CHAPTER 1:

TEST DESCRIPTIONS

SOIL AND AGGREGATE COMPACTION

1.1 OVERVIEW OF TEST METHODS

1.1.1 MARTCP ROUNDING PROCEDURE, MARTCP METHOD SA-1.1

This method addresses rounding-off of numbers from test results and calculations.

1.1.2 AASHTO T 99 – THE MOISTURE-DENSITY RELATIONS OF SOILS USING A 2.5 kg (5.5 lb) RAMMER AND A 305 mm (12 inch) DROP

This is a laboratory run test that determines the maximum theoretical dry density of soils utilizing a 5.5 lb. hammer dropped at a height of 12 inches to compact layers of soil in a standard mold. The test is used to define the optimum level of soil or aggregate that can be compacted into a unit volume with a level of compactive energy that is similar to that obtained by standard construction equipment.

Fig 1.1 T 99/T 180 Test Apparatus

1.1.3 AASHTO T 180 – MOISTURE-DENSITY RELATIONS OF SOILS USING A 4.55 kg (10 lb) RAMMER AND A 457 mm (18 inch) DROP

This is a method of determining the maximum theoretical dry density of soils. This test differs from the procedure described in AASHTO T 99 in that a 10 lb. hammer is dropped at a height of 18 inches on layers of soil in a standard mold. This test is used to define the optimum amount of soil or aggregate that can be compacted in a unit volume when conditions require a higher level of compactive energy such as very high volumes of heavy vehicular traffic.

1.1.4 MARTCP NUCLEAR MOISTURE/DENSITY GAUGE PROCEDURE, MARTCP METHOD SA-1.2

The procedure defined in this manual has been adopted from procedures used by member states of this region. The nuclear gauge is widely accepted. It is a simple test to quickly determine the density and moisture content of soils and aggregates placed in roadway construction.

1.1.5 MARTCP PERCENT MOISTURE CONTENT PROCEDURE, MARTCP METHOD SA-1.3

The procedure defined in this manual has been adopted from procedures used by member states of this region. This procedure establishes a uniform test method for pan-drying soils and aggregate samples on the project. This procedure can prove highly beneficial when determining moisture contents of soil samples containing a large percentage of high plasticity clays compared to other test procedures.

1.2 DETAILED DESCRIPTION OF TEST METHODS

1.2.1 MARTCP ROUNDING PROCEDURE, MARTCP METHOD SA-1.1

This method addresses rounding-off of numbers from test results and calculations.

For questions involving significant figures and rounding-off of numbers, the policy for the region is defined below. In most instances, the individual state specifications and test procedures will define the level of accuracy needed for the test results.

If the number following the last number to be retained is less than 5, the last number to be retained is left unchanged and the numbers(s) following the last number to be retained is/are discarded.

If the number following the last number to be retained is larger than 5, increase the last number to be retained by 1 and discard the number(s) following the last number to be retained.

If the number following the last number to be retained is 5, and there are no numbers beyond 5, only zeros, the last number to be retained is increased by 1 if odd, or left unchanged if even, and the number(s) following the last number to be retained is/are discarded.

If the number(s) following the last number to be retained is 5 and there is/are number(s) following the 5, the last number to be retained is increased by one regardless of being odd or even. The number(s) following the last number to be retained is/are discarded.

1.2.2 DENSITY AND MOISTURE CONTENT OF SOIL AND SOIL/AGGREGATE IN-PLACE BY NUCLEAR METHODS (SHALLOW DEPTH) - MARTCP METHOD SA-1.2 (Ref. AASHTO METHODS T 310)

Density is defined as mass (weight) divided by volume and, for a given mass (weight), is a function of volume **(D = W/V)**. The more closely pressed together the individual particles of a quantity of material are, the more dense it is. The farther apart they are, separated by air spaces (voids), the less dense the material is. When the individual particles of the same mass (weight) of material are pressed tightly together (compacted), the mass (weight) takes up less volume than when the particles are farther apart. In order to ensure that the embankment, base course, or other earthwork structure will be strong enough to support its intended design load, it must be compacted, made dense. Most specifications will require that the field earthwork be compacted to a specified percent of a target density called maximum density. The nuclear gauge is one device that is used to determine if the earthwork in the field has met this requirement (in-place density). To determine the dry density of a soil in-place it is necessary to also determine the moisture content of the soil.

1.2.2.1 NUCLEAR GAUGE

The nuclear gauge is a portable instrument containing a radioactive source, electronics and rechargeable battery packs. The gauge uses radiation (a gamma source and a gamma detector) to obtain several different readings. These readings are then calculated to acquire a number for in-place or dry density for soils and soil-aggregate mixtures. Density readings for depths between 50mm and 300mm (2 in. and 12 in.) (depending upon the method used) can be determined.

1.2.2.2 SUMMARY OF TESTING

Since a density reading and a moisture reading are required to determine dry density, both values have to be determined. A separate radioactive source is necessary for each technique. The nuclear gauge may have a radioactive source at the tip of its probe or source rod and another source located in the body of the gauge. Some gauges may have both sources located in the probe. At the back of the gauge, at opposite ends from the probe are detector tubes (Geiger-Muller tubes). Once the test is underway, these detector tubes pick up or count the gamma rays that travel through the material to them and relay this count to the master controls inside the body of the gauge. A certain percentage of gamma rays emitted by the source is absorbed by the soil, a certain percentage is scattered in the material and a certain percentage will pass through the material. The detector counts the rays that pass through the material and this count is relayed to the master control, called a scaler, by means of electrical impulses. The number of rays counted depends on the density of the material. The higher the density of the material the lower the gamma ray count.

1.2.2.3 MOISTURE

The nuclear gauge uses a fast neutron source and a thermal neutron detector which determines the intensity of slow or moderated neutrons. Neutrons have an affinity for hydrogen. Hydrogen is an excellent material for slowing down neutrons. Moisture is determined by the relationship of nuclear count to mass of water per unit volume of soil. The more water that is present, the more hydrogen atoms that will be slowed down and reflected back to the detector tubes to be counted. The moisture content is used in conjunction with the density measurement to determine dry density.

1.2.2.4 DENSITY TESTING

Three methods for determining density are: Method A, or Backscatter mode, Method B, Direct Transmission, and Method C, Air Gap. The air gap method, which some older gauge models utilized, has now been antiquated by technology.

Each method uses a different test geometry (the geometric space of the test area changes) and should be used where appropriate. Generally, backscatter is used when the properties of the first few inches are concerned (such as density of hot mix asphalt), and direct transmission is used when the properties of 50 mm - 300 mm (2 in.-12 in.) are concerned (such as 150 mm [6 in.] lifts of compacted backfill).

1.2.2.5 DIRECT TRANSMISSION

To determine in-place density with a nuclear gauge, you will first prepare a smooth area on which to place the gauge. The guide plate can be used to smooth the test site and to check the surface to make sure the gauge will sit flush on the material. A small hole is formed through the layer or lift being tested. Place the gauge on the prepared area, in the same orientation as the guide plate, with the probe directly over the hole. Insert the probe into the hole and operate the gauge in accordance with the manufacturer’s instructions.

1.2.2.6 BACKSCATTER

To determine in-place density in the backscatter mode, perform the test in the same manner as described under Direct Transmission, with the exception of forming the hole and lowering the probe. Operate the gauge in backscatter mode in accordance with the manufacturer's instructions.

Special considerations are required when reporting density measurements as determined by the nuclear gauge. It should be noted that the volume of soil or soil-aggregate represented in the measurements is indeterminate and will vary with the source - detector geometry of the equipment used and with the characteristics of the material tested. In general, and with all other conditions constant, the more dense the material, the smaller the volume involved in the measurement. The density so determined is not necessarily the average density within the volume involved in the measurement. For the usual density conditions, the total count is largely determined by the upper 75 mm to 100 mm (3 to 4 inches) of soils and soil aggregates.

1.2.2.7 COMMON TESTING ERRORS

Test results may be affected by the following:

1) Soil chemical composition
2) Soil not homogenous
3) Equipment not calibrated properly
4) Surface texture
5) Testing to close to a vertical wall or other mass (e.g., cars, construction equipment, body of water, large pipe)
6) Groups of observers gathered too close to device during operation
7) Presence of asphaltic materials, recycled pcc, cement, lime, flyash, etc. in soil materials.

1.2.2.8 SAFETY

The device used for density testing is like any other tool you use on the job. It is there to make your job of taking accurate density readings easier and more efficient. It can be dangerous if used improperly. However, this device is different in that the danger it poses is invisible. Radiation poisoning is very serious. This is why taking proper safety precautions is so vital when dealing with this machine at any level. Safety rules are simple to follow and will cause you very little inconvenience. If you follow them correctly, the nuclear gauge will be one of the safest tools you use. There are two important facts to remember when working with nuclear gauges. One, the gauge is radioactive and, two, it is very expensive. It must always be handled carefully and treated with the utmost respect. It is important to take care of the nuclear gauge, but it is also important to take care of yourself while you are using it. You should not be afraid of radiation, but should have a healthy respect for it. By realizing the dangers involved, you will know the importance of following safety regulations carefully.

1.2.2.9 CLEANING

The nuclear gauge must be kept as clean as possible at all times. Dirt and dust from the field can build up and cause delicate mechanisms within the machine to malfunction. The device must be cleaned before and after use. When cleaning, put the source rod in the safe storage position. This safe position is obtained by making sure that the index rod is pulled up to the top position and that the trigger button is released. To clean the outside of the device, use mild soap and water on a damp cloth. Before use, wipe the bottom of the device with a long handled brush or equivalent to remove any dust and moisture. Turn the bottom away from you when doing this. Do the same when you are finished taking your reading. Make sure to clean off the standard block.

1.2.2.10 STANDARDIZATION OF GAUGE

Standardization of the gauge is required each day prior to usage, during the day, if required by state specifications, or whenever gauge readings are suspect. In order to check the standardization, the gauge must be turned on and warmed up prior to use according to the manufacturer's instructions (usually 5 minutes, although older models may require up to 20 minutes).

1. Make sure the bottom of the gauge and the top of the standard block are clean. The standard block must be the one assigned to the gauge.

2. Place the standard block a minimum of 3 m (10 feet) from any vertical object.

3. Place the gauge on the standard block. Make sure the gauge is sitting flush on the block.

4. Take at least four one-minute repetitive readings or a four minute count on the block at the settings recommended by the manufacturer. This constitutes one standardization check.

5. If the mean of four repetitive readings or one four-minute reading is outside the tolerance range from the reference standard value allowed by the state specifications, take another standardization check (four one-minute readings or one four-minute reading). If the second standardization check is outside the allowable tolerance, the stability and drift should be checked by the manufacturer or as required by state specifications. If the second

standardization check is within the allowable tolerance, the gauge is in working order.

6. If the stability and drift tests show that the gauge is working properly, then a new reference standard should be established (by taking the average of at least 10 subsequent standard counts). If the stability and drift tests are not within the manufacturer's specified limits, the gauge should be repaired and recalibrated.

1.2.2.11 NOTE ABOUT TRENCH CORRECTION

When within 0.6 m (2 ft) of a wall in a trench, the gauge might read the hydrogen contained in the wall as well as the material under test. In such a situation use the trench correction program contained within the gauge or as specified by the state specifications. This program will instruct you to place the standard block in the trench and then take a second reference count which will be compared to the standard. At this point adjustments (if necessary) will be made or as specified by the state specifications.

1.2.2.12 PROCEDURE (METHOD A, BACKSCATTER)

1. Select a location where the gauge will be at least 0.6 m (2 feet) away from any vertical projection.

2. 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.

3. Plane an area of sufficient size to a smooth condition to obtain maximum contact between the gauge and the material being tested.

4. The maximum void space beneath the gauge shall not be more than 3 mm (1/8 in.). Use native fines or fine sand to fill these voids. This filled area should not equal more than 10% of the surface area beneath the gauge. Several trial seatings may be necessary in order to achieve maximum contact between the gauge and the material to be tested.

5. Operate the warmed up and standardized gauge in backscatter mode in accordance with the manufacturer's instructions. Take one or more one-minute readings, which will determine the in-place wet or dry density of the soil.

1.2.2.13 PROCEDURE (METHOD B, DIRECT TRANSMISSION)

1. Select a location where the gauge will be at least 0.6 m (2 feet) away from any vertical projection. Special considerations may apply when taking readings close to walls in a trench.

2. 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.

3. Plane an area of sufficient size to a smooth condition to obtain maximum contact between the gauge and the material being tested.

4. The maximum void space beneath the gauge shall not be more than 3 mm (1/8 in.). Use native fines or fine sand to fill these voids. This filled area should not equal more than 10% of the surface area beneath the gauge. Several trial seatings may be necessary in order to achieve maximum contact between the gauge and the material to be tested.

5. Make a hole perpendicular to the prepared surface using the guide plate and drive rod. Stand on the plate while driving the rod. The hole should not cause the gauge to tilt from the plane of the prepared area. The hole must be (generally specified as 50 mm (2 inches)) deeper than the desired test depth. The source rod must not rest on the bottom of the hole.

6. Place the gauge over the hole and extend the probe into the hole to the depth required for the test. Seat the gauge firmly on the test site.

7. Pull gently on the gauge so that the probe will contact the side of the hole toward the center of the gauge. The probe must be in contact with the hole in order to take effective readings.

8. Operate the warmed up and standardized gauge in direct transmission mode in accordance with the manufacturer’s instructions. Make sure the source rod is locked in the desired position and the depth settings on the gauge corresponds to the source rod depth. Take one or more one-minute readings, which will determine the in-place wet or dry density of the soil. Operating a gauge in direct transmission mode is basically setting the probe at correct depth to determine the wet or dry density of the soil. The density gauge also measures moisture content of the area under test and can display an instantly converted dry density value for the test location. Gauges made by different manufacturers have similar, but distinct, user interfaces. Operators familiar

with the basics of nuclear density testing will probably be able to utilize any gauge style.

1.2.2.14 MOISTURE CONTENT PROCEDURE

Most gauges will measure the density and moisture at the same time. The unit will now display the unit weight of water measured. Pressing a control button on most gauges will result in the dry density being displayed automatically. The nuclear gauge reads hydrogen ions as water. It also can be affected by minerals or chemicals that are neutron absorbers (e.g., boron, cadmium). Because of this, the mineral composition of a soil may cause the moisture content determined by a nuclear gauge to be inaccurate. Since density and moisture content bear a direct relationship to each other, an inaccurate moisture content will yield an inaccurate density reading.

Fig. 1.2 Equipment for Field Moisture and Density Testing

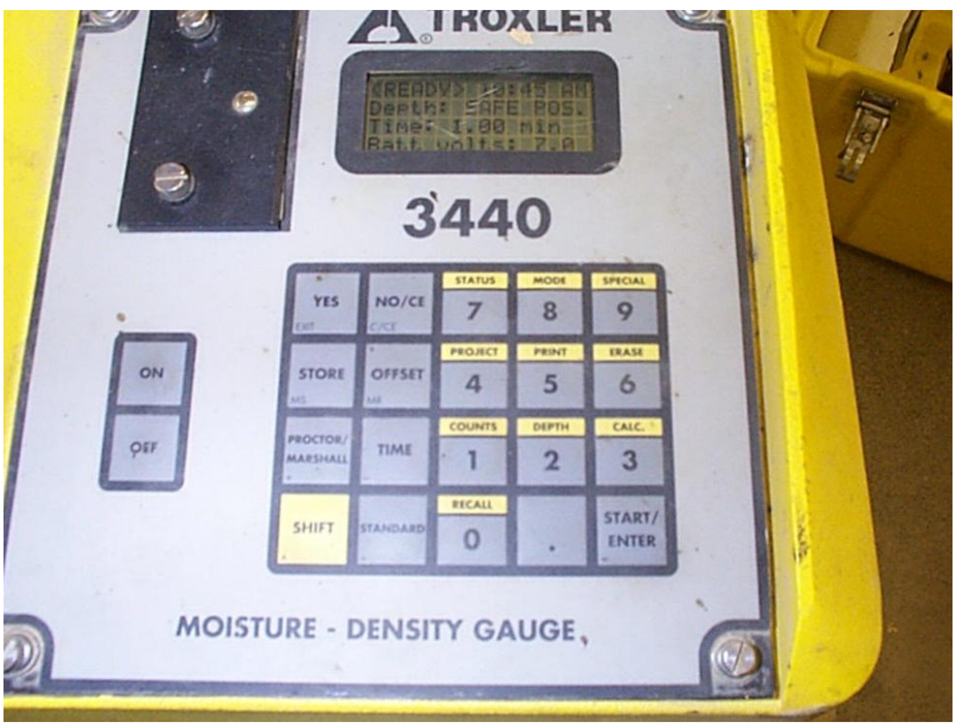


Fig. 1.3 Nuclear Moisture – Density Gauge Control Panel

Fig. 1.4 Nuclear Moisture – Density Gauge Display Panel

Fig. 1.5 Nuclear Gauge Calibration Block

Fig. 1.6 Nuclear Gauge Energy Source

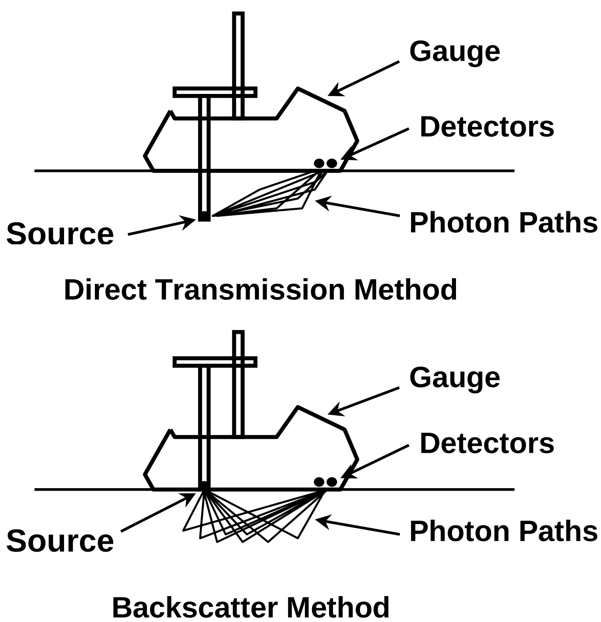


Fig. 1.7 Energy Paths – Direct Transmission and Backscatter Methods

Fig. 1.8 Nuclear Gauge on Calibration Block

Fig. 1.9 Nuclear Gauge Locked for Safety when Not in Use

1.2.3 FIELD MOISTURE CONTENT - DETERMINATION OF FIELD MOISTURE CONTENT BY DRYING, MARTCP METHOD SA-1.3

1.2.3.1 SCOPE:

The moisture content of a material influences its ability or inability to be excavated, consolidated, moved, screened, weighed, dried out, or reabsorbed. Moisture content calculations used for soils and aggregates are by convention figured as the mass of water driven out of the material through drying over the dry mass of the material. The moisture content is used to calculate a variety of properties, including density, plasticity, permeability, and more.

1.2.3.2 MATERIALS AND EQUIPMENT:

1. An electric hot plate or a gas burner
2. Scale or balance as required by state specifications.
3. Metal container, such as a large frying pan or equivalent.
4. Pointing trowel or large spoon.

1.2.3.3 TEST PROCEDURE:

1. Select a representative quantity of material based on the following table, or state specifications:

TABLE 1.1
Aggregate Moisture Content Test Sample Sizes

Nominal Maximum Size, mm (in.)	Minimum Sample Mass, kg (lbs.)
4.75 (No. 4)	0.5 (1.1)
9.5 (3/8)	1.5 (3.3)
12.5 (1/2)	2.0 (4.4)
19.0 (3/4)	3.0 (6.6)
25.0 (1)	4.0 (8.8)
37.5 (1 ½)	6.0 (13.2)
50.0 (2)	8.0 (17.6)
All soils moisture content sample sizes must be a minimum of 500 grams	

2. Weigh a clean, dry container

3. Place the sample in the container and weigh.

4. Place the container on the stove or hot plate and, while drying, mix the sample continuously to expedite drying and prevent burning of the aggregate. Always use a low flame or heat setting.

5. When the sample looks dry, remove it from the stove, cool, and weigh. Put sample back on the stove, continue drying for another two to three minutes, cool, and re-weigh. When a constant weight has been achieved, the sample is dry. Record the weight of the sample and the container. **Note:** Care must be taken to avoid losing any of the sample.

1.2.3.4 COMMON TESTING ERRORS

1. Spillage or loss of sample – loss of sample voids test results

2. Insufficient sample quantity (size) to yield accurate results

3. Overheating sample during drying process causing a loss of organic material or partial oxidation of other sample constituits

1.2.3.5 CALCULATIONS:

1. Moisture content of aggregate:

$$w,\% = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

Where:

$w,\%$ = percent moisture,
W_{wet} = weight of wet aggregate and container,
W_{dry} = weight of dry aggregate and container, and
W_{con} = weight of container.

1.2.3.6 REPORT:

Report the moisture content according to required state specifications.

1.2.4 AASHTO T 99/T 180 – MOISTURE-DENSITY RELATIONSHIP OF SOILS AND SOIL-AGGREGATE MIXTURES

1.2.4.1 SUMMARY OF PROCEDURE

This procedure determines the moisture-density relationship of soils and soil-aggregate mixtures. It is sometimes referred to as the standard proctor or the modified proctor test. A quantity of soil or soil and aggregate mixture is prepared at a determinable moisture content and compacted in a standard mold using a manual or mechanical rammer. The wet mass of this compacted sample is divided by the volume of the mold to determine the wet density. Moisture content testing on the material from the compacted mass is used to determine the dry density of this material. This procedure is repeated at varied moisture contents

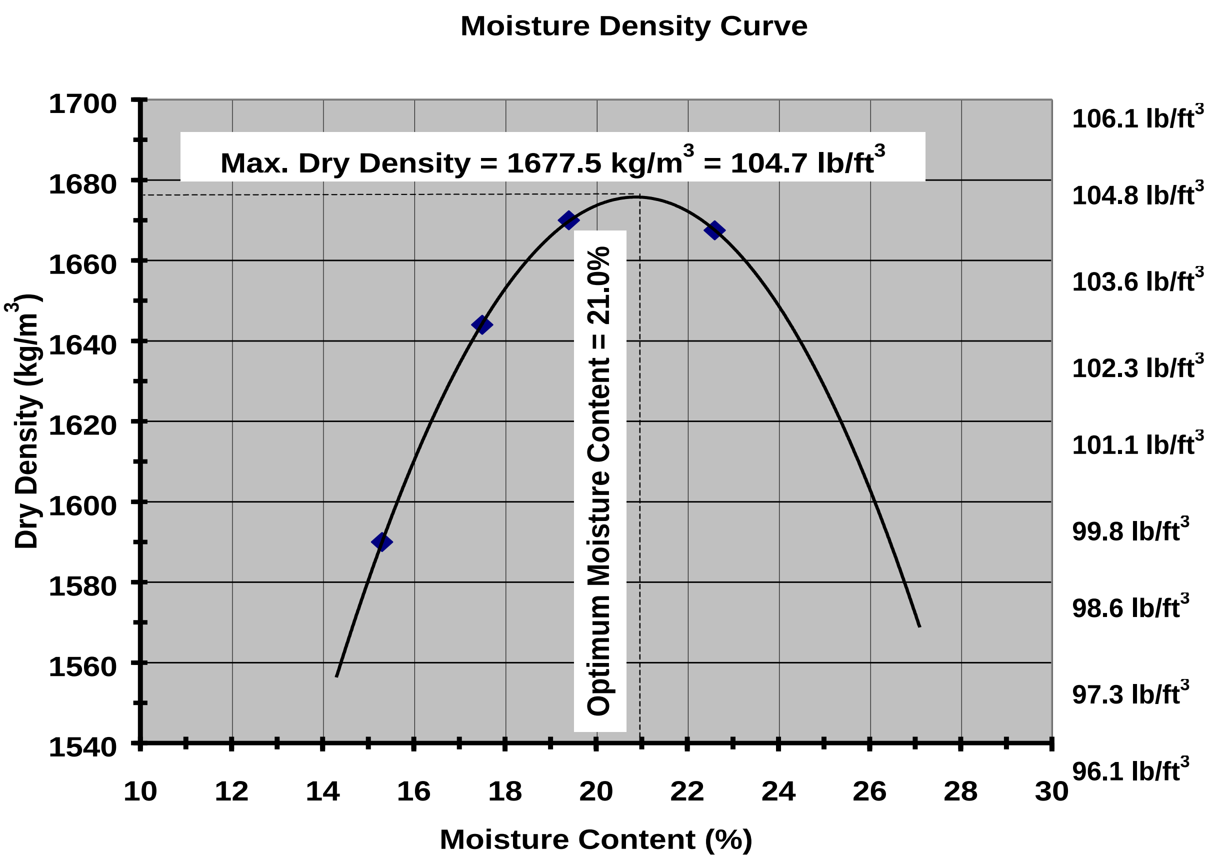


Fig. 1.10 Example Moisture-Density Curve

and the results are plotted on a graph as shown in Figure 1.10. A smooth line is drawn through the points to obtain a curve. The maximum density and optimum moisture content are determined by selecting a point at the peak of the curve.

1.2.4.2 TYPICAL TEST RESULTS

Typical maximum density and optimum moisture that can be expected as the result of a standard compaction test (AASHTO T 99) are given below (Table 1.2). A modified compaction test (AASHTO T 180) will yield 10 to 15 percent higher maximum densities and 20 to 30 percent lower optimum moisture due to the greater compactive effort used (as described in Table 1.3).

TABLE 1.2
Typical Values of Maximum Density and Optimum Moisture for Common Types of Soil (using AASHTO T 99)

Unified Soil Classification	Soil Description	Range of Max. Densities kg/m^3 (lbs/ft^3)	Range of Optimum Moisture (%)
CH	Highly Plastic Clays	1200-1680 (75-105)	19-36
CL	Silty Clays	1520-1920 (95-120)	12-24
ML	Silts and Clayey Silts	1520-1920 (95-120)	12-24
SC	Clayey Sands	1680-2000 (105-125)	11-19
SM	Silty Sands	1760-2000 (110-125)	11-16
SP	Poorly-graded Sands	1600-1920 (100-120)	12-21
SW	Well-graded Sands	1760-2080 (110-130)	9-16
GC	Clayey Gravel w/sands	1840-2080 (115-130)	9-14
GP	Poorly-graded gravels	1840-2000 (115-125)	11-14
GW	Well-graded Gravels	2000-2160 (125-135)	8-11

TABLE 1.3 Differences Between Standard (T 99) and Modified (T 180) Moisture-Density Tests		
	Standard	Modified
Rammers Mass (Manual and Mechanical)	2.495 kg (5.5 lb)	4.536 kg (10.0 lb)
Drop of Rammer to Soil Surface	305 mm (12.0 in.)	475 mm (18.0 in.)
Number Layers Placed when Filling Mold	3	5

Figure 1.11 Apparatus for T 99 and T 180

1.2.4.3 EQUIPMENT

Before beginning any procedure, you must first assemble all the equipment you will need to perform the test. You will need the following equipment per AASHTO T 99/T 180 as shown in Figure 1.11 above, Tables 1.3 and 1.4, and as indicated below.

1) Rammers: The difference between the two procedures (standard and modified) is the mass and freefall of the rammer used to compact the soil or soil and aggregate mixture in the mold and the number of layers placed into the compaction mold for compaction.

2) Mechanical compacting ram: If a mechanical compacting ram is used, it must be calibrated to produce results repeatable with the manual methods using ASTM method D2168.

3) Compaction block, with a mass not less than 90 kg (200 lb).

4) Molds: Depending on the method, either a 101.6 mm (4 in.) or a 152.4 mm (6 in.) mold, solid wall metal cylinder, with dimensions and capacities as shown in Table 1.4.

5) Scales and balances meeting state requirements.

6) Oven, stove or other drying device, meeting state requirements.

7) Straightedge: At least 250 mm (10 in.) length, made of hardened steel with one beveled edge. The straightedge is used to plane the surface of the soil even with the top of the mold. The straightedge should not be so flexible that it leaves a concave surface when trimming the soil from the top of the compacted sample.

8) Engineering Curve

9) Sieves: 50.0 mm (2 in.), 19.0 mm (3/4 in.), and a 4.75 mm (No. 4) conforming to the requirements of AASHTO M92.

10) Mixing Tools: Sample pans, spoons, scoops, trowels, used for mixing the sample with water.

11) Containers: Corrosion resistant with close fitting lids to retain moisture content of prepared soil samples.

12) Graduated cylinders for adding water.

1.2.4.4 COMMON TESTING ERRORS

1) The soil is not thoroughly mixed to achieve uniform moisture.
2) The wrong mold is used for the test.
3) The mold is out of calibration tolerances.
4) The compaction block is not of sufficient mass.
5) The compaction block is unstable.
6) The wrong rammer is used for the test.
7) The drop of the rammer is incorrect.
8) The manual rammer is not lifted to the full stroke.
9) The manual rammer is not held vertically when the blows are delivered.
10) The rammer is not properly cleaned between uses.
11) The mechanical rammer is out of calibration.
12) The wrong number of blows is delivered with the rammer.
13) The mechanical rammer has the wrong compaction face.
14) The lifts vary in thickness.
15) The straightedge may become worn with use - replace as necessary.
16) The sample is not properly dried or the moisture content sample is improperly taken.
17) The points are not plotted correctly on the graph.

1.2.4.5 METHODS

AASHTO T 99 and T 180 stipulates four distinct test methods for these procedures which are Method A, Method B, Method C, and Method D (Table 1.5). The method to be used should be indicated in the applicable specification.

TABLE 1.4
Moisture-Density Methods and Associated Mold Sizes

	Method A	Method B	Method C	Method D
Mold Size	101.60 mm (4 in.)	152.40 mm (6 in.)	101.60 mm (4 in.)	152.40 mm (6 in.)
Material Size	Passing 4.75 mm (No. 4)	Passing 4.75 mm (No. 4)	Passing 19.0 mm (3/4 in.)	Passing 19.0 mm (3/4 in.)
Blows per Layer	25	56	25	56
Standard (T 99)	3 Layers using 2.495 kg (5.5 lb) rammer, 305 mm (12 in.) drop			
Modified (T 180)	5 Layers using 4.536 kg (10 lb) rammer, 457 mm (18 in.) drop			

Use caution when selecting the test method to be used. AASHTO test method designations are distinct from ASTM methods listed in D 698 and D 1557. ASTM also contains three Methods (A, B, or C) which correspond to different mold dimensions than the AASHTO counterparts.

The step by step procedures for AASHTO T 99 and T 180 are essentially the same. The differences in the two procedures are indicated in Table 1.4. AASHTO T 99 will always use 3 layers and a 2.495 kg (5.5 lb) rammer with 305 mm (12 in.) drop for all methods. AASHTO T 180 will always use 5 layers and a 4.536 kg (10 lb) rammer with 457 mm (18 in.) drop.

AASHTO stipulates for each method that material must pass the designated sieve (Table 1.5). Any material retained on the designated sieves is discarded, unless the oversize correction procedure is to be used, (See "Rock Replacement" below.)

1.2.4.6 SAMPLE PREPARATION

1. If the sample is wet, dry it until it becomes friable under a trowel. Aggregations in a friable soil sample will break apart easily. Avoid breaking apart the natural particles when breaking up the soil aggregations.

2. Sieve the sample over the specified sieve for the method being performed. Discard any oversize material retained on the specified sieve.

NOTE: Oversize Material Replacement - It may be necessary to maintain the same percentage of coarse material in the lab sample as was found in the field. If oversize material replacement is required, the material to be tested should be screened through a 50 mm (2 in.) and 19 mm (3/4 in.) sieve, to ascertain the amount of material retained on the 19 mm (3/4 in.) sieve. An equal mass of material which passes the 19 mm (3/4 in.) sieve, but is retained on the 4.75 mm (No. 4) sieve, is then obtained from the remaining portion of the sample. This material is recombined with the test sample prior to compaction. When this procedure is followed, it is necessary to prepare a larger quantity of material for testing.

3. Thoroughly mix the remaining sample. Obtain at least enough material to fill the mold when compacted and provide enough extra material to ensure adequate material for determination of moisture content and increase in density as more water is added.

NOTE: This method uses the same soil or soil-aggregate sample for each “point” on the density curve. If the soil or soil-aggregate mixture to be tested is a clayey material which will not easily mix with water, or where the soil material is fragile and will break apart from the repeated blows of the compaction rammer, it may be necessary to prepare individual portions for each density point. In most cases enough material should be sampled from the field to permit four individual “points” starting 4% below the anticipated optimum moisture content, and then each subsequent “point” increased by 2% moisture. Optimum moisture content should be “bracketed” by the prepared samples in order to provide a more accurate moisture-density curve.

4. Prepare the sample(s) and mix with water to produce the desired moisture content. If the four "points" are prepared in advance, store the prepared material in moisture tight containers.

The following example illustrates how to calculate the amount of water to be added to the soil or soil-aggregate material as a percentage of the sample's original mass.

A sample of 6090 g needs to be prepared with approximately 2% additional moisture. 6090 g is multiplied by 1.02% to yield a sample mass of 6210 g.

$$6090 \times 1.02 = 6210 \text{ g}$$

$$6210 - 6090 = 120 \text{ g}$$

Therefore, 120 g of water should be added to bring the moisture content up by approximately 2%. Since water has a mass of one gram per milliliter, 120 mL of water should be added.

1.2.4.7 PROCEDURE

1. Record the mass of the mold and base plate (without the extension collar) to the nearest 5 grams.

NOTE: While compacting the sample, make sure the mold rests on a rigid and stable foundation or base which will not move.

2. Place a representative portion of the sample into the mold. Place material layers using three approximately equal lifts, to give a total compacted depth of about 127 mm (5 in.) for the standard method (AASHTO T 99). Place five approximately equal layers to give a total compacted depth of about 127 mm (5 in.) for the modified method (AASHTO T 180).

3. Use the 2.495 kg (5.5 lb) rammer for standard moisture density test (AASHTO T 99) or the 4.536 kg (10 lb) rammer for modified moisture density test (AASHTO T 180).

4. Apply the required number of blows to the specimen layer (25 blows for Methods A and C, 56 blows for Methods B and D).

5. When compacting the specimen using the manual rammer, uniformly distribute the blows over the entire surface area of the sample.

NOTE:

- Do not lift the rammer and sleeve from the surface of the sample while compacting.
- Hold the rammer perpendicular to the sample and mold during compaction.

6. Repeat Steps 1 through 5 for each subsequent layer.

7. Remove the extension collar from the mold and trim the sample even with the top edge of the mold using a straightedge. Clean the mold and base plate of any loose particles. If there are voids in the surface of the compacted sample, fill them with loose soil collected from around the baseplate. Re-trim the sample even with the top edge of the mold. Clean mold of loose particles if necessary.

8. Weigh the mold with sample and record to the nearest 5 grams.

9. Remove the compacted soil or soil-aggregate sample from the mold and slice vertically through the center of the specimen. Obtain a representative sample from one of the cut faces, determine the moist mass immediately and record. Dry in accordance with MARTCP SA 1.3, to determine moisture content.

10. Break up the remainder of the sample from the mold. Add the broken up sample to the remainder of the sample being used for the test.

11. Add additional water to the sample to increase the overall moisture content by about 2% (as described in Step 4 of Sample Preparation). The increased moisture content should never be more than 4%. **If separate density points were prepared prior to performing the procedure, skip this step.** Continue compacting samples with moisture contents increasing by roughly 2% until there is a drop or no change in the calculated wet density.

1.2.4.8 CALCULATIONS

1. Calculate the wet density of the material as follows: (**in metric units**)

   a) Methods A & C: (volume of four inch (101.6 mm) mold = 0.0333 ft^3)

$$D_{wet} = \frac{(W_{s+m} - W_m)}{0.0333\ ft^3} \times \frac{35.3\ ft^3}{m^3} = (W_{s+m} - W_m) \times 1{,}060$$

b) Methods B & D: (volume of six inch (152.4 mm) mold = 0.075 ft^3)

$$D_{wet} = \frac{(W_{s+m} - W_m)}{0.075\ ft^3} \times \frac{35.3\ ft^3}{m^3} = (W_{s+m} - W_m) \times 470.7$$

where: D_{wet} = Wet Density, kg/m^3
W_{s+m} = Mass of the wet sample and mold, kg
W_m = Mass of the mold, kg
3.28 ft = 1 m

In English units:

c) Methods A & C: (volume of four inch mold = 0.0333 ft^3)

$$D_{wet} = \frac{(W_{s+m} - W_m)}{0.0333\ ft^3} \times \frac{2.205\ lb}{kg} = (W_{s+m} - W_m) \times 66.22$$

d) Methods B & D: (volume of six inch mold = 0.075 ft^3)

$$D_{wet} = \frac{(W_{s+m} - W_m)}{0.075\ ft^3} \times \frac{2.205\ lb}{kg} = (W_{s+m} - W_m) \times 29.40$$

where: D_{wet} = Wet Density, lb/ft^3
W_{s+m} = Mass of the wet sample and mold, kg
W_m = Mass of the mold, kg
2.205 lb = 1 kg

2. Calculate the moisture content for each compacted sample by dividing the water content (loss between wet mass and dry mass of moisture sample) by the dry mass of the sample and multiplying by 100.

$$w,\% = \frac{(W_{wet} - W_{dry})}{(W_{dry} - W_{con})} \times 100$$

where: w,% = percent moisture,
W_{wet} = weight of wet aggregate and container (g or lb),
W_{dry} = weight of dry aggregate and container (g or lb), and
W_{con} = weight of container (g or lb).

3. Calculate the dry density (D_{dry}) for each compacted sample based on the corresponding moisture sample for each compacted specimen.

$$D_{dry} = \frac{D_{wet}}{(100 + w,\%)} \times 100$$

where: D_{dry} = dry density, (kg/m^3 or lb/ft^3)
D_{wet} = wet density, (kg/m^3 or lb/ft^3)
w,% = moisture content of sample

4. Plot each compaction point for dry density on graph paper with density on the y-axis and moisture content on the x-axis as shown on Figure 1.12.

5. Form a smooth line using the engineer's curve by connecting the plotted points to form two curves. As close as possible to the intersection, round the peak to form a smooth, continuous line.

6. The moisture content corresponding to the peak of the curve will be termed the "optimum moisture content."

7. The dry density corresponding to the peak of the curve will be termed "maximum dry density."

1.2.4.9 EXAMPLE CALCULATION

The following example moisture density relationship (Table 1.5a metric, Table 1.5b English) is calculated as a Modified (AASHTO T 180), Method A (Large Rammer, Small Mold). Remember that the mass of the wet soil needs to be expressed per the unit volume of the mold used. The mass of the wet soil in kilograms is multiplied by 1060.0 (30.0 English) to determine the wet density in kg/m^3 (lb/ft^3).

TABLE 1.5a Modified Method A Moisture-Density Relationship Computation **(Metric)**				
Point No.	1	2	3	4
Mass of mold and soil (kg)	6.065	6.130	6.190	6.185
Mass of mold (kg)	4.295	4.295	4.295	4.295
Mass of wet soil (kg)	1.770	1.835	1.895	1.890
Wet Density (kg/m^3)	1876.2	1945.1	2008.7	2003.4
Moisture Contents				
A = Mass of container and wet soil (g)	373.5	397.5	385.2	387.3
B = Mass of container and dry soil (g)	336.9	354.9	339.7	338.9
C = Mass of container (g)	115.2	123.2	115.4	122.8
w = Moisture content (%)	16.5	18.4	20.3	22.4
D_{dry} = Dry density (kg/m^3)	1610.5	1642.8	1669.7	1636.8

TABLE 1.5b Modified Method A Moisture-Density Relationship Computation **(English)**				
Point No.	1	2	3	4
Mass of mold and soil (kg)	6.065	6.130	6.190	6.185
Mass of mold (kg)	4.295	4.295	4.295	4.295
Mass of wet soil (kg)	1.770	1.835	1.895	1.890
Wet Density (lb/ft^3)	117.2	121.5	125.5	125.2
Moisture Contents				
A = Mass of container and wet soil (g)	373.5	397.5	385.2	387.3
B = Mass of container and dry soil (g)	336.9	354.9	339.7	338.9
C = Mass of container (g)	115.2	123.2	115.4	122.8
w = Moisture content (%)	16.5	18.4	20.3	22.4
D_{dry} = Dry density (lb/ft^3)	100.6	102.6	104.3	102.3

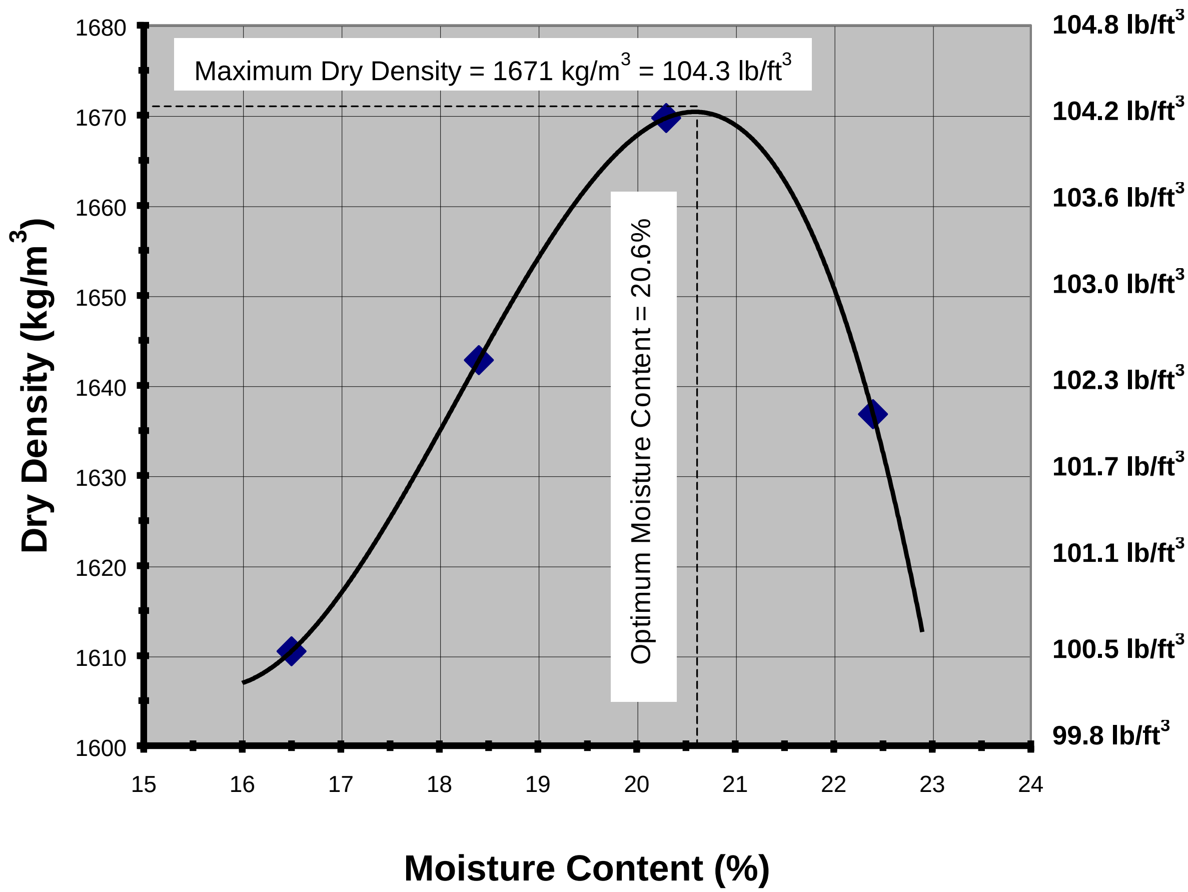


Figure 1.12. Graphic plot of the moisture-density relationship in Table 1.6a and Table 1.6b, illustrating determination of maximum dry density and optimum moisture.

1.2.5 AASHTO T 191 - DENSITY OF SOIL IN-PLACE BY THE SAND-CONE METHOD

This test uses the sand-cone apparatus to determine the in-place density of soil or soil aggregate mixtures. Density is used to calculate the compaction levels of the constructed soil or soil aggregate layers. Compaction is densifying a material by a process of pressing the individual soil grain particles more closely together. Compaction or densification is usually accomplished by mechanical compactor devices (sheep foot compactor, vibratory compactor). Proper compaction improves the engineering properties of the soil mass. Density is a function of mass (weight) divided by its volume. Percent density is the ratio of the in-place density to the maximum (target) density as determined in the laboratory according to standard testing procedures.

1.2.5.1 SUMMARY

Prior to testing, calibrations must be done to determine the volume of the sand-cone apparatus, the sand density, and the weight of sand in the large cone. To determine the in-place density using the sand-cone first: excavate a hole as deep as the thickness of the compacted lift. Remove all material and weigh. After weighing, use a representative sample to determine the moisture content. Then measure the volume of the hole, which is the volume of the soil sample in its undisturbed condition before removal, is measured by filling the hole with sand whose unit mass (weight) is known. The mass of the sand required to fill the hole is converted into volume. The mass of the soil removed from the hole divided by the volume of the hole is the wet density of the soil.

1.2.5.2 COMMON TESTING ERRORS

1) Equipment not calibrated properly
2) Soil weighed contained stones larger than No. 4.75 mm (No. 4) sieve
3) Vibrating jar while sand is flowing into test hole
4) Moisture content not properly determined

1.2.5.3 EQUIPMENT NEEDED

Before beginning any procedure, you must first assemble all the equipment you will need to perform the test. To determine in-place density using a sand-cone, you will need:

1) Density apparatus, consisting of a 4 L (1 gal) jar and a detachable appliance consisting of a cylindrical valve with an orifice 12.7mm (½ in.) in diameter and having a small funnel continuing to a standard G mason jar top on one end

and a large funnel on the other end. The valve shall have stops to prevent rotating the valve past the completely open or completely closed positions (See Figure 1.13).

2) Sand: Should be a clean, non-cementitious sand with few or no particles passing the 0.075 mm (No. 200) sieve, and none retained on the 2.00 mm (No. 10) sieve. AASHTO T 191 requires that the bulk density of the sand be measured several times to ensure that the sand does not have a variation in bulk density greater than 1 percent.

3) Balances: AASHTO M 231, Class G20 (over 5 Kg through 20 Kg principle sample mass, sensitivity of 5 g or 0.1%); and AASHTO M231 Class G (2 Kg or less, sensitivity of 0.1 g or 0.1%).

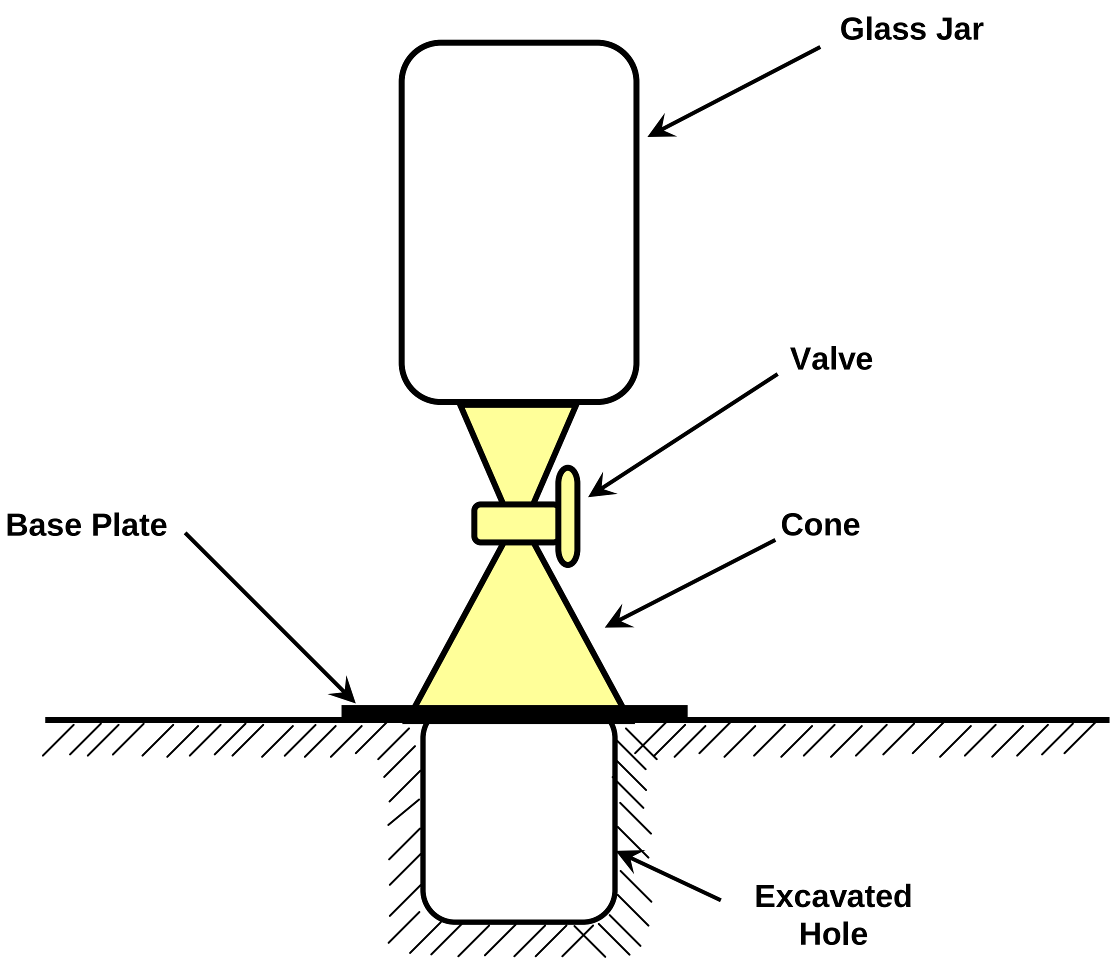


Fig. 1.13 - Sand-cone Device

4) Drying equipment: Suitable for drying moisture content samples, usually a hot plate or Sterno stove in the field.

5) Miscellaneous equipment: Digging tools for test hole, which might include a small pick, chisels, spoons, scoops, etc.; suitable container for drying moisture sample (small pan), buckets or canvas bags to retain density sample, cache of density sand, thermometer for water temperature determination (if calibrating cone in field), brush for fines.

1.2.5.4 EQUIPMENT PREPARATION

Determine the volume of the jar and attachment up to and including the volume of the valve orifice.

1. Screw the metal top on the empty jar , weigh and record the mass. It is advisable to use a rubber gasket, such as a Mason canning ring, to prevent the water used in the calibration from leaking. The gasket should remain on the jar at all times. Removal will change the volume.

   Note: Use water at a temperature of 65 to 68^{O} F (18.3 to 20^{O} C).

2. Place the apparatus in the upright position, open valve and pour water through the funnel into the jar. When water level is slightly above top of valve, close the valve.

3. Carefully blot up the excess water above valve, wipe off any water which may have spilled on the jar.

4. Weigh and record the mass.

5. Weight of water equals mass of the jar filled with water minus the mass of the empty jar.

$$\text{Volume (m}^3\text{)} = \frac{\text{Mass of Water (kg)}}{1000\ \text{kg/m}^3\ \ \text{(Density of Water)}}$$

$$\text{Volume (ft}^3\text{)} = \frac{\text{Weight of Water (lb)}}{62.4\ \text{lb/ft}^3\ \ \text{(Density of Water)}}$$

Perform the above steps a minimum of three times, or as necessary to obtain consistent results.

Determine the bulk density of the sand (D_{bulk}) to be used in the test.

1. Place the empty apparatus upright on a firm, level surface, close the valve, and fill the funnel with sand.

2. Open the valve and, keeping funnel at least half full of sand, fill the apparatus. Close the valve sharply and empty excess sand.

3. Weigh apparatus with the sand and determine the net mass of sand by subtracting the mass of the apparatus.

4. Calculate the bulk density of the sand as follows:

$$D_{bulk} = \frac{W}{V}$$

where: D_{bulk} = bulk density of the sand, kg/m^3 or lb/ft^3
W = mass of sand required to fill the apparatus, kg or lb
V = volume of the apparatus, m^3 or ft^3

Calculate the bulk density of the sand to the nearest 0.1 kg/m^3 or lb/ft^3. If a second apparatus is used then use the volume of the secondary apparatus in place of V.

5. Special considerations when determining the bulk density of the sand: avoid any vibration of the sand during the mass/volume calculation. Vibration could cause the bulk density of the sand to be higher than normal. Check the bulk density of the sand regularly (at least once a day before taking tests). Slight changes in moisture or degradation of the sand during storage and transport may affect the sand density determination. It is also acceptable to determine the bulk density of the sand using other volumetric containers, provided that the bulk density as determined by these other methods is shown to be equal the bulk density of the sand as determined by the sand-cone.

Example calculation: Determining Bulk Density of Sand

Volume of Apparatus is 0.134 cubic feet, mass of sand required to fill apparatus is 5.933 kg.

$$D_{bulk} = \frac{W}{V}$$

where: D_{bulk} = bulk density of the sand, kg/m^3 or lb/ft^3
W = mass of sand required to fill the apparatus, kg or lb
V = volume of the apparatus, m^3 or ft^3

(Metric) $\mathbf{D_{bulk} = (5.933\ kg) / (0.134\ ft^3 \times 0.0283\ m^3/ ft^3)}$
$\mathbf{= 1564.5\ kg/m^3}$

(English) $\mathbf{D_{bulk} = (5.933\ kg \times 2.205\ lb/kg) / (0.134\ ft^3)}$
$\mathbf{= 97.6\ lb/ft^3}$

Determining the Mass of Sand Required to Fill the Cone

1. Put sand into the apparatus and close the valve.

2. Invert the apparatus on a clean, level, surface so that the cone is facing down. If a base plate is used normally during testing then it must be used during the calibration phase as well.

3. Open the valve and allow the sand to flow until it stops. Close the valve sharply and weight the apparatus with the remaining sand in the jar. Determine the loss of sand and record as the weight of sand required to fill the cone.

4. Replace the sand used for this determination and close the valve. The sand-cone is now ready and calibrated for use.

5. Considerations when determining the amount of sand required to fill the cone:

   When testing soils that will not permit a uniform and level testing area, AASHTO T 191 Note 7 recommends measuring the mass of sand required to fill the cone and the unbounded testing surface in lieu of measuring just the sand required to fill the cone. This is a special situation and is used to compensate for sand loss to uneven surfaces.

1.2.5.5 FINDING THE MASS OF SAND IN THE HOLE (Figures 1.14 and 1.15)

PROCEDURE

1. Make sure the jar is filled with enough sand to fill the hole volume and the cone. Weigh the apparatus with the sand prior to use. This mass will be used to determine a loss of sand after it has been used to fill the excavated hole and cone.

2. Prepare the surface of the location to be tested so that it is a level plane.

3. Seat the inverted apparatus on the prepared plane surface and mark the outline of the funnel. Alternately, place the base plate on the level surface.

NOTE: Step 4 not listed in AASHTO T 191, adapted from ASTM D 1556-90.

4. Remove the soil from the area outlined by the cone or within the area bounded by the base plate hole. Take care not to disturb the soil that will bound the hole while removing the soil from the volume of the test hole. The volume of the hole is dependent upon maximum particle size (Table 1.7) of the material being tested in conformance to AASHTO T 191, Table 1. A larger jar and cone may be needed when the volume exceeds 0.1 cubic feet.

Table 1.7 Minimum volume of test hole for maximum particle size.

Maximum Particle Size		Minimum Test Hole Volume, ft^3	Minimum Mass for Moisture Content, g
mm	US Standard		
4.75	No. 4	0.025	100
12.5	1/2 in.	0.05	250
25.0	1 in.	0.075	500
50.0	2 in.	0.1	1000

The walls of the hole should slope slightly inward and the bottom should be reasonably flat or concave. The hole should be kept as free as possible of pockets, overhangs, and sharp obtrusions since these affect the accuracy of the test. Soils that are essentially granular require extreme care and may require digging a conical shaped test hole. Place all excavated soil and any soil loosened during digging in a moisture tight container that is marked to identify the test number. Take care to avoid the loss of any materials. Protect this material from any loss of moisture until the mass has been determined and a specimen has been obtained for a water content determination.

5. Weigh and record the material removed from the test hole. Retain a representative portion of the sample to determine the moisture content of the soil, making sure that the moisture sample conforms to the minimum mass requirements in Table 1.6. Determine the moisture content of the soil using AASHTO T 265 or another acceptable rapid dry method.

6. Seat the apparatus in a hole or on the base plate and open the valve. Allow the sand to flow from the cone, filling the hole and the cone apparatus. Once the sand has ceased flowing, sharply close the valve. There should be no vibration in the immediate area during this operation.

7. Weigh the apparatus with the remaining sand and subtract this from the original weight of the apparatus filled with sand. This is the mass of sand used for the test. Subtract the mass of the sand previously determined to fill the cone from the mass of the sand used for the test. This is the mass of sand used to fill the excavated hole.

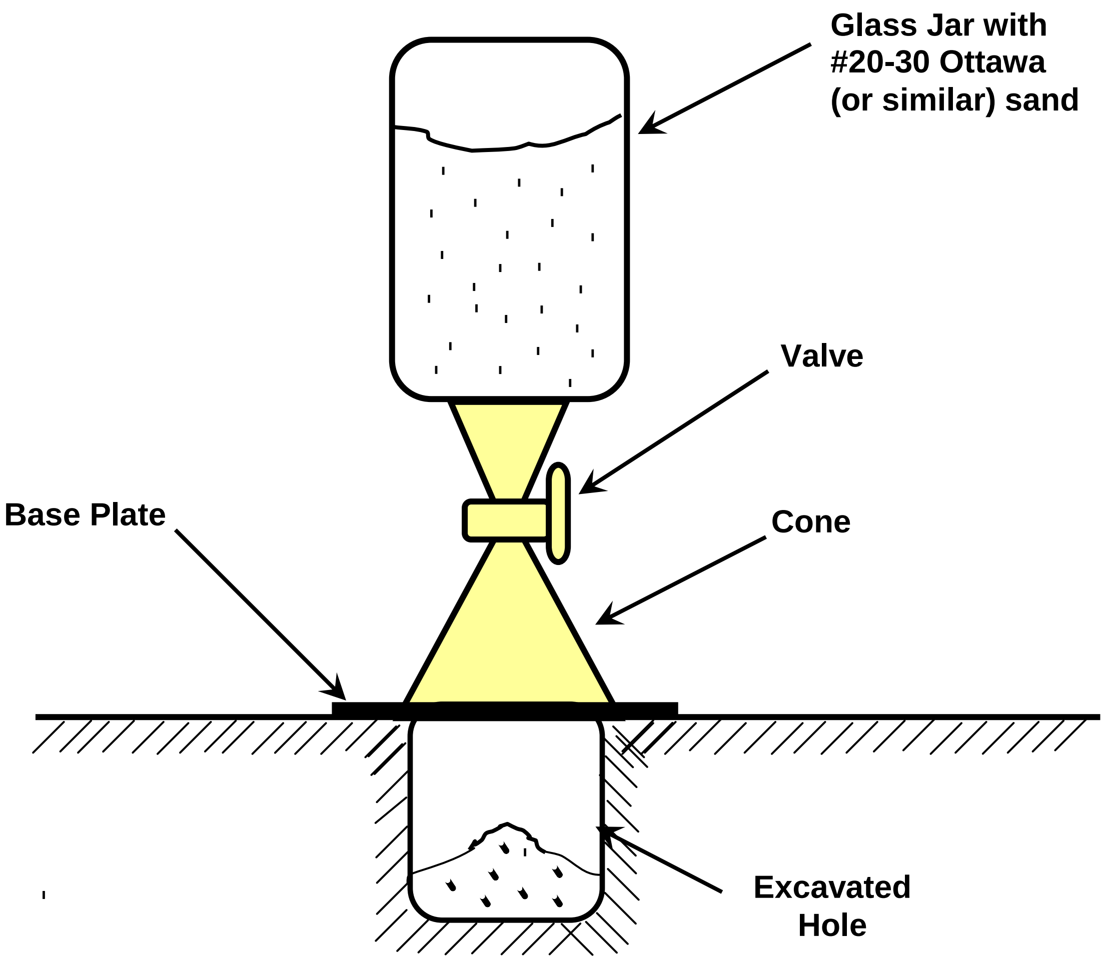


Fig. 1.14 - Sand-cone Device With Sand Filling Cone and Hole

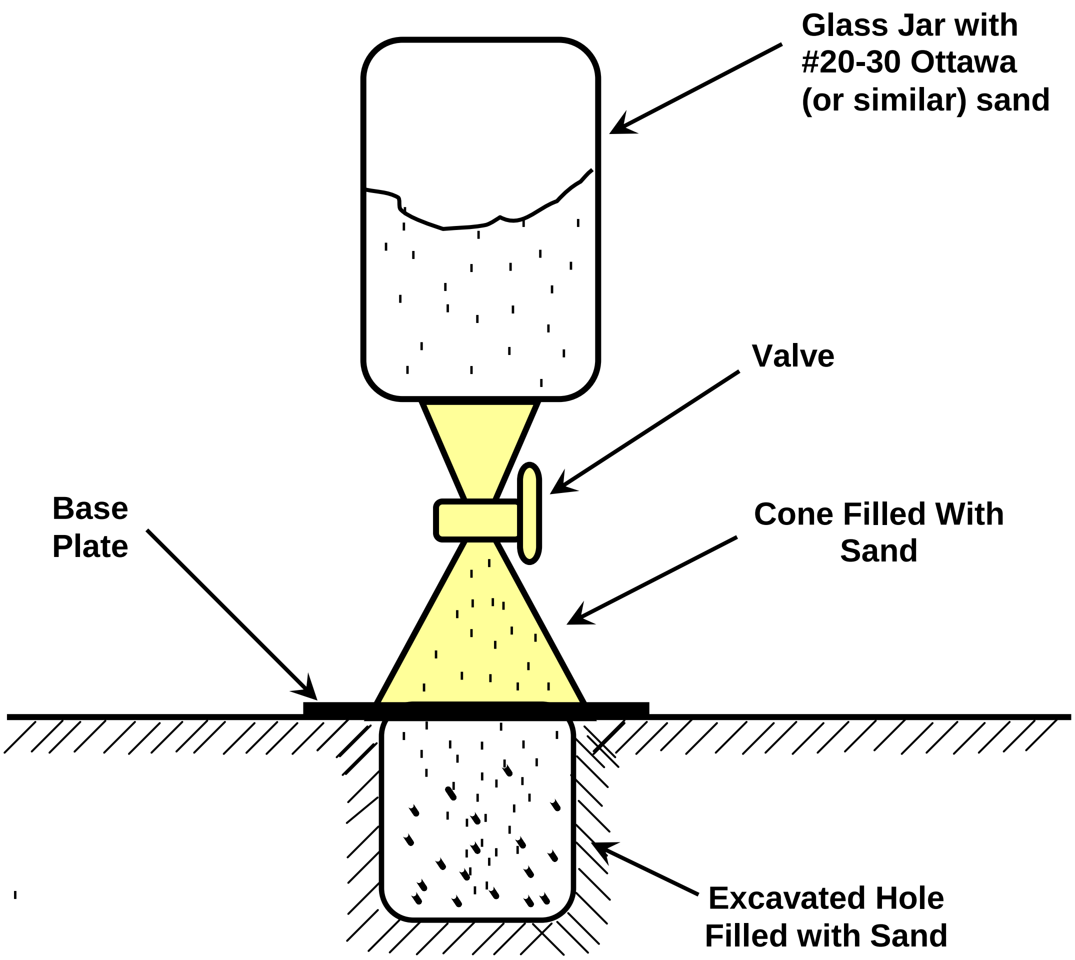


Fig. 1.15 - Sand-cone Device With Hole and Cone Filled

1.2.5.6 CALCULATIONS

Calculate the moisture content (w,%) and the dry mass (W_{dry}) of the material removed from the test hole as follows:

$$w,\% = \frac{(w_{wet} - w_{dry})}{w_{dry}} \times 100$$

$$\mathbf{W}_{dry} = \frac{\mathbf{W}_{wet}}{(w,\% + 100)} \times 100$$

where:
w,% = percentage of moisture content of material from test hole
w_{wet} = moist mass of moisture sample, g
w_{dry} = dry mass of moisture sample, g
$\mathbf{W}_{wet}$ = moist mass of the material from the test hole, kg or lb
$\mathbf{W}_{dry}$ = dry mass of material from the test hole, kg or lb

Calculate the moisture content to the nearest 0.1 percent.

Calculate the dry mass of the material removed from the test hole to the nearest 0.01 kg or lb.

Calculate the dry density (D_{dry}) of the material as follows:

$$V = \frac{W_{S1} - W_{S2}}{D_{bulk}}$$

$$D_{dry} = \frac{\mathbf{W}_{dry}}{V}$$

where:
V = volume of test hole, m^3 or ft^3
W_{S1} = mass of sand used, kg or lb
W_{S2} = mass of sand in funnel, kg or lb
D_{dry} = dry density of the tested material, kg/m^3 or lb/ft^3
$\mathbf{W}_{dry}$ = dry mass of material from the test hole, kg or lb

Calculate the in-place dry density of the material tested to the nearest 0.1 kg/m^3 or lb/ft^3.

Determining Percent Relative Compaction (RC,%)

Determine the Percent of Relative Compaction (percentage of the maximum density as determined by the laboratory moisture density relation) by dividing the field result by the laboratory result and multiplying by 100.

$$RC,\% = \frac{D_{dry}}{D_{lab}} \times 100$$

where: RC,% = percentage of relative compaction
D_{dry} = dry density of tested material, kg/m^3 or lb/ft^3
D_{lab} = laboratory maximum dry density per AASHTO T 99 or T 180, kg/m^3 or lb/ft^3

1.2.5.7 EXAMPLE CALCULATIONS

Determining moisture content (w,%) and dry mass of material (W_{dry}) from hole:

Moist mass of moisture sample is 271.6 g, dry mass of moisture sample is 257.9 g, moist mass of sample from test hole is 3.23 kg (7.12 lb).

$$w,\% = \frac{(w_{wet} - w_{dry})}{w_{dry}} \times 100 = \frac{(271.6\text{ g} - 257.9\text{ g})}{257.9\text{ g}} \times 100 = 5.3\%$$

$$\mathbf{W}_{dry} = \frac{\mathbf{W}_{wet}}{(w,\% + 100)} \times 100 = \frac{3.23\text{ kg}}{(5.3 + 100)} \times 100 = 3.07\text{ kg}$$

In English Units:

$\mathbf{W}_{dry}$ = [(7.12 lb)/(5.3 + 100)] x 100 = 6.76 lb

where: w,% = percentage of moisture content of material from test hole
w_{wet} = moist mass of moisture sample, g
w_{dry} = dry mass of moisture sample, g
$\mathbf{W}_{wet}$ = moist mass of the material from the test hole, kg or lb
$\mathbf{W}_{dry}$ = dry mass of material from the test hole, kg or lb

Determining Dry Density (D_{dry}) of Material:

2405.0 g of sand were used to fill the hole, 240.0 g of sand filled the funnel.

$$V = \frac{W_{S1} - W_{S2}}{D_{bulk}} = \frac{(2405\text{ g} - 240\text{ g})(1\text{ kg}/1000\text{ g})}{1564.5\text{ kg/m}^3} = 0.00138\text{ m}^3$$

$$D_{dry} = \frac{\mathbf{W}_{dry}}{V} = \frac{3.07\text{ kg}}{0.00138\text{ m}^3} = 2224.6\text{ kg/m}^3$$

In English Units:

$V = (0.00138\text{ m}^3)(35.31\text{ ft}^3/\text{ m}^3) = 0.0487\text{ ft}^3$

$D_{dry} = 6.76\text{ lb} / 0.0487\text{ ft}^3 = 138.8\text{ lb/ft}^3$

where: V = volume of test hole, m^3 or ft^3
W_{S1} = mass of sand used, kg or lb
W_{S2} = mass of sand in funnel, kg or lb
D_{dry} = dry density of the tested material, kg/m^3 or lb/ft^3
$\mathbf{W}_{dry}$ = dry mass of material from the test hole, kg or lb

Determining Relative Percent Compaction (RC,%):

Optimum laboratory dry density as determined by AASHTO T 99 or T 180 is 2276.4kg/m^3 (142.1 lb/ft^3).

In Metric:

$$RC,\% = \frac{D_{dry} \times 100}{D_{lab}} = \frac{2224.6 \text{ kg/m}^3 \times 100}{2276.4 \text{kg/m}^3} = 97.7\%$$

In English:

$$RC,\% = \frac{D_{dry} \times 100}{D_{lab}} = \frac{138.8 \text{ lb/ft}^3 \times 100}{142.1 \text{ lb/ft}^3} = 97.7\%$$

where: RC,% = percentage of maximum dry density as determined by AASHTO T 99 or T 180
D_{dry} = dry density of tested material, kg/m^3 or lb/ft^3
D_{lab} = laboratory maximum dry density per AASHTO T 99 or T 180, kg/m^3 or lb/ft^3

Remember that the final density will be corrected for any oversize particles as outlined in: **Correction for Coarse Particles in the Soil Compaction Test, AASHTO T 224.**

1.2.6 AASHTO T 272 - FAMILY OF CURVES / ONE POINT METHOD

The Family of Curves is a conversion tool developed to provide maximum dry density and optimum moisture for soils commonly used in highway construction. The curves show the moisture/density relationships of various soils or soils containing aggregate so that if the wet density and moisture content of a soil is known, its maximum dry density and optimum moisture can be read from the curve for that soil.

Soils are composed of various combinations of sand, silt, and clay. Where a material fits on the Family of Curves depends on the composition of the material. Sandy or silty soils fit on the curves with higher maximum densities, clay soils fit those curves with lower maximum densities. Since sands do not hold water, the maximum density of sandy soil will occur at a lower percent moisture content than for soils which contain fines.

1.2.6.1 SUMMARY OF TESTING

Because of the wide variation in the soils encountered in any geographical area, it is difficult for the inspector who performs the in-place density tests to identify the soil at a specific site and relate it to the proper laboratory maximum density test. A method has been developed to enable the inspector to determine in the field the maximum density of soil encountered for each in-place density test. It consists of compacting the soil in a standard AASHTO T 99 compaction mold, determining its wet density and moisture content, and using this data with a Family of Curves to determine the maximum dry density. This procedure is commonly referred to as the One-Point Method.

1.2.6.2 TYPICAL TEST RESULTS

This test provides the same results as a AASHTO T 99 Moisture – Density Relations of Soils Using 2.5 kg (5.5 lb) Rammer and a 305 mm (12 in.) drop.

1.2.6.3 COMMON TESTING ERRORS

1) This method can be used for any soil that develops a classic parabolic “Proctor Curve.” **It is not applicable for free draining granular materials**.
2) Failure to protect samples from changes in moisture content will affect the results of this test.
3) Not placing the mold on a substantial base, 90 kg (200 lb) of concrete or equivalent, while compacting the specimen will cause loss of compactive effort and adversely affect the results.

4) Level all scales before weighing.
5) Protect scales from drafts that would affect the accuracy of weighing.
6) Use care in reading the graphs used in this method, it is very easy to misinterpret the data. Read and record, then read again.

1.2.6.4 TEST METHODOLOGY

EQUIPMENT

Before beginning any procedure, you must first assemble all the equipment you will need to perform the test. For this procedure you will need the following.

1) A 101.6 mm (4 in.) mold, having a capacity of 0.000943 m^3 (0.0333 ft^3), with an internal diameter of 101.60 mm (4.000 in.), and a height of 116.43 mm (4.584 in.).

2) A 152.4 mm (6 in.) mold, having a capacity of 0.002124 m^3 (0.07500 ft^3), with an internal diameter of 152.40 (6.000 in.), and a height of 116.43 mm (4.584 in.).

3) A metal rammer with a mass of 2.495 kg (5.5 lb), and having a flat circular face of 50.8 mm (2.000 in.) diameter, and a controlled height of fall of 305 mm (12.00 in.). The rammer shall be equipped with a guide-sleeve to control the height of the drop. The guide-sleeve shall have a least four vent holes, no smaller than 9.5 mm (3/8 in.) diameter, spaced approximately 90 degrees (1.57 radians) apart and approximately 19 mm (3/4 in.) from each end. There shall provide sufficient clearance so the free fall of the rammer shaft and head is unrestricted.

4) One straightedge 250 mm (10 in.) long with a beveled edge and at least one longitudinal surface.

5) Sieves, 50 mm (2 in.), 19.0 mm (3/4 in.), and 4.75 mm (No. 4).

6) Balances or Scales conforming to AASHTO M231

7) A set of Typical Moisture-Density Curves

8) Supply of clean water.

9) Miscellaneous tools such as mixing pans, trowel, putty knife and a plastic or glass bottle with a sprinkling cap.

10) Sample extruder consisting of a hydraulic jack and frame to remove compacted samples from the mold. **Optional item.**

11) A thermostatically controlled drying oven capable of maintaining a temperature of 110 ± 5^{o}C (230 ± 9^{o}F) for drying moisture samples.

METHOD “A” PROCEDURE

SAMPLE

Remove approximately 3.2 kg (7 lb), or as state specified, of representative soil from the test site for use in this procedure, after performing the in-place density test. If the Sand-Cone Method was used, be careful not to contaminate the sample with silica sand. Remove oversize material from this sample using the 4.75 mm (No. 4) sieve, by passing the entire sample over the sieve and separating the material into that which is retained on the sieve and that which passes the sieve. Test the material, which passed the sieve and discard the retained material. Record on the test data sheet “Test performed on material passing 4.75 mm (No. 4) sieve.“

PROCEDURE

Dry out, or thoroughly mix the selected sample with sufficient water, to approximately 4 percentage points below optimum moisture content. Greater accuracy in the determination of the maximum density will result as the moisture content approaches optimum moisture content. **Moisture content of the sample should never exceed the optimum water content.**

Form a specimen by compacting the prepared soil in the 101.6 mm (4 in.) mold (with the collar attached) in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 305 mm (12 in.) above the soil surface when a sleeve-type rammer is used. During compaction, the mold shall rest firmly on a dense, uniform, rigid and stable foundation. (A block of concrete, with a mass of not less than 90 kg (200 lb) supported by a relatively stable foundation; a sound concrete floor: and for field applications, such surfaces as found in concrete box culverts, bridges, and pavements will meet this last requirement.)

Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Determine the mass of the mold and wet soil by weighing them in kilograms to the nearest five grams. Subtract the mass of the mold from the mass of the soil and mold combined. Multiply the mass of wet soil and record the result as wet density, D_{wet}, in kg/m^3 (lb/ft^3), of compacted soil.

Remove the material from the mold and slice vertically through the center. Take a representative sample from one of the cut faces, weighing not less than 100 grams and determine the moisture content. For tests run in conjunction with a nuclear density gage, the moisture content from that test may be used for this purpose, if allowed by local specification.

METHOD "B" PROCEDURE

SAMPLE

Select a representative sample in accordance with Method "A", except that it shall have a mass of approximately 7 kg (15lb).

PROCEDURE

Follow the procedure as described for Method "A", except for the following:

Form a specimen by compacting the prepared soil in the 152.4 mm (6 in.) mold (with the collar attached) in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Compact each layer by 56 uniformly distributed blows from the rammer dropping free from a height of 305 mm (12 in.) above the soil surface when a sleeve-type rammer is used. During compaction, the mold shall rest firmly on a dense uniform, rigid and stable foundation. (A block of concrete, with a mass of not less than 90 kg (200 lb) supported by a relatively stable foundation; a sound concrete floor, and for field applications, such surfaces as found in concrete box culverts, bridges, and pavements will meet this last requirement.)

Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Determine the mass of the mold and wet soil by weighing them in kilograms to the nearest 5 grams and record the mass. Subtract the mass of the mold from the mass of the soil and mold combined. Multiply the mass of wet soil by and record the result as wet density, D_{wet}, in kg/m^3 (lb/ft^3), of compacted soil.

Remove the material from the mold and slice vertically through the center. Take a representative sample from one of the cut faces, weighing not less than 100 grams and determine the moisture content. For tests run in conjunction with a nuclear density gage, the moisture content from that test may be used for this purpose , if allowed by local specification.

METHOD "C" PROCEDURE

This method can be used for any soil that develops a classic parabolic " Proctor Curve." It is not applicable to free draining granular materials.

SAMPLE

Remove approximately 5 kg (11 lb) of representative soil from the test site for use in this procedure, after performing the in-place density test. If the Sand-Cone Method was used, be careful not to contaminate the sample with silica sand. Remove oversize material from this sample using the 19.0 mm (0.75 in.) sieve, by passing the entire sample over the sieve and separating the material into that which is retained on the sieve and that which passes the sieve. Test the material, which passed the sieve and discard the retained material. Record on the test data sheet "Test performed on material passing 19.0 mm sieve."

PROCEDURE

Dry out, or thoroughly mix the selected sample with sufficient water, to approximately four percentage points below optimum moisture content. Greater accuracy in the determination of the maximum density will result as the moisture content approaches optimum moisture content. **Moisture content of the sample should never exceed the optimum water content.**

Form a specimen by compacting the prepared soil in the 101.6 mm (4 in.) mold (with the collar attached) in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 305 mm (12 in.) above the soil surface when a sleeve-type rammer is used. During compaction, the mold shall rest firmly on a dense uniform, rigid and stable foundation. (A block of concrete, with a mass of not less than 90 kg (200 lb) supported by a relatively stable foundation; a sound concrete floor: and for field application, such surfaces as found in concrete box culverts, bridges, and pavements will meet this last requirement.)

Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Determine the mass of the mold and wet soil by weighing them in kilograms to the nearest 5 grams and record the mass. Subtract the mass of the mold from the mass of the soil and mold combined. Multiply the mass of wet soil by 1060 and record the result as wet density, D_{wet}, in kg/m^3 (lb/ft^3), of compacted soil.

Remove the material from the mold and slice vertically through the center. Take a representative sample from one of the cut faces, weighing not less than

100 grams and determine the moisture content. For tests run in conjunction with a nuclear density gage, the moisture content from that test may be used for this purpose, if allowed by state specification.

METHOD "D" PROCEDURE

This method can be used for any soil that develops a classic parabolic " Proctor Curve." It is not applicable to free draining granular materials.

SAMPLE

Select a representative sample in accordance with Method "C", except that it shall have a mass of approximately 11 kg (24 lb).

PROCEDURE

Follow the procedure as described for Method "C", except for the following:

Form a specimen by compacting the prepared soil in the 152.4 mm (6 in.) mold (with the collar attached) in three approximately equal layers to give a total compacted depth of about 125 mm (4 in.). Compact each layer by 56 uniformly distributed blows from the rammer dropping free from a height of 305 mm (12 in.) above the soil surface when a sleeve-type rammer is used. During compaction, the mold shall rest firmly on a dense uniform, rigid and stable foundation. (A block of concrete, with a mass of not less than 90 kg (200 lb) supported by a relatively stable foundation such as a sound concrete floor, or for field applications, such surfaces as found in concrete box culverts, bridges, and pavements will meet this last requirement.)

Following compaction, remove the extension collar, carefully trim the compacted soil even with the top of the mold by means of the straightedge. Determine the mass of the mold and wet soil by weighing them in kilograms to the nearest 5 grams and record the mass. Subtract the mass of the mold from the mass of the soil and mold combined. Multiply the mass of wet soil and record the result as wet density, D_{wet} , in kg/m^3 (lb/ft^3), of compacted soil.

Remove the material from the mold and slice vertically through the center. Take a representative sample from one of the cut faces, weighing not less than 100 grams and determine the moisture content. For tests run in conjunction with a nuclear density gage, the moisture content from that test may be used for this purpose , if allowed by local specification.

1.2.6.5 CALCULATIONS

See AASHTO T 99, Section 11, Maximum Density and Optimum Moisture Content Determination

To undertake the use of this procedure, the user must have a Family of Curves produced in accordance with the Appendix procedure outlined in AASHTO T 272 relevant to the soils anticipated to be encountered in the geographical area. With the dry mass and moisture content calculated as in Section 1.2.4.9, plot those values on the Family of Curves (see Figure 1.16).

If the one-point falls on one of the curves in the Family of Curves, the maximum dry mass and optimum moisture content defined by that curve shall be used. If the one-point falls within the family but not on a curve, a new curve shall be drawn through the plotted one-point parallel and in the same general shape with the nearest curve on the family of curves, the maximum dry mass and optimum moisture content as defined by that new curve shall be used. If the one-point plotted within or on the family of curves does not fall in the range of 80 to 100 percent of optimum moisture content, compact another specimen, using the same material, at an adjusted moisture content that will place the one-point within that range.

NOTE: In order to ensure that you have correctly identified the curve that matches the soil, the point must fall near the curve peak (no more than 4% below optimum moisture content). Note, that while AASHTO allows the point to fall at a 4% deviation from the optimum moisture content, many agencies have tighter restrictions. If the point falls on the dry side below the acceptable range, the moisture content of the soil is not high enough. Repeat the test with a fresh sample of the same material at a higher moisture content. Estimate the amount of moisture needed to bring the soil to the peak of the curve. With experience, you will be able to do this easily. Be careful. You do not want to add so much water that you will have to dry the material and repeat the test. Rarely, the point may fall on the wet side of the curve's peak. If this happens, dry the material and repeat the test. Add moisture using trial and error.

1.2.6.6 REPORT

1) The method used (Method A, B, C, and D).

2) The optimum moisture content as a percentage to the nearest whole number.

3) The maximum mass to the nearest 0.1 kg/m^3 (0.1 lb/ft^3).

4) In Methods C & D, indicate if the material retained on the 19.0 mm (0.75 in.) sieve was removed or replaced.

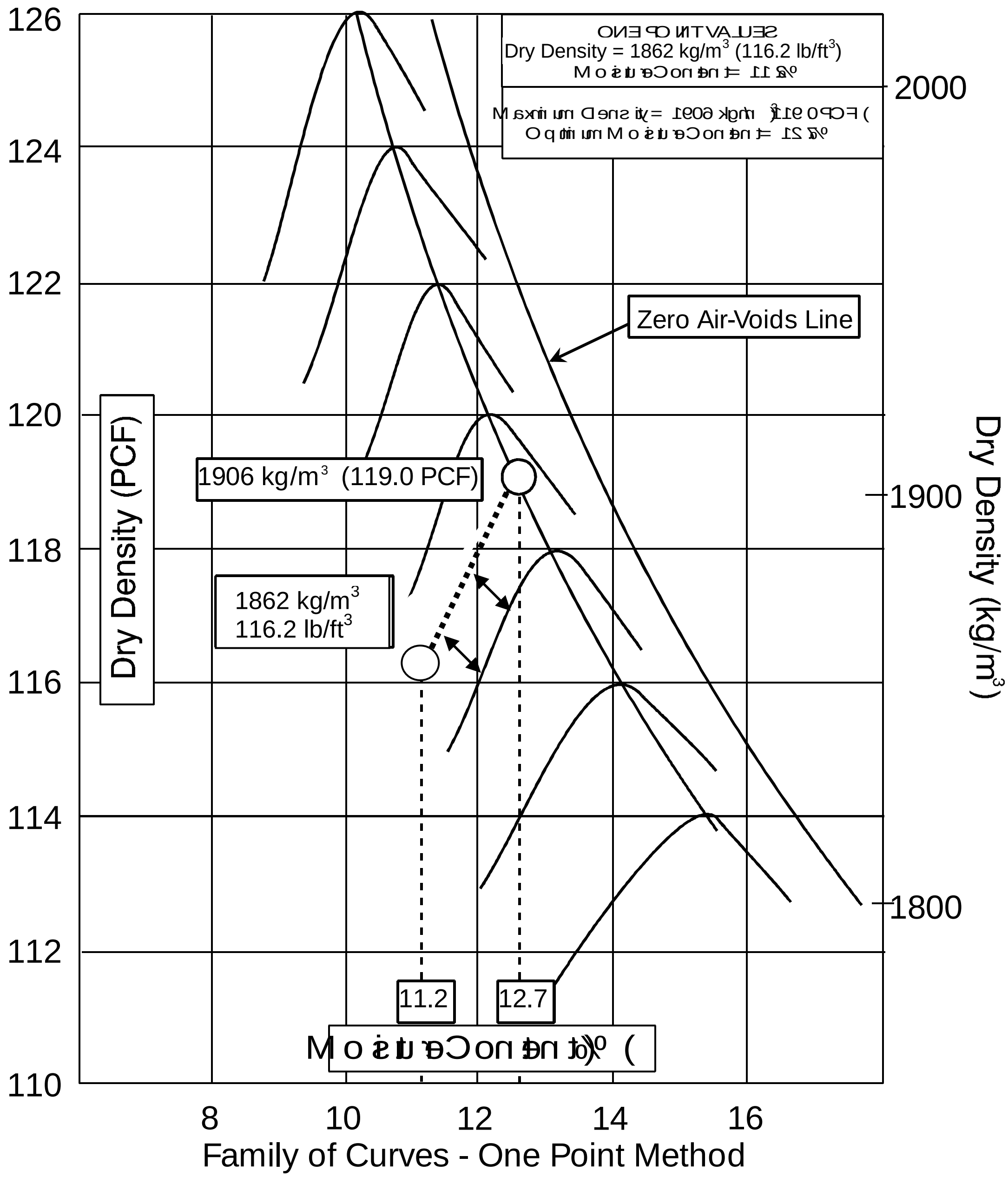


Fig. 1.16 Examples of Curves

1.2.7 RANDOM SAMPLING OF CONSTRUCTION MATERIALS, MARTCP METDOD SA-1.4

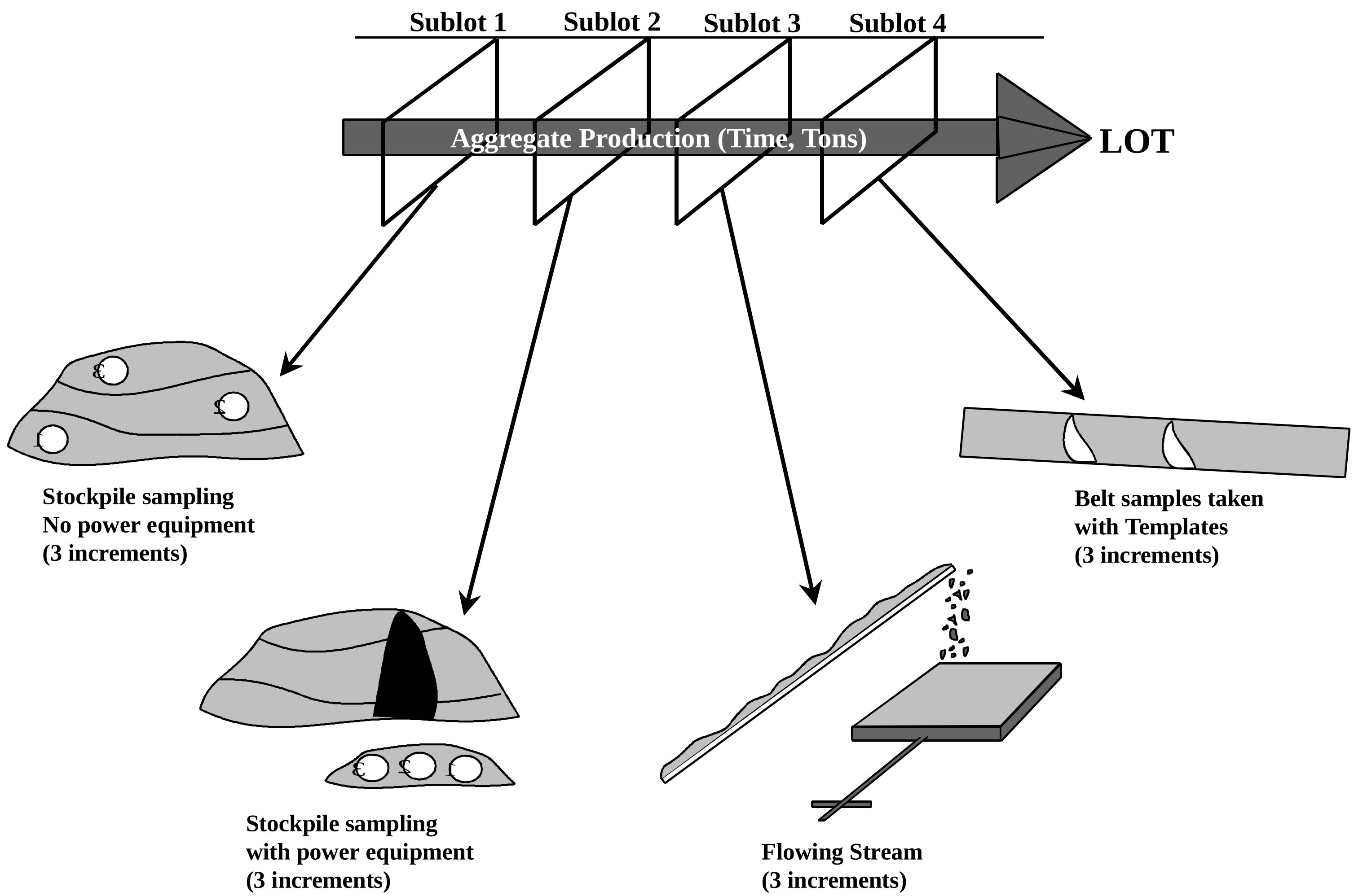
This section provides guidelines for the selection of random locations or times at which samples or tests of construction materials are to be taken.

Highway construction materials are typically accepted or rejected based on the test results of small representative samples. Consequently, acceptance or rejection of materials is highly dependent on how well a small sample represents a larger quantity of material. If the samples are not truly representative of the larger quantity, acceptable material could be rejected, or substandard material accepted. Correct sampling methods are critical to the validity of the sample test results. Sampling performed incorrectly will lead to test results that do not reflect the true characteristics of the material or product being tested.

The actions required to obtain a good sample (such as how to take the sample, where to take it, what tools to use and the size of sample) are covered in the appropriate materials control program and guidelines specified by the agency for use on the project. Reference should be made to these instructions on sampling requirements.

When a sample is not representative or random, it is said to be biased. Examples of biased sampling that should not be used include sampling an embankment at a given interval, such as every 500 cubic meters (650 yd^3); sampling borrow material at a given frequency, such as every fifth truckload, or taking samples at a given time frequency, such as every hour on the hour. Random sampling is used to eliminate bias in selecting a location or time for sampling. A random sample is any sample which has an equal chance of being selected from a large quantity. In other words, there is an equal chance for all locations and all fractions of a large quantity of material to be sampled (see Figure 1.17).

Random unbiased samples must represent the true nature of the material. Samples should not be obtained on a predetermined basis or based on the quality of the material in a certain area. If sampling is not performed on a random basis, the quality of the sample can be artificially modified causing the sample to no longer be representative of the larger quantity. Specifications will identify lot size, location and frequencies for sampling and testing. A lot is defined as a given quantity of material that is to be sampled. The lot is a predetermined unit which may represent a day's production, a specified quantity of material, a specified number of truckloads, or an interval of time. Agencies will usually specify the lot size and sampling frequency. Although these frequencies may appear to be a violation of random sampling, they are given as a minimum amount of sampling, not as a specific frequency. Lots are often divided into sublots. The number of sublots used to represent the lot will be determined by the agency and specifications. It may be necessary to take multiple samples and



Sampling Situations for Aggregate

Figure 1.17 Example of random sampling techniques

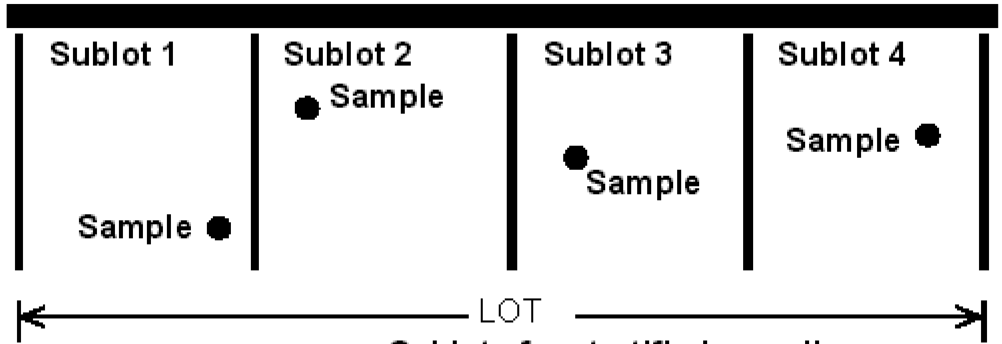


Fig. 1.18 **Sublots for stratified sampling.**

combine them to represent a unit. For example, three samples may be taken from a borrow source and combined to form a composite sample. Several composite samples will then be tested to determine the compliance of a sublot or lot to the specifications. The use of random samples from sublots is referred to as stratified random sampling. Stratified random sampling assures that samples are taken from throughout the entire lot and are not concentrated in one area of the lot (see Figure 1.18).

Quality control/quality assurance specifications are developed based on statistical theory, which is valid only when random sampling is performed. QC/QA specifications are statistically based on a normal distribution (bell curve) of uniform material production. If samples are biased or not random, the test results will not fit in the normal distribution, and the QC/QA specification will no longer be valid.

Random sampling is usually accomplished with the use of random number generators or tables of random numbers. Most calculators and computers contain a random number generator that merely requires the operator to hit a button. The automated random number generators use programmed tables of random numbers similar to the tables included later. A random numbers table is simply a random arrangement of numbers.

ASTM D 3665 is a method for determining random locations or time intervals for sampling and testing. Individual states within the Mid-Atlantic Region have developed various random numbers tables that are much easier to use and less time consuming. Table 1.7 is an example of a table currently being used in the Region. It is not important which table or method is used as long as random numbers are incorporated into the selection process.

The table of random numbers contains 5 sections with 2 columns of numbers in each section. The first column of numbers in each section is for determining the test site along the centerline or roadway. The second column of numbers is for determining the offset (distance from the centerline or edge of pavement). Either column of numbers can be used for selecting single numbers such as to determine which lift to test.

To use the table, select a random starting point on the table by tossing a pencil upon the page or blindly pointing out a location with the finger. The selection of random numbers will consist of a pair of random numbers. Once the point is located, select the number in the first column for the length and the corresponding number in the right column for the offset. When more than one pair of random numbers is needed, continue selecting the pairs of numbers down the page. If the bottom of the page is reached, go to the top of the next section to the right or to the top of the first section on the left side of the page if the bottom of the right most section of the page is reached. When selecting lifts to be tested or times to sample, only single random numbers are needed and can be obtained from any of the columns of numbers.

***Example 1*:**

The lot size is 900 m^3 (1170 yd^3) of embankment material. The area to be tested is 150 m long and 40 m wide and a lift thickness of 150 mm (6 in.). For this example, the Specifications require that at least 5 compaction tests be performed with one test in each of the 5 sublots. Divide the length of the lot by 5 (150/5). The right side of the lot closest to centerline will be used to measure the offset distance for the tests. Each sublot would be 30 m long (98 ft) and 40 m (131 ft.) wide. Five sets of random numbers are needed to determine where the tests will be performed.

Random numbers:
Set 1: .481 .791
Set 2: .599 .966
Set 3: .464 .747
Set 4: .675 .654
Set 5: .279 .707

Multiply the length of each sublot 30 m (98.4 ft) and the width by 40 m (131.2 ft) by the random numbers.

Sublot 1	.481 (30) = 14.4 m (47.3 ft)	.791 (40) = 31.6 m (103.8 ft)
Sublot 2	.599 (30) = 18.0 m (59.0 ft)	.966 (40) = 38.6 m (126.8 ft)
Sublot 3	.464 (30) = 14.0 m (45.7 ft)	.747 (40) = 29.9 m (98.0 ft)
Sublot 4	.675 (30) = 20.2 m (66.4 ft)	.654 (40) = 26.2 m (85.8 ft)
Sublot 5	.279 (30) = 8.4 m (27.5 ft)	.707 (40) = 28.3 m (92.8 ft)

Once the location of the test sites for each sublot has been calculated, then the test sites can be located by measuring the calculated distance from the beginning of the sublot and the offset from the right side of the sublot.

1. *Example 2*:

The specifications require at least one aggregate sample to be obtained from the production belt during each day of production. Aggregate is being manufactured between the hours of 8:00 a.m. and 4:00 p.m.

Determine the number of minutes of production during the day .

8 hours times 60 minutes equals 480 minutes.

Select a random number from the Random Numbers Table.

.488

Multiply the number of minutes (480) by the random number.

480 (.488) = 234 minutes

The time to sample would be 234 minutes from 8:00 a.m. or at 11:54 a.m.

TABLE 1.7 - RANDOM NUMBERS

.858	.082	.886	.125	.263	.176	.551	.711	.355	.698
.576	.417	.242	.316	.960	.819	.444	.323	.331	.179
.687	.288	.835	.636	.596	.174	.866	.685	.066	.170
.068	.391	.739	.002	.159	.423	.629	.631	.979	.399
.140	.324	.215	.358	.663	.193	.215	.667	.627	.595
.574	.601	.623	.855	.339	.486	.065	.627	.458	.137
.966	.529	.757	.308	.025	.836	.200	.055	.510	.656
.608	.910	.944	.281	.539	.371	.217	.882	.324	.284
.215	.355	.645	.460	.719	.057	.237	.146	.135	.903
.761	.883	.771	.388	.928	.654	.815	.570	.539	.600
.869	.222	.115	.447	.658	.989	.921	.924	.560	.447
.562	.036	.302	.673	.911	.512	.972	.576	.838	.014
.481	.791	.454	.731	.770	.500	.980	.183	.385	.012
.599	.966	.356	.183	.797	.503	.180	.657	.077	.165
.464	.747	.299	.530	.675	.646	.385	.109	.780	.699
.675	.654	.221	.777	.172	.738	.324	.669	.079	.587
.279	.707	.372	.486	.340	.680	.928	.397	.337	.564
.338	.917	.942	.985	.838	.805	.278	.898	.906	.939
.316	.935	.403	.629	.130	.575	.195	.887	.142	.488
.011	.283	.762	.988	.102	.068	.902	.850	.569	.977
.683	.441	.572	.486	.732	.721	.275	.023	.088	.402
.493	.155	.530	.125	.841	.171	.794	.850	.797	.367
.059	.502	.963	.055	.128	.655	.043	.293	.792	.739
.996	.729	.370	.139	.306	.858	.183	.464	.457	.863
.240	.972	.495	.696	.350	.642	.188	.135	.470	.765

APPENDICIES

APPENDIX A

MOSTURE-DENSITY RELATIONS OF SOILS PRESENTATION

STANDARD METHOD AASHTO T 99
MODIFIED METHOD AASHTO T 180

Slide 1

M	**Mid**
A	**Atlantic**
R	**Region**
T	**Technician**
C	**Certification**
P	**Program**

Moisture-Density Relations of Soils

Standard Method - AASHTO T 99
Modified Method - AASHTO T 180

Notes:

Slide 2

WHY we do Moisture-Density testing?

Soils form the foundation for most highway structures. The final structure, whether it is a pavement or a bridge structure, can only be as durable as the foundation upon which it rests.

Compaction of the soil is necessary in order to assure that the soil or soil aggregate structure will perform and support its intended design loads. Material that is densely compacted will support more load than uncompacted material.

Notes:

Slide 3

a.k.a…..

Standard Proctor Test
or
Modified Proctor Test

Notes:

Slide 4

Methods:

Four distinct test methods for T 99 and T 180

	Method A	Method B	Method C	Method D
Mold Size	101.60mm (4 in.)	152.40mm (6 in.)	101.60mm (4 in.)	152.40mm (6 in.)
Material Size	Passing 4.75mm (No. 4)	Passing 4.75mm (No. 4)	Passing 19.0mm (3/4 in.)	Passing 19.0mm (3/4 in.)
Blows per Layer	25	56	25	56
Standard (T 99)	3 Layers; 2.495 kg (5.5 lb) rammer; 305 mm (12 in.) drop			
Modified (T 180)	5 Layers; 4.536 kg (10 lb) rammer; 457 mm (18 in.) drop			

Notes:

Slide 5

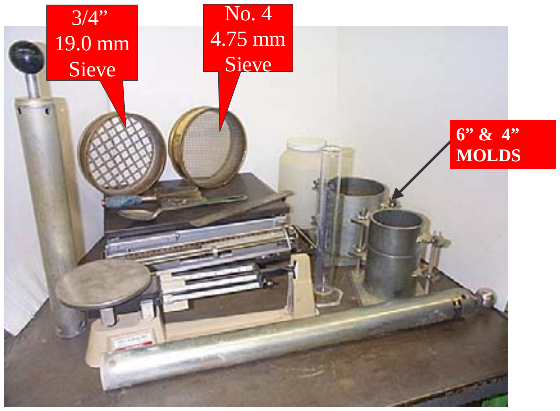
FIELD EQUIPMENT NEEDED

Notes:

Slide 6

Notes:

Slide 7



Notes:

Slide 8

Sample Preparation

Follow these steps to prepare sample:

-If the sample is wet, dry it on a hot plate not exceeding 60°C until it becomes friable.

- Aggregations in a friable soil sample will break apart easily.
- Avoid breaking apart the natural particles when breaking up soil aggregations.

-Sieve the sample over the specified sieve for the method being used:

- Methods A & B use a 4.75 mm sieve
- Methods C & D use a 19.0 mm sieve

Notes:

Slide 9

Dry sample until it becomes friable under a trowel / spoon.

Slide 10

Sieve the sample over the specified sieve for the Method being performed. (A & B use the 4.75 mm No. 4 sieve; C & D use the 19.0mm 3/4"). Discard any material retained on the specified sieve.

Notes:

Slide 11

Thoroughly mix the remaining sample.

Notes:

Slide 12

Sample Preparation (Cont..)

-Thoroughly mix the remaining sample.

- Obtain at least enough material to fill the mold when compacted and provide enough extra material to ensure adequate material for determinations of moisture content and increase in density as more water is added.
- NOTE: This method allows the use of the same soil sample for each "point" on the density curve.
  - If the soil is a clayey material which will not easily mix with water or where the soil material is fragile and breaks apart from the repeated blows of the rammer, it may be necessary to prepare individual portions for each point.

-Prepare the sample(s) and mix with water to produce the desired moisture content.

Notes:

Slide 13

Obtain enough material to fill the mold when compacted and provide enough extra material to ensure adequate material for determination of moisture content.

Notes:

Slide 14

Compacting Sample - Manual Method

Safety Gloves are a good idea!

Notes:

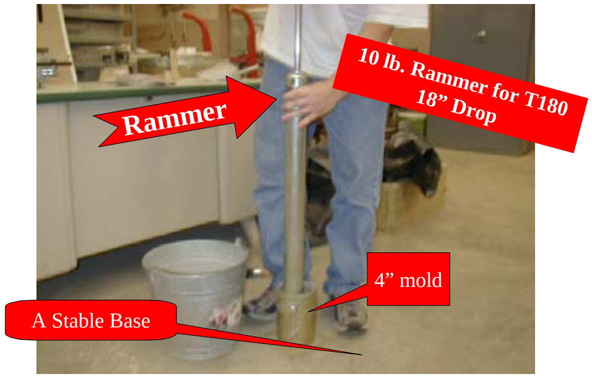
Slide 15

Starting First Layer

Notes:

Slide 16

5 Even Layers for T 180



Notes:

Slide 17

3 Even Layers for T 99

Notes:

Slide 18

Ready to be Trimmed

Notes:

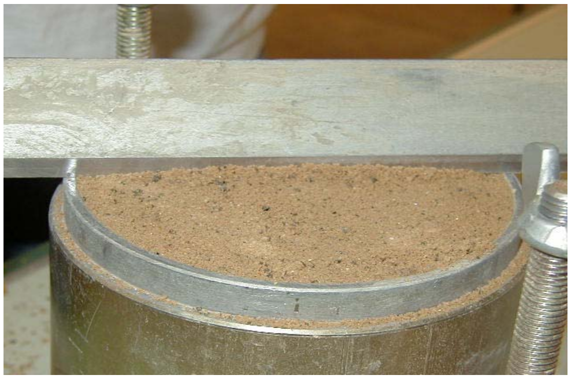
Slide 19

Straight Edge

Notes:

Slide 20

Striking-Off Sample



Notes:

Slide 21

Clean around Base

Notes:

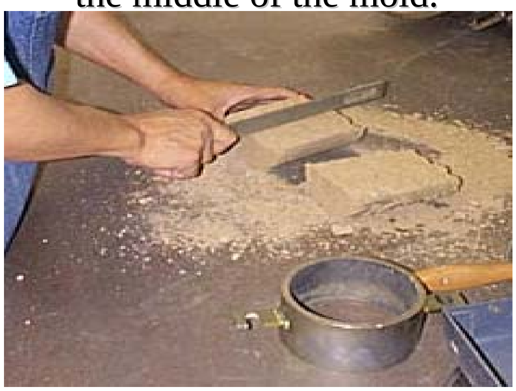
Slide 22

Weigh the Molds

Notes:

Slide 23

Obtaining Moisture Sample from the middle of the mold.



Notes:

Slide 24

Watch your fingers

Notes:

Slide 25

Taking Moisture Sample

Notes:

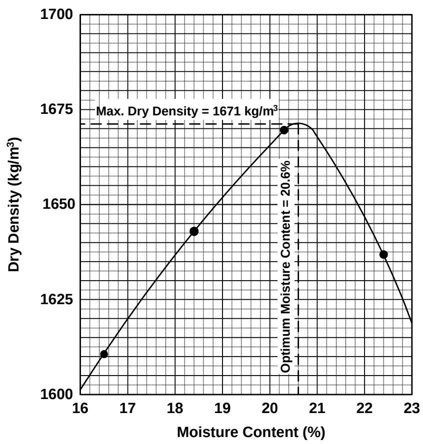
Slide 26

Weighing Moisture Samples

Notes:

Slide 27

Final Product



Notes:

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Some Common Testing Errors

- The Soil is not thoroughly mixed to achieve uniform moisture.
- The manual rammer is not held vertically when the blows are delivered
- The rammer is not properly cleaned between uses.
- The incorrect rammer is used.
- The manual rammer is not lifted to the full stroke.

Notes:

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THE END

Notes:

APPENDIX B

IN-PLACE DENSITY BY SANDCONE PRESENTATION

AASHTO T 191

Slide 1

M
A
R
T
C
P

Mid Atlantic Region Technician Certification Program

Density of soil in-place by The Sand Cone method AASHTO T-191

Notes:

Slide 2

Why test for density?

The density of a material influences its ability to consolidate or move.

Density is used to calculate the compaction levels of the constructed soil or soil aggregate layers.

Notes:

Slide 3

Density

Density is a function of mass (weight) divided by its volume.

Percent density is the ratio of the in-place density to the maximum (target) density as determined in the laboratory according to standard testing procedures.

Notes:

Slide 4

Materials and Equipment

Sampling supplies

Notes:

Slide 5

Materials and Equipment

Sand cone

Notes:

Slide 6

Materials and Equipment

Sand

Notes:

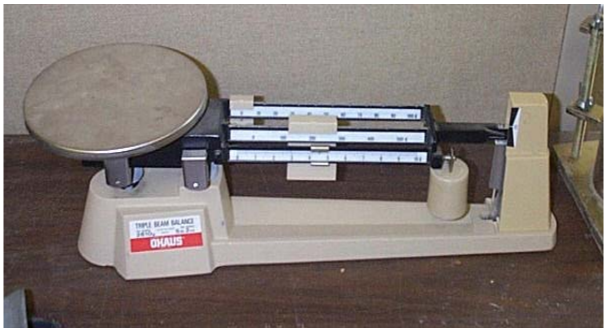
Slide 7

Balances and Scales

Notes:

Slide 8

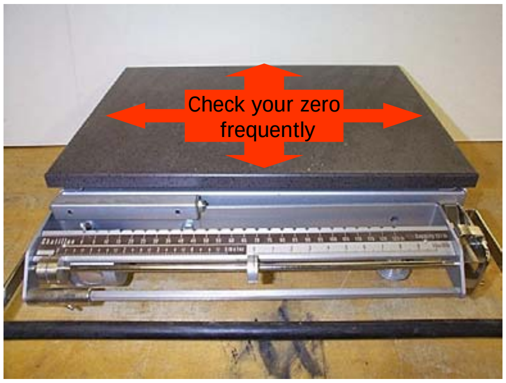
Triple Beam Balance



Notes:

Slide 9

Postal Scale



Notes:

Slide 10

Hot Plate

Notes:

Slide 11

Miscellaneous Equipment

Notes:

Slide 12

Pointing trowel, large spoon, wire brush, stencil brush and gloves

Notes:

Slide 13

Metal container, such as a large frying pan or equivalent

Notes:

Slide 14

Sample Containers

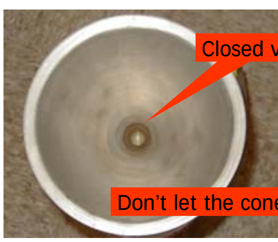
Notes:

Slide 15

Test Procedures

Determine the bulk density of the sand to be used in the test.

1. Place the empty apparatus upright on a firm, level surface, close the valve and fill the funnel with sand.



Notes:

Slide 16

Test Procedures cont.

2. Open valve and keep the funnel at least half full of sand. Fill the apparatus until full.

Notes:

Slide 17

Test Procedures cont.

2. (cont.) Close the valve sharply and empty the excess sand.

Notes:

Slide 18

Test Procedures cont.

3. Weigh the apparatus with the sand and determine the net mass of sand by subtracting the mass of the apparatus.

Notes:

Slide 19

Test procedures cont.

4. Calculate the bulk density of the sand.

Calculate the density of the sand to the nearest 0.1 pcf. If a secondary apparatus is used, then use the volume of the secondary apparatus

Notes:

Slide 20

Test Procedure cont.

5. Avoid any vibration of the sand during the mass/volume calculation.

Notes:

Slide 21

Determining the Mass of sand required to fill the Cone.

1. Put sand into the apparatus and close the valve.

Notes:

Slide 22

Test Procedure cont.

2. Invert the apparatus on a clean, level surface so that the cone is facing down. (Always use a base plate for both calibration, and the actual field testing).

Notes:

Slide 23

Test procedures cont.

3. Open the valve and allow the sand to flow until it stops. Close the valve sharply and weigh the apparatus with the remaining sand in the jar. Determine the loss of sand and record it as the weight of sand required to fill the cone.

Notes:

Slide 24

Test procedures

4. Replace the sand used for this determination and close the valve, and reweigh. The sand cone is now ready and calibrated for use.

Notes:

Slide 25

Finding the weight (mass) of sand in the hole.

Notes:

Slide 26

Test procedures

1. Fill the jar with enough sand to fill the hole volume and the cone/funnel. Weigh the apparatus with the sand prior to use.

Make sure that you close the valve and dump off excess material.

Notes:

Slide 27

Test procedures

2. Prepare the surface of the location to be tested so that it is smooth and level for the base plate.

Notes:

Slide 28

Test procedures

3. Seat the base plate on the prepared surface.

Notes:

Slide 29

Test procedures

4. Remove the soil from within the area bounded by the base plate hole. The volume of the hole is dependent upon the maximum particle size.

Notes:

Slide 30

Test procedures

4. (Continued) The walls of the hole should slope inward and the bottom should be concave. Take care to avoid the loss of any material.

Notes:

Slide 31

Test procedures

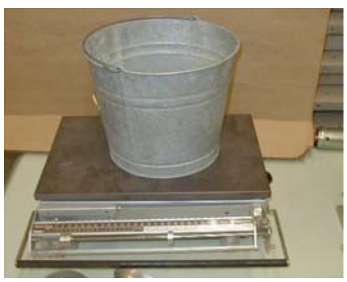
4. (continued) Place all excavated or loosened soil/stone in a moisture tight container.

Notes:

Slide 32

Test procedures

5. Weigh and record the material removed from the test hole. Retain a representative portion of the sample to determine the moisture content using MARTCP SA-1.3



Notes:

Slide 33

Test procedures

6. Seat the apparatus over the hole or on the base plate and open the valve. Allow the sand to flow from the apparatus, filling the hole and the cone/funnel.

Notes:

Slide 34

Test procedures

6. (continued) Once the sand has ceased flowing, sharply close the valve. There should be no vibration in the immediate area during this operation.

Notes:

Slide 35

Test procedures

7. Weigh the apparatus with the remaining sand and subtract this from the original weight of the apparatus filled with sand.

Notes:

Slide 36

Test procedures

7. (cont.) Subtract the weight (mass) of the sand previously determined to fill the apparatus from the weight (mass) of the sand used for the test. This is the weight (mass) of sand used to fill the excavated hole.

Notes:

Slide 37

Possible Problems

- Loss of materials
- Vibrations
- Incorrect determination of mass of sand

Notes:

Slide 38

THAT'S ALL FOLKS!

Notes:

APPENDIX C

IN-PLACE DENSITY BY NUCLEAR METHODS

MARTCP METHOD SA-1.2

Slide 1

M
A
R
T
C
P

Mid Atlantic Region
Technician
Certification
Program

In-Place Density by Nuclear Methods

MARTCP METHOD SA-1.2

Notes:

Slide 2

Why test for Density and Moisture?

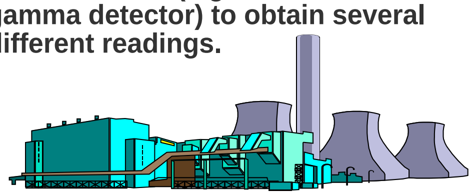
To insure that the embankment, base course or other earthwork structure will be strong enough to support its intended design load.

Notes:

Slide 3

The Nuclear Gauge

The nuclear gauge is a portable instrument containing radioactive sources and electronics. The gauge uses radiation (a gamma source and a gamma detector) to obtain several different readings.

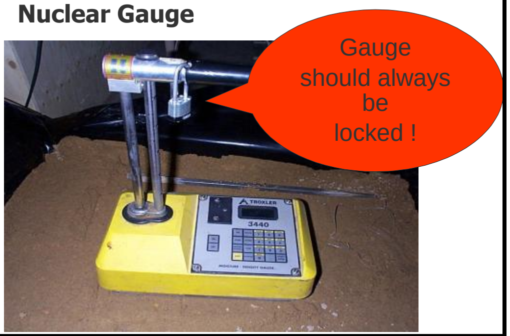


Notes:

Slide 4

Materials and Equipment

Nuclear Gauge



Notes:

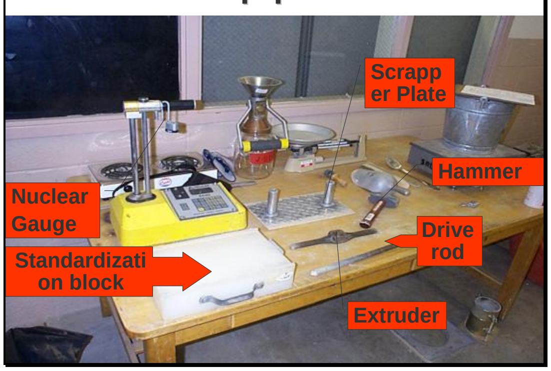
Slide 5

Miscellaneous Equipment

Notes:

Slide 6

Materials and Equipment

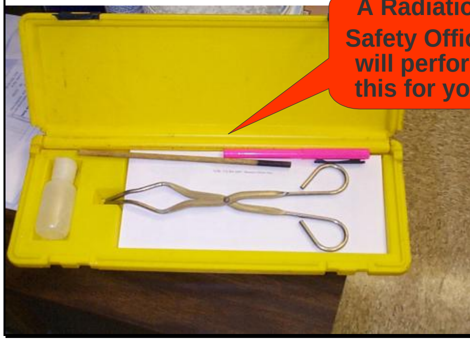


Notes:

Slide 7

Materials and Equipment

Leak Kit



Notes:

Slide 8

Standardization of the Gauge

Notes:

Slide 9

Standardization of Gauge

Standardization of nuclear gauge is required daily prior to use, whenever gauge readings are suspect, and as required by state specifications.

1. Warm up the gauge (see owners manual for required warm-up time).

Notes:

Slide 10

Standardization of Gauge

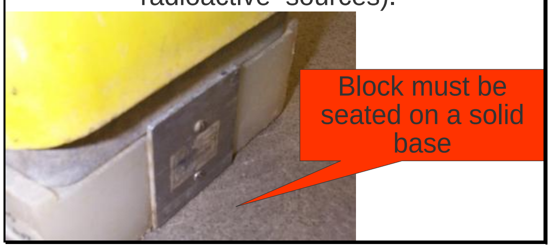
2. Place the standard block at least 3 m (10ft) away from any raised vertical object.

Notes:

Slide 11

Standardization of Gauge

3. Make sure that the bottom of gauge is clean. Place the unit on Standardization Block (gauge must be seated properly against the butt plate, away from other radioactive sources).



Notes:

Slide 12

Standardization of Gauge

4. Take at least four one minute count readings or four minute count reading.

5. If mean of readings is outside of the tolerance range, take another standard count. If the second standard count is outside of the tolerance range, the stability and drift should be checked.

Notes:

Slide 13

Standardization of Gauge

If the second standardization check is within allowable tolerance, the gauge is in working order.

6. If stability and drift tests pass, then you are ready to take a compaction test.

Notes:

Slide 14

Trench Correction

When the gauge is within 0.6 m (2 ft) of a wall or trench face, the gauge might read the hydrogen contained in the walls as well as the material under test.

In this situation, the trench correction must be used. Follow manufactures instructions for the type of gauge you are using.

Notes:

Slide 15

Procedure

Method A, Backscatter

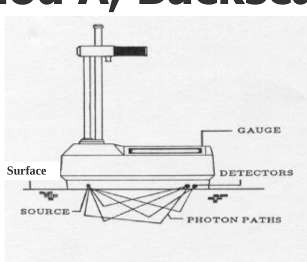


FIGURE A-2
BACKSCATTER GEOMETRY

Notes:

Slide 16

Procedure (Method A, Backscatter)

1. Select a location where the gauge will be at least 0.6 m (2 ft) away from any vertical projection.

Notes:

Slide 17

Procedure (Method A, Backscatter)

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

Notes:

Slide 18

Procedure (Method A, Backscatter)

3. Plane an area of sufficient size to a smooth condition to obtain maximum contact between the gauge and the material being tested.

Notes:

Slide 19

Procedure (Method A, Backscatter)

4. The maximum void space beneath gauge shall not exceed 3 mm (1/8”). Use native fines or fine sand to fill these voids (filled areas should not exceed 10 % of the area beneath the gauge).

Notes:

Slide 20

Procedure (Method A, Backscatter)

5. Once gauge is warmed up and standardized, take a one or more one minute readings in the backscatter mode. This will determine the (gauge derived) dry and wet density.

Notes:

Slide 21

Method B, Direct Transmission

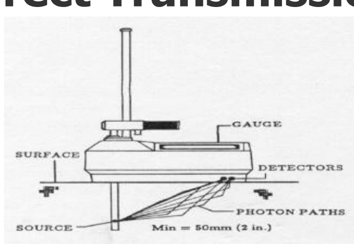


FIGURE A-1
DIRECT TRANSMISSION

Notes:

Slide 22

Procedure: Method B, Direct Transmission

Repeat steps 1 through 4 from the Backscatter method for site preparation.

Notes:

Slide 23

Procedure: Method B, Direct Transmission

5. Make a hole perpendicular to the prepared surface using the guide plate and drive rod.


Notes:

Slide 24

Procedure: Method B, Direct Transmission

5. (continued) The hole must be at least 50 mm (2 inches) deeper than the desired test depth. The source rod must not rest on the bottom of the hole.


Notes:

Slide 25

Procedure: Method B, Direct Transmission

6. Place the gauge over the hole and extend the probe into the hole to the depth required for the test (seat firmly).

Notes:

Slide 26

Procedure: Method B, Direct Transmission

7. Pull the gauge so that the probe is in contact with the side of the hole.This is required in order to take effective readings.

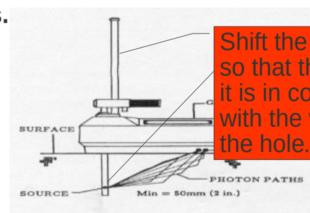


FIGURE A-1
DIRECT TRANSMISSION

Shift the gauge so that the probe it is in contact with the wall of the hole.

Notes:

Slide 27

Procedure: Method B, Direct Transmission

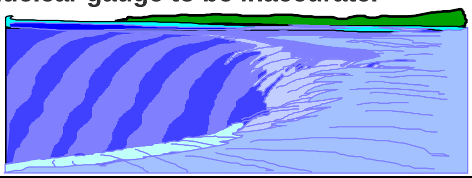
8. Take one or more one-minute readings, which will determine the (gauge derived) wet or dry density of the soil.

Notes:

Slide 28

Moisture Content Procedure

Most gauges measure the density and moisture at the same time. The nuclear gauge reads hydrogen ions as water. Various minerals and chemicals are neutron absorbers. These may cause the moisture content determined by a nuclear gauge to be inaccurate.

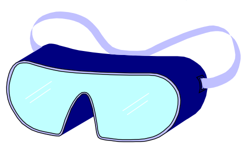


Notes:

Slide 29

Possible Problems

- Improper Calibration Methods
- Exposed source rods
- Damaged Equipment
- Unsafe Techniques
- Overheating
- Out-dated units
- Vibrations



Notes:

Slide 30

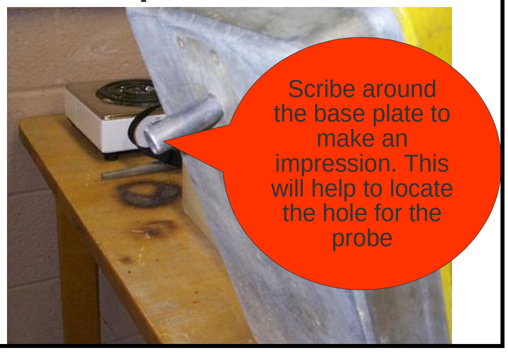
- **Improper Standardization Methods**

  Properly seat the Gauge on the Standardization Block when running a standard count.

Notes:

Slide 31

Never expose the source rod



Notes:

Slide 32

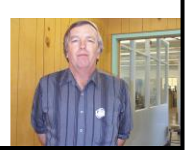
Damaged Equipment

Notes:

Slide 33

Safe Technique Tips:

1. Never leave a gauge unattended.
2. Always transport in the box, locked.
3. Store 10ft. min. away from work stations.
4. Wear Film Dosimeter Badge when with unit.
5. Check with your State regarding Safety requirements.



Notes:

Slide 34

Overheating

If the Gauge is used in direct sunlight on a hot day for a long period of time, it may develop Over- heating problems.

This can be indicated as a shut down of the computer in the apparatus.

The remedy to this is to store the unit in a cool and dark place for short period of time. This will allow the Gauge to reset.

Notes:

Slide 35

Out-Dated Equipment

Notes:

Slide 36

Vibrations

Notes:

APPENDIX D

FIELD MOISTURE TEST PRESENTATION

MARTCP SA-1.3

Slide 1

M
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P

Mid Atlantic Region
Technician Certification
Program

Field Moisture Test

MARTCP METHOD SA-1.3

Notes:

Slide 2

Why test for moisture content?

The moisture content of a material influences its ability or inability to be excavated, consolidated, moved, screened, weighed, dried out, or reabsorbed.

The moisture content is used to calculate a variety of properties, including density, plasticity, permeability and more.

Notes:

Slide 3

Materials and Equipment

Notes:

Slide 4

Drying Apparatuses

Propane Gas Stoves

Notes:

Slide 5

Drying Apparatuses

Electric Hot Plate

Notes:

Slide 6

Balances and Scales

Notes:

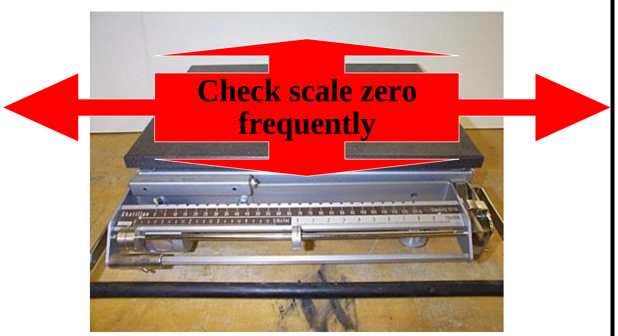
Slide 7

Triple Beam Balance

Notes:

Slide 8

Postal Scale



Notes:

Slide 9

Miscellaneous Equipment

Notes:

Slide 10

Metal container, such as a large frying pan or equivalent.

Notes:

Slide 11

Pointing trowel, large spoon, wire brush, stencil brush and gloves

Notes:

Slide 12

Sample Containers

Notes:

Slide 13

Test Procedure:

1. Select a representative quantity of material based on the following chart:

Aggregate Moisture Content Sample Sizes	
Nominal Maximum Size, mm (in.)	Minimum Sample Mass
4.75 (#4)	0.5 kg/ 1.1 lbs.
9.5 (3/8).	1.5 kg/ 3.3 lbs
12.5 (1/2)	2 kg/ 4.4 lbs.
19.0 (3/4)	3 kg/ 6.6 lbs.
25.0 (1)	4 kg/ 8.8 lbs.
37.5 (1 1/2)	6 kg/ 13.2 lbs.
50.0 (2)	8 kg/ 17.6 lbs.
All Soils Moisture Content Sample Sizes must be a minimum of 500 grams	

Notes:

Slide 14

Test Procedure, continued

2. Weigh a clean, dry container and record the weight (tare).

Notes:

Slide 15

Test Procedure, continued

3. Place the sample in the container and weigh. Then record the value minus the tare weight.

Notes:

Slide 16

Test Procedure, continued

4. Place the container on the stove or hot plate and mix the sample continuously to expedite drying and prevent burning of soil.

Notes:

Slide 17

Test Procedure, continued

4. Place the container on the stove or hot plate and mix the sample continuously to expedite drying and prevent burning of the aggregate.

Notes:

Slide 18

Test Procedure, continued:

5. When the sample looks dry, remove it from the stove, cool and weigh. Put sample back on the stove, continue drying for another two to three minutes, cool and reweigh. If there is less than 0.1 percent difference between the weights, the sample is dry. Record the weight of the sample, minus the container.

Notes:

Slide 19

Reweigh the Dried Sample (Soils)

5. continued Place the sample back on the stove. Continue drying for another two to three minutes, cool and reweigh. If there is less than 0.1 percent difference between the weights, the sample is dry. Record the weight of the sample and the container.

Notes:

Slide 20

Weighing Dried Aggregate

Notes:

Slide 21

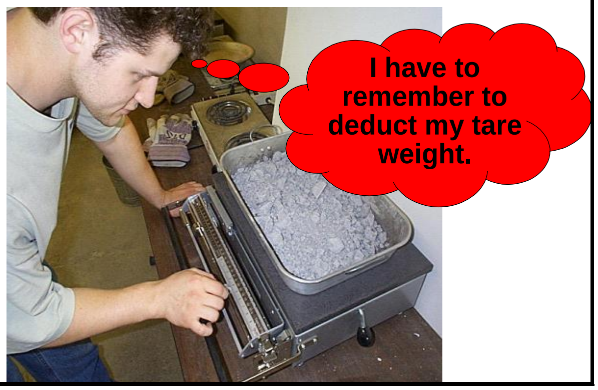
Re-heating the Aggregate Sample

Don't forget to wear your safety gloves when working with hot items.

Notes:

Slide 22

Re-weighing the re-dried Aggregate Sample



Notes:

Slide 23

Soil Moisture Sample

Notes:

Slide 24

Graded Aggregate Moisture Sample

Notes:

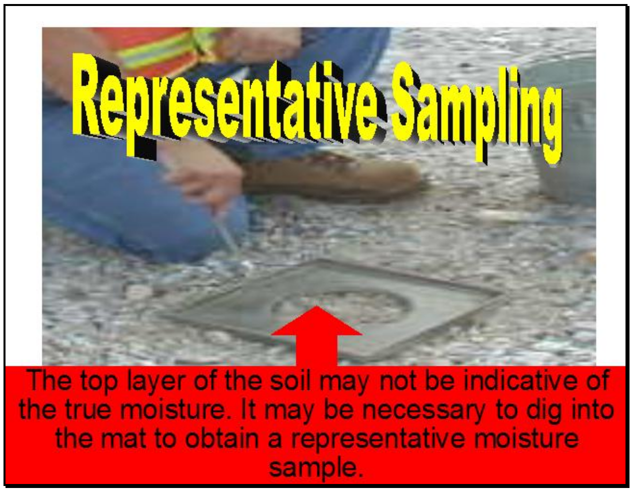
Slide 25

Possible Problems

- Non-representative Sampling
  - Insufficient Sample
    - Loss of Sample
      - Overheating

Notes:

Slide 26



Notes:

Slide 27

Obtaining Representative Sample

Notes:

Slide 28

Insufficient Sample Size

Notes:

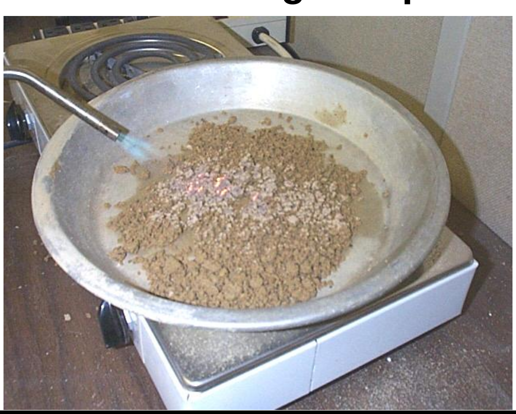
Slide 29

Loss of Sample

Notes:

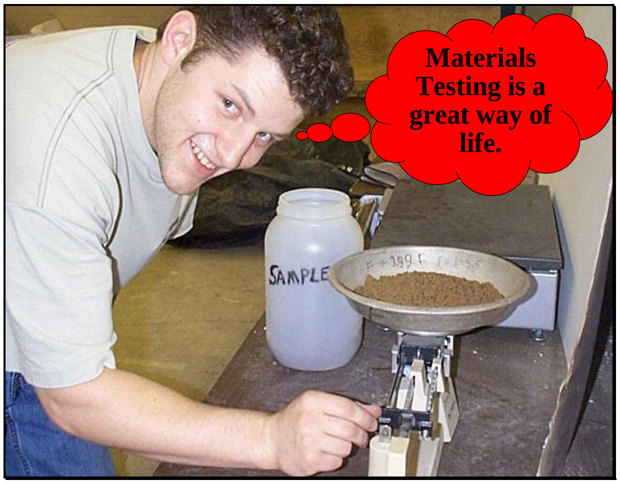
Slide 30

Overheating Sample



Notes:

Slide 31



Notes:

Slide 32

THAT'S ALL FOLKS!

Notes: