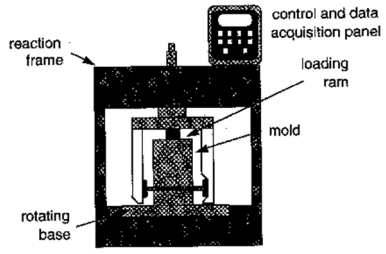
Superpave Volumetric Mixture Design and Analysis Handbook

Volume III

Laboratory Study Manual

(2026)



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Preface

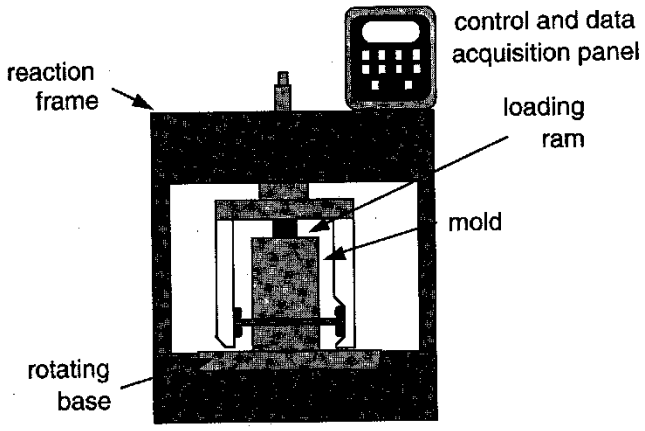
This study manual was developed by heavily drawing from the M-TRAC training manual, which was created under the sponsorship of the Federal Highway Administration (FHWA). The M-TRAC manual was part of a multi-regional effort to assist states with meeting the Code of Federal Regulations, Part 637, requirements for "qualified" personnel to perform material sampling and testing for quality control and quality acceptance (QC/QA). The group's ultimate goal was to promote reciprocity of this "qualification" across state lines. The development team members were **Tom Deddens**, formerly with the Asphalt Institute; **John Hinrichsen**, Asphalt Technician of the Iowa Department of Transportation; and **Rebecca McDaniel**, then Technical Director of the North Central Superpave Center at Purdue University. The authors of this compilation acknowledge and appreciate this pioneering effort to have uniformity in training for bituminous material sampling and testing.

This study manual introduces the tests taught in the Superpave Field Technician (SF) Training classes at Kansas State University. The "Table of Contents" lists the Kansas test methods for this volume. The first page of each test method lists references to other standards. Knowledge of specific procedures and tests is necessary before proceeding to other standard tests.

Training participants are expected to use the mathematical rounding rules KDOT recommends when performing calculations for qualification testing.

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 / AASHTO T312)
(https://www.youtube.com/watch?v=fwjEJlzBi6I)



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NOTE

This discussion and KT-58 refer to the following KT Methods:

* KT-6/AASHTO T84 & 85, Specific Gravity and Absorption of Aggregate

* KT-15/AASHTO T166, Bulk Specific Gravity and Unit Weight of Compacted Asphalt Mixtures

* KT-25/AASHTO T168, Standard Method of Test for Sampling Bituminous Paving Mixtures

* KT-39/AASHTO T209, Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures

* KT-56/AASHTO T283, Resistance of Compacted Asphalt Mixture to Moisture Induced Damage

GLOSSARY

C_x= Correction factor for specific gravity after "x" number of gyrations (**$C_x = h_{final} / h_x$**)

h_x = Height after "x" number of gyrations

h_{final}= Height after final/maximum number of gyrations

Corrected $\%G_{mm}$ = the density of a specimen determined at x number of gyrations and expressed as a percentage of the maximum theoretical specific gravity of the mixture, corrected for the fact that it has been determined based on the bulk density of the Superpave gyratory specimen compacted to the maximum number of gyrations.

N-initial (N_{ini}) = the initial number of gyrations, a relatively low number of gyrations based on the design traffic volume, and used to analyze the early densification properties of the Superpave mix during construction.

N-design (N_{des}) = the design number of gyrations based on the design traffic level used in the Superpave mixture design.

N-maximum (N_{max}) = the maximum number of gyrations applied to a specimen, based on the design traffic volume, and used to assess the densification properties of the Superpave mixture after many years in service.

PREPARING AND DETERMINING THE DENSITY OF HMA SPECIMENS BY MEANS OF THE SUPERPAVE GYRATORY COMPACTOR

Compacted samples of the Superpave mix are used to determine the volumetric and mechanical properties during the mix design phase and for quality control/quality assurance during construction. These volumetric properties are then evaluated to select a mix design or to control the mixture quality during production. The specimens produced with the Superpave gyratory compactor very closely simulate the mixture's density, aggregate orientation, and structural characteristics on the roadway.

The gyratory compactor prepares specimens for later analysis of the mixture's volumetric properties, evaluation of mixture densification properties, moisture sensitivity, field quality control, and/or other testing purposes.

This text will explain how to compact samples of the Superpave mix using the Superpave gyratory compactor and determine their percent compaction. This method may be used with laboratory-prepared specimens, as in the mix design process, or with plant-mixed material during construction.

Common Testing Errors

- Do not place a paper protection disk at the bottom or on the top of the specimen.
- Not placing the top plate.
- Do not preheat the mold and base plate.
- Do not quickly charge the mold with the mix in one lift without spading or rodding.
- Do not compact the mixture at the proper temperature.
- Do not remove the paper disks while the specimen is still warm.

TEST METHODOLOGY

Apparatus

- Superpave Gyratory Compactor: The compactor may include a printer or a computer and software for collecting and printing the data. (*Pine AFGC125X referenced in this manual*)
- Specimen molds and top and bottom plates
- Thermometer
- Balance readable to **0.1 g**
- Oven, thermostatically controlled with a range from 50 to 260 ºC with ± 3ºC tolerance
- Calibration equipment recommended by the compactor manufacturer
- Safety equipment: insulated gloves, long sleeves, etc.
- Miscellaneous equipment: paper disks, lubricating materials recommended by compactor manufacturer, scoop or trowel for moving mixture, funnel or other device for ease of loading mixture into mold (optional).

Calibration

The means of calibrating the gyratory compactor vary with different manufacturers. Refer to the operation manual of the particular brand and model of gyratory available for use. Calibration of the following items should be verified at the noted intervals of the Contractor's Quality Control Plan approved by the State or according to the manufacturer's recommendations (as applicable):

Item	Tolerance	Calibration/Verification Interval (months)
Height	Record to the nearest 0.1 mm, Compact to 115 ± 5 mm	12*
Angle (Internal)	1.16° ± 0.02°	12*
Pressure	600 ± 18 kPa	12*
Speed of Rotation	30.0 ± 0.5 gyrations per minute	12*

*6 for large Pine Models AFGC125X

Verify the dimensions, hardness, and smoothness of the mold and plate. Also, check the oven temperature; according to KT-58 section 4.2, the oven must maintain the temperature required for short-term aging.

Sample Preparation

Samples for compaction in the gyratory may be obtained in one of two ways: a mixture may be prepared in the laboratory, or plant-mixed material may be obtained from the roadway behind the paver.

A finished specimen height of 115 ± 5 mm is required to determine volumetric properties for mix design or quality control. When compacting specimens for testing in KT-56, *Resistance of Compacted Bituminous Mixture to Moisture-Induced Damage, a specimen height of 95 ± 5 mm is required. In this case, the batch mass must be varied to provide the desired specimen height at a specified air void content; samples are then compacted to the specified height rather than for a fixed number of gyrations (See KT-56 for more details).*

Laboratory Prepared Materials

Preparing samples of the mixture in the laboratory requires batching out the aggregates, mixing the proper amount of asphalt binder, conditioning the prepared mixture, heating the mixture to compaction temperature, and compacting the specimen. The steps involved in preparing the mix in the laboratory are as follows:

1. Weigh out appropriate amounts of the required aggregate size fractions and combine them in a bowl to the proper batch mass. Typically, a batch mass of 4,500 grams of aggregate will provide enough material for a finished specimen height of 115 ± 5 mm.

2. Heat the asphalt binder and the combined aggregate in an oven to the appropriate mixing temperature for the binder to be used. This temperature is determined from an equi-viscous temperature chart or will be provided by the binder supplier. The appropriate temperature range for mixing is defined as the range of temperatures that produces a viscosity of 0.17 ± 0.02 Pa·s for the unaged binder. This ensures that the binder is fluid enough to coat the aggregate particles. *Some modified binders do not follow these temperature-viscosity relationships; the manufacturer's recommendations should be followed.*

3. The heated aggregate should be placed in the mixing bowl and thoroughly dry-mixed. Make a crater at the center of the aggregate in the bowl and weigh in the required amount of asphalt binder. Begin mixing immediately.

4. A mechanical mixer is recommended for preparing laboratory mixtures. Mixing should continue until the asphalt binder is uniformly distributed over the aggregate particles.

5. Determine the proper compaction temperature range for the asphalt binder used. This range yields a binder viscosity of approximately 0.28 ± 0.03 Pa·s. *Modified binders may not conform to these mixing and compaction temperatures, so the manufacturer's recommendations should be followed.*

6. After mixing, spread the loose mixture in a flat, shallow pan and short-term age it as follows:

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 2 hours ± 5 minutes at the specified mixture's compaction temperature. The compaction temperature varies depending on the grade of binder used and can be determined from state specifications or the binder supplier's recommendations. *(Note: The compaction temperature range of an HMA mixture is defined as the range of temperatures where the unaged asphalt binder has a kinematic viscosity of 280 ± 30 mm²/S (approximately 0.28 ± 0.03 Pa·s) measured by ASTM D4402. The target compaction temperature is generally the mid-point of this range. When using modified asphalts, the binder manufacturer's recommendation for compaction temperature should be considered.)*

Stir mixture every 60 ± 5 minutes to maintain uniform aging.

After 2 hours ± 5 minutes, remove the mixture from the oven. The aged mixture is now ready for further tests.

7. Place the mold and base plates in an oven, allowing the pieces to reach the established compaction temperature before the estimated beginning of the compaction process.

Plant-Mixed Materials

No aging or conditioning is required when plant-mixed materials are sampled from the roadway behind the paver (KT-25). The mixture must be brought to the proper compaction temperature and then compacted and analyzed if the temperature has dropped below the compaction temperature. Place the material in an oven at the compaction temperature and bring the mixture to the proper temperature by careful, uniform heating. The mix should be stirred periodically to help ensure uniform heating. Generally, the shortest heating time that will bring the mixture to the compaction temperature is preferred. Avoid overheating the mix. When the compaction temperature has been reached, proceed with specimen compaction as outlined below.

Compaction Procedure

Once the mixture sample has reached the proper compaction temperature, it is compacted in the Superpave gyratory compactor. For most purposes, the finished specimens will be used to calculate volumetric properties and compacted to a fixed number of gyrations. When preparing specimens for testing under KT-56, Resistance of Compacted Bituminous Mixture to Moisture-Induced *Damag*e, specimens may be compacted to a fixed height to produce a specified air void content.

The procedure **to compact to a fixed number of gyrations** is as follows:

1. Ensure that the gyratory compactor has been turned on and allowed to warm up for the time the manufacturer recommends. Verify all settings for angle, pressure, and number of gyrations.

2. When the compaction temperature has been reached, remove the mold and base plate from the oven. Put the base plate in position in the mold and place a paper disk in the bottom of the mold. If necessary, apply some lubricant to the top and base plates.

3. Thoroughly mix the material. Charge the mixture into the mold in one lift. A funnel or other device may place the mixture into the mold. Avoid segregating the mix in the mold, but work quickly so the mixture does not cool excessively during loading. Verify the temperature of the material. The temperature of the material is to be at the midpoint of the established compaction temperature ± 1.5°C for the specified PG asphalt. Level the mix in the mold, place a paper disk on top, and put the top plate on top of the paper disk.

4. Place the mold in the Superpave gyratory according to the manufacturer's recommendations. (Some gyrator compactors allow charging the mold with mix after the mold has been positioned in the compactor.) Lubricate the mold or gyratory parts as recommended by the manufacturer.

5. Apply the load to the mixture in the mold according to the manufacturer's recommendations. The pressure applied should be 600 ± 18 kPa.

6. Apply the gyratory internal angle of 1.16°± 0.02° to the specimen.

7. Input the desired number of gyrations ($N_{max)}$ to apply to the Superpave compactor control panel. Start the compaction process and compact to the required number of gyrations. The number of gyrations to apply is determined from Table 1 and is based on the expected design traffic volume in Equivalent Single Axle Loads (ESALs) over a 20-year design life. This information is provided in the special provisions for the project. Compact to the desired number of gyrations. Volumetric and densification properties are determined at N_{ini} and $N_{des,}$ as well as N_{max}, as described later.

8. The gyratory compactor will stop automatically after reaching the specified N_{max}. Remove the angle from the specimen and raise the loading ram if needed *(this is done automatically on some compactor models).*

9. Remove the mold from the compactor and extrude the specimen. Take care not to distort the specimen when removing it from the mold. With some mixtures, a cooling period of 5 to 10 minutes may be necessary; a fan may help speed up the cooling process. Remove the paper disks while the specimen is warm to avoid excessive sticking.

Table 1 Gyratory Compaction Effort

20-year Design ESALs (millions)		Compaction Parameter		
		N_{ini}	N_{des}	N_{max}
< 0.3 ***		6	50	75
0.3 to <3 ***		7	75	115
3 to <30		8	100	160
> 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 properties

(***) Some projects may use Nini = 6 & Ndes = 60 with no Nmax requirement

Density Procedure

When compacting specimens to determine volumetric properties for mix design or quality control/quality assurance, it is necessary to know the specimen height, bulk specific gravity, and mixture maximum theoretical specific gravity. This requires the following additional steps:

1. Prepare a loose sample of the same mixtures and determine the maximum theoretical specific gravity (G_{mm}) by KT-39 or AASHTO T209, *Maximum Specific Gravity of Bituminous Paving Mixture*s.

2. Compact a specimen using a Superpave Gyratory compactor and the maximum number of gyrations (N_{max}) for the project. Record the height of the specimen to the nearest 0.1 mm after each gyration.

3. Measure and record the mass of the compacted specimen to the nearest 0.1 g. Determine the bulk specific gravity (G_{mb}) of the compacted specimen by KT-15, Procedure III or AASHTO T166, Method A, *Bulk Specific Gravity of Compacted Bituminous Paving Mixtures Using Saturated Surface Dry Specimen*s.

Calculations

Using the measured bulk specific gravity of the final compacted specimen and the measured maximum specific gravity of a loose sample of the mixture and knowing the height of the specimen at different numbers of gyrations, it is possible to calculate the corrected $\%G_{mm}$ of the specimen. The corrected $\%G_{mm}$ at any number of gyrations is expressed as a percentage of the mix's maximum theoretical specific gravity (Gmm). This allows for the determination of the air void content of the specimen at any number of gyrations (100 - $\%G_{mm}$).

The $\%G_{mm}$ at any number of gyrations is calculated as follows:

1. Calculate the **correction factor** (C_x) for specific gravity after "x" number of gyrations as:

$$\mathbf{C_x = h_{final} / h_x}$$

where: h_x = height of the specimen (in mm) during compaction at x gyrations, and
h_{final} = height of the specimen (in mm) after N_{max} gyrations.

2. The corrected bulk specific gravity G_{mb} (corrected) of a specimen at any level (x) of gyration can be computed as:

$$G_{mb} \text{ (corrected)} = G_{mb} \text{ (measured)} \times h_{final} / h_x$$

Where:

G_{mb} (measured) is the bulk specific gravity of the extruded specimen *(determined using KT-15, Procedure III/AASHTO T 166, Method A).*

3. The % G_{mm} at any gyration level is then calculated as:

$$[G_{mb} \text{ (corrected)} / G_{mm}] * 100,$$

where: G_{mm} is the maximum theoretical specific gravity of the mixture *(determined according to KT-39/AASHTO 209)*

4. Report the $\%G_{mm}$ to the nearest 0.1 percent, and the average $\%G_{mm}$ value for the two companion specimens is typically used.

[Note: the relative density is described as "corrected" because of the calculation process. The volumetric properties of the compacted specimen at any compaction level are calculated based on the specimen's bulk specific gravity (Gmb) measured at N_{max} according to KT-15, Procedure III/AASHTO T166, Method A. To compute $\%G_{mm}$ at any gyration level, the "corrected" or "back-calculated" bulk specific gravity needs to be determined at that level from the measured bulk specific gravity (G_{mb}) of the specimen measured at N_{max}. The "height ratio" correction factor is used to back-calculate the "corrected" bulk specific gravity at any level of gyration. The calculations are as described above and in the following example.]

Example:

Given: G_{mb} (Measured bulk specific gravity) = 2.369
G_{mm} (Theoretical maximum theoretical specific gravity) = 2.403
h_{final} (The height of the specimen at N_{max}) = 117.5 mm

Calculate % Gmm at N_{ini} = 8 gyrations, h_8 = 135.4 mm
N_{des} = 100 gyrations, h_{100} = 119.4 mm
N_{max} = 160 gyrations, h_{160} = 117.5 mm

At x = 8 gyrations level:

C_8 = (117.5 mm/135.4 mm) = 0.868
G_{mb} (corrected) = 2.369 x C_8 = 2.369 x 0.868 = 2.056
% Gmm = 2.056/2.403 x 100 = 85.6%

At x = 100 gyrations level:

C_{100} = (117.5 mm/119.4 mm) = 0.984
G_{mb} (corrected) = 2.369 x C_{100} = 2.369 x 0.984 = 2.331
% Gmm = (2.331/2.403) x100 = 97.0%

At x = 160 gyrations level:

C_{160} = (117.5 mm/117.5 mm) = 1.0
G_{mb} (corrected) = 2.369 x C_{160} = 2.369 x 1.0 = 2.369
% Gmm = (2.369/2.403) x 100 = 98.6%

% Air Voids at N_{des} = 100 - %G_{mm} @ N_{des} (x= 100)
= 100 - 97.0
= 3%

Review Questions

1) The required sample height for the design mix in the gyratory compaction is _____ ± _____ mm.

2) The vertical pressure applied by the gyratory compactor is _____ ± _____ kPa.

3) The internal angle of gyration is _____ ± _____°.

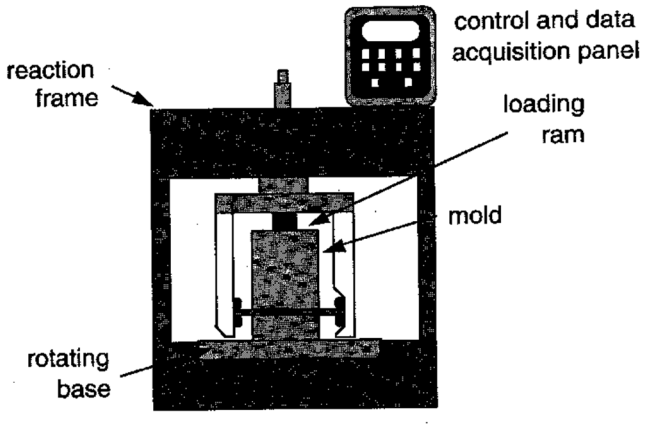
4) The number of revolutions per minute is _____.

5) Does the compaction temperature depend on the type of PG binder? _____
(Yes or No)

BULK SPECIFIC GRAVITY AND UNIT WEIGHT OF COMPACTED ASPHALT MIXTURES

(KT-15, Procedure III / AASHTO T166)

(https://www.youtube.com/watch?v=DqPykaenkFU)



NOTE

This discussion and KT-15 refer to the following KT Methods:

* KT-25/AASHTO T168, Standard Method of Test for Sampling Bituminous Paving Mixtures

* KT-58/AASHTO T312, Method For Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

GLOSSARY

Specific gravity: the ratio of the mass in air of a given volume of material to the mass in air of an equal volume of water.

Saturated surface dry (SSD): the condition of a material when it has absorbed as much water as it can during a specified period in its water-permeable pores, but the outside of the material has no free water.

BULK SPECIFIC GRAVITY AND UNIT WEIGHT OF COMPACTED ASPHALT MIXTURES

The compaction of a Superpave mixture in the field and the laboratory is vital to determining mixture quality control. The bulk specific gravity (G_{mb}) of compacted specimens can be defined on pavement cores or laboratory compacted specimens. Using a saturated surface-dry specimen, the bulk specific gravity of compacted bituminous mixtures is used to determine air voids (V_a). It may be used to compare roadway compaction tests and laboratory compacted specimens.

The G_{mb} is determined by measuring the volume of the specimen by displacement when submerged in water. Measure the specimen's dry, submerged, and SSD mass to determine the G_{mb}.

The submerged mass is subtracted from the SSD mass to determine the mass of an equal volume of displaced water. Dividing the dry mass of the specimen by the mass of an equal volume of water yields G_{mb}.

KT-15, Procedure III, is applicable when the water absorption is **less than 2.0 %.**

Common Testing Errors

- The submerged specimen touches the side of the water container.
- The water temperature is not 25˚± 1˚C (77˚± 2˚F).
- Specimens with high voids (>10%) may absorb excess water.
- Dirty water is used.
- Specimens not cooled to 25˚± 3˚C (77˚± 5˚F) or less.

TEST METHODOLOGY

Apparatus

- Balance (accurate to 0.1 gram).
- Oven for heating specimens
- Submersion basket
- Water bath
- Damp towel

Sample Preparation (Field mix)

The sample should be obtained using KT-25/AASHTO T168. The mixture should then be compacted for testing using KT-58/AASHTO T312.

Testing Procedure

Cool the specimen to room temperature at 25 ± 3˚C (77 ± 5˚F) and record the dry mass to the nearest 0.1 g. The specimen is then immersed in a 25 ± 1˚C (77 ± 2˚F) water bath and saturated at 4 ± 1 minutes. Determine the mass in water to the nearest 0.1 g. Remove the immersed saturated specimen from the water bath and damp dry with a moist absorbent cloth as quickly as possible. The specimen is then weighed. Any water seeping from the specimen during the weighing operation is part of the saturated specimen.

Note: If desired, the sequence of testing operations can be changed to expedite the test results. For example, the mass of a saturated, damp, dry specimen can be taken first. Then, the saturated specimen in water can be weighed. The dry mass of the specimen can be determined last.

Calculations

Calculate the bulk specific gravity of the specimen as follows:

$$G_{mb} = A / (B-C)$$

Where:

A = dry mass,
B = SSD mass, and
C = submerged mass.

Report bulk specific gravity to <u>three</u> decimal places.

Example

Given: Dry mass of the specimen (A) = 4,799.0 g
SSD mass of the specimen (B) = 4,801.0 g
The submerged mass of the specimen (C) = 2,799.0 g.

G_{mb} = 4799.0/ (4801.0 - 2799.0)
= 2.397

Review Questions

1) In the KT-15 test method, the mass of the dry sample in the air is determined at _____ ± _____ ºC.

2) In the KT-15 test method, Procedure III, the sample is immersed in water before weighing for

_____± _____ min.

3) In KT-15, the temperature of water bath is _____ ± _____ ºC.

4) The percent water absorption for the specimen for test in KT-15 Procedure III should be less than

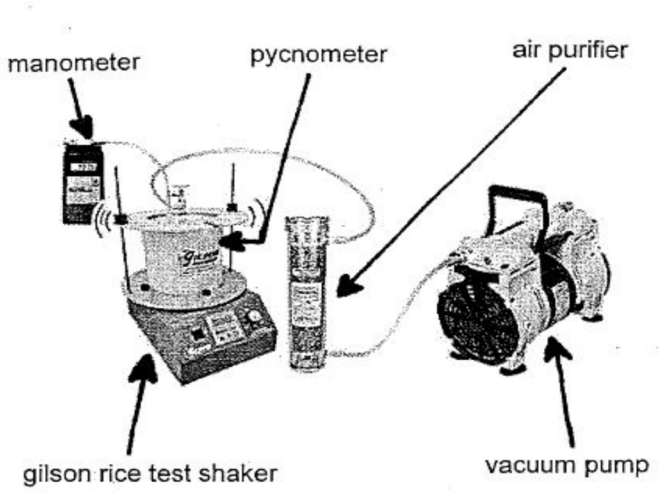
_____%.

5) If the dry mass of a Superpave gyratory plug is 4,440 g, the mass in water is 2,600 g, and the

SSD mass is 4,490 g, then the bulk specific gravity is _____?

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF ASPHALT PAVING MIXTURES

(Kansas Test Method KT-39/AASHTO T209)
(https://www.youtube.com/watch?v=49wrBLTdh0g)



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NOTE

This discussion and KT-39 refer to the following KT Method:

* KT-25/AASHTO T168, Standard Method of Test for Sampling Bituminous Paving Mixtures

* KT-58/AASHTO T312, Method For Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor

GLOSSARY

Specific gravity: the ratio of the mass in air of a given volume of material to the mass in air of an equal volume of water.

Pycnometer: a vessel of known volume used to measure the volume of a material placed in it by determining how much water is displaced.

Mercury Manometer: a tube sealed at one end and filled with mercury, which, when subjected to a vacuum, will register a comparison between the applied vacuum and the nearly total vacuum in the sealed end. The vacuum degree is expressed as absolute or residual pressure in mm. Smaller numbers (lower pressure) indicate more vacuum.

Digital Manometer: A digital, electronic manometer designed to read absolute pressure. The vacuum degree is also expressed as absolute or residual pressure in mm.

Maximum Aggregate Size: one sieve size larger than the "nominal maximum aggregate size." For reference, the "nominal maximum aggregate size" is one sieve larger than the first sieve that retains more than 10 percent of the aggregate. *(Note: This terminology and these definitions are used for Superpave mixtures and may not apply to other types of mixtures*.)

Tare: setting the balance to zero with a mass on top *(usually an empty container)* so that when a sample is placed in the container, it can be placed on the balance, and only the sample mass will be displayed.

THEORETICAL MAXIMUM SPECIFIC GRAVITY OF ASPHALT PAVING MIXTURES

The volumetric properties of compacted Superpave mixtures must be controlled during design and production to produce durable pavements. James Rice invented a test to measure the specific gravity of a loose mixture with all air removed. This specific gravity is known as the maximum specific gravity (G_{mm}). It is the ratio of the mass of the loose sample to the mass of an equal volume of water at the standard temperature of 25 C (77° F).

G_{mm} is used along with the compacted mixture's bulk specific gravity (Gmb) to determine air voids (V_a) and the percent compaction achieved in the field.

This text will explain the flask method for determining the maximum specific gravity. Due to its lower variability, the flask method is the preferred test method.

Common Testing Errors

- Not breaking up the sample completely.
- Not maintaining 27 ± 3 mm of Hg absolute pressure, which could be attributed to one of the following:
    a. Air bubble in mercury manometer*
    b. Manometer not connected directly to pycnometer*
    c. Clogged or leaking vacuum lines
    d. Moisture or foreign material getting into the vacuum pump
- Not agitating the sample enough.
- The flask does not stay suspended in the water, i.e., it hits the bottom of the water bath.
- Not checking water temperatures.
- Uncoated particles or particles that rupture under vacuum, which absorb water.
- Overheating absorptive materials.

* During this training period, only digital manometers will be used

TEST METHODOLOGY - FLASK METHOD

Apparatus

- Pycnometer or flask
- Thermometer
- Mercury/Digital Manometer
- Vibrating Table
- Scale
- Vacuum pump, tubing and connectors

Sample Preparation

- If the sample is not tested soon after it has been sampled, it will cool down and may need to be reheated in the oven before the G_{mm} test can be run. If necessary, heat the sample only enough to soften it so that separation is possible.
- If necessary, reduce the sample to the proper size by quartering or other suitable means to ensure a representative sample. See Table 2 below for the required sample size.

Table 2 Required Sample Size

Nominal Maximum Aggregate Size	Minimum Sample Size
25.0 mm (1 in.)	2,500 g
19.0 mm (3/4 in.)	2,000 g
12.5 mm (½ in.)	1,500 g
9.5 mm (3/8 in.)	1,000 g
4.75 mm (#4)	500 g

- Separate the particles of coarse aggregate. Break up any clumps of fine aggregate so that no clump is larger than 6.3 mm (¼ in.). Stirring or spading the mixture as it cools will prevent clumps. If the clumps are challenging to break up, warming the mixture for a few minutes will be helpful.
- Allow the mixture to cool to room temperature before testing.

Calibration of Flask

- The mass of the flask is calibrated when immersed in water while the water is maintained at 77 ± 2°F (25 ± 1°C). Record the mass to the nearest 0.1 g. This is mass "d" (lower case 'd') for the weigh-in water method.

Test Procedure

- Place the flask on a scale and add the sample. Record the sample's mass to the nearest 0.1 gm. This mass is the dry sample mass in air "A."

- Add enough water to cover the sample completely.

- Connect the flask to the vacuum system and remove the entrapped air. Maintain a vacuum, measured by a mercury/digital manometer, of 27 ± 3 mm absolute pressure for 14 ± 0.5 minutes. A mechanical device continuously agitates to help release the air bubbles.

- After the 14-minute vacuum period is complete, slowly release the vacuum *(not to exceed 60 mm of Hg per second)* and proceed with the following determination:

- *Weighing in water*: Suspend the flask and sample in the water bath and determine the mass after 10 ± 1 minute immersion. Verify that the water bath temperature is 77 ± 2 °F (25 ± 1 °C). Call this mass "e" (lowercase 'e'). Subtract the mass of the calibrated flask (d) from the mass of the flask and sample immersed in water (e) to determine the mass of the sample in water "C".

Calculations

Weighing in water:

Maximum Specific Gravity (G_{mm}) = A/(A-C)

where: A = Mass of dry sample in air, g, and
C = Mass of water displaced by loose, airless mixture sample at 77 °F (25 °C).

Report the Maximum Specific Gravity (G_{mm}) to **three decimal places**.

Example

Given: Mass of dry sample in the air (A) = 1545.0 g
Mass of water displaced by the sample (C) = 917.7 g

$$G_{mm} = \frac{1545.0}{(1545.0 - 917.7)} = 2.463$$

Review Questions

1) The temperature of the water bath in KT-39 is _____ ± _____ ºC.

2) After separation, lumps with fine aggregates in KT-39 will not be larger than _____ mm.

3) The vacuum applied to remove entrapped air in KT-39 is _____ ± _____ mm of Hg.

4) For under water weighing, in KT-39 the sample is suspended in water for _____ ± _____ minute.

5) The sample size for a mix with a 12.5 mm maximum aggregate size is _____ g.

6) The KT-39 sample from behind the paver is obtained by _____. (Splitting or Quartering)

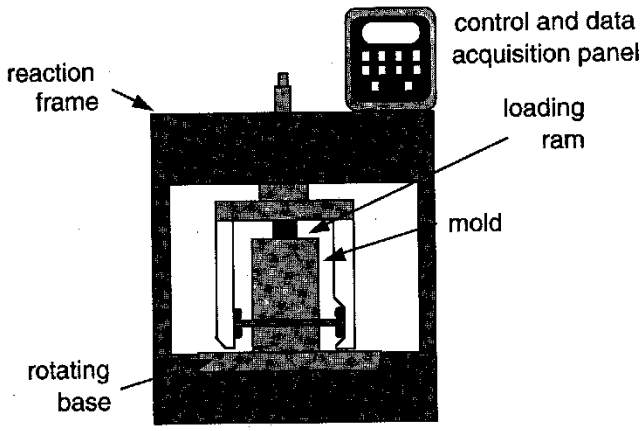
7) The maximum specific gravity (G_{mm}) is reported to _____ decimal places.

8) The KT-39 sample for the design mixture is aged in a preheated draft oven at compaction temperature for _____ hours.

DETERMINING THE ASPHALT CONTENT AND GRADATION OF HOT MIX ASPHALT CONCRETE BY THE IGNITION METHOD

(Kansas Test Method KT-57 / AASHTO T308)

(https://www.youtube.com/watch?v=pMe9i75g6mI)



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NOTE

This discussion and KT-57 refer to the following KT Methods:

* KT-1/AASHTO T2 & 248, Sampling Aggregates

* KT-25/AASHTO T168, Standard Method of Test for Sampling Bituminous Paving Mixtures

* KT-26/AASHTO T40, Sampling Asphalt Materials

* KT-34/AASHTO T30, Sieve Analysis of Extracted Aggregate

GLOSSARY

Ignition oven: A muffle furnace designed explicitly to burn off organic components from a material at high temperatures.

Correction factor: The difference between the actual and the measured asphalt content.

Sample basket: A sample container designed in the ignition oven allows the heated air to move through the sample. Each oven manufacturer provides baskets designed for use in their oven.

Nominal Maximum Aggregate Size: One sieve size larger than the first sieve that retains more than 10 percent of the aggregates *(Note: This terminology and definition is used for Superpave mixtures and may not apply to other types of mixtures.)*

DETERMINING THE ASPHALT CONTENT AND GRADATION OF HOT MIX ASPHALT CONCRETE BY THE IGNITION METHOD

Maintaining the proper asphalt content consistency in the Superpave paving mixture is crucial in producing quality pavement. Various means of determining asphalt content, such as chemical extraction or nuclear gauges, have been used for many years. Newer technology has been perfected by the National Center for Asphalt Technology (NCAT). This process uses a high-temperature oven, commonly called a muffle furnace, to burn off the asphalt. The asphalt content can be determined by comparing the mass of the sample before and after the burn-off. Some aggregates tend to break down at the high temperatures used in the test, and, therefore, a correction factor for each mix may be needed to get accurate results. After the asphalt content has been determined, the aggregate left behind can be tested for gradation and other properties. *(Note: Some aggregates have demonstrated significant breakdown at the high temperatures applied in this test and may produce erroneous gradation and specific gravity test results.)* Although the technician may encounter very hot materials and must use proper precautions, this is the easiest and safest method to determine asphalt content and provide a clean aggregate for further testing. This test method is appropriate for field labs conducting quality-control tests and Agency labs performing independent assurance, verification, and acceptance testing.

Common Testing Errors

- Moisture in the sample.
- Materials used for calibration were not the same as project materials.
- Inaccurate asphalt content was used for calibration.
- Improper loading of sample baskets.

Two methods listed in KT-57 may be used for this test. They are the same; the difference is related to the type of equipment used. Some ignition ovens have built-in scales and processors that can detect when the test is complete and report the results (method A). Other ovens require the operator to determine the endpoint and calculate the results (method B). The calibration and sample preparation processes are the same for both methods.

Apparatus

- Balance (accurate to 0.1 g)
- Approved ignition oven
- Sample baskets provided by the oven manufacturer
- Safety equipment: insulated gloves, face shield, long sleeves, etc.
- Timer (method B)

Calibration

- Determine the correct sample size for the mixture to be tested from the following chart:

Nominal Max. Agg. Size, mm	Sieve Size	Minimum Mass Specimen, g
4.75	No. 4	1,200
9.5	3/8 in.	1,200
12.5	1/2 in.	1,500
19.0	3/4 in.	2,000
25.0	1 in.	3,000
37.5	1½ in.	4,000

- Using the aggregates and binder produced for the project, mix two samples in the lab at the design asphalt content. Before mixing, prepare a butter mix with the designed asphalt content to condition the mixing bowl.
- Weigh a sample basket on a scale and record the mass. If the sample has cooled, dry it in a 110 ºC ± 5 ºC oven to a constant mass. Place the sample in the basket. Spread the sample

in a thin layer, but avoid placing material near the edge of the basket. Record the mass of the sample at room temperature. For automatic ovens (method A), enter the mass of the sample into the oven processor.

- Place the sample in the ignition oven, preheated to 500°C and burn off the asphalt according to the manufacturer's recommendation.

> **NOTE:** ***When using an ignition oven, temperatures over 538°C (1000oF) may be encountered. Use caution when handling hot samples or opening the oven.*** **SAFETY FIRST.**

- The automatic ovens (method A) will stop the test when all asphalt is burned off. Remove the sample from the oven and allow it to cool for approximately 30 minutes. Once the sample has cooled to room temperature, weigh and record the final mass. Calculate the asphalt content.

- For manual ovens (method B), allow the sample to burn for at least 40 minutes after the ignition oven has cycled through the initial burn-off phase. Remove the sample from the oven and allow it to cool to approximately room temperature (at least 30 minutes). Weigh and record the mass of the sample. Record the final mass of the sample to the nearest 0.1 g. Repeat burn-off until a visual inspection indicates complete burn-off has been accomplished.

- A calibration factor will be established by testing calibration samples for each mix type. If the difference between the measured asphalt contents of the two samples exceeds 0.15%, repeat the calibration process with two more samples and discard the high and low results. Compare the percent asphalt from ignition to the actual asphalt content of the calibration samples. Subtract the actual percent asphalt from the measured percent for each sample and average the two results. This will be the correction factor that must be applied to all tests on the same mixture. Record the correction factor (C_F).

A third aggregate sample should be prepared but not mixed with asphalt for information-only purposes. The gradation of this "blank" sample can then be compared to the gradation of one of the burned-off calibration samples to evaluate the amount of aggregate breakdown.

Sample Preparation

- If moisture is present in the sample, dry it in an oven at 110o ± 5oC or determine the moisture content and record it. If necessary, reduce the sample to the proper size by quartering or other suitable means to produce a representative sample. Preheat the sample, if needed, as described above for calibration.

Test Procedure

- Weigh a sample basket on a scale and record the mass. If the sample has cooled, preheat the sample in a 110ºC ± 5ºC oven for 30 minutes. Place the sample in the basket. Spread the sample in a thin layer, but avoid placing material near the edge of the basket. Allow the sample to cool to room temperature. Record the mass of the sample. For automatic ovens (method A), enter the mass of the sample into the oven processor.

- Place the sample in the ignition oven, preheated to 500ºC and burn off the asphalt according to the manufacturer's recommendation.

- The automatic ovens (method A) will stop the test when all the asphalt is burned off. Remove the sample from the oven and allow it to cool for approximately 30 minutes. Once the sample has cooled to room temperature, weigh and record the final mass. Calculate the uncorrected asphalt content by subtracting the final mass from the original mass to get the loss from the ignition and dividing by the original sample mass. Then, the calibration factor is applied to determine the corrected asphalt content.

- For manual ovens (method B), allow the sample to burn for at least 40 minutes after the ignition oven has cycled through the initial burn-off phase. Remove the sample from the oven and allow it to cool to approximately room temperature (at least 30 minutes). Weigh and record the mass of the sample. Record the final mass of the sample to the nearest 0.1 g. Repeat burn-off until a visual inspection indicates complete burn-off has been accomplished.

Report the asphalt content by ignition to two decimal places.

Example: ***Calibration factor determination***

Percent asphalt in the calibration sample (AC%) = 5.00%
Original dry mass of the calibration sample (Ws) = 2,507.5 g
The final mass of the burned off-calibration sample (Wa) = 2,370.7 g

Calibration factor, C_f = [(Ws-Wa)/Ws * 100] - AC%
= (2507.5 - 2370.7)/2507.5 * 100 - 5.00%
= 5.46 - 5.00 = 0.46

Corrected asphalt content determination:

The original dry mass of the test sample = 2,512.4 g
The final mass of the burned-off test sample = 2,379.5 g

Corrected asphalt content = [(Ws-Wa)/Ws * 100] - C_f

= (2512.4 - 2379.5)/2512.4 * 100 - 0.46%
= 5.29% - 0.46%
= 4.83%

Review Questions

1) The sample in KT-57 is obtained by _____.
(Quartering/Splitting)

2) The sample in KT-57 is dried at _____ ± _____ ºC to constant mass.

3) For calibration in KT-57, the minimum number of samples required is _____.

4) Additional tests are necessary for KT-57 if the calibration factors differ by more than _____%.

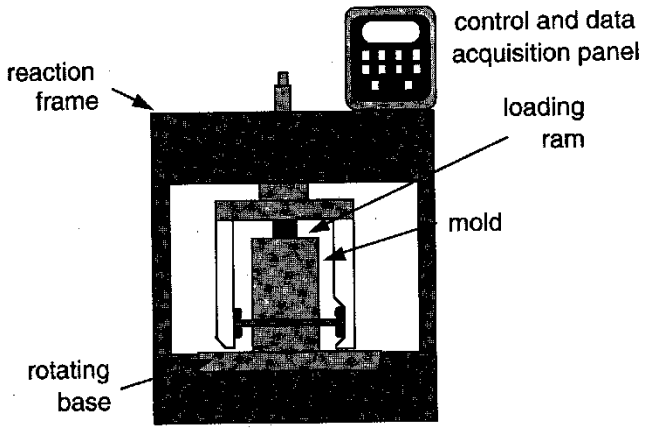
5) The sample size in the KT-57 test for a nominal maximum aggregate size of 12.5 mm is _____ g.

6) The ignition furnace used in KT-57 is preheated to _____ ºC or the calibration temperature.

RESISTANCE OF COMPACTED ASPHALT MIXTURE TO MOISTURE-INDUCED DAMAGE

(Kansas Test Method KT-56 / AASHTO T283)

(https://www.youtube.com/watch?v=QPeihnO3dXU)



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NOTE

This discussion and KT-56 refer to the following KT Methods:

* KT-6/AASHTO T84 & 85, Specific Gravity and Absorption of Aggregate

* KT-14/AASHTO T245 & 269, Marshall Test of Bituminous Mixes

* KT-15/AASHTO T166, Bulk Specific Gravity and Unit Weight of Compacted Asphalt Mixtures

* KT-25/AASHTO T168, Standard Method of Test for Sampling Bituminous Paving Mixtures

* KT-32, Method of Test for Density of Compacted Asphalt Mixtures by Nuclear Method

* KT-39/AASHTO T209, Theoretical Maximum Specific Gravity of Asphalt Paving Mixtures

* KT-58/AASHTO T312, Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) by Means of the Superpave Gyratory Compactor

GLOSSARY

Tensile strength: a measure of the force required to pull apart a material.

Loading jack: a mechanical device or machine that can apply a constant loading rate.

RESISTANCE OF COMPACTED ASPHALT MIXTURE TO MOISTURE-INDUCED DAMAGE

Superpave mixtures may be sensitive to the presence of water in the pavement. Water will cause the asphalt to separate from the aggregates. Since the asphalt is the "glue" that holds the aggregates together, rapid failure of the pavement can be expected if the asphalt cannot act as a binder. This phenomenon is often referred to as **stripping**. To help prevent stripping, additives, such as hydrated lime or liquid anti-stripping chemicals, may be required. KT-56/AASHTO T283 is a test method that can be used to determine if the mixtures are susceptible to stripping and can also be used to evaluate the effectiveness of anti-stripping additives.

The test is performed by compacting specimens to an air void level of **6.5 to 7.5** percent. Three specimens are selected as a control set and tested dry without moisture conditioning, and three more are conditioned by saturating with water, then freezing, thawing, and hot water soaking. The specimens are then tested for indirect tensile strength by loading at a constant rate and measuring the load required to break the specimen. The average tensile strength of the conditioned specimens is compared to that of the dry control specimens to determine the tensile strength ratio (TSR). This test may also be performed on cores taken from compacted pavement.

Common Testing Errors

- Voids in the conditioned specimens are not approximately the same as in the dry, unconditioned specimens.
- Conditioned specimens are not properly saturated with water.
- Conditioned specimens were not soaked for 24 hours in a water bath at 60 ± 1oC (140 ± 2oF).

TEST METHODOLOGY - FLASK METHOD

Apparatus

- Vacuum container for saturating specimens
- Balance and water bath
- Water bath able to maintain 60 ± 1ºC (140 ± 2ºF)
- Pans (cake pans)
- Loading jack and force measuring device
- Loading head to hold the specimen
- Forced air oven able to maintain 60 ± 1ºC (140 ± 2 ºF)
- Freezer able to maintain -18 ± 5 ºC (0 ± 10 º F)
- Plastic wrap and heavy-duty leakproof plastic bags
- 10 mL graduated cylinder (optional)

Sample Preparation

- The specifications for the specimen are 150 mm diameter (6 in) and 95 ± 5mm (3.75 ± 0.20 in) thick.
- Preparation of Mixes: Individual aggregates or reclaimed material and virgin aggregates are combined by taking proportionate amounts of each size fraction for each aggregate in a separate pan for each test specimen. The aggregate quantity should be sufficient to produce a specimen that meets the above specifications. The asphalt content is the design asphalt content. Then, the aggregate and the asphalt are heated within the limits of mixing temperature. The heated aggregates are charged in the mixing bowl, and asphalt is added. The mixture is then mixed thoroughly for at least 2 minutes. Care is taken to keep the entire sample in the mixing bowl during the process. Before or after compaction, the mix is aged at room temperature for 24 ± 1 hours. The mixture is then placed in an oven set at the appropriate compaction temperature and aged for 2 hours as outlined in KT-58 section 4.6. The plant mixed sample is obtained by quartering. No aging is required for this sample.
- The mixture is then compacted to 7 ± 0.5 percent air voids. This level of voids can be

obtained by adjusting the number of revolutions in KT-58. The exact procedure must be determined experimentally for each mixture before compacting the specimens for each test. The specimens are then extracted and allowed to cool to room temperature.

Evaluation of Test Specimen and Grouping

- The theoretical maximum specific gravity of the mixture *(for design mixture, the sample is prepared at design asphalt content*) is determined by KT-39. The specimen thickness is determined to the nearest 0.01 mm (0.001 in) at approximately quarter points on the periphery of the plug. The results are averaged and recorded. The diameter is also determined to the nearest 0.01 mm (0.001 in). KT-15, Procedure III, determines the bulk specific gravity. The volume of specimens is expressed in mL. The air voids are calculated to the *nearest 0.1%* using the following formula:

  % Air Voids = 100 (Theoretical Maximum Specific Gravity - Bulk Specific Gravity)/ Theoretical Maximum Specific Gravity

- The specimens are sorted into two subsets of three specimens each so that the average air voids of the two subsets are approximately equal.

Moisture Conditioning

- Put the specimens to be conditioned into the vacuum container and fill them with potable water so that at least 25 mm (1 in.) of water covers them. Apply a partial vacuum (250 to 650 mm of Hg) to the container for a short time (5 to 10 minutes). Release the vacuum and allow the specimens to sit submerged in the water for another 5 to 10 minutes. Determine the bulk specific gravity of the saturated specimens. Compare the saturated surface dry (SSD) mass of the saturated specimens to the dry mass of the specimens before saturation. The difference will be the volume of absorbed water. Compare the volume of absorbed water to the original volume of air voids to determine the amount of saturation. Absorbed water must be between 70 to 80 percent of the original volume of air voids. If the volume of absorbed water is less than 70 percent, repeat the vacuum saturation procedure. If the volume of absorbed water exceeds 80 percent, the specimens have been damaged and must be discarded and replaced.

- For the freeze cycle, wrap the saturated specimens tightly with plastic wrap, place them in a plastic bag with 10 mL of water, and seal the bag. Place the bag in the freezer at -18 ± 5ºC (0 ± 10 º F) for at least 16 hours. Remove the bags from the freezer and place them in the water bath at 60 ± 1ºC (140 ± 2ºF) for 24 ± 1 hours. Remove the plastic bag and plastic wrap from the specimens as soon as possible after placement in the water bath.

Test Procedure

- After the 24-hour soak, remove the specimens and place them in a water bath at 25 ± 0.5oC (77 ± 1oF) for 2 hours ± 10 minutes. The bath should return to 25 ± 0.5oC (77 ± 1oF)

within 15 minutes after the warm specimens are placed. The unconditioned specimens, still sealed in plastic, must also be placed in a 25 ± 0.5ºC (77 ± 1ºF) bath for at least 2 hours ± 10 minutes.

- Remove the conditioned plugs from the water bath. Quickly dry the saturated specimen with a damp absorbent cloth and weigh the specimen. Any water that seeps from the specimen during the weighing operation is considered part of the saturated specimen. Place the specimen in the basket or bucket and determine its mass to the nearest 0.5 g while immersed in water at 77 ± 1ºF (25 ± 0.5ºC). The mass of the specimen in water shall be determined as quickly as possible after the specimen is immersed. Determine the height and diameter of the plug before breaking.

- Place the specimen between the two bearing plates in the loading machine. Apply the load to the specimen at a constant rate of 51 mm (2 in) per minute along its diameter.

- As the load is applied, watch for and note the maximum load observed. Continue loading until a vertical crack appears, and record the maximum load. Remove the specimen from the machine and pull at the crack. Inspect the interior surface for stripping and record the observations.

Calculations

Calculate the tensile strength as follows:

$$S_t \text{ (Metric)} = 2{,}000\ (P) / (\pi)(t)(D)$$

$$S_t \text{ (English)} = 2\ (P) / (\pi)(t)(D)$$

Where:

S_t = tensile strength, kPa (psi)
P = maximum load, Newtons (lbf)
t = specimen thickness, mm (in)
D = specimen diameter, mm (in)

The tensile strength ratio is then calculated as:

$$\text{Percent Tensile Strength Ratio (\%TSR)} = 100\ (S_2) / (S_1)$$

where: S_1 = average tensile strength of dry subset, and
S_2 = average tensile strength of conditioned subset.

Note: If an anti-stripping agent is used, include the agent in all asphalt mixtures for the conditioned and unconditioned subsets.

Review Questions

1) The height of the gyratory plug for KT-56 test is approximately _____ ± _____mm.

2) The air voids of the compacted KT-56 specimens should be _____ ± _____%.

3) If the bulk specific gravity (KT-15, procedure III) of a KT-56 specimen is 2.322 and the maximum specific gravity (KT-39) is 2.444 then the air void content is _____%.

4) The percent saturation of the conditioned sample in KT-56 should be between _____and _____%.

5) The test temperature during the indirect tensile strength test in KT-56 is _____ ºC.

6) The conditioned samples in KT-56 are kept in the freezer at _____± _____ºC for a minimum of 16 hours.

7) The conditioned samples in KT-56 are thawed in a water bath at _____± _____ ºC for _____ ± _____ hours.

8) In the KT-56 test procedure, the load is applied during the tensile strength test at a constant rate of
_____ mm/min.

Answers to Review Questions

KT-58
1) 115 ± 5 mm
2) 600 ± 18 kPa
3) 1.16 ± 0.02 º
4) 30 ± 0.5 revs/min
5) Yes

KT- 15
1) 25 ± 3 ºC
2) 4 ± 1 min
3) 25 ± 1 ºC
4) 2 %
5) 2.349

KT-39
1) 25 ± 1 ºC
2) 6.3 mm
3) 27 ± 3 mm of Hg
4) 10 ± 1 min
5) 1,000 g
6) Quartering
7) 3
8) 2 hours

KT-57
1) Quartering
2) 110 ± 5 ºC
3) 2
4) 0.15 %
5) 1,500 g
6) 500 ºC

KT-56
1) 95 ± 5 mm
2) 7.0 ± 0.5 %
3) 5.0 %
4) 70 and 80
5) 25 ºC
6) -18 ± 5 ºC
7) 60 ± 1 ºC, 24 ± 1 hrs
8) 51 mm/min