5.16.58 METHOD FOR PREPARING AND DETERMINING THE DENSITY OF HOT MIX ASPHALT (HMA) SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR (Kansas Test Method KT-58)

a. SCOPE

a.1. This standard covers the compaction of cylindrical specimens of hot mix asphalt (HMA) using the Superpave gyratory compactor.

a.2. The values stated in SI units are to be regarded as the standard.

a.3. This standard may involve hazardous materials, operations and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

b. REFERENCED DOCUMENTS

b.1. KT-6; Specific Gravity and Absorption of Aggregate

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

b.3. KT-39; Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures

b.4. AASHTO M 231; Balances Used in Testing of Materials

b.5 AASHTO T 312; Preparing and Determining the Density of Hot –Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

b.6. ASTM D 4402; Test Method for Viscosity Determinations of Unfilled Asphalts Using the Brookfield Thermosel Apparatus

c. SIGNIFICANCE AND USE

c.1. This standard is used to prepare specimens for determining the mechanical and volumetric properties of HMA. The specimens simulate the density, aggregate orientation and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

c.2. This test method may be used to monitor the density or test specimens during their preparation. It may also be used for field control of an HMA production process.

d. APPARATUS

d.1. Superpave Gyratory Compactor - An electrohydraulic or electromechanical compactor, with a ram and ram heads as described in **d.3.** that are restrained from revolving during compaction. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 $\pm$ 6 kPa to a specimen cross section during compaction[a]. The compactor shall tilt specimen molds at an internal angle of 1.16 ± 0.02 degrees and gyrate specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction. The compactor shall be designed to permit the specimen mold to revolve freely on its tilted axis during gyration.

Note **a**: This stress calculates to 10600 ± 106 N total force for 150 mm specimens.

d.1.a. Specimen Height Measurement and Recording Device: When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen to the nearest 0.1 mm during compaction once per gyration.

d.1.b. The built-in reporting system shall include a printer connected to an RS232C port capable of printing test information. The information shall include specimen height per gyration. The system should include a computer and suitable software for data acquisition and reporting.

d.2. Specimen Molds - Specimen Molds shall have steel walls that are at least 7.5 mm thick and are hardened to at least Rockwell C 48. The inside finish of the molds shall have a root mean square (rms) of 1.60 μm or smoother[b]. Molds shall have an inside diameter of 149.9000 to 150.0000 mm (5.902 to 5.906 in) and at least 250 mm high.

NOTE **b**: Smoothness measurement is in accordance with ANSI B 46.1. One source of supply for a surface comparator, which is used to verify the rms value of 1.60 μm, is GAR Electroforming, Danbury, Connecticut.

d.3. Ram Heads and Mold Bottoms - Ram heads and mold bottoms shall be fabricated from steel with a minimum Rockwell hardness of C 48. The ram heads shall have a means for staying fixed to the ram and perpendicular to its axis. The platen side of each mold bottom shall be flat and parallel to its face. All ram and base plate faces (the sides presented to the specimen) shall be ground flat to meet smoothness requirement in **d.2.** and shall have a diameter of 149.70 to 149.75 mm.

d.4. Thermometers: Armored, glass or dial-type thermometers with metal stems for determining temperature of aggregates, asphalt and asphalt mixtures between 50 to 450°F (10 to 232°C).

d.5. Balance: A balance meeting the requirements of AASHTO M 231, Class G2 for determining the mass of aggregates, asphalt and asphalt mix.

d.6. Oven: An oven, thermostatically controlled with a range from 122 to 500°F (50 to 260°C) with 5.4°F (± 3°C) tolerance, for heating aggregates, asphalt, asphalt mix and equipment as required. The oven shall be capable of maintaining the temperature required for short-term aging.

d.7. Miscellaneous: flat bottom metal pans for heating aggregates; scoop for batching aggregates; containers; gill-type tins; beakers; containers for heating asphalt; large mixing spoon or small trowel; large spatula; welders gloves for handling hot equipment; paper disks; mechanical mixer (optional); and lubricating materials recommended by compactor manufacturer.

e. HAZARDS

Use standard safety precautions and protective clothing when handling hot asphalt mixtures and preparing test specimens.

f. STANDARDIZATION

Items requiring periodic verification of calibration include the ram pressure, the angle of gyration, the gyration frequency, the LVDT (or other means used to continuously record the specimen height) and oven temperature. Verification of the mold and platen dimensions and the inside finish of the mold are also required. When the computer and software options are used, periodically verify the data processing system output using a procedure designed for such purposes. Verification of calibration, system standardization and quality checks may be performed by the manufacturer, other agencies providing such services or in-house personnel.

g. PREPARATION OF APPARATUS

g.1. Immediately prior to the time when the paving mix is ready for the placement in the mold, turn on the main power for the compactor for the manufacturer's required warm-up period.

g.2. Verify machine settings are correct for angle, pressure and number of gyrations[c].

NOTE **c**: The required number of gyrations is shown in **TABLE 1**.

g.3. Lubricate any bearing surfaces as needed.

g.4. Lightly lubricate the surface of the rotating base along with the surface of the four rollers.

g.5. When monitoring specimen height, the following additional item of preparation is required. Immediately prior to the time when paving mix is ready for placement in the mold, turn on the device for measuring and recording the height of the specimen and verify that the readout is in the proper units, mm, and that the recording device is ready. If used, prepare the computer to record the height data and enter the header information for the specimen.

h. COMPACTION PROCEDURE

Refer to the attached Addendum if using hydrated lime as an antistripping agent.

h.1. Preparation of aggregates: Weigh the appropriate aggregate fractions into a separate pan and combine to the desired batch weight. The batch weight will vary based on the ultimate disposition of the test specimens. If a target air void level is desired, as would be the case for Superpave abbreviated mix analysis and/or full mix analysis performance specimens, batch weights will be adjusted to create a given density in a known volume. When specimens are to be used for determination of volumetric properties, the batch weights will be adjusted to result in a compacted specimen having dimensions of either 150 mm in diameter and 115 $\pm$ 5 mm in height[d] or 100 mm in diameter and 63.5 $\pm$ 2 mm in height[d] at the maximum number of gyrations.

NOTE **d**: It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4,500 g of aggregate for 150 mm plugs and 1,200 g of aggregate for 100 mm plugs are required to achieve this height for aggregates with combined bulk specific gravities of 2.55.

h.2. Place the aggregate and the asphalt binder container in the oven and heat to the required mixing temperature.

h.2.a. The mixing temperature range is defined as the range of temperatures where the unaged asphalt binder[e] has a kinematic viscosity of 170 $\pm$ 20 mm^2/s (approximately 0.17 $\pm$ 0.02 Pa-s for an asphalt binder density of 1.00 g/cm^3) measured in accordance with ASTM D4402[f].

NOTE **e**: Modified asphalts may not adhere to the equi-viscosity requirements noted and the manufacturer's recommendations should be used to determine mixing and compaction temperatures.

NOTE **f**: The SI unit of kinematic viscosity is m^2/s; for practical use, the submultiple mm^2 is recommended. The more familiar centistoke, a *cgs* unit of kinematic viscosity, is a ratio of asphalt binder viscosity to density. For an asphalt binder with equal density to 1.000 g/cm^3, a kinematic viscosity of 170 mm^2/s is equivalent to a viscosity of 0.17 Pa-s measured in accordance with ASTM D4402.

h.3. Charge the mixing bowl with the heated aggregate in one pan and dry mix thoroughly. Form a crater in the dry blended aggregate and weigh the required amount of asphalt binder into the mix. Immediately initiate mixing.

h.4. Mix the aggregate and asphalt binder as quickly and thoroughly as possible to yield a paving mix having a uniform distribution of asphalt binder. As an option, mechanical mixing may be used.

h.5. After completing the mixture preparation, place the loose mix in a shallow, flat pan and short-term age it as follows:

h.5.a. Place the mixture on a baking pan and spread it to an even thickness. Place the mixture and pan in the aging oven set at compaction temperature for 2 hours $\pm$ 5 minutes.

h.5.a.1. The compaction temperature range is defined as the range of temperature where the unaged asphalt binder[g] has a kinematic viscosity of 280 $\pm$ 30 mm^2/s (approximately 0.28 $\pm$ 0.03 Pa-s) measured in accordance with ASTM D4402.

NOTE g: Modified asphalts may not adhere to the equi-viscosity requirements noted and the manufacturer's recommendations should be used to determine mixing and compaction temperatures.

h.5.b. Stir mixture every 60 $\pm$ 5 minutes to maintain uniform aging.

h.5.c. After 2 hours $\pm$ 5 minutes, remove the mixture from the forced draft oven. The aged mixture is now ready for further conditioning or testing as required.

h.6. Place the compaction mold and base plate in an oven permitting the pieces to reach the established compaction temperature prior to the estimated beginning of the compaction process (during the time the mixture is being conditioned in accordance with **h.5.**).

h.7. If loose HMA plant mix is used, the mixture shall be brought to the compaction temperature range by careful uniform heating in an oven immediately prior to molding.

h.8. When compaction temperature is achieved, remove the heated mold and base plate from the oven and place a paper disk on the bottom of the mold.

h.9. Thoroughly mix the material and place the mixture quickly into the mold in one lift and verify the temperature of the material. The temperature of the material is to be at the midpoint of the established compaction temperature 3^{o}F ($\pm$ 1.5^{o}C) for the specified PG asphalt. Care should be taken to avoid segregation in the mold. After all the mix is in the mold, temperature verified, then level the mix and place another paper disk on top of the leveled material and add the top plate.

h.10. Load the specimen mold with the paving mix into the compactor and center the mold under the loading ram.

h.11. Lower the ram until the pressure on the specimen reaches 600 $\pm$ 60 kPa.

h.12. Apply a 1.16 $\pm$ 0.02 degrees internal angle to the mold assembly and begin the gyratory compaction.

h.13. Allow the compaction to proceed until the desired number of gyrations is reached and the gyratory mechanism shuts off.

h.14. Remove the angle from the mold assembly, raise the loading ram, remove the mold from the compactor and extrude the specimen from the mold[**h**].

NOTE **h**: Specimen can be extruded from the mold immediately for most HMA paving mixes. For lean, rich or tender mixtures, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding the specimen.

h.15. Remove the paper disks from the top and bottom of the specimens[**i**]. Before reusing the mold, place it in an oven until the mold reaches compaction temperature. The use of multiple molds will speed up the compaction process.

NOTE **i**: The extruded specimen may not be a right angle cylinder. Specimen ends may need to be sawed to conform to the requirements of specific performance tests.

i. DENSITY PROCEDURE

i.1. When the specimen height is to be monitored, the following steps are required in addition to those specified in **h.**

i.1.a. Determine the maximum specific gravity (G_{mm}) of the loose mix in accordance with KT-39 using a companion sample. The companion sample shall be aged to the same extent as the compaction sample.

i.1.b. Record the specimen height to the nearest 0.1 mm after each revolution.

i.1.c. Record the mass of the extruded specimen to the nearest gram and determine the bulk specific gravity (G_{mb}) of the extruded specimen in accordance with KT-15, Procedure III.

j. DENSITY CALCULATIONS

j.1. Calculate the uncorrected relative density (C_{ux}) at any point in the compaction process using the following equation:

$$C_{ux} = \frac{100(W_m)}{V_{mx} G_{mm} G_w}$$

where:

C_{ux} = uncorrected relative density at any point during compaction expressed as a percent of the theoretical maximum specific gravity.
W_m = the mass of the specimen in grams.
G_{mm} = theoretical maximum specific gravity of the mix.
G_w = the unit of water, 1 g/cm^3.
X = the number of gyrations.
V_{mx} = the volume of the specimen, in cm^3, at any point based on the diameter (d) and height (h_x) of the specimen at the point (use mm for height and diameter measurements[j].) It can be expressed as:

$$V_{mx} = \frac{\pi d^2 h_x}{4(1000)}$$

Note **j:** This formula gives volume in cm^3 to allow direct comparison with specific gravity.

j.2. At the completion of the bulk specific gravity test, determine the percent compaction (C_x) at any point in the compaction process as follows:

$$C_x = \frac{100(G_{mb} h_m)}{G_{mm} h_x}$$

where:

C_x = Corrected relative density expressed as a percentage of the maximum theoretical specific gravity.
G_{mb} = Bulk specific gravity of the extruded specimen.
h_m = Height in mm of the extruded specimen.
h_x = Height in mm of the specimen after "x" gyrations.

k. REPORT

k.1. Project number

k.2. Date of test

k.3. Start time of test

k.4. Specimen identification

k.5. Percent binder in specimen, nearest 0.1 percent

k.6. Average diameter of the mold used (d), nearest 0.01 mm

k.7. Mass of the specimen (W_m), nearest g

k.8. Theoretical maximum specific gravity (G_{mm}) of the specimen by KT-39, nearest 0.001

k.9. Bulk specific gravity (G_{mb}) of the specimen by KT-15 (Procedure III), nearest 0.001

k.10. Height of the specimen after each gyration (h_2), nearest 0.1 mm

k.11. Relative density (C_x) expressed as a percent of the theoretical maximum specific gravity, nearest 0.1 percent

TABLE 1. SUPERPAVE GYRATORY COMPACTION EFFORTS

DESIGN ESALs (millions)	TRAVELWAY		
	N_{ini}	N_{des}	N_{max}
< 0.3	6	50	75
0.3 to < 3	7	75	115
3 to < 30	8	100	160
$\geq$ 30	9	125	205
	SHOULDER		
A*	6	50	75
B*	**	**	**

* At the contractor's option A or B may be used.
** Use traveled way design traffic properties for B.

ADDENDUM TO KT-58
FOR INCLUDING LIME AS AN ANTISTRIPPING AGENT

The following information provides KT-58 with steps to incorporate hydrated lime as an antistripping agent.

Delete **h.1.** and **h.2.** and replace with the following:

h.1. Preparation of aggregates: Weigh the appropriate aggregate fractions into a separate pan and combine to the desired batch weight. The batch weight will vary based on the ultimate disposition of the test specimens. Include the hydrated lime weight required to meet the specified percent of lime for the project as part of the total batch weight. The total aggregate weight should include lime, virgin aggregate, and reclaimed material (if applicable). If a target air void level is desired, as would be the case for Superpave abbreviated mix analysis and/or full mix analysis performance specimens, batch weights will be adjusted to create a given density in a known volume. If specimens are to be used for determination of volumetric properties, the batch weights will be adjusted to result in a compacted specimen having dimensions of 150 mm in diameter and 115 ± 5 mm in height[d] at the maximum number of gyrations.

NOTE **d**: It may be necessary to produce a trial specimen to achieve this height requirement. Generally, 4500 g of aggregate for 150 mm plugs and 1200 g of aggregate for 100 mm plugs are required to achieve this height for aggregates with combined bulk specific gravities of 2.55.

h.1.a. Determine the SSD condition (KT-6) for the combined aggregate gradation. Add three percent of moisture to the percent moisture required to reach the SSD condition of the combined aggregate.

h.1.b. Place the combined virgin aggregate and hydrated lime in a mixing bowl. Carefully mix until the hydrated lime is combined with the aggregate. Add the appropriate water content, as determined in **h.1.a.**, and thoroughly mix.

h.1.c. Oven dry the aggregate mix at 230 ± 9°F (110 ± 5°C) to a constant mass.

h.2. Combine the virgin aggregate material with the reclaimed material, if applicable, and thoroughly mix. Place the aggregate and the asphalt binder container in the oven and heat to the required mixing temperature.