*Materials sampling and testing methods and documentation procedures prescribed in chapter 8 of the CMM are mobilized into the contract by standard spec 106.3.4.1 and standard spec 106.3.4.3.1.*

## 8-55.1 Field Test Procedures for Moisture-Density Relationship of Gravelly Soils

### 8-55.1.1 Scope

This method of test is intended for determining the relationship between the moisture content and density of soils containing appreciable quantities of R-4.75 mm (No. 4) material.

### 8-55.1.2 Apparatus

- Molds and Detachable Base Plate: Standard 4-inch molds having a capacity of 1/30 cu. ft. and base plate. The molds may not be the split type.
- Rammer: A rammer of 2-inch diameter having a flat circular face and weighing 5.5 lbs. The rammer must be equipped with a suitable arrangement to control the height of drop to a free fall of 12-inch above the elevation of the soil.
- Sample Extruder (Optional): Not needed with split molds.
- Balances: A balance or scale of at least 25 lbs. capacity sensitive to 4.5 g (0.01 lbs.), and a balance of at least 1,000 g capacity sensitive to 0.1 g, or other suitable scales or balances.
- Drying Equipment: An oven, hot plate, stove, or other device for heating and drying the sample uniformly and as rapidly as possible without damaging the material. The drying pan should be large enough to permit manipulation of material without loss by spilling.
- Straightedge: A steel straightedge 12 inches in length and having one beveled edge.
- Sieves: Standard 8-inch diameter sieves. Sizes 50 mm (2-inch), 19.0 mm (3/4-inch) and 4.75 mm (No. 4).
- Mixing Tools: Miscellaneous tools such as mixing pan, spoon, trowel, spatula, knife, etc.

### 8-55.1.3 Sample

1. If the soil sample is damp when received from the field, dry it until enough moisture has been lost so that it becomes friable under a trowel. Drying may be in air or by heating, but the temperature of the sample should not exceed about 60ºC (140ºF). Then thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.
2. Select a representative portion of the sample, completely dry it and determine the percentage retained on the 4.75 mm (No. 4) sieve. This value will be needed for comparison with the amount of R-4.75 mm (No. 4) material present in field density tests.
3. Select a representative sample, weighing approximately 14 lbs., or more, of the soil prepared as described in Step 1 above. Sieve it over the 50 mm (2-inch) and 19.0 mm (3/4-inch) sieves. Discard the coarse material retained on the 50 mm (2-inch) sieve. Weigh the material passing the 50 mm (2-inch) sieve and retained on the 19.0 mm (3/4-inch) sieve, and replace it with an equal weight of material passing the 19.0 mm (3/4-inch) sieve and retained on the 4.75 mm (No. 4) sieve. Take the material for replacement from the remaining portion of the sample.

### 8-55.1.4 Procedure

1. Thoroughly mix the selected representative sample with sufficient water to dampen it to a moisture content that is sufficiently below the optimum moisture content to form an adequate relationship to succeeding points.
2. Form a specimen by compacting the prepared soil in the 101 mm (4-inch) mold (with collar attached) in three equal layers to give a total compacted depth of about 127 mm (5-inches). Compact each layer by 25 uniformly distributed blows from the rammer, dropping free from a height of 305 mm (12-inches) above the elevation of the soil. During compaction, the mold must rest on a uniform, rigid foundation. Following compaction, remove the extension collar and carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material must be patched with smaller size material. Weigh the mold and moist soil. Multiply the weight of the compacted specimen and mold, minus the weight of the mold, by 1060, and record the result as the wet density in kilograms per cubic meters (or by 30 and record the wet density as pounds per cubic foot of compacted soil).
3. Remove the material from the mold and slice vertically through the center. Take a representative sample of the material from one of the cut faces, weigh immediately, dry to constant weight and determine the moisture content. The moisture content sample must weigh not less than 500 g.
4. Thoroughly break up the remainder of the material until it will pass a 19.0 mm (3/4-inch) sieve and 90% of the soil aggregations will pass a 4.75 mm (No. 4) sieve, as judged by the eye. Add water in sufficient amounts to increase

the moisture content of the soil sample by one or two percentage points, and repeat the above compaction and moisture determination procedures. Continue this series of determinations until there is either a decrease or no change in the wet weight per cubic meter or per cubic foot of the compacted soil.

This procedure has been found satisfactory in most cases. However, in instances where the soil material is fragile in character and will reduce significantly in grain size due to repeated compaction, and in cases where the soil is a heavy textured clayey material into which it is difficult to incorporate water, a separate and new sample must be used in each compaction test. In these cases, separate samples must be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture contents selected must bracket the optimum moisture content, thus providing samples which, when compacted, will increase in weight to the maximum density and then decrease in weight. The samples of soil-water mixtures must be placed in covered containers and allowed to stand for not less than 12 hours before making the moisture-density test. This soaking permits time for uniform dispersion of the moisture throughout the sample before compaction.

#### 8-55.1.5 Calculations

Calculate the moisture content and the dry weight of the soil as compacted for each trial, as follows:

$$W = \frac{W_1}{w + 100} X\ 100$$

$$w = A - \frac{B}{B - C} X\ 100$$

Where:

w = percentage of moisture in the specimen, based on oven-dry weight of soil;

A = weight of container and wet soil;

B = weight of container and dry soil;

C = weight of container;

W = dry weight, in pounds per cubic foot of compacted soil;

$W^1$ = wet weight, in pounds per cubic foot of compacted soil.

#### 8-55.1.6 Plotting Moisture-Density Relationship

The above calculations must be made to determine the moisture content and corresponding oven-dry weight per cubic foot (density) for each of the compacted soil samples. The densities of the soil must be plotted as ordinates (y axis) and corresponding moisture contents as abscissas (x axis).

##### 8-55.1.6.1 Optimum Moisture Content

When the densities and corresponding moisture contents for the soil have been determined and plotted, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve is termed the "optimum moisture content" of the soil under the above compaction.

##### 8-55.1.6.2 Maximum Density

The oven-dry weight per cubic foot of the soil at optimum moisture content is termed "maximum density" under the above compaction.

### 8-55.2 Field Determination of Density for Embankments

#### 8-55.2.1 Embankments

Embankments are constructed under the requirements of standard compaction unless special compaction is required. When special compaction is required, the field density requirements can be checked by the nuclear method.

#### 8-55.2.2 Compliance Testing

When special compaction is required under the contract, sufficient check tests of in-place density must be made to provide reasonable assurance of specification compliance within rates of frequency. The rates of density testing described below are a minimum for extremes of ideal and worst conditions expected to be encountered in embankment construction (Conditions I and II), and a minimum for backfilling operations (Condition III). Within these extremes, the engineer will select a rate of testing frequency using the exemplified conditions as guide. Also, generally more frequent testing will be done in the early stages of the work and reduced as conditions become stabilized and operations routine.

#### 8-55.2.2.1 Condition I

One test per 20,000 C.Y. minimum. Condition I is defined by uniformity of soil type, moisture content, and operations of hauling, placing, and compacting; a relatively flat moisture density curve indicating little effect on density by appreciable variation in moisture content; visual evidence of adequate and uniform support under heavy construction equipment; and consistently satisfactory results of previous testing at great frequency.

#### 8-55.2.2.2 Condition II

One test per 20,000 C.Y. Condition II is defined by a substantial variation in soil type or moisture content in short distances or erratic operations of hauling, placing or compacting; a moisture-density relationship resulting in a steep-slope curve; visual evidence of sponginess or variable support under heavy construction equipment; and a previous test indicating frequent unsatisfactory compaction.

#### 8-55.2.2.3 Condition III

Condition III is defined by short confined backfill areas.

- Abutment backfill - 1 test per structure minimum.
- Mainline culverts - 1 test per 3 culverts minimum.

#### 8-55.2.2.4 Information Testing

Standard spec 207.3.6.2 does not contain a numerical density requirement. It is desirable, however that sufficient testing be done on all projects so that data will be made available to indicate the approximate level of compaction that is being achieved statewide as related to the normal variables of contract, inspection personnel, soil types, weather conditions, and other pertinent factors.

Therefore, on all projects on which "Standard Compaction" is a requirement, a program of random testing for density, as related to the maximum density determined under AASHTO Designation: T 99, Method C, should be performed.

At least three tests will be made on each major soil type as sands, silts, clays, sandy clay, silty clay, etc. If the volume of soils exceeds 500,000 cubic yards, three tests will be run for each 500,000 cubic yards and three tests for each total or partial increment exceeding this. Where smaller volumes are involved, additional tests are valuable but are not required.

Tests will be made by nuclear methods. These tests should be made on a random basis. Be certain that compaction for the lift is completed before testing. Each in-place density test should be correlated to the proper maximum density and optimum moisture test for the soil tested. This means that AASHTO Designation: T 99 must be made on all principal soil types for the project.

The data attained should be reported to the Geotechnical Section of Technical Services. The field density should be reported as a percent of maximum density and moisture as a percent of optimum moisture. Note the depth below grade, for this affects consideration as to whether densities should be compared to 95% or 90% compaction depending on depth below grade. Also note if densities are corrected for R-4.75 mm (R-4) fractions.