5.16.13 FIELD DENSITY TESTS OF SOILS, TREATED BASE COURSES, AND WATER BOUND BASE COURSES (Kansas Test Method KT-13)

a. SCOPE

This method of test covers the procedure for measuring the "in-place" density of soils and granular base courses. The density of a material is defined as the ratio of the mass of material to the volume of the same mass of material. The tests described consist of measuring the volume that a given mass of soil or base material occupies when it is in-place. KT-13 reflects testing procedures found in AASHTO T 191 and T 205.

b. REFERENCED DOCUMENTS

b.1. KT-11; Moisture Test

b.2. KT-15; Bulk Specific Gravity and Unit Weight of Compacted Asphalt Mixtures

b.3. KT-43; Moisture Content of Asphalt Mixtures or Mineral Aggregates - Microwave Oven Method

b.4. AASHTO M 231; Weighing Devices Used in the Testing of Materials

b.5. AASHTO T 180; Moisture-Density Relations of Soils Using a 4.54 Kg (10 lb) Rammer and a 457 mm (18 in) Drop

b.6. AASHTO T 191; Density of Soil In-Place by the Sand-Cone Method

b.7. AASHTO T 205; Density of Soil In-Place by the Rubber-Balloon Method (deleted in 2000)

c. APPARATUS

c.1. General.

c.1.a. Balances: AASHTO M231; Class G2 and G20.

c.1.b. Oven capable of maintaining a uniform temperature of approximately 110°C (230°F) or a hot plate with a buffer consisting of a pan of sand or thick steel plate placed between the drying pan and the flame. If available, a microwave oven as described in KT-43 may be used.

c.1.c. Equipment or shelter to protect balance from wind currents and the samples from exposure to the sun and wind.

c.1.d Soil auger

c.1.e. Miscellaneous equipment including standard drying pans, trowel, large spoon, hammer, chisels, heavy bladed knife, square point shovel, 300 mm (12 in) straight edge.

c.2. Sand Density Apparatus

c.2.a. The density apparatus shall consist 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 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[a].

Note a: The apparatus[1] described here represents a design that has proven satisfactory. Other apparatus of similar proportions will perform equally well so long as the basic principles of the sand-volume determination are observed. This apparatus, when full, can be used with test holes having a volume of approximately 2.7 L (0.1 cu ft). The base plate is optional; its use may make leveling more difficult but permits test holes of larger diameter and may reduce loss in transferring soil from test-hole to container as well as afford a more constant base for tests in soft soils. When the base plate is used it shall be considered a part of the funnel in the procedures of this test method.

c.2.b. Sand: Any clean, dry, free-flowing, uncemented sand having few, if any, particles passing the 75 µm (#200) or retained on the 2.00-mm (#10) sieves. In selecting a sand for use several bulk density determinations should be made using the same representative sample for each determination. To be acceptable the sand shall not have a variation in bulk density greater than 1 percent.

c.3. Rubber-Balloon Density Apparatus

c.3.a. Calibrated Vessel: A calibrated vessel designed to contain a liquid within a relatively thin, flexible, elastic membrane (rubber balloon)for measuring the volume of the test hole under the conditions of this method. The apparatus shall be equipped so that an externally controlled pressure or partial vacuum can be applied to the contained liquid. It shall be of such mass and size that it will not cause distortion of the excavated test hole and adjacent test area during the performance of the test. Provision shall be made for placing masses (surcharge) on the apparatus. There shall be a volume indicator for determining to the nearest 0.006 liter (0.00025 cu ft.) any change in volume of the test hole. The flexible membrane shall be of such size and shape as to fill the test hole completely without wrinkles or folds inflated within the test hole, and its strength shall be sufficient to withstand such pressure as is necessary to ensure complete filling of the test hole[b].

Note b: The description given above is intended to be non restrictive. Any apparatus using a flexible (rubber) membrane and liquid that will measure the as-dug volume of a hole in soils or bases, under the conditions of this method, to an accuracy of one percent is satisfactory.

d. TEST PROCEDURE

d.1. Sand Density Method[2]

d.1.a. Determine the loose unit weight of sand in kg/m^3 (lb/ft^3) as follows:

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[1] See AASHTO T 191 figure 1 for size requirements.

[2] Sand Density Method is KDOT method only. AASHTO has no similar method.

d.1.a.1. Fill the cylindrical container of known volume to slightly overflowing by pouring the dry sand at a uniform rate from the spout of the pouring container. The spout is held approximately 50 mm (2 in) above the top of the container.

d.1.a.2. Strike off the excess sand level with top of the container, being extremely careful to avoid jarring the container during the process. Conduct a total of three tests to determine the loose unit weight of the sand and use the average value obtained when computing the "in-place" density of the material being tested.

d.1.b. Select the area where density is to be measured, determine and record the station, distance from center line, and elevation as distance below the final grade.

d.1.c. Trim off all raised or uneven spots to produce a smooth, flat surface not less than 450 mm (18 in) square, using a square point shovel or other suitable tool, and remove all loose material from the area.

d.1.d. Drill or cut a test hole through the depth of the material being tested and save all material removed, protecting the sample from weather conditions which might change the moisture content.

d.1.e. Weigh the material, record the mass, dry the entire sample or a representative portion to constant mass. Weigh and record the dry mass.

Note c: If the "Speedy" moisture tester is used to determine the moisture content, the procedure set forth in KT-11 is followed. The dry mass of material is calculated as shown in item **d.1.i.6.** of this test method.

d.1.f. Determine and record the mass of the pouring container with a volume of sand somewhat greater than the volume of the test hole.

d.1.g. Fill the test hole level full of sand by pouring the sand at a uniform rate while holding the spout 50 mm (2 in) above the top of the test hole, as was done when calibrating the sand. The straight edge should be used to insure that the sand is level with the surface of the material surrounding the test hole.

d.1.h. Weigh the pouring container and remaining sand and record the mass.

d.1.i. Calculations.

d.1.i.1. Density of Dry Sand (V)

$$V = \frac{U}{T}$$

Where: U = Mass of sand in container (kg [lb])
T = Volume of Container (m^3 [ft^3])

NOTE: 1 m^3 = 1000 L 1 L = 1000 mL

d.1.i.2. Moisture Content of Material (%) (W)

$$\%W = \frac{100(A-B)}{B}$$

Where: A = Wet Mass of Material Removed from Test Hole.
B = Dry Mass of Material Removed from Test Hole.

d.1.i.3. Mass of Sand in Test Hole (kg (lb)) (G)

$$G = (E-F)$$

Where: E = Initial Mass of Sand Plus Pouring Container
F = Final Mass of Sand Plus Pouring Container

d.1.i.4. Volume of Test Hole (H)

$$H = \frac{G}{V} \quad (m^3\ [ft^3])$$

Where: G = Mass of Sand in Test Hole (kg [lb])
V = Density of Sand (kg/m^3 [lb/ft^3])

d.1.i.5. In-place Dry Density of Material Being Tested (J)

$$J = \frac{B}{H} \quad (kg/m^3\ [lb/ft^3])$$

Where: B = Dry Mass of Material Removed from Test Hole.
H = Volume of Test Hole.

d.1.i.6. Mass of dry material removed from the test hole (when "Speedy" moisture tester or a portion of the sample is used to determine moisture content) (B):

$$B = \frac{100(A)}{(N+100)} \quad (kg\ [lb])$$

Where: A = Mass of Wet Material Removed from Test Hole.
N = Percent Moisture of Wet Material Removed from Test Hole.

Note d: The use of KDOT Form No. 676 in work book form simplifies the above calculations.

d.2. Sand Cone Method

d.2.a. Determination of volume of jar and attachment up to and including the volume of the valve orifice as follows[e]:

d.2.a.1. Weigh the assembled apparatus and record.

d.2.a.2. Place the apparatus upright and open the valve.

d.2.a.3. Fill the apparatus with water until it appears over the valve.

d.2.a.4. Close the valve and remove excess water.

d.2.a.5. Weigh the apparatus and water and determine the temperature of the water.

d.2.a.6. Repeat the procedure described in steps d.2.a.2 to d.2.a.5. at least twice. Convert the mass of water, in grams, to milliliters by correcting for the temperature as given in section c.2.e.1. The volume used shall be the average of three determinations with a maximum variation of 3 mL.

Note e: The volume in this procedure is constant as long as the jar and attachment are in the same relative position. If the two are to be separated, match marks should be made to permit reassembly to this position.

d.2.b. Determination of Bulk Density of Sand[f & g]:

Note f: Vibration of the sand during any mass-volume determination may increase the bulk density of the sand and decrease the accuracy of the determination. Appreciable time intervals between the bulk density determinations of the sand and its use in the field may result in change in the bulk density caused by a change in the moisture content or effective gradation.

Note g: It is possible to determine the bulk density of the sand in other containers of known volume that dimensionally approximate the largest test hole that will be dug. The general procedure used is that given in Section c.2.d for determining the volume of the test hole. If this procedure is to be followed it shall be determined that the resulting bulk density equals that given by the jar determination.

d.2.b.1. Place the empty apparatus upright on a firm, level surface; close the valve and fill the funnel with sand.

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

d.2.b.3. Weigh the apparatus and sand. Determine the net mass of sand by subtracting the mass of the apparatus.

d.2.c. Determination of mass of Sand Filling the Funnel[i & j]:

d.2.c.1. Put sand in the apparatus and obtain the mass of the apparatus and sand.

d.2.c.2. Seat the inverted apparatus on a clean, level, plane surface.

d.2.c.3. Open the valve and keep open until the sand stops running.

d.2.c.4. Close the valve sharply. Weigh the apparatus with remaining sand and determine the loss of sand. This loss represents the mass of sand required to fill the funnel.

Note h: For each container/bag of sand there will be a unique cone correction and sand calibration factor. Each sand-cone and matched base plate will also have a set of unique cone corrections and bulk sand densities. If more than one sand-cone apparatus is available, the sand-cone and base plate should be marked and the associated correction/density factors recorded.

d.2.c.5. Replace the sand removed in the funnel determination and close the valve.

Note i: This determination may be omitted if the procedure given in Note g is followed. When the base plate is used, it shall be considered a part of the funnel.

Note j: Where test holes of maximum volume are desired it is possible, after the bulk density determination, to settle the sand by vibration and increase the mass of sand available shall be determined by re-weighing.

d.2.d. Determination of Density of Soil in-Place:

d.2.d.1. Prepare the surface of the location to be tested so that it is a level plane.

d.2.d.2. Seat the inverted apparatus on the prepared plane surface and mark the outline of the funnel[k].

Note k: In soils such that leveling is not successful, a preliminary test shall be run at this point measuring the volume bounded by the funnel and ground surface. This step requires balances at the test site or emptying and refilling the apparatus. After this measurement is complete, carefully brush the sand from the prepared surface.

d.2.d.3. Seat the apparatus in the previously marked position, open the valve, and after the sand has stopped flowing, close the valve.

d.2.d.4. Weigh the apparatus and remaining sand. Determine the -mass of sand used in the test.

d.2.d.5. Weigh the material that was removed from the test hole.

d.2.d.6. Mix the material thoroughly and secure and weigh a representative sample for moisture determination.

d.2.d.7. Dry and weigh the soil sample for moisture content determination in accordance with KT 11 **b.2**.

d.2.d.8. The minimum test hole volumes suggested in determining the in place density of soil mixtures are given in Table 5.16.13-1. This table shows the suggested minimum mass of the moisture content sample in relation to the maximum particle size in soil mixtures.

Table 5.16.13-1: Minimum Field Test Hole Volumes and Minimum Moisture Content Sample Sizes Based on Maximum Size of Particle

Maximum Particle Size		Minimum Test Hole Volume,		Minimum Moisture Content
mm	Alternate	cm^3	cu ft	Sample,g
4.75	(No. 4 sieve)	700	(0.025)	100
12.5	(½ in.)	1400	(0.050)	250
25.0	(1 in.)	2100	(0.075)	500
50.0	(2 in.)	2800	(0.100)	1000

d.2.e. Calculations:

d.2.e.1. Calculate the volume of the density apparatus as follows:

$$V_1 = GT$$

Where: V_1 = volume of the density apparatus, cm^3
G = grams of water required to fill apparatus, and
T = Water temperature-volume correction shown in Table 5.16.13-2, column 3.

Calculate the volume of the density apparatus to the nearest 0.000003 m^3 (0.0001 ft^3).

d.2.e.2. Calculate the bulk density of the sand as follows:

$$W_1 = \frac{62.427\ W_2}{V_1}$$

Where: W_1 = bulk density of the sand, (lb/ft^3)
W_2 = grams of sand required to fill apparatus and
V_1 = volume of apparatus in cubic centimeters

Calculate the bulk density of the sand to the nearest 0.1 lb/ft^3.

dc.2.e.3. Calculate the moisture content and the dry -mass of material removed from the test hole:

$$M = \frac{100(W_3 - W_4)}{W_4}$$

$$W_6 = \frac{0.2205\ W_5}{(M+100)}$$

Where: M = percentage of moisture in material from test hole.
W_3 = moist mass of moisture sample, g
W_4 = dry mass of moisture sample, g
W_5 = moist mass of material from test hole, g
W_6 = dry mass of material from test hole, lb.

Calculate the moisture content to the nearest 0.1 percent and the dry mass of material removed from the test hole to the nearest 0.01 lb.

d.2.e.4. Calculate the in-place dry density of the material tested:

$$V = \frac{W_7 - W_8}{453.6\ W_1}$$

$$W = \frac{W_6}{V}$$

Where: V = volume of test hole, ft^3 ,
W_7 = grams of sand used,
W_8 = grams of sand in funnel, and
W = dry density of the tested material, in pounds per cubic foot.

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

Note l: It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory maximum density determined in accordance with AASHTO T 99. This relation can be determined by dividing the in-place density by the maximum density and multiplying by 100.

Note m: 0.001 g/cm^3 = 1kg/m^3

d.3. Rubber-Balloon Method.

d.3.a. The apparatus is generally not suitable for very soft soil which will deform under slight pressure or in which the volume of the hole cannot be maintained at a constant value.

d.3.b. Calibration Check of Volume Indicator

d.3.b.1. Verify the procedure to be used and the accuracy of the volume indicator by using the apparatus to measure containers or molds of determinable volume that dimensionally simulate test holes that will be used in the field. The apparatus and procedure shall be such that these volumes will be measured to within 1.0 percent[n]. Containers of different volumes shall be used so that calibration of the volume indicator covers the range of anticipated test hole sizes.

Note n: The molds described in the Test for moisture-Density Relations of Soils, using T 99 and in the Test for Moisture-Density Relations of Soils, using T180 or other molds prepared to simulate actual test holes may be used. Where several sets of apparatus are used, it may be desirable to cast duplicates of actual test holes. These sets should represent the range of sizes and irregularities in the walls of test holes that will be encountered. These fabricated holes can be used as standards for the calibration check of the volume indicator. This can be accomplished by forming plaster of Paris negatives in the test holes and using these as forms for portland cement concrete castings. After removing the plaster of Paris negative from the concrete casting, the inside surface of the fabricated holes should be sealed watertight and their volume determined as indicated in section d.

d.3.b.2. Determine the mass of water, in grams, required to fill one of the containers. Slide a glass plate carefully over the top of the container in such a manner as to ensure that the container is filled completely with water. A thin film of cup grease smeared on the top surface of the container will make a watertight joint between the glass plate and the top of the container. Calculate the volume of the container, in cubic feet, by dividing the mass of water, in grams, used to fill the container by 28,317 grams per cu ft. Repeat this procedure until three values are secured for the volume of the container having a maximum range of variation of 0.0001 cu ft. Repeat the procedure for each of the containers to be used in the calibration check.

d.3.c. Calibration Check Test.

d.3.c.1. Place the rubber-balloon apparatus on a relatively smooth horizontal surface and take an initial reading on the volume indicator. Transfer the apparatus to one of the containers and take the reading on the volume indicator when the rubber-balloon completely fills the container[o & p]. Apply pressure to the liquid in the apparatus until there is no change indicated on the volume indicator. Note and record the pressure. Depending on the type of apparatus, this pressure may be as high as 49kPa (5 psi). It will usually be necessary to add mass (surcharge) to the apparatus to prevent it from rising[q]. Note and record the total amount of mass added. The difference between the initial and final readings of the volume indicator is the indicator volume value for the container. The membrane may be withdrawn from the container by applying a partial vacuum to the liquid in the apparatus. Repeat the procedure for the other containers.

Note o: If the calibration container or mold is airtight, it may be necessary to provide an air escape, since the rubber membrane can entrap within the container and cause an erroneous volume measurement. After the volume of the container has been determined with water and prior to the insertion of the rubber balloon, small air escape-holes may be provided by placing lengths of small-diameter string over the edge of the container and down the inside wall slightly beyond the bottom center. This will permit air leakage during the filling of the container with the membrane. If such a procedure is necessary in the laboratory, it may be necessary to use a similar procedure on tightly bonded soil in the field.

Note p: Before any measurements are made, it may be necessary to distend the rubber balloon and remove air bubbles adhering to the inside of the membrane by kneading.

Note q: In field tests the additional mass (surcharge) will increase the stress in the unsupported soil surrounding the test hole and will tend to cause it to deform. Using a base plate may reduce the stress.

d.3.d. Prepare the surface of the material to be tested and place the balloon-density apparatus on the prepared surface and maintain its position by driving nails through the holes in the base plate and into the soil.

d.3.e. Place a surcharge on the apparatus and apply the same pressure to the liquid as was applied during the calibration check tests. Read and record the volume of liquid shown on the volume indicator.

d.3.f. Apply sufficient vacuum to the inside of the chamber to withdraw the liquid and balloon into the chamber.

d.3.g. Drill or cut a test hole through the hole in the base plate and 100 to 150 mm (4 to 6 in) into the material to be tested. Carefully save all material removed. The hole shall be of the minimum volume shown in Table 3.

d.3.h. Protect the sample from weather conditions which might change the moisture content. Record the wet mass of all material removed from the test hole.

d.3.i. Dry the entire sample or a representative portion to constant mass. Determine and record the dry mass.

d.3.j. Place the balloon density apparatus over the test hole in exactly the same position as was used for the initial reading and apply the same surcharge mass to the apparatus and the same pressure to the liquid as was applied during the initial reading[r].

Note r: Attention is called to instances in weak soils where the pressure applied to the liquid in the vessel can deform the test hole to such an extent as to give an erroneous volume. In such instances, the apparatus shall be modified and recalibrated using less surcharge mass and pressure on the liquid in the vessel, or it may be necessary to resort to another method such as the sand cone method already described in this specification.

d.3.k. Read and record the volume of liquid shown on the volume indicator.

d.3.l. Withdraw the liquid and rubber membrane from the test hole and into the container by developing a vacuum inside the container with the vacuum phase of the pump.

d.3.m. Calculations:

d.3.m.1. Moisture content of material (%) (W)

$$W = \frac{100(A-B)}{B}$$

Where: A = Mass of wet material removed from test hole.
B = Mass of dry material removed from test hole.

d.3.m.2. Calculate the wet density, δ_m, of the soil removed from the test hole, in pounds per cubic foot or liters, as follows:

$$\delta_m = \frac{\text{mass of moist soil}}{\text{volume of test hole}}$$

d.3.m.3. Calculate the dry density, δ_d, of the soil removed from the test hole, in pounds per cubic foot, as follows:

$$\delta_d = \frac{\delta_m}{W + 100} \quad X\ 100$$

Table 2: Minimum Field Test Hole Volumes and Minimum Moisture Content Sample Sizes Based on Maximum Size of Particle

Maximum Particle Size		Minimum Test Hole Volume,		Minimum Moisture Content
mm	Alternate	cm^3	cu ft	Sample,g
4.75	(No. 4 sieve)	700	(0.025)	100
12.5	(½ in.)	1400	(0.050)	250
25.0	(1 in.)	2100	(0.075)	500
50.0	(2 in.)	2800	(0.100)	1000
63.0	(2½ in.)	3800	(0.135)	1500