MOISTURE-DENSITY RELATIONS OF CEMENTITIOUSLY TREATED MIXTURES

1. SCOPE

1.1 This method covers procedures for determining the relationship between moisture content and the density of cement treated mixtures when compacted at varying hydration curing times dependent on and consistent with construction operation procedures.

1.2 This test method may involve 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 whoever uses this test method to consult and establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. APPARATUS

2.1 Requirements for the frequency of equipment calibration and verification are found in Appendix A3 of the Materials Testing Manual.

2.2 4 inch proctor mold having a capacity of approximately 1/30 cubic foot, with an internal diameter of 4.000 plus 0.024 or minus 0.016 inches and a height of 4.584 plus 0.005 or minus 0.008 inches. The mold shall have a nominal wall thickness of 1/4 inch. It shall be equipped with an extension collar approximately 2-3/8 inches high.

2.3 A hand or mechanical rammer weighing 5.50 $\pm$ 0.02 pounds, having a flat face, and equipped with a suitable arrangement to control the height of drop to a free fall of 12 $\pm$ 0.06 (1/16) inches above the elevation of the soil. The rammer face shall be circular with a diameter of 2.000 plus 0.010 or minus 0.015 inches.

2.4 Hardened-steel straightedge, at least 10 inches in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.01 inch per 10 inches (0.1 percent) of length with the portion used for trimming the soil.

2.5 A circular sample follower with a diameter slightly less than the inner diameter of the proctor mold to aid in the removal of the mold collar.

2.6 Scale or balance capable of measuring the maximum weight to be determined, accurate to at least 0.1 g.

2.7 Oven capable of maintaining a temperature of 230 ± 9 °F.

2.8 Sieves of sizes as required for screening conforming to the requirements of ASTM E11.

2.9 Miscellaneous mixing tools and pans.

3. SAMPLE PREPARATION

3.1 If the sample is damp when received, it shall be dried until it becomes friable under a trowel. Drying may be accomplished by air drying or by the use of a drying apparatus such that the temperature of the sample does not exceed 140 °F. Prepare the sample for testing by separating the Plus No. 4 Material and breaking up the remaining soil aggregations to pass the No. 4 sieve in such a manner as to avoid reducing the natural size of individual particles.

3.2 Select and prepare five separate 2500 g test samples, corresponding to the sieve analysis of the total sample, in accordance with the following procedure.

3.3 Determine the gradation of the sample in accordance with ARIZ 201. For samples containing Plus 3/4 Inch Material, the material retained on the 1/2 inch, 3/8 inch, 1/4 inch, and No. 4 sieves shall be stored separately. Aggregate retained on the 3/4 inch sieve shall not be used, but its percentage shall be distributed proportionately among the aforementioned sieves.

3.4 Determine a Percent Retained Factor for calculating the Adjusted Percent Retained by the following:

$$\% \text{ Retained Factor} = \frac{\text{Total Retained on 3/4” Sieve}}{\text{Cumulative \% Retained on 1/2”, 3/8”, 1/4”, and No. 4 Sieves}}$$

Record the Percent Retained Factor to at least four decimal places.

3.5 Calculate the Adjusted Percent Retained for the 1/2 inch, 3/8 inch, 1/4 inch and No. 4 sieves by the following:

Adjusted Percent Retained = (% Retained x % Retained Factor) + % Retained

Record the adjusted percent retained for each sieve to the nearest hundredth.

3.6 The sum of the new Adjusted Percent Retained values should total 100% when rounded.

3.7 Multiply each of the newly Adjusted Percent Retained values by 2500, then divide by 100, to obtain the quantity of material for each sieve size that should be combined to create each sample.

NOTE: Due to rounding in the procedure, the sample may not equal exactly 2500 g.

3.8 An example of a coarse sieve analysis which requires adjusting to prepare test samples of 2500 g is shown in Table 1.

TABLE 1

Sieve Size	% Retained	Rounded Adjusted % Retained	Weight in g (2500 g sample)	Accumulative Total
2”	0			
2-1/2”	0			
1”	8			
3/4”	4			
1/2”	4	7.20	180	180
3/8”	1	1.80	45	225
1/4"	5	9.00	225	450
#4	5	9.00	225	675
Pass #4	73	73.00	1825	2500
Total	100	100	2500	

4. COMPACTION

4.1 Add to the prepared samples the required amount of cementitious material as determined in ARIZ 220, “Cement Content Required for Cement Treated Mixtures.” If this has not yet been determined, an estimate shall be made and

this amount added. Mix thoroughly to a uniform color. Add sufficient water to dampen the mixture to approximately four to six percentage points below the estimated optimum moisture content, and mix thoroughly. Cover and allow to cure for 5 minutes to aid dispersion of the moisture.

4.2 Form a specimen by compacting the prepared mixture in the four inch mold (with the extension collar attached) in three equal layers to give a total compacted depth of about 5 inches. Compact each layer with 25 uniformly distributed blows from the rammer, dropping free from a height of 12 inches. While each layer is being compacted, the remainder of material shall be in a pan covered by a damp cloth. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation.

4.3 Following compaction, carefully remove the extension collar. It may be necessary to use a follower to retain the soil in the mold while removing the collar to prevent damage or disturbance of the soil below the top of the mold. Carefully trim the compacted specimen even with the top of the mold by means of the straightedge. If any voids are created during trimming, these shall be filled with fine material and smoothed off. Determine the wet density, “WD”, of the compacted specimen by the following:

$$WD = \frac{M1 - M2}{VM \times 453.6 \text{ (grams/lb)}}$$

Where:
- WD = Wet density of compacted specimen, lb./cu. ft.
- M1 = Weight of compacted specimen and mold, grams
- M2 = Weight of the mold, grams
- VM = Volume of the mold, cu. ft., determined in accordance with ARIZ 225, Appendix A

4.4 Remove the material from the mold and slice vertically through the center. Take a representative minimum 300 gram sample from the full length and width of one of the cut faces. Weigh immediately, and dry to a constant weight in an oven at $230 \pm 9\ ^{\circ}F$ to determine the moisture content in accordance with AASHTO T 265. Record the weight of wet soil to the nearest 0.1 gram as "WW", and record the weight of oven dry soil to the nearest 0.1 gram as "DW". Calculate percent moisture and record to the nearest 0.1 percent by the following:

$$\% \text{ Moisture} = \frac{WW - DW}{DW} \times 100$$

Where: WW = Weight of wet soil, grams
DW = Weight of dry soil, grams

4.5 Calculate the dry density and record to the nearest 0.1 lb./cu. ft. by the following:

$$DD = \frac{WD}{\% \text{ Moisture} \times 100} \times 100$$

Where: DD = Dry density of compacted soil, lb./cu. ft.
WD = Wet density of compacted soil, lb./cu. ft.

Repeat the procedure in Subsections 4.1 through 4.5 for the sample, increasing the moisture content for each specimen by approximately two percentage points, as necessary to establish a moisture-density curve which rises to a peak and then falls away.

4.6 Maximum density and optimum moisture content shall be determined as described in Subsections 7.1 through 7.4 of ARIZ 225.

Repeat the procedures in Subsections 4.1 through 4.6 on samples allowed to cure prior to compaction for the following curing time periods: 5 minutes, 30 minutes, and 60 minutes. (It will not be necessary to make a four-hour determination for all mixtures. This need should be established on an individual basis.) These separate determinations shall be used for developing a family of curves for use for compaction control with each curve designated according to its respective curing time. If it is determined that the delay in compaction time (i.e., the curing time between incorporation of the cement and compaction) will not vary throughout the project construction schedule, then the number of delayed compaction curves can be limited to only those applicable without running the complete family.