Designation: D4221 – 17

Standard Test Method for Dispersive Characteristics of Clay Soil by Double Hydrometer[1]

This standard is issued under the fixed designation D4221; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This test method provides an indication of the natural dispersive characteristics of clay soils by comparing the amount of particles finer than 2-µm as determined by this method compared to the amount of particles finer than 2-µm as determined by Test Method D7928(**1**).[2] In order to do this comparison, two similar specimens must be obtained from the sample.

1.2 This test method follows the procedure given in Test Method D7928 with the exception that the soil slurry is not mechanically dispersed and no dispersing agent is added.

1.3 This test method is applicable only to soils where the position of the plasticity index versus liquid limit plots (Test Methods D4318) falls on or above the "A" line (Practice D2487) and more than 12 % of the soil fraction is finer than 2-µm as determined in accordance with Test Method D7928(**2**).

1.4 Since this test method may not identify all dispersive clay soils, other tests such as, pinhole dispersion (Test Methods D4647/D4647M), crumb (Test Methods D6572) (**3-5**) and the analysis of pore water extraction (Test Methods D4542) (**4-7**) may be performed individually or used together to help verify dispersion.

1.5 *Units*—The values stated in SI units are to be regarded as the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this test method.

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

1.6.1 The procedures used to specify how data are collected/recorded or 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 this standard to consider significant digits used in analysis methods for engineering design.

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

1.8 *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:*[3]

D653 Terminology Relating to Soil, Rock, and Contained Fluids

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

D4542 Test Methods for Pore Water Extraction and Determination of the Soluble Salt Content of Soils by Refractometer

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[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.06 on Physical-Chemical Interactions of Soil and Rock.

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[2] The boldface numbers in parentheses refer to the list of references appended to this standard.

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

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

D4647/D4647M Test Methods for Identification and Classification of Dispersive Clay Soils by the Pinhole Test

D6026 Practice for Using Significant Digits in Geotechnical Data

D6572 Test Methods for Determining Dispersive Characteristics of Clayey Soils by the Crumb Test

D6913 Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

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

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *dispersive clays, n*—soils that deflocculate easily and rapidly without significant mechanical assistance in water of low-salt concentration.

3.2.1.1 *Discussion*—Such soils usually have a high proportion of their adsorptive capacity saturated with sodium cation although adsorbed lithium and magnesium may also play a role (**6**). Such soils also generally have a high shrink-swell potential, have low resistance to erosion, and have low permeability in an intact state.

4. Summary of Test Method

4.1 This test method is used to determine the percent dispersion of a soil. In order to calculate the percent dispersion, two similar specimens are obtained from a representative sample and then a sedimentation (hydrometer) analysis is performed on each specimen to determine the amount of particles finer than 2-µm. The sedimentation analysis is performed following Test Method D7928 for both specimens, except that one of the specimens is de-aired and is not mechanically or chemically dispersed.

4.2 The percent dispersion is calculated by dividing the percent passing the 2-µm size from the de-aired, not dispersed specimen by the percent passing the 2-µm size from the specimen that was dispersed and by multiplying the result by 100.

5. Significance and Use

5.1 Dispersive clays are those which normally deflocculate when exposed to water of low-salt concentration, the opposite of aggregated clays that would remain flocculated in the same soil-water system (**3, 4, 7**). Generally, dispersive clays are highly erosive, possibly subject to high shrink-swell potential, may have lower shear strength, and have lower permeability rates than aggregated clays.

5.2 When the percent dispersion equals 100, it indicates a completely dispersive clay-size fraction. When the percent dispersion equals 0, it indicates completely nondispersive clay-size fraction.

5.3 Available data (**1**) indicates that the test method has about 85 % reliance in predicting dispersive performance (85 % of dispersive clays show more than 35 % dispersion).

5.4 Since this test method may not identify all dispersive clays, design decisions based solely on this test method may not be conservative. It is often run in conjunction with the crumb test (D6572) (**4, 7**), the pinhole test (D4647/D4647M), or the analysis of the pore water extract (D4542) (**4, 7**), or combination thereof, to identify possible dispersive clay behavior.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personal 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 this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depends on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 Section 6 of Test Method D7928 describes the equipment and tools needed for performing the sedimentation (hydrometer) analysis portion of this standard.

6.2 *Container*—An airtight, glass or equivalent inert container with enough capacity to hold the minus No. 10 (2.0-mm) specimen(s).

6.3 *Filtering Flask*—A 500-mL filtering flask with a rubber stopper and a side tube capable of withstanding a vacuum.

6.4 *Vacuum System*—A vacuum pump or water aspirator capable of producing a vacuum between 508 and 635 mm of Hg on the vacuum gauge.

7. Reagents

7.1 Section 7 of Test Method D7928 describes the reagents needed for performing the mechanically and chemically dispersed sedimentation (hydrometer) analysis portion of this standard.

7.2 *Distilled Water*—Distilled or demineralized water with a pH between 5.5 and 7 is the only permissible test fluid for use in the sedimentation portion of the test. The use of tap water is not permitted.

8. Sampling

8.1 *General*—This test method does not address, in any detail, procurement of the sample. It is assumed the sample is obtained using appropriate methods and is representative of the material under evaluation. The testing agency must preserve all samples in accordance with Practice D4220/D4220M, Group B, except if the as-received sample does not meet those requirements. In which case, the water content of the sample does not have to be maintained. Section 9 of Test Method D6913 gives additional information regarding sampling from different sources.

8.2 Follow the steps given in 8.4 of Test Method D7928, including the mass requirements given in Table 1 of that standard, to obtain the reduced sample from which the test specimens are to be obtained.

9. Preparation of the Test Specimens

9.1 *Specimen Procurement*—This standard presents two preparation methods to obtain the sedimentation specimens:

moist and air-dried. Moist and air-dried refers to the condition of the sample as it is being reduced to an appropriate particle size and mass. The test shall not be performed on oven-dried soil. The air-dried method shall only be used on samples received in the air-dried state (Note 2). Since some fine-grained air-dried soils aggregate, a mortar and rubber covered pestle is used to break up aggregations. Care must be taken to avoid disintegration or reduction of individual particles. Use only enough force as necessary to break up the aggregations without destroying the individual particles. Additional guidance for splitting materials to obtain a representative specimen is given in Test Method D6913, Annex A2.

9.2 See 9.2 and 9.3 of Test Method D7928 for the moist and air-dried preparation methods, respectively.

9.3 If the reduced sample contains particles larger than the No. 10 (2.0-mm) sieve, the soil must be separated using a No. 10 (2.0-mm) sieve. Process the entire reduced sample over the No. 10 (2.0-mm) sieve using a rubber scraper and, if needed, distilled water to aid in working the soil through the sieve. Check that the soil retained on the sieve does not contain aggregations of finer particles. Any aggregations should be broken and passed through the sieve. It is not necessary that the separation be totally complete, but the soil passing the sieve must be representative. The amount of soil passing the No. 10 (2.0-mm) sieve must be sufficient to obtain two specimens for sedimentation analysis and one water content determination.

9.4 If there is sufficient minus No. 10 (2.0-mm) soil, split or quarter this soil into at least three portions: one for the water content determination and two for the sedimentation analyses. The water content specimen must contain 50 ± 10 g of soil. If there is insufficient minus No. 10 (2.0-mm) soil, do not obtain a water content specimen. Obtain the dry mass of the minus No. 10 (2.0-mm) soil at the end of the test as discussed in 11.12 of Test Method D7928. See Note 11 in Test Method D7928.

9.5 If sufficient soil is available, immediately use one of the three specimens for determination of the water content in accordance with Test Methods D2216 and record the water content, w_c to the nearest 0.1 %. Immediately place the other two specimens into separate airtight containers. If the water content is to be determined at the end of the test, immediately place the two specimens in air tight containers to prevent moisture change.

NOTE 2—Air drying causes irreversible changes to the clay particles that cause permanent flocculations and decreases the fine fraction. (**8**)

10. Procedure

10.1 *Mechanically and Chemically Dispersed*—Use one of the specimens stored in one of the containers to determine the amount of particles finer than 2-µm in accordance with Test Method D7928. The stirring apparatus shall be used to disperse the specimen.

10.2 *Not Mechanically or Chemically Dispersed:*

10.2.1 Determine and record the moist mass of soil, M_m, equivalent to 25 g of dry soil, M_d, using the following equation:

$$M_m = M_d \times \left(1 + \frac{w_c}{100}\right) \quad (1)$$

where:

M_m = mass of moist soil, nearest 0.01 g,
M_d = mass of dry soil, nearest 0.01 g, and
w_c = water content, nearest 0.1 %.

10.2.2 Place approximately 125 mL of distilled water in the filtering flask.

10.2.3 Using one of the specimens stored in one of the containers, take the moist mass, M_m, amount as determined in 10.2.1, and place it into the filtering flask with the distilled water.

10.2.4 Place a rubber stopper into the mouth of the filtering flask and connect the flask to the vacuum pump. If the soil was received in the air-dried state, it should be soaked for a minimum of 2 h before the filtering flask is connected to the vacuum pump. Under most conditions, 508 to 584 mm of Hg is sufficient to de-air the specimen.

10.2.5 Start the vacuum pump and apply full vacuum. If bubbles do not appear, the vacuum is insufficient.

10.2.6 At 3 min, 5 min, and 8 min after application of vacuum, swirl the flask several times in a rotating manner to assist in removing entrapped air.

10.2.7 Turn off the vacuum pump and disconnect the flask from the vacuum pump after a total evacuation time of 10 min.

10.2.8 Transfer all of the slurry from the flask into the sedimentation cylinder. Use the wash/rinse bottle filled with distilled water as needed to make sure all of the slurry is transferred to the cylinder. Add distilled water to the sedimentation cylinder to bring the bottom of the meniscus of the slurry to the 1000 mL ± 1 mm mark.

10.2.9 Follow the procedure starting in 11.7 and through 11.14 of Test Method D7928; except that if the water content was not determined as discussed in 9.4 of this method, after 11.10 follow the steps given in 11.12 before continuing on to 11.13 and 11.14 of Test Method D7928. The dry mass obtained according to 11.12.3 of Test Method D7928 will not contain dispersant, therefore, the result obtained is the dry mass of the specimen, M_d, not M_{dd}.

10.2.10 *Temperature-Density Correction*—Because one of the specimens does not have the chemical dispersant added, the temperature-density correction used in calculating the percent finer for this specimen, as described in 10.2 of Test Method D7928, must be made using distilled water.

11. Calculation

11.1 Calculate and record the mass percent finer for both specimens using the equations given in 12.4 of Test Method D7928.

11.2 Calculate and record the maximum particle diameter in suspension for both specimens using the equation given in 12.6 of Test Method D7928.

11.3 Calculate and record the percent dispersion to the nearest 1 % using the following equation:

$$\%Dispersion = \left(\frac{N_{m,2\mu m,nd}}{N_{m,2\mu m,d}}\right) \quad (2)$$

where:

$N_{m,2\mu m,nd}$ = mass percent finer than 2-µm not dispersed, nearest 1 %

$N_{m,2\mu m,d}$ = mass percent finer than 2-µm dispersed, nearest 1 %

12. Report: Test Data Sheet(s)/Form(s)

12.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.6 and D6026.

12.2 Record as a minimum the following general information (data):

12.2.1 Identification of the soil/material being tested, such as the project identification, boring number, sample number, and depth.

12.2.2 Test number, if any, testing dates and the initials of the person(s) who performed the test.

12.2.3 The sample preparation method used: moist or air-dried.

12.2.4 The specific gravity of the specimen and indicate if the value is assumed or measured.

12.2.5 The apparatus identification used during the test as listed in 13.2.5 of D7928 and the following from this method:

12.2.5.1 Vacuum pump identification number.

12.2.5.2 Filter flask identification number.

12.2.6 Description and classification of the soil in accordance with Practice D2488 or when Atterberg limit data are available, Practice D2487.

12.2.7 Describe any soil/material that was excluded from the specimen and any problems encountered during testing.

12.2.8 Indicate any prior testing performed on the specimen.

12.3 Record as a minimum the following test specimen data as it applies to both test specimens:

12.3.1 The information as listed in Test Method D7928, 13.3.1 through 13.3.15 as applicable to each specimen.

12.3.2 The percent dispersion.

NOTE 3—When comparing historical test data versus new data, consider adding a note to the report indicating the distinction between the data using 5 µm versus 2 µm as the particle size diameter for which percent dispersion is based upon and also consider noting, if the stirring apparatus was not used to disperse the soil. The percent dispersion could be different for the same soil when the test is evaluated using different particle diameters or if another means of dispersing the soil was used instead of the stirring apparatus.

13. Precision and Bias

13.1 *Precision:*

13.1.1 *Single-Operator Precision*—The single-operator coefficient of variation has been found to be 3.9 %. Therefore, results of two properly conducted tests by the same operator with the same equipment should not be considered suspect unless they differ by more than 11.1 % of their mean.

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

14. Keywords

14.1 clays; deflocculation; dispersion; dispersive clay; erosion; gradation; hydrometer analysis; jugging; particle size; piping; sedimentation analysis

REFERENCES

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(6) Bell, J.G., and Maude, R.R., “Dispersive Soils: A Review from the South Africa Perspective,” *Quarterly Journal of Engineering Geology*, Vol 27, 1994, pp. 195-210.

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(8) Sridharan, A. Jose, B.T., and Abraham, B.M., Technical Note on “Determination of Clay Size Fraction of Marine Clays,” *Geotechnical Testing Journal*, GTJODJ, Vol. 14, No. 1, March 1991, pp. 103-107.

SUMMARY OF CHANGES

Committee D18 has identified the location of selected changes to this test method since the last issue, D4221–11, that may impact the use of this test method. (July 1, 2017)

(1) Reworded the scope section and added 1.6.
(2) Removed references to D422 and replaced with D7928.
(3) Updated References section.
(4) Updated Terminology section.
(5) Reworded 4.1 and 4.2.
(6) Deleted Note 5 and moved it to 5.2 and renumbered the section.
(7) Updated Note 1 to current language.
(8) Apparatus section updated to include the equipment from D7928.
(9) Added Reagents and Sampling sections; renumbered rest of standard.
(10) Added text regarding Preparation of the Test Specimens.
(11) Added new Notes 2 and 3 and removed previous Notes 2, 3 and 4. Text in Note 4 moved to 10.2.10.
(12) Indicated in the Procedure section the difference in testing the two specimens.
(13) Added to calculate mass percent finer and the diameter to the Calculation section.
(14) Updated equations 1 and 2.
(15) Updated the Report section.
(16) Added "sedimentation analysis" to Keywords section.
(17) Added reference 8 to References section.

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