# HCMTCB SOILS CERTIFICATION

# KEY ELEMENTS LIST

Release Date: September 15, 2008

**AASHTO T 87** Dry Preparation of Disturbed Soil and Soil Aggregate Samples for Test

## KEY ELEMENTS

### Apparatus

1. Any suitable drying device is acceptable provided the temperature does not exceed 60°C (140°F)
2. A series of sieves commonly used for soil sample preparation for various tests include:

    19.00 mm (3/4 in.)
    4.75 mm (No. 4)
    2.00 mm (No. 10)
    0.425 mm (No. 40)

3. Pulverizing equipment should include a mortar and rubber-covered pestle or a mechanical device with a power-driven rubber-covered muller.
4. Sample sizes should be adjusted to required values for individual tests using riffle samplers, sample splitter, or quartering cloth.

### Sample Size

1. The amount of soil required to perform individual tests include:
    a. Particle Size Analysis of Soils (T 88)

        Portion of soil sample smaller than 2.00 mm (No. 10) sieve

        110 g for sandy soils
        60 g for silty or clayey soils

        (Note: The recommended test specimen sizes are for hydrometer analysis. Without the hydrometer analysis, larger test specimens may be used for convenience.)

        Portion of soil sample larger than 4.75 mm (No. 4) or 2.00 mm (No. 10) sieve

        Sample size is a function of largest particle size (see table in ¶ 3.1.1)

    b. Percent finer than 75 μm (No. 200) (T 11)

        100 g or more of whole (unprocessed) Liquid Limit/ Plastic Limit sample, oven-dried (110º ± 5ºC [230º ± 9ºF])

    c. Liquid Limit (T 89)

        100 g of minus 0.425 mm (No. 40) material

    d. Plastic Limit (T 90)

        20 g of minus 0.425 mm (No. 40) material

    e. Compaction (T 99)

        Sample size is a function of the method (A, B, C, D) selected (see ¶ 3 of T 99)

### Sample Preparation

1. Thoroughly dry soil sample in air or drying device at a temperature not to exceed 60°C (140°F)
2. Pulverize soil sample using acceptable pulverizing equipment

3. When pulverizing soil samples, the equipment should break up the aggregations (clods) of soil particles without reducing the size of the individual soil grains
4. Adjust soil sample size to individual test requirements using appropriate sieves

**AASHTO T 248** Reducing Samples of Aggregate to Testing Size

## KEY ELEMENTS

### Apparatus

1. Method A. A sample splitter with an equal number of equal width chutes but not less than a total of 8 for coarse aggregates or 12 for fine aggregates or fine-grained soils, which discharge alternately to each side of the splitter.

2. Method B. A scoop, shovel, or trowel; a quartering cloth (canvas); a broom or brush.

3. Method C. A scoop, shovel, or trowel for mixing and a small scoop or spoon for sampling.

### Sample Size

1. Samples of aggregate obtained in the field shall be taken in accordance with T 2 or as required by individual test methods.

### Procedure

1. Selection of Method A, B, or C is dependent on aggregate size, coarse or fine, and the amount of moisture present in the test sample. See section 5. Method A, B, or C can be used for fine aggregate and Method A or B can be used for coarse aggregate.

2. Method A. Mechanical Splitter, see section 8

3. Method B. Quartering, see section 10

3. Method C. Miniature Stockpile Sampling, see section 12

**AASHTO T 11** Material Finer Than 75-mm (No. 200) Sieve in Mineral Aggregates by Washing

## KEY ELEMENTS

### Apparatus

1. A balance with sufficient capacity and readable to 0.1% of the soil sample mass accuracy.
2. A nest of two sieves, the lower being a 75-mm (No. 200) sieve and the upper being a sieve with openings in the range of 2.36 mm (No. 8) to 1.18 mm (No. 16) should be used.
3. An oven of sufficient size and capable of maintaining a uniform temperature of 110° ±5°C (230° ±9°F) shall be used.
4. Any acceptable wetting/dispersing agent that will promote fine soil particle separation.

### Sample Size

1. The minimum soil sample size is a function of the nominal maximum particle size, as follows:

| Maximum Particle Size | Minimum Sample Size, g |
|---|---|
| 2.36 mm (No. 8) | 100 |
| 4.75 mm (No. 4) | 500 |
| 9.5 mm (3/8 in.) | 1000 |
| 19.0 mm (3/4 in.) | 2500 |
| 37.5 mm (1-1/2 in.) | 5000 |

### Procedure

1. Procedure A involves soaking and washing the predried soil sample in plain water.
2. Procedure B involves soaking and washing the predried soil sample in water with a wetting agent.
3. The procedure consists of drying to a constant weight a selected representative sample and determining its dry mass (B in g). The soil sample is soaked, agitated, wet sieved, and the "washed" aggregate is dried and its dry mass determined (C in g). The material finer than the 75-mm (No. 200) sieve (A) is calculated by:

$$A = \frac{B - C}{D} \times 100$$

## KEY ELEMENTS

### Apparatus

1. A balance with sufficient capacity and readable to 0.1% of the soil sample mass accuracy.

2. An oven of sufficient size and capable of maintaining a uniform temperature of 110° ±5°C (230° ±9°F) shall be used.

3. A mechanically operated stirring apparatus capable of a speed not less than 10000 rpm with stirring paddle and dispersion cup.

4. A nest of sieves (minimum 8) with the following sieves normally used:

| Standard Designation (mm) | Alternate Designation |
|---|---|
| 75 | 3 in. |
| 50 | 2 in. |
| 25 | 1 in. |
| 9.5 | 3/8 in. |
| 4.75 | No. 4 |
| 2.00 | No. 10 |
| 0.425 | No. 40 |
| 0.075 | No. 200 |

5. A dispersing agent consisting of a solution of sodium hexametaphosphate (40 g of material in one liter of distilled water).

### Sample Size

1. For the portion retained on the 2.00-mm (No. 10) sieve, the minimum soil sample size required for the dry sieve analysis is a function of the nominal maximum particle size, as follows:

| Maximum Particle Size (mm) | (in.) | Minimum Sample Size (g) |
|---|---|---|
| 9.5 | (3/8) | 500 |
| 25 | (1) | 2000 |
| 50 | (2) | 4000 |
| 75 | (3) | 5000 |

2. For the portion passing the 2.00-mm (No. 10) sieve, the minimum sample size required for washing over the 0.075-mm (No. 200) sieve is 100 g for sandy soils and 50 g for silty or clayey soils.

3. The minimum sample size required for hygroscopic moisture determination is 10 g of minus 2.00-mm (No. 10) material.

**Procedure**

1. The sample prepared according to T 87 is separated on the 2.00-mm (No. 10) sieve to meet the above minimum sample size requirements.
2. The portion of the sample retained on the 2.00-mm (No. 10) sieve is separated using the coarser sieves listed above. The portion retained on each sieve is weighed and the mass recorded.

NOTE: With the hydrometer portion omitted, the remainder of the test method is a wet wash over the 0.075-mm (No. 200) sieve followed by a dry sieve analysis.

3. The hygroscopic moisture determination is conducted on the portion passing the 2.00-mm (No. 10) sieve.

4. The portion of the sample passing the 2.00-mm (No. 10) sieve is mixed with the dispersing agent, agitated, and washed over the 0.075-mm (No. 200) sieve. Intermediate sieve sizes may be used depending on the soil sample. The portion retained on the 0.075-mm (No. 200) sieve is dried, weighed, and the mass is recorded.

5. The dried portion retained on the 0.075-mm (No. 200) sieve is separated using finer sieves, typically the 0.425-mm (No. 40) sieve, although other fine sieves may be used (i.e., No. 20, 30, 50, 80, 100). The portion retained on each sieve is weighed and the mass recorded.

6. Accumulated values of recorded weights and percentages are calculated and may be plotted to obtain a grain size distribution curve.

**AASHTO T 89** Determining the Liquid Limit of Soils

## KEY ELEMENTS

### Apparatus

1. A liquid limit device, manually or mechanically operated, consistent with the dimensions and tolerances shown in Figure 1.
2. A grooving tool, curved preferred but flat (ASTM D 4318) is acceptable as an alternative, consistent with the dimensions and tolerances shown in Figure 1.
3. A balance with sufficient capacity and readable to 0.1% of the soil sample mass accuracy.
4. An oven of sufficient size and capable of maintaining a uniform temperature of 110° ± 5°C (230° ± 9°F) shall be used.
5. Miscellaneous items including porcelain dishes, spatulas, water containers, tare containers, and cleaning equipment (i.e., sponges, towels, paper towels, etc.).
6. Distilled or demineralized water.

### Adjustment

1. All adjustment screws, retaining pins and screws should be tight.
2. All surfaces in contact with the soil, contact between brass cup and cam, and point of impact of brass cup should be checked for wear.
3. Height of drop of the brass cup should be adjusted to 10.0 ± 0.2 mm.

### Sample Size

1. The liquid limit should be conducted on a representative sample consisting of 100 g of minus 0.425 mm (No. 40) material prepared as specified in T 87.

### Procedure

1. Method A is a 3-point determination of the liquid limit with individual data points falling into impact ranges of 25–35, 20–30, and 15–25 impacts.
2. Method B is a 1-point determination of the liquid limit with duplicate data points falling into an impact range of 22–28 impacts. Final calculation of the liquid limit requires the use of standardized factors (ODOT data card) or the nomograph shown in Figure 4.
3. Water contents for all test specimens are determined according to AASHTO T 265 and calculated as follows:

$$\text{Percent Moisture} = \frac{\text{Mass of Water}}{\text{Mass of Dried Soil}} \times 100$$

4. Method A requires the plotting of a flow curve (line) using the water content (abscissae) and number of impacts (ordinates, log scale) data. A best fit straight line is drawn through the data points and the water content at 25 impacts is defined as the liquid limit.
5. Never add dry soil to the liquid limit test specimen once the mixing of water and hydration of the soil particles have begun.
6. If the liquid limit test specimen is too wet (i.e., impact count below 15), dry the specimen by agitation with the spatula.

**AASHTO T 90** Determining the Plastic Limit and Plasticity Index of Soils

## KEY ELEMENTS

### Apparatus

1. A ground glass plate or piece of smooth unglazed paper on which to roll the soil sample.
2. A balance with sufficient capacity and readable to 0.1% of the soil sample mass accuracy.
3. An oven of sufficient size and capable of maintaining a uniform temperature of 110° ± 5°C (230° ± 9°F) shall be used.
4. Miscellaneous items including porcelain dishes, spatulas, water containers, tare containers, and cleaning equipment (i.e., sponges, towels, paper towels, etc.).
5. Distilled or demineralized water.

### Sample Size

1. The plastic limit shall be conducted on a representative sample consisting of 20 g of minus 0.425 mm (No. 40) material prepared as specified in T 87.

### Procedure

1. Mix soil and water until a firm consistent mass is obtained, take a small portion of the test specimen and roll on the glass plate with the fingers until the thread begins to crumble at 3.2 mm (1/8 in.). Several trials should be conducted to obtain the required water content sample.
2. Water contents for all test specimens are determined according to AASHTO T 265 and calculated as follows:

$$\text{Percent Moisture} = \frac{\text{Mass of Water}}{\text{Mass of Dried Soil}} \times 100$$

3. Never add dry soil to the plastic limit test specimen once the mixing of water and hydration of the soil particles have begun.
4. If the plastic limit test specimen is too wet, dry the specimen by manipulation with the hand.
5. Calculate the plasticity index of a soil as the difference between its liquid limit and plastic limit:

Plasticity Index = Liquid Limit – Plastic Limit

6. When the liquid limit or plastic limit cannot be determined, report the plasticity index as NP (nonplastic).
7. When the plastic limit is equal to or greater than the liquid limit, report the plasticity index as NP (nonplastic).

**AASHTO M 145** Classification of Soil and Soil-Aggregate Mixtures for Highway Construction Purposes (AASHTO Soil Classification System)

## KEY ELEMENTS

1. The AASHTO soil classification system classifies soils into seven groups based on particle size distribution, liquid limit, and plasticity index. Evaluation of soils within each group is made by means of a "Group Index" (GI) which is an empirical correlation based on percent minus No. 200 sieve, liquid limit, and plasticity index. A description of the various groups within the system is presented in the following:

a. **Granular Materials.** Containing 35% or less passing 0.075-mm (No. 200) sieve, Note 1.

**Group A-1:** The typical material of this group is a well-graded mixture of stone fragments or gravel, coarse sand, fine sand, and a nonplastic or feebly plastic soil binder. However, this group includes also stone fragments, gravel, coarse sand, volcanic cinders, etc., without soil binder.

**Subgroup A-1-a** includes those materials consisting predominantly of stone fragments or gravel, either with or without a well-graded binder of fine material.

**Subgroup A-1-b** includes those materials consisting predominantly of coarse sand either with or without a well-graded soil binder.

**Group A-3:** The typical material of this group is fine beach sand or fine desert blow sand without siIty or clay fines or with a very small amount of nonplastic silt. The group includes also stream-deposited mixtures of poorly-graded fine sand and limited amounts of coarse sand and gravel.

**Group A-2:** This group includes a wide variety of "granular" materials that are borderline between the materials that fall into Groups A-1 and A-3, and silt-clay materials of Groups A-4, A-5, A-6, and A-7. It includes all materials containing 35% or less passing the 0.075- mm sieve which cannot be classified as A-1 or A-3, due to fines content or plasticity or both, in excess of the limitations for those groups.

**Subgroups A-2-4 and A-2-5** include various granular materials containing 35% or less passing the 0.075 mm sieve and with a minus 0.425 mm (No. 40) portion having the characteristics of the A-4 and A-5 groups. These groups include such materials as gravel and coarse sand with silt contents or plasticity indexes in excess of the limitations of group A-1, and fine sand with nonplastic silt contents in excess of the limitations of Group A-3.

**Subgroups A-2-6 and A-2-7** include materials similar to those described under Subgroups A-2-4 and A-2-5 except that the fine portion contains plastic clay having the characteristics of the A-6 or A-7 group.

Note 1: Classification of materials in the various groups applies only to the fraction passing the 75-mm sieve. Therefore, any specification regarding the use of A-1, A-2, or A-3 materials in construction should state whether boulders (retained on 3-in. sieve) are permitted.

b. **Silt-Clay Materials.** Containing more than 35% passing the 0.075-mm sieve.

**Group A-4:** The typical material of this group is a nonplastic or moderately plastic silty soil usually having the 75% or more passing the 0.075 mm sieve. The group includes also mixtures of fine silty soil and up to 64% of sand and gravel retained on the 0.075 mm sieve.

**Group A-5**: The typical material of this group is similar to that described under Group A-4, except that it is usually of diatomaceous or micaceous character and may be highly elastic as indicated by the high liquid limit.

**Group A-6**: The typical material of this group is a plastic clay soil usually having 75% or more passing the 0.075-mm sieve. The group includes also mixtures of fine clayey soil and up to 64% of sand and gravel retained on the 0.075-mm sieve. Materials of this group usually have high volume change between wet and dry states.

**Group A-7**: The typical material of this group is similar to that described under Group A-6, except that it has high liquid limits characteristic of a A-5 group and may be elastic and subject to high volume change.

**Subgroup A-7-5** includes those materials with moderate plasticity indexes in relation to liquid limit and which may be highly elastic and subject to considerable volume change.

**Subgroup A-7-6** includes those materials with high plasticity indexes in relation to liquid limit and which are subject to extremely high volume change.

Note 2: Highly organic soils (peat or muck) may be classified as an A-8 group. Classification of these materials is based on visual inspection, and is not dependent on percentage passing the 0.075-mm (No. 200) sieve, liquid limit, or plasticity index. The material is composed primarily of partially decayed organic matter, generally has a fibrous texture, dark brown or black color, and odor of decay. These organic materials are unsuitable for use in embankments and subgrades. They are highly compressible and have low strength.

## UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)
## (ASTM D 2487)

The USCS classifies soils into six major soil types (gravel, sand, silt, clay, organic, peat) based on particle size distribution, liquid limit, and plasticity index. The classification system uses a two-symbol designation in which the first symbol represents soil type and the second symbol describes the condition of the soil type with respect to gradation or plasticity of the soil. The soil type and subgroup symbols used in USCS are:

| | Soil Type | Symbol | Subgroup | Symbol |
|---|---|---|---|---|
| **Coarse-Grained** | Gravel | G | Well Graded | W |
| | | | Poorly Graded | P |
| | | | Silty | M |
| | Sand | S | Clayey | C |
| **Fine-Grained** | Silt | M | LL < 50% | L |
| | Clay | C | LL > 50% | H |
| | Organic | O | | |
| | Peat | Pt | | |

The major soil type/subgroup symbol combinations used in the USCS are:

1. Gravels or sands are

   GW, GP, SW, or SP

   if less that 5% passes the No. 200 sieve; G = gravel; S = sand;
   W = well-graded; P = poorly-graded. The well- or poorly-graded designations depend on $C_u$ and $C_z$ as defined in the accompanying table.
2. Gravels and sands are

   GM, GC, SM, or SC

   if more than 12% passes the No. 200 sieve; M = silt; C = clay. The silt or clay designation is determined by performing the liquid and plastic limits on the minus No. 40 fraction and using the A-line chart.

3. Gravels and sands are

   GW-GC SW-SC GP-GC SP-SC GW-GM SW-SM GP-GM SP-SM

   if between 5 and 12% of the material passes the No. 200 sieve.

4. Fine-grained soils (more than 50% passes the No. 200 sieve) are

   ML, OL, or CL

   if the liquid limits are less than 50%; M = silt; O = organic soils; C = clay.

5. Fine-grained soils are

   MH, OH, CH

   if the liquid limits are greater than 50%; H = higher than 50%.

**AASHTO T 99** The Moisture-Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop

## KEY ELEMENTS

### Apparatus

1. A compaction mold, 101.6 mm (4 in.) or 152.4 mm (6 in.) depending on method selected, consistent with the dimensions and tolerances shown in Figure 1 or 2, respectively.

1a. Any mold more than 50 percent out of tolerance should be removed from testing service.

2. A rammer, manually or mechanically operated, consistent with the weight, dimensions, and tolerances given in paragraph 2.2.1 or 2.2.2.

3. A balance with sufficient capacity and readable to 0.1 percent of the soil sample mass accuracy.

4. An oven of sufficient size and capable of maintaining a uniform temperature of 110 ± 5°C (230 ± 9°F) shall be used.

5. A sample extruder to remove the compacted soil specimen from the mold.

6. Miscellaneous items including mixing pans, mixing tools, straightedge, trimming knives, water containers, tare containers, and cleaning equipment.

### Sample Size

1. The mass and maximum particle size of the soil sample for the compaction test depend on the method selected as follows:

| | Mold Size | Max. Particle Size | Sample Size |
|---|---|---|---|
| Method A | 101.6 mm (4 in.) | 4.75 mm (No. 4) | 3 kg (7 lb) |
| Method B | 152.4 mm (6 in.) | 4.75 mm (No. 4) | 7 kg (16 lb) |
| Method C | 101.6 mm (4 in.) | 19.0 mm (3/4 in.) | 5 kg (11 lb) |
| Method D | 152.4 mm (6 in.) | 19.0 mm (3/4 in.) | 11 kg (25 lb) |

### Procedure

1. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum.

2. Compact the soil specimen in three uniform layers with 25 or 56 impacts per layer, depending on method selected.

3. Mold, soil, and compaction rammer should rest on a dense, uniform, rigid and stable base (i.e., a mass of concrete weighing 90 kg [200 lb] or a stable concrete floor).

4. After compaction, remove the collar, strike off the soil extending above the edge of the mold, and determine the mass of the soil and mold. If the compacted soil extends more than 12.7 mm (1/2

in.) above the edge of the mold or if depressions from the compaction rammer are evident after striking off the soil, the compaction specimen should be removed without weighing and the compaction point rerun.

5. After extruding the compaction specimen, cut the specimen along the long axis and collect the water content sample from a slice over the entire cut surface, which represents all three layers of the specimen.

6. Thoroughly break up the remainder of the test specimen and return it to the test sample, add the next increment of water ($\approx$ 2 to 2.5%), mix thoroughly, and repeat the compaction process at the new water content.

7. If the soil is clayey, use a separate soil specimen for each compaction point with the soil specimen and the selected amount of water equilibrating for at least 12 hours.

8. Calculate the wet unit mass (wet density), water content, and dry unit mass (dry density) according to paragraph 11.

9. Use water content and dry unit mass (dry density) data to plot the moisture-density relation-ship and define the optimum moisture content and maximum dry density from the peak of the compaction curve.

**AASHTO T 180** Moisture-Density Relations of Soils Using a 4.54-Kg (10-lb) Rammer and a 457-mm (18-in.) Drop

## KEY ELEMENTS

### Apparatus

1. A compaction mold, 101.6 mm (4 in.) or 152.4 mm (6 in.), depending on method selected, consistent with the dimensions and tolerances shown in Figure 1 or 2, respectively.

1a. Any mold more than 50% out of tolerance should be removed from testing service.

1b. The volume of the mold should be calibrated in accordance with T 19/T 19M (Section 8).

2. A rammer, manually or mechanically operated, consistent with weight, dimensions, and tolerances given in ¶ 3.2.1 or 3.2.2.

3. A balance with sufficient capacity and readable to 0.1% of the soil sample mass accuracy.

4. An oven of sufficient size and capable of maintaining a uniform temperature of 110° ± 5°C (230° ± 9°F) shall be used.

5. A sample extruder to remove the compacted soil specimen from the mold.

6. Miscellaneous items including mixing pans, mixing tools, straightedge, trimming knives, water containers, tare containers, and cleaning equipment.

### Sample Size

1. The mass and maximum particle size of the soil sample for the compaction test depend on the method selected as follows:

| | Mold Size | Max. Particle Size | Sample Size |
|---|---|---|---|
| Method A | 101.6 mm (4 in.) | 4.75 mm (No. 4) | 3 kg (7 lb) |
| Method B | 152.4 mm (6 in.) | 4.75 mm (No. 4) | 7 kg (16 lb) |
| Method C | 101.6 mm (4 in.) | 19.0 mm (3/4 in.) | 5 kg (11 lb) |
| Method D | 152.4 mm (6 in.) | 19.0 mm (3/4 in.) | 11 kg (25 lb) |

2. This test method applies to soil mixtures with 40% or less retained on the 4.75 mm (No. 4) sieve, when Method A or B is used; and 30% or less retained on the 19.0 mm (3/4 in.) sieve, when Method C or D is used. Material retained on these sieves is defined as oversized particles (coarse particles).

3. If the compaction test sample contains oversize particles and the test sample is used for field density control, corrections must be made according to T 224 (Correction for Coarse Particles in the Soil Compaction Test) to properly compare the field density with the laboratory compacted

(reference) test sample. If no minimum percentage of coarse particles is specified, corrections shall be applied to compaction test samples with more than 5% (by weight) of oversize particles.

4. If the specified maximum oversized tolerances are exceeded, other methods of establishing compaction control must be used, i.e., test fills.

**Procedure**

1. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four percentage points below optimum.
2. Compact the soil specimen in three uniform layers with 25 or 56 impacts per layer, depending on method selected.
3. Mold, soil, and compaction rammer should rest on a dense, uniform, rigid, and stable base (i.e., a mass of concrete weighing 90 kg [200 lb] or a stable concrete floor).
4. After compaction, remove the collar, strike off the soil extending above the edge of the mold, and determine the mass of the soil and mold. If the compacted soil extends more than 12.7 mm (1/2 in.) above the edge of the mold or if depressions from the compaction rammer are evident after striking off the soil, the compaction specimen should be removed without weighing and the compaction point rerun.
5. After extruding the compaction specimen, cut the specimen along the long axis and collect the water content sample from a slice over the entire cut surface, which represents all three layers of the specimen.
6. Thoroughly break up the remainder of the test specimen and return it to the test sample, add the next increment of water (≈2 to 2.5%), mix thoroughly, and repeat the compaction process at the new water content.
7. If the soil is clayey, use a separate soil specimen for each compaction point with the soil specimen and the selected amount of water equilibrating for at least 12 hours.
8. Calculate the wet unit mass (wet density), water content, and dry unit mass (dry density) according to ¶ 12.
9. Use water content and dry unit mass (dry density) data to plot the moisture-density relationship and define the optimum moisture content and maximum dry density from the peak of the compaction curve.

**AASHTO T 224** Correction for Coarse Particles in the Soil Compaction Test

## KEY ELEMENTS

### Scope

1. This standard method describes a procedure for adjusting the dry densities of soil and soil aggregate mixtures to compensate for differing percentages of coarse (oversize) particles on either the 4.75-mm (No. 4) or 19.0-mm (3/4-in) sieve.

2. The standard method provides two methods for correcting dry densities:

   - laboratory to field dry density

   - field to laboratory dry density

   Comparisons are made between field dry densities and maximum dry densities determined by T 99 or T 180.

3. The standard method applies to:

   - soil-aggregate mixtures with 40% or less retained on the 4.75-mm (No. 4) sieve for method A or B of T 99 or T 180.

   - soil-aggregate mixtures with 30% or less retained on the 19.0-mm (3/4-in) sieve for method C or D of T 99 or T 180.

   The minimum percentage of oversize particles for application of the correction is 5%.

### Apparatus

"See AASHTO T 99 or T 180" (Paragraph 3)

### Procedure (Laboratory to Field Dry Density)

### Sample Size/Preparation

1. During sample preparation for the compaction test (T 99 or T 180) the following information needs to be collected in order to correct for oversize particles (laboratory to field, para. 4.1).

   - total mass ($M_{MT}$) of prepared (T 87) and reduced (T 248) soil sample.

   NOTE: Soil samples collected from the field for sample preparation and compaction testing should be at least twice as large as the minimum sample size requirements of T 99 or T 180.

NOTE: If the mass (weight) of the prepared compaction test specimen is less than the required minimum sample size, add an equal weight (e.g. equal to weight of oversize particles) of fine particles to the test specimen.

- total mass of ($M_{MF}$) of fine particles in soil sample (minus 4.75-mm (No. 4) sieve for method A or B or minus 19.0-mm (3/4-in) sieve for method C or D).

- total mass ($M_{MC}$) of oversize particles in soil sample (plus 4.75-mm (No. 4) sieve for method A or B or plus 19.0-mm (3/4-in) sieve for method C or D).

- residual moisture content for prepared soil sample of fine particles ($MC_{FR}$), oversize particles ($MC_{CR}$), and total sample ($MC_{TR}$).

NOTE: Express moisture content as decimal.

- Bulk Specific Gravity (BSG or $G_M$), dry-weight basis, of oversize particles (measure using T 85 or estimate based on aggregate type and experience or assume 2.60).

**Correction Procedure**

1. Using information collected during compaction test sample preparation calculate the following values to correct for oversize particles.

- $M_{DF} = \frac{M_{MF}}{1 + MC_{FR}}, \quad M_{DC} = \frac{M_{MC}}{1 + MC_{CR}}, \quad M_{DT} = \frac{M_{MT}}{1 + MC_{TR}}$

- $P_F = \frac{M_{DF}}{M_{DF} + M_{DC}} \times 100, \quad P_C = \frac{M_{DC}}{M_{DF} + M_{DC}} \times 100$

*$P_F$= % fine particles* *$P_C$= % coarse (oversize) particles*

2. Correct laboratory compaction test results for comparison with field dry density and moisture content.

- corrected moisture content, percent:

- $MC_{COR} = (MC_F \times P_F) + (MC_C \times P_C)$

*where: $MC_F$ = optimum moisture content from compaction test, decimal*
*$MC_C$ = moisture content of coarse particles (field condition), decimal*

- corrected dry density (unit weight) of total soil sample (e.g. fine+coarse particles)

- $D_{Dry} = \frac{100 D_F K}{D_F P_C + K P_F}$

*where:* $D_F$ *= maximum dry density (unit weight) from compaction test*
*K = 1000 x BSG* ($G_M$) *of coarse particles for* $Kg/m^3$
*K = 62.4 x BSG* ($G_M$) *of coarse particles for pcf*
*K = 9.81 x BSG*($G_M$) *of coarse particles for* $KN/m^3$

**Procedure (Field to Laboratory Dry Density)**

**Sample Size/Preparation**

1. During field compaction, the following information needs to be collected at a field density test site and on a field sample in order to correct for oversize particles (field to laboratory, para. 4.2).

   - total wet density of field compacted soil (D)

   - total mass of field sample ($M_{MT}$)

   - moisture content total field sample ($MC_T$)

   - moisture content of fine particles in field sample ($MC_F$)

   - moisture content of oversize particles in field sample ($MC_C$)

   - total mass of fine particles ($M_{MF}$)

   - total mass of oversize particles ($M_{MC}$)

**Correction Procedure**

1. Using information collected from a field density test and soil sample collected from the test site, calculate the following values to correct for oversize particles.

   - $M_{DF} = \frac{M_{MF}}{1 + MC_F}$, $M_{DC} = \frac{M_{MC}}{1 + MC_C}$, $M_{DT} = \frac{M_{MT}}{1 + MC_T}$

   - $P_F = \frac{M_{DF}}{M_{DF} + M_{DC}} \times 100$, $P_C = \frac{M_{DC}}{M_{DF} + M_{DC}} \times 100$

   $P_F$*= % fine particles* $P_C$*= % coarse (oversize) particles*

2. Calculate the dry density (unit weight) of the field sample:

- $D_d = \dfrac{D}{1 + MC_T}$

then calculate the adjusted dry density (unit weight) of the fine particles of the field sample:

- $D_{dF} = \dfrac{D_d P_F}{100 - \left( \dfrac{D_d P_C}{K} \right)}$

*where: K = 1000 x BSG($G_M$) of coarse particles for Kg/$m^3$*
*K = 62.4 x BSG ($G_M$) of coarse particles for pcf*
*K = 9.81 x BSG ($G_M$) of coarse particles for KN/$m^3$*

3. Compare $D_{dF}$ to maximum dry density (unit weight) from corresponding compaction test.

**AASHTO T 85** Specific Gravity and Absorption of Coarse Aggregate

## KEY ELEMENTS

### Apparatus

1. A balance with sufficient capacity and readable to 0.1% of the soil sample mass accuracy. The balance should be equipped with a suitable apparatus for suspending the sample container in water from the center of the weighing platform of the balance and a suspended apparatus (wire) to hold the sample container.
2. A wire basket sample container (with 3.35-mm (No. 6) or finer mesh) with a capacity of 4 to 7 L for 37.5-mm (1 ½ in) normal maximum aggregate size or smaller and a larger container as needed for testing larger aggregate sizes.
3. Water tank for complete immersion of sample container and aggregate sample while suspended below the balance, equipped with an overflow outlet for maintaining constant water level.
4. Sieves – 4.75-mm (No. 4) or other sizes as needed.
5. An oven of sufficient size and capable of maintaining a uniform temperature of $110^o \pm 5^o$ C ($230^o \pm 9^o$ F).

### Sample Size

1. Sample aggregate in accordance with AASHTO T 2.
2. Reduce aggregate sample to approximate quantity needed in accordance with the AASHTO T 248.
3. Discard all material passing a 4.75–mm (No. 4) sieve by dry sieving and thoroughly washing the reduced aggregate sample to remove dust and other coatings from the surface.
4. The minimum mass of test specimen is given below:

| Nominal Maximum Size, mm (in) | Minimum Mass of Test Sample, kg (lb) |
|---|---|
| 12.5 (½) or less | 2 (4.4) |
| 19.0 (¾) | 3 (6.6) |
| 25.0 (1) | 4 (8.8) |
| 37.5 (1½) | 5 (11) |
| 50 (2) | 8 (18) |
| 63 (2½) | 12 (26) |
| 75 (3) | 18 (40) |
| 90 (3½) | 25 (55) |
| 100 (4) | 40 (88) |
| 112 (4½) | 50 (110) |
| 125 (5) | 75 (165) |
| 150 (6) | 125 (276) |

Note discussion for testing large sized aggregate in separate size fractions.

**Procedure**

1. Dry aggregate test specimen to constant mass at $110^o \pm 5^o$ C ($230 \pm 9^o$ F), cool to room temperature (1-3 hours for test specimens of 37.5-mm (1½-in) nominal maximum size or smaller and longer for larger sized aggregates), then immerse the aggregate test specimen in water at room temperature for 15 to 19 hours.

2. Remove aggregate test specimen from water and roll in a large absorbent cloth until all visible films of water are removed. A moving stream of air may be used to assist in drying. Determine the mass (g) of the aggregate test specimen in the saturated-surface-dry condition (SSD). Record the mass as "B".

3. Immediately place the saturated-surface-dry aggregate test specimen in the sample container and immerse the sample container and sample in water at $23.0^o \pm 1.7^o$ ($73.4^o \pm 3^o$ F), taking care to remove all trapped air. Determine the net mass (g) of the immersed aggregate test specimen and record as "C".

4. Dry aggregate test specimen to constant mass at $110^o \pm 5^o$ C ($230^o \pm 9^o$ F), cool at room temperature to a temperature comfortable to handle and determine the mass (g) of the dry aggregate test specimen. Record the mass as "A".

**Calculations**

1. Bulk Specific Gravity $= \dfrac{A}{B-C}$

2. Bulk Specific Gravity (SSD) $= \dfrac{B}{B-C}$

3. Apparent Specific Gravity $= \dfrac{A}{A-C}$

4. Absorption $= \dfrac{B-A}{A} \; x \; 100$

**AASHTO T 310** In-Place Density and Moisture Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

## KEY ELEMENTS

### Apparatus

1. A Nuclear Density/Moisture Gauge consisting of: a sealed high energy gamma radiation source (i.e., cesium or radium), a gamma detector, a fast neutron source, and a slow neutron detector.

2. A Reference Standard for standardization of the equipment.

3. Site preparation equipment including a template for leveling the site and guiding the drive pin, a drive pin for hole preparation, hammer or slide driver, and pin extractor.

### Equipment Calibration

1. The Nuclear Density/Moisture Gauge should be calibrated at least once every 12 months and after any repair work. Calibration shall be in accordance with manufacturer's written procedures and conducted by the manufacturer, the user, or an independent vendor.

### Standardization

1. Standardization of the nuclear density/moisture gauge on the reference standard is required at the start of each day's use and a permanent record of these data maintained.

2. Standardization shall be performed with the equipment at least 10 m (30 ft) from any other nuclear density/moisture gauges and clear of any large masses of water or other items that might affect the reference counts.

3. Standard reference counts should be taken in the same environment as the actual measurement counts.

4. Use the manufacturer's recommended procedure for determining compliance with the gauge calibration curves (i.e., mean of four repetitive readings within set limits).

### Site Selection/Preparation

1. Selection of the in-place density and moisture content test site should be random, without any form of operator bias and referenced to station, offset, and elevation.

2. Select test site where the gauge will be at least 0.15 m (6 in.) away from any vertical projection.

3. Prepare the test site by removing all loose and disturbed material and additional material as necessary to expose the top of the material to be tested.

4. Prepare a horizontal area of sufficient size to accommodate the gauge by planing the area to a smooth surface to obtain maximum contact between the gauge and material being tested. Use native fines or fine sand to fill voids and smooth the surface.

**Procedure (Direct Transmission Method)**

1. Turn on gauge and allow it to stabilize according to the manufacturer's recommendation.

2. Take standard reference counts, as noted above.

3. Select and prepare site, as noted above.

4. Drive a hole into the material being tested with the drive pin approximately 0.05 m (2 in.) deeper than the desired measurement depth and extract the drive pin. Hole should be vertical and plumb (i.e., with aid of template).

5. Mark the footprint of the template to allow placement of the gauge over the test site/hole.

6. Place the gauge on the marked test site and extend the source rod to the desired test depth and assure contact between source rod and side of hole in the direction of the gamma measurement.

7. Secure and record one or more one-minute readings (i.e., wet density, dry density, moisture content, percent compaction.

**Interferences**

1. Note the influence of factors that may affect test results such as chemical composition, test site heterogeneity, surface texture, other radioactive sources, and proximity of construction-related equipment.

**AASHTO T 272** Family of Curves—One-Point Method

## KEY ELEMENTS

### Definitions

1. A family of curves is a group of typical soil moisture-density relationships determined using T 99, which reveal certain similarities and trends characteristic of the soil type and source (i.e., borrow pit(s) or cut section(s)).

### Procedure

1. A family of curves is developed by grouping and plotting moisture-density relationships for a given soil source by grain size distribution and plasticity characteristics.
2. A family of curves is used to check the quality of reference moisture-density relationships by running a 1-point compaction test using a sample from a field compacted layer, say adjacent to an in-place density test.
3. The sample is prepared at the field moisture content, compacted using T 99 procedures, and the results plotted on the family of curves. Adjacent relationships are used to plot an "average" moisture-density relationship which is then used to define an optimum moisture content and maximum dry density for the soil sample.