FIELD DENSITY AND MOISTURE CONTENT OF SOIL AND SOIL-AGGREGATE MIXTURES BY THE NUCLEAR METHOD

(An Arizona Method)

SCOPE

1. (a) This method is used to determine the in-place density and moisture content of compacted soil and soil-aggregate mixtures to a depth of 12 inches with a nuclear gauge. This test method is especially suited for soils of a specified gradation such as aggregate base course, or fine soils of a consistent nature. Rock correction of the Proctor maximum density requires excavation of the soils at the test site to determine rock content, which increases the time required for the test and decreases test efficiency. This method is acceptable for normal soil and aggregate density testing, including pumping and heaving soils, but should not be used for open-graded aggregate.

(b) An example is provided in Figure 1 for the calculations and determinations referenced herein.

SAFETY

2. (a) This test method involves hazardous materials, operations, and equipment. This test method does not purport to address all of the safety problems associated with its use. It is the responsibility of whomever uses this test method to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

(b) Safety procedures for operation, transport and storage of nuclear gauges shall be in accordance with the manufacturer's recommendations and the applicable regulations of the Arizona Radiation Regulatory Agency (ARRA).

APPARATUS

3. The apparatus shall consist of the following:

(a) Moisture/Density Nuclear gauge capable of determining densities by the direct transmission method. Calibration of the gauge shall be performed in accordance with AASHTO T238, Subsection 3.1., on an annual basis. Adjustment of the calibration curve for field soil conditions shall be done as needed in accordance with AASHTO T238, Subsection 3.3.

(b) Reference standard block or test stand to obtain standard counts for moisture and density which are used to check the gauge stability.

(c) Nuclear gauge transport case and labels which comply with A.R.R.A. Regulations.

(d) Charging cord, if applicable.

(e) Scraper plate and drill rod guide.

(f) Drill rod.

(g) Hammer for driving the drill rod to make the hole for the direct transmission probe.

(h) A #10 sieve or a supply of dry, fine-sieved sand to be used as a sand blanket for surface irregularities at the test site and a fine brush for sand removal.

(i) A #4 and 3/4 inch sieve for use in removing plus #4 or plus 3/4 inch material for rock correction, depending upon the proctor method.

(j) A 3 inch sieve for determining the presence of oversize rock material.

(k) Safety goggles for eye protection, steel-toed footwear, and the radiation exposure badge.

(l) Information packet for the nuclear gauge which shall contain the following items:

1) Moisture/Density Calibration Tables (if required), and a standard count log book.

2) Manufacturer's Gauge Operation Manual for the nuclear gauge.

3) Applicable documentation necessary to meet requirements of ARRA for gauge safety.

4) Blank test forms for use on the applicable nuclear gauge (See Figure 2).

(m) Calculator for necessary computations.

(n) Miscellaneous equipment including watch, pencils, writing paper, ruler, eraser, clip board, and hand cart as required.

GAUGE STABILITY CHECK

4. A density standard count and moisture standard count shall be taken at the beginning of each day of testing at the project where the field density testing is to be performed. The gauge stability check shall be performed as follows:

(a) Place the reference standard block on any asphalt, concrete, compacted aggregate or similar surface which is dry and level. The reference standard block should be at least 24 inches away from any vertical projection, at least 15 feet away from any large object, or vehicle, and at least 50 feet away from another nuclear gauge.

(b) Seat the nuclear gauge on the reference block in accordance with the gauge operation manual. It is very important that the gauge is seated properly on the standard reference block.

(c) Remove the lock on the source handle and make sure the source handle is in the safe or stored position (the top notch on the index rod).

(d) Turn the gauge on (in standby power condition) and allow it to warm-up, if neccessary, for the recommended time as given in the gauge operation manual, normally 15 minutes.

(e) After the warm-up period, take a standard moisture count and a standard density count.

(f) Record the moisture and density standard counts in the proper columns of the standard count log book along with the appropriate additional information, such as date, time, temperature, and location.

(g) Return the gauge to the standby power condition. The gauge should be left in the standby mode for subsequent testing.

(h) Determine if the standard counts are within the limits for normal operation in accordance with the gauge operation manual. This is usually done by comparing the standard counts to the average of the four previous standard counts or utilizing an internal statistical test which is available on some gauges. Additional standard counts may be necessary if initially the gauge does not appear to be operating properly. If the gauge does not meet the normal operating parameters as specified by the Standard Count procedure in the gauge operation manual, the gauge should not be used for testing. It should be sent in for servicing to determine the problem.

> NOTE: Some gauges will store standard counts for later use in calculations performed by the gauge itself. The most recent standard counts will usually be stored automatically over preexisting standard counts.

(i) On a weekly basis, compare the average of the four most recent standard counts with the average of four standard counts immediately after gauge calibration or at least three months previous, whichever is shorter. If the accumulative shift in standard count exceeds 2% for moisture or 3% for density, the nuclear gauge should be recalibrated.

SITE PREPARATION

5. (a) Select a location for the field density test at random where the gauge will be at least 24 inches from any vertical projection such as a trench wall, retaining wall or pipe, at least 15 feet away from any vehicle, and at least 50 feet away from another nuclear gauge. If within 24 inches of a vertical projection, refer to section 8, Trench Correction.

(b) Remove all loose, disturbed, and excess material as necessary to reach the top of the compacted lift to be tested. Prepare a horizontal area sufficient in size to accommodate the gauge using the scraper plate supplied with the gauge. Plane the area to a smooth condition removing loose stones to obtain maximum contact between the gauge and the soil or aggregate being tested. Make sure the gauge sits solidly on the test site without rocking.

(c) Use native fines which pass a #10 sieve, or fine dry sand to fill voids only, and level the excess with the scraper plate. The total area of voids filled with fines or sand should be minimized as much as possible.

OBTAINING NUCLEAR MOISTURE AND DENSITY COUNTS

6. (a) Nuclear Density Counts and Moisture Counts shall be obtained by inserting the probe into the soil at the test site. (Refer to the gauge operation manual.) Prior to density count determination, select the mode of testing as follows based on the lift thickness of the soil or aggregate being tested:

LIFT THICKNESS "T" INCHES	TRANSMISSION MODE
$T < 2$	Backscatter
$2 \leq T < 4$	Direct - 2 inch
$4 \leq T < 6$	Direct - 4 inch
$6 \leq T < 8$	Direct - 6 inch
$8 \leq T \leq 12$	Direct - 8 inch
$12 < T$	See 6(b) Below

(b) Tests which require the density for a lift greater than 12 inches in thickness require an initial surface test to determine the density of the upper portion of the lift. Then the soil must be excavated downward to allow another test or tests to determine the density of the lower portion of the lift.

(c) To prepare the gauge for direct transmission testing, place the scraper plate drill rod guide on the test site so that the access hole for the probe will be at the desired location.

(d) Securely hold the scraper plate in place while driving the drill rod into the material. The hole should be at least 2 inches deeper than the depth to be tested. Safety goggles and steel-toed footwear should be worn while driving the drill rod. Note the depth marks on the drill rod. It would be desirable to turn the drill rod slightly after every other blow to allow easier removal.

(e) Remove the drill rod by pulling straight up in order to avoid disturbing the access hole.

(f) Remove the scraper plate and clear away all loose surface material. Using fine material as stated previously, fill any voids caused by driving the drill rod.

(g) Carefully place the gauge over the access hole and extend the probe into the hole to the desired direct transmission mode depth according to the lift thickness as outlined previously. Do not force the probe into the hole. If the probe will not extend into the hole, pull the probe back up. Lift up the gauge and check for a probe imprint. This will help determine if a slight change in the position of the gauge is necessary to allow the probe to enter the hole. Once the probe is in the hole, gently push it down. Some minor shifting of the gauge may be required to extend the probe in gravelly soils. However, if an obstruction is encountered, it may be necessary to use the drill rod again to open up the hole.

(h) Once the probe is fully extended to the direct transmission depth, pull the gauge firmly, toward the scaler or readout end of the gauge, so that the probe is in firm contact with the soil or aggregate on the scaler side of the hole.

(i) Take density and moisture counts for a minimum one minute time period by pressing the proper button on the gauge. Both counts normally will occur simultaneously during the count period (Refer to the gauge operation manual).

(j) After the count period, press the proper button to obtain the moisture count. Record the moisture count on the data sheet, as "MC". Also, in a similar manner, obtain the density count. Record the density count on the data sheet, as "DC". It is also possible to get a wet density and moisture content readout in lbs./cu.ft. at this time for gauges capable of storing the standard counts and calculating these values (Refer to the gauge operation manual). If so, obtain these values and record on the test data sheet as "WD" and "M" respectively. The gauge may also be capable of calculating the moisture content in %, "M%", and the dry density in lbs./cu.ft., "DD". If so, these values may be recorded on the test data sheet. However, the gauge internal calculations may require some additional corrections as required by the test location or soil type. Refer to Sections 8 and 9 for further information on the trench and moisture corrections.

(k) In those instances when the soil or soil-aggregate mixture being tested in-place is not homogeneous and/or contains substantial variations in the rock content, it may be necessary to rotate the gauge 90 degrees at each test site and obtain an additional moisture and wet density reading at that position. If the new moisture and wet density readings differ by 5% or less from the original readings, the two readings may be averaged for use in later calculations. If they differ from the original readings by more than 5%, the gauge should be moved to a new test site.

PROCTOR DENSITY ROCK CORRECTION

7. (a) For determining the percent compaction based on the maximum proctor densities determined by Method A (Arizona Test Method 225 or 232) or Alternate Method D (Arizona Test Method 245 or 246), a rock correction may be

required for the amount of plus No. 4 (Method A) or plus 3/4 inch (Alternate Method D) rock or coarse aggregate in the material tested by the nuclear gauge.

(b) If it appears that 10% of the material will be retained on the No. 4 sieve (Method A) or 3/4 inch sieve (Alternate Method D), excavate the area occupied by the base of the gauge at the testing location to the depth of the test, which is normally the lift thickness. If an average rock correction is to be utilized, refer to 7(f).

(c) Obtain a minimum 3000 gram (7 pound) sample of excavated material and weigh to the nearest gram. Record the weight of this sample as "A". Sieve this material first over a 3 inch sieve to determine the presence of any oversize rock material. If any oversize rock is encountered, proceed to 7(d). If not, sieve the material over a No. 4 sieve (Method A) or 3/4 inch sieve (Alternate Method D), and record the weight of retained material as "B". Proceed to 7(e).

(d) If any rock is retained on the 3 inch sieve, this shall be reported with a note stating that the density is not determinable due to rock being retained on the 3 inch sieve. Additional attempts should be made to locate an area where the test can be accomplished.

(e) Calculate the percent of coarse particles, "PR" according to the following equation:

$$PR = \frac{B}{A} \times 100$$

Where: PR = Percent of coarse aggregate or rock particles retained on either the No. 4 sieve for Method A or the 3/4 inch for Alternate Method D.

B = Weight of coarse aggregate or rock particles retained on the No. 4 sieve (Method A) or 3/4 inch sieve (Alternate Method D).

A = Weight total of sample which is sieved.

(f) If the material has from 10 to 50 percent (10 to 60 percent in the case of an Aggregate Base) retained on the No. 4 sieve (Method A) or 10 to 50 percent retained on the 3/4 inch sieve (Alternate Method D), the maximum proctor density will require a rock correction. Record the data at the appropriate locations on the data sheet.

(g) If the percent retained on the No. 4 sieve or 3/4 inch exceeds the maximum values listed above (50 or 60 percent), report the percent rock with a note stating that the density is not determinable due to excess rock. Additional attempts should be made to locate an area where a test can be accomplished. Also, if the proctor is a Method A proctor, an Alternate Method D proctor may be considered for this material.

> Note: When conditions prevent the determination of density at a specific location, due to the presence of excesssive rock or rock retained on the 3 inch sieve, the compactive effort in those areas should be the same as that performed in surrounding locations where the required density was found through testing to be satisfactory.

(h) If, from the results of a minimum of five samples, it is indicated that no rock is retained on the 3 inch sieve and the percent rock retained on the No. 4 or 3/4 inch sieve is within a 12% range (plus or minus 6% from the average), then an average percent of rock based on the five samples may be utilized. However, if a failing density test results from utilization of this average percent of rock, then the test site must be excavated and the actual percent of rock must be determined in accordance with 7(c) and 7(d) above. If there is a visible change in the material including the percent of rock, then a new proctor is required and a new average percent of rock must be determined.

TRENCH CORRECTION

8. (a) Moisture and dry density test results may be affected when a gauge is operated within 24 inches of a vertical projection such as a trench wall, pipe or retaining wall which contains moisture. The density counts, determined in the direct transmission mode, should not be affected, but moisture counts will possibly be affected. Without a trench correction, the moisture content determined could be higher than the actual moisture content which would cause the dry density determined to be too low. If the density test passes without a trench correction, then a trench correction would not be necessary.

(b) When a trench correction is necessary, refer to the gauge operation manual for the proper procedure in making a trench correction. Usually it is necessary that a moisture count be taken on the standard block in the trench at the same position and orientation that the moisture count for the density test is taken.

(c) Based on the original standard moisture count and the moisture count taken on the standard block in the trench, a trench correction may be made internally in most gauges by a calculation process or by an external manual moisture count shift. Refer to gauge operation manual for the proper input of the trench correction. Be sure to delete this correction after each test since each test location would have a different correction.

MOISTURE CORRECTION

9. (a) Moisture and dry density test results may be affected by hydrogen in the soil unrelated to actual moisture. Only the moisture reading is affected. The wet density reading is not affected.

(b) The moisture correction is obtained by determining the difference between the average oven dry moisture contents and the average nuclear gauge moisture contents for five or more samples obtained per paragraph 7(c). The oven-dry moisture content in percent, "TW", will be determined for each representative sample according to AASHTO T265. The sample shall include all plus No. 4 or 3/4 inch material, since the nuclear gauge measures total moisture. If the moisture is determined by the Speedy Moisture Tester and the sample contains material retained on the No. 4 sieve, the "Speedy" results must be adjusted in accordance with the following formula to obtain the percent moisture of the total sample.

$$TW = \frac{[W(100 - PR)] + PR}{100}$$

Where: TW = % moisture content in total sample
W = % moisture in Pass No. 4 material
PR = % rock retained on the No. 4 sieve

(c) A moisture correction is needed if the difference calculated indicates that the gauge moisture results are more than 1% higher or lower than the oven dry or Speedy results. Moisture corrections of 1% or less may be disregarded.

(d) Most gauges have the capability for correction of the moisture content in % by an internal calculation or an external moisture count shift. Simply apply the moisture correction up or down as applicable in the gauge according to the procedures in the gauge operation manual. Future density calculations within the gauge will apply this moisture count shift until it is deleted by the operator.

MOISTURE-DENSITY CALCULATIONS

10. Calculations shall be performed as follows:

(a) Record the standard counts for moisture and density on the data sheet in the spaces for "MS" and "DS" respectively.

(b) Most current gauges have the internal capability to calculate the moisture content in lbs./cu.ft. and %, the wet density in lbs./cu.ft., and the dry density in lbs./cu.ft. If so, record "M", "M%", "WD" and "DD" at the appropriate locations on the test data form. Also, list any corrections which have been input into the gauge and apply to these calculations. If it is necessary to use count ratios and calibration tables to determine the moisture content, wet density, and dry density, this should be done in accordance with the procedures in the gauge operation manual. Any data calculated in this manner should also be recorded on the test data sheet at the proper location.

(c) Determine from the correction data obtained in Section 7 whether a rock correction is necessary. If so, determine the rock corrected maximum density using the maximum proctor dry density and percent rock according to the Rock Correction Method, ARIZ 227.

(d) The percent of compaction, based on the maximum dry density (corrected, if necessary) is determined and reported to the nearest whole percent.

$$\% \text{ compaction} = \frac{DD \times 100}{MD \text{ or } CMD}$$

Where: MD = Maximum Proctor Dry Density (if no rock correction)

CMD = Corrected Maximum Density (if rock correction is necessary).

NOTE: If a rock correction is not necessary, many current nuclear gauges have the capability to perform all of the other density and moisture calculations internally, with results shown in the display or output to an external printer or computer. Refer to the gauge operation manual to take advantage of all possible gauge options.

REPORT

11. Record the pertinent moisture and density data on the test form along with the test number, location and other information required. An example is given in Figure 1. A blank test form is provided in Figure 2.

ARIZONA DEPARTMENT OF TRANSPORTATION
FIELD DENSITY/MOISTURE OF SOILS BY THE NUCLEAR METHOD
ARIZONA TEST METHOD 235

TRACS Number H 9999 01C
Project Code 8888
Date JAN. 13, 1993
Tested By JOE DOGOOD
Material Type EMBANKMENT
Test Number 22
Proctor Number EM #1
Material Source INPLACE
Test Location S.R. #51, STA. 97+00, 60' Lt. ℄

Project Number F-099-9(11)
Contractor BUILD M. GOOD, INC.
Badge Number 19
Gauge Type 5001
Gauge Number 1146
Proctor Type METHOD A
Lift 7

STANDARD COUNTS

Density Standard (DS) 3239.4
Moisture Standard (MS) 415.1

FIELD COUNTS

Density Count (DC) 1645.8
Wet Density (WD) 126.7 PCF
Dry Density (DD) 124.0 PCF
Moisture Count (MC) 93.3
Moisture Content (M) 2.7 PCF
Moisture Content (M%) 2.2 %

ROCK CORRECTION [IF NECESSARY] (ARIZ 227)

Wet Wt. of Material (A) 24.72 lb.
Wet Wt. Retained (B) 6.07 lb.
Percent Rock (PR)
PR = (B/A) x 100 = 25 %

TRENCH CORRECTION [IF NECESSARY]

Trench Moist. Stand. (TMS) ________
Trench Moist. Count (TMC) ________
Trench Correction (TC)
TC = TMC - TMS = ________

MOISTURE CORRECTION [IF NECESSARY]

Moisture Correction ________ %
Input into gauge [YES/NO] ________

PROCTOR DATA (ARIZ 225 or 245)

Max. Dry Density (MD) 121.0 PCF
Coarse Agg. Sp. Gr. (SG) 2.609
Optimum Moisture 11.5 %
Proctor % Rock Retained 43 %
Corrected Maximum Dry Density (CMD) [For Rock Correction]:

$$CMD = \frac{[(100 - PR) \times (MD)] + [(56.2) \times (PR) \times (SG)]}{100} = 127.4 \text{ PCF}$$

ONE POINT PROCTOR DATA (ARIZ 232 or 246)

Wt. of Mold and Soil (M1) ________ lb
Mold Volume (VM) ________ CF
Moisture Content ________ %
Max. Dry Density (MD) ________ PCF
Wt. of Mold (M2) ________ lb
Wet Density (M1-M2)/VM ________ PCF
Density Curve I.D. ________
Corr. Max. Dry Dens. (CMD) ________ PCF

COMPACTION COMPLIANCE CALCULATION

Required Compaction 95 %
Pass ✓ Fail ________
Percent Compaction =
(DD x 100)/MD or CMD = 97.3 %

Remarks: ________

Lab Supervisor TED HEADMAN
Date 1-13-93

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FIGURE 1

ARIZONA DEPARTMENT OF TRANSPORTATION
FIELD DENSITY/MOISTURE OF SOILS BY THE NUCLEAR METHOD
ARIZONA TEST METHOD 235

TRACS Number ______________ Project Number ______________
Project Code ______________ Contractor ______________
Date ______________ Badge Number ______________
Tested By ______________ Gauge Type ______________
Material Type ______________ Gauge Number ______________
Test Number ______________ Proctor Type ______________
Proctor Number ______________ Lift ______________
Material Source ______________
Test Location ______________

STANDARD COUNTS

Density Standard (DS) ______________ Moisture Standard (MS) ______________

FIELD COUNTS

Density Count (DC) ______________ Moisture Count (MC) ______________
Wet Density (WD) ______________PCF Moisture Content (M) ______________PCF
Dry Density (DD) ______________PCF Moisture Content (M%) ______________%

ROCK CORRECTION [IF NECESSARY] (ARIZ 227)

Wet Wt. of Material (A) ______________ Percent Rock (PR)
Wet Wt. Retained (B) ______________ PR = (B/A) x 100 = ______________%

TRENCH CORRECTION [IF NECESSARY]

Trench Moist. Stand. (TMS) ______________ Trench Correction (TC)
Trench Moist. Count (TMC) ______________ TC = TMC - TMS = ______________

MOISTURE CORRECTION [IF NECESSARY]

Moisture Correction ______________% Input into gauge [YES/NO] ______________

PROCTOR DATA (ARIZ 225 or 245)

Max. Dry Density (MD) ______________PCF Optimum Moisture ______________%
Coarse Agg. Sp. Gr. (SG) ______________ Proctor % Rock Retained ______________%
Corrected Maximum Dry Density (CMD) [For Rock Correction]:

$$CMD = \frac{[(100 - PR) \times (MD)] + [(56.2) \times (PR) \times (SG)]}{100} = \_\_\_\_\_\_\_\_\_\_ PCF$$

ONE POINT PROCTOR DATA (ARIZ 232 or 246)

Wt. of Mold and Soil (M1) ______________lb Wt. of Mold (M2) ______________lb
Mold Volume (VM) ______________CF Wet Density (M1-M2)/VM ______________PCF
Moisture Content ______________% Density Curve I.D. ______________
Max. Dry Density (MD) ______________PCF Corr. Max. Dry Dens. (CMD) ______________PCF

COMPACTION COMPLIANCE CALCULATION

Required Compaction ______________% Percent Compaction =
Pass ______________ Fail ______________ (DD x 100)/MD or CMD = ______________%

Remarks: ______________
____
____

Lab Supervisor ______________ Date ______________

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FIGURE 2