Designation: D 5080 – 00

# Standard Test Method for Rapid Determination of Percent Compaction[1]

This standard is issued under the fixed designation D 5080; 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 describes the procedure for rapidly determining the percent compaction and the variation from optimum moisture content of an in-place soil for use in controlling construction of compacted earth. These values are obtained by developing a three-point compaction curve at the same moisture content as the in-place soil without knowing the value of the moisture content. The soil used for the compaction curve is normally the same soil removed from the in-place density test. For the remainder of this designation, this test method will be referred to as the *rapid method*.

1.2 This test method is normally performed for soils containing more than 15 % fines (minus No. 200 sieve size).

1.3 When gravel-size particles are present in the soil being tested, this test method is limited to a comparison of the minus No. 4 sieve-size fraction of the in-place density material to a laboratory compaction test of minus No. 4 sieve-size material (Method A of Test Methods D 698). Subject to the limitations of Practice D 4718, this test method is also applicable to comparisons of other sieve-size fractions (for example, Method C of Test Methods D 698) or other compactive efforts (for example, Test Methods D 1557) if new moisture adjustment values are determined (see 6.1 and Appendix X2).

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

1.4.1 The use of balances or scales recording pounds of mass (lbm), or the recording of density in pounds of mass per cubic foot (lbm/ft$^3$) should not be regarded as nonconformance with this test method.

1.5 *This standard does not purport to address all of the safety problems, 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.* For specific hazard statements, see Section 9.

## 2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 698 Test Methods for Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 5.5-lb (2.49-kg) Rammer and 12-in. (305-mm) Drop[2]

D 1556 Test Method for Density of Soil In-Place by the Sand-Cone Method[2]

D 1557 Test Methods for Moisture-Density Relations of Soils and Soil Aggregate Mixtures Using 10-lb (4.54-kg) Rammer and 18-in. (457-mm) Drop[2]

D 2167 Test Method for Density and Unit Weight of Soil In-Place by the Rubber Balloon Method[2]

D 2216 Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures[2]

D 2922 Test Method for Density of Soil and Soil-Aggregate In-Place by Nuclear Methods (Shallow Depth)[2]

D 2937 Test Method for Density of Soil In Place By the Drive-Cylinder Method[2]

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 Construction[2]

D 4718 Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles[2]

E 11 Specification for Wire-Cloth Sieves for Testing Purposes[3]

## 3. Terminology

3.1 *Definitions*—Except as follows in 3.2, all definitions are in accordance with Terminology D 653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *added water, z*—amount of water, expressed as a percentage, which is added to wet soil before compacting a specimen in the rapid method. If the moisture content of the wet soil is decreased, the amount of "added water" is a negative number (for example, − 2.0 %).

3.2.2 *C value*—ratio, expressed as a percentage, of in-place wet density at field moisture content to the wet density of a laboratory compacted specimen prepared at field moisture content. The *C* value is a comparison of compactive effort of field compaction equipment to standard laboratory compactive effort.

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

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

[3] *Annual Book of ASTM Standards*, Vol 04.01.

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

3.2.3 *compaction curve at field moisture content*— plot showing the relationship between wet density at field moisture content (converted wet density) and the percent of "added water."

3.2.4 *converted wet density,* $\rho wet_c$—wet density of a compacted specimen after being converted (by correcting for the amount of "added water") to the wet density at field moisture content.

3.2.5 *D value*—ratio, expressed as a percentage, of in-place wet density at field moisture content to laboratory maximum wet density as determined from a compaction curve developed at field moisture content as determined by the rapid method. The *D* value is the rapid method equivalent of percent compaction.

3.2.6 *field moisture content,* $w_f$—moisture content of the minus No. 4 fraction of in-place soil.

3.2.7 *field wet density,* $\rho wet_f$—wet density as determined from an in-place density test.

3.2.8 *maximum wet density at field moisture content,* $\rho m$—wet density defined by the peak of the laboratory compaction curve at field moisture content.

3.2.9 $w_f - w_o$—expression for the difference between the in-place moisture content and the optimum moisture content as determined by the rapid method.

## 4. Summary of Test Method

4.1 A representative sample of soil is obtained in conjunction with performing Test Method D 1556, D 2167, D 2922, or D 2937. Soil specimens are compacted in accordance with Method A of Test Methods D 698. At least three specimens are compacted, the first at field (in-place) moisture content, and each of the remaining at different moisture contents. A parabolic curve is assumed as defined by the three compaction points, and the peak point of the curve is determined mathematically. The ratio of in-place wet density at field moisture content to laboratory maximum wet density is determined. An approximation of the difference between optimum moisture content and field moisture content is determined. After the actual field moisture content is determined by ovendrying (usually the next day), the dry densities, unit weights, and optimum moisture content are calculated.

## 5. Significance and Use

5.1 The rapid method is performed to quickly evaluate percent compaction and variation from optimum moisture content of soils used in construction without knowing the value of field moisture content at the time of the test.

5.1.1 Test results are usually determined within 1 to 2 h from the start of the test.

5.1.2 The value of percent compaction obtained using the rapid method will be the same as the percent compaction calculated using dry density values.

5.1.3 The value of the difference between field moisture content and optimum moisture content will be approximate, but will be within $\pm$ 0.1 to 0.2 percentage point of the difference calculated once the field moisture content is known.

5.2 Test results may be used to determine if the compacted material meets density and moisture control values that are specified as a percentage of a standard maximum density and optimum moisture content such as determined in Method A of Test Methods D 698. A three-point compaction curve is used in place of the four- or five-point curve required in Test Methods D 698.

5.3 This test method is based on the assumption that a three-point compaction curve is a parabola at the section of the curve close to optimum moisture content so that the peak point of the curve can be determined mathematically. This assumption results in the major difference between this test method and obtaining the maximum density and optimum moisture content from a full five-point compaction curve.

5.4 Once the field ovendry moisture content has been determined, the values of dry density, dry unit weight, and optimum moisture content can be calculated (see Note 1).

5.5 This test method can also be used for foundation or borrow area material to compare in-place dry density and unit weight and moisture content to laboratory maximum dry density and unit weight and optimum moisture content.

5.6 This test method has the advantage that the maximum density value can be obtained on the same soil excavated during the in-place density test.

NOTE 1—Since there is no need to immediately determine the moisture contents of material from the in-place density test or the laboratory compaction points, use of rapid moisture content determinations such as microwave, direct heat, nuclear, etc., is not needed. However, if desired, the percent compaction and variation from optimum moisture content may be determined using dry density values based on rapid moisture content test methods. Using three compaction points and determining the maximum density mathematically would still apply. However, the rapid moisture content methods may give results that differ from the accepted oven-dried moisture content values and will lengthen the time of performing this test method.

NOTE 2—The quality of the result 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 assure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means for evaluating some of those factors.

## 6. Interferences

6.1 The moisture adjustment values were determined based on average density and optimum moisture content values of a large number of soil samples containing only minus No. 4. sieve-size particles. The soil being tested should be compared with the information in Appendix X2. For soils having properties significantly different, the moisture adjustment values may not be applicable. If this is the case, new adjustment values must be determined for the specific soil (see Appendix X2).

6.2 For samples significantly dry or wet of their optimum moisture content ( + 6.0 %, − 4.0 %), the values $w_f - w_o$ are less accurate.

## 7. Apparatus

7.1 Equipment for determining the in-place density as required by this test method used.

7.2 Equipment for preparing laboratory compaction specimens as required for Method A of Test Methods D 698.

7.3 *Graduated Cylinder*, 100-mL capacity, graduated to 1 mL.

7.4 *Mixer*, electric, bench, 3-speed, ⅓-hp, 60-cycle, 115-V motor or other appropriate device for mixing the soil with water.

7.5 *Electric Fan*, or other drying device.

7.6 *Sieve*, a 4.75-mm (No. 4) sieve conforming to the requirements of Specification E 11.

7.7 *Miscellaneous Equipment*—Brushes, knife, mixing pans, scoop, etc., for mixing or trimming soil specimens; bucket with lid or other suitable container for retaining the test sample.

## 8. Reagents and Materials

8.1 Tapwater that is free of acids, alkalies, and oils and is generally suitable for drinking should be used for wetting the soil prior to compaction.

## 9. Hazards

9.1 *Safety Hazards*—While there are no safety hazards specific to this test method, there are safety precautions in the referenced test designations that are applicable.

9.2 *Technical Hazards*—The test specimens should be prepared and compacted as quickly as possible to minimize moisture loss. If the test is not performed immediately, store the sample in a moisture-proof container to prevent the loss of moisture. A determination of the moisture content before and after storage is recommended.

## 10. Calibration and Standardization

10.1 Verify that equipment used in conjunction with this procedure is currently calibrated in accordance with the applicable procedure. If the calibration is not current, perform the calibration before using the equipment for this procedure.

## 11. Procedure

11.1 The procedure for performing this test method is divided into four sections as follows:

11.1.1 Obtain in-place density,

11.1.2 Compact specimens and obtain compaction curve,

11.1.3 Determine maximum point from compaction curve, *D* value, and $w_f - w_o$, and

11.1.4 Complete test for record.

NOTE 3—Since the calculations are an integral part of the procedure, the calculations are included in the sections on procedure.

### OBTAIN IN-PLACE DENSITY

11.2 Perform the test for determining in-place wet density in accordance with Test Method D 1556, D 2167, D 2922, or D 2937. If the soil being tested contains gravel, determine the in-place wet density of the minus No. 4 (4.75-mm) sieve size fraction of the soil in accordance with Practice D 4718.

11.3 The soil used to determine the compaction curve is the material excavated during the in-place density test. While a minimum soil sample of 7 kg of minus No. 4 (4.75-mm) sieve size material is required for this test, a sample size of at least 12 kg is recommended. The actual sample amount will depend on the percent of plus No. 4 sieve-size particles present and if the soil is very wet or dry of optimum moisture content.

11.3.1 If the in-place density is obtained using Test Method D 2922 (nuclear method), a representative sample of the soil being tested must be obtained.

11.3.2 If sufficient material is not obtained from the in-place density test excavation, obtain additional soil from around the excavation. The additional material must be representative of the soil tested for in-place density.

11.3.2.1 If the in-place density test is to represent the full depth of a compacted lift, obtain any additional material only from the compacted lift being tested.

11.3.2.2 If the excavation for the in-place density test has been contaminated with sand or has been wetted (as from the sand-cone or water replacement methods), the additional material must be obtained by excavating nonaffected soil as close as practical to the original excavation.

11.4 Pass the soil obtained from the in-place density test through a No. 4 (4.75-mm) sieve.

11.5 Thoroughly mix the material passing the No. 4 (4.75-mm) sieve to ensure an even distribution of moisture throughout the soil. The mixing should be performed as quickly as practical to prevent moisture loss.

11.6 Determine the moisture content of a representative specimen in accordance with Method D 2216.

11.7 Keep the minus No. 4 material in a moisture-proof container to prevent moisture loss.

### COMPACT SPECIMENS AND OBTAIN COMPACTION CURVE

11.8 Compact a specimen of the minus No. 4 material at field moisture content in accordance with Method A of Test Methods D 698 and calculate the wet density of the specimen.

11.8.1 The wet density for the first specimen compacted is referred to as the *first specimen wet density* or $\rho wet_{first}$.

11.9 At this point, calculate the *C* value. The *C* value is calculated before proceeding because, if it is less than the *D* value (percent compaction) required in the specifications, the in-place density has failed to meet the specifications. The *D* value obtained from the rapid method test is always equal to or less than the *C* value.

11.9.1 Calculate and record the *C* value in percent as follows:

$$C \text{ value} = \frac{\rho \text{wet}_f}{\rho \text{wet}_{\text{first}}} \times 100 \tag{1}$$

where:

$C$ value = comparison of field compactive effort to standard laboratory compactive effort, %,

$\rho \text{ wet}_f$ = wet density from the in-place density test, Mg/m$^3$ (lbm/ft$^3$), and

$\rho\text{wet}_{\text{first}}$ = first specimen wet density, Mg/m$^3$ (lbm/ft$^3$).

11.10 Prepare a second specimen for compaction with 2 % added water. This compaction specimen is referred to as the *second specimen*.

NOTE 4—This test method is written with the second specimen always having 2 % water added. When the in-place density is extremely wet of the optimum moisture content, the second specimen may be a dried-back specimen and the test completed following the principles discussed in this test method.

11.10.1 Place 2.50 kg of soil from the original sample into a mixing pan.

11.10.2 Measure exactly 50 mL of water. This amount of water will increase the moisture content of the soil approximately 2.0 %. This is referred to as *2 % added water* ( +2.0). Although any moisture increment of 1 % or more may be used, the procedure is written for an increment of 2 %.

11.10.3 Thoroughly mix the soil while sprinkling or spraying the water onto the soil to ensure an even distribution of moisture throughout the material. The mixing should be performed as quickly as possible to prevent moisture loss. Cover the mixing pan with a plastic bag, wet towels, or other cover to prevent moisture loss.

11.10.4 Compact the specimen and calculate the wet density of the specimen in accordance with Test Methods D 698.

11.10.5 Calculate and record the converted wet density (density at field moisture content) of the specimen as follows:

$$\rho wet_c = \frac{\rho wet}{1 + (z/100)} \quad (2)$$

where:

$\rho\ wet_c$ = converted wet density of compacted specimen, Mg/m$^3$ (lbm/ft$^3$),
$\rho wet$ = wet density of compacted specimen, Mg/m$^3$ (lbm/ft$^3$),
$z$ = amount of water added to soil before compacting specimen, %, and
100 = constant to convert to decimal.

11.11 Prepare a third compaction specimen. Water will be either added or subtracted.

11.11.1 Before the third specimen can be compacted, compare the wet densities of the first two compaction specimens. If the converted wet density of the second specimen is greater than or equal to the wet density of the first specimen, follow 11.11.2. If the converted wet density of the second specimen is less than the wet density of the first specimen, follow 11.11.4.

11.11.1.1 If the converted wet density of the second specimen is less than the wet density of the first specimen, and the difference is within 0.05 Mg/m$^3$ (3 lb/ft$^3$), the requirement for drying the soil (11.11.4) may be eliminated (see Annex A1). The alternate procedure is referred to as the *1 %* method.

11.11.2 Prepare a third specimen by adding water.

11.11.2.1 Place 2.50 kg of soil from the original sample into a mixing pan.

11.11.2.2 Measure 100 mL of water. This amount will increase the moisture content of the soil approximately 4 %. This is referred to as *4 % added water* ( +4.0).

11.11.2.3 Thoroughly mix the soil while sprinkling or spraying the water onto the soil. The mixing should be performed as quickly as possible to prevent moisture loss.

11.11.2.4 Compact the specimen and calculate the wet density of the specimen in accordance with Method A of Test Methods D 698.

11.11.2.5 Calculate and record the converted wet density according to 11.10.5.

11.11.2.6 If the converted wet density of the third specimen is less than or equal to that of the second specimen, proceed to 11.12. If the converted wet density of the third specimen is greater than that of the second specimen, an additional specimen must be compacted in accordance with 11.11.3.

11.11.3 Prepare additional specimen(s) by adding water.

11.11.3.1 Repeat 11.11.2.1-11.11.2.5 except *increase* the amount of added water by 2 % more than that of the previous specimen (that is, +6.0 %, +8.0 %, etc.). Before compacting material to which 6 % or more water was added, the material should be rescreened through the No. 4 (4.75-mm) sieve. Rescreening breaks down any balls of soil and assists in even moisture distribution.

11.11.3.2 Repeat 11.11.3.1 until the converted wet density of the current specimen is less than or equal to the converted wet density of the previous specimen. Proceed to 11.12.

11.11.4 Prepare a third specimen by subtracting water.

11.11.4.1 Place 2.50 kg of soil from the original sample into a mixing pan.

11.11.4.2 Dry the soil until a 50-g mass loss occurs without loss of soil. This decreases the moisture content of the soil by approximately 2 %. This is referred to as *minus* 2 % added water (−2.0). The soil must be thoroughly mixed after drying.

NOTE 5—The soil specimen may be dried fairly quickly (5 to 10 min) by using a fan, hair dryer, or other device to blow dry air across the pan of soil while slowly mixing the soil. In a humid climate, other methods to quickly dry the soil may be required. If heat is applied, the soil must cool to room temperature before compacting. Moisture loss during cooling must be considered.

11.11.4.3 Compact the specimen and calculate the wet density of the specimen in accordance with Method A of Test Methods D 698.

11.11.4.4 Calculate and record the converted wet density in accordance with to 11.10.5. When the soil is dried back, the amount of "added water," *z*, used to calculate the converted wet density, is a negative number (that is, $z = -2.0$ %).

11.11.4.5 If the converted wet density of the third specimen is less than or equal to the wet density of the first specimen, proceed to 11.12. If the converted wet density of the third specimen is greater than the wet density of the first specimen, an additional specimen must be compacted in accordance with 11.11.5.

11.11.5 Prepare additional specimen(s) by subtracting water.

11.11.5.1 Repeat 11.11.4.1-11.11.4.4 except decrease the amount of "added water" by 2 % more than that of the previous specimen (that is, − 4.0 %). Before compacting material from which 4 % or more water was subtracted, the material should be thoroughly mixed and rescreened through the No. 4 (4.75-mm) sieve, if necessary, to break down any balls of soil and to assist in even moisture distribution.

11.11.5.2 Repeat 11.11.5.1 until the converted wet density of the current specimen is less than or equal to the converted wet density of the previous specimen. Proceed to 11.12.

## DETERMINE MAXIMUM POINT FROM COMPACTION CURVE, *D* VALUE, AND $w_f - w_o$

11.12 Label the points from the three compaction specimens Point *A*, *B*, and *C*, in order, starting with the specimen with the least amount of "added water" (driest). If more than three specimens were compacted, select the specimen with the highest converted wet density and label as Point *B*; select the specimen which has 2 % less" added water" than Point *B*, and label as Point *A*; select the specimen which has 2 % more "added water" than Point *B*, and label as Point *C*. See Fig. 1.

NOTE 6—For simplicity, all the compaction specimens will be referred to as converted (converted to density at field moisture content) even though the first compaction specimen was compacted at field moisture content and therefore was not converted.

NOTE 7—In those few cases where the density of Point *A* and the density of Point *B* are equal, then the points must be labeled *A*, *C*, *B*, rather than *A*, *B*, *C*. Note 8 will not be valid for this case.

11.13 Assign the following notation to the values from the three compaction points:

$$x_A = \text{added water at Point } A, \% \tag{3}$$

$$x_B = \text{added water at Point } B, \%$$

$$x_C = \text{added water at Point } C, \%$$

These values may be negative or positive numbers or zero, for example, −2.0, +2.0, 0.0.

$$y_A = \text{converted density of Point } A, \text{Mg/m}^3 \text{ (lbm/ft}^3\text{)} \tag{4}$$

$$y_B = \text{converted density of Point } B, \text{Mg/m}^3 \text{ (lbm/ft}^3\text{)}$$

$$y_C = \text{converted density of Point } C, \text{Mg/m}^3 \text{ (lbm/ft}^3\text{)}$$

11.14 Calculate the value $x_1$ as follows:

$$x_1 = x_B - x_A \tag{5}$$

11.15 Calculate the value $x_2$ as follows:

$$x_2 = x_C - x_A \tag{6}$$

NOTE 8—If 2 % increments are used, $x_1$ always equals 2.0 and $x_2$ equals 4.0.

11.16 Calculate the value $y_1$ as follows:

$$y_1 = y_B - y_A \tag{7}$$

11.17 Calculate the value $y_2$ as follows:

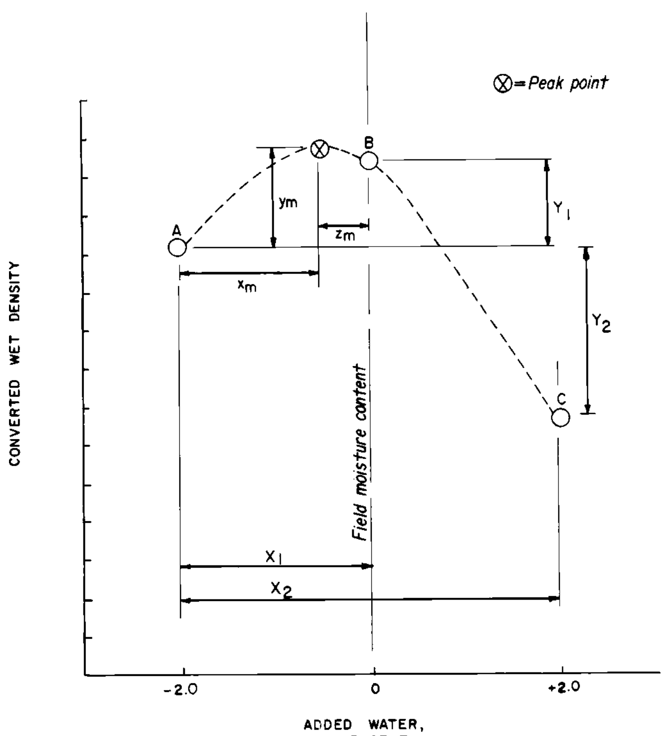


FIG. 1 Determining Peak Point of Compaction Curve

$$y_2 = y_C - y_A \tag{8}$$

11.18 Calculate the value $x_m$ as follows:

$$x_m = \frac{1}{2}\left[ x_1 + \frac{(x_2 - x_1)\left(\frac{y_1}{x_1}\right)}{\left(\frac{y_1}{x_1}\right) - \left(\frac{y_2}{x_2}\right)} \right] \tag{9}$$

11.19 Calculate the value $z_m$ as follows:

$$z_m = x_A + x_m \tag{10}$$

11.20 Calculate the value $y_m$ as follows:

$$y_m = \frac{-(x_m{}^2 y_1)}{x_1(x_1 - 2x_m)} \tag{11}$$

11.21 Calculate the maximum wet density at field moisture content as follows:

$$\rho_m = y_A + y_m \tag{12}$$

where:
$\rho_m$ = maximum wet density at field moisture content, Mg/m$^3$ (lbm/ft$^3$).
=

11.22 Calculate the value $w_f - w_o$ as follows:

$$w_f - w_o = -(z_m + MA) \tag{13}$$

where:
$w_f - w_o$ = difference in moisture content between the field and optimum moisture, %, and
*MA* = moisture adjustment, %.

Obtain *MA* from Fig. 2 by plotting $\rho_m$ and $z_m$ and selecting the curved line closest to the plotted point. The number corresponding to this line is *MA*, for example, −0.2.

NOTE 9—A negative value of $w_f - w_o$ indicates the in-place soil is drier than the optimum moisture content, a positive value indicates the in-place soil is wetter than the optimum moisture content.

NOTE 10—The moisture adjustment is necessary because when water is added to the soil before compacting the specimen, the percentage of "added water" is calculated based on the mass of *wet* soil rather than the mass of the *dry* soil (the actual moisture content is not known at this time). So 2 % "added water" is only an approximation and an adjustment must be made to $z_m$ to get the value $w_f - w_o$. The values for this adjustment have been calculated and then plotted on Fig. 2 (see 6.1).

11.23 Calculate and record the *D* value in percent as follows:

$$D \text{ value} = \frac{\rho wet_f}{\rho_m} \times 100 \tag{14}$$

where:
*D* value = rapid method equivalent of percent compaction; comparison of in-place density to laboratory maximum density, %,
$\rho wet_f$ = field wet density, Mg/m$^3$ (lbm/ft$^3$) (from 11.2 through 11.7),
$\rho_m$ = maximum wet density at field moisture content, Mg/m$^3$ (lbm/ft$^3$) (from 11.12 through 11.23), and
100 = constant to convert to percent.

## COMPLETE TEST FOR RECORD

11.24 The following calculations are made after the field moisture content has been determined.

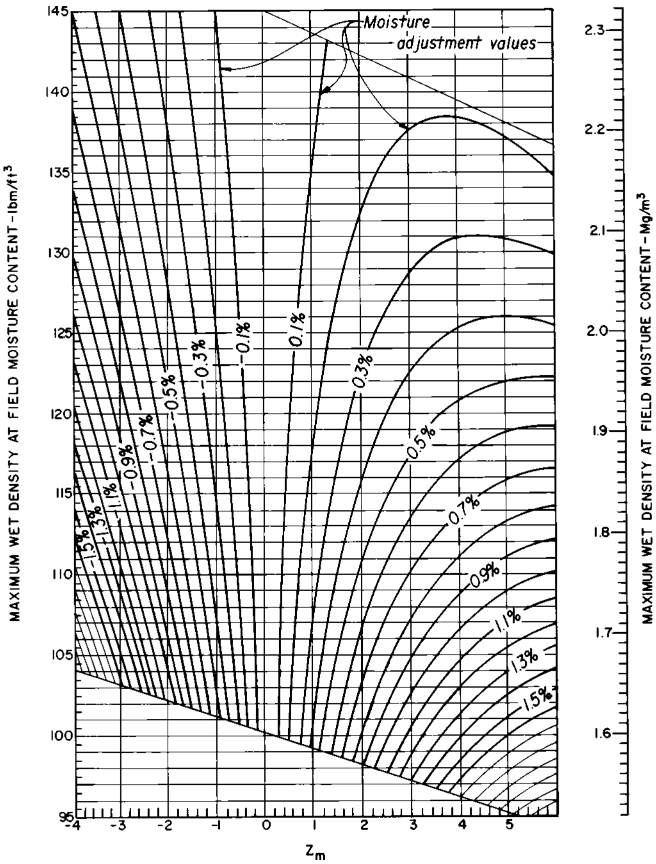


**FIG. 2 Moisture Adjustment Values**

11.24.1 Calculate the dry density for the in-place density test, laboratory maximum density, and first compaction specimen as follows:

$$\rho d = \frac{\rho \text{wet}}{1 + (w_f/100)} \quad (15)$$

where:
$\rho d$ = dry density, Mg/m$^3$ (lbm/ft$^3$),
$\rho$wet = wet density, Mg/m$^3$ (lbm/ft$^3$), and
$w_f$ = field moisture content, %.

NOTE 11—*D* and *C* values on the basis of dry density after determining the field moisture content may differ (±0.1 percentage point) from the *D* and *C* values reported on a wet basis on the day of the test. This difference is due to the way the numbers are rounded. The *D* and *C* values reported on the day of the test are the basis for acceptance or rejection even though values on computer-generated reports may be slightly different.

11.24.2 Calculate the dry unit weight for the in-place density test, laboratory maximum unit weight, and first compaction specimen as follows:

$$\gamma d = 9.807 \times \rho d \quad (16)$$

where:
$\gamma d$ = dry unit weight, kN/m$^3$,
$\rho d$ = dry density, Mg/m$^3$, and
9.807 = conversion factor, Mg/m$^3$ to kN/m$^3$.

11.24.3 Calculate the optimum moisture content as follows:

$$w_o = w_f + [(1 + w_f/100) \times (z_m)] \quad (17)$$

where:
$w_o$ = optimum moisture content, %,
$w_f$ = field moisture content, %, and
$z_m$ = from 11.19, %.

## 12. Report

12.1 Report the following information:
12.1.1 Test location, elevation, and identifying number,
12.1.2 Method of determining in-place density,
12.1.3 Test hole volume,
12.1.4 In-place wet density, total or minus No. 4 fraction, or both,
12.1.5 In-place dry density, total or minus No. 4 fraction, or both,
12.1.6 In-place dry unit weight, total or minus No. 4 fraction, or both,
12.1.7 In-place moisture content(s), total or minus No. 4 fraction, or both, and test method(s) used,
12.1.8 Maximum dry density and dry unit weight, and optimum moisture content,
12.1.9 *D* value, *C* value, and $w_f - w_o$,
12.1.10 Test apparatus description,
12.1.11 Comments on test, as applicable, and
12.1.12 Visual description of the material.

## 13. Precision and Bias

13.1 *Precision*—Test data on precision is not presented due to the nature of the soil and rock materials tested by this test method. It is not feasible and too costly at this time to have ten or more agencies participate in an in situ testing program at a given site. Also, it is not feasible to produce multiple test locations having uniform properties. Any variation observed in the data is just as likely to be due to specimen variation as operator laboratory testing variation.

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

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

## 14. Keywords

14.1 compaction control; density; field density; field test; moisture content; moisture control; moisture-density; rapid compaction control; unit weight

# ANNEX

**(Mandatory Information)**

## A1. "ONE PERCENT" METHOD TO DETERMINE PEAK POINT OF COMPACTION CURVE

### A1.1 Scope

A1.1.1 This annex outlines an alternate procedure for preparing the third compaction specimen and determining the maximum point of the compaction curve at field moisture content.

A1.1.2 This procedure eliminates the requirement for drying soils when the field moisture content is near optimum moisture content.

A1.1.3 This procedure can only be used when the second compaction specimen has a converted wet density lower than the wet density of the first compaction specimen and the difference is 0.05 Mg/m$^3$ or less.

NOTE A1.1—This method assumes that the two wet densities plot near the peak point of the parabola.

### A1.2 Procedure—Obtain Compaction Curve

A1.2.1 Prepare the third specimen by adding 1 % water as follows:

A1.2.1.1 Place 2.50 kg of soil from the original sample (see 11.5) into a mixing pan.

A1.2.1.2 Measure 25 mL of water. This amount of water will increase the moisture content of the soil by approximately 1 %. This is referred to as "1 % added water," ( +1.0).

A1.2.1.3 Thoroughly mix the soil while sprinkling or spraying the water onto the soil. The mixing should be performed as quickly as possible to prevent moisture loss.

A1.2.1.4 Compact the specimen, and calculate the wet density of the specimen in accordance with Method A of Test Methods D 698.

A1.2.1.5 Calculate and record the converted wet density in accordance with 11.10.5.

### A1.3 Determine Maximum Point from Compaction Curve and $w_f - w_o$

A1.3.1 Label the values from the three compaction specimens as A, B, and C, in order of increasing moisture content, starting with the specimen compacted at field moisture content. Follow the directions in 11.13 through 11.22 to calculate the maximum density of the compaction curve and $w_f - w_o$.

# APPENDIXES

**(Nonmandatory Information)**

## X1. RATIONALE

### X1.1 History of Standard

X1.1.1 The rapid method has been used by the Bureau of Reclamation since the mid 1950's. Since that time, it has also been used by several other organizations. It was first proposed as an ASTM standard in 1970.[4]

X1.1.2 The theory and development of the rapid method is presented in Engineering Monograph No. 26.[5]

[4] *Special Procedures for Testing Soil and Rock for Engineering Purposes, STP 479*, ASTM, 1970.

[5] Available from the Bureau of Reclamation, P.O. Box 25007, Denver, CO 80225.

### X1.2 Applicability

X1.2.1 Use of this test method for construction control should be agreed upon by all parties involved since the results may not exactly duplicate the results if the compaction curve were obtained in accordance with Test Methods D 698. The use of three compaction points, mathematically determining the peak of the compaction curve, and the lack of standing time for the prepared specimens may affect the value obtained for the maximum density. However, the results are similar enough that expediency can justify the use of this test method as an acceptable construction control technique.

## X2. APPLICABILITY OF MOISTURE ADJUSTMENT VALUES

X2.1 During the procedure, water is added to wet soil. The percentage of water added is based on the wet mass of the soil since the actual moisture content is not known. An adjustment can be made to obtain a more accurate approximation of the $w_f - w_o$ value by using Fig. 2 as discussed in 11.22.

X2.2 The moisture adjustment values are based on a best fit curve of over 1300 points of wet density at optimum moisture content versus optimum moisture content as shown on Fig. X2.1.[6]

[6] Hilf, Jack W., "A Rapid Method of Construction Control for Embankments of Cohesive Soil," *Engineering Monograph No. 26*, Bureau of Reclamation, 5th Printing, August 1981.

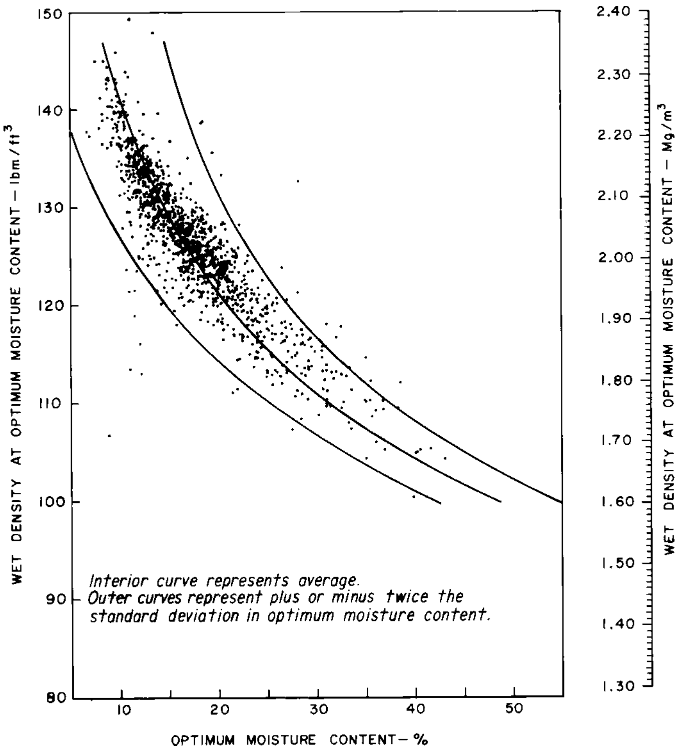


**FIG. X2.1 Wet Density Versus Optimum Moisture Content**

X2.3 The properties of the soil being tested should be checked with Fig. X2.1 to see if the soil values plot within the limits of ±2 standard deviations. For data within these limits, the value of $w_f - w_o$ determined by the rapid method will be within ±0.1 to 0.2 percentage point of the difference between the in-place moisture content and the optimum moisture content when these two values are determined by ovendrying.

X2.4 If the soils fall outside the acceptable limits, special moisture adjustment values must be developed for that soil. Instructions can be found in Appendix B of Engineering Monograph No. 26.[5]

X2.5 The data used to develop Fig. X2.1 and Fig. 2 came from the Bureau of Reclamation compaction test which uses a $\frac{1}{20}$-ft$^3$ mold, 3 layers, 25 blows per layer of a 5.5-lbm rammer dropped 18 in. Only minus No. 4 soil particles are compacted. The compactive effort is 12 375 ft-lb/ft$^3$ which is comparable to Method A of Test Methods D 698. Moisture adjustment values will probably have to be separately developed for soils with very low or high specific gravities or compacted with a different compactive effort.

## SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (1993) that may impact the use of this standard.

(1) Section 2—Added Practice D 3740 to list of Referenced Documents.
(2) Section 5—Added new note on the use of Practice D 3740.
(3) Revised the numbering of existing notes.
(4) Section 13—Revised Precision and Bias statement to conform to D18 policy.
(5) Added Summary of Changes.