SUPERPAVE ASPHALT MIXTURE DESIGN ILLUSTRATED

LEVEL 1 LAB METHODS

NATIONAL ASPHALT TRAINING CENTER
DEMONSTRATION PROJECT 101

TECHNOLOGY
APPLICATIONS

Innovation Through Partnerships

Notice

1. Report No. FHWA-SA-94-004	2. Government Accession No.	3. Recipient's Catalog No.

4. Title and Subtitle SUPERPAVE Asphalt Mixture Design Illustrated Level 1 Lab Method S	5. Report Date November 1994
	6. Performing Organization Code
7. Author(s) R.M.Anderson, and R. B. McGennis	8. Performing Organization Report No.
9. Performing Organization Name and Address Asphalt Institute P.O. Box 14052 Lexington, KY 40512-4052	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. DTFH61-92-C-00098
12. Sponsoring Agency Name and Address Federal Highway Administration Office of Technology Applications 400 Seventh St., SW Washington, DC 20590	13. Type of Report and Period Covered Final Report December 1992-November 1994
	14. Sponsoring Agency Code HTA-21

15. Supplementary Notes

FHWA Technical Representative - J.R. Bukowski

16. Abstract

This manual provides sequential, illustrated steps for performing the SUPERPAVE test procedures on asphalt mixtures, level 1 design. It also serves as a self-contained laboratory reference document on those procedures. These tests and procedures represent the results of the SHRP 5 -year research effort to investigate and improve asphalt mix design technology. This manual was developed under the FHWA's National Asphalt Training Center

17. Key Words Asphalt mix, asphalt cement, gyratory compactor, indirect tensile tester, level 1 design, mixture design, shear tester, SHRP, SUPERPAVE.	18. Distribution Statement No restrictions. This document is available to the public from the National Technical Information Service, Springfield, Virginia 22161		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 62	22. Price

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FOREWORD

From October 1987 through March 1993, the Strategic Highway Research Program (SHRP) conducted a $50 million research effort to develop new ways to specify, test, and design asphalt materials. Near the end of SHRP, the Federal Highway Administration assumed a leadership role in the implementation of SHRP research. An integral part of FHWA's implementation strategy was a project to develop a nationally accessible training center aimed at educating both agency and industry personnel in the proper use and application of the final SHRP asphalt products collectively referred to as Superpave™. This project was administered by the FHWA's Office of Technology Applications and designated Demonstration Project 101, the National Asphalt Training Center (NATC).

The NATC resides at the Asphalt Institute's Research Center in Lexington, Kentucky. While the day-to-day affairs of the NATC are directed by Institute personnel, course development and technical direction were duties shared by a team of engineers and technologists from the Asphalt Institute, the Pennsylvania State University, the University of Texas at Austin, the National Center for Asphalt Technology, Marathon Oil Company, and FHWA.

The objective of the educational program is to train students in the practical applications of SHRP asphalt products. It is composed of two parts: Superpave asphalt binder technology and Superpave asphalt mixture design and analysis. The purpose of this manual is to provide a laboratory instructional reference that will be used by students at the Center as they are instructed in Superpave Level 1 mixture design. This instruction occurs principally in the NATC laboratories. The manual is written for technicians and engineers with no previous training in Superpave, but with some knowledge in asphalt materials and mix design. Other instructional aids at the Center include student texts that are used in the classroom portion of training.

Included in Appendix A of this manual is a set of AASHTO Provisional Standards. While this manual provides an illustrated overview of these test methods but it is not intended to replace them. The AASHTO Standards provide detailed information pertaining to all aspects of the tests and form the most important tool in properly performing testing.

The illustrated procedures contained in this manual should be used with great caution. It was developed during the last stages of SHRP and in the first few months following SHRP's completion. While the test procedures were largely complete by this time, specific details of the procedures were (and still are) changing. The steps outlined in this manual follow, as closely as possible, the procedures outlined in the standards contained in Appendix A. *Users of the manual are strongly encouraged obtain the latest versions of the AASHTO test procedures as the most up-to-date reference.*

Because this manual was prepared for use at the National Asphalt Training Center, it is written around the testing equipment and related items used for training at the Center. Users should be aware that future developments in test equipment, etc. may conflict with information in this manual. In such cases, users should implicitly follow operational guides and instructions from the equipment manufacturers along with the most current AASHTO standards.

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November 1994
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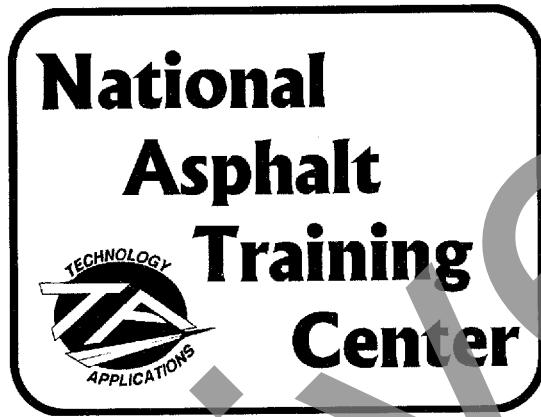# TABLE OF CONTENTS

National Asphalt Training Center

TECHNOLOGY APPLICATIONS

Superpave Gyratory Compactor

Test Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the SUPERPAVE™ Gyratory Compactor

This document outlines the basic steps in preparing loose HMA test specimens according to AASHTO Provisional Method TP4, Edition 1B (September 1993). It provides an illustrated overview but is not intended to replace the standard test method which contain detailed information pertaining to all aspects of the test.

1. This procedure outlines preparation of HMA test specimens using the Superpave Gyratory Compactor (SGC). It includes guidelines for mixing as well as compacting test specimens. The SGC consists of a compactor, specimen molds, and ram heads and mold bottoms. Test specimens are comprised of HMA that has been short term aged for 4 hours at 135° C. Two Superpave gyratory compactors are shown in Figure 1.

2. Various sample sizes are used, depending on their final disposition. For compacted specimens that will be used in Superpave Level 1, the specimen size is 150 mm diameter by 115 mm height, which requires approximately 4700 g of aggregate. One other sample should be prepared and remains uncompacted. It is used for determination of maximum theoretical specific gravity by AASHTO T 209. Its size varies according to aggregate size and ranges from 1000 to 2500 grams. Moisture damage testing using AASHTO T283 requires specimen height of 95 mm or about 3700 g of aggregate. If samples are being prepared for performance testing, the specimen height is 135 mm, which requires approximately 5500 g of aggregate.)
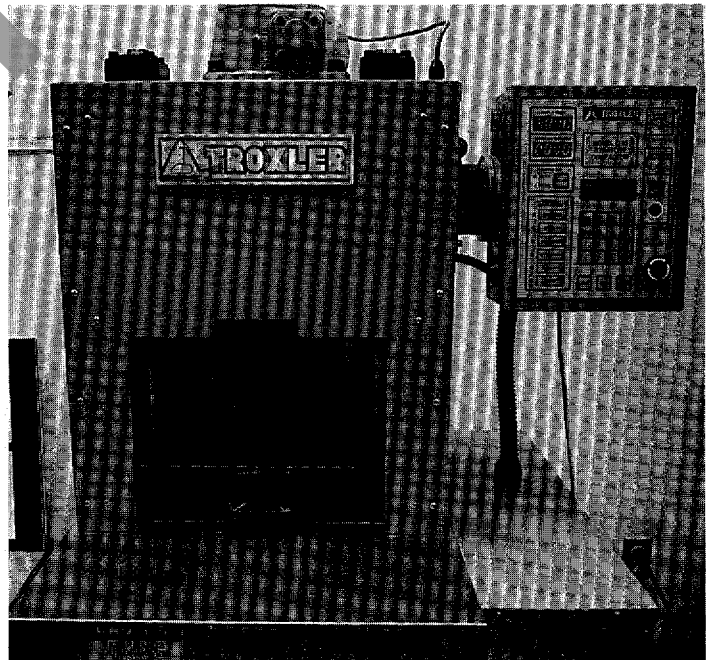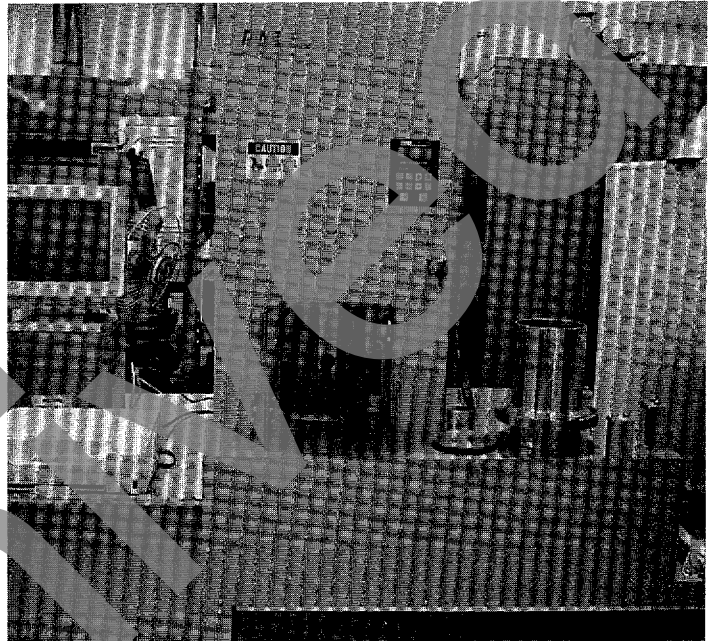
Figure 1. Superpave Gyratory Compactors

3. Determine the equiviscous mixing and compaction temperatures using a plot of viscosity versus temperature (Figure 2). Viscosity is measured by any convenient method such as ASTM D 4402. To construct this chart. Determine the viscosity at two temperatures such as 135° and 165° C. Select mixing and compaction temperatures to provide binder viscosities of 0.17 Pa·s (± 0.02 Pa·s) and 0.28 Pa·s (± 0.03 Pa·s), respectively. Note that this approach was developed for unmodified asphalts. If a modified asphalt is to be used, the asphalt manufacturer should be consulted for the proper mixing and compaction temperatures.
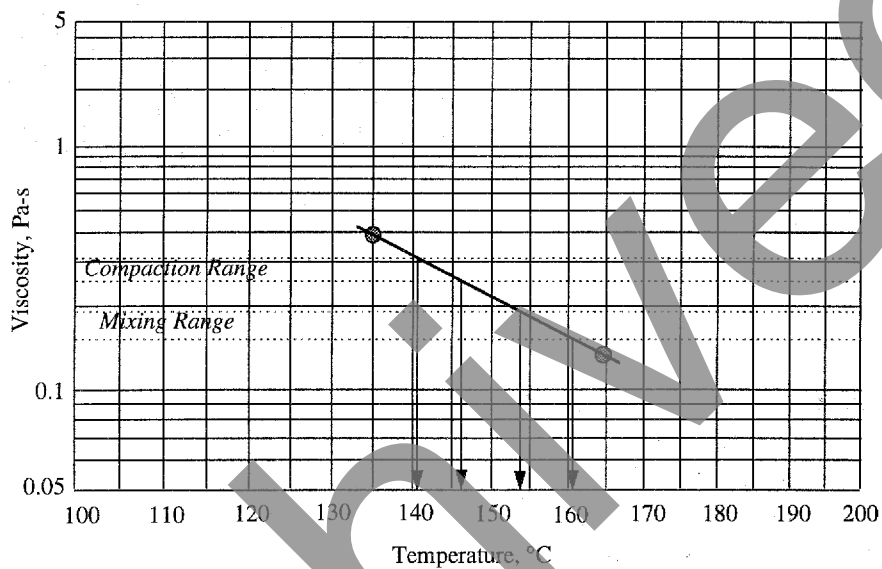

Figure 2. Temperature-Viscosity Chart

4. Prepare a batching sheet showing component aggregate and asphalt binder batching weights. Weigh into a pan the proper weights of each aggregate component (Figure 3).

Figure 3. Batching Aggregate

5. Place the pan containing aggregate in an oven at approximately 15° C higher than the established mixing temperature (Figure 4). Two to four hours are required for the aggregate to equilibrate at the selected temperature. While aggregate is heating, heat all mixing implements such as spatulas, mixing bowl, and other tools.

Figure 4. Aggregate in Oven

6. Before mixing, heat the asphalt binder to the desired mixing temperature. This time that needs to be allowed for this step varies depending on the size of binder sample and method of heating.

7. Before mixing, equilibrate a forced draft oven to 135° C, which will be used to short term age the test specimens immediately after mixing.

8. Place the hot mixing bowl on a scale. Zero the scale. Charge the mixing bowl with the heated aggregate. Use a short dry mixing period (e.g., 5 seconds) if necessary. Form a crater in the blended aggregate. If necessary, add or subtract small amounts of minus 2.36 mm material to achieve the proper batch weight and zero the scale. Pour sufficient asphalt (Figure 5) into the crater to achieve the desired batch weight.
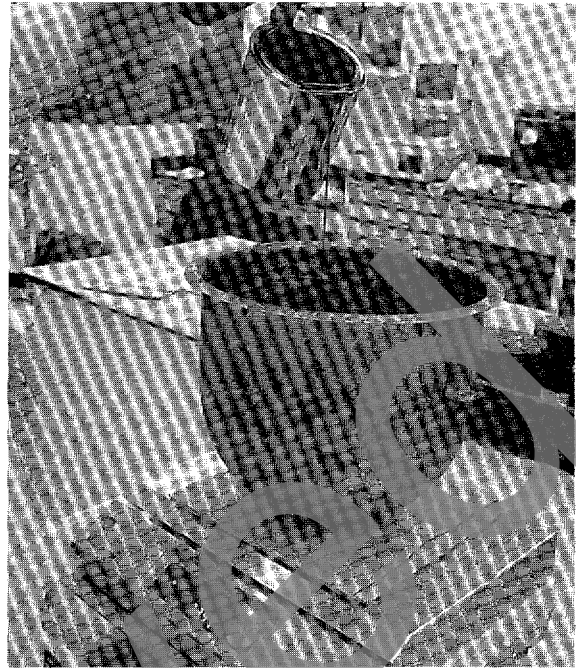

Figure 5. Pouring Hot Asphalt

9. Remove the mixing bowl from the scale and mix using a mechanical mixer or other suitable device (Figure 6). Mix the specimen until the aggregate is thoroughly coated (typically 60 - 90 seconds).
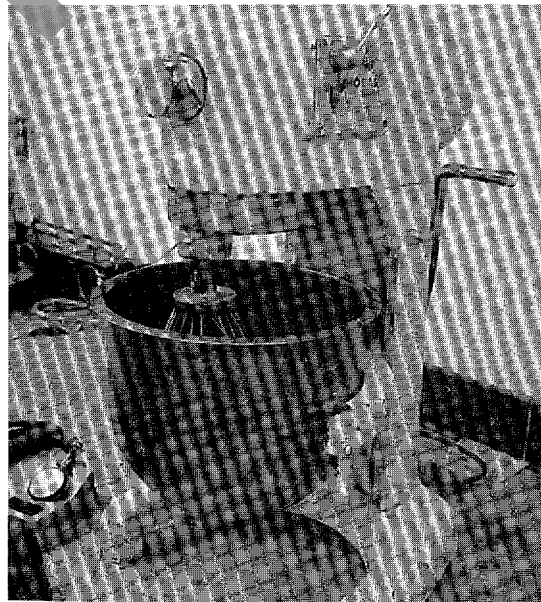

Figure 6. Mechanical Mixer

10. Place the mix in a flat shallow pan (Figure 7). The thickness of the loose mix in the pan should result in a spread rate of 21 to 22 kg/m^2. Place the pan in the forced draft oven at 135° C. Allow the specimen to short term age for 4 hours. During this period, the mixture should be stirred every hour.

Figure 7. Short Term Aging of Mixed Specimen

11. Repeat this procedure until the desired number of specimens are secured. A time interval of approximately 20 minutes should be used between mixing each specimen to allow for proper timing of gyratory compaction steps.

12. If specimens are to be used for compaction, proceed with compaction at the end of the short term aging period.

13. Alternatively, if mixture is to be used to determine maximum theoretical specific gravity, proceed at the end of the short term aging period using AASHTO T 209 (Figure 8).
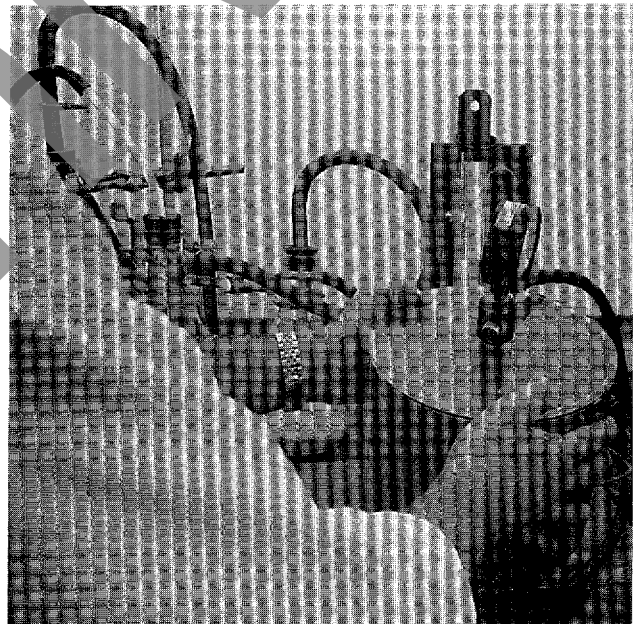

Figure 8. Maximum Theoretical Specific Gravity Apparatus

14. While mixture specimens are short term aging, prepare the compactor. Turn on the power to the compactor. Verify that the data acquisition device (either a computer or RS232 serial port) is functioning. Verify that the compaction pressure is set at the proper value, 600 kPa. Zero the revolution counter and set the desired number of gyrations ($N_{maximum}$). If necessary, verify that the angle and speed of gyration are set to their proper values, $1.25° \pm 0.02°$ and 30 rpm, respectively (Figures 9 and 10).
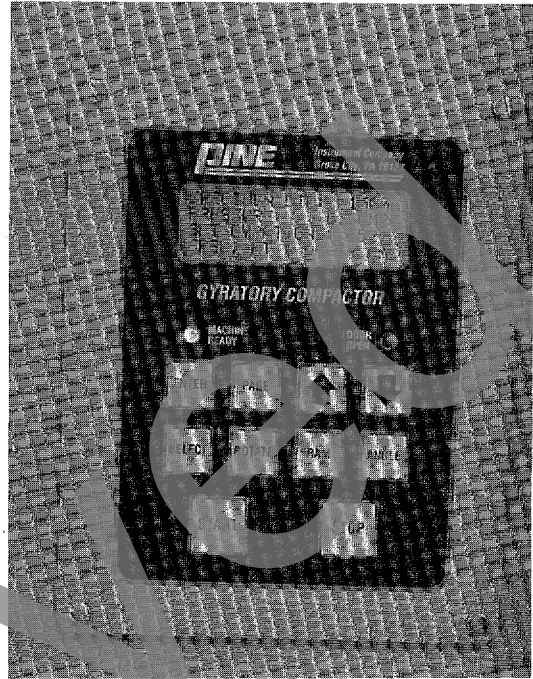

Figure 9. Preparation of the SGC
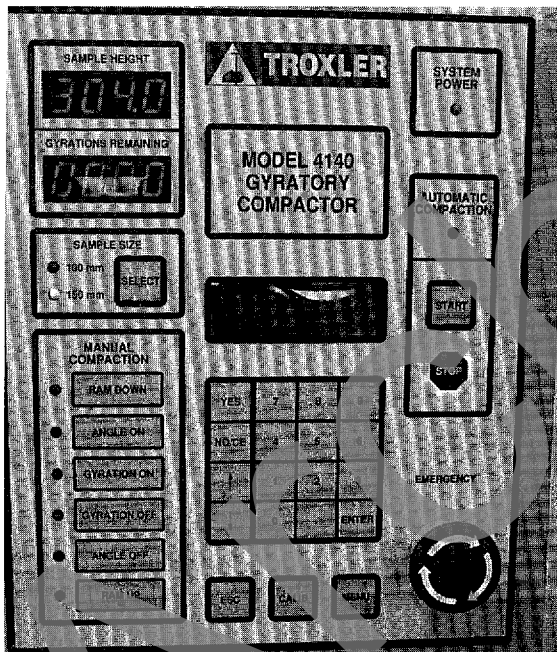
Figure 10. Preparation of the SGC

15. Approximately 30 minutes before compaction of the first specimen, place the compaction molds and base/top plates in a forced draft oven at the equiviscous compaction temperature (Figure 11).
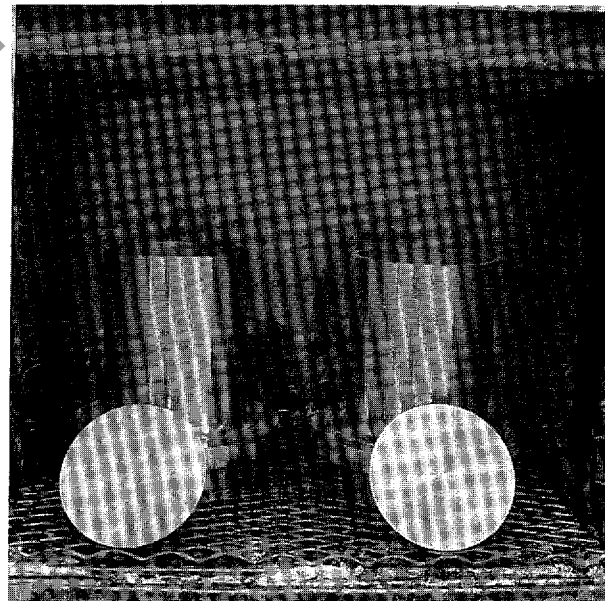
Figure 11. Molds and Plates in Oven

16. At the end of the short term aging period, remove the mixture from the oven and equilibrate the mixture at the proper compaction temperature. If the compaction temperature is greater than 135° C, place the mixture in another oven (Figure 12) until it reaches the desired compaction temperature but for no longer than 30 minutes. If the compaction temperature is less than 135° C, place the mixture on a counter top until the temperature reaches the desired compaction temperature.

Figure 12. Equilibration of Loose Specimen to Compaction Temperature

17. Remove a mold and base plate from the oven. Place the base plate in the mold. Place a paper disk on top of the base plate (Figure 13).

Figure 13. Inserting Paper Disk

18. Place the short term aged mixture, at the proper compaction temperature, in the mold (Figure 14). Slightly round the top of the mixture (Figure 15). Place a paper disk on top of the material. If required, place a top plate on top of the paper disk.

Figure 14. Loading Mold with Mixture
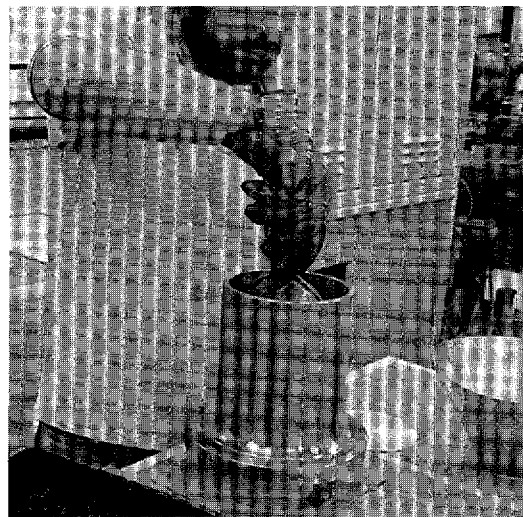
Figure 15. Rounding the Top of the Mixture

19. Load the mold containing the specimen into the compactor (Figure 16). During this step, handle the mold and base plate so that the base plate remains in the bottom of the mold. If required by the compactor manufacturer, at the start of the compaction procedure, lightly oil bearing surfaces as needed.

Figure 16. Loading Mold Containing Mixture Into the SGC

20. Center the mold under the loading ram and actuate the ram loading system so that the ram extends down into the mold cylinder and contacts the specimen. The ram will cease moving when the specimen offers 600 kPa of resisting pressure (Figure 17).
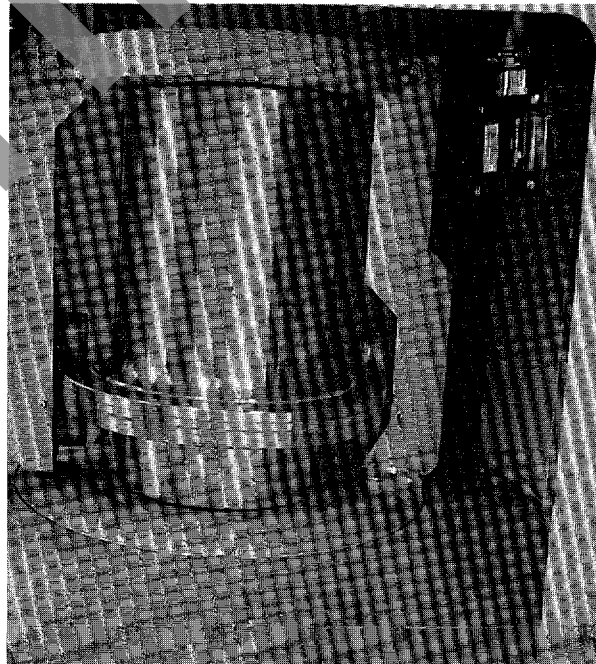
Figure 17. Mold Containing Mixture in Compactor (Angle Applied)

21. Apply the proper angle of gyration (1.25°) and start the compaction process. In Figure 18, the compaction angle is set using the keypad controls. Compaction will proceed until the set number of gyrations has been reached. During compaction, the ram loading system will continue updating ram position so that the ram pressure remains constant at 600 kPa. Specimen height during compaction is continually monitored by a transducer. Once per revolution, the transducer sends a height measurement to the data acquisition device, either a printer or personal computer.

Figure 18. Application of the SGC Compaction Angle (1.25°)

22. After $N_{maximum}$ the compactor will cease compacting. Release the angle of gyration and raise the loading ram.

23. Remove the mold containing the compacted specimen from the compactor and extrude the specimen from the mold using a suitable extruder (Figure 19). If necessary, a 5 minute cooling period is allowable to facilitate specimen removal from the mold without undue distortion.
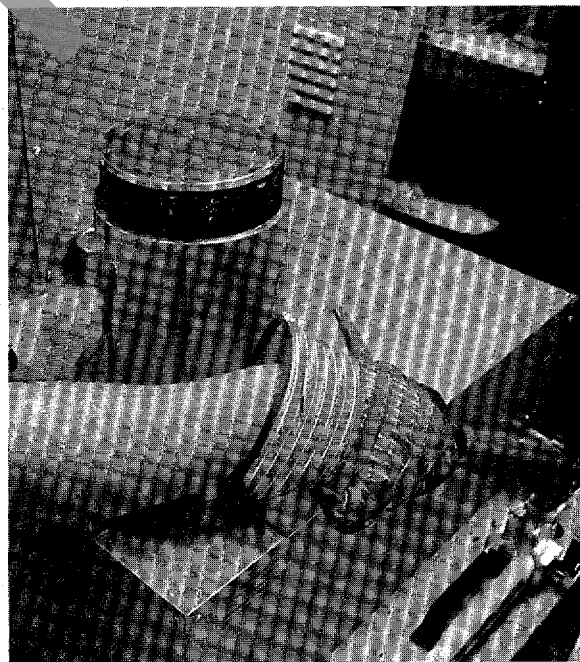
Figure 19. Specimen Extrusion

24. Remove paper disks from the top and bottom of the specimen (Figure 20). Place the specimen on a countertop where it will not be disturbed during cooling.

Figure 20. Removal of Paper Disks

25. Place the mold and base plate back in the oven at the compaction temperature for at least 5 minutes. This period allows the mold to regain the proper compaction temperature prior to reuse. Additional molds will preclude this step.

26. Repeat this procedure for each specimen. Specimens should be identified with a suitable marker (Figure 21).
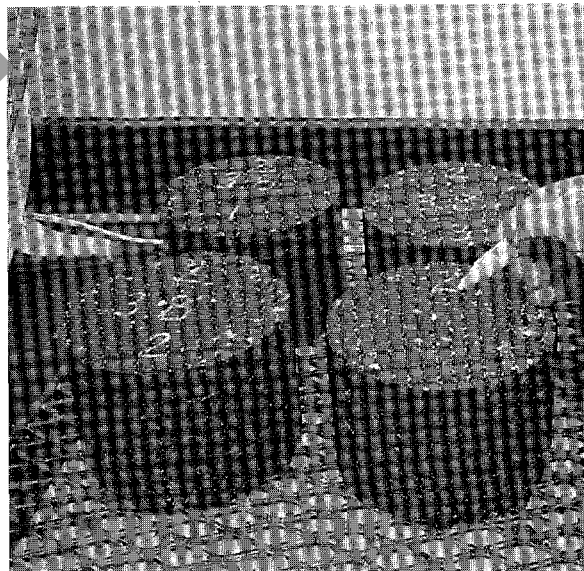
Figure 21. Identification of Specimens

27. Calibration items include: angle of gyration, ram pressure, speed of gyration, and height transducer. Compactors are furnished with a calibration kit that includes the necessary equipment and procedures to accomplish this task. Oven temperature calibration is also necessary.
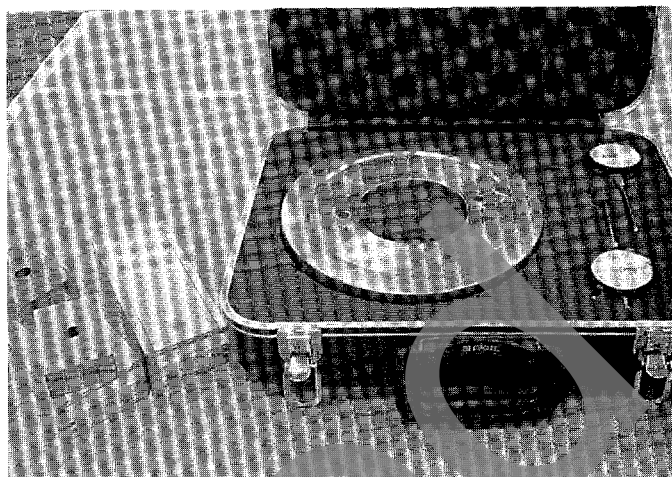
Figure 22. SGC Calibration Items

28. Data gathered during compaction by the SGC includes specimen height after each gyration. This is used to compute estimated specimen bulk specific gravity (G_{mb}). Data reduction is accomplished by either the Superpave software or by the operator manually inputting specimen height values into a computer spreadsheet, which in turn, reduces the data.
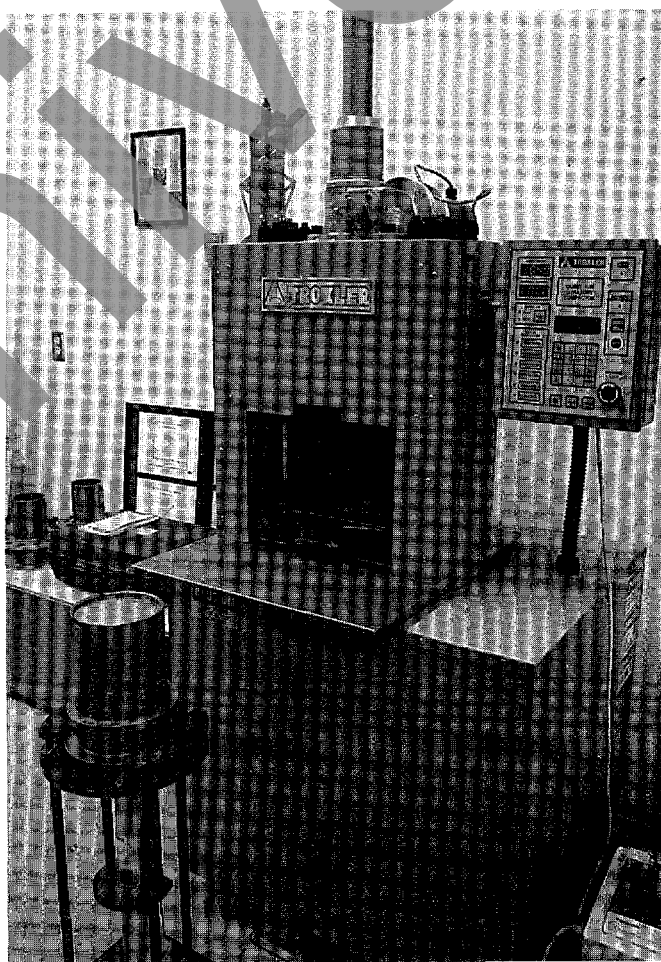
Figure 23. Superpave Gyratory Compactor

National Asphalt Training Center
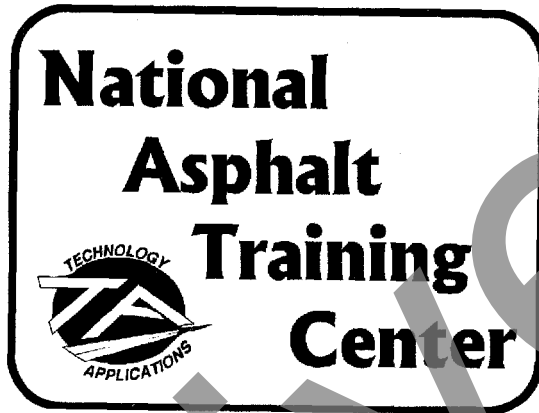
Rotational Viscometer

Test Method for Measuring Viscosity of Asphalt Binders Using a Rotational Coaxial Cylinder Viscometer

This document outlines the basic steps in measuring the viscosity of asphalt binders using a rotational coaxial cylinder viscometer according to procedures outlined by ASTM D 4402. It provides an illustrated overview, but it is not intended to replace the standard test method which contains detailed information pertaining to all aspects of the test. This overview assumes that the operator is using a Brookfield (or similar) Viscometer (DV-II+) with a Thermosel™ temperature control system.

1. This procedure outlines determination of high temperature viscosity of asphalt binders. The apparatus consists of a rotational coaxial cylinder viscometer (Figure 1) and a unit to control temperature (Figure 2). The test is performed on unaged binders.
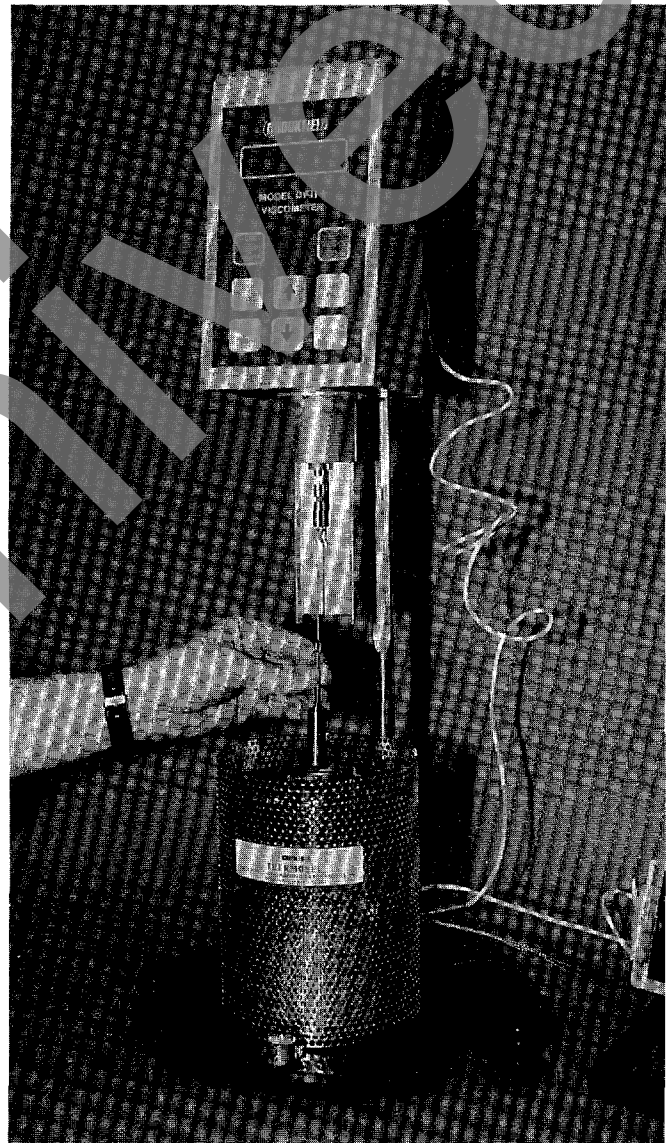
Figure 1. Rotational Viscometer with Spindle Attached

2. Turn on the Thermosel™ (Figure 2). Set the desired test temperature, usually 135 ° C, on the Thermosel controller by holding the set button and turning the set point knob until the digital display reads the proper temperature.

3. Place the sample chamber into the sample chamber holder and then both into an oven at 135° C. In the same oven, place a "3-ounce" container containing the asphalt sample. Also place the spindle in the oven.

4. Turn on the viscometer and remove spindle if necessary. Level the viscometer and thermo container using the bubble indicators on each device.

Figure 2. Temperature Control System (background is thermo-container and controller; foreground is insulating cap, spindle, sample chamber, and extraction tool)

5. By using the keypad on the front of the viscometer (Figure 3), push the "Select Spindle" button and press arrow keys until the proper spindle number is displayed. For most unmodified asphalts, spindle nos. 21 and 27 are used. For soft asphalts or modified asphalts, consult the Thermosel system operator's manual for the proper spindle. The spindle used is determined by the anticipated viscosity of the fluid being tested.

Figure 3. Viscometer Keypad

6. When the digital display on the thermosel indicates the desired temperature has been reached, remove the sample chamber still in its holder from the oven and place both on a scale accurate to the nearest 0.1 g. Tare the scale.
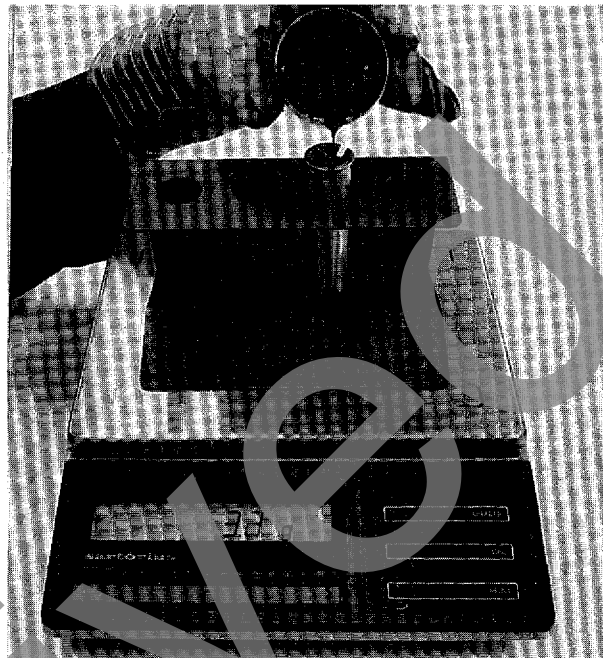
Figure 4. Pouring Sample Into Chamber

7. Pour the required amount of asphalt binder in to the sample chamber (Figure 4). The amount of asphalt used depends on the spindle size. For spindle no. 27, 10.5 ml of asphalt is the correct amount to be loaded into the sample chamber. Consult the operator's manual for the proper sample size for other spindles.

8. Using the extraction tool, remove the sample chamber containing the hot sample from the chamber holder and place it in the thermo-container (Figure 5).
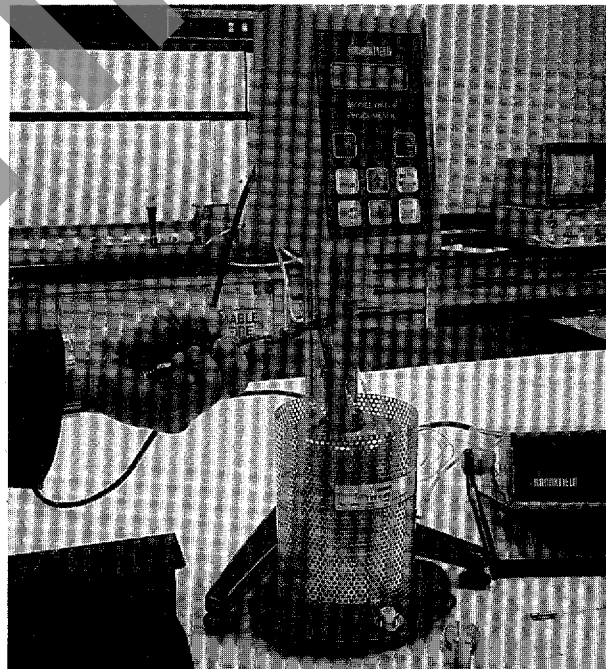
Figure 5. Placing Sample Chamber in Thermo-Container

9. Align the thermo container with the viscometer. To accomplish this, lower the viscometer by turning the height adjustment knob until the alignment bracket makes contact with the rear vertical face and horizontal face of the locating ring on the thermo-container (Figure 6). From this position, raise the viscometer approximately 1.5 mm. Since this is such a critical measurement, a reference point should be marked on the rear vertical face of locating ring to facilitate precise vertical positioning.
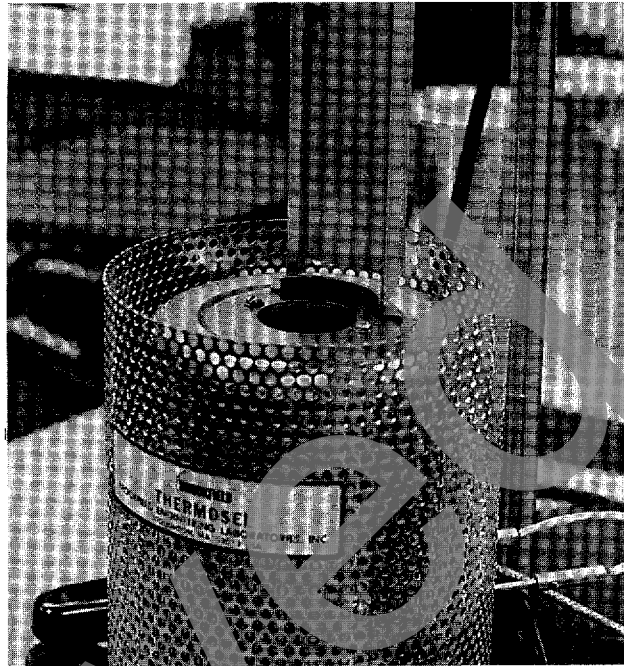
Figure 6. Alignment Bracket and Locating Ring

10. Remove the spindle from the oven and attach it to the spindle extension (Figure 7). The spindle extension is a stiff wire with a loop on one end and a female coupling on the other. To attach the spindle, simply insert the loop through the small hole in the top of the spindle.
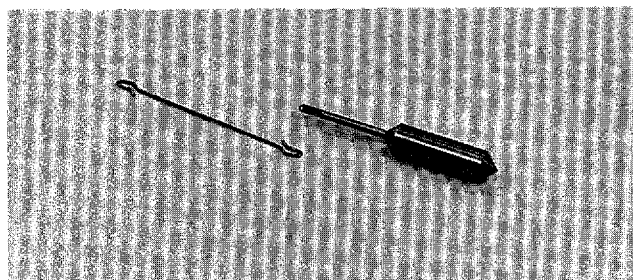
Figure 7. Spindle and Extension

11. Gently lower the spindle into the sample chamber containing the hot sample. Lower it enough so that the female coupling on the end of the spindle extension can be screwed onto the male viscometer coupling nut (Figure 8).

Figure 8. Attaching Spindle Extension with Viscometer Coupling Nut
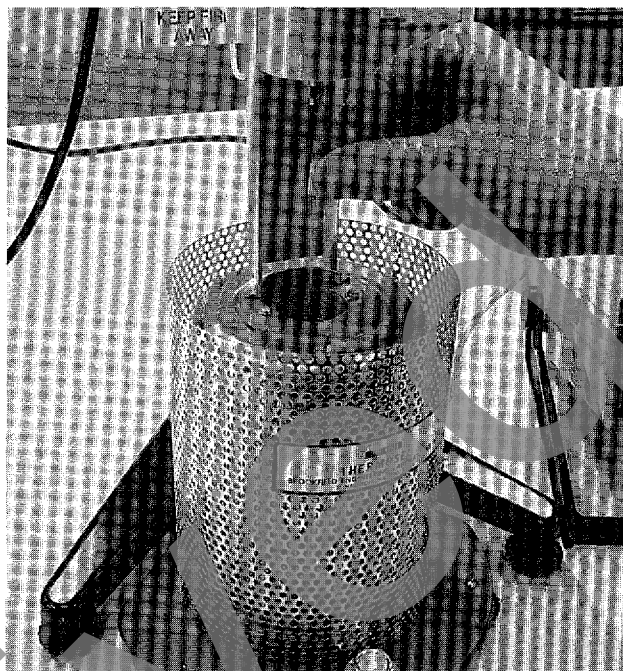
12. Place the insulating cap over the opening in the thermo container (Figure 9). Equilibrate the sample temperature for a period of approximately 30 minutes. During this period, occasionally observe the digital temperature display on the controller to verify that the temperature is rising toward the test temperature.
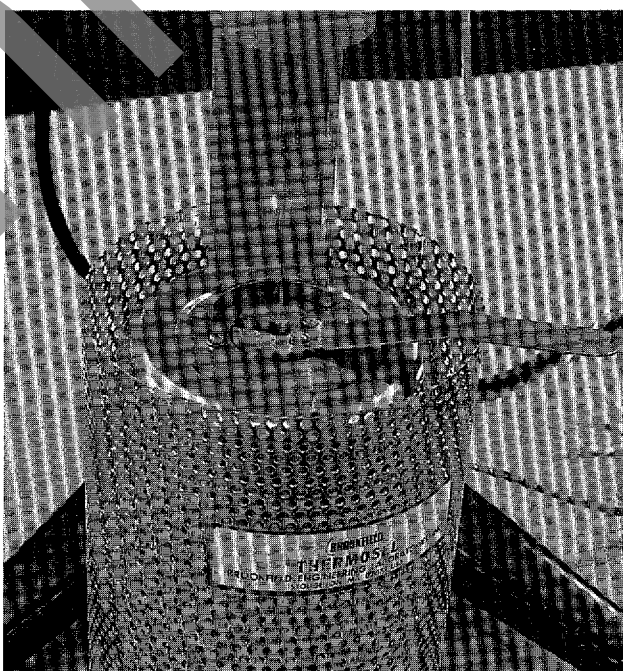
Figure 9. Insulating Cap on Thermo-Container

13. Set the viscometer motor speed by pressing the "Speed" key on the viscometer keypad (Figure 10). Use the arrow keys to set the desired testing speed, 20 rpm. For relatively soft binders, the speed may need to be increased in order to increase the viscometer torque value so that it is within the acceptable range of 2 to 98 percent torque.

14. Set the display to read viscosity by pressing the "Set Display" key until viscosity in centipoises (cP) is shown in the upper left corner of the display. During the equilibration period, observe the viscosity. The viscosity will normally decrease as the temperature of the sample rises. When the viscosity reading remains constant, the temperature is considered equilibrated.

Figure 10. Viscometer Keypad

15. Read and record a viscosity value at one-minute intervals for a total of three readings. The viscosity measurements are in units of centipoises (cP). Convert cP to Pascal·seconds (Pa·s) by dividing cP by 1000.

16. The following items should be reported:

- test temperature,
- spindle number,
- spindle speed, rpm, and
- viscosity, Pa·s, nearest 0.1 Pa·s.

17. Total time, including sample and equipment preparation, to perform this procedure should be less than an hour for a skilled operator.

18. To clean the sample chamber, remove it from the thermo-container using the extraction tool and discard the sample. Allow the hot sample chamber to cool about 5 minutes. Clean the sample chamber using mineral spirits or other suitable solvent. The sample chamber should be wiped with a clean cloth so that no solvent residue remains. Acetone is effective in removing solvent residue.
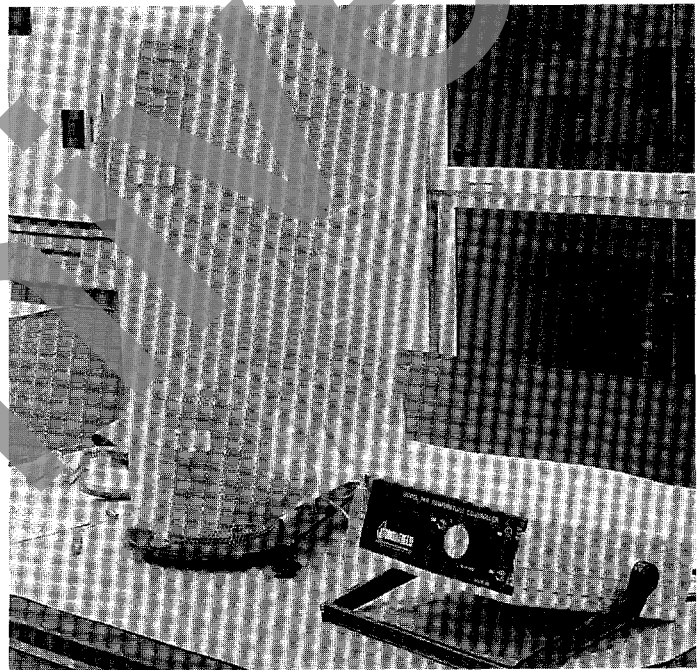
Figure 11. Rotational Viscometer

APPENDIX A

National Asphalt Training Center
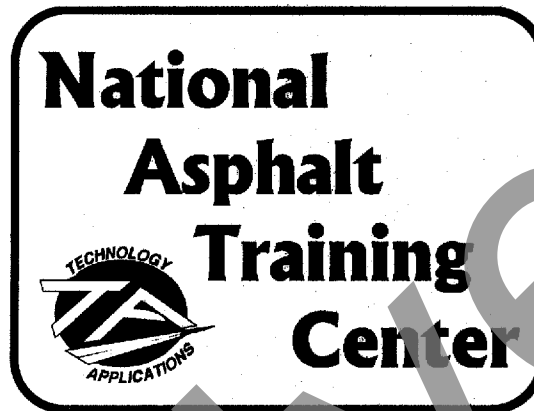
AASHTO Provisional Standards

Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyratory Compactor (TP4)

Volumetric Analysis of Compacted Hot Mix Asphalt (PP19)

Standard Practice for Short and Long Term Aging of Hot Mix Asphalt (HMA) (PP2)

Determining the Maximum Specific Gravity of Bituminous Paving Mixtures (TP39)

AASHTO Provisional Standard

Standard Method for Preparing and Determining
the Density of Hot Mix Asphalt (HMA) Specimens
by Means of the SHRP Gyratory Compactor

AASHTO Designation: TP4
Edition 1B

September 1993

*This is Edition 1B of the provisional standard (PS) based on the
technical substance provided by the Strategic Highway Research
Program (SHRP) researchers. The PS was collated and
formatted jointly by the AASHTO and SHRP Staffs.*

*This PS is being referred to the AASHTO Subcommittee on
Materials (SCOM) for a review, ballot and approval. If the
approval process produces changes, an amended version of the
PS shall be published as the second edition.*

AMERICAN ASSOCIATION OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
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Standard Method for Preparing and
Determining the Density of Hot Mix Asphalt (HMA)
Specimens by Means of the SHRP Gyratory Compactor

AASHTO Designation: TP4[1]

1. Scope

1.1 This standard covers the compaction of 150 mm diameter test specimens of hot mix asphalt (HMA) using the SHRP gyratory compactor. It also covers the monitoring of specimen density during compaction.

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

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

2. Referenced Documents

2.1 AASHTO Standards:

M231   Specification for Standard Masses and Balances Used in the Testing of Highway Materials

PP20   Short and Long Term Aging of Modified and Unmodified Bituminous Mixtures

T166   Bulk Specific Gravity of Compacted Bituminous Mixtures

T209   Maximum Specific Gravity of Bituminous Paving Mixtures

2.2 ASTM Standards:

D4402   Method of Viscosity Determinations of Unfilled Asphalt Using the Brookfield Thermosel Apparatus

3. Significance and Use

3.1 This standard is used to prepare specimens for determining the mechanical properties of HMA. The specimens simulate the density, aggregate orientation,

and structural characteristics obtained in the actual roadway when proper construction procedure is used in the placement of the paving mix.

3.2 This test method may be used to monitor the density of test specimens during their preparation as described in the SUPERPAVE™ Pavement Design Manual. It may also be used for field control of an HMA production process.

> Note 1 -- It is expected that the density of every specimen after gyration number 10 will approach a straight line when plotted versus the base 10 logarithm of the number of gyrations. The line will become asymptotic as it approaches 100 percent of the theoretical maximum specific gravity.

4. Apparatus

4.1 Gyratory Compactor - An electrohydraulic compactor, as shown in Figure 1, with a ram and ram heads as described in Section 4.3 that are restrained from revolving during compaction. The axis of the ram shall be perpendicular to the platen of the compactor. The ram shall apply and maintain a pressure of 600 ± 18 kPa to a specimen cross section with a diameter of 150 mm. (Note 2) The compactor shall tilt specimen molds at an angle of 22 ± 0.35 mrad (1.25 ± 0.02 degrees) and gyrate specimen molds at a rate of 30.0 ± 0.5 gyrations per minute throughout compaction. The compactor shall be designed to permit a 150 mm diameter mold to revolve freely on its tilted axis during gyration.

> Note 2 -- This stress calculates to 10600 ± 320 N total force for 150 mm specimens.

4.1.1 Specimen Height Measurement and Recording Device - When specimen density is to be monitored during compaction, a means shall be provided to continuously measure and record the height of the specimen to the nearest 0.05 mm during compaction once per gyration.

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[1]This standard is based on SHRP Product 1014.

4.1.2 Computer and Software (Optional) - An IBM compatible PC with hard drive, floppy disk drive, and RS232C serial port and software with capabilities that include establishing specimen header information; receiving and recording height of specimen data once per gyration; and subsequently preparing the test report described in Section 11.

4.2 Specimen Molds - Specimen Molds shall have steel walls that are at least 8.5 mm thick and are hardened to at least Rockwell C 48. The inside finish of the molds shall have a root mean square (rms) of 0.40 μm or smoother.(Note 3) Molds shall have an inside diameter of 149.90 to 150.00 mm and be at least 250 mm high.

> Note 3 -- Smoothness measurement is in accordance with ANSI B 46.1. One source of supply for a surface comparator, which is used to verify the rms value of 0.40 μm, is GAR Electroforming, Danbury, Connecticut.

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

4.4 Thermometers - Armored, glass, or dial-type thermometers with metal stems for determining temperature of aggregates, asphalt and asphalt mixtures between 10°C to 232°C.

4.5 Balance - A balance meeting the requirements of M231, Class G5 for determining the mass of aggregates and asphalt.

4.6 Oven - An oven, thermostatically controlled to ± 3°C, for heating aggregates, asphalt, and equipment as required. The oven shall be capable of maintaining the temperature required for short term aging in accordance with PP20.

4.7 Miscellaneous - flat bottom metal pans for heating aggregates - scoop for batching aggregates - containers, gill-type tins, beakers, containers for heating asphalt - large mixing spoon or small trowel - large spatula - welders gloves for handling hot equipment - paper disks, 150 mm diameter - light lubricating oil - mechanical mixer (optional)

5. Hazards - Use standard safety precautions and protective clothing when handling hot paving mix and preparing test specimens.

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

7. Preparation of Apparatus

7.1 Immediately prior to the time when the paving mix is ready for placement in the mold, turn on the main power on the compactor.

7.2 Without a specimen in the compaction apparatus, set the vertical pressure to 600 ± 18 kPa.

7.3 Verify that the automatic counter is reset and is set to shut off when the proper number of gyrations has been reached.

> Note 4 -- The required number of gyrations is obtained from the procedures described in the SUPERPAVE™ Pavement Design Manual.

7.4 Lightly oil the surface of the rotating base along with the surface of the four rollers.

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

8. Compaction Procedure

8.1 Weigh cumulatively into a separate pan for each test specimen the quantity of each size fraction of aggregate required to produce a batch that will result in a compacted specimen 150 mm in diameter and 100 ± 1 mm in height. This will normally require approximately 4000 g of aggregate. It is generally desirable to prepare a trial specimen prior to preparing all the aggregate batches. If the trial specimen height falls outside of the desired range, adjust the amount of material used for the specimens accordingly.

8.2 Place the pans and the asphalt binder container in the oven and heat to the required mixing temperature.

8.2.1 The mixing temperature range is defined as the range of temperatures where the unaged asphalt binder has a kinematic viscosity of 170 ± 20 mm^2/s (approximately 0.17 ± 0.02 Pa·s for an asphalt binder density of 1.000 g/cm^3) measured in accordance with ASTM D4402.

> Note 5 -- The SI unit of kinematic viscosity is m^2/s; for practical use, the submultiple mm^2/s is recommended. The more familiar centistoke is a *cgs* unit of kinematic viscosity; it is equal to 1 mm^2/s. The kinematic viscosity is the ratio of the viscosity of the asphalt binder to its density. For an asphalt binder with a density equal to 1.000 g/cm^3, a kinematic viscosity of 170 mm^2/s is equivalent to a viscosity of 0.17 Pa·s measured in accordance with ASTM D4402.

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

8.4 Discard any asphalt binder held at mixing temperature for more than 1 hour.

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

8.6 After completing the mixture preparation, place the loose mix in a shallow, flat pan and short-term age it in accordance with PP20.

8.7 Place a compaction mold and base plate in a 150°C oven for 45 to 60 minutes prior to the estimated beginning of the compaction (during the time the mixture is being conditioned in accordance with PP20).

8.8 After the 4 hour conditioning period specified in PP20, remove the pan of paving mix from the oven and allow it to achieve the proper compaction temperature. Stir frequently to assure temperature uniformity.

8.8.1 The compaction temperature range is defined as the range of temperatures where the unaged asphalt binder has a kinematic viscosity of 280 ± 30 mm^2/s (approximately 0.28 ± 0.03 Pa·s) measured in accordance with ASTM D4402.

8.9 If the compaction temperature is greater than 135°C, place the mix in another oven for a brief time (maximum of 30 minutes) to achieve the required temperature.

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

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

8.12 Place the mixture into the mold in one lift. Care souldl be taken to avoid segration in the mold. After all the mix is in the mold, level the mix and place another paper disk on top of the leveled material.

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

8.14 Lower the ram until the pressure on the specimen reaches 600 kPa ± 18 kPa.

8.15 Apply a 22.0 ± 0.35 mrad ($1.25 \pm 0.02°$) angle tilt to the mold assembly and begin the gyratory compaction.

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

8.17 Remove the angle from the mold assembly, raise the loading ram, remove the mold from the compactor, and extrude the specimen from the mold.

Note 6 -- This can be accomplished immediately for most HMA paving mixes. For lean, rich, or tender mixtures, a cooling period of 5 to 10 minutes in front of a fan may be necessary before extruding the specimen.

8.18 Remove the paper disks from the top and bottom of the specimens.

Note 7 -- Before reusing the mold, place it in an oven for at least 5 minutes. The use of multiple molds will speed up the compaction process.

Note 8 -- The extruded specimen is not a right angle cylinder. Specimen ends may need to be sawed to conform to the requirements of specific tests.

9. Density Procedure

9.1 When the specimen density is to be monitored, the following steps are required in addition to those specified in Section 8.

9.1.1 Determine the maximum specific gravity (G_{mm}) of the loose mix in accordance with T209 using a companion sample. The companion sample shall be aged to the same extent as the compaction sample.

9.1.2 Record the specimen height to the nearest 0.05 mm after each revolution.

9.1.3 Record the mass of the extruded specimen to the nearest gram and determine the bulk specific gravity (G_{mb}) of the extruded specimen in accordance with T166.

10. Density Calculations

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

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

where:

C_{ux} = uncorrected relative density at any point during compaction expressed as a percent of the maximum theoretical specific gravity

W_m = the mass of the specimen in grams

G_{mm} = theoretical maximum specific gravity of the mix

G_w = the unit weight of water, 1 g/cm^3

x = the number of gyrations

V_{mx} = the volume of the specimen, in cm^3, at any point based on the diameter (d) and height (h_x) of the specimen at that point (use "mm" for height and diameter measurements.). It can be expressed as:

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

Note 9 -- This formula gives volume in cm^3 to allow direct comparison with specific gravity.

10.2 At the completion of the bulk specific gravity test, determine the percent compaction (C_x) as follows:

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

where:

C_x = Corrected relative density expressed as a percentage of the maximum theoretical specific gravity

G_{mb} = Bulk specific gravity of the extruded specimen

h_m = Height in millimeters of the extruded specimen

h_x = Height in millimeters of the specimen after "x" gyrations

11. Report

11.1 Project name

11.2 Date of test

11.3 Start time of test

11.4 Specimen identification

11.5 Percent binder in specimen, nearest 0.1 percent

11.6 Average diameter of the mold used (d), nearest 0.01 mm

11.7 Mass of the specimen (W_m), nearest gram

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11.8 Maximum specific gravity (G_{mm}) of the specimen by T209, nearest 0.001

11.9 Bulk specific gravity (G_{mb}) of the specimen by T166, nearest 0.001

11.10 Height of the specimen after each gyration (h_x), nearest 0.05 mm

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

12. Precision and Bias

12.1 Precision - The research required to determine the precision of this procedure has not been conducted.

12.2 Bias - Research required to determine the bias of this procedure has not been conducted.

13. Keywords - gyratory, compaction, density
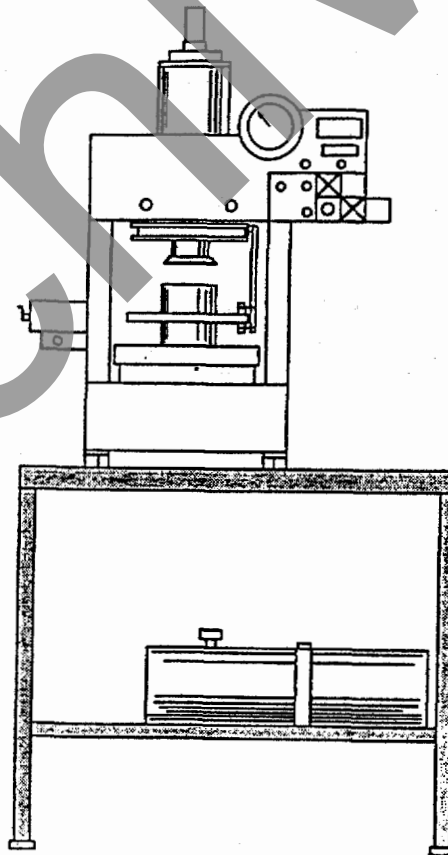

Figure 1 -   Gyratory Compactor

AASHTO Provisional Standard

Standard Practice for Volumetric Analysis
of Compacted Hot Mix Asphalt (HMA)

AASHTO Designation PP19
First Edition

September 1993

AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS
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Standard Practice for
Volumetric Analysis of
Compacted Hot Mix Asphalt (HMA)

AASHTO Designation: PP19[1]

1. Scope

1.1 This standard provides procedures to accomplish the volumetric analysis of compacted modified and unmodified HMA specimens.

1.2 This standard presents methods for determining (1) the volume percent of air voids (P_a, also termed the air voids content), (2) the volume percent of voids in the mineral aggregate (VMA), (3) the effective volume of asphalt binder (V_{fa}, also termed the voids filled with asphalt, Note 1), and (4) the effective asphalt content (P_{be}) of compacted HMA specimens. Values of these properties are calculated from the measured specific gravities of the asphalt binder, the coarse and fine aggregate, and the compacted HMA.

> Note 1 -- This quantity is usually expressed as the percent voids filled with asphalt binder, Pfa; this is the portion of the percent voids in the mineral aggregate that are filled with asphalt binder (Section 6.7).

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

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

2. Referenced Documents

2.1 AASHTO Standards:

T84	Specific Gravity and Absorption of Fine Aggregate
T85	Specific Gravity and Absorption of Coarse Aggregate
T100	Specific Gravity of Soils
T164	Quantitative Extraction of Bitumen from Bituminous Paving Mixtures
T166	Bulk Specific Gravity of Compacted Bituminous Mixtures
T168	Method of Sampling Bituminous Paving Mixtures
T170	Recovery of Asphalt from Solution by the Abson Method
T209	Maximum Specific Gravity of Compacted Bituminous Mixtures
T228	Specific Gravity of Semi-Solid Bituminous Materials

3. Terminology

3.1 Description of Terms Specific to this Standard

3.1.1 Air Voids, V_a, n - the total volume of the small pockets of air between the coated aggregate particles throughout a compacted paving mixture, expressed as percent of the bulk volume of the compacted paving mixture. (Note 2)

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[1]This standard is based on SHRP Product P004 and Asphalt Institute Manual MS-2, Mix Design Methods For Asphalt Concrete, 5th Edition, Chapter VI, Analysis of Compacted Paving Mixtures, The Asphalt Institute, Lexington, Kentucky, 1988 Printing.

Note 2 - Term defined in Asphalt Institute Manual MS-2.

3.1.2 Voids in the Mineral Aggregate, VMA, n - the volume of intergranular void space between the aggregate particles of a compacted paving mixture that includes the air voids and the effective asphalt content, expressed as a percent of the total volume of the specimen. (Note 2)

3.1.3 Effective Asphalt Content, P_{be}, n - the total asphalt content of a paving mixture less the portion of asphalt binder that is lost by absorption into the aggregate particles. (Note 2)

3.1.4 Voids Filled with Asphalt, V_{fa}, n - the portion of the voids in the mineral aggregate that contain asphalt binder. This represents the volume of the effective asphalt content. It is calculated by the equation:

$$V_{fa} = VMA - V_a$$

3.1.5 Bulk Specific Gravity, G_{sb}, n - the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids normal to the material) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature. (Note 2)

3.1.6 Effective Specific Gravity, G_{se}, n - the ratio of the mass in air of a unit volume of a permeable material (excluding voids permeable to asphalt) at a stated temperature to the mass in air (of equal density) of an equal volume of gas-free distilled water at a stated temperature. (Note 2)

3.1.7 Theoretical Maximum Specific Gravity, G_{mm}, n - the ratio of the mass of a given volume of voidless ($V_a = 0$) HMA at a stated temperature (usually 25°C) to a mass of an equal volume of gas-free distilled water at the same temperature.

3.1.8 Volume of Absorbed Asphalt, V_{ba}, n - the volume of asphalt binder in the HMA that has been absorbed into the pore structure of the aggregate. It may be calculated by the equation:

$$V_{ba} = V_a + V_b - VMA$$

where V_b is the volume of the total mass of asphalt binder in the HMA. V_{ba} is the volume of asphalt binder in the HMA that is not accounted for by the effective asphalt content.

4. Significance and Use

4.1 The proper design and field control of HMA volumetric parameters are critical to achieving satisfactory long-term pavement performance.

5. Procedure

5.1 Determine the percent of asphalt binder and aggregate by the total mass of the mixture using T164, and report the values determined as P_b and P_s, respectively. Recover the asphalt binder in the extract using T170.

5.2 Separate the aggregate into three fractions: the coarse aggregate fraction (material retained on the 4.75-mm sieve), the fine aggregate fraction, and the mineral filler fraction (material passing the 0.075-mm sieve). Determine the percent of each fraction by the total mass of the aggregate and report as P_1, P_2 and P_3, respectively.

5.3 Measure the specific gravity of: the asphalt binder using T228, the coarse aggregate using T85, the fine aggregate using T84, and the mineral filler using T100. Report the specific gravity values determined as G_b, G_1, G_2 and G_3, respectively.

Note 3 - The accuracy of determinations of specific gravity for mix design is extremely important. When specific gravities are determined to less than three decimal places (four significant figures), an absolute error in the calculation of the air voids content of as much as 0.8 percent can occur (e.g. an actual value of 4.2

percent may be measured anywhere in the range of 3.4 to 5.0 percent). Therefore, balances of appropriate sensitivity to yield four significant figures should be used to measure the masses employed in the specific gravity determinations.

5.4 Measure the theoretical maximum specific gravity of the uncompacted HMA using T209 and report as G_{mm}. (Note 3)

Note 4 -- Caution should be used when measuring the theoretical maximum specific gravity of HMA containing highly absorptive aggregates. Work conducted in SHRP Contract A-003B demonstrated that absorption may continue over a period of hours, and the value of G_{mm} may change significantly until absorption is completed.

5.5 Measure the bulk specific gravity of the compacted HMA using T166 and report as G_{mb}. (Note 3)

6. Calculations

6.1 Calculate the bulk specific gravity, G_{sb}, of the combined aggregate recovered from the HMA by the following equation:

$$G_{sb} = \frac{(P_1 + P_2 + P_3)}{\left[\dfrac{P_1}{G_1} + \dfrac{P_2}{G_2} + \dfrac{P_3}{G_3}\right]}$$

6.2 Calculate the effective specific gravity of the aggregate, G_{se}, by the following equation:

$$G_{se} = \frac{(100 - P_b)}{\left(\dfrac{100}{G_{mm}} - \dfrac{P_b}{G_b}\right)}$$

6.3 Calculate the absorbed asphalt, P_{ba}, as a percent by mass of the aggregate by the following equation:

$$P_{ba} = \frac{(100 G_b)(G_{se} - G_{sb})}{(G_{sb} G_{se})}$$

6.4 Calculate the effective asphalt content, P_{be} of the HMA by the following equation:

$$P_{be} = P_b - \left[\frac{(P_{ba} P_s)}{100}\right]$$

6.5 Calculate the percent voids in the mineral aggregate, VMA, by the following equation:

$$VMA = 100 - \left[\frac{(G_{mb} P_s)}{G_{sb}}\right]$$

where: P_s is the percent of aggregate by the total mass of the mixture.

6.6 Calculate the percent air voids, P_a, in the compacted HMA by the following equation:

$$P_a = 100\left[\frac{(G_{mm} - G_{mb})}{G_{mm}}\right]$$

6.7 Calculate the percent of voids filled with asphalt binder, P_{fa}, as a portion of the voids in the mineral aggregate by the following equation:

$$P_{fa} = VMA - P_a$$

7. Report

7.1 Report specific gravity results to the nearest 0.001 and percent voids (VMA, P_a and P_{fa}) to the nearest 0.1 percent.

8. Precision and Bias - Precision and bias statements are contained in the referenced test standards.

9. Keywords - Volumetric analysis, specific gravity(s), air voids, voids in mineral aggregate, voids filled with asphalt, effective asphalt content.

Standard Practice for Short and Long Term
Aging of Hot Mix Asphalt (HMA)

AASHTO Designation: PP2
First Edition

January 1994

*This is the first edition of the provisional standard (PS) based
on the technical substance provided by the Strategic Highway
Research Program (SHRP) researchers. The PS was collated
and formatted jointly by the AASHTO and SHRP Staffs.*

*This PS is being referred to the AASHTO Subcommittee on
Materials (SCOM) for a review, ballot and approval. If the
approval process produces changes, an amended version of the
PS shall be published as the second edition.*

AMERICAN ASSOCIATION OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
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Standard Practice for
Short and Long Term Aging
of Hot Mix Asphalt (HMA)

AASHTO Designation PP2[1]

1. Scope

1.1 This practice describes procedures for the short and long term aging of compacted and uncompacted hot mix asphalt (HMA). Two types of aging are described: 1) short term aging of uncompacted HMA to simulate the precompaction phase of the construction phase, and 2) long term aging of compacted HMA to simulate the aging that occurs over the service life of a pavement. The long term aging procedures are preceded by the short term aging procedure.

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

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

2. Referenced Documents - AASHTO Standards

TP4 Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of the SHRP Gyratory Compactor

TP38 Method for Preparing and Determining the Air Voids of Hot Mix Asphalt (HMA) Specimens by Means of the Rolling Wheel Compactor

3. Summary of Practice - For short term aging a mixture of aggregate and asphalt binder is aged in a forced draft oven for 4 h at 135°C. For long term aging a compacted mixture of aggregate and asphalt binder is aged in a forced draft oven for 5 days at 85°C.

4. Significance and Use - The properties and performance of HMA can be more accurately predicted by using aged test samples. The short term aging procedure described in this practice is designed to simulate the aging the mixture will undergo during plant mixing and construction. The long term aging procedure is designed to simulate the total aging the compacted mixture will undergo during 7 to 10 years of service.

5. Apparatus

5.1 Oven - A forced draft oven thermostatically controlled capable of maintaining any desired temperature setting from room temperature to 260°C to within ± 1°C.

5.2 Loading Device - A loading device capable of applying a static load of 56 kN to the specimen at the rate of 72.00 ± 0.05 kN/minute.

5.3 Thermometers - Thermometers having a range from 50 to 260°C and readable to 1°C.

5.4 Miscellaneous - metal oven pan for heating aggregates, a shallow metal oven pan for heating uncompacted asphalt concrete mixtures, a metal spatula or spoon, oven gloves

6. Hazards - This standard involves the handling of hot asphalt binder, aggregate, and hot asphalt mixes which can cause severe burns if allowed to contact skin. Follow standard safety precautions to avoid burns.

7. Procedure - Short Term Aging

7.1 The short term aging procedure applies to laboratory prepared loose mix only.

7.2 Place the mixture on a baking pan and spread it to an even thickness of approximately 21 to 22

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[1]This standard is based on SHRP Product 1031.

kg/m². Place the mixture and pan in the aging oven for 4 h ± 5 minutes at a temperature of 135°C ± 1°C.

7.3 Stir the mixture every hour to maintain uniform aging.

7.4 After 4 h, remove the mixture from the forced draft oven. The aged mixture is now ready for further conditioning or testing as required.

8.. Procedure - Long Term Aging

8.1 The long term aging procedure applies to laboratory prepared mixtures that have been subjected to the short term aging procedures described in Section 7, plant mixed HMA and compacted roadway specimens.

8.2 Preparing Specimens from Loose HMA

8.2.2 Compact specimens in accordance with TP4 or TP38.

8.2.3 Cool the compacted test specimen to 60 ± 1°C in an oven set at 60°C.

> Note 1 -- Conditioning at 60°C will take approximately 2 h for test specimens of appropriate size.

8.2.4 After cooling the test specimen to 60°C, level the specimen ends by applying a static load to the specimen at a rate of 72 ± 0.05 kN/min. Release the load at the same rate when the specimen ends are level or when the load applied reaches a maximum of 56 kN.

8.2.5 Cool the test specimen at room temperature for 16 ± 1 h.

> Note 2 -- Specimen cooling is usually scheduled as an overnight step.

8.2.6 Extrude the specimen from the compaction mold.

8.3 Preparing Compacted Roadway Specimens

8.3.1 Condition compacted roadway test specimens to 60°C ± 1°C in an oven set at 60°C. (Note 1)

8.3.2 Cool test specimens at room temperature 16 ± 1 h.

8.4 Place the compacted test specimens on a rack in the aging oven for 120 ± 0.5 h at a temperature of 85° C + 1° C.

8.5 After 120 h, turn the oven off, open the doors and allow the test specimen to cool to room temperature. Do not touch or remove the specimen until it has cooled to room temperature.

> Note 4 - Cooling to room temperature will take approximately 16 h.

8.6 After cooling to room temperature, remove the test specimen from the oven. The aged specimen is now ready for testing as required.

9. Report

9.1 Report the asphalt binder grade, asphalt binder content (nearest 0.1 percent) and the aggregate type and gradation, if applicable.

9.2 Report the following short term aging conditions if applicable:

9.2.1 plant mixing temperature (nearest 1°C),

9.2.2 laboratory mixing temperature (nearest 1°C),

9.2.3 short term aging temperature in Laboratory (nearest 1° C), and

9.2.4 short term aging duration in Laboratory (nearest minute).

9.3 Report the following long term aging conditions if applicable:

9.3.1 compaction temperature (nearest 1° C),

9.3.2 long term aging temperature (nearest 1° C), and

9.3.3 long term aging duration (nearest minute)

10. Keywords. hot mix asphalt, bituminous concrete, bituminous paving mixtures, aging, short term aging, long term aging

AASHTO Provisional Standard

Standard Test Method for Determining the
Maximum Specific Gravity of Bituminous
Paving Mixtures

AASHTO Designation: TP39
Edition 1A

September 1994

This is Edition 1A of the provisional standard (PS) based on the technical substance provided by the Strategic Highway Research Program (SHRP) researchers. The PS was collated and formatted jointly by the AASHTO and SHRP Staffs.

This PS is being referred to the AASHTO Subcommittee on Materials (SCOM) for a review, ballot and approval. If the approval process produces changes, an amended version of the PS shall be published as the second edition.

AMERICAN ASSOCIATION OF STATE HIGHWAY AND
TRANSPORTATION OFFICIALS
444 North Capitol Street, N.W., Suite 249
Washington, D.C. 20001

Standard Test Method for Determining the
Maximum Specific Gravity of Bituminous Paving Mixtures

AASHTO Designation: TP39[1]

1. Scope

1.1 This test method covers the determination of the theoretical maximum specific gravity and density of uncompacted bituminous paving mixtures at 25°C (77°F).

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

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 AASHTO Standards:

T168 Test Methods for Sampling Bituminous Paving Mixtures

2.2 ASTM Standards:

D4311 Practice for Determining Asphalt Volume Correction to a Base Temperature
E1 Specification for ASTM Thermometers
E12 Terminology Relating to Density and Specific Gravity of Solids, Liquids, and Gases

3. Terminology

3.1 The terms specific gravity and density used in this test method are in accordance with definitions in ASTM E12.

3.2 Definitions:

3.2.1 Density, as determined by this test method - the mass of a cubic meter (cubic foot) of the material at 25°C (77°F).

3.2.2 Residual pressure, as employed by this test method - the pressure in a vacuum vessel when vacuum is applied.

3.2.3 Specific gravity, as determined by this test method - the ratio of a given mass of material at 25°C (77°F) to the mass of an equal volume of water at the same temperature.

4. Summary of Test Method - A weighed sample of oven-dry paving mixture in the loose condition is placed in a tared vacuum vessel. Sufficient water at a temperature of 25°C is added to completely submerge the sample. Vacuum is applied for 15 min to gradually reduce the residual pressure in the vacuum vessel to 30 mm of Hg or less. At the end of the vacuum period, the vacuum is gradually released. The volume of the sample of paving mixture is obtained either by (9.5.1) immersing the vacuum container with sample into a water bath and weighing or by (9.5.2) filling the vacuum container full of water and weighing in air. At the time of weighing the temperature is measured and the mass is determined. From the mass and volume measurements, the specific gravity or density at 25°C is calculated. If the temperature employed is different from 25°C an appropriate correction is applied.

5. Significance and Use

5.1 The theoretical maximum specific gravities and densities of bituminous paving mixtures are intrinsic properties whose values are influenced by the composition of the mixtures in terms of types and amounts of aggregates and bituminous materials.

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[1]This standard is based on SHRP Product 1026

8.3 Calibrate the large-size plastic pycnometer (Type F) by accurately determining the mass of water required to fill it over a range of temperature from about 20 to 65°C (70 to 150°F), and construct a calibration curve of mass versus temperature as shown in Figure 3. Care should be taken to follow exactly the same procedure in calibration as in conducting a test.

8.3.1 The following filling procedure may be used for the model with latched lid and vented stopper. The domed lid is latched in place and the pycnometer (Type F) nearly filled with water. Leave about 50 mm (2 in.) empty. The release of air bubbles may be facilitated by applying vacuum and by jarring (dropping first one side then the other of the pycnometer (Type F) about 10 mm (1/2 in.) on the bench surface). This vacuum application and bubble release procedure should take about 10 minutes so that the temperature equilibrium between the shell and the water approximates that attained when running a test. The final water is then gently poured in until the level is about one half up into the neck. Any air bubbles caught against the dome that cannot be released by jarring or by swirling the water may be "pricked" or pushed to the surface with a bent wire. Insert the vented stopper using only enough force to just seat the stopper and immediately wipe the excess water off the top.

8.3.2 For the models with quick disconnect vacuum line and unlatched lid, the filling procedure is as follows. With the inlet valve closed, apply vacuum of about 250 mm (10 in.) of Hg. Open the inlet valve slowly letting water in until the level reaches 25 mm (1 in.) below the top of the dome and close the valve. Continue applying vacuum and release the bubbles by jarring and rapping the vessel with a rubber mallet. Slowly open the inlet valve and allow more water in until the water overflows into the aspirator (vacuum) line and then close the valve. This vacuum application and bubble release procedure should take about 10 minutes so that the temperature equilibrium between the shell and the water approximates that attained when running a test. Disconnect by pulling out at the quick-disconnect joint below the gage.

8.3.3 The outside of the pycnometer (Type F) is then wiped dry, the mass of the full pycnometer determined, and the temperature of the water measured.

Note 6 - The shape of the calibration curve is a function of two opposing factors which can be rationally defined. As the temperature is increased, the container itself expands (adding mass to the pycnometer line in Figure 4) and the density of the contained water decreases (resulting in loss of mass-"water" line in Figure 4). These relationships are shown in Figure 4 for a typical large-size pycnometer (Type F). The "water" curve may be constructed by multiplying the volume at 25°C (77°F) by the difference in density of water at 25°C, which is 0.9970, and at the calibration temperature.

Difference due to water expansion = $V_{25}(0.9970 - dw)$

$$\text{Since } V_{25} = \frac{M_{25}}{0.9970}$$

$V_{25}(0.9970 - dw) \text{ reduces to } M_{25}\left(1 - \frac{dw}{0.9970}\right)$

where:
V_{25} = volume of water to fill container at 25°C (77°F), cm³,
M_{25} = mass of water to fill container at 25°C (77°F), g, and
dw = density of water at calibration temperature, Mg/m³.

8.3.4 The rate of change in capacity of the container due to thermal expansion of the pycnometer itself is essentially constant over the temperature range from 20 to 65°C (70 to 150°F). Thus, the Pycnometer line in Figure 4 can be drawn through the 0 at 25° (77°F) point knowing only the slope of the straight line relationship. The slope can be established by averaging at least five calibration weighings at some elevated temperature, adding the loss due to water expansion and subtracting the mass at 25°C, M_{25}, to give the gain in capacity due to expansion of the container. The difference in mass divided by the difference in temperature is the slope of the

pycnometer line. For a polycarbonate pycnometer of about 13500 mL capacity, the slope thus established was 2.75 g/°C (1.53 g/°F). This is believed to be typical constant.

8.3.5 The bending of the calibration curve (Figure 3) due to these offsetting thermal factors thus minimizes experimental error due to temperature effects in the normal working range, 25°C, for both the volumeteric flask (Type C) and the pycnometer containers (Types D, E and F). Defining the calibration curve makes it possible to correct for temperature, rather than "bring-to-temperature," thereby eliminating the cost of a water bath and making it feasible to improve accuracy by testing larger samples and to materially reduce testing time.

8.4 While calibration of the flask, Type F, or of either pycnometer (Types D or E), need be done only once, the calibration should be checked occasionally, particularly at 25°C. The equipment must be kept clean and free from any accumulation that would change the mass if the volume calibration is to remain constant. Care should be taken to use only neutral solvents, especially with plastic containers while glass vessels should not be subjected to high vacuum if they are scratched or damaged.

9. Procedure

9.1 Separate the particles of the sample of paving mixture by hand, taking care to avoid fracturing the aggregate, so that the particles of the fine aggregate portion are not larger than 6.3 mm (1/4 in.). If a sample of paving mixture is not sufficiently soft to be separated manually, place it in a flat pan, and warm it in an oven until it can be separated as described.

9.2 Unless the paving mixture has been prepared in a laboratory using oven-dry aggregates, oven-dry the sample to constant mass at a temperature of 105 ± 5°C (221 ± 9°F). This drying and any required warming for particle separation as described in 9.1 should be combined as a single operation to minimize reheating effects.

9.3 Cool the sample to room temperature, place it in a tared container and weigh. Designate the net mass of the sample as A. Add sufficient water at a temperature of approximately 25°C (77°F) to cover the sample completely.

9.4 Remove air trapped in the sample by applying gradually increased vacuum until the residual pressure manometer reads 30 mm of Hg or less. Maintain this residual pressure for 15 minutes. Agitate the container and contents during the vacuum period either continuously by a mechanical device, or manually by vigorous shaking at intervals of about 2 minutes. Glass vessels should be shaken on a resilient surface such as a rubber or plastic mat, and not on a hard surface, so as to avoid excessive impact while under vacuum.

> Note 7 - It has been found that by using this combination of residual pressure (30 mm Hg) and vacuuming time (15 minutes), the need for running the supplementary procedure (Section 11) can generally be avoided when thoroughly coated mix is used.

9.5 At the end of the vacuum period, gently relase the vacuum and proceed with one of the following determinations:

9.5.1 Weighing in water - Suspend the container and contents in the water bath and determine the mass after 10 ± 1 minute immersion. Measure the water bath temperature, and if different from 25 ± 1°C (77 ± 1.8°F), correct the mass to 25°C using the calibration temperature adjustment developed in 7.11. Designate the mass of the sample in water at 25°C as C.

9.5.2 Weighing in air - Fill the flask (Type C), or any one of the pycnometers (Type D, E or F) with water and adjust the contents to a temperature of 25 ± 1°C (77 ± 1.8°F). Determine the mass of the container (and contents), completely filled, in accordance with 7.2, within 10 ± 1 minute after completing 9.4. Designate this mass as E.

> Note 9 - See Appendix X1 for correcting the theoretical maximum specific gravity when measurements are made at temperatures other than 25°C.

Table 1
Influence of Temperature Corrections to a Measured Volume at 20°C of a Given Mass of
Loose Paving Mixture, to Provide the Required Theoretical Maximum Specific Gravity at 25°C

Temperature °C	Volume Loose Mix at 20°C	Volume Correction for Temp Change	Corrected Volume at 20°C, Loose Mix	Mass of Loose Mix	Specific Gravity, Loose Mix
31	492.77	0.2046	492.975	1251.3	2.5383
30[A]	492.77	0.1860	492.956	1251.3	2.5384
29[A]	492.77	0.1674	492.937	1251.3	2.5385
28[A]	492.77	0.1488	492.919	1251.3	2.5386
27[A]	492.77	0.1302	492.900	1251.3	2.5386
26[A]	492.77	0.1116	492.882	1251.3	2.5387
25[A]	492.77	0.0930	492.863	1251.3	2.5388
24[A]	492.77	0.0744	492.844	1251.3	2.5389
23[A]	492.77	0.0558	492.826	1251.3	2.5390
22[A]	492.77	0.0372	492.807	1251.3	2.5391
21[A]	492.77	0.0186	492.789	1251.3	2.5392
20	492.77	0.0000	492.772	1251.3	2.5393
19	492.77	-0.0186	492.751	1251.3	2.5394

[A]Range less than 0.0005.

Note 1 - Strictly speaking, the above table shows that the specific gravity for this particular mix, as measured at 20°C just fails to meet the corrected theoretical maximum specific gravity at 25°C, 2.5388 versus 2.5393, that is by 0.0005, and that a temperature correction would be required.

Note 2 - If the measurement for volume had been made at 21°C, the table indicates that no temperature correction would have been necessary, because the measurement at 21°C would have satisfied the theoretical maximum specific gravity at 25°C, 2.5388 versus 2.5392, a difference of less than 0.0005.
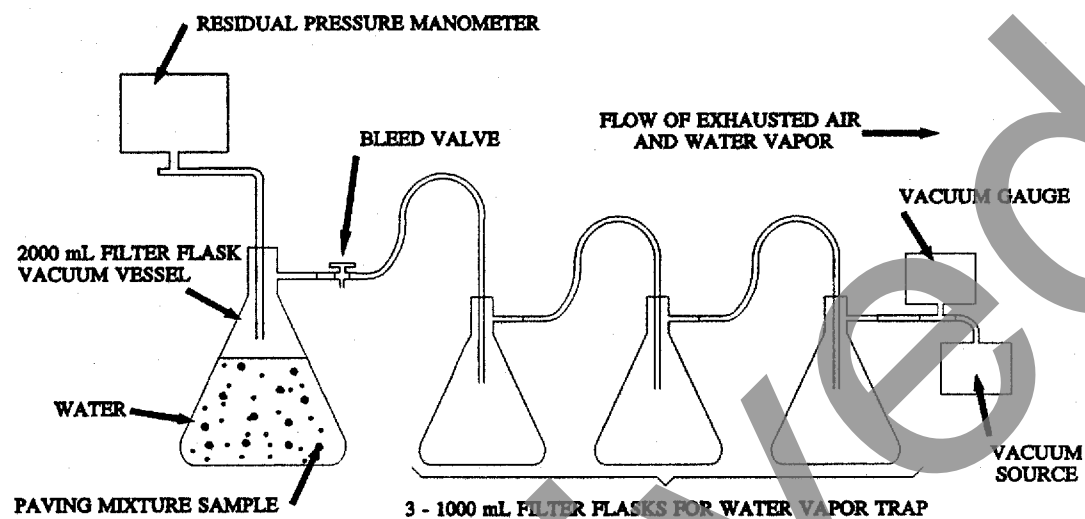
Figure 1: An Example of the Correct Arrangement of Testing Apparatus (Note -- The purpose of the train of small filter flasks is to trap water vapor from the vacuum vessel, that otherwise would enter the oil in the vacuum pump and decrease the pump's ability to provide high vacuum.)
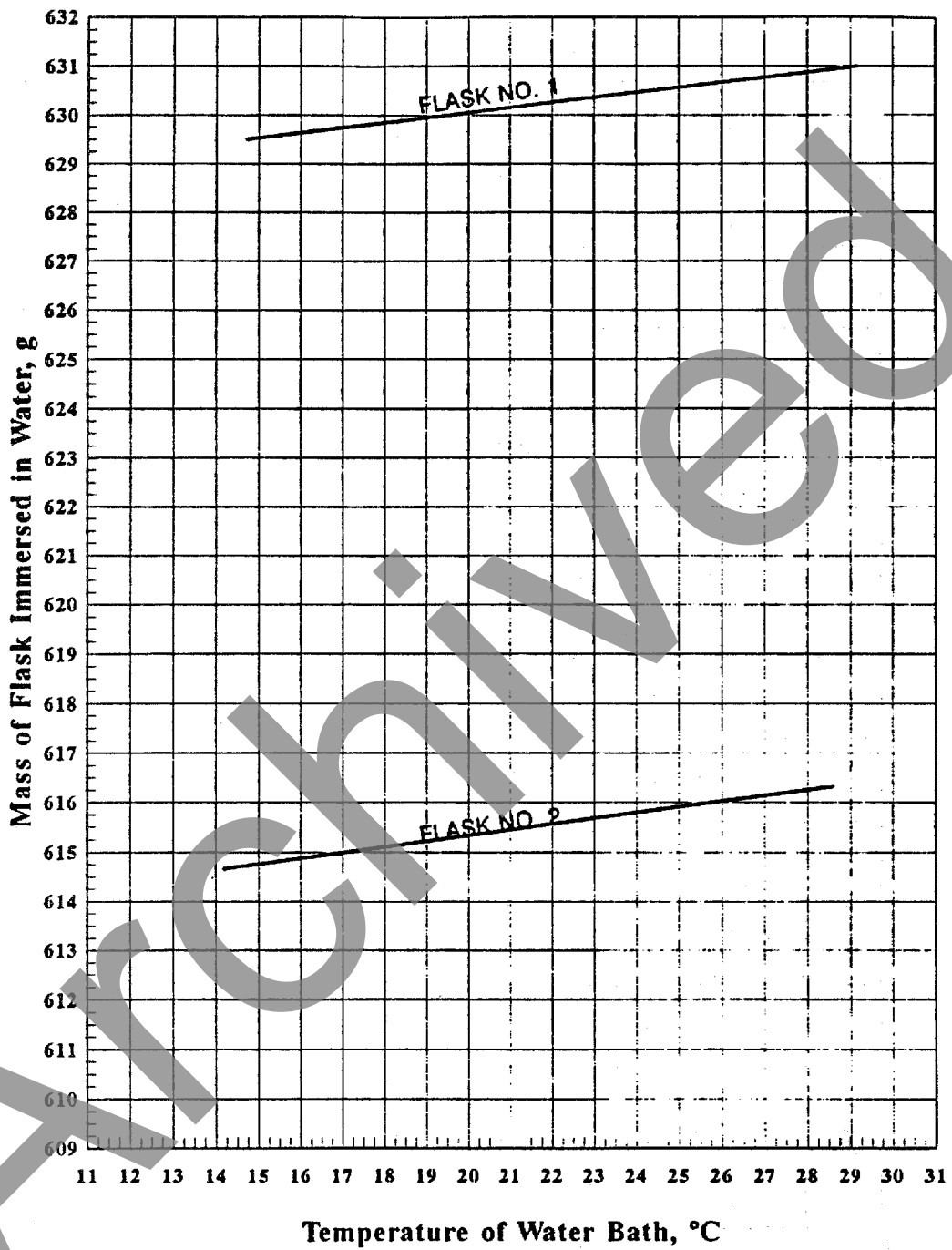
Figure 2: Example Calibration Curve for Volumetric Flask (B).

MASS IN GRAMS

Temperature of Water, °C
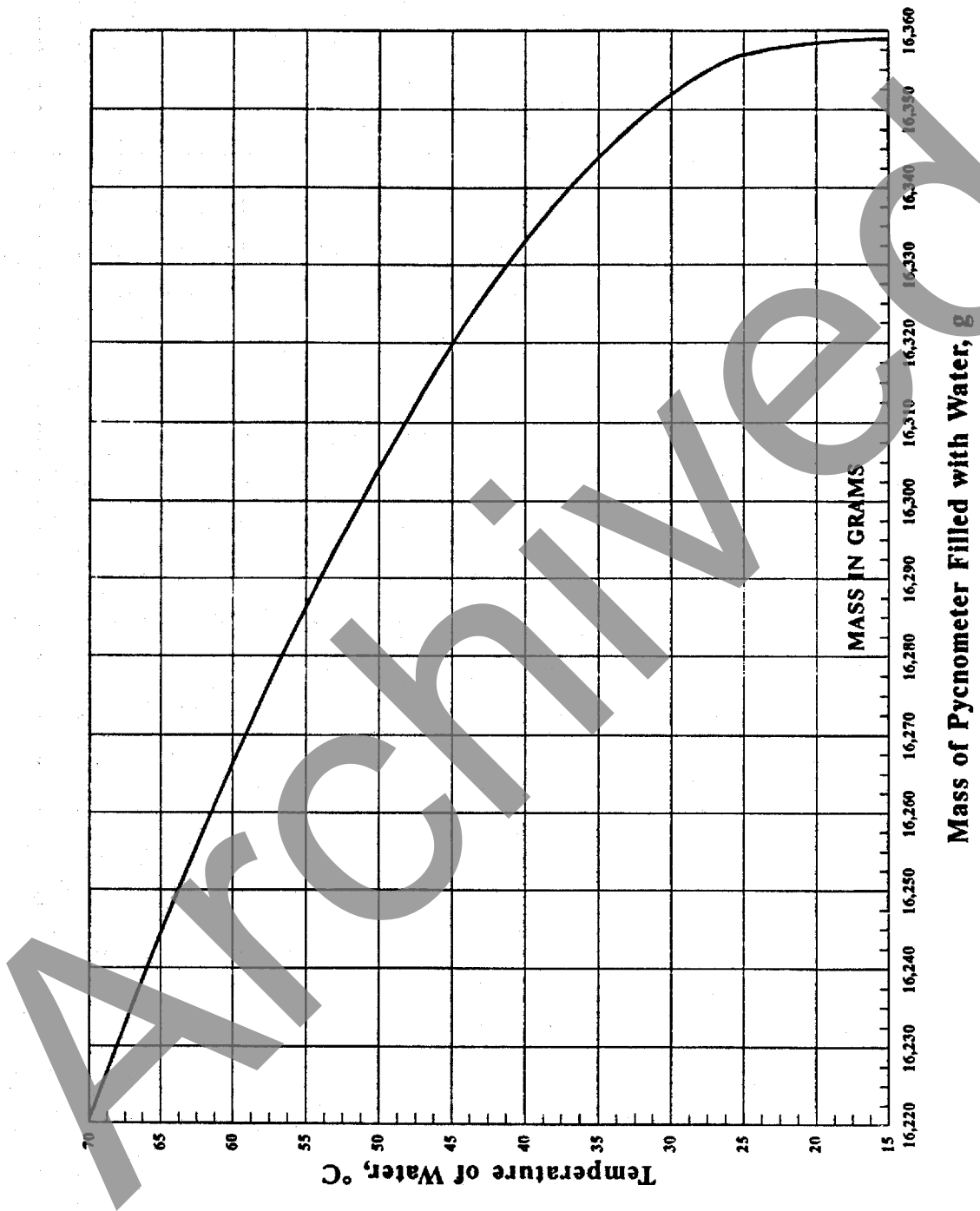
Mass of Pycnometer Filled with Water, g

Figure 3: Example Calibration Curve for Pycnometer (D).
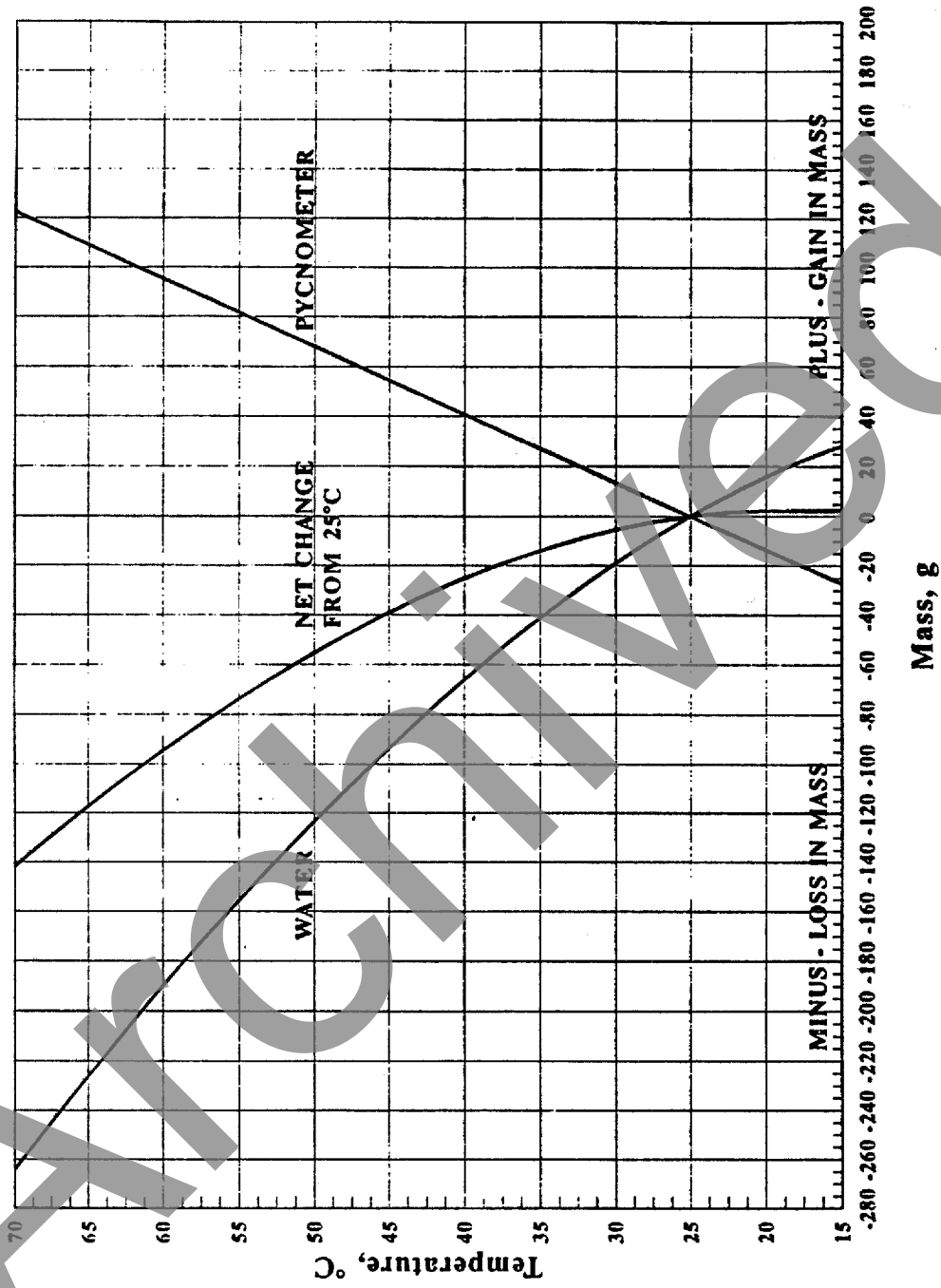
Figure 4: Effect of Change in Density of Water and Volume of Pycnometer (D) with Change in Temperature
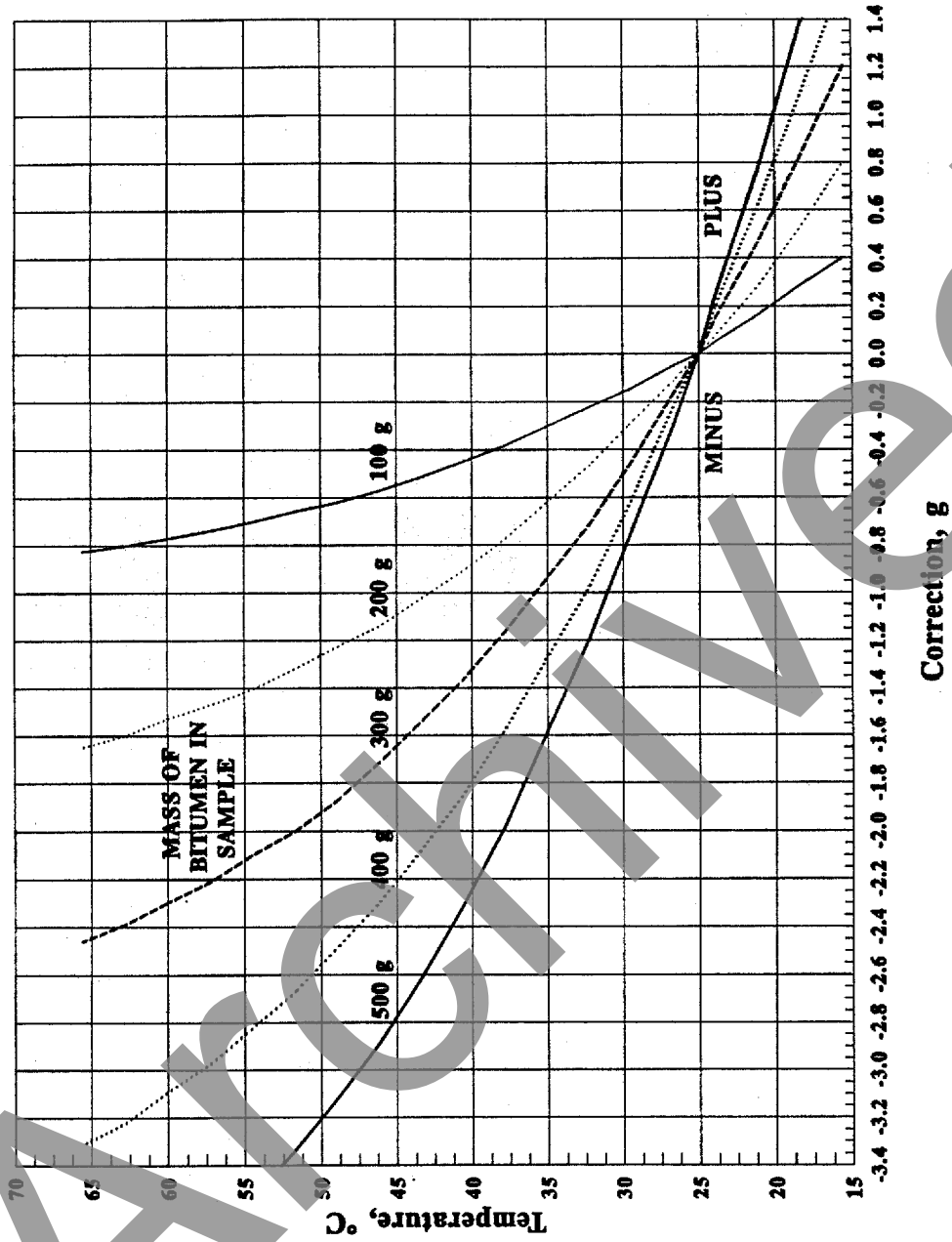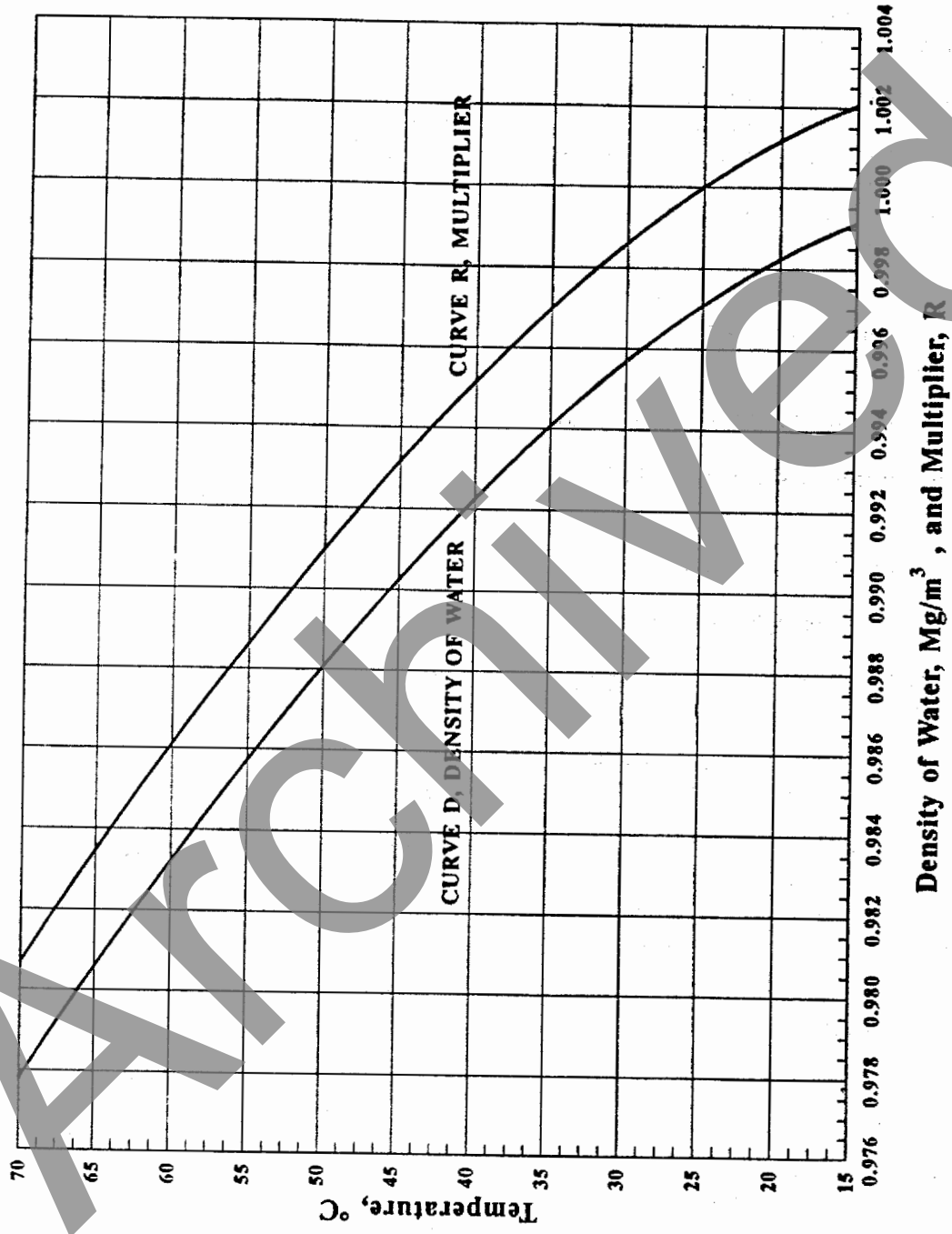
Figure 5: Correction Curves for Expansion of Bitumen, H, in Eq.3

Figure 6: Curves D and R for Eq. 3

APPENDIX X1 - Theoretical Maximum Specific Gravity For a Loose Paving Mixture
(Nonmandatory Information)

X1.1 Scope

X1.1.1 The objectives of this Appendix are to indicate a method for correcting the theoretical maximum specific gravity to 25°C when measurements are made at temperatures other than 25°C and to indicate the range of temperature in °C above or below 25°C within which no temperature correctioin is required, because the measured theoretical maximum specific values are shown to be 0.004 or less than the value for 25°C.

X1.2 Indicated Values - The following are indicated for the theoretical maximum specific gravity of a loose paving mixture:

X1.2.1 Mass of loose paving mixture = 1251.3 g.

X1.2.2 Volume of loose paving mixture at 20°C = 492.77 mL.

X1.2.3 Asphalt content = 5.0 percent of total mix.

X1.2.4 Specific gravity of asphalt at 20°C = 1.029

X1.2.5 AASHTO bulk specific gravity of aggregate = 2.714.

X1.2.6 Cubical coefficient of expansion of asphalt at 20°C = 6.2×10^{-4} mL/mL/°C. (ASTM Practice D4311)

X1.2.7 Cubical coefficient of expansion of aggregate at 20°C = 2.2×10^{-5} mL/mL/°C. (Krebs and Walker, Highway Materials, McGraw-Hill Inc., 1971, P. 274)

X1.3 Basis of Calculation for One Gram of Loose Paving Mixture at 20°C

X1.3.1 Mass of asphalt = 0.05 g.

X1.3.2 Volume of asphalt:
= 0.05/1.029 = 0.0486 mL

X1.3.3 Mass of aggregate = 0.95 g.

X1.3.4 Volume of aggregate:
= 0.95/2.714 = 0.3500 mL

X1.3.5 Volume of asphalt plus aggregate in one gram of loose paving mixture at 20°C:
= 0.0486 + 0.3500 = 0.3986 mL.

X1.4 Basis of Calculation for Volume Change of One Gram of Loose Paving Mixture for One °C from 20°C

X1.4.1 Volume change for asphalt:
= $6.2 \times 10^{-4} \times 0.0486$
= 0.3013×10^{-4} mL
= 3.0130×10^{-5} mL

X1.4.2 Volume change for aggregate:
= $2.2 \times 10^{-5} \times 0.3500$
= 0.77×10^{-5} mL

X1.4.3 Volume change for one gram of loose paving mixture for one °C change in temperature from 20°C:
= $3.0130 \times 10^{-5} + 0.7700 \times 10^{-5}$
= 3.7830×10^{-5} mL.

X1.5 Volume Correction

X1.5.1 For a difference in water temperature of one °C above or below 20°C, a correctionn to the volume of water displaced by one gram of loose paving mixture can be made by the following equation:

$$\text{Correction} = \Delta T \times K_T \times V_T \text{ mL}$$

where:
ΔT = 1°C
K_T = volume change for one gram of loose paving mixture for one °C change in temperature above or below 20°C = 3.7830×10^{-5} mL.
V_T = volume of water for corresponding 1251.3 g mass of loose paving mixture at test temperature of 20°C = 492.77 mL.

Substituting in equation gives:

$\text{Correction} = 1 \times 3.7830 \times 10^{-5} \times 492.77$ mL
= 0.01864 mL per gram at 20°C

APPENDIX B

National Asphalt Training Center

TECHNOLOGY APPLICATIONS
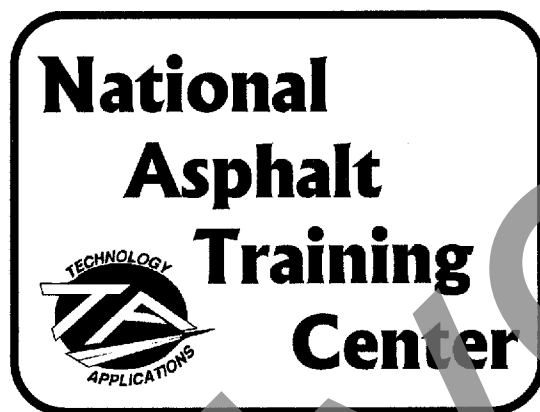
AASHTO Standards for

Bulk Specific Gravity of Compacted Bituminous Specimens Using Saturated Surface-Dry Specimens (T166)

Standard Method of Test
for

Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens

AASHTO DESIGNATION: T 166-88

1. SCOPE

1.1 This method of test covers the determination of bulk specific gravity of specimens of compacted bituminous mixtures as defined in AASHTO M 132, Terms Relating to Density and Specific Gravity of Solids, Liquids and Gases.

1.2 This method should not be used with samples that contain open or interconnecting voids and/or absorb more than 2 percent of water by volume, as determined by AASHTO T 166.

1.3 The bulk specific gravity of the compacted bituminous mixtures may be used in calculating the unit weight of the mixture.

2. TEST SPECIMENS

2.1 Test specimens may be either laboratory-molded bituminous mixtures or from bituminous pavements. The mixtures may be surface or wearing course, binder or leveling course, or hot-mix base.

2.2 Size of Specimens—It is recommended, (1) that the diameter of cylindrically molded or cored specimens, or the length of the sides of sawed specimens, be at least equal to four times the maximum size of the aggregate; and (2) that the thickness of specimens be at least one-and-one-half times the maximum size of the aggregate.

2.3 Pavement specimens shall be taken from pavements with core drill, diamond or carborundum saw, or by other suitable means.

2.4 Care shall be taken to avoid distortion, bending, or cracking of specimens during and after the removal from pavement or mold. Specimens shall be stored in a safe, cool place.

2.5 Specimens shall be free from foreign materials such as seal coat, tack coat, foundation material, soil, paper, or foil.

2.6 If desired, specimens may be separated from other pavement layers by sawing or other suitable means.

METHOD A

3. APPARATUS

3.1 *Balance*—Conforming to the requirements of M 231, for the class of balance required for the principle sample weight of the sample being tested. The balance shall be equipped with suitable suspension apparatus and holder to permit weighing the specimen while suspended from the center of scale pan of balance (Note 1).

NOTE 1—The holder should be immersed to a depth sufficient to cover it and the test sample during weighing. Wire suspending the holder should be the smallest practical size to minimize any possible effects of a variable immersed length.

3.2 *Water Bath*—for immersing the specimen in water while suspended under the balance, equipped with an overflow outlet for maintaining a constant water level.

4. PROCEDURE

4.1 Dry the specimen to a constant mass (Note 2). Cool the specimen to room temperature at $25 \pm 5°C$ ($77 \pm 9°F$), and record the dry mass, A. Immerse each specimen in water at $25 \pm 1°C$ ($77 \pm 2°F$) for 3 to 5 minutes and record the immersed mass, C. Remove the specimen from the water, surface dry by blotting with a damp towel, and determine the surface-dry mass, B (Note 3).

NOTE 2—Constant mass shall be defined as the mass at which further drying at 52 ± 3 C (125 ± 5 F) does not alter the mass 0.05 percent. Samples saturated with water shall initially be dried overnight at 52 ± 3 C (125 ± 5 F) and then weighed at two-hour drying intervals. Recently molded laboratory samples which have not been exposed to moisture do not require drying.

NOTE 3—A temperature in the range of 20 to 30°C (68 to 86°F) shall be called room temperature in accordance with ASTM E 171.

NOTE 4—If desired, the sequence of testing operations may be changed to expedite the test results. For example, first the immersed mass (C) can be taken, then the surface-dry mass (B) and finally the dry mass (A).

5. CALCULATION

5.1 Calculate the bulk specific gravity of the specimens as follows (report the value up to three decimal places):

$$\text{Bulk Sp. Gr.} = \frac{A}{B - C}$$

where:

A = mass in grams of sample in air,
B = mass in grams of surface-dry specimen in air,
C = mass in grams of sample in water.

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

$$\text{Percent Water Absorbed by Volume} = \frac{B - A}{B - C} \times 100$$

5.3 If the percent water absorbed by the specimen in Section 5.2 exceeds 2 percent, use AASHTO T 275 (Bulk Specific

Gravity of Compacted Bituminous Mixtures Using Paraffin. Coated Specimens).

METHOD B

6. APPARATUS

6.1 Balance conforming to the requirements of M 231, for the class of balance required for the principle sample weight of the sample being tested.

6.2 Water Bath, Thermostatically controlled so as to maintain the bath at 25 ± 0.5 C (77 ± 0.9 F).

6.3 Thermometer, ASTM 17 C (17 F), having a range of 19 to 27 C (66 to 80 F), graduated in 0.1 C (0.2 F) subdivisions.

6.4 Volumeter[1], cacibrated to 1,200 ml or appropriate capacity depending upon the size of test sample. The volumeter shall have a tapered lid with a capillary bore.

7. PROCEDURE

7.1 Dry the specimen to constant mass (see Note 2). Cool the specimen to room temperature at 25 ± 1 C (77 ± 2 F) and record the dry mass. Immerse in water bath and let saturate for at least 10 minutes. At the end of the 10-minute period, fill a calibrated volumeter with distilled water at 25 C (77 F). Remove the immersed and saturated specimen from the water bath, quickly damp dry the saturated specimen with a damp towel and as quickly as possible weigh the specimen. Any water which seeps from the specimen during the weighing operation is considered as a part of the saturated specimen.

---

[1] Aluminum Volumeters of different sizes available from Pine Instrument Co., 101 Industrial Drive, Grove City, PA 16127 and Rainhart Co., 604 Williams St., Austin, TX 78765 have been found suitable.

7.2 Place the weighed saturated specimen into the volumeter and let stand for at least one minute. Bring the temperature of the water to 25 C (77 F), and cover the volumeter making certain that some water escapes through the capillary bore of the tapered lid. Wipe the volumeter dry with a dry absorbent cloth and weigh the volumeter and contents (Note 4).

NOTE 5—If desired, the sequence of testing operations can be changed to expedite the test results. For example, first the mass of saturated damp dry specimen can be taken. Then the volumeter containing the saturated specimen and water can be weighed. The dry mass of the specimen can be determined last.

8. CALCULATIONS

8.1 Calculate the bulk specific gravity of the sample as follows (report the value up to three decimal places):

$$\text{Bulk Specific Gravity} = \frac{A}{B + D - E}$$

where:

A = mass in grams of dry specimen,
B = mass in grams of surface-dry specimen,
D = mass in grams of volumeter filled with water at 25 C (77 F), and
E = mass in grams of volumeter filled with specimen and water at 25 C (77 F).

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

$$\text{Percent Water Absorbed by Volume} = \frac{B - A}{B + D - E} \times 100$$

8.3 If the percent water absorbed by the specimen in Section 8.2 exceeds 2 percent, use AASHTO T 275 (Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens).

METHOD C (RAPID TEST)

9. PROCEDURE

9.1 This procedure can be used for testing specimens which are not required to be saved and which contain substantial amount of moisture. Specimens obtained by coring or sawing can be tested the same day by this method.

9.2 The testing procedure shall be the same as given in Sections 4 and 7 except the sequence of operations. The dry mass (A) of the specimen is determined last as follows.

9.3 Place the specimen in a large flat bottom drying pan of known weight. Place the pan and specimen in a 110 ± 5 C (230 ± 9 F) oven. Leave the specimen in the oven until it can be easily separated to the point where the particles of the fine aggregate-asphalt portion are not larger than ¼ in. (6.4 mm). Place the separated specimen in the 110 C (230 F) oven and dry to a constant mass (Note 2).

9.4 Cool the pan and specimen to room temperature at 25 ± 1 C (77 ± 2 F). Weigh the pan and specimen, subtract the mass of the pan and record the dry mass, A.

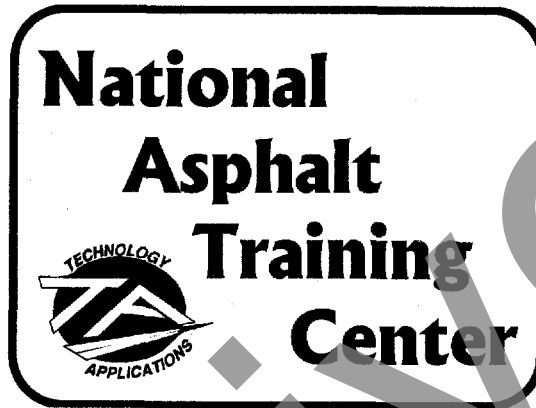### 10. CALCULATIONS

10.1 Calculate the bulk specific gravity in Sections 5.1 and 8.1.

11. PRECISION

11.1 Duplicate specific gravity results by the same operator should not be considered suspect unless they differ more than 0.02.
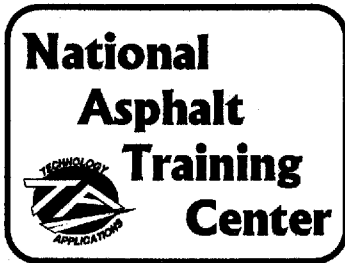
APPENDIX C

National Asphalt Training Center

TECHNOLOGY APPLICATIONS

Forms for Acquiring Test Results

Volumetric Analysis of Compacted Specimens

National Asphalt Training Center

Date: _____ Tech: _____

Mix ID: _____ % Asphalt: _____

Sample ID			

Bulk Specific Gravity (G_{mb}):

Mass in Air, g	**A**			
Mass in Water, g	**B**			
SSD Mass in Air, g	**C**			
Volume, cm^3	**D=C-B**			
G_{mb}	**E=A/D**			

Air Void Content (P_a):

G_{mm}	**F**			
%G_{mm}	**G=100×E/F**			
P_a, %	**100-G**			

- -

Sample ID			

Bulk Specific Gravity (G_{mb}):

Mass in Air, g	**A**			
Mass in Water, g	**B**			
SSD Mass in Air, g	**C**			
Volume, cm^3	**D=C-B**			
G_{mb}	**E=A/D**			

Air Void Content (P_a):

G_{mm}	**F**			
%G_{mm}	**G=100×E/F**			
P_a, %	**100-G**			

National Asphalt Training Center

Maximum Theoretical Specific Gravity of Asphalt Concrete

Date: _____ Tech: _____

Mix ID: _____ % Asphalt: _____ (H)

Sp Grav Asphalt: _____ (K)

Sample ID		
Sample and Bowl Mass in Air, g	A	
Bowl Mass in Air, g	B	
Sample Mass in Air, g	C=A-B	
Sample and Bowl in Water, g	D	
Bowl in Water, g	E	
Sample in Water, g	F=D-E	
Sample Volume, cm^3	G=C-F	
G_{mm}	C/G	
Average G_{mm}	J	
Average G_{se}	$\dfrac{(100\text{-}H)}{(100/J)\text{-}(H/K)}$	

Viscosity, Pa-s (vertical axis): 5, 1, 0.1, 0.05

Temperature, °C (horizontal axis): 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200

Compaction Range

Mixing Range

National Asphalt Training Center

(After ASTM D 2493)

Printed By
Federal Highway Administration
Office of Technology Applications
U.S. Department of Transportation
400 Seventh Street, SW
Washington, D.C. 20590

HTA-21/5-95(3M)QE