

Colorado Procedure 80-13

Standard Method of Test for

In-Place Density and Moisture Content of Soil and Soil-Aggregate by the Nuclear Method

1. SCOPE

1. This test method describes the procedure for determining the in-place density and moisture of soil and soil-aggregate by use of nuclear moisture/density gauges. This procedure is to be used to measure densities at depths of 4, 6 & 8 inches only. Interferences (conditions that can provide incorrect measurements) of the nuclear test are discussed in AASHTO T 310-01.

2. REFERENCED DOCUMENTS

2.1 *Colorado Procedures:*

CP 15 Certification of Consultant Nuclear Moisture/Density Gauges

CP 25 Calculation of Percent Relative Compaction of Soils and Soil-Rock Mixtures

CP 75 Stratified Random Sampling of Materials

CP-L 5302 Calibration of CDOT Nuclear Moisture / Density Gauges

3. SIGNIFICANCE

- 3.1 The test method described is used for the in-place determination of the density and water content of soil and soil-aggregate.
- 3.2 The test method is used for acceptance testing of compacted soil and soil-aggregate.
- 3.3 Test results may be affected by chemical composition, sample heterogeneity, and, to a lesser degree, material density, and the surface texture of the material being tested. The test also exhibits spatial bias in that the gauge is more sensitive to water contained in the material close to the surface.

4. APPARATUS

- 4.1 *Nuclear Moisture/Density (M/D) Gauge* – The M/D gauge shall meet the requirements of CP 15 or CP-L 5302.
- 4.2 *Reference Standard* – A block of material used for checking gauge operation, correction of source decay, and to establish conditions for a reproducible reference count rate.
- 4.3 *Site Preparation Device* – A plate, straightedge, or other suitable leveling tools, which may be used for planing the test site to the required smoothness, and for guiding the drive pin to prepare a perpendicular hole.

- 4.4 *Drive Pin* – A pin not to exceed the diameter of the source rod by more than 1/8th of an inch.
- 4.5 *Drive Pin Extractor* – A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

5. HAZARDS

- 5.1 The gauge utilizes radioactive material that may be hazardous to the health of the user unless proper precautions are taken. Users of the gauge must become familiar with applicable safety procedures and government regulations.

6. CALIBRATION / CERTIFICATION

- 6.1 Calibration Certification of the gauge shall be per CP 15 or CP-L 5302.

7. STANDARDIZATION

- 7.1 All Nuclear Moisture/Density (M/D) Gauges are subject to long-term aging of the radioactive sources, detectors, and electronic systems, which may change the relationship between count rates and the material density and water content. To offset this aging, gauges are calibrated as a ratio of the measurement count rate to a count rate made on a reference standard.
- 7.2 Standardization of the gauge on the reference standard is required at the start of each day's use, after the gauge has been turned off, or when a gauge's readings are in question. A permanent record of this data shall be retained. The standardization shall be performed with the gauge at least 33 ft away from other nuclear gauges and clear of large masses of water, hydrogenous material, or other items that may affect the reference count rates. Standard counts should be taken in the same environment as the actual measurement counts.
- 7.3 Turn the gauge on and allow it to stabilize according to the manufacturer's recommendations.
- 7.4 Place the gauge on the reference standard as recommended by the gauge manufacturer, and perform a four-minute standard count.
- 7.5 Compare the standard count obtained in Subsection 7.4 to the average of the previous 4 days' standard counts. If the density standard count is not within 1% of the density 4-day average or the moisture standard count is not within 2% of the moisture 4-day average rerun the standard count. If the above conditions are not met contact your On-site Radiation Safety Officer or contact the gauge manufacturer for further guidance. Record the standard counts on CDOT Form 746 and 427.

8. PROCEDURE

- 8.1 Using CP 75 Random Sampling procedures, select both longitudinal and transverse test locations where the test position is at least 6 inches from any vertical projection.
- 8.2. Prepare the test site in the following manner:

- 8.2.1. Remove all loose and disturbed material, and remove additional material as necessary to expose the top of the material to be tested.
- 8.2.2. Prepare a horizontal area, sufficient in size to accommodate the gauge by planing the area to a smooth condition to obtain maximum contact between the gauge and material being tested.
- 8.2.3. The maximum void beneath the gauge shall not exceed 1/8th of an inch. Use minus #4 native fines to fill these voids and smooth the surface with the site preparation device. The depth of the filler shall not exceed 1/8th of an inch. The area covered by the fill shall not exceed 10% of the test site.
- 8.2.4. Using the hole-forming device, make a hole, perpendicular to the prepared surface. The depth of the hole shall be at least 2 inches deeper than the selected test depth and aligned such that the insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.
- 8.2.5. Remove the hole-forming device carefully to prevent the distortion of the hole, damage to the surface, or loose material falling into the hole.
- 8.3. Proceed with testing in the following manner:
 - 8.3.1. Place the gauge on the material to be tested and align the source rod directly above the hole.
 - 8.3.2. Lower the source rod into the hole to the desired test depth. Pull back gently on the gauge towards the operator so that the source rod is in direct contact with the backside of the hole. Enter the depth of measurement on the scaler.

Note 1: Failure to enter the actual depth of the reading into the scaler will yield incorrect density results.
 - 8.3.3. Keep all other radioactive sources at least 33 feet away from the gauge to avoid affecting the measurement.
 - 8.3.4. Perform four one-minute readings and record the dry density and percent moisture on CDOT Form 427.

Note 2: Most gauges report both wet & dry density and moisture content in PCF and percent moisture. It is important to record the correct reading from the gauge.
 - 8.3.5. Obtain a sample of the soil or soil-aggregate as required in CP 23 or CP 25. The sample should be collected from beneath the M/D gauge, between the hole and the end of the gauge. The depth of the sample shall be 2 inches deeper than the test depth.
- 8.4. A percent moisture check shall be run at least once for each soil classification or soil-aggregate (rock) type on the project.
 - 8.4.1. Using, a minimum 500g portion of the sample obtained for CP 23 or CP 25 to determine the moisture content according to AASHTO T 265.
 - 8.4.2. The gauge's percent moisture is valid if it is \pm 1% of the moisture content determined by AASTHO T 265.

- 8.4.3 If the gauge's percent moisture is not within 1% then AASHTO T265 shall be used for determining the MC at each location. The Wet density from the gauge will be recorded and the dry density calculated for determining percent compaction.

$$D_D = \frac{W_D}{1 + \frac{M}{100}}$$

Where:

D_D = Dry Density, lbs/ft³

W_D = Wet Density, lbs/ft³

M = percent moisture from T 265.

Note 3: This check is to make sure that the chemical composition of the soil or soil-aggregate mixture does not interfere with the gauge's moisture content determination.

9. CALCULATIONS

- 9.1 Average the gauge readings obtained in Subsection 8.3.4.

10. REPORT

- 10.1 CDOT Form 746, Nuclear Moisture/Density Gauge Log.

<https://www.codot.gov/library/forms/cdot0746.pdf/view>

- 10.2 CDOT Form 427, Nuclear Soils-Moisture/Density Test.

<https://www.codot.gov/library/forms/cdot0427.pdf/view>