



Standard Test Method for Determination of Water (Moisture) Content of Soil By Direct Heating¹

This standard is issued under the fixed designation D 4959; 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 covers procedures for determining the water (moisture) content of soils by drying with direct heat, such as using a hotplate, stove, blowtorch, etc.

1.2 This test method can be used as a substitute for Test Method D 2216 when more rapid results are desired to expedite other phases of testing and slightly less accurate results are acceptable.

1.3 When questions of accuracy between this test method and Method D 2216 arise, Method D 2216 shall be the referee method.

1.4 This test method is applicable for most soil types. For some soils, such as those containing significant amounts of halloysite, mica, montmorillonite, gypsum, or other hydrated materials, highly organic soils or soils that contain dissolved solids, (such as salt in the case of marine deposits), this test method may not yield reliable water content values.

1.5 The values stated in SI units are to be regarded as standard.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids²

D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock²

D 3740 Practice for Minimum Requirements for Agencies Engaged in the Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction²

D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Testing Soil, Rock, and Related Construction Materials²

3. Terminology

3.1 *Definitions*—All definitions are in accordance with Terms and Symbols D 653.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *direct heating*—a process by which the soil is dried by conductive heating from the direct application of heat in excess of 110°C to the specimen container, such as provided by a hot plate, gas stove or burner, heatlamps, or other heat sources. Direct application of heat by flame to the specimen is not appropriate.

3.2.2 *water (moisture) content*—the ratio, expressed as a percentage, of the mass of water in a given mass of soil to the mass of the solid particles.

4. Summary of Test Method

4.1 A moist soil specimen is placed in a suitable container and its mass is determined. It is then subjected to drying by the application of direct heat until dry by appearance, removed from the heat source, and its new mass is determined. This procedure is repeated until the mass becomes constant within specified limits.

4.2 The difference between the masses of the moist specimen and the dried specimen is used as the mass of water contained in the specimen. The water content (expressed as a percentage) is determined by dividing the mass of water by the dry mass of soil, multiplied by 100. For a given soil type and specimen size, the time to achieve a constant dry mass can be noted and used to estimate drying time for subsequent tests of the same soil type using the same size specimen and drying apparatus.

5. Significance and Use

5.1 The water content of a soil is used throughout geotechnical engineering practice both in the laboratory and in the field. The use of Test Method D 2216 for water content determination can be time consuming and there are occasions when a more expedient method is desirable. Drying by direct heating is one such method. Results of this test method have been demonstrated to be of satisfactory accuracy for use in field control work, such as in the determination of water content, and in the determination of in-place dry unit weight of soils.

5.2 The principal objection to the use of the direct heating

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² *Annual Book of ASTM Standards*, Vol 04.08.

for water content determination is the possibility of overheating the soil, thereby yielding a water content higher than would be determined by Test Method D 2216. While not eliminating this possibility, the incremental drying procedure in this test method will minimize its effects. Some heat sources have settings or controls that can also be used to reduce overheating. Loose fitting covers or enclosures can also be used to reduce overheating while assisting in uniform heat distribution.

5.3 The behavior of a soil when subjected to direct heating is dependent on its mineralogical composition, and as a result, no one procedure is applicable for all types of soils or heat sources. The general procedure of this test method applies to all soils, but test details may need to be tailored to the soil being tested.

5.4 When this test method is to be used repeatedly on the same or similar soil from a given site, a correction factor can usually be determined by making several comparisons between the results of this test method and Test Method D 2216. A correction factor is valid when the difference is consistent for several comparisons, and is reconfirmed on a regular specified basis.

5.5 This test method may not be appropriate when precise results are required, or when minor variations in water content will affect the results of other test methods, such as borderline situations where small variations in the measured water content could affect acceptance or rejection.

5.6 This test method is not appropriate for specimens known to contain flammable organics or contaminants, and other test methods should be utilized in these situations.

NOTE 1—The quality of the results produced by this test method 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 D 3740 are generally considered capable of competent and objective testing/sampling/inspection. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself ensure reliable results. Reliable results depend on many factors; Practice D 3740 provides a means of evaluating some of those factors.

6. Interferences

6.1 When testing sand and gravel size particles, additional care must be taken to avoid the possibility of particle shattering.

6.2 Due to the localized high temperatures in the soil during testing, the physical characteristics of the soil may be altered. Degradation of individual particles may occur, along with vaporization, chemical transition, or loss of organics. Therefore, specimens used in this test method should not be used for other tests subsequent to drying (see Note 2).

NOTE 2—The subsequent use of specimens dried by direct heating in other test methods is discouraged.

7. Apparatus

7.1 *Direct Heat Source*—Any source or heat that can be directed to the soil specimen to raise the specimen temperature to or above 110°C. Commonly used sources include electric, gas, butane or oil-fired stoves, and hotplates, blowtorches, heat lamps, hair driers, space heaters, etc. Heat sources that directly apply open flame to the specimen may cause extreme degradation of the specimen along with oxidation of and depositing

of soot in the specimen and should not be used.

7.2 *Balances*—A balance having a minimum capacity of 2 Kg, and meeting the requirements of Specification D 4753 for a balance of 0.1-g readability.

7.3 *Specimen Containers*—Suitable containers made of material resistant to corrosion and a change in mass upon repeated heating, cooling, and cleaning. One container is needed for each water content determination.

7.4 *Container Handling Apparatus*—Gloves or suitable holder for moving hot containers after drying.

7.5 *Miscellaneous (as needed)*—Mixing tools such as spatulas, spoons, etc.; eye protection, such as safety glasses or goggles; cigarette papers, and knives.

8. Hazards

8.1 Container holders or gloves are recommended for handling hot containers. Some soil types can retain considerable heat, and serious burns could result from improper handling.

8.2 Suitable eye protection such as safety glasses or goggles is recommended due to the possibility of particle shattering during heating, mixing, or mass determinations.

8.3 Highly organic soils, and soils containing oil or other contaminants may ignite during drying with direct heat sources. Means for smothering flames to prevent operator injury or equipment damage should be available during testing. Fumes given off from contaminated soils or wastes may be toxic, and should be vented accordingly.

8.4 Due to the possibility of steam explosions, or thermal stress shattering of porous or brittle aggregates, a vented covering over the sample container may be appropriate to prevent operator injury or equipment damage. This also prevents scattering of the test specimen during the drying cycle while aiding in uniform heating of the specimen.

9. Samples

9.1 Perform the water content determination as soon as practical after sampling to prevent water loss and damage to potentially corrodible containers.

9.2 Prior to testing, store samples in non-corrodible airtight containers at a temperature between approximately 3 and 30°C and in an area that prevents direct exposure to sunlight.

10. Test Specimens

10.1 Select a representative portion of the total sample. If a layered soil or more than one soil type is encountered, select an average portion or individual portions of each, and note which portion(s) were tested in the report of the results.

10.1.1 For bulk samples, select the test specimen from the material after it has been thoroughly mixed. The mass of moist material selected shall be in accordance with Table 1.

TABLE 1 Test Specimen Masses

Sieve Size Retaining More Than 10 % of Sample, mm	Minimum Mass of Moist Specimen, g ^A
2.0 (No. 10)	200 to 300
4.75 (No. 4)	300 to 500
19.0 (No. ¾)	500 to 1000

^ALarger specimens may be used and are encouraged. Generally, inherent test inaccuracies are minimized by using specimens with as large a mass as practical.

10.1.2 For small samples, select a representative portion in accordance with the following procedure:

10.1.2.1 For cohesionless soils, mix the material thoroughly, then select a test specimen having a mass of moist material in accordance with Table 1.

10.1.2.2 For cohesive soils, remove about 3 mm of material from the exposed periphery of the sample and slice the remaining specimen in half (to check if the material is layered), prior to selecting the test specimen. If the soil is layered, see 10.1. Breaking or cutting of cohesive samples to approximately 6 mm particles speeds drying and prevents crusting or overheating the surface while drying the interior.

10.2 Using a test specimen smaller than the minimum mass indicated in Table 1 requires discretion, though it may be adequate for the purpose of the test. Note a specimen having a mass less than the previously indicated value in the report of results.

NOTE 3—When working with a small sample containing a relatively large coarse-grained particle, it may be appropriate not to include this particle in the test specimen, depending on the use of test results. If this is done, such exclusion should be noted in the report of the results.

10.3 When the result of a water content determination by the use of this test method is to be compared to the results of another method, such as Test Method D 2216, obtain a second specimen during selection of the specimen for this comparison. Take precautions to obtain a specimen that represents the same water content as closely as possible. Protect the comparison specimens from water loss by transporting and storing the specimens in sealed containers. A correction factor can be determined for use on subsequent water content determinations on the same soil types from the same site when the difference is relatively constant using several comparisons. Check the correction factor on a regular, specified basis. Recognize that different technicians, heat sources, and such may result in different correction factors.

11. Conditioning

11.1 Prepare, process, and test all specimens as quickly as possible to minimize unrecorded moisture loss.

11.2 Cut or break up the soil into small size aggregations to aid in obtaining more uniform drying of the specimen, taking care to avoid any loss of soil.

11.3 If the specimens are not being tested immediately, place the specimens in containers that can be closed and stored in an area not exposed to direct sunlight, to prevent loss of moisture prior to initial mass determinations.

12. Procedure

12.1 Determine the mass of a clean, dry container, and record.

12.2 Place the soil specimen in the container, and immediately determine and record the mass of the soil and container.

12.3 Apply heat to the soil specimen and container, taking care to avoid localized overheating. Continue heating while stirring the specimen to obtain even heat distribution. Continue application of heat until the specimen first appears dry. A comparatively uniform color should result. Avoid localized burnt or darkened appearance of any part of the soil by intermittent mixing and stirring.

12.3.1 Experience with a particular soil type indicates when shorter or longer initial drying periods can be used without overheating.

NOTE 4—A piece of dry, light-weight paper or tissue, such as cigarette paper, placed on the surface of the apparently dry soil will curl or ripple if the soil still contains significant water.

12.4 After an initial heating period has been completed (soil appears dry), remove the container and soil from the heat source and cool to allow handling and prevent damage to the balance. Determine and record the mass of the soil and container.

12.5 Return the container and soil to the heat source for an additional application of heat.

12.6 With a small spatula or knife, carefully stir and mix the soil, taking care not to lose any soil.

12.7 Repeat 12.3 through 12.5 until the change between two consecutive mass determinations would have an insignificant effect on the calculated water content. A change of 0.1 % or less of the dry mass of the soil for the last two determinations should be acceptable for most specimens.

12.8 Use the final dry mass determination in calculating the water content.

12.9 When routine testing of similar soils is contemplated, the drying times and number of cycles may be established and correlated for each heat source and used for subsequent determinations. When pre-determined drying times and cycles are utilized, periodic verification in accordance with the procedure in 12.7 should be performed to assure that the results of the final dry mass determination are equivalent.

13. Calculation

13.1 Calculate the water content of the soil as follows:

$$w = [(M_1 - M_2)/(M_2 - M_c)] \times 100 = M_w/M_s \times 100 \quad (1)$$

where:

w = water content, %,

M_1 = mass of container and moist specimen, g,

M_2 = mass of container and dried specimen, g,

M_c = mass of container, g,

M_w = mass of water, g, and

M_s = mass of solid particles, g.

14. Report

14.1 Report the following information:

14.1.1 Identification of the sample (material) being tested, by location (boring number, sample number, test number, etc.),

14.1.2 Water content of the specimen to the nearest 1 %,

14.1.3 Indication of the test specimen mass, including a note if less than the minimum indicated in Table 1,

14.1.4 Indication of test specimens containing more than one soil type (layered, and the like),

14.1.5 Indication of any material (size and amount) excluded from the test specimen,

14.1.6 Initial mass of test specimen prior to drying, and the mass after the incremental drying periods,

14.1.7 Identification of the type of direct heat source, drying settings, drying times, and number of cycles used, when standardized drying is utilized, and

14.1.8 Identification of comparison test(s) if performed, the

method of test utilized and any correction factors applied (see Note 5).

NOTE 5—Water content determinations conducted in accordance with Test Method D 2216 or other methods may be recorded on the same report. This is not a mandatory requirement, but may be convenient when the results of the two methods are to be compared.

15. Precision and Bias

15.1 *Precision*—Test data on precision is not presented due to the nature of the soil materials being tested by this test method. It is not feasible and too costly at this time to have ten or more agencies participate in a round-robin testing program. Also, it is not feasible or too costly to produce multiple specimens that have uniform physical properties. Any variation observed in the data is just as likely to be due to specimen variation as operator or laboratory testing variation.

15.2 The precision of this test method is operator-dependent, and is a function of the care exercised in performing the steps of the procedure, giving particular attention to careful control and systematic repetition of the procedures used.

15.2.1 Subcommittee D18.08 is seeking any data from users of this test method that might be used to make a limited statement on precision.

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

16. Keywords

16.1 acceptance tests; compaction control; density; direct heating; laboratory moisture tests; moisture content; moisture control; quality control; rapid method; soil moisture; test procedure

SUMMARY OF CHANGES

In accordance with Committee D-18 policy, this section identifies the location of changes to this standard since the last edition (1994) that may impact the use of this standard.

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| <ul style="list-style-type: none"> (1) Editorially revised the title. (2) Editorially revised 1.2. (3) Revised Section 2 to include Practice D 3740. (4) Revised Section 5 to include Note 1 referencing Practice D 3740. | <ul style="list-style-type: none"> (5) Revised the numbering of existing notes. (6) Revised precision and bias statement to conform to D-18 policy. (7) Added Summary of Changes. |
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