King Faisal University
ENGINEERING
KFU
Uniqueness - Partnership - Success

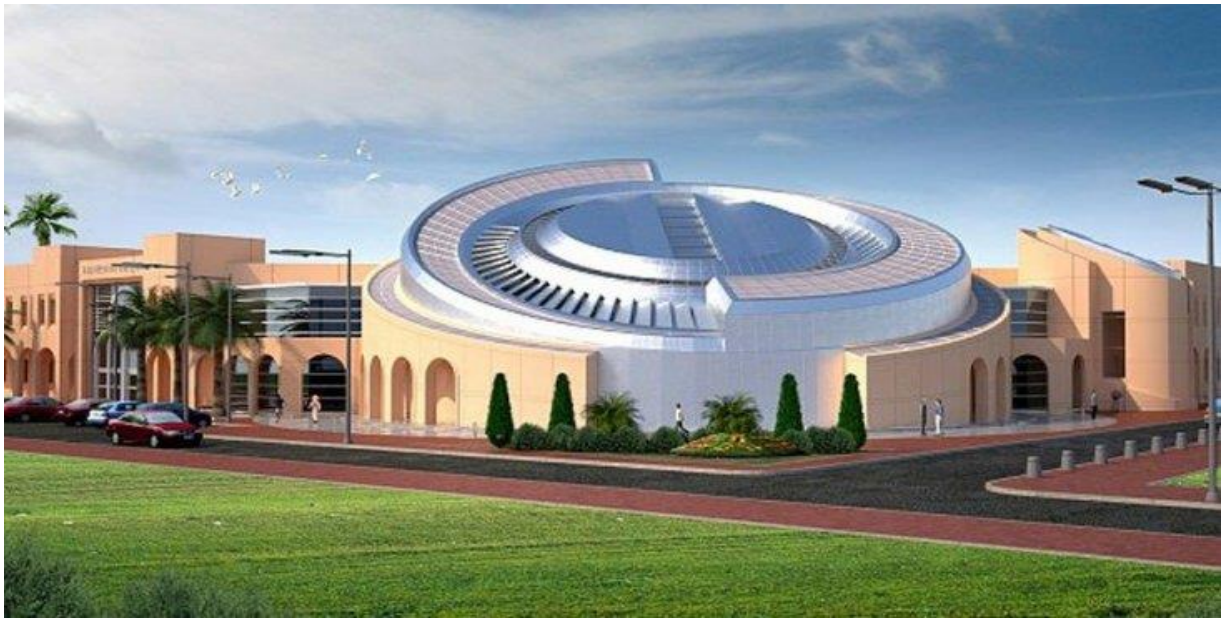
KING FAISAL UNIVERSITY

College Of Engineering

DEPARTMENT OF CIVIL & ENVIRONMENTAL ENGINEERING

CEE341: Highway Engineering

"Lab Manual"



Prepared By: **Engr. M. Aniq Gul**

Major Topics covered and schedule in weeks:

Topic	Week #	Courses Covered
Introduction and General overview of HMA Mix Design	1	CEE-340
Cleveland open-cup method for determination of Flash point and Fire point of Asphalt	2	CEE-340
Viscosity determination of Asphalt at elevated temperatures using a Rotational Viscometer (RV)	3	CEE-340
Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)	4	CEE-340
Determination of the Effect of Heat and Air on an Asphalt using Rolling Thin-Film Oven Test (RTFO) Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)	5	CEE-340
Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates	6	CEE-340
Measurement of Surface Frictional Properties Using the British Pendulum Tester	7	CEE-340
Standard Test Method for Preparation of Hot Mix Asphalt (Marshall Sample Compaction)	8	CEE-340
Standard Test Method for Preparation of Hot Mix Asphalt (Superpave Sample Compaction)	9	CEE-340
Standard test method for determination of Asphalt Mix Specific gravity using asphalt Bulk Specific Gravity Device.	10	CEE-340
	11	CEE-340
Standard test method for determination of Asphalt Mix Theoretical Maximum Specific Gravity	12	CEE-340
Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures	13	CEE-340
Project Submission/Presentation	14	CEE-340
Final Exam	15	CEE-340

Specific Outcomes of Instruction (Lab Learning Outcomes):

1. Understand Performance Grade (PG) specification of asphalt. (6)
2. Understand the SUPERPAVE mix design process. (6)
3. Conduct experiments and evaluate various properties of Bitumen using Modern Superpave equipment. (6)
4. Conduct experiments and evaluate various properties of Asphalt mixes using Modern Superpave equipment. (6)
5. Work as a team to complete tasks and present it in proper format. (3,5)

Student Outcomes (SO) Addressed by the Lab:

#	Outcome Description General Engineering Student Outcomes	Contribution
1.	an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	
2.	an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3.	an ability to communicate effectively with a range of audiences	M
4.	an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5.	an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	H
6.	an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	H
7.	an ability to acquire and apply new knowledge as needed, using appropriate learning strategies	

Table of Content

Experiment 1
Determination of Flash point and Fire point of Asphalt

I. Objective:

Flash point: is defined as the lowest temperature at which the vapor of the test specimen starts to ignite under the specified conditions of the test.

Fire point: is defined as the lowest temperature at which the test specimen will sustain burning for five seconds under the specified conditions of the test.

II. Test Standard

ASTM D92-90, (2000), *"Standard Test Method for Flash and Fire Points by Cleveland Open Cup."*

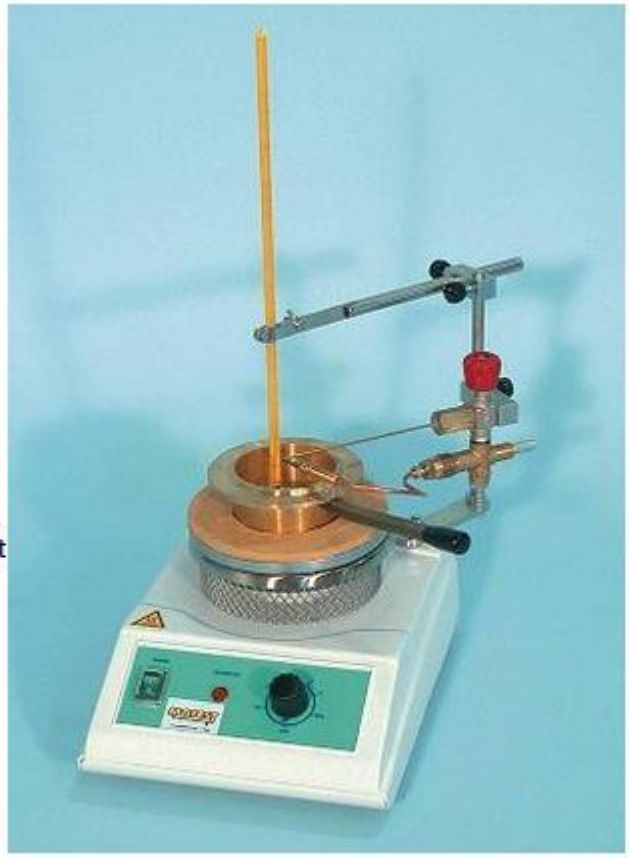
III. Theory:

1. Flash point can be used to measure the tendency of the material to catch flames. It is one of the properties which can be used to assess the overall flammability of the material.
2. Flash point is used to class flammable and combustible materials according to safety regulations.
3. Flash point can be used to obtain an idea about the presence of volatile and flammable substances in a, theoretically, non-flammable material.
4. Fire point is used to measure combustibility of the material.

IV. Apparatus:

The main apparatus is called the Cleveland Open Cup Apparatus. It consists of the following:

1. Test cup.
2. Heating plate.
3. Test flame.
4. Thermometer capable of measuring high temperatures up to 500°C.



Flash point apparatus

V. Procedure:

1. Make sure that the sample is fluid. If the sample is not fluid, then heat it carefully making sure that the temperature does not exceed 60ºC below the probable flash point.
2. Fill the cup with the sample to the specified level. Take care not to overfill the cup.
3. Air bubbles or foams should be carefully removed. Make sure that the surface is foam or air bubble-free surface before starting the test.
4. If foam could not be removed, then discard the sample completely and prepare a new one.
5. Let the apparatus stand on a leveled steady place. Protect from strong sunlight.
6. Wash the test cup carefully using some solvent in order to remove any traces of oils or residuals.
7. Support the thermometer in a vertical position at 6.4 mm from the bottom of the cup. Locate the thermometer halfway between the center and the side of the cup.

8. Fill the cup with the sample to the specified level. Take care not to overfill the cup. Air bubbles or foams should be carefully removed as mentioned earlier.
9. Light the test flame adjusting the flame to a diameter of 3 to 5 mm.
10. Start heating the sample with a relatively high speed (14ºC to 17ºC per minute). Continue until the temperature is about 60ºC below the probable flash point then decrease the heat so that the rate of heating is about 5ºC to 6ºC per minute.
11. When the temperature is about 30ºC below the probable flash point, apply the flame to the sample. The flame should be passed along the center of the sample and also about the circumference in a smooth way. The flame must be at a distance of not more than 2 mm above the plane of the edge of the can. Watch for possible ignition. The passing of the flame across the cup should be in about one second.
12. Repeat step 7 every increase of 2ºC.
13. Record the temperature at which flash ignition occurs. Record this value as the flash point.
14. Continue heating with the same rate (5ºC to 6ºC per minute) and repeat steps 7 and 8.
15. Record the temperature at which ignition occurs and burning continues for a minimum period of 5 seconds. Record this value as the fire point of the tested material.

VI. Experimental Work:

1. The final result should be rounded to the nearest 2ºC.
2. The difference between two successive tests performed by the same operator in the same laboratory should not exceed 8ºC.
3. The difference between two single and independent results performed at different laboratories should not exceed 17ºC for the flash point or 14ºC for the fire point.
4. If the results obtained do not conform to the conditions 2 and 3, the test must be repeated with new samples.
5. The method is suitable for temperatures above 80ºC.

Experiment 2
Determination of Asphalt viscosity at Elevated Temperatures

I. Objective:

The Rotational Viscometer is used to determine the viscosity of asphalt binders in the high temperature range of manufacturing and construction. This measurement is used in the Superpave PG asphalt binder specification. The RV test can be conducted at various temperatures, but since manufacturing and construction temperatures are fairly similar regardless of the environment, the test for Superpave PG asphalt binder specification is always conducted at 275°F (135°C). The basic RV test measures the torque required to maintain a constant rotational speed (20 RPM) of a cylindrical spindle while submerged in an asphalt binder at a constant temperature (typically 275°F (135°C)). This torque is converted to a dynamic viscosity and displayed automatically by the RV.

II. Test Standard

ASTM D4402 / D4402M -12: *"Standard Test Method for Viscosity Determination of Asphalt at Elevated Temperatures Using a Rotational Viscometer."*

III. Theory:

The RV test helps ensure that the asphalt binder is sufficiently fluid for pumping and mixing. The viscosity of asphalt binder at high manufacturing and construction temperatures (generally above 275°F (135°C)) is important because it can control the following:

- **Pumpability.** The ability of the asphalt binder to be pumped between storage facilities and into the HMA manufacturing plant.
- **Mixability.** The ability of the asphalt binder to be properly mixed with and to coat aggregate and other HMA constituents in the HMA manufacturing plant.
- **Workability.** The ability of the resultant HMA to be placed and compacted with reasonable effort.

IV. Apparatus:

The main apparatus consists of the following:

1. Rotational Viscometer
2. Temperature controller
3. Environmental chamber
4. Spindles

V. Procedure:

1. Preheat spindle, sample chamber, and viscometer environmental chamber (Thermosel) to 275°F (135°C).
2. Heat un-aged asphalt binder until fluid enough to pour. Stir the sample, being careful not to entrap air bubbles.
3. Pour appropriate amount of asphalt binder into sample chamber. The sample size varies according to the selected spindle and equipment manufacturer.
4. Insert sample chamber into RV temperature controller unit and carefully lower spindle into sample.
5. Bring sample to the desired test temperature (typically 275°F (135°C)) within approximately 30 minutes and allow it to equilibrate at test temperature for 10 minutes.
6. Rotate spindle at 20 RPM, making sure the percent torque as indicated by the RV readout remains between 2 and 98 percent.

7. Once the sample has reached temperature and equilibrated, take three viscosity readings from RV display, first reading should be noted after 30 minutes and allow three minutes between each reading. Viscosity is reported as the average of three readings.

VI. Experimental Work:

Parameter Measured:

Dynamic (or absolute) viscosity

Specifications:

Material	Value	Specification	Property of Concern
Unaged Binder	Dynamic Viscosity	≤ 3 Pa*s	Pumping, mixing & workability

Typical Values

RV viscosities depend upon the material measured and the test temperature. Superpave testing is done at 275°F (135°C) and typical dynamic viscosity values for asphalt binders at this temperature are 0.2 to 2 Pa·s. The Asphalt Institute recommends using a value of about 0.28 Pa·s for compaction temperatures.

Some representative dynamic viscosities are:

- PG 64-22 asphalt binder at 275°F (135°C) ≈ 0.570 Pa·s
- PG 76-22 asphalt binder at 275°F (135°C) ≈ 1.800 Pa·s (1 cP = 0.001 Pa·s)

Experiment 3
Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer (DSR)

I. Objective:

This test method covers the determination of the dynamic shear modulus and phase angle of asphalt binders when tested in dynamic (oscillatory) shear using parallel plate geometry.

The test temperature for this test is related to the temperature experienced by the pavement in the geographical area for which the asphalt binder is intended to be used. The complex shear modulus is an indicator of the stiffness or resistance of asphalt binder to deformation under load. The complex shear modulus and the phase angle define the resistance to shear deformation of the asphalt binder in the linear viscoelastic region.

II. Test Standard

ASTM D7175-08 *"Standard Test Method for Determining the Rheological Properties of Asphalt Binder Using a Dynamic Shear Rheometer."*

III. Theory:

Asphalt binders are viscoelastic. This means they behave partly like an elastic solid (deformation due to loading is recoverable – it is able to return to its original shape after a load is removed) and partly like a viscous liquid (deformation due to loading is non-recoverable – it cannot return to its original shape after a load is removed). Having been used in the plastics industry for years, the DSR is capable of quantifying both elastic and viscous properties. This makes it well suited for characterizing asphalt binders in the in-service pavement temperature range. The dynamic shear rheometer (DSR) is used to characterize the viscous and elastic behavior of asphalt binders at medium to high temperatures. This characterization is used in the Superpave PG asphalt binder specification. As with other Superpave binder tests, the actual temperatures anticipated in the area where the asphalt binder will be placed determine the test temperatures used. The basic DSR test uses a thin asphalt binder sample sandwiched between two circular plates. The lower plate is fixed while the upper plate oscillates back and forth across the sample at 10 rad/sec (1.59 Hz) to create a shearing action. DSR tests are conducted on unaged, RTFO aged and PAV aged asphalt binder samples. The test is largely software controlled.

IV. Apparatus:

The main apparatus consists of the following:

1. Dynamic Shear Rheometer (DSR) Test System
2. Test Plates

3. Environmental Chamber
4. Internal DSR Temperature Measurement Device
5. Loading Device
6. Data Acquisition System
7. Specimen Mold (optional)
8. Trimming Tool
9. Reference Temperature Measurement Device

V. Procedure:

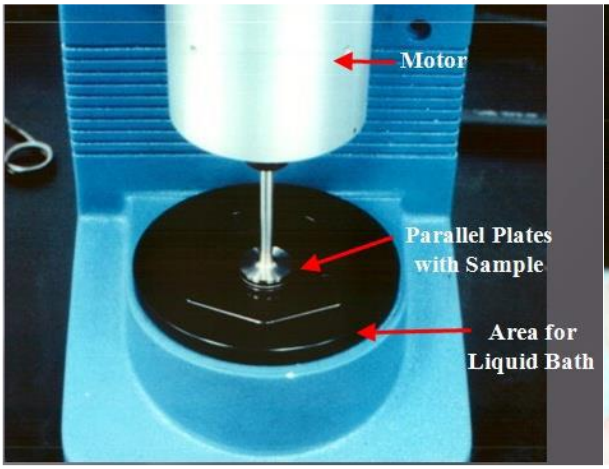
Preparation of a sample:

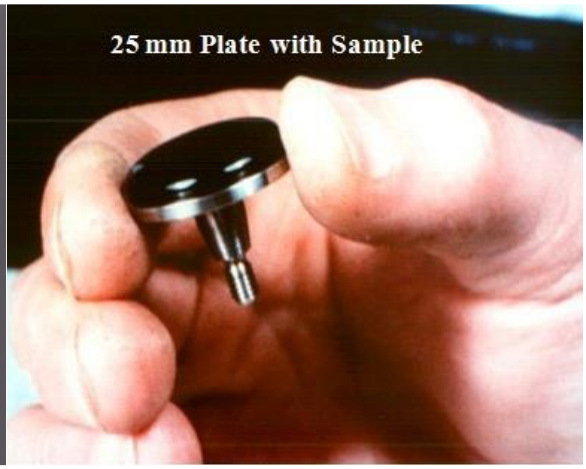
1. Heat the asphalt binder sample from which the test specimen is prepared in a container in an oven until it is sufficiently fluid to pour. Cover the sample and stir it occasionally during the heating process to ensure homogeneity and to remove air bubbles. Cold samples must be heated prior to testing. During heating process do not allow the temperature of the binder to exceed 163°C.
2. Pour the hot asphalt binder into a silicone mold to form a convex surface. Do not trim the surface of the binder. Allow the mold to cool to room temperature. As soon as the binder and mold have cooled to room temperature, loosen the binder from the mold by flexing the rubber mold. Gently press the convex (top) surface of the pellet against one of the preheated test plates forcing the asphalt binder to adhere to the plate. The filled mold should be cooled at room temperature by placing the mold on a flat laboratory bench surface without chilling. Pull the silicone rubber mold from the binder, close the gap to the test gap plus the gap required to form the bulge. Testing shall be completed within two hours of pouring the hot asphalt binder into the mold. Discard any test results if the testing is not completed within two hours of being poured into the silicone mold.
3. Immediately after the specimen has been placed on one of the test plates as described above, move the test plates together until the gap between the plates equals the testing gap plus the gap closure required to create the bulge. Trim excess binder by moving a heated trimming tool around the edges of the plates so that the asphalt binder is flush with the outer diameter of the plates.
4. When the trimming is complete, decrease the gap by the amount required to form a slight bulge at the outside face of the test specimen. The gap required to create a bulge is Rheometer specific and depends upon factors such as the design of the Rheometer and the temperature difference between the trimming temperature and test temperature.

Typical closure values for creating the gap are 0.05 mm for the 25-mm plate and 0.10 mm for the 8-mm plate.

Test Procedure

5. Set the temperature controller to the temperature required to obtain the test temperature in the test specimen between the test plates. Allow the DSR to reach thermal equilibrium within ± 0.1°C of test temperature. The test shall be started five to ten minutes after the test specimen has reached thermal equilibrium.
6. When testing at multiple temperatures, start at the lowest test temperature for the 25-mm plate and start at the highest test temperature for the 8-mm plate.
7. Initiate the testing within five to ten minutes after reaching thermal equilibrium at each test temperature. The testing at subsequent temperatures should be done as quickly as possible to minimize the effect of molecular associations (steric hardening) that can cause an increase in modulus if the specimen is held in the rheometer for a prolonged period of time.
8. When testing at multiple temperatures all testing should be completed within two hours of preparing the test specimen. Start the application of the load and obtain a measurement of the complex modulus, phase angle, and frequency after applying 8 to 16 initial loading cycles.
9. Obtain a test measurement by averaging data for an additional 8 to 16 loading cycles using the analytical technique and software provided by the manufacturer. When conducting tests at more than one frequency, start testing at the lowest frequency and increase to the highest frequency.





VI. Experimental Work:

The DSR is capable of measuring asphalt response over a range of temperature, frequency, and strain levels. However, G* and δ are required for Superpave specification testing at specific conditions. The DSR software calculates G* and δ. Therefore, it is a simple matter of comparing results with requirements of the Superpave specification to determine compliance.

G* is divided by sin δ to develop a "high temperature stiffness" factor that addressed rutting; G* is multiplied by sin δ to develop an "intermediate temperature stiffness" factor that addresses fatigue cracking.

Parameters Measured:

1. Complex modulus (G*)
2. Phase angle (δ)

Specifications:

Material	Value	Specification	HMA Distress of Concern
Unaged Binder	G*/Sinδ	≥ 1.0 kPa (0.145 psi)	Rutting
RTFO Residue	G*/Sinδ	≥ 2.2 kPa (0.319 psi)	Rutting
PAV Residue	G*Sinδ	≤ 5000 kPa (725 psi)	Fatigue Cracking

Typical Values:

The complex modulus (G*) can range from about 0.07 to 0.87 psi (500 to 6000 Pa), while the phase angle (δ) can ranges from about 50 to 90°. A δ of 90° is essentially complete viscous behavior. Polymer-modified asphalt binders generally exhibit a higher G* and a lower δ. This means they are, in general, a bit stiffer and more elastic than unmodified asphalt cements.

Experiment 4
Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt by Rolling Thin-Film Oven (RTFO) Test

I. Objective:

This test method is intended to measure the effect of heat and air on a moving film of asphaltic materials. This test method provides a means for conditioning asphalt binder to simulate the hardening that occurs during the mixing and compaction of hot mix asphalt. The test method also provides the mass change that occurs during the test. The residue from RTFO is further aged using PAV test method. Also the residue from RTFO and PAV can further be tested on DSR for SUPERPAVE Performance Grading.

II. Test Standard

ASTM: D 2872 – 04 *"Standard Test Method for Effect of Heat and Air on a Moving Film of Asphalt (Rolling Thin-Film Oven Test) (AASHTO T 240-06)."*

III. Theory:

One of the basic tenets of the Superpave PG binder specification is that tests should be as closely tied with field performance as possible. Seeing as the constituent asphalt binder in HMA undergoes significant aging during the manufacturing and placement processes, a method to simulate the aging is important in investigating and predicting early age HMA pavement behavior and distresses. Specifically, the Superpave PG binder specification calls for short term aged asphalt binder to be tested at high temperatures to determine fatigue and rut resistance. The RTFO was developed as an improvement to the Thin-Film Oven Test (TFOT) for short term asphalt binder aging. The TFOT placed asphalt binder samples in shallow pans (of the same dimensions as those used for the PAV) and then heated them in an oven for an extended period of time to accomplish simulated aging.

Asphalt Binder aging by Loss of Volatiles

Although many different factors contribute to asphalt binder aging, the key component of concern for the RTFO is the loss of volatiles. The loss of smaller molecules from the asphalt binder, often termed "volatiles" increases an asphalt's viscosity.

Loss of Volatiles Occurrence

Asphalt binders typically lose volatiles during the manufacturing and placemen processes. The elevated temperature of these processes ages the asphalt binder by driving off a substantial amount of volatiles. Field tests have shown that in-place asphalt binder does not lose a significant amount of volatiles over its life.

Aging Simulation

The RTFO aging procedure is used to simulate aging during mixing and placement, while the PAV aging procedure is used to simulate aging during in-service life. Therefore, asphalt binder tests concerned with mix and placement properties (such as the DSR) are conducted on RTFO aged samples, while asphalt binder tests concerned with in-service performance (such as the DSR, BBR and DTT) are performed on samples first aged in the RTFO and then in the PAV.

RTFO Aging of Modified Asphalt Binders

The RTFO has problems with highly viscous binders (e.g., some polymer modified asphalt binders and PG 70-XX and higher) because they do not flow properly in the bottles as they are rotated.

IV. Apparatus:

The main apparatus consists of the following:

1. RTFO Carriage
2. Thermometer
3. Temperature controller
4. Container (RTFO Bottles)
5. Air Supply Compressor

V. Procedure:

Specimen Preparation

To prepare for RTFO aging, a binder sample is heated until sufficiently fluid to pour. In no case should the sample be heated to 150° C. RTFO bottles are loaded with 35 ± 0.5 g of binder. The RTFO has an eight bottle capacity; however, the contents of two bottles must be used to determine mass loss. If mass loss is being determined, the two bottles containing samples should be cooled and weighed to the nearest 0.001 g. Otherwise, the RTFO residues from the eight bottles are poured into a single container and stirred to ensure homogeneity. RTFO residue should be poured from the coated bottle and as much of the remaining residue as practical should be scraped out. This material may be used for DSR testing or transferred into PAV pans for additional aging or equally proportioned into small containers and stored for future use.

Procedure

The RTFO oven must be preheated at the aging temperature, 163° ± 0.5°C, for a minimum of two hours prior to use (AASHTO), in previous manuals it was 16 hours.. The thermostat should be set so that the oven will return to this temperature within 10 minutes after the sample bottles

are loaded. Bottles are loaded into the carriage with any unused slots filled with empty bottles. The carriage should be started and rotated at a rate of 15 ± 0.2 rev/min. The air flow should be set at a rate of 4000 ± 200 ml/min. The samples are maintained under these conditions for 85 minutes. If mass loss is being determined, the mass loss sample and bottles are allowed to cool to room temperature and weighed to the nearest 0.001 g.

VI. Experimental Work:

Data Presentation

The primary purpose of RTFO procedure is the preparation of aged binder materials for further testing and evaluation with the Superpave binder tests. The RTFO procedure is also used to determine the mass loss, a measure of the material vaporized by the RTFO procedure. A high mass loss value would identify a material with excessive volatiles, and one that could age excessively.

Parameters Measured:

Mass change of a sample as a percent of initial mass. The RTFO is primarily used to simulate short term asphalt binder aging for use in other tests.

Specifications:

Material	Value	Specification	Property of Concern
Unaged binder	Mass loss1	≤ 1.0%	None

Typical Values:

Mass loss is reported as the average of the two samples after RTFO aging, and is calculated by this formula:

Mass Loss, % = [(Original mass - Aged mass)/Original Mass] x 100 %

Typical mass loss is in the range of 0.05 to 0.5 percent.

Experiment 5
Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)

I. Objective:

This practice covers the accelerated aging (oxidation) of asphalt binders by means of pressurized air and elevated temperature. This is intended to simulate the changes in rheology which occur in asphalt binders during in-service oxidative aging. It is normally intended for use with residue from RTFOT, which is designed to simulate aging during mixing and placement. Residue from this conditioning practice may be used to estimate the physical or chemical properties of asphalt binders after several years of in-service aging in the field.

II. Test Standard

ASTM D6521 – 08 *"Standard Practice for Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)."*

III. Theory:

The Pressure Aging Vessel (PAV) provides simulated long term aged asphalt binder for physical property testing. Asphalt binder is exposed to heat and pressure to simulate in-service aging over a 7 to 10 year period. Many HMA distresses either initiate or become more severe in older pavements. Therefore, a method to simulate aged asphalt binder is important in investigating and predicting these types of distresses. The Superpave PG binder specification calls for long term aged asphalt binder to be tested at intermediate and cold temperatures to determine fatigue and low temperature cracking resistance.

Although many different factors contribute to asphalt binder aging, the key component of concern for the PAV is oxidation. Oxidation increases an asphalt's viscosity with age up until a point when the asphalt is able to quench (or halt) oxidation through immobilization of the most chemically reactive elements. Oxidation can occur in the field during two distinct stages of a pavement's life:

1. **Mixing and placement:** During mixing and placement the asphalt binder is rapidly aged by volatilization (through elevated temperature) and oxidation (through its large contact area with the heated aggregate). Predominate aging mechanism during this stage is the loss of volatiles resulting from elevated mixing and placement temperatures; oxidation is secondary.
2. **In-service:** Over the life of an in-service HMA pavement the constituent asphalt binder slowly ages as the oxygen from the surrounding environment percolates through the HMA and chemically reacts.

IV. Apparatus:

The main apparatus consists of the following:

1. Pressure Vessel
2. Pressure and Temperature Controlling Devices
3. Temperature Controlling Device
4. Temperature and Pressure Measuring Devices
5. Stainless Steel Pans
6. Balance
7. Temperature and Vacuum Measuring Devices
8. Vacuum System

V. Procedure:

Pour the asphalt residue from RTFO test into the PAV pans. The asphalt binder placed in the pans must be weighed to 50 ± 0.5 g. open the vessel, remove the pan holder, and place the pans in the holder. Return the holder to the vessel and close and tighten the cover.

The conditioning pressure of 2.1 MPA is applied automatically after setting the input data. The conditioning time starts when the pressure is first applied. Significance aging occurs only when air is forced into the asphalt binder as the pressure is applied. Once the pressure is applied, the pressure must be maintained for 20 hrs ± 10minutes.

The temperature must not deviate from the conditioning temperature (90, 100, 110°C) by more than ±0.5°C.

The pressure is released over a period of 9 ± 1 minute by controlling the bleed value. Once the pressure is released, open the vessel; remove the pan holder from vessel. The residue should be poured in one or more container for future testing.

VI. Experimental Work:

Parameters Measured:

The PAV is used to simulate asphalt binder aging for use in other tests associated with performance graded asphalt binder.

Specifications:

Temperature	Simulation
194°F (90°C)	cold climate
212°F (100°C)	moderate climate
230°F (110°C)	hot climate

Experiment 6
Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates

I. Objective:

This test method is used primarily to determine the grading of materials proposed for use as aggregates or being used as aggregates. The results are used to determine compliance of the particle size distribution with applicable specification requirements and to provide necessary data for control of the production of various aggregate products and mixtures containing aggregates. The data may also be useful in developing relationships concerning porosity and packing.

II. Test Standard

ASTM C 136 – 05 *"Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates."*

III. Theory:

The gradation and size test is used to determine aggregate particle size distribution. Size distribution is perhaps the single most important aggregate quality associated with the control of HMA mixtures. Aggregate gradation and size affect HMA volumetric properties as well as mixture permeability and workability. The particle size distribution, or gradation, of the constituent aggregate is one of the most influential characteristics in determining how an HMA mixture will perform as a pavement material. Aggregate gradation influences almost every important HMA property including stiffness, stability, durability, permeability, workability, fatigue resistance, skid resistance and resistance to moisture damage. Gradation is often expressed in graphical form. Typically gradation graphs use concepts of maximum density gradation and its expression in equation form to plot a special graph referred to as the FHWA 0.45 power graph.

The desired gradation for a particular HMA mixture is dependent upon its intended use and desired characteristics, predicted loading, environmental conditions, as well as material, structural and mix properties. Therefore, gradation requirements for specific HMA mixtures can vary widely. The vast majority of the HMA placed in the U.S. is dense-graded. Maximum aggregate size can affect HMA in several ways. Instability (rutting, shoving) may result from excessively small maximum sizes; and poor workability and/or segregation may result from excessively large maximum sizes. Maximum aggregate size can be defined in two different ways:

Maximum aggregate size. The smallest sieve through which 100 percent of the aggregate sample particles pass. Superpave mix design defines the maximum aggregate size as "one sieve larger than the nominal maximum size."

Nominal maximum aggregate size (NMAS). The largest sieve that retains some of the aggregate particles but generally not more than 10 percent by weight. Superpave mix design defines nominal maximum aggregate size as "one sieve size larger than the first sieve to retain more than 10 percent of the material."

IV. Apparatus:

The main apparatus consists of the following:

1. Balances
2. Sieves
3. Mechanical Sieve Shaker
4. Oven

V. Procedure:

1. Obtain an aggregate sample of adequate mass from one of the following locations: aggregate stockpiles, bins, dump trucks, conveyor belt, or the roadway.
2. Mix and reduce the sample to an amount suitable for testing. This process of reducing a sample size is often referred to as "splitting" the sample.
3. Dry the test sample to a constant mass and determine the sample's dry mass.
4. If using the washed procedure, place the dry sample in a container and cover with water. Agitate the sample to completely separate all particles finer than the No. 200 (0.075 mm) sieve from the coarser aggregate, and to bring the fine material into suspension. Immediately decant the wash water containing the suspended solids over a nest of sieves consisting of a No. 200 (0.075 mm) sieve and an upper sieve with openings in the range of No. 8 (2.36 mm) to No. 16 (1.18 mm).
5. If using the washed procedure, repeat step 4 until the wash water is clear.
6. If using the washed procedure, return the material retained on the nested sieves to the washed sample by flushing with water. Dry the washed sample to a constant mass and allow to cool. Determine mass of the sample after washing.
7. Select applicable sieves to obtain the information required by the specifications covering the material to be tested. Sieve sizes typically used for Superpave mix design are 1½ in, 1.0 in, ¾ in, ½ in, 3/8 in, No. 4, No. 8, No. 16, No. 30, No. 50, No. 100 and No. 200 (37.5, 25.0, 19.0, 12.5, 9.5, 4.75, 2.36, 1.18, 0.600, 0.300, 0.150 and 0.075 mm) sieves. Assemble the sieves in order of decreasing size of opening from top to bottom and place the nest of sieves over a pan.
8. Pour the sample into the top sieve in the nest.

9. Sieve the material in a mechanical sieve shaker.
10. Determine the mass of the material retained on each sieve size. Record the cumulative mass retained for each sieve size (the mass retained on a specific sieve size and the mass retained on all sieves with larger openings).

VI. Experimental Work:

Parameters Measured

Percent retained or percent passing each sieve size by mass and material finer than the 0.075 (No. 200) sieve.

Specifications

Super pave mix design specifies aggregate gradation control points for mixes of NMAS 0.375 inch (9.5 mm), 0.5 inch (12.5 mm), 0.75 inch (19.0 mm), 1.0 inch (25.0 mm) and 1.5 inch (37.5 mm). Figure 10 shows just one of these sizes in a pile at a fully fractionated aggregate quarry.

Typical Values

There is no standard gradation and size for Superpave mix design. Generally, gradation and size will meet gradation control points defined in the Superpave mix design specification (AASHTO M 323). However, many state and local agencies specify their own gradation control points, which can differ from standard Superpave gradation control points. Although gradation and size will vary by a HMA's intended use, location and material availability, a majority of Superpave HMA mixes are 0.5 inch (12.5 mm) or 0.75 inch (19.0 mm) NMAS dense graded mixtures.

Experiment 7
Measurement of Surface Frictional Properties Using the British Pendulum Tester

I. Objective:

In this experiment the will be used to evaluate the skid resistance of a pavement surface. This test method is used to evaluate the highway surface frictional properties. Such measurements are, of course, made with the surface wetted, but the rubber shoe of the pendulum tester displaces enough water so that the hydrodynamic effects (which influence friction at higher speeds and which are controlled by the coarser features of the surface) are practically absent. The rubber responds essentially only to micro-texture.

The tester is a dynamic pendulum impact type tester which is based on the energy loss occurring when a rubber slider edge is propelled across a test surface. The apparatus may be used for both laboratory and field tests on flat surfaces, and also for polished stone value measurements on curved laboratory specimens from accelerated polishing wheel tests. The values measured are referred to as British Pendulum (tester) numbers (BPN) for flat surfaces, and polished stone values (PSV) for specimens subjected to accelerated polishing effect.

II. Test Standard

ASTM E 303 *"Standard Test Method for Measuring Surface Frictional Properties Using the British Pendulum Tester."*

III. Theory:

The highway surface should have some sort of roughness to facilitate friction between the car wheel and pavement surface. Skid resistance is a measure of the resistance of the pavement surface to sliding or skidding of the vehicle. It is a relationship between the vertical force and the horizontal force developed as a tire slides along the pavement surface. Therefore, the texture of the pavement surface and its ability to resist the polishing effect of traffic is of prime importance in providing skidding resistance.

Polishing of the aggregate is the reduction in micro-texture, resulting in the smoothing and rounding of exposed aggregates. This process is caused by particle wear on a microscopic scale and is difficult to quantify. Low-speed friction measurements, such as the British Portable Friction Tester, have been used in an attempt to quantify polishing.

IV. Apparatus:

The main apparatus consists of the following:

1. British Pendulum tester.

2. Slider bonded with a 6mm by 25m by 75mm rubber strip for testing flat surfaces.
3. Contact path gauge (thin ruler).
4. Water container.
5. Brush.
6. Thermometer.

V. Procedure:

Test Preparation:

1. Field test surfaces shall be brushed and flushed with clean water.
2. Level the instrument accurately by turning leveling screws until the bubble is centered in the spirit level.
3. Raise pendulum mechanism by loosening locking knob (directly behind pendulum pivot) and turn either of pair of head movement knobs at center of tester to allow slider to swing free of test surface. Tighten locking knob firmly.
4. Place pendulum in release position and rotate the drag pointer counter clockwise until it comes to rest against adjustment screw on pendulum arm.

5. Release pendulum and note pointer reading. If reading is not zero, loosen locking ring and rotate friction ring on bearing spindle slightly and lock again.
6. Repeat test and adjust friction ring until the pendulum swing carries pointer to zero.
7. Place spacer under adjusting screw of lifting handle.
8. Lower pendulum so edge of slider just touches surface.
9. Lock pendulum head firmly, raise lifting handle, and remove spacer.
10. Raise slider by lifting handle, move pendulum to the right of the lower slider, and allow pendulum to move slowly to left side until edge of slider touches surface.
11. Place the contact path gauge beside slider and parallel to direction of swing to verify length of contact path.
12. Raise slider, using lifting handle, and move pendulum to left, then slowly lower until slider edge again comes to rest on surface. If the length of the contact path is not between 124 and 127 mm on flat test specimens measured from trailing edge to trailing edge of the rubber slide, adjust by raising or lowering instrument with the front leveling screws. Readjust level of instrument if necessary.
13. Place pendulum in release position and rotate the drag pointer counter-clockwise until it comes to rest against adjustment screw on pendulum arm.

Test Procedure:

1. Apply sufficient water to cover the test area thoroughly.
2. Execute one swing, but do not record reading.
3. Always catch the pendulum during the early portion of its return swing. While returning the pendulum to its starting position, raise the slider with its lifting handle to prevent contact between the slider and the test surface and return the pendulum and the pointer to their starting position.
4. Immediately, make four more swings, rewetting the test area each time and record the results. After each drop repeat Step 4.
5. Recheck the slide contact length on completion of the test.

VI. Experimental Work:

Report: Record the British Pendulum tester Number (BPN) as the average of the four test values.

Experiment 8
Standard Test Method for Preparation of Hot Mix Asphalt (Marshall Sample Compaction)

I. Objective:

Compacted bituminous mixture specimens molded by this procedure are used for various physical tests such as stability, flow, indirect tensile strength, fatigue, creep, and modulus. Density and voids analysis are also conducted on specimens for mixture design and evaluation of field compaction. This method describes a procedure for the preparation of Marshall test specimens used in the design of bituminous mixtures, as well as specimens from field samples required for the determination of Marshall properties of dense and open-graded bituminous pavement mixtures.

II. Test Standard

ASTM D6926-10: *"Standard Practice for Preparation of Bituminous Specimens Using Marshall Apparatus."*

III. Theory:

The basic concepts of the Marshall mix design method were originally developed by Bruce Marshall of the Mississippi Highway Department around 1939 and then refined by the U.S. Army. Currently, the Marshall method is used in some capacity by about 38 states. The Marshall method seeks to select the asphalt binder content at a desired density that satisfies minimum stability and range of flow values. The most promising method eventually proved to be the Marshall Stability Method developed by Bruce G. Marshall at the Mississippi Highway Department in 1939. WES took the original Marshall Stability Test and added a deformation measurement (using a flow meter) that was reasoned to assist in detecting excessively high asphalt contents. This appended test was eventually recommended for adoption by the U.S. Army because:

- It was designed to stress the entire sample rather than just a portion of it.
- It facilitated rapid testing with minimal effort.
- It was compact, light and portable.
- It produced densities reasonably close to field densities.

WES continued to refine the Marshall method through the 1950s with various tests on materials, traffic loading and weather variables. Today the Marshall method, despite its shortcomings, is probably the most widely used mix design method in the world. It has probably become so

widely used because it was adopted and used by the U.S. military all over the world during and after WWII and it is simple, compact and inexpensive.

IV. Apparatus:

The main apparatus consists of the following:

1. Specimen Mold Assembly.
2. Specimen Extractor.
3. Compaction Hammers.
4. Compaction Pedestal.
5. Specimen Mold-Holder.
6. Ovens, Heating Pots or Hot Plates.
7. Mixing Apparatus.
8. Miscellaneous Equipment (Oven, mixing tools, thermometer, balance and gloves).

V. Procedure:

Preparation and Compaction of Test Specimens

1. Preparation of Aggregates—Dry aggregates to constant weight. Oven drying should be done at 105 to 110°C (221 to 230°F). After cooling, separate the aggregates by dry-sieving into the desired size fractions.
2. Determination of Mixing and Compacting Temperatures—The asphalt cement used in preparing the samples must be heated to produce viscosities of 170 6 20 cP (0.17 6 0.02 Pa·s) and 0.28 6 0.03 Pa·s (280 6 30 cP) for mixing and compacting, respectively.
3. Mixture Preparation—Specimens may be prepared from single batches or multiple batches containing sufficient material for three or four specimens.
4. Compaction of Specimens—Thoroughly clean the specimen mold assembly and the face of the compaction hammer and heat them either in boiling water, in an oven, or on a hot plate to a temperature between 200 and 300°F (90 and 150°C). Place a piece of nonabsorbent paper, cut to size, in the bottom of the mold before the mixture is introduced. Place the mixture in the mold, spade the mixture vigorously with a heated spatula or trowel 15 times around the perimeter and 10 times over the interior. Place another piece of nonabsorbent paper cut to fit on top of the mix. Temperature of the mixture immediately prior to compaction shall be within the limits of the compaction temperature. For mechanical compactors, it will be necessary for the laboratory to establish the mechanical equivalency for the equipment as compared to 75 blows per side of the hand hammer.

5. After compaction remove the base plate, collar and paper disks. Then allow the mold to cool until warm to the touch (approximately 40°C). Fans may be used when more rapid cooling is desired. Cooling by submerging in water is not permitted.
6. Remove the specimen from the mold by means of an extrusion jack or other compression device, and then place flat side down on a smooth, level surface until ready for testing.
7. Allow the extruded samples to stand on a smooth flat surface at room temperature for a minimum of one hour before any further testing is performed.

VI. Experimental Work:

The report shall include at least the following information:

1. Sample identification (number, laboratory mixed, or plant mixed, and so forth),
2. Type of bituminous material, source, and content,
3. Type(s) of aggregate, source, and grading,
4. Type and time of curing prior to compaction,
5. Type of hammer (that is, manually held or fixed and mechanically or manually operated hammer and flat or slanted foot),
6. Number of blows/side,
7. Mixing temperature,
8. Compaction temperature, and
9. Type and time of cooling.

To ensure consistency during hand compaction, place an empty mold in the compaction mold holder and rest the hammer in the mold. While standing, the operator's eye level should be the same height as the bottom of the hammer handle. If the eye level is below, place a step stool adjacent to the compaction pedestal to adjust the operator's height accordingly. Mechanical mixing is preferred in the preparation of mix design samples. Handle all hot equipment with heat resistant gloves. Always use the hand guards with the hand hammers. Wear proper protective safety gear for each operation.

Experiment 9
Standard Test Method for Preparation of Hot Mix Asphalt (Superpave Sample Compaction)

I. Objective:

This test method is used to prepare specimens for determining the volumetric and physical properties of compacted HMA mix. This test method is useful for monitoring the density of test specimens during the compaction process. This test method is suited for the laboratory design and field control of HMA.

II. Test Standard

ASTM D6925-09: *"Standard Test Method for Preparation and Determination of the Relative Density of Hot Mix Asphalt (HMA) Specimens by Means of the Superpave Gyratory Compactor."*

III. Theory:

One of the principal results from the Strategic Highway Research Program (SHRP) was the Superpave mix design method. The Superpave mix design method was designed to replace the Hveem and Marshall methods. The volumetric analysis common to the Hveem and Marshall methods provides the basis for the Superpave mix design method. The Superpave system ties asphalt binder and aggregate selection into the mix design process, and considers traffic and climate as well. The compaction devices from the Hveem and Marshall procedures have been replaced by a gyratory compactor and the compaction effort in mix design is tied to expected traffic. Under the Strategic Highway Research Program (SHRP), an initiative was undertaken to improve materials selection and mixture design by developing:

- A new mix design method that accounts for traffic loading and environmental conditions.
- A new method of asphalt binder evaluation.
- New methods of mixture analysis.

When SHRP was completed in 1993 it introduced these three developments and called them the Superior Performing Asphalt Pavement System (Superpave). Although the new methods of mixture performance testing have not yet been established, the mix design method is well-established. The Superpave mix design method consists of 7 basic steps:

1. Aggregate selection.
2. Asphalt binder selection.
3. Sample preparation (including compaction).

4. Performance Tests.
5. Density and voids calculations.
6. Optimum asphalt binder content selection.
7. Moisture susceptibility evaluation.

IV. Apparatus:

The main apparatus consists of the following:

1. Superpave Gyratory Compactor
2. Specimen Molds
3. Mold Plates and Ram Heads
4. Thermometers
5. Balance
6. Oven

V. Procedure:

Preparation and Compaction of Test Specimens

1. Weigh and combine the appropriate aggregate fractions to the desired specimen weight. The specimen weight will vary based on the ultimate disposition of the test specimens. If a target air void level is desired, specimen weights will be adjusted to create a given density in a known volume. If the specimens are to be used for determination of volumetric properties, the weights will be adjusted to result in a compacted specimen having dimensions of 150 mm in diameter and 115 ± 5 mm in height at the required number of gyrations. Generally, 4500 to 4700 g of aggregate are required to achieve this height for aggregates with combined bulk specific gravities of 2.55 to 2.70 respectively.
2. Place the blended aggregate specimens and asphalt binder in an oven and bring to the required mixing temperature. Heat the mixing container and all necessary mixing implements to the required temperature.
3. Mix the asphalt binder and aggregate as quickly and thoroughly as possible to yield an asphalt mixture having a uniform distribution of asphalt binder. Because of the large batch weights, a mechanical mixer is preferable for the mixing process. After completing the mixing process, subject the loose mix to short-term conditioning for 2 h ± 5 min at the compaction temperature 63°C. Stir the mix after 60 ± 5 min to maintain uniform conditioning.

4. Place a compaction mold assembly in an oven at the required compaction temperature 65°C for a minimum of 45 min prior to the compaction of the first mixture specimen.

5. The compaction temperature range 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 for an asphalt binder density of 1.000 g/cm3) measured in accordance with Test Method D4402.

6. At the end of the conditioning period, remove the loose mix sample and the compaction mold assembly from the oven. Place a paper disk inside the mold to aid separation of the specimen from the base plate after compaction.

7. Quickly place the mixture into the mold using a transfer bowl or other suitable device. Take care to minimize segregation of the mixture in the mold. After the mixture has been completely loaded into the mold place a paper disk on the mixture to avoid material adhering to the ram head or top mold plate. If necessary, place the top mold plate on top of the paper disk.

8. Load the compaction mold into the SGC and initiate the compaction process. In most SGCs, this is an automatic process consisting of pressing a key to start the compaction process. The compactor will apply a vertical pressure, induce the angle, and begin compaction. Compaction shall proceed to the desired endpoint—either a required number of gyrations (for determination of volumetric properties), or a specified height (for use in physical property testing).

9. At the end of the compaction process, remove the mold assembly from the SGC. After a suitable cooling period, extrude the compacted specimen from the mold, and remove the paper disks.

10. Place the extruded specimen on a flat surface in an area where it can cool, undisturbed, to room temperature.

VI. Experimental Work:

The Superpave gyratory compactor establishes three different gyration numbers:

1. $N_{initial}$. The number of gyrations used as a measure of mixture compatibility during construction. Mixes that compact too quickly (air voids at $N_{initial}$ are too low) may be tender during construction and unstable when subjected to traffic. Often, this is a good indication of aggregate quality – HMA with excess natural sand will frequently fail the $N_{initial}$ requirement. A mixture designed for greater than or equal to 3 million ESALs with 4 percent air voids at N_{design} should have at least 11 percent air voids at $N_{initial}$.

2. N_{design}. This is the design number of gyrations required to produce a sample with the same density as that expected in the field after the indicated amount of traffic. A mix with 4 percent air voids at N_{design} is desired in mix design.

3. N_{max}. The number of gyrations required to produce a laboratory density that should never be exceeded in the field. If the air voids at N_{max} are too low, then the field mixture may compact too much under traffic resulting in excessively low air voids and potential rutting. The air void content at N_{max} should never be below 2 percent air voids.

Typically, samples are compacted to N_{design} to establish the optimum asphalt binder content and then additional samples are compacted to N_{max} as a check. Previously, samples were compacted to N_{max} and then Ninitial and N_{design} were back calculated. Table 6 lists the specified number of gyrations for Ninitial, N_{design} and N_{max} while Table 7 shows the required densities as a percentage of theoretical maximum density (TMD) for Ninitial, N_{design} and N_{max}. Note that traffic loading numbers are based on the anticipated traffic level on the design lane over a 20-year period regardless of actual roadway design life

20-yr Traffic Loading (in millions of ESALs)	**Number of Gyrations**		
	$N_{initial}$	**N_{design}**	**N_{max}**
Less than 0.3	6	50	75
0.3 to < 3	7	75	115
3 to < 10*	8 (7)	100 (75)	160 (115)
10 to < 30	8	100	160
≥ 30	9	125	205
* When the estimated 20-year design traffic loading is between 3 and < 10 million ESALs, the agency may, at its discretion, specify Ninitial = 7, Ndesign = 75 and Nmax = 115.			

Experiment 10
Standard test method for determination of Asphalt Mix Specific gravity using asphalt Bulk Specific Gravity Device

I. Objective:

This test method covers the determination of bulk specific gravity and density of specimens of compacted bituminous mixtures. The results obtained from this test method can be used to determine the unit weight of compacted dense bituminous mixtures and in conjunction with Test Method D3203, to obtain percent air voids. These values in turn may be used in determining the relative degree of compaction. Since specific gravity has no units, it must be converted to density in order to do calculations that require units. This conversion is made by multiplying the specific gravity at a given temperature by the density of water at the same temperature.

II. Test Standard

ASTM: D2726 – 10 *"Standard Test Method for Bulk Specific Gravity and Density of Non-Absorptive Compacted Bituminous Mixtures."*

III. Theory:

Superpave mix design is a volumetric process; key properties are expressed in terms of volume. However, direct volume measurements are difficult, therefore weight measurements are usually made and then converted to a volume based on material specific gravities. Bulk specific gravity is involved in most key mix design calculations including air voids, VMA and, indirectly, VFA. Correct and accurate bulk specific gravity determinations are vital to proper mix design. An incorrect bulk specific gravity value will result in incorrectly calculated air voids, VMA, VFA and ultimately result in an incorrect mix design.

IV. Apparatus:

The main apparatus consists of the following:

1. Balance
2. Water Bath

V. Procedure:

Sampling: Specimens may be either laboratory-molded bituminous mixtures or from bituminous pavements. Pavement specimens shall be taken from pavements with a core drill.

Procedure:

Mass of Dry Specimen in Air: Determine the mass by weighing the specimen after it has been standing in air at room temperature for at least 1 h.

Mass of Specimen in Water: Completely submerge the specimen in the water bath at 25 ± 1°C (77± 1.8°F) for 3 to 5 min then determine the mass by weighing in water. Designate this mass as C. If the temperature of the specimen differs from the temperature of the water bath by more than 2°C (3.6°F), the specimen shall be immersed in the water bath for 10 to 15 min, instead of 3 to 5 min.

Mass of Saturated Surface-Dry Specimen in Air: Surface dry the specimen by blotting quickly with a damp cloth towel and then determine the mass by weighing in air.

VI. Experimental Work:

Calculation:

Calculate the bulk specific gravity of the specimen as follows:

$$\text{Bulk sp gr} = A/(B - C)$$

where:

A = mass of the dry specimen in air, g;

$(B - C)$ = mass of the volume of water for the volume of the specimen at 25°C;

B = mass of the saturated surface-dry specimen in air, g; and

C = mass of the specimen in water, g.

Calculate the density of the specimen as follows:

$$\text{Density} = \text{Bulk sp gr} \times 997.0 \text{ (or } 62.24)$$

where:

997.0 = density of water in kg/m^3 at 25°C (0.9970 g/cm^3)

Calculate the percent water absorbed by the specimen (on volume basis) as follows:

$$\text{Percent water absorbed by volume} = \frac{B - A}{B - C} \times 100$$

Typical values for bulk specific gravity range from 2.200 to 2.500 depending upon the bulk specific gravity of the aggregate, the asphalt binder content, and the amount of compaction.

Experiment 11
Standard test method for determination of Asphalt Mix Theoretical Maximum Specific Gravity

I. Objective:

The theoretical maximum specific gravity (Gmm) of a HMA mixture is the specific gravity excluding air voids. Thus, theoretically, if all the air voids were eliminated from an HMA sample, the combined specific gravity of the remaining aggregate and asphalt binder would be the theoretical maximum specific gravity. Theoretical maximum specific gravity can be multiplied by the density of water (62.4 lb/ft3 or 1000 g/L) to obtain a theoretical maximum density (TMD) or "Rice" density (named after James Rice, who developed the test procedure).

Theoretical maximum specific gravity is a critical HMA characteristic because it is used to calculate percent air voids in compacted HMA. This calculation is used both in Superpave mix design and determination of in-place air voids in the field. Theoretical maximum specific gravity is determined by taking a sample of loose HMA (i.e., not compacted), weighing it and then determining its volume by calculating the volume of water it displaces. Theoretical maximum specific gravity is then the sample weight divided by its volume.

II. Test Standard

AASHTO T 209 and ASTM D 2041: *"Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures."*

III. Theory:

The theoretical maximum specific gravity test is integral to Superpave mix design as well as field quality assurance. Theoretical maximum specific gravity is used along with bulk specific gravity values from field cores and laboratory compacted specimens to calculate air voids and the in-place air voids of a HMA pavement. It is also used to calculate the amount of asphalt absorbed in a HMA mixture (Vba) , which is then used in determining the effective asphalt content (Pbe). The basic premise of the maximum specific gravity is to divide the mass of the sample by the volume of the sample excluding the air voids. The mass is determined by measuring the dry mass of the sample either at the beginning of the test or after it has been dried at the end of the test. The volume is calculated by weighing the mass of the water displaced by the sample and dividing by the unit weight of water. As previously discussed, theoretical maximum specific gravity is needed to calculate air void content; therefore, it is involved in in-place air void determination during HMA pavement construction. In-place air void measurements are used as a measure of compaction. This is because compaction reduces the volume of air in HMA. Therefore, the characteristic of concern in compaction is the volume of air within the compacted HMA. This volume is typically quantified as a percentage of air voids

by volume and expressed as “percent air voids”. Percent air voids is calculated by comparing a test specimen’s bulk specific gravity (Gmb) with its theoretical maximum specific gravity (Gmm) and assuming the difference is due to air. Once Gmm is known, portable non-destructive devices can be used to measure HMA density in-place. The terms “percent air voids” and “density” are often used interchangeably. Although this is not wrong, since density is used to calculate percent air voids, the fundamental parameter of concern is always percent air voids.

IV. Apparatus:

The main apparatus consists of the following:

1. Vacuum Bowls
2. Vacuum Flask for Weighing in Air Only
3. Balance
4. Vacuum Pump
5. Mechanical Agitation Device

V. Procedure:

Test samples may be representative of a mixture prepared in the laboratory or in a HMA plant. The mixture should be loose and broken up so that the fine aggregate is separated into particles smaller than 0.25 inches (6.25 mm) taking care not to fracture aggregate.

1. Place a loose sample at room temperature into a vacuum container and record the dry mass. If Weighing in Water is chosen in step 5, glass, plastic or metal bowls as well as thick-walled flasks or vacuum desiccators are used. If Weighing in Air is chosen in step 5, flasks or pycnometers are used.
2. Completely cover the sample by adding water at approximately 77°F (25°C) to the container.
3. Remove entrapped air in the sample by applying a vacuum of 27.75 mm Hg (3.7 kPa) to the pycnometer or flask for 15 minutes. The container should be agitated continuously by mechanical means or shaken vigorously by hand every two minutes.
4. Slowly release the vacuum.
5. Weigh the sample in water or air:
6. Weighing in water. Suspend the container (which is filled with the sample and water) in a water bath at 77°F (25°C) for 10 minutes and record the mass.

7. Weighing in air. Fill the container completely with water at 77°F (25°C). Determine the mass of the completely filled container within 10 minutes of releasing the vacuum.

VI. Experimental Work:

A loose sample of either laboratory or plant produced HMA is weighed while dry (to determine its dry mass) and then a short procedure is used to determine the sample's volume. The theoretical maximum specific gravity is then the sample's mass divided by its volume.

Parameters Measure

Maximum specific gravity.

Specifications

There is no specification for theoretical maximum specific gravity, but it is used to calculate other specified parameters such as air voids (Va) in laboratory compacted mixtures and in-place density in the field.

Typical Values

Typical values for theoretical maximum specific gravity range from approximately 2.400 to 2.700 depending on the aggregate specific gravity and asphalt binder content. Unusually light or heavy aggregates may result in a value outside this typical range.

Calculate the Theoretical Maximum Specific Gravity of the specimen as follows:

$$Theoretical\ \ Maximum\ Specific\ \ Gravity = G_{mm} = \frac{A}{(A + D - E)}$$

Where:

A = sample mass in air (g)

D = mass of flask filled with water (g)

E = mass of flask and sample filled with water (g)

Experiment 12
Standard Method of Test for Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures

I. Objective:

This test measures the rutting and moisture susceptibility of an asphalt mixture specimen. A laboratory-compacted specimen of asphalt mixture, a saw-cut slab specimen, or a core taken from a compacted pavement is repetitively loaded using a reciprocating steel wheel. The specimen is submerged in a temperature-controlled water bath at a temperature specified by the agency. The deformation of the specimen, caused by the wheel loading, is measured. The impression is plotted as a function of the number of wheel passes. An abrupt increase in the rate of deformation may coincide with stripping of the asphalt binder from the aggregate in the asphalt mixture specimen.

II. Test Standard

AASHTO T 324-17 *"Hamburg Wheel-Track Testing of Compacted Asphalt Mixtures."*

III. Theory:

Laboratory wheel-tracking devices are used to run simulative tests that measure HMA qualities by rolling a small loaded wheel device repeatedly across a prepared HMA specimen. Performance of the test specimen is then correlated to actual in-service pavement performance. Laboratory wheel-tracking devices can be used to make rutting, fatigue, moisture susceptibility and stripping predictions. In general, these wheel tracking devices have potential for rut and other measurements but the individual user must be careful to establish laboratory conditions (e.g., load, number of wheel passes, temperature) that produce consistent and accurate correlations with field performance.

IV. Apparatus:

The main apparatus consists of the following:

1. Hamburg Wheel-Tracking Device
2. Balance
3. Ovens
4. Superpave Gyratory Compactor (SGC)
5. Bowls, spoon, spatula, etc.

V. Procedure:

Laboratory-Produced Asphalt Mixture:

Batch mixture proportions in accordance with the desired job mix formula. Use the mixing temperature at which the asphalt binder achieves a viscosity of 170 ± 20 cSt. For modified asphalt binders, use the mixing temperature recommended by the binder manufacturer. Dry-mix the aggregates and mineral admixture (if used) first, then add the correct percentage of asphalt binder. Mix the materials to coat all aggregates thoroughly. (Wet-mix the aggregates if using a lime slurry or other wet material.) Condition test samples at the appropriate compaction temperature in accordance with the shortterm conditioning procedure for mechanical properties. Use the compaction temperature at which the asphalt binder achieves a viscosity of 280 ± 30 cSt.

Compacting SGC Cylindrical Specimens—Compact two 150-mm (6-in.) diameter specimens in accordance with T 312. Specimen thickness must be at least twice the nominal maximum aggregate size, generally yielding a specimen 38 to 100 mm (1.5 to 4 in.) thick. Allow compacted specimens to cool at normal room temperature on a clean, flat surface until cool to the touch.

Cutting SGC Cylindrical Specimens and Field Cores—Cut specimens after they have cooled to room temperature using a wet or dry saw. Saw the specimens along equal secant lines (or chords) such that when joined together in the molds, there is no space between the cut edges. The amount of material sawed from the SGC cylindrical specimens may vary to achieve a gap width no greater than 7.5 mm (0.3 in.) between the molds.

SGC Cylindrical and Field Core Specimen Mounting—Rigidly mount the 150-mm [5.91-in.] or 152-mm [6-in.] diameter samples in the mounting tray using HDPE molds meeting the dimensions outlined in Figure 2 or use plaster of paris. For HDPE molds, place the molds in the mounting tray and insert the cut specimens in the molds. Shim the molds in the mounting tray as necessary. Secure the molds into the mounting tray. If plaster of paris is used, pour the plaster to a height equal to that of the specimen to fill the air space between the specimen and the sides of the mounting tray.

Place the mounting tray(s) with the test specimens into the device. Adjust the height of the specimen tray as recommended by the manufacturer, and secure by hand-tightening the bolts.

Turn the testing device and computer on.

Start the software used to communicate with the testing device.

Enter the pertinent project information and testing configuration requirements.

Select the test temperature based on the applicable specifications.

Select the maximum allowable rut depth based on the applicable specifications.

Select the maximum number of passes based on the applicable specifications.

Enter a start delay of 45 min to precondition the test specimens. The temperature of the specimens in the mounting tray will be the test temperature selected on completion of this preconditioning period.

The wheel-tracking device will stop when 20,000 passes have occurred, when some other predetermined number of passes has occurred, or when the test has achieved the maximum impression depth established in Section 8.6.2. The device will also disengage if the average LVDT displacement (read from the micro-control unit, not the screen) is 40.90 mm (1.6 in.) or greater for an individual specimen. Note that the screen readout subtracts the initial LVDT reading from the total displacement.

VI. Experimental Work:

For the purposes of this method, a "test" is defined as:

1. Two 320-mm (12.5-in.) long by 260-mm (10.25-in.) wide slab specimens, two 250-mm (10-in.) core specimens, or two 300-mm (12-in.) core specimens representing similar material run in the Hamburg Wheel-Tracking Device simultaneously; or

2. Four 150-mm (6-in.) diameter specimens grouped in pairs (1 and 1a) representing similar material run in the Hamburg Wheel-Tracking Device simultaneously.

The test results will be reported as the average value of either specimens (a) or both pairs of specimens. Plot the rut depth versus number of passes for each test. Figure 3 shows a typical plot of the output produced by the Hamburg Wheel-Tracking Device.