sieve analysis. To reduce these samples to an appropriate specimen size, several techniques are applicable. The type and sizes of particles contained within the sample will influence the specimen processing and selection. Practice C702 provides details of mechanical splitting, quartering and miniature stockpile sampling for aggregate. When testing soils, these methods are adapted based on soil type. The goal is to have the specimen accurately represent the sample. Loss of particles (finer sizes) and segregation of particles are the most common problems when obtaining a specimen and most frequently occur during low or no moisture situations. Likewise, it is difficult to obtain a representative specimen if the sample contains excess or free water.

A2.1.1 *Mechanical Splitting*—This method is used only on dry samples that contain little or no fines. If the sample appears to create dust during the splitting, the sample has lost fines and mechanical splitting should be limited. For all soils, the splitting method may be used a maximum of two times, see 10.4.4. The splitter or riffle box shall conform to 6.9. The sample is placed in a feeder pan and distributed evenly throughout the pan. Pour the sample from the pan, into the hopper/feed chute, open the gate, if applicable, and allow the specimen to feed into the two catch pans. This process can be repeated once.

A2.1.2 *Quartering*—This method can be used on moist samples (see Practice C702), however it is often difficult and requires effort to collect all the finer particles. The sample is placed on a clean nonporous smooth surface (floor or sheet) and is thoroughly mixed using shovels, scoops, or spoons as appropriate for the sample size. Then, mound the sample into a cone-type shape by placing each shovelful or scoop on top of the preceding material. Flatten the cone to form a disk. Using a straight edge, or knife, divide the disk into wedge-shaped quarters. Remove two opposing quarters. Remix the remaining two quarters. Repeat this process until the mass of the remaining two quarters is greater than the minimum mass requirement, but less than 1.5 times the minimum mass requirement. If the sample is in a dry state, then this process can be repeated only once.

A2.1.3 *Miniature Stockpile Sampling*—This method is only applicable for moist samples. The sample is placed on a clean nonporous smooth surface and is thoroughly mixed using shovels, scoops or spoons as appropriate for the sample size. Then, mound the sample into a cone-type shape by placing each shovel full or scoop on top of the preceding shovel full or scoop of material. If desired, flatten the cone to form a disk. Using a scoop, obtain material from at least five locations in the pile. Scoop until the mass of the specimen is greater than the minimum mass requirement. Do not attempt to take very small scoops in order to obtain an exact mass because this

could skew the particle-size distribution. In some cases, when working with relatively small samples and materials finer than the ⅜-in. (9.5-mm) sieve, a single scoop should be adequate.

A2.2 *Sample Processing Recommendations Based on Soil Type*—Estimate the soil classification using D2488. Then, use the following recommendations in conjunction with those given in Sections 9 and 10.

A2.2.1 *Clean Gravel (GW, GP) and Clean Sand (SW, SP)*—The condition of this sample should be moist or dry (air or oven). Either moist or dry (air or dry) processing can be used, although moist processing is probably easier, especially for sandy soils. The sample will require composite sieving if there are gravel size particles, see 10.3. If sample splitting is necessary to obtain a specimen, the sample can be mechanically split (dry processing), quartered (moist or dry processing), or sampled from a miniature stockpile (moist processing), to obtain a specimen. Refer to 10.4.1 (moist), 10.4.2 (air dried) or 10.4.3 (oven dried) for additional guidance.

A2.2.2 *Gravel with Fines (GM, GC, GC-GM, GW-GM, GW-GC, GP-GM, GP-GC)*—These soil types are the most difficult to obtain a gradation. The difficulty increases with increasing plasticity of the fines. The sample/specimen *will* require composite sieving due to the gravel size particles, see 10.3. Some of the fines may adhere to the gravel particles. Moist processing can be difficult, but with dry processing, it is often impossible or impractical to obtain a representative specimen. If the fine material appears to be wetter than the plastic limit (Test Method D4318), air-dry the sample until it is not sticky, but is still moist. If sample reduction is necessary, the sample can be quartered or sampled from a miniature stockpile to obtain a specimen. Then, it can be processed over the designated separating sieve as described in 10.5.2.

A2.2.3 *Sand with Silt Fines (SW-SM, SP-SM, SM)*—These soils should be processed in a moist state, see 10.5.1. The sample may require composite sieving if there is a wide range of particle sizes. The fines will frequently segregate from the sand and care must be taken to obtain a representative specimen. Moist processing will reduce the probability of segregation of fines. If sample reduction to obtain a specimen is needed, the sample can be quartered, or sampled from a miniature stockpile to obtain a specimen. Then, if composite sieving is necessary, it can be processed over the designated separating sieve as described in 10.5.2

A2.2.4 *Sand with Clay and Silt Fines or Clay Fines (SW-SC, SP-SC, SC, SC-SM) and Clays (CL, CL-ML, CH)*—These soils are processed in a moist state. If the fine material appears to be wetter than the plastic limit (Test Method D4318), air-dry the sample until it is not sticky, but is still moist. Complete drying of these materials usually creates hard lumps that can be difficult to disperse or break apart, see 10.5.2. The sample may require composite sieving if there is gravel size particles, see 10.3. If sample reduction is needed, the sample can be quartered, or sampled from a miniature stockpile to obtain a specimen. Then, if composite sieving is necessary, it can be processed over the designated separating sieve as described in 10.5.2.

A2.2.5 *Silts with Sand or Gravel, or Both (ML, MH)*—These soils are processed in a moist state. If the fine material appears to be wetter than the plastic limit (Test Method D4318), air-dry the sample until it is not sticky, but is still moist. The material may contain large particles and therefore require composite sieving, see 10.3. If sample reduction is needed, the sample can be quartered, or sampled from a miniature stockpile to obtain a specimen. Then, if composite sieving is necessary, it can be processed over the designated separating sieve as described in 10.5.2.

A2.2.6 *Organic Soils with Sand or Gravel, or Both (OL, OH)*—The organic soils are processed moist. If the material appears to be wetter than the plastic limit (Test Method D4318), air-dry the sample until it is not sticky, but is still moist. The material may contain large particles and therefore require composite sieving. Some of the organic material may easily break apart during processing. If sample reduction is needed, the sample can be quartered, or sampled from a miniature stockpile to obtain a specimen. Then, if composite sieving is necessary, it can be processed over the designated separating sieve as described in 10.5.2.

APPENDIXES

(Nonmandatory Information)

X1. EXAMPLE TEST DATA SHEETS/FORMS

X1.1 *General*—Two example data sheets are presented. Fig. X1.1 presents a data sheet that may be used in processing bulk samples in which a sieve-analysis specimen, or other testing, or both is needed. Fig. X1.2 presents a data sheet that may be used to record the sieve analysis data.

LABORATORY BULK SAMPLE PROCESSING INFORMATION:

Revision Date: 11/05/03

Project Number: _____ Task Number: _____ Boring No.: _____

Project Name: _____ Assignment Number: _____ Sample Number: _____

Project Engineer: _____ Depth (ft): _____

Initial Visual Classification: ☐ See Visual Description Form (S-103), or _____

HCl Reaction: ☐ None; ☐ Weak; ☐ Strong _____

Mica Content: ☐ None; ☐ Low; ☐ Medium; ☐ High

Composite Sample No.: _____ Combined Sample Numbers: _____

SAMPLE PROCESSED FOR:		TYPE OF SAMPLE:		STATE OF SAMPLE BEFORE PROCESSING:		AS-RECEIVED WATER CONTENT:			
Compaction:		Bulk:		As Received:		Container No.:			
Classification Test(s):		SPT:		Air Dried:		Mass of Container and Wet Specimen, M1 (g):			
Engineering Test(s):		Mod. California:		Oven Dried:		Mass of Container and Dry Specimen, M2 (g):			
Soil-Bentonite Mix:		Thin Walled Tube:		Other:		Mass Container, M3 (g):			Average
Other:		Other:				**AS-RECEIVED WATER CONTENT, w_o (%)**			
						Circle Approx. Max. Grain Size in "Sample": 3" 1- 1/2" 3/4" 3/8" #4 #10 <#10			

SOIL AGGREGATION BROKEN UP BY: (check proper box(s))		
Processing Through Sieve:		
Mech. Pulverizer:		For
Type:		____
Hand Rolled Drum:		Minutes
Mortar & Pestle:		
Other:		

PROCESSING DEGREE OF DIFFICULTY	
Easy:	
Difficult:	
Very Difficult:	

DESIGNATED SPLITTING SIEVE SIZE:

	FINE FRACTION:	
MASS	Mass of Partial Moist Soil - 1, (g):	
	Mass of Partial Moist Soil - 2, (g):	
	Mass of Partial Moist Soil - 3, (g):	
	Mass of Partial Moist Soil - 4, (g):	
	Total Mass of Moist Fine Fraction, M4 (g):	
	Total Mass of Dry Fine Fraction, M5 (g):	
WATER CONTENT	Subspecimen Container No.:	
	Cont. & Moist Subspecimen, M1 (g):	
	Cont. & Dry Subspecimen, M2 (g):	
	Mass of Container, M3 (g):	
	Water Content, w (%)	

COARSE FRACTION:	
Container No.	
Container & Moist Soil, M1 (g):	
Container & Dry Soil, M2 or M6 (g):	
Container & Soil after Washing & Drying, (g):	
Mass of Container, M3 or M7 (g):	
Mass of Dry Coarse Fraction, M8 (g)	
Water Content of Coarse Fraction, w (%)	

TOTAL MASS OF DRY SPECIMEN, M9 (g):	
(Circle: Moist or Dry) Mass of Cobbles/Boulders, (1) (g):	
Max. Dia. of Cobble/Boulder, inch or _____:	

☐ See back of form for preliminary coarse fraction sieving. Remarks: _____

Note (1) Mass of cobbles/boulders not included in total mass of dry specimen.

(2) Water content specimen for moist soils is obtained by representative scoop or quartering; while for non-moist soils, a splitter is used.

w & w_o = ((M1–M2)/(M2–M3)) × 100

M5 = M4/((1+ (w/100))

M9 = M5 + M8 M8 = M6 – M7

PROCESSED BY: _____ DATE: _____

TESTED BY: _____ DATE: _____

DRY MASS BY: _____

CALCULATED BY: _____

CHECKED BY: _____

SPOT CHECKED BY: _____

REVIEWED BY: _____

Copy of ProcessBulkSample.xls, Bulk Sample 11/05/03

FIG. X1.1 Example Bag Sample Processing Data Sheet

GRADATION OF SOILS : by Sieving using Soil Sieve Sizes (ASTM D XXXX)

Project Number: _____ Boring No.: _____ Test Method: ☐ Method A; or ☐ Method B File Name: _____

Project Name: _____ Sample No. _____ Mfr./Model of Large Sieve Shaker: _____

Project Engineer: _____ Depth (ft) : _____ Mfr./Model of 8" Sieve Shaker: _____

Initial Visual Classification: _____

SPECIMEN: Selected From: — **Selection Method(s) & Sieve Range:** — **State of Material When Specimen Selected**

Selection: Bulk Sample: ☐ Thin-Walled Tube: ☐ Composite Sieving Used: ☐ No; ☐ Yes

SPT Sample: ☐ Engr. Property Test Designated Separating Sieve Size given below (2): Method(s) Moist Air-Dry Oven

Mod Calif. Sample: ☐ Specimen's WC: ☐ _____ Whole specimen used: N/A ☐ ☐ ☐

Other: _____ _____ First Subspecimen, selec. by: ___ & ___ ☐ ☐ ☐

Second Subspecimen, selec. by: ___ & ___ ☐ ☐ ☐

Selection Methods: (a) Splitter (use only on dry soils and do not repeat the process more than a couple of times) or (b) Quatering (moist soils only); or (c) Representative scoop after mixing, or slice of intact sample; (use for moist soils or those which will not segregate)

Preparation: — **Oven-Dried Soil Broken Up Before:** — **By:** — Remarks: _____

Sieve Specimen: Selecting Partial Sample: ☐ No; ☐ Yes Mortar & Pestle ☐

Oven-Dried: ☐ Sieving 1st Coarser Sieve Set: ☐ No; ☐ Yes Pulverizer ☐

Air-Dried: ☐ Sieving 2nd Coarser Sieve Set: ☐ No; ☐ Yes Hand ☐

As-Received State: ☐ Sieving Finer Sieve Set: ☐ No; ☐ Yes Other _____

Washing:	N/A	Yes	No	Soaked For:	Dispersent Used:	Dispersion Appratus Used & Type (Ultrasonic/Shaken):
Test Specimen:	☐	☐	☐	____(min)	☐ No; ☐ Yes	☐ No; ☐ Yes _____
Coarse Portion:	☐	☐	☐	____(min)	☐ No; ☐ Yes	☐ No; ☐ Yes _____
SubS or 2nd CP:	☐	☐	☐	____(min)	☐ No; ☐ Yes	☐ No; ☐ Yes _____
2nd Subspecimen:	☐	☐	☐	____(min)	☐ No; ☐ Yes	☐ No; ☐ Yes _____

Used coarser sieve over No. 200 Washing Sieve: ☐ No; ☐ Yes

If Yes, Sieve Size: _____

MASS OF TEST SPECIMEN				**Washed Specimen**			**Water Content (*W*)**	
	Total Test Specimen	Subspecimen First	Subspecimen Second	Retained Washed Soil (after washing)			☐ As Received or Subspecimen (First)	
Min. sieve size in sieving sequence(1)				Coarse Portion	SubS / 2nd CP	2nd Subspec.	Container No.:	
Container Number							Moist+Cont.(g):	
Mass Dry Soil + Container, (g)							Dry+Cont.(g):	
Mass Container, (g)							Cont.(g):	
Mass Dry Soil, M_d (g)							***W*, %**	
Percent Loss on Washing, (%):								

SIEVING RESULTS

Size of Large Sieves at:

See (2)	Sieve No.	Cumulative Mass Retained, CMR_N (g)	% Passing Sieve	Percent Passing, PP_N
☐	3"			
☐	2"			
☐	1 1/2"			
☐	1"			
☐	3/4"			
☐	1/2"			
☐	3/8"			
☐	4			
☐	1st Pan		2nd Pan (g):	

Req. Mass of Test Spec. for 1% (kg)	See (2)	Sieve No. /(3)	Cumulative Mass Retained, CMR_N (g)	% Passing Sieve	Percent Passing, PP_N
3" = 50	☐	1"/1,100			
1 1/2" = 10	☐	3/4"/900			
3/4" = 1.1	☐	1/2"/570			
3/8"=0.15-0.25	☐	3/8"/550			
#4 = 0.50-0.1	☐	4 /325			
#10 = 0.05-0.1	☐	10 /180			
Sieve Time (min):		20 /115			
Large = ____		40 /75			
Small = ____		60 / 60			
		100 / 40			
		140 / 30			
		200 / 20			
		1st Pan		2nd Pan (a):	

Size of Small Sieves at: 8" Dia. or

Notes : (1) Sieve size given, denotes min. sieve size used in the appropriate sieve set.

(2) X in box denotes designated separating sieve size

(3) Allowable amount of soil retained on 8" sieve.

Mica Noted: ☐ No; ☐ Yes Amount Adjective: _____

SUMMARY: Shape, Filter, & etc. Parameters

%COBBLES N/A D_{60} _____ D_{85} _____

% GRAVEL _____ D_{30} _____ D_{15} _____ Remarks: _____

% SAND _____ D_{10} _____ D_{50} _____

% FINES _____ C_u = _____ C_c = _____

The above D_n values denotes particle size (mm) at the corresponding TPP_n.

Coefficient of Curvature, $C_c = (D_{30})^2 / (D_{60} \times D_{10})$

Coefficient of Uniformity, $C_U = D_{60} / D_9$

N/A - not applicable. CP - coarser portion

SubS - subspecimen

	Set-Up By:	Dry Mass By:	Washed By:	
Test Specimen:				Calculated By:
Coarse Portion:				Checked By:
Fine Portion:				Spot Checked By:
Date:				Reviewed By:

FIG. X1.2 Example Gradation of Soils Data Sheet

X2. PRECISION: EXAMPLE CALCULATIONS

X2.1 *General*—Two sets of example calculations are provided for comparing test results (sieve analyses) obtained within and between laboratories. The first example, Fig. X2.1, presents results for sieve analyses using Method A (data to the nearest whole percentage) and based upon the triplicate test precision data. The second example, Fig. X2.2, presents results for sieve analyses using Method B (data to the nearest 0.1 %) and based upon the triplicate and single test precision data.

Method A - Example Calculations for Within Laboratory Precision (Repeatability)
Based Upon Triplicate Test Precision Data

Equation for Repeatability Standard Deviation: $As_{r,n} = 0.022 \times avgPR_n + 0.21$ or 0 if $avgPR_n$ is equal to or less than 2%

Alternate Sieve Size	Lab 14 Test Results: Percent Passing, PP_n Trial Number 1	2	Percent Retained, PR_n Trial Number 1	2	Average Percent Retained, $avgPR_n$	Method A - Repeatability Standard Deviation, $As_{r,n}$	Repeatability Limit, r (1)	Absolute Difference Between PR_n Values, ΔPR_n	ΔPR_n minus r	Acceptability: ΔPR_n =or< r Yes or No
No.4	100	100	0	0	N/A	N/A	N/A	N/A	N/A	N/A
10	80	81	20	19	19.5	0.639	2	1	–1	Yes
20	59	61	21	20	20.5	0.661	2	1	–1	Yes
40	33	33	26	28	27	0.804	2	2	0	Yes
60	10	11	23	22	22.5	0.705	2	1	–1	Yes
100	4	4	6	7	6.5	0.353	1	1	0	Yes
140	3	3	1	1	1	0	0	0	0	Yes
200	2	2	1	1	1	0	0	0	0	Yes
									Precision Acceptance:	Valid Duplicates

Method A - Example Calculations for Between Laboratory Precision (Reproducibility)
Based Upon Triplicate Test Precision Data

Equation for Reproducibility Standard Deviation: $As_{r,n} = 0.073 \times avgPR_n + 0.43$

Alternate Sieve Size	Percent Passing, PP_n Laboratory ID 1A	23A (2)	Percent Retained, PR_n Laboratory ID 1A	23A	Average Percent Retained, $avgPR_n$	Method A - Reproducibility Standard Deviation, $As_{R,n}$	Reproducibility Limit, R (1)	Absolute Difference Between PR_n Values, ΔPR_n	ΔPR_n minus R	Acceptability: ΔPR_n =or< R Yes or No
No.4	100	100	0	1	N/A	N/A	N/A	N/A	N/A	N/A
10	81	81	19	19	19	1.817	5	0	–5	Yes
20	60	58	21	23	22	2.036	6	2	–4	Yes
40	35	27	25	31	28	2.474	7	6	–1	Yes
60	11	9	24	18	21	1.963	5	6	1	No
100	3	3	8	6	7	0.941	3	2	–1	Yes
140	2	2	1	1	1	0.503	1	0	–1	Yes
200	2	0	0	2	1	0.503	1	2	1	No
									Precision Acceptance:	Non-acceptable

Note: (1) A special spreadsheet function is used to round values without any extra digits; therefore, the displayed value is the value in the cell.
(2) Some data was adjusted to create non-acceptable data.

FIG. X2.1 Precision Example Calculations: Method A—Triplicate Test Precision Data

Method B - Example Calculations for Within Laboratory Precision (Repeatability)
Based Upon Triplicate Test Precision Data

Equation for Repeatability Standard Deviation: $Bs_{r,n} = 0.022 \times avgPR_n + 0.21$ or 0.02, whichever is larger

Lab 14 Test Results										
Alternate Sieve Size	Percent Passing, PP_n Trial Number A	B	Percent Retained, PR_n Trial Number A	B	Average Percent Retained, $avgPR_n$	Method A-Repeatability Standard Deviation, $Bs_{r,n}$	Repeatability Limit, r (1)	Absolute Difference Between PR_n Values, ΔPR_n	ΔPR_n minus r	Acceptability: ΔPR_n = or< r Yes or No
No. 4	100.0	100.0	0.0	0.0	N/A	N/A	N/A	N/A	N/A	N/A
10	80.0	80.8	20.0	19.2	19.60	0.3916	1.1	0.8	−0.3	Yes
20	59.4	60.6	20.6	20.2	20.40	0.4074	1.1	0.4	−0.7	Yes
40	33.1	33.5	26.3	27.1	26.70	0.5315	1.5	0.8	−0.7	Yes
60	10.5	11.1	22.6	22.4	22.50	0.4488	1.2	0.2	−1.0	Yes
100	3.6	3.7	6.9	7.4	7.15	0.1464	0.4	0.5	0.1	No
140	2.6	2.9	1.0	0.8	0.90	0.0232	0.1	0.2	0.1	No
200	2.0	2.0	0.6	0.9	0.75	0.0203	0.1	0.3	0.2	No
									Precision Acceptance:	Invalid Duplicates

Method B - Example Calculations for Between Laboratory Precision (Reproducibility)
Based Upon Single Test Precision Data

Equation for Reproducibility Standard Deviation: $Bs_{R,n} = 0.0462 \times avgPR_n + 0.357$ or 0.382, whichever is larger

Alternate Sieve Size	Percent Passing, PP_n Laboratory ID 1A	26	Percent Retained, PR_n Laboratory ID 1A	26	Average Percent Retained, $avgPR_n$	Method A-Reproducibility Standard Deviation, $As_{R,n}$	Reproducibility Limit, R (1)	Absolute Difference Between PR_n Values, ΔPR_n	ΔPR_n minus R	Accceptability: ΔPR_n = or< R Yes or No
No. 4	100.0	100.0	0.0	1.0	N/A	N/A	N/A	N/A	N/A	N/A
10	80.9	81.0	19.1	19.0	19.05	1.2371	3.4	0.1	−3	Yes
20	59.9	60.9	21.0	20.1	20.55	1.3064	3.6	0.9	−3	Yes
40	34.7	34.6	25.2	26.3	25.75	1.5467	4.3	1.1	−3	Yes
60	10.8	12.2	23.9	22.4	23.15	1.4265	4.0	1.5	−3	Yes
100	3.4	3.6	7.4	8.6	8.00	0.7266	2.0	1.2	−1	Yes
140	2.3	2.4	1.1	1.2	1.15	0.4101	1.1	0.1	−1	Yes
200	1.8	1.9	0.5	0.5	0.50	0.3820	1.1	0.0	−1	Yes
									Precision Acceptance:	Acceptable

Note: (1) A special spreadsheet function is used to round values without any extra digits; therefore, the displayed value is the value in the cell.

FIG. X2.2 Precision Example Calculations: Method B—Triplicate and Single Test Precision Data