STANDARD OPERATING PROCEDURE NO. 40

GRAVIMETRIC MOISTURE CONTENT

REVISION LOG				
Revision Number	Description	Date		
40.0	Original SOP	10/23/03		
40.1	Incorporated comments from Sigda	11/6/03		
40.2	Revisions to sample collection by Sigda	2/17/04		
40.3	Revisions by PJP	5/19/2004		
40.4	Revised by KMD as per comments from GMLR	10/25/2004		
40.5	Revised by LFG	10/25/2004		
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40v9	Checked for audit KMD	2/14/2007		
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40v10	Editorial by SKA	10/24/08		

1.0 PURPOSE AND SCOPE

This Standard Operating Procedure describes the method for determining gravimetric moisture content. Gravimetric moisture content is used to estimate the moisture content of the material at a specific time [Gardner, 1986; Jury et al., 1991; Hillel, 1998]. Moisture content is the ratio of the weight of the water contained in a soil sample to the weight of the solid fraction of the soil sample. If the material's bulk density is known, then the gravimetric water content can be converted to volumetric moisture content. If the energy state (matric suction) is measured, then the material's in-situ matric potential relationship, also called the soil-water characteristic curve (SWCC) or moisture retention curve, can be determined. Observations of in situ matric potential and moisture content values are critical to modeling the seepage and stability of the rock piles (Fredlund, D. G., 2002; Fredlund, D. G. et al., 1994; Fredlund, M. D. et al., 1996, 1997).

2.0 RESPONSIBILITIES AND QUALIFICATIONS

The Characterization Team Leader will have the overall responsibility for implementing this SOP. He/she will be responsible for assigning appropriate staff to implement this SOP and for ensuring that the procedures are followed accurately.

All personnel performing these procedures are required to have the appropriate health and safety training. In addition, all personnel are required to have a complete understanding of the procedures described within this SOP, and to receive specific training regarding these procedures, if necessary.

All environmental staff and assay laboratory staff are responsible for reporting deviations from this SOP to the Team Leader.

3.0 DATA QUALITY OBJECTIVES

This SOP addresses objectives 1 and 7 in the data quality objectives outlined by Virginia McLemore for the "Geological and Hydrological Characterization at the Molycorp Questa Mine, Taos County, New Mexico".

- Determine how the hydrogeochemistry and water balance dynamics influence rock pile weathering and stability.
- Determine if pyrite oxidation, moisture content, and microbe populations affect rock pile weathering and stability.

4.0 RELATED STANDARD OPERATING PROCEDURES

The procedures set forth in this SOP are intended for use with the following SOPs:

- SOP 1 Data management (including verification and validation)
- SOP 2 Sample management (including chain of custody)
- SOP 3 Surveying GPS
- SOP 4 Taking digital photographs
- SOP 5 Sampling outcrops, rock piles, and drill core (solid)
- SOP 6 Drilling, logging, and sampling of subsurface materials (solid)
- SOP 7 Decontamination of sampling equipment
- SOP 33 Particle size analysis
- SOP 35 Volumetric moisture content
- SOP 36 Sample preservation, storage, custody and shipping

The procedures set forth in this SOP are also intended for use with the drill plans and sampling plans. This SOP embodies the information contained in ASTM Standards, designation D-2216 (Appendix 2) and D-4718 (Appendix 3).

5.0 EQUIPMENT LIST

5.1 Field Sample Collection:

- Moisture content jars with lids
- Scoops
- Packing tape
- Ziploc bags
- GPS set to correct coordinate system
- Rock hammer or scoop to collect samples

- Boxes or coolers to store moisture content jars
- Thermometer
- Indelible marker and waterproof labels
- gravimetric moisture content sample field forms (Appendix 1)

5.2 <u>Laboratory Testing</u>:

- Scale
- Clean, dry specimen containers
- Weights to calibrate scale
- Oven
- Standard sieves No. 3/4 and No. 4.
- Gravimetric moisture content forms (Appendix 1)
- Weighing tares

6.0 COLLECTION OF SAMPLES

Samples from drill holes, test pits, and trenches should be collected and sealed immediately to minimize exposure to the atmosphere and to avoid drying. Exposure of samples to ambient surface conditions of longer than a few minutes can cause significant changes in moisture content through evaporation, precipitation, spills, etc. The rate of change in moisture content is a function of the differences in temperature and relative humidity between the sample's original environment and the surface environment.

The sample mass collected should be proportional to the range of grain and clast sizes contained in the material of interest. The minimum mass of moist material selected should be representative of the total sample and shall be in accordance with Table 1. Larger sample masses are required for representative samples of stony or rocky soils compared to sandy or silty sediments or soils. However, collecting smaller masses of finer-grained material from stony or rocky soils does not necessarily cause a bias in a particular study because variably, saturated flow will generally be confined to the finer-grained fraction, not the cobbles or larger clast sizes. The shaded values in the following table should be preferentially collected when working with coarse rock pile material.

Table 1. The minimum sample mass that should be collected according to the maximum particle size contained in a sample.

Maximum particle	Standard sieve	Minimum mass
size (100% passing)	size	(g)
2 mm or less	No. 10	20
4.75 mm	No. 4	20
9.5 mm	3/8 in	50
19 mm	³ / ₄ in	250
37.5 mm	1 ½ in	1,000
75 mm	3 in	5,000

If the material contains cobbles, gravel, or both, test options may be used which result in discarding particles retained on a specific sieve (for example the No. 4 (4.75-mm) or the

3/4-in. (19-mm), and the test is performed on the finer fraction. In this case, the water content relations determined by the tests reflect the characteristics of the actual material tested, and not the characteristics of the total soil material from which the test specimen was obtained. Thus, when the minimum mass of material for testing cannot be sampled, an alternative testing procedure must be followed so that the water content can be adjusted to the total sample particle size.

Photographs of the rockpile material and the collecting sites should be taken before the sample is collected for moisture content testing, if possible.

Samples are collected, labeled, preserved, and transported according to SOPs 1, 2 and 36.

7.0 PROCEDURES

- 1. If possible, photograph the core, pit, or trench with a scale bar before collecting the sample.
- 2. Take a GPS reading.
- 3. Collect a sample of rock pile material and place it in a moisture content jar and seal the jar.
- 4. Label the moisture content jar with a weatherproof label and an indelible marker and seal it with packing tape.
- 5. Seal the moisture content jar in a small Ziploc bag and label the bag with indelible marker. Seal the bag in another Ziploc.
- 6. Complete sample form (Appendix 1). Keep samples cool in an ice chest if necessary. Transport samples to the laboratory (SOP 36 Shipping).
- 7. Log samples into laboratory following chain of custody procedures (SOP 2).
- 8. Calibrate scales using standard weights. The calibration weights should be appropriate for the mass of the samples collected.
- 9. Measurement precision should be selected as a function of the sample mass to be measured (see Table 1). For sample masses less than 500 g, the weight precision should be within 0.01 g. Precisions for larger sample masses should be scaled up similarly: e.g., sample masses between 0.5 and 2 kg should have measurement precision in the order of 0.1 g.
- 10. Perform the test according to one of the following two procedures:

1) When using the entire sample:

- Determine and record the mass of the clean and dry specimen container, without the lid (if used), to within the appropriate precision.
- To prevent mixing of specimens and the yielding of incorrect results, all containers and lids must be numbered and the container numbers recorded on the laboratory data sheets.
- Place the container (without the lid, if used) containing the moist material in the drying oven. Dry the material to a constant mass keeping the drying oven at 110±5°C. In most cases, drying a test specimen overnight (about 12 to 16 hours) is sufficient.

- After the material has dried to a constant mass, remove the container from the oven. Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands. Determine the mass of the container and oven-dried material using the same type/capacity balance that was used above for weighing the moist sample. Record this value on the test sample form (Appendix 1).
- Calculate the gravimetric water content as follows:

$$w = [(M_{cws} - M_{cs}) / (M_{cs} - M_c)]$$
 (1)

where:

w = gravimetric water content in %

Mcws = mass of container and wet specimen in grams

Mcs = mass of container and oven dry specimen in grams

Mc =mass of container in grams

2) For samples that require the removal of coarse particles:

- Pass sample through the ¾ inch sieve and separate the passing and retained fractions. If 100% of the material passes through the ¾ inch sieve, sieve it again through sieve No. 4 (4.75 mm) and separate those passing and remaining fractions.
- Determine the mass of the moist, fine fraction of the sample and the mass of the moist oversize fraction (retained on No. 4 or 3/4 inch sieves) of the total sample.
- Determine the water content of the fine and coarse fractions in accordance with the procedures listed in section 7.0, step 10.
- Take the percentage of each fraction from the grain size curve of the material obtained through its particle size analysis (see SOP 33 Particle Size Analysis).
- Calculate the corrected water content of the total material (combined finer and oversize fractions), as follows:

$$Cw = (w_F P_F + w_C P_C) \tag{2}$$

where:

Cw = corrected gravimetric water content of combined and oversize fractions

 w_F = water content of finer fraction expressed as a decimal

 w_C = water content of oversize fraction expressed as a decimal

 P_F = percent of finer fraction by weight

 P_C = percent of oversize fraction by weight

11. Record the data using the gravimetric moisture content sub-form (see Appendix 1) and distribute the results to the team leader and hydrology PI for inclusion in the database.

8.0 QUALITY ASSURANCE/QUALITY CONTROL

Verify the accuracy of the thermometer. Laboratory scales should be calibrated using standard weights prior to measuring. Oven temperature should be checked and maintained to within 5 degrees C.

9.0 DOCUMENTATION

Record field numbers according to SOP 2, date collected, time collected, hole or test pit number, depth of sample, sample temperature, air temperature, and initials of person collecting the sample on the field sample form (Appendix 1).

10.0 REFERENCES

ASTM D-2216, 1988, "Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass", ASTM International. 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.

ASTM D-4718, 1987, "Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles", ASTM International. 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.

Fredlund, D. G., 2002, Use of soil-water characteristic curves in the implementation of unsaturated soil mechanics: Keynote address presented at the 3rd International Conference on unsaturated soils, Recife, Pernambuco, Brazil, March 10-13.

Fredlund, D. G., Xing, A., and Huang, S., 1994, Predicting the permeability function for unsaturated soils using the soil-water characteristic curve: Canadian Geotechnical Journal, v. 31, p. 533-546.

Fredlund, M. D., Sillers, W. S., Fredlund, D. G., and Wilson, G. W., 1996, Design of a knowledge based system for unsaturated soil properties: 3rd Canadian Conference on Computing in Civil and Building Engineering, 19 p.

Fredlund, M. D., Wilson, G. W., and Fredlund, D. G., 1997, Indirect procedures to determine unsaturated soil property functions: Proceedings of the 50th Canadian Geotechnical Conference, Ottawa, Ontario, 9 p.

Gardner, W.H., 1986, Water Content, in *Methods of Soil Analysis Part 1. Physical and Mineralogical Methods*, Agronomy Monograph No. 9, Soil Science Society of America, Madison, WI, USA, p. 493-544.

Hillel, D., 1998, Environmental Soil Physics, Academic Press, New York, p.129-142.

Jury, W.A., Gardner, W.R., and Gardner, W.H., 1991, *Soil Physics*, John Wiley and Sons, New York, p.45-47.

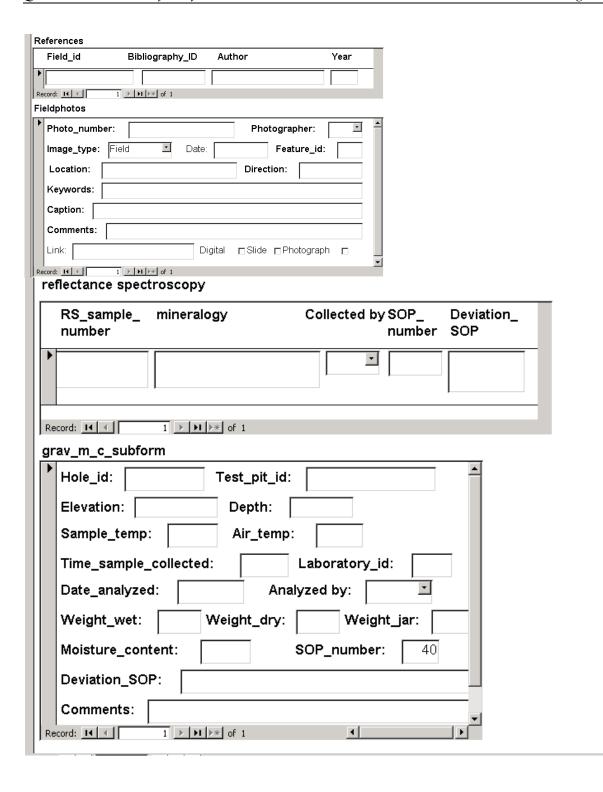
APPENDIX 1. SAMPLE COLLECTION AND TESTING FORMS

APPENDIX 2. ASTM D-2216 - Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

APPENDIX 3. ASTM D-4718 - Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles

APPENDIX 1. SAMPLE COLLECTION AND TESTING FORMS

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FIELD SAMPLE FORM					
Field_id: Feature_id:					
Collected by: Media:					
Date_collected: Elevation: Depth:					
UTM_easting: Method_of_obtaining_elevation:					
UTM_northing: Location_assurrance:					
UTM_zone: Waypoint: Point_of_location:					
Method_of_sample_collection:					
Type_of_sample: Sample_descrition:					
Reason_for_sampling:					
Sample_location:					
Location_description _of_sample:					
Location comments:					
SOP_number: Deviation_SOP:					
HANDSPECIMEN DESCRIPTION					
field_description:					
color: Sorting:					
grain_size: Hardness:					
alteration: Structure:					
Grain_angularity: Plasticity:					
general_appearance:					
Cementation: Cement_minerals:					
handspecimen.comments:					
special_features:					
mineralogy:					
lithology: symbol: water content:					



APPENDIX 2. ASTM D-2216



AMERICAN SOCIETY FOR TESTING AND MATERIALS 100 Barr Harbor Dr., West Conshohocken, PA 19428 Reprinted from the Annual Book of ASTM Standards, Copyright ASTM

Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass¹

This standard is issued under the fixed designation D 2216; 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 the laboratory determination of the water (moisture) content by mass of soil, rock, and similar materials where the reduction in mass by drying is due to loss of water except as noted in 1.4, 1.5, and 1.7. For simplicity, the word "material" hereinafter also refers to either soil or rock, whichever is most applicable.
- 1.2 Some disciplines, such as soil science, need to determine water content on the basis of volume. Such determinations are beyond the scope of this test method.
 - 1.3 The water content of a material is defined in 3.2.1.
- 1.4 The term "solid material" as used in geotechnical engineering is typically assumed to mean naturally occurring mineral particles of soil and rock that are not readily soluble in water. Therefore, the water content of materials containing extraneous matter (such as cement, and the like) may require special treatment or a qualified definition of water content. In addition, some organic materials may be decomposed by oven drying at the standard drying temperature for this method (110°C). Materials containing gypsum (calcium sulfate dihydrate or other compounds having significant amounts of hydrated water) may present a special problem as this material slowly dehydrates at the standard drying temperature (110°C) and at very low relative humidities, forming a compound (calcium sulfate hemihydrate) which is not normally present in natural materials except in some desert soils. In order to reduce the degree of dehydration of gypsum in those materials containing gypsum, or to reduce decomposition in highly organic soils, it may be desirable to dry these materials at 60°C or in a desiccator at room temperature. Thus, when a drying temperature is used which is different from the standard drying temperature as defined by this test method, the resulting water content may be different from standard water content determined at the standard drying temperature.

 $N\mbox{\scriptsize OTE}$ 1—Test Methods D 2974 provides an alternate procedure for determining water content of peat materials.

1.5 Materials containing water with substantial amounts of soluble solids (such as salt in the case of marine sediments)

when tested by this method will give a mass of solids which includes the previously soluble solids. These materials require special treatment to remove or account for the presence of precipitated solids in the dry mass of the specimen, or a qualified definition of water content must be used. For example, see Noorany² regarding information on marine soils.

- 1.6 This test method requires several hours for proper drying of the water content specimen. Test Method D 4643 provides for drying of the test specimen in a microwave oven which is a shorter process. Also see Gilbert³ for details on the background of this test method.
- 1.7 This standard requires the drying of material in an oven at high temperatures. If the material being dried is contaminated with certain chemicals, health and safety hazards can exist. Therefore, this standard should not be used in determining the water content of contaminated soils unless adequate health and safety precautions are taken.
- 1.8 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 Fluids⁴
- D 2974 Test Methods for Moisture, Ash, and Organic Matter of Peat and Other Organic Soils⁴
- D 4220 Practice for Preserving and Transporting Soil Samples⁴
- D 4318 Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils⁴
- D 4643 Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method⁴
- D 4753 Specification for Evaluating, Selecting, and Specifying Balances and Scales for Use in Soil and Rock Testing⁴

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¹ This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity and Density Characteristics of Soils

Plasticity and Density Characteristics of Soils.

Current edition approved Feb. 10, 1998. Published January 1999. Originally published as D 2216 – 63 T. Last previous edition D 2216 – 92.

² Noorany, I., "Phase Relations in Marine Soils", Journal of Geotechnical Engineering, ASCE, Vol. 110, No. 4, April 1984, pp. 539–543.

³ Gilbert, P.A., "Computer Controlled Microwave Oven System for Rapid Water Content Determination", Tech. Report GL-88-21, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, November 1988. ⁴ Annual Book of ASTM Standards, Vol 04.08.

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



- D 6026 Guide for Using Significant Digits in Calculating and Reporting Geotechnical Test Data⁵
- E 145 Specification for Gravity-Convection And Forced-Ventilation Ovens⁶

3. Terminology

- $3.1\,$ Refer to Terminology D 653 for standard definitions of terms.
 - 3.2 Definitions of Terms Specific to This Standard:
- 3.2.1 water content (of a material)—the ratio expressed as a percent of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material. A standard temperature of $110^{\circ} \pm 5^{\circ}\mathrm{C}$ is used to determine these masses.

4. Summary of Test Method

4.1~A test specimen is dried in an oven at a temperature of $110^{\circ} \pm 5^{\circ}\mathrm{C}$ to a constant mass. The loss of mass due to drying is considered to be water. The water content is calculated using the mass of water and the mass of the dry specimen.

5. Significance and Use

- 5.1 For many materials, the water content is one of the most significant index properties used in establishing a correlation between soil behavior and its index properties.
- 5.2 The water content of a material is used in expressing the phase relationships of air, water, and solids in a given volume of material.
- 5.3 In fine-grained (cohesive) soils, the consistency of a given soil type depends on its water content. The water content of a soil, along with its liquid and plastic limits as determined by Test Method D 4318, is used to express its relative consistency or liquidity index.

6. Apparatus

- 6.1 *Drying Oven*, thermostatically-controlled, preferably of the forced-draft type, meeting the requirements of Specification E 145 and capable of maintaining a uniform temperature of 110 \pm 5°C throughout the drying chamber.
- 6.2 Balances—All balances must meet the requirements of Specification D 4753 and this section. A Class GP1 balance of 0.01g readability is required for specimens having a mass of up to 200 g (excluding mass of specimen container) and a Class GP2 balance of 0.1g readability is required for specimens having a mass over 200 g. However, the balance used may be controlled by the number of significant digits needed (see 8.2.1 and 12.1.2).
- 6.3 Specimen Containers—Suitable containers made of material resistant to corrosion and change in mass upon repeated heating, cooling, exposure to materials of varying pH, and cleaning. Unless a dessicator is used, containers with close-fitting lids shall be used for testing specimens having a mass of less than about 200 g; while for specimens having a mass of sgreater than about 200 g, containers without lids may be used (see Note 7). One container is needed for each water content determination.
 - ⁵ Annual Book of ASTM Standards, Vol 04.09.
 - ⁶ Annual Book of ASTM Standards, Vol 14.02.

- Note 2—The purpose of close-fitting lids is to prevent loss of moisture from specimens before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination.
- 6.4 *Desiccator*—A desiccator cabinet or large desiccator jar of suitable size containing silica gel or anhydrous calcium sulfate. It is preferable to use a desiccant which changes color to indicate it needs reconstitution. See 10.5.
- Note 3—Anhydrous calcium sulfate is sold under the trade name Drierite.
- 6.5 Container Handling Apparatus, gloves, tongs, or suitable holder for moving and handling hot containers after drying.
- 6.6 Miscellaneous, knives, spatulas, scoops, quartering cloth, sample splitters, etc, as required.

7. Samples

- 7.1 Samples shall be preserved and transported in accordance with Practice 4220 Groups B, C, or D soils. Keep the samples that are stored prior to testing in noncorrodible airtight containers at a temperature between approximately 3 and $30^{\circ}\mathrm{C}$ and in an area that prevents direct contact with sunlight. Disturbed samples in jars or other containers shall be stored in such a way as to prevent or minimize moisture condensation on the insides of the containers.
- 7.2 The water content determination should be done as soon as practicable after sampling, especially if potentially corrodible containers (such as thin-walled steel tubes, paint cans, etc.) or plastic sample bags are used.

8. Test Specimen

- 8.1 For water contents being determined in conjunction with another ASTM method, the specimen mass requirement stated in that method shall be used if one is provided. If no minimum specimen mass is provided in that method then the values given below shall apply. See Howard⁷ for background data for the values listed.
- 8.2 The minimum mass of moist material selected to be representative of the total sample shall be in accordance with the following:

Maximum particle size (100 % passing)	Standard Sieve Size	Recommended minimum mass of moist test spec- imen for water content reported to ±0.1 %	Recommended minimum mass of moist test specimen for water content reported to ±1 %
2 mm or less	No. 10	20 g	20 g [△]
4.75 mm	No. 4	100 g	20 g [∧]
9.5 mm	%⊢in.	500 g	50 g
19.0 mm	¾-in.	2.5 kg	250 g
37.5 mm	11∕2 in.	10 kg	1 kg
75.0 mm	3-in.	50 kg	5 kg

ATo be representative not less than 20 g shall be used.

8.2.1 The minimum mass used may have to be increased to obtain the needed significant digits for the mass of water when reporting water contents to the nearest 0.1 % or as indicated in 12.1.2.

⁷ Howard, A. K., "Minimum Test Specimen Mass for Moisture Content Determination", Geotechnical Testing Journal, A.S.T.M., Vol. 12, No. 1, March 1989, pp. 39-44

- 8.3 Using a test specimen smaller than the minimum indicated in 8.2 requires discretion, though it may be adequate for the purposes of the test. Any specimen used not meeting these requirements shall be noted on the test data forms or test data sheets.
- 8.4 When working with a small (less than 200g) specimen containing a relatively large gravel particle, it is appropriate not to include this particle in the test specimen. However, any discarded material shall be described and noted on the test data forms or test data sheets.
- 8.5 For those samples consisting entirely of intact rock, the minimum specimen mass shall be 500 g. Representative portions of the sample may be broken into smaller particles, depending on the sample's size, the container and balance being used and to facilitate drying to constant mass, see 10.4. Specimen sizes as small as 200 g may be tested if water contents of only two significant digits are acceptable.

9. Test Specimen Selection

- 9.1 When the test specimen is a portion of a larger amount of material, the specimen must be selected to be representative of the water condition of the entire amount of material. The manner in which the test specimen is selected depends on the purpose and application of the test, type of material being tested, the water condition, and the type of sample (from another test, bag, block, and the likes.)
- 9.2 For disturbed samples such as trimmings, bag samples, and the like, obtain the test specimen by one of the following methods (listed in order of preference):
- 9.2.1 If the material is such that it can be manipulated and handled without significant moisture loss and segregation, the material should be mixed thoroughly and then select a representative portion using a scoop of a size that no more than a few scoopfuls are required to obtain the proper size of specimen defined in 8.2.
- 9.2.2 If the material is such that it cannot be thoroughly mixed or mixed and sampled by a scoop, form a stockpile of the material, mixing as much as possible. Take at least five portions of material at random locations using a sampling tube, shovel, scoop, trowel, or similar device appropriate to the maximum particle size present in the material. Combine all the portions for the test specimen.
- 9.2.3 If the material or conditions are such that a stockpile cannot be formed, take as many portions of the material as practical, using random locations that will best represent the moisture condition. Combine all the portions for the test specimen.
- 9.3 Intact samples such as block, tube, split barrel, and the like, obtain the test specimen by one of the following methods depending on the purpose and potential use of the sample.
- 9.3.1 Using a knife, wire saw, or other sharp cutting device, trim the outside portion of the sample a sufficient distance to see if the material is layered and to remove material that appears more dry or more wet than the main portion of the sample. If the existence of layering is questionable, slice the sample in half. If the material is layered, see 9.3.3.
- 9.3.2 If the material is not layered, obtain the specimen meeting the mass requirements in 8.2 by. (1) taking all or one-half of the interval being tested; (2) trimming a represen-

tative slice from the interval being tested; or (3) trimming the exposed surface of one-half or from the interval being tested.

Note 4—Migration of moisture in some cohesionless soils may require that the full section be sampled.

9.3.3 If a layered material (or more than one material type is encountered), select an average specimen, or individual specimens, or both. Specimens must be properly identified as to location, or what they represent, and appropriate remarks entered on the test data forms or test data sheets.

10. Procedure

- 10.1 Determine and record the mass of the clean and dry specimen container (and its lid, if used).
- 10.2 Select representative test specimens in accordance with Section 9
- 10.3 Place the moist test specimen in the container and, if used, set the lid securely in position. Determine the mass of the container and moist material using a balance (see 6.2) selected on the basis of the specimen mass. Record this value.

Note 5—To prevent mixing of specimens and yielding of incorrect results, all containers, and lids if used, should be numbered and the container numbers shall be recorded on the laboratory data sheets. The lid numbers should match the container numbers to eliminate confusion.

Note 6—To assist in the oven-drying of large test specimens, they should be placed in containers having a large surface area (such as pans) and the material broken up into smaller aggregations.

10.4 Remove the lid (if used) and place the container with moist material in the drying oven. Dry the material to a constant mass. Maintain the drying oven at $110 \pm 5^{\circ}\mathrm{C}$ unless otherwise specified (see 1.4). The time required to obtain constant mass will vary depending on the type of material, size of specimen, oven type and capacity, and other factors. The influence of these factors generally can be established by good judgment, and experience with the materials being tested and the apparatus being used.

Note 7—In most cases, drying a test specimen overnight (about 12 to 16 h) is sufficient. In cases where there is doubt concerning the adequacy of drying, drying should be continued until the change in mass after two successive periods (greater than 1 h) of drying is an insignificant amount (less than about 0.1 %). Specimens of sand may often be dried to constant mass in a period of about 4 h, when a forced-draft oven is used.

Note 8—Since some dry materials may absorb moisture from moist specimens, dried specimens should be removed before placing moist specimens in the same oven. However, this would not be applicable if the previously dried specimens will remain in the drying oven for an additional time period of about 16 h.

10.5 After the material has dried to constant mass remove the container from the oven (and replace the lid if used). Allow the material and container to cool to room temperature or until the container can be handled comfortably with bare hands and the operation of the balance will not be affected by convection currents and/or its being heated. Determine the mass of the container and oven-dried material using the same type/capacity balance used in 10.3. Record this value. Tight fitting lids shall be used if it appears that the specimen is absorbing moisture from the air prior to determination of its dry mass.

Note 9—Cooling in a desiccator is acceptable in place of tight fitting lids since it greatly reduces absorption of moisture from the atmosphere during cooling especially for containers without tight fitting lids.

3

11. Calculation

11.1 Calculate the water content of the material as follows:

$$w = [(M_{cws} - M_{cs})/(M_{cs} - M_{c})] \times 100 = \frac{M_{w}}{M_{c}} \times 100$$
 (1)

where:

w = water content, %,

 $M_{cws} = {
m mass}$ of container and wet specimen, g, $M_{ns} = {
m mass}$ of container and oven dry specimen, g,

 M_c = mass of container, g,

 $M_w^c = \text{mass of water } (M_w = M_{cws} - M_{cds}), \text{ g, and}$ $M_s = \text{mass of solid particles } (M_s = M_{cds} - M_c), \text{ g.}$

12. Report

12.1 Test data forms or test data sheets shall include the following:

12.1.1 Identification of the sample (material) being tested, such as boring number, sample number, test number, container number etc.

12.1.2 Water content of the specimen to the nearest 1 % or 0.1 %, as appropriate based on the minimum sample used. If this method is used in concert with another method, the water content of the specimen should be reported to the value required by the test method for which the water content is being determined. Refer to Guide D 6026 for guidance concerning significant digits, especially if the value obtained from this test method is to be used to calculate other relationships such as unit weight or density. For instance, if it is desired to express dry unit weight to the nearest 0.1 lbf/f³(0.02 kN/m³), it may be necessary to use a balance with a greater readability or use a larger specimen mass to obtain the required significant digits the mass of water so that the water content can be determined to the required significant digits. Also, the significant digits in Guide D 6026 may need to be increased when calculating phase relationships requiring four significant digits.

12.1.3 Indicate if test specimen had a mass less than the minimum indicated in 8.2.

- 12.1.4 Indicate if test specimen contained more than one material type (layered, etc.).
- 12.1.5 Indicate the temperature of drying if different from 110 \pm 5°C.
- 12.1.6 Indicate if any material (size and amount) was excluded from the test specimen.
- 12.2 When reporting water content in tables, figures, etc., any data not meeting the requirements of this test method shall be noted, such as not meeting the mass, balance, or temperature requirements or a portion of the material is excluded from the test specimen.

13. Precision and Bias

- 13.1 Statement on Bias—There is no accepted reference value for this test method; therefore, bias cannot be determined.
 - 13.2 Statements on Precision:
- 13.2.1 Single-Operator Precision (Repeatability)—The single-operator coefficient of variation has been found to be 2.7 percent. 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 7.8 percent of their mean.⁸
- 13.2.2 Multilaboratory Precision (Reproducibility)⁹—The multilaboratory coefficient of variation has been found to be 5.0 percent. Therefore, results of two properly conducted tests by different operators using different equipment should not be considered suspect unless they differ by more than 14.0 percent of their mean.

14. Keywords

14.1 consistency; index property; laboratory; moisture analysis; moisture content; soil aggregate; water content

SUMMARY OF CHANGES

Committee D-18 has identified the location of selected changes to this standard since the last issue. (D 2216-92) that may impact the use of this standard.

- (I) Title was changed to emphasize that mass is the basis for the standard.
- (2) Section 1.1 was revised to clarify "similar materials".
- (3) New 1.2 was added to explain a limitation in scope. The other sections were renumbered as appropriate.
- (4) An information reference was included in 1.5.
- (5) An information reference was included in 1.6
- (6) A new ASTM referenced document was included in 2.1.
- (7) New Footnotes 2, 3, and 5 were added and identified. Other footnotes were renumbered where necessary for sequential identification.
- (8) Information concerning balances was added in 6.2
- (9) Section 6.3 was revised to clarify the use of close-fitting lids, and a reference to Note 8 was added.

- (10) In 6.4, "anhydrous calcium phosphate" was changed to "anyhydrous calcium sulfate" to correct an error and to agree with Note 3.
- (11) A typo in 8.1 was corrected from "before" to "below" and a footnoted reference was added for information.
- (12) A portion of 8.2 was deleted for clarity.
- (13) A new 8.2.1 was added to clarify minimum mass requirements.
- (14) Sections 8.3, 8.4, 9.3.3, and 12.1 were changed to substitute "test data form/sheet" for "report".
- (15) Footnote seven was identified.
- (16) Section 9.2.1 was revised to improve clarity and intent.
- (17) The word "possible" was changed to "practical" in 9.2.3.

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 $^{^{\}rm 8}$ These numbers represent the (1s) and (d2s) limits as described in Practice C 670.

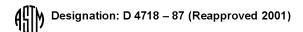
^{670.} 9 These numbers represent the (1s %) and (d2s %) limits as described in Practice C 670.

- (18) Section 9.3.1 and 9.3.2 were revised to improve clarity and for practicality.
- (19) A reference to Guide D 6026 was added in 12.1.2.
- (20) Footnotes 8 and 9 were added to 13.2.1 and 13.2.2, respectively. These were inadvertently omitted from the 1992
- version. These explanations provide clarity and information to the user.
- (21) A Summary of Changes was added to reflect D-18's policy.

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APPENDIX 3. ASTM D-4718



Standard Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles¹

This standard is issued under the fixed designation D 4718; 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.

This standard has been approved for use by agencies of the Department of Defense.

1. Scope

- 1.1 This practice presents a procedure for calculating the unit weights and water contents of soils containing oversize particles when the data are known for the soil fraction with the oversize particles removed.
- 1.2 The practice also can be used to calculate the unit weights and water contents of soil fractions when the data are known for the total soil sample containing oversize particles.
- 1.3 This practice is based on tests performed on soils and soil-rock mixtures in which the portion considered oversize is that fraction of the material retained on the No. 4 sieve. Based on these tests, this practice is applicable to soils and soil-rock mixtures in which up to 40 % of the material is retained on the No. 4 sieve. The practice also is considered valid when the oversize fraction is that portion retained on some other sieve, such as the ³/₄-in. sieve, but the limiting percentage of oversize particles for which the correction is valid may be lower. However, the practice is considered valid for materials having up to 30 % oversize particles when the oversize fraction is that portion retained on the ³/₄-in. sieve.
- 1.4 The factor controlling the maximum permissible percentage of oversize particles is whether interference between the oversize particles affects the unit weight of the finer fraction. For some gradations, this interference may begin to occur at lower percentages of oversize particles, so the limiting percentage must be lower for these materials to avoid inaccuracies in the computed correction. The person or agency using this practice shall determine whether a lower percentage is to be used.
- 1.5 This practice may be applied to soils with any percentage of oversize particles subject to the limitations given in 1.3 and 1.4. However, the correction may not be of practical significance for soils with only small percentages of oversize particles. The person or agency specifying this practice shall specify a minimum percentage of oversize particles below which the practice need not be applied. If a minimum percentage is not specified, 5 % shall be used.
 - 1.6 This practice may not be applicable to soil-rock mix-

tures which degrade under field compaction.

1.7 This practice offers a set of instructions for performing one or more specific operations. This document cannot replace education or experience and should be used in conjunction with professional judgment. Nat all aspects of this practice may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

2. Referenced Documents

- 2.1 ASTM Standards:
- C 127 Test Method for Specific Gravity and Absorption of Coarse Aggregate²
- D 698 Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort³
- D 1556 Test Method for Density and Unit Weight of Soil In Place by the Sand-Cone Method 3
- D 1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft³ (2,700 kN-m/m³))
- D 2167 Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method³
- D 2216 Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass³
- D 2922 Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)³
- D 3017 Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth)³
- D 4253 Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table³
- E 11 Specification for Wire-Cloth Sieves for Testing Purposes⁴

3. Significance and Use

3.1 Compaction tests on soils performed in accordance with

Annual Book of ASTM Standards, Vol 04.08.
 Annual Book of ASTM Standards, Vol 14.02.

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 $^{^{\}rm I}$ This practice is under the jurisdiction of ASTM Committee D18 on Soil and Rockand is the direct responsibility of Subcommittee D18.03 on Texture, Plasticity, and Density Characteristics of Soils.

Current edition approved July 31, 1987. Published September 1987.

² Annual Book of ASTM Standards, Vol 04.02.

Test Methods D 698, D 1557, and D 4253 place limitations on the maximum size of particles that may be used in the test. If a soil contains cobbles or gravel, or both, test options may be selected which result in particles retained on a specific sieve being discarded (for example the No. 4 (4.75-mm) or the ³/₄-in. (19-mm) or other appropriate size), and the test performed on the finer fraction. The unit weight-water content relations determined by the tests reflect the characteristics of the actual material tested, and not the characteristics of the total soil material from which the test specimen was obtained.

- 3.2 It is common engineering practice to use laboratory compaction tests for the design, specification, and construction control of soils used in earth construction. If a soil used in construction contains large particles, and only the finer fraction is used for laboratory tests, some method of correcting the laboratory test results to reflect the characteristics of the total soil is needed. This practice provides a mathematical equation for correcting the unit weight and water content of the tested finer fraction of a soil, to determine the unit weight and water content of the total soil.
- 3.3 Similarly, this practice provides a means for correcting the unit weight and water content of field compacted samples of the total soil, so that values can be compared with those for a laboratory compacted finer fraction.

Note 1-When this practice is used for construction control, the using agency should specify whether the maximum unit weight value used for reference is the unit weight including oversize fraction or the unit weight of the finer fraction. Calculated values of percent compaction based on this correction practice will vary depending on which unit weight value is used for reference

4. Procedure

- 4.1 Correction of Unit Weight and Water Content for Total Sample
- 4.1.1 Prepare the sample from which compaction test specimens are to be taken in accordance with provisions of Test Methods D 698, D 1557, or D 4253. Determine the mass of the moist fine fraction of the sample and the mass of the moist oversize (plus No. 4 or plus 3/4-in., or other appropriate size) fraction of the total sample. If Test Methods D 4253 is used, the correction for water content does not apply. Determine the water content of each of the two fractions in accordance with Method D 2216. Calculate the mass of the dry finer fraction and the dry oversize fraction as follows:

$$M_D = M_M/(1+w) \tag{1}$$

where:

 M_D = mass of the dry material (finer or oversize fraction),

 M_M = mass of the moist material (finer or oversize fraction), g, and

= water content of the respective finer or oversize fractions expressed as a decimal.

4.1.2 Calculate the percentage of the finer fraction and of the oversize fraction of the sample by dry weight as follows:

$$P_F = 100 \, M_{DF} / (M_{DF} + M_{DC}) \tag{2}$$

and

$$P_C = 100 \, M_{DC} / (M_{DF} + M_{DC}) \tag{3}$$

where:

= percent of finer fraction by weight, = percent of oversize fraction by weight,

 P_C = percent of oversize masses M_{DF} = mass of dry finer fraction, and = mass of dry oversize fraction.

- 4.1.3 Determine the bulk specific gravity (G_M) of the oversize fraction as set forth in Test Method C 127.
- 4.1.4 Calculate the corrected water content and corrected dry unit weight of the total material (combined finer and oversize fractions), as follows:

$$C_{w} = (w_F P_F + w_C P_C) \tag{4}$$

where:

corrected water content of combined and oversize fractions.

water content of finer fraction expressed as a deci-

water content of oversize fraction expressed as a decimal.

and

$$C\delta_D = 100 \, \delta_F G_M \delta_W / (\delta_F P_C + G_M \delta_W P_F) \tag{5}$$

where:

corrected unit dry weight of the total material (combined finer and oversize fractions),

bulk specific gravity,

= dry unit weight of the finer fraction, and

= unit weight of water $(62.42 \text{ lbf/ft}^3 \text{ or } 9.802 \text{ kN/m}^3)$.

- 4.2 Correction of Unit Weight and Water Content for Finer Fraction of a Soil Sample
- 4.2.1 When it is desired to compare the unit weight and water content of a field-compacted soil containing oversize particles with the results of laboratory compaction tests on the finer fraction, the following procedure may be used:
- 4.2.1.1 A sample of the total material is obtained in the field at the desired test location in conjunction with a unit dry weight (δ_D) and water content (w) determination by methods such as Test Methods D 1556, D 2167, or D 2922 and D3017 combined. Since this practice is usually used for materials containing coarse gravel and cobble size particles, special care should be taken to assure that the volume of material sampled is adequate to accurately represent the material in the field at the test location.
- 4.2.1.2 Remove the oversize particles (plus No. 4 or 3/4-in., or other appropriate size) from the field sample and determine the percentage of oversize particles in the total sample. If, in the laboratory testing of the materials, the bulk specific gravity and the water content of the oversize particles have been determined, these values may be used in the calculations. Otherwise, it will be necessary to determine the bulk specific gravity by Test Method C 127.
- 4.2.1.3 Calculate the water content of the finer fraction of the field sample as follows:

$$w_F = (100 \, w - w_C P_C) / P_F \tag{6}$$

4.2.1.4 Calculate the dry unit weight of the finer fraction of the field sample as follows:

$$\delta_F = \delta_D G_M \delta_w P_F / (100 G_M \delta_w - \delta_D P_C) \tag{7}$$

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5. Report

- 5.1 The report shall contain the following:
- 5.1.1 The identification of the sample.
- 5.1.2 The method used in compacting the sample.
- 5.1.3 The method used to obtain the field sample (as appropriate).
 - 5.1.4 The sieve size used to separate the oversize particles.
 - 5.1.5 The percentage by weight of oversize particles.
- 5.1.6 The value of bulk specific gravity, $G_{M^{\circ}}$ used in the calculations.
- 5.1.7 For laboratory compacted samples, the dry unit weight and water content of the finer fraction, and the corrected value for the total sample.
- 5.1.8 For samples obtained in the field, the dry unit weight and water content of the total sample, and the corrected value for the finer fraction.

6. Keywords

6.1 oversize particles; unit weight; water content

APPENDIX

(Nonmandatory Information)

X1. RATIONALE

X1.1 The calculations to correct the unit weight and water content of soil samples containing oversize particles are based on the premise that the percentage of such particles is small enough that they do not interfere with the compaction of the finer fraction during the compaction process. Thus, the finer fraction of the soil will achieve the same unit weight and water content with the oversize particles absent as with them present. The equation used for the calculation of unit weight is based on the work of Ziegler.⁵

X1.2 Tests conducted by the Bureau of Reclamation⁶, ⁷ and

the Waterways Experiment Station⁸ indicate that the limiting oversize particle (plus No. 4 sieve) content may be as high as 40 %. It is necessary in evaluating such studies to ensure that the gradation of the finer fraction does not change as the oversize particle content changes. The upper limit of oversize particles in this practice has been set at 40 % of the plus No. 4 material and 30 % of the plus 3/4-in. material.

X1.3 It is assumed that in a moist, compacted sample of soil containing oversize particles, those oversize particles absorb moisture from the surrounding medium. The maximum water content that the oversize particles can achieve approaches as a limit the percent absorption of the oversize fraction, as measured by Test Method C 127. The water content of the oversize fraction also may be measured directly by Method D 2216.

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⁵ Ziegler, E. J., "Effect of Materials Retained on the No. 4 Sieve on the Compaction Test of Soil," *Proceedings*, Highway Research Board, Vol. 28, 1948, pp 409–414.

⁶ Merriam, J., "Research on Compaction Control Testing for Gravelly Soils," Earth Research Program Report EM662, U.S. Bureau of Reclamation, Denver, CO, August 1963.

⁷ Holtz, W. G., and Lowitz, C. A., "Compaction Characteristics of Gravelly Soils," U.S. Bureau of Reclamation Earth Laboratory Report No. 509, Denver, CO, September 1957.

⁸ Donaghe, R. T., and Townsend, F. C., "Compaction Characteristics of Earth-Rock Mixtures," Report 2 "Blended Material," Misc. Paper S-73-25, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MI, August 1975.