HOT MIX ASPHALT (HMA)
TECHNICIAN TRAINING MANUAL

Developed by
FHWA Multi-Regional Asphalt Training and Certification Group
1999

Development Team

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Preface

This training manual was developed as part of a multi-regional effort to assist states with meeting the requirements of the Code of Federal Regulations, Part 637, for "qualified" personnel to perform material sampling and testing for quality control and quality acceptance (QC/QA).

The ultimate goal of the group is also to promote reciprocity of this "qualification" across state lines. To that end, the group recommends that each training program cover the procedures and specifications listed here as a minimum core. The core materials should include presentation of the current AASHTO procedures. Individual state requirements, if needed, should be presented in addition to, not instead of, the approved AASHTO versions.

Because Superpave is being implemented on an ever-increasing frequency and is seen as the mix design system of the future, only those tests and specifications applicable to the Superpave system are presented here. Some of the tests are applicable to Marshall or Hveem mix designs as well, however, those design methods are not included.

AASHTO standards are listed in the Table of Contents in the recommended order of presentation. Prerequisites for the standards are listed on the first page of each one. Knowledge of certain methods and tests is necessary before proceeding to other standards.

Files are provided in both Word and WordPerfect formats. Each individual file consists of the AASHTO designation for the subject.

Students are to use the mathematical rounding rules recommended by each agency in performing calculations for qualification testing.

SAMPLING BITUMINOUS MATERIALS

AASHTO T 40

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
1999

NOTE

There are no prerequisites
for this training package.

GLOSSARY

Asphalt cement: Also referred to as "asphalt binder," allowing for the addition of modifiers to the asphalt cement. Asphalt is a product normally refined from crude petroleum. There are a few natural asphalt deposits such as Trinidad Lake. Asphalt is a black tar-like material that is solid at low temperatures and liquid at high temperatures. This allows it to be used as a paving cement by mixing and placing in a liquid state then the natural cooling produces a solid but flexible pavement.

The performance grading (PG) system of classifying asphalt binders is based on the high and low temperatures expected to be found in the pavement during its' life. For example, a PG 58-28 is expected to stay stiff at a temperature of 58E C and yet remain flexible at a temperature of 28EC.

SAMPLING OF BITUMINOUS MATERIALS

This discussion of sampling bituminous materials is limited to the sampling of asphalt cement. Sampling of bituminous materials is covered under AASHTO T168. Asphalt cement quality is important to producing quality Hot Mix Asphalt (HMA). Using the correct grade of asphalt insures that the HMA pavement will perform as expected under the conditions encountered in the field. The producers of asphalt cement are responsible for the quality of their product and must operate under a quality control plan. Proper sampling is a key component of any Quality Control/Quality Assurance plan.

As in sampling many products, safety is a major factor. Be sure to always wear the proper safety attire and use extreme caution around hot asphalt cement.

Sampling locations for asphalt cement include the following:

< from the producer's storage facility,

< from shipment, or

< from the Hot Mix Asphalt producer's plant.

The location of the sample should be as directed by the State Highway Agency.

There are two methods for sampling asphalt cement:

1. By the use of a sample valve attached to the line or tank.

2. Dipping a sampling device into the asphalt from above.

The use of a sample valve is the preferred method.

The asphalt cement samples need to be placed in the proper containers. Always use caution when handling containers filled with hot asphalt cement.

Common Sampling Errors

< Not wasting material before taking a sample from a valve.

< Improper sample container.

TESTING METHODOLOGY

Apparatus

< Safety apparel including - insulated gloves, face shield, long sleeve shirts, long pants, and boots.

< Dipper (when dip sampling)

< Sample containers - these containers need to be clean, tight-sealing metal cans of the proper size. **Do not use solvents to clean cans.** Use a clean dry cloth to wipe off any material from the outside of the sample cans.

Sampling Procedure - Sampling from a valve (tanks, lines, pipes)

When sampling asphalt cement from a valve, waste at least four liters (one gallon) of the material through the valve before taking the sample. After the material has been wasted, the sample container may be filled.

Sampling Asphalt Cement

NOTE

Always check with the owner concerning any special safety issues in the operation of the sampling valves.

Safety is extremely important when sampling asphalt cement.

Sampling Procedure - Dip Sampling (tanks, tankers, tank cars, barges, distributors)

Asphalt cement in storage may be sampled by lowering a sample device into the material from an access hatch in the top of the tank. The dip sampler is lowered into the material to the proper depth, opened, and allowed to fill. The sampler is then carefully withdrawn and the entire contents of the sampler is then poured into the sample container.

Properly identify all samples by marking the cans (not just the lids) with the type of material, the date, the time, and the sample location, as a minimum.

SAMPLING BITUMINOUS PAVING MIXTURES

AASHTO T 168

Developed by
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1999

NOTE

There are no prerequisites
for this training package.

GLOSSARY

Hot Mix Asphalt: a mixture of aggregate and asphalt cement, sometimes including modifiers, that is produced by mixing hot dried aggregate with heated asphalt in a plant designed for the process.

Template: a device used to create a sample area, often no more than a steel box without a top. If the template is inserted after the material is spread, it does not have a bottom. Templates have the advantage of avoiding any segregation during sampling.

SAMPLING BITUMINOUS PAVING MIXTURES

This discussion concerns obtaining samples of bituminous paving mixtures for laboratory testing. Proper sampling is a key component of any Quality Control/Quality Assurance plan. Hot mix asphalt (HMA) is best sampled at the last point in the construction process where loose mixture is available. This is normally behind the laydown machine before the rollers begin compacting the mixture. Samples of HMA are normally analyzed for their "volumetric" properties, such as the percent air voids by volume. Some agencies also require HMA to be tested for asphalt content and aggregate gradation. When sampling HMA, it is important to obtain enough material to perform all the required tests plus extra material for retesting, if needed.

There are two methods for sampling bituminous paving mixtures. The mixture may be sampled from the roadway or out of a truck. Truck sampling is used only when roadway sampling is not practical.

Safety is very important when sampling hot mix asphalt due to the temperature of the mixture. Always wear protective garments and shoes to keep the hot mix asphalt from coming in contact with the skin. As with any construction project, being alert to traffic is important.

Common Sampling Errors

- Obtaining the entire sample from a single location.
- Not removing all the material from within a template.
- Contaminating the sample with underlying material
- Segregating the material while sampling.

SAMPLING METHODOLOGY

Apparatus

- Square ended shovel or scoop
- Template (roadway sampling)
- Clean sample container
- Protective clothing, insulated gloves, safety shoes

Roadway Sampling

Random sampling locations should be determined. Sample the uncompacted mat by placing a template through the entire lift of HMA, or using a square pointed shovel to create a sample area with vertical faces. Remove all material from within the template or between the vertical faces and place in a clean sample container. Avoid contaminating the sample with any underlying material. At least three increments should be obtained for each sample.

Template Placed in Asphalt Mat

Cleaning Asphalt Off Template into Sample Container

Truck Sampling

When roadway sampling is not practical, then truck sampling should be used.

Sample from the truckload by first removing approximately one foot of material from the outside of the mass. Using a square shovel or scoop, remove enough material from the sample area to provide approximately one-third of the sample size. Care must be taken to avoid segregating the material while sampling. Place each increment in the clean sample container. At least three increments should be obtained for each sample. Increments from more than one truckload should be included in the sample.

Sampling From a Truck

Scraping Sample Off Shovel into Sample Box

Sample Identification

Properly identify each sample by marking the sample container with a project identifier, the type of material, date, time, and the sample location. This is the minimum information that should be included with each sample.

PRACTICE FOR SUPERPAVE VOLUMETRIC DESIGN FOR HOT MIX ASPHALT (HMA)
AASHTO PP 28

AND

SPECIFICATION FOR SUPERPAVE VOLUMETRIC MIX DESIGN
AASHTO MP 2

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation, is a prerequisite for this training package.

- AASHTO TP 4, Standard Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) by Means of the SHRP Gyratory Compactor.
- AASHTO T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.
- AASHTO T 209, Maximum Specific Gravity of Bituminous Paving Mixtures.
- AASHTO T 283, Resistance of Compacted Bituminous Mixture to Moisture Induced Damage.
- AASHTO PP 2 Standard Practice for Mixture Conditioning of Hot Mix Asphalt (HMA)
- AASHTO PP 19, Volumetric Analysis of Compacted Hot Mix Asphalt (HMA)

GLOSSARY

Absorbed asphalt volume (V_{ba}) - the volume of asphalt binder absorbed into the aggregate (equal to the difference in aggregate volume calculated with bulk specific gravity and effective specific gravity).

Air Voids (V_a) - 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.

Asphalt Content (P_b) - the percent by mass of asphalt binder in the total mixture.

Bulk Specific Gravity ($G_{1,2,n;}$ G_{sb}, G_{mb}) - the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids connected to the surface of the aggregate particle) at a stated temperature relative to the mass in air of an equal volume of gas-free distilled water at a stated temperature. Can apply to individual aggregate stockpiles (G_1 through G_n), the blended aggregate (G_{sb}) or the mix (G_{mb}).

Dust to Binder Ratio ($P_{0.075}/P_{be}$) - ratio by weight of the percentage of aggregate passing the 0.075 µm (#200) sieve ($P_{0.075}$) to the effective asphalt content (P_{be}).

Effective Asphalt Volume (V_{be}) - the volume of asphalt binder which is *not* absorbed into the aggregate.

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

ESAL's - Equivalent Single Axle Loads, a measure of the damage done by an axle load expressed relative to the damage done by an 18,000 pound axle load.

HMA - Hot Mix Asphalt

Maximum aggregate size - one size larger than the nominal maximum aggregate size. (Note: This terminology and definition apply only to Superpave mix design.)

Nominal maximum aggregate size - one size larger than the first sieve that retains more than 10 percent of the aggregate. (Note: This terminology and definition apply only to Superpave mix design.)

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

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

Volume of Absorbed Asphalt (V_{ba}) - the volume of asphalt binder in the HMA that has been absorbed into the pore structure of the aggregate.

SUPERPAVE VOLUMETRIC DESIGN FOR HMA

This discussion addresses the standard practice of calculating the volumetric properties (e.g., the air voids (Va) in the total mix, the voids in the mineral aggregate (VMA), and the voids filled with asphalt (VFA)) of a Hot Mix Asphalt (HMA) mixture in terms of measured aggregate and mixture properties. Determination of the volumetric properties is central to the Superpave mix design process. Volumetric properties and the compaction characteristics from the Superpave Gyratory Compactor (SGC) are the measures used to evaluate the suitability of a trial mixture. The volumetric properties of a compacted mixture are specific to the combination of liquid asphalt binder, meeting the criteria of AASHTO MP1, and a blend of aggregates, which complies with the Superpave consensus property requirements. Typically, a number of aggregate blends will need to be examined in order to determine the least expensive combination of aggregates and asphalt that meet the criteria specified in AASHTO MP2.

The reader is referred to either of two publications for a thorough explanation of this mix design process and the terminology and theory associated with it. These publications are the following: *Superpave Level 1 Mix Design*, Superpave Series No. 2 (SP-2), Asphalt Institute, and the corresponding FHWA publication entitled *Background of Superpave Asphalt Mixture Design and Analysis*, Pub. # FHWA-SA-95-003, February 1995. During the study of one of these publications, the reader should become very familiar with concepts such as the bulk, effective, and apparent specific gravities. The reader should be able to determine the bulk specific gravity of the aggregate blend. The reader should understand that this value is not necessarily constant for a given aggregate blend since it may vary with facies changes and changes in mineralogy of a given aggregate source. The reader should understand the meaning of the maximum theoretical specific gravity and the manner in which it decreases with increasing asphalt content. The reader should also note that, for absorptive aggregates, the maximum theoretical specific gravity increases with time for a given total asphalt content and results in a corresponding reduction in the effective asphalt content of the mix. The reader should understand that, with absorptive aggregates, the effective specific gravity will change with time as asphalt is absorbed and it cannot be used in lieu of the bulk specific gravity of the aggregate blend when determining the VMA.

In addition to being able to calculate volumetric properties such as air voids, voids mineral aggregate, and voids filled asphalt, the reader should also know the manner in which the Superpave criteria limits vary with regard to the nominal maximum size of the aggregate. The reader will need to be able to plot the variation of each of these volumetric properties with variation in asphalt content and then be able to select an appropriate asphalt content that satisfies the various Superpave criteria. The reader is referred to Chapter 5 of *Mix Design Methods for Asphalt Concrete and Other Hot-Mix Types*,

MS-2, Sixth Edition, Asphalt Institute, for an explanation of the proper means to select an asphalt content with regard to the VMA curve.

The reader will also need to know whether a given mix compacted in the SGC satisfies the compaction limitations imposed on mixes by the Superpave criteria specified in AASHTO MP 2.

GENERALIZED MIX DESIGN PROCESS

There are four major steps in the volumetric mix design process. These steps consist of (1) Material Selection, (2) Selection of a Design Aggregate Structure, (3) Selection of a Design Asphalt Content, and (4) Evaluation of the Moisture Sensitivity of the Mixture.

Materials Selection - This process includes the selection of both an asphalt grade and aggregates that meet the Superpave criteria. The first step in this process is to determine the traffic in ESAL's that the proposed pavement will be subjected to during its intended life. This information is typically included in the contract documents and is used in both the selection of asphalt grade and aggregate materials. The selection of asphalt grade also necessitates an understanding of the climatic; e.g., temperature; environment in which the pavement will be located. This includes both the seven-day maximum high temperature and the single-day minimum low temperature for that particular geographic location. Climatic information of this type has been collected for over 20 years from over 7000 weather stations located in North America and is readily available from the FHWA. Adjustments can also be made to the reported recommended grade to account for heavy traffic, slow-moving traffic, or both. The most reliable procedure is to use the performance grade of asphalt specified in the contract documents.

As stated previously, the requirement for aggregate quality is also directly related to the anticipated traffic. Aggregate quality is also related to the depth (e.g., distance from the pavement surface) at which a given material will be used within a pavement structure. The quality criteria for Superpave aggregates are presented in the AASHTO specification MP 2 and the referenced texts. In order to be used in Superpave mixtures, the aggregate blends must meet two sets of criteria known as source properties and consensus properties. The source properties are established by the specifying agency and are specific to the geology of a particular region while the consensus properties are mandatory for all Superpave aggregate blends. Source property requirements may apply to each aggregate stockpile, but consensus properties apply to the combined blend of multiple stockpiles.

Selection of a Design Aggregate Structure - Once a group of aggregates has been identified, the combination of these aggregates with regard to the percentage of each used to make the aggregate blend will need to be determined. Not all blends of aggregates are satisfactory. The blend of aggregates needs to be such that the Superpave volumetric criteria are satisfied. Aggregate blends can either be coarse (below the maximum density line and the restricted zone) or fine (above the maximum density line and around the restricted zone). The referenced manuals suggest three aggregate structures be considered -- one fine, one coarse and one intermediate. The majority of Superpave mixes have been coarse mixes. Once a blend of aggregates has been selected to meet the

gradation requirements, the blended aggregate must also be shown to meet the Superpave consensus aggregate criteria.

The most difficult part of designing an aggregate structure is the creation of the VMA necessary to meet the volumetric criteria. A great amount of research has been conducted on the exact procedure to use for creating VMA and is presented in numerous technical papers. It is typically a trial and error process. However, there are some general guidelines that will assist in the creation of VMA. The following is a non-inclusive list of techniques that may be tried to increase VMA:

1. movement away from the maximum density line,
2. use of highly angular particles,
3. use of particles with a rough surface texture,
4. use of different shaped particles,
5. use of different composition of materials, i.e., siliceous vs. calcareous, and
6. reduction in the amount of $P_{0.075}$ used in the mix.

Selection of a satisfactory aggregate structure will consider economics in addition to satisfying the volumetric criteria. This may result in a large number of potential blends being considered.

Selection of the Design Asphalt Content - Selection of a trial asphalt content to initiate the design process will generally be made either on the basis of past experience or in accordance with the procedure described in the referenced literature. The proposed aggregate blend will then be combined with various proportions of asphalt from 0.5% lean to 1% rich of the trial asphalt content at 0.5% intervals resulting in a total of four asphalt contents being initially considered. A sufficient amount of the proposed aggregate blend will need to be prepared to permit two samples to be compacted in the SGC and the maximum specific gravity (Rice test) to be determined at each of the four asphalt contents. Preparation of the asphalt/aggregate mixtures for the SGC samples should be timed such that a minimum of 20 minutes is allotted between batches. Preparation of each asphalt/aggregate mixture at each asphalt content is considered one batch. Batched samples should be conditioned in a closed draft oven for a minimum of 2 hours prior to compacting the samples in the SGC. (See PP2 for details.) This is to permit time for the aggregates to absorb asphalt. All samples, including those for SGC and Rice tests, should be cured the same amount of time.

Keep in mind that the procedure used for design in the laboratory will need to closely match the field conditions at the time of construction. Failure to consistently test the materials at the same time interval will result in highly erratic maximum specific gravity values and possibly failure to achieve the required VMA.

After the necessary testing has been accomplished, the calculation of the volumetric parameters can begin. Calculation of these volumetric parameters is an iterative process that requires good note keeping and organizational skills. It is very important to use numeric values that correctly correspond

with the sample being tested. Use of a carefully constructed, accurate, computer spreadsheet is highly recommended. The averaged results of the various volumetric calculations need to be plotted relative to the corresponding asphalt content. The design asphalt content is selected as that which satisfies the specified volumetric criteria at 4 percent air voids. (See PP 19 for details.)

Evaluation of the Moisture Sensitivity of the Mixture - The identification of the combination of a design aggregate structure and a design asphalt content indicates that the mix design process is, hopefully, nearing completion. The mixture now only needs to demonstrate that it is capable of surviving the moisture sensitivity test without premature failure. This test is preformed in accordance with AASHTO T-283 specifications. It requires that a total of six replicate samples consisting of the proposed aggregate blend and asphalt binder, at the design binder content, be prepared and compacted to approximately 7% air voids. This group of samples is divided into two subsets with three of the samples being identified as the unconditioned control samples and the other three being identified as conditioned samples. At the end of the conditioning period all of the samples are loaded to failure in indirect tension. If the combination of asphalt binder and aggregate blend results in a mixture where the ratio of the strength of the conditioned to the unconditioned samples is 80% or more, then the mixture passes the test. If the combination of asphalt and the aggregate blend results in a mixture where the ratio of conditioned to unconditioned samples is less than 80%, then the mixture fails and the design process starts over. Alternatively, the use of anti-strip agents in the mix design may be considered.

Volumetric Analysis of Compacted Hot Mix Asphalt (HMA)

AASHTO PP 19

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance, is a prerequisite for this training package.

AASHTO T 84, Specific Gravity and Absorption of Fine Aggregate

AASHTO T 85, Specific Gravity and Absorption of Coarse Aggregate

AASHTO T 100, Specific Gravity of Soils

AASHTO TP 53, Method for Determining the Asphalt Content of Hot Mix Asphalt (HMA) by the Ignition Method

AASHTO T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures

AASHTO T 168, Sampling of Bituminous Paving Mixtures

AASHTO T 209, Maximum Specific Gravity of Compacted Bituminous Mixtures

GLOSSARY

Absorbed asphalt volume (V_{ba}) - the volume of asphalt binder absorbed into the aggregate (equal to the difference in aggregate volume calculated with bulk specific gravity and effective specific gravity).

Air Voids (V_a) - 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.

Asphalt Content (P_b) - the percent by mass of asphalt binder in the total mixture.

Bulk Specific Gravity ($G_{1,2,n;}$ G_{sb}, G_{mb}) - the ratio of the mass in air of a unit volume of a permeable material (including both permeable and impermeable voids connected to the surface of the aggregate particle) at a stated temperature relative to the mass in air of an equal volume of gas-free distilled water at a stated temperature. Can apply to individual aggregate stockpiles (G_1 through G_n), the blended aggregate (G_{sb}) or the mix (G_{mb}).

Effective Asphalt Volume (V_{be}) - the volume of asphalt binder which is *not* absorbed into the aggregate.

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

ESAL's - Equivalent Single Axle Loads, a measure of the damage done by an axle load expressed relative to the damage done by an 18,000 pound axle load.

HMA - Hot Mix Asphalt

Maximum aggregate size - one size larger than the nominal maximum aggregate size. (Note: This terminology and definition apply only to Superpave mix design.)

Nominal maximum aggregate size - one size larger than the first sieve that retains more than 10 percent of the aggregate. (Note: This terminology and definition apply only to Superpave mix design.)

Theoretical Maximum Specific Gravity (G_{mm}) - 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.

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

Volume of Absorbed Asphalt (V_{ba}) - the volume of asphalt binder in the HMA that has been absorbed into the pore structure of the aggregate.

Calculation of Volumetric Parameters of Hot Mix Asphalt (HMA)

This discussion addresses the standard practice for calculation of the various volumetric parameters used in the control of production of HMA. (Analysis for design purposes is described in AASHTO PP28.) Input values for the calculation of the various parameters are obtained from other AASHTO test procedures. Calculation procedures are presented for the following parameters: (1) air void content (V_a), the volume percent of air voids in the compacted asphalt mixture; (2) voids filled with asphalt (VFA), the percent volume of the VMA filled with asphalt; (3) voids in the mineral aggregate (VMA), the volume percent of voids in the mineral aggregate present in the compacted asphalt mixture including the volume of air and the volume of effective asphalt; and (4) the effective asphalt content (P_{be}), the percent of the total asphalt content not absorbed into the aggregate and available to bind the mixture together.

TEST METHODOLOGY

Test Procedure

HMA material for this analysis will be production HMA material preferably obtained from behind the paver or from another agreed-upon production source. The HMA sample material obtained in the field should be stored temporarily in an insulated container for transport from the field to the laboratory. Once in the laboratory, the sample should immediately be quartered on a clean, metal-surfaced table. Two of the quarters should then be placed in pans and inserted into an oven to re-heat the material to the compaction temperature. These samples will be used for determination of the bulk specific gravity of specimen compacted in the SHRP Gyratory Compactor (SGC). The third quarter should be placed into a pan and permitted to cool to ambient temperature. It will be used in the determination of the maximum specific gravity. The fourth quarter should be placed in a pan, labeled, and set aside for determination of the asphalt and aggregate content.

Once the bulk specific gravity samples have attained the proper compaction temperature, procedures for compaction of the material in the SGC should begin. Samples should be compacted in accordance with procedure described in AASHTO TP 4. The resulting plugs of compacted material should be extruded from the compaction molds and set aside to cool to ambient temperature.

While these samples are cooling, the fourth sample can be inserted into the ignition furnace for the determination of the asphalt and aggregate contents. This test should be performed in accordance with TP-53. The results of this test should be recorded as P_b and P_s.

During the time the third quartered sample is cooling to room temperature it should be thoroughly crumbled into small fractions of asphalt coated particles. Once this material has cooled to 25°C (77°F) the test for the determination of the maximum specific gravity can begin. This test should be performed in accordance with AASHTO T-209. The results of this test should be recorded as G_{mm}.

Note: It is especially important, when absorptive aggregates are used for production of the mix, that the time elapsed between the time the mix was produced and the time at which the mixture was permitted to cool to a temperature below the compaction temperature is similar to the time that the mix was permitted to "cure" during the mix design process. Failure to attain similarity between these times will result in differences between the maximum density values determined in design and those determined during production in the field. This may result in a failure to attain the desired VMA values during production.

The reader should also note: The accuracy of the various specific gravity calculations is extremely important. When specific gravities are determined to an accuracy 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 reported anywhere in the range of 3.4 to 5.0 percent). Therefore, a scale capable of making measurements to four significant figures should be used for the measurement of mass for the various specific gravity calculations.

Once the plugs of compacted material have cooled to approximately 25°C (77°F) the determination of the bulk specific gravity of the compacted mixture can begin. The bulk specific gravity should be determined in accordance with T 166. The results of this test should be recorded as G_{mb}.

The bulk specific gravity of the individual aggregate stockpiles should be determined on a weekly or, at least, monthly basis. A representative sample should be obtained of each stockpile of aggregate. The size of the sample required is related to the maximum aggregate size of the stockpile sampled. The particle gradation and bulk specific gravity should be determined for each fraction using the appropriate AASHTO test procedure (T 84 or 85). The percent of each fraction in the aggregate blend relative to the total mass of the aggregate blend should be recorded and reported as P_1, P_2, P_3, etc. The bulk specific gravity should be reported as G_1, G_2, G_3, etc., to correspond to the numbering of the percentage of each stockpile used in the aggregate blend.

Calculations

After the completion of the various tests, the first parameter to calculate is the bulk specific gravity of the aggregate blend of the constituents of the particular HMA mixture in production (G_{sb}). This calculation is simply a weighted average of the constituent specific gravities:

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

Next calculate the effective specific gravity (G_{se}) of the aggregate by the following equation with the

understanding that G_b is the specific gravity of the asphalt binder obtained from the asphalt supplier, and P_b is the percent of binder used in the mix:

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

Once the effective specific gravity and the bulk specific gravity of the aggregate blend have been calculated, an estimate of the absorbed asphalt content (P_{ba}) can be made using the following equation:

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

Understanding that the absorbed asphalt content is expressed as a percentage of the mass of the aggregate, an estimate of the effective asphalt content (P_{be}) of the HMA mixture can be made using the following equation:

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

Calculate the percent voids in the mineral aggregate (VMA) using the following equation where P_s represents the percent of aggregate by the total mass of the mixture:

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

Calculate the percent air void (V_a) in the compacted HMA using the following equation:

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

Calculate the percent of voids filled with asphalt binder (VFA) as a portion of the voids in the mineral aggregate using the following equation:

$$VFA = VMA - V_a$$

Report these values in the appropriate locations on the data sheet provided by your employer. Specific gravity results should be reported to the nearest 0.001 and VMA, VFA and V_a should be reported to the nearest 0.1%.

Note: *Follow the rounding rules specified by your state.*

STANDARD METHOD FOR PREPARING AND DETERMINING THE DENSITY OF HOT MIX ASPHALT (HMA) SPECIMENS BY MEANS OF THE SHRP GYRATORY COMPACTOR

AASHTO TP4

Developed by
FHWA Multi-Regional Asphalt Training and Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation, is a prerequisite for this training package.

•AASHTO 168, Sampling Bituminous Paving Mixtures

•AASHTO PP 2, Short and Long-Term Mixture Conditioning of Hot Mix Asphalt

GLOSSARY

Corrected relative density (C_x) = the density of a specimen determined at x number of gyrations and expressed as a percentage of the maximum theoretical specific gravity of the mixture, corrected for the fact that the cylinder is not a smooth sided cylinder.

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

N-design (N_{des}) = the design number of gyrations, also determined based on climate and design traffic level and used for design of the asphalt mixture.

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

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

Compacted samples of hot mix asphalt (HMA) are used to determine the volumetric and mechanical properties of the mixture during the mix design phase and for quality control/quality assurance during construction. These volumetric and/or mechanical properties are then evaluated to select a mix design or control the mixture during production. The specimens produced with the gyratory compactor simulate the density, aggregate orientation and structural characteristics of this mixture in the actual roadway.

The gyratory compactor is used to prepare specimens for later analysis of the volumetric properties of the mixture, evaluation of mixture densification properties, evaluation of moisture sensitivity, field quality control or other testing purposes.

This text will explain the method of compacting samples of hot mix asphalt and determining their percent compaction using the SHRP gyratory compactor. This method may be used with laboratory fabricated specimens, as in the mix design process, or with plant-mixed material during construction.

Common Testing Errors

- Not placing a paper protection disk on the bottom or top of the specimen.
- Not compacting the mixture at the proper temperature.
- Not properly verifying the calibration of the compactor prior to use.
- Not leveling off the specimen using dwell gyrations or a square load.
- Not removing the paper disks while specimen is still warm.
- Not preheating the mold and base plate.
- Not charging the mold with mix quickly, in one lift without spading or rodding.

TEST METHODOLOGY

Apparatus

- Superpave Gyratory Compactor, including a device for measuring and recording the height of the specimen throughout the compaction process. The compactor may also include a printer or a computer and software for collecting and printing the data.
- Specimen molds
- Thermometer
- Balance readable to 1 gram
- Oven
- Calibration equipment recommended by compactor manufacturer
- Safety equipment: insulated gloves, long sleeves, etc.
- Miscellaneous equipment: paper disks, lubricating materials recommended by compactor manufacturer, scoop or trowel for moving mixture, funnel or other device for ease of loading mixture into mold (optional).

Calibration

The means of calibrating the gyratory vary with different manufacturers. Refer to the operation manual of the particular brand and model of gyratory available for use. Calibration of the following items should be verified at the noted intervals or according to manufacturers' recommendations:

Item	Tolerance	Calibration Interval
Height	Record to nearest 0.1 mm, Compact to 115 $\pm$ 5 mm	Daily
Angle	1.25° $\pm$ 0.02°	Every 1-3 months
Pressure	600 $\pm$ 18 kPa	Every 6 months
Speed of Rotation	30.0 $\pm$ 0.5 gyrations per minute	After mechanical changes or every 6 months

Mold and platen dimensions, hardness and smoothness should also be verified. Oven temperature should be verified; oven must be capable of maintaining the temperature as required for PP2, *Practice for Short and Long Term Aging of Hot Mix Asphalt (HMA).*

Sample Preparation

Samples for compaction in the gyratory may be obtained in one of two ways; mixture may be prepared in the laboratory or plant-mixed material may be obtained from roadway or truck samples.

For the determination of volumetric properties for mix design or quality control, a finished specimen height of 115 $\pm$ 5 mm is desired. When producing specimens for testing under AASHTO T283, *Resistance of Compacted Bituminous Mixture to Moisture Induced Damage*, a finished specimen height of 95 mm is required and for Superpave mix analysis, a specimen height of 140 mm is desired. In these two cases, the batch weights must be varied to provide the desired specimen height at a specified air void content; samples are then compacted to the specified height rather than a fixed number of gyrations. (See AASHTO T283 for more details.)

Laboratory Prepared Materials

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

1. Weigh out the appropriate amounts of the required aggregate size fractions and combine in a bowl to the proper batch weight. Typically, a batch weight of 4500 - 4700 grams of aggregate will provide enough material for a finished specimen height of 115 $\pm$ 5 mm, if the combined aggregate specific gravity is between 2.55 - 2.70.

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

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

4. A mechanical mixer is recommended for preparing laboratory mixtures because mixing such a large quantity of material by hand is difficult. Mixing should continue until the asphalt binder is uniformly distributed over the aggregate particles.
5. Determine the proper compaction temperature range for the asphalt binder used. This is defined as the range of temperatures that yields a binder viscosity of approximately 0.28 ± 0.03 Pa–s. Modified binders may not conform to these mixing and compaction temperatures, so the manufacturer's recommendations should be followed.

6. After mixing, spread the loose mixture in a flat, shallow pan and short term condition the mixture as detailed in PP2, *Practice for Short and Long Term Mixture Conditioning of Hot Mix Asphalt (HMA).*

7. Place the compaction mold and base plate in an oven to preheat at the required compaction temperature for a period of 30 to 60 minutes prior to the start of compaction.

8. Following the short term conditioning period, bring the mixture to the proper compaction temperature, if different from the conditioning temperature, by placing it in another oven at the compaction temperature for up to 30 minutes.

9. After the mixture comes to the proper compaction temperature, proceed with compaction in the gyratory as outlined below.

Plant-Mixed Materials

When plant-mixed materials are sampled from the roadway or truck, no short term aging is required. The mixture must be brought to the proper compaction temperature then compacted and analyzed as described below. Place the material in an oven at the compaction temperature and bring the mixture to the proper temperature by careful, uniform heating. The mix should be stirred periodically to help assure uniform heating. In general, the shortest heating time that will bring the mixture to the compaction temperature is preferred. Avoid over-heating the mix. When the compaction temperature has been reached, proceed with specimen compaction as outlined below.

Compaction Procedure

Once the mixture sample has reached the proper compaction temperature, it is compacted in the gyratory. For most purposes, the finished specimens will be used to calculate volumetric properties and the specimens will be compacted to a fixed number of gyrations. When preparing specimens for testing under AASHTO T283, *Resistance of Compacted Bituminous Mixture to Moisture*

Induced Damage, or in Superpave mix analysis, specimens may be compacted to a fixed height to produce a specified air void content.

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

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

2. Verify that height recording device is turned on and is reading in the proper units. Height calibration should be verified daily.

3. When the compaction temperature has been reached, remove the mold and base plate from the oven. Put the base plate in position in the mold and place a paper disk in the bottom of the mold.

4. Charge the mixture into the mold in one lift. A funnel or other device may be used to place the mixture into the mold. Take care to avoid segregating the mix in the mold, but work quickly so that the mixture does not cool excessively during loading. Level the mix in the mold and place a paper disk on top.

5. Place the mold in the gyratory as per manufacturer's recommendations. (Some gyratories allow charging the mold with mix after the mold has been positioned in the compactor.) Lubricate the mold or gyratory parts as recommended by the manufacturer.

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

7. Apply the gyratory angle of $1.25° \pm 0.02°$ to the specimen.

8. Input the desired number of gyrations (N_{max}) to apply on the gyratory control pad. Start the compaction process and compact to the required number of gyrations. The number of gyrations to apply is determined from the following table and is based on the expected design traffic volume in Equivalent Single Axle Loads (ESALs) over a 20-year design life; this information is usually provided in the contract documents. Compact to the desired number of gyrations according to PP28. Volumetric and densification properties are determined at N_{ini} and N_{des} as well as N_{max}, as described on the following page (from PP28).

Design ESALs (million)	Compaction Parameters			Typical Roadway Application[2]
	$N_{initial}$	N_{design}	N_{max}	
<0.3	6	50	75	Applications include roadways with very light traffic volumes such as local roads, county roads, and city streets where truck traffic is prohibited or at a very minimal level. Traffic on these roadways would be considered local in nature, not regional, intrastate, or interstate. Special purpose roadways serving recreational sites or areas may also be applicable to this level.
0.3 to < 3	7	75	115	Applications include many collector roads or access streets. Medium-trafficked city streets and the majority of county roadways may be applicable to this level.
3 to < 30	8	100	160	Applications include many two-lane, multilane, divided, and partially or completely controlled access roadways. Among these are medium to highly trafficked city streets, many state routes, US highways, and some rural interstates.
> 30	9	125	205	Applications include the vast majority of the US Interstate system, both rural and urban in nature. Special applications such as truck-weighing stations or truck-climbing lanes on two-lane roadways may also be applicable to this level.

(1) Design ESALs are the anticipated project traffic level expected on the design lane over a 20-year period. Regardless of the actual design life of the roadway, determine the design ESALs for 20 years and choose the appropriate N_{design} level.

(2) Typical Roadway Applications as defined by *A Policy on Geometric Design of Highway and Streets*, 1994, AASHTO.

Note: When specified by the agency and the top of the design layer is ≥ 100 mm from the pavement surface and the estimated design traffic is ≥ 0.3 million ESALs, decrease the estimated design traffic level by one, unless the mixture will be exposed to significant main line and construction traffic prior to being overlaid. If less than 25 % of the layer is within 100 mm of the surface, the layer may be considered to be below 100 mm for mixture design purposes.

Note: When the design ESALs are between 3 to < 10 million ESALs the agency may, at their discretion, specify $N_{initial}$ at 7, N_{design} at 75, and N_{max} at 115, based on local experience.

9. The gyratory will stop automatically when the specified N_{max} has been reached. Remove the angle from the specimen and raise the loading ram if needed (this is done automatically on some gyratories).

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

Density Procedure

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

1. Prepare a loose sample of the same mixtures and determine the maximum theoretical specific gravity (G_{mm}) in accordance with AASHTO T209, *Maximum Specific Gravity of Bituminous Paving Mixtures*.

2. Using the gyratory's height recording system, record the height of the specimen to the nearest 0.1 mm after each gyration.

3. Measure and record the mass of the compacted specimen to the nearest 1 g. Determine the bulk specific gravity (G_{mb}) of the compacted specimen in accordance with AASHTO T166, *Bulk Specific Gravity of Compacted Bituminous Paving Mixtures Using Saturated Surface Dry Specimens*.

Calculations

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

Calculate the corrected relative density of the specimen at any number of gyrations as follows:

$$C_x = (G_{mb}h_m/G_{mm}h_x)\times 100\%$$

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 (determined using T166)
G_{mm} = Maximum theoretical specific gravity of the mixture (determined according to T209)
h_m = Height of the extruded specimen in millimeters
h_x = Height of the specimen during compaction at x gyrations, in millimeters

Report the relative density, C_x, to the nearest 0.1 percent.

[Note: the relative density is described as "corrected" because of the assumptions that underlie the calculations. The calculation of the volumetric properties of the compacted specimen at any point in the compaction process begins with the assumption that the specimen is a smooth sided cylinder 150mm in diameter with a height equal to the specimen height at the number of gyrations of interest, typically N_{ini}, N_{des} or N_{max}. The uncorrected bulk specific gravity of the specimen can then be calculated based on the measured mass of the specimen and the volume of a smooth sided cylinder. The actual bulk specific gravity of the specimen is measured at N_{max} according to AASHTO T166. The uncorrected bulk specific gravity of the specimen is also calculated at N_{max}. The ratio of the measured bulk specific gravity to the uncorrected bulk specific gravity at N_{max} can be used as a correction factor to backcalculate the corrected bulk specific gravity at any number of gyrations. Using the correction factor corrects for the fact that the compacted specimen is not a smooth sided cylinder but does in fact have some surface irregularities and open texture. In other words, the actual volume of the specimen is less than the volume of a smooth sided cylinder due to this surface texture. The corrected bulk specific gravity of the specimen, then, is actually greater than the uncorrected bulk specific gravity because the volume is smaller. These assumptions and calculations are implicitly included in the calculations as described here.]

Example:

Given: G_{mb}, measured bulk specific gravity = 2.369
G_{mm}, maximum theoretical specific gravity = 2.403
h_m, height of extruded specimen = 117.5 mm

Calculate C_x at N_{ini} = 8 gyrations, h_8 = 135.4 mm
N_{des} = 109, h_{109} = 119.4 mm
N_{max} = 174, h_{174} = 117.5 mm

$C_8 = (2.369 \times 117.5 \text{ mm}/2.403 \times 135.4 \text{ mm}) \times 100\% = 85.6\%$
$C_{109} = (2.369 \times 117.5 \text{ mm}/2.403 \times 119.4 \text{ mm}) \times 100\% = 95.3\%$
$C_{174} = (2.369 \times 117.5 \text{ mm}/2.403 \times 117.5 \text{ mm}) \times 100\% = 98.6\%$

GYRATORY COMPACTOR

Gyratory Compactor

Pouring Mix into the Mold

Placing Mold into the Compactor

Mold in Compactor Ready to Test

BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING SATURATED SURFACE-DRY SPECIMENS

AASHTO T 166

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T 168, Sampling Bituminous Paving Mixtures

- AASHTO TP 4, Method For Preparing and Determining the Density of Hot Mix Asphalt (HMA) Specimens by Means of a Gyratory Compactor.

GLOSSARY

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

Saturated surface dry (SSD): the condition of a material when it has absorbed as much water as it can and the outside of the material has no free water.

BULK SPECIFIC GRAVITY OF COMPACTED BITUMINOUS MIXTURES USING SATURATED SURFACE-DRY SPECIMENS

The compaction of Hot Mix Asphalt (HMA) both in the field and in the laboratory is an important characteristic to be determined for mixture quality control. The bulk specific gravity of compacted specimens can be determined on pavement cores or laboratory compacted specimens. The bulk specific gravity of compacted bituminous mixtures (G_{mb}), using a saturated surface-dry specimen, is used to determine air voids (V_a) and may be used for comparison between roadway compaction tests and laboratory compacted specimens.

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

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

Common Testing Errors

- Submerged specimen touches the side of the water container.
- Water temperature is not 25°±1°C (77°±1.8°F).
- Specimens with high voids (>10%) may absorb excess water. (Use AASHTO T 275)
- Dirty water used.
- Specimens not cooled to 25°±5°C (77°±9°F).

TEST METHODOLOGY

Apparatus

< Balance (accurate to 0.1 gram).

< Oven for heating specimen

< Submersion basket

< Container for water

< Damp towel

Sample Preparation

The sample should be secured using AASHTO T 168. The mixture should then be prepared for testing using AASHTO TP 4, AASHTO T 245, or another suitable compaction method.

Testing Procedure

Once the specimen has been compacted using one of the above methods, it must be cooled to 25E±5E (77E±9EF). Weigh the dry specimen and record the dry mass (A) to the nearest 0.1g.

Submerge the specimen in water that is at a temperature of 25E±1EC (77E±1.8EF) and suspend it from the scale being careful not to trap any air bubbles under the specimen. Record the submerged mass (C) to the nearest 0.1g after the specimen has stabilized in the water for 3 to 5 minutes. *(Note: For samples greater than 1000 g, a balance readable to 1 g may be used.)*

Weighing Specimen to Determine G_{mb}

Remove the specimen from the water and quickly blot the specimen surface dry. Weigh the specimen and record the SSD mass (B) to the nearest 0.1g.

Blotting Sample Dry

Calculations

Calculate the bulk specific gravity of the specimen as follows:

$$G_{mb} = \frac{A}{B-C}$$

where:

A = dry mass
B = SSD mass
C = submerged mass

Report bulk specific gravity to three decimal places.

Example

Given: Dry mass of the specimen (A) = 4799.0 g
SSD mass of the specimen (B) = 4801.0 g
Submerged mass of the specimen (C) = 2799.0 g

$$Gmb = \frac{4799.0}{4801.0 \& 2799.0} = 2.397$$

STANDARD PRACTICE FOR MIXTURE CONDITIONING OF HOT MIX ASPHALT (HMA)

AASHTO PP2

Developed by
FHWA Multi-Regional Asphalt Training and Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation, is a prerequisite for this training package.

- AASHTO T 168, Sampling Bituminous Paving Mixtures

GLOSSARY

Long term mixture conditioning - a laboratory aging procedure used to simulate the effects of bituminous mixture aging that occur over the service life of a pavement.

Oxidation - a type of chemical reaction that occurs between asphalt and oxygen that changes the stiffness of the asphalt.

Short term mixture conditioning - a laboratory procedure used to simulate the effects of bituminous mixture aging and asphalt absorption that occur during production and placement of hot mix asphalt in a hot mix plant.

MIXTURE CONDITIONING OF HOT MIX ASPHALT (HMA)

Samples of bituminous mixtures prepared in the laboratory have different properties from mixtures produced in a hot mix asphalt plant for a number of reasons. One of these reasons is that the hot mix ages as it goes through the plant, and during storage and transportation, until it cools down. The asphalt binder reacts with oxygen in the air and becomes harder and more brittle. Some volatile fractions of the binder may also be driven off at the high temperatures encountered during construction. Absorption of some of the asphalt into the aggregate can also occur at high temperatures during construction while the binder is still fluid enough to migrate into the pores of the aggregate. Aging continues at a slower rate throughout the service life of the pavement. The aging (or oxidation) reaction proceeds at a higher rate in hot climates or during the summer months when the temperatures are higher.

It is important to account for these changes in the mixture properties when preparing mixtures in the lab. One way to account for these changes is to condition the laboratory mixtures in such a way as to simulate the aging that happens during construction and service. The short term mixture conditioning procedure is used to simulate the aging that occurs during construction (up to the point of compaction) and is used during the mix design procedure. Long term aging is used to simulate the aging that occurs over the many years the pavement is in service. Consequently, long term aging is used when performing tests to simulate mixture properties late in the life of the pavement, such as when analyzing the resistance of a mixture to low-temperature cracking using Superpave mixture analysis and the indirect tension tester. Long term mixture conditioning follows short term conditioning for laboratory-prepared mixtures.

This text will outline the procedures used for short and long term aging of bituminous mixtures. Short term aging is routinely used for mix design and other purposes, while long term aging is less commonly used.

Common Testing Errors

- Failure to calibrate the oven temperature resulting in aging at an improper temperature.
- Not spreading the mixture uniformly across a pan of sufficient size.
- Failing to record the start time for the aging procedures.
- Short term aging plant mixed material.
- Failing to stir the mix every 60 ± 5 minutes to ensure uniform aging.

TEST METHODOLOGY

Apparatus

- Oven capable of maintaining temperatures from room temperature up to 150° ± 3°C (302° ± 5.4°F).
- Loading device capable of applying a static 56 kN load at a rate of 72.00 ± 0.05 kN/minute.
- Thermometers covering the range from 50°C to 260°C (122°F to 500°F) readable to the nearest 1°C (2°F).
- Miscellaneous shallow metal cake pan for aging loose mix, metal spatula or spoon for stirring, oven gloves.

Mixture Conditioning for Volumetric Mix Design

Sample Preparation

Short term mixture conditioning for volumetric mix design is applicable to laboratory-prepared mixtures only. Mixtures are prepared by mixing as described in TP 4 or elsewhere.

After mixing at the proper mixing temperature for the binder used, the loose mix is spread evenly in a pan to an even thickness of between 25 and 50 mm (1 to 2 in.).

Procedure

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

Stir the mixture after 60 ± 5 minutes to ensure uniform aging.

At the end of the aging period, remove the mixture from the oven and complete sample preparation as required for the tests to be conducted.
Report the mixture properties and aging conditions. Specifically, report the binder grade and content (to the nearest 0.1%) and the aggregate type and gradation, if possible. For the conditioning information, report the laboratory mixing temperature and short term mixture conditioning temperature to the nearest 1°C (2°F) and the short term conditioning duration to the nearest 1 minute.

Mixture Conditioning for Mechanical Property Testing - Long Term Mixture Conditioning

Sample Preparation

The long term mixture conditioning procedure can be applied to laboratory-prepared samples following short term aging, to plant-mixed HMA or to compacted roadway samples when needed to simulate long term aging effects. This mixture conditioning step is used when samples will be tested for mechanical properties, such as indirect tensile creep or strength.

Loose Mix (Laboratory-prepared or Plant-mix)
Laboratory-prepared mixture should be conditioned following the procedure described for volumetric mixture design above, except that the conditioning should be completed for 4 h ± 5 minutes at a temperature of 135° ± 3°C (275 ± 5.4°F). Plant-mixed material does not need to be short term conditioned.

Compact the HMA sample according to TP4 to the level of compaction required for the tests to be conducted. Do not extrude the specimen from the mold.

Condition the compacted sample by cooling in the mold to 60° ± 3°C (140° ± 5.4°F). This typically takes about 2 hours.

The ends of the specimen may not be parallel. The ends are squared up by applying a static load in a testing device. Increase the load from 0 kN at a rate of 72.00 ± 0.05 kN/minute. Release the load at the same rate when the ends of the specimen are level or when the load reaches a maximum of 56 kN.

Remove the specimen from the testing machine and allow to cool 16 ± 1 hours at room temperature. The sample should be extruded from the compaction mold after cooling for 2-3 hours.

Compacted Roadway Specimens
Condition the specimen to 60 ± 1°C (140° ± 1.8°F) by placing it in a 60°C (140°F) oven for approximately 2 hours. Cool the specimen at room temperature for approximately 16 ± 1 hours.

Procedure

Place the prepared specimen on a rack in an oven set to 85 ± 3°C (185° ± 5.4°F). Long term condition the specimen for 120 ± 0.5 hours. After that time period, turn off the oven and open the door. Allow the oven and specimen to cool to room temperature. This typically takes about 16 hours. Do not touch or remove the specimen from the oven until the end of this cooling period.

Remove the specimen from the oven and test as required.

MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES

AASHTO T 209

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
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NOTE

Successful completion of the following training material, including examination and performance evaluation, is a prerequisite for this training package.

- AASHTO T 168, Sampling Bituminous Paving Mixtures

GLOSSARY

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

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

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

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

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

MAXIMUM SPECIFIC GRAVITY OF BITUMINOUS PAVING MIXTURES

The volumetric properties of Hot Mix Asphalt (HMA) must be controlled during design and production in order to produce durable pavements. James Rice invented a test to measure the volume of a mixture with all the air voids removed. The maximum specific gravity (G_{mm}) of a bituminous mixture is the ratio of the mass of the loose sample to the mass of an equal volume of water at the standard temperature of 25EC (77EF).

G_{mm} is used along with the bulk specific gravity (G_{mb}) of the compacted mixture to determine air voids (P_a). It is often used also for determining the percent of compaction in laboratory specimens or during roadway compaction.

This text will explain the flask method for determining the maximum specific gravity. The flask method is the preferred test method due to the lower variability of the method.

Common Testing Errors

- Not breaking up the sample completely.
- Not maintaining less than 30 mm absolute pressure which could be attributed to one of the following:
    a. Air bubble in mercury manometer
    b. Manometer not connected directly to pycnometer
    c. Clogged vacuum lines
    d. Moisture or foreign material getting into the vacuum pump
- Not agitating the sample enough.
- Air bubbles trapped in the pycnometer when the cover is placed on it.
- Temperatures of water not checked.
- Uncoated particles or particles that rupture under vacuum which absorb water.
- Overheating absorptive materials.

TEST METHODOLOGY - FLASK METHOD

Apparatus

Pycnometer and Flask

- Pycnometer or flask
- Thermometer
- Mercury Manometer
- Vibrating Table (optional)
- Pycnometer top or cover glass
- Scale
- Vacuum pump, tubing and connectors

Sample Preparation

If the sample is not tested soon after it has been sampled, it will cool down and need to be reheated in the oven before the G_{mm} test can be run. If necessary, heat the sample only enough to soften it.

Reduce the sample to the proper size, if necessary, by quartering or other suitable means that will ensure a representative sample. See Table 1 below.

Maximum Aggregate Size	Minimum Sample Size
25.0 mm (1 in.)	2500 g
19.0 mm (3/4 in.)	2000 g
12.5 mm (1/2 in.)	1500 g
9.5 mm (3/8 in.)	1000 g
4.75 mm (#4)	500 g

Table 1

Separate the particles of coarse aggregate. Break up any clumps of fine aggregate so that no clump is larger than 6.5 mm (¼ in.). Stirring or spading the mixture as it cools will prevent clumps. If the clumps are difficult to break up, warming the mixture for a few minutes will be helpful.

Stirring Sample and Breaking Clumps

Allow the mixture to cool to room temperature before proceeding with the test.

Calibration of Pycnometer

The flask or pycnometer is calibrated by filling the vessel with water. The water temperature needs to be 25EC (77EF). Place the cover or a glass cover plate on the vessel, being sure that no air bubbles are trapped. Dry the outside of the vessel, cover, and then weigh it. Record the mass to the nearest 0.1 gram. This is mass D, the mass of the pycnometer filled with water at the test temperature. If temperatures other than 25EC (77EF) are encountered during testing, the vessel should be calibrated at a higher and a lower temperature. A calibration curve will then need to be developed for the pycnometer.

Test Procedure

Tare the pycnometer on a scale and add the sample. Record the mass of the sample to the nearest 0.1 gram. This mass is the dry sample in air (A).

Add enough water to completely cover the sample.

Connect the pycnometer to the vacuum system and remove the entrapped air. Maintain a vacuum, as measured by a mercury manometer, of 30 mm or less absolute pressure for 15±2 minutes. Continuous agitation is recommended to help release the air bubbles. This agitation can best be completed with the use of a vibrating table. If continuous agitation is not possible, rock or shake the pycnometer at approximately 2 minute intervals for the duration of the air removal.

After the 15 minute vacuum period is complete, slowly release the vacuum and allow the pycnometer and sample to sit for 10±1 minute.

The pycnometer may be placed in a 25EC (77EF) water bath for the ten minutes or water of the proper temperature may be added to fill the pycnometer. If a waterbath is not used, the temperature of the water in the pycnometer needs to be adjusted to 25E±1EC (77E±1.8EF).

If it is not possible to maintain the proper temperature, correction factors for the change in density of the water and the asphalt cement must be used in conjunction with a calibration curve for the pycnometer.

Place the top or cover glass on the pycnometer, being sure that there are no air bubbles trapped inside. Dry the outside of the pycnometer. Weigh the pycnometer and record the mass to the nearest 0.1 gram. This is the mass of the pycnometer filled with the sample and water at the test temperature (E).

(Note: For samples greater than 1000 g, a balance readable to 1 g may be used.)

Sample Being Tested

Calculations

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

where: A = Mass of dry sample in air
D = Mass of pycnometer filled with water at test temperature
E = Mass of pycnometer filled with the sample and water at test temperature

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

Example

Given: Mass of dry sample in air (A) = 2020.0 g
Mass of pycnometer filled with water at test temperature (D) = 7800.0 g
Mass of pycnometer filled with sample and water at test temperature (E) = 9000.0 g

$$\frac{2020.0}{2020.0 + 7800.0 - 9000.0} = 2.463$$

METHOD FOR DETERMINING THE ASPHALT CONTENT OF HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD

AASHTO TP 53

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

, AASHTO T 168

GLOSSARY

Ignition oven: A muffle furnace specifically designed for the purpose of burning off organic components from a material at high temperatures.

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

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

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

METHOD FOR DETERMINING THE ASPHALT CONTENT OF HOT MIX ASPHALT (HMA) BY THE IGNITION METHOD

Consistently maintaining the proper asphalt content in HMA paving mixtures is a key factor in producing quality pavements. Various means of determining asphalt content, such as chemical extraction or nuclear gauges, have been used for many years. Recently, a new technology has been perfected by the National Center for Asphalt Technology (NCAT). This new technology uses a very high temperature oven, commonly called a muffle furnace, to burn off the asphalt. By comparing the mass of the sample before and after the burn off, the asphalt content can be determined. Some aggregates break down at the high temperatures employed in the test, and, therefore, a correction factor for each mix may be needed to produce accurate results. After the asphalt content is determined, the aggregate that is left can be tested for gradation and other properties. *(Note: Some aggregates have demonstrated significant breakdown at the high temperatures applied in this test and may produce erroneous gradation and specific gravity test results. In some cases where the breakdown is consistent, an appropriate correction factor can be determined and applied. For those materials for which no consistent correction factor can be determined, test results on the aggregate should be considered for informational use only and not used for acceptance or rejection of the mix.)* Although the technician may encounter very hot materials and must use proper precautions, this is the easiest and safest method available for determining asphalt content and providing clean aggregate for further testing. This test method is appropriate for both field labs conducting quality control tests and Agency labs performing independent assurance, verification and acceptance testing.

Common Testing Errors

- Moisture in the sample.
- Aggregate correction factor not used.
- Materials used for calibration were not the same as project materials.
- Inaccurate asphalt contents used for calibration.
- Improper loading of sample baskets.

TEST METHODOLOGY

There are two methods listed in AASHTO TP 53 which may be used for this test. They are basically the same; the difference is related to the type of equipment used. Some ignition ovens have built in scales and processors that can detect when the test is complete and report the results (method A). Other ovens require the operator to determine the end point and calculate the results (method B). The calibration and sample preparation are the same for both methods.

Apparatus

< Balance (accurate to 0.1 g)

< Approved ignition oven

< Sample baskets provided by the oven manufacturer

< Safety equipment: insulated gloves, face shield, long sleeves, etc.

< Timer (method B)

Calibration

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

Nominal Max. Aggr. Size, mm	Sieve Size	Min. Sample Mass, g
4.75	No. 4	1200
9.5	3/8 in.	1200
12.5	½ in.	1500
19.0	3/4 in.	2000
25.0	1 in.	3000
37.5	1½ in.	4000

Using the aggregates and binder produced for the project, mix two samples in the lab at the Job Mix Formula (JMF) intended asphalt content.

Weigh a sample basket on a scale and record the mass. If the sample has cooled, preheat the sample in a 125EC (257EF) oven for 25 min. Place the sample in the basket. Spread the sample in a thin layer, but avoid placing material near the edge of the basket. Record the mass of the sample. For automatic ovens (method A) enter the mass of the sample into the oven processor.

Place the sample in the ignition oven and burn off the asphalt according to the manufacturers recommendation.

NOTE
Temperatures in excess of 538EC (1000EF) may be encountered when using an ignition oven. Use caution when handling hot samples or opening the oven.
SAFETY FIRST

The automatic ovens (method A) will stop the test when all the asphalt is burned off and will calculate the apparent percent asphalt.

For manual ovens (method B), allow the sample to burn for at least 45 min., remove from the oven and allow to cool. Weigh and record the mass of the sample. Return the sample to the oven. After the oven has returned to its set temperature, allow the sample to burn off for an additional 15 min. Repeat the burn off - cool - weigh routine until two consecutive weighings of the sample do not change more than 0.01 percent of the original mass of the sample. Record the final mass of the sample. Calculate the apparent percent asphalt by subtracting the final mass from the original mass to get the loss from ignition then dividing by the original sample mass.

If the difference between the two samples exceeds 0.15%, repeat the calibration process with two more samples and discard the high and low results. Compare the apparent percent asphalt from ignition to the actual asphalt content of the calibration samples. Subtract the apparent percent asphalt from the actual percent for each sample and average the two results. This will be the correction factor which must be applied to all tests on the same mixture. Record the correction factor.

If the correction factor exceeds 0.5% it may be necessary to repeat the calibration procedure at a lower temperature. If a lower temperature is required to produce a consistent correction, this temperature should be recorded and all HMA samples of that material should be tested at the same temperature as the calibration samples.

If the State Highway Agency requires the gradation of the aggregate to be checked on test samples, a third sample of aggregate should be prepared but not mixed with asphalt. The gradation of this “blank” sample can then be compared to the gradation of one of the burned off calibration samples to evaluate

the amount of aggregate breakdown.

Sample Preparation

If moisture is present in the sample, dry the sample in an oven at 105 ± 5E C (221 ± 9E F), or determine the moisture content and record it. If necessary, reduce the sample to the proper size by quartering or other suitable means that will produce a representative sample. Preheat the sample, if needed, as described above for calibration.

Test Procedure

Place the sample in the sample basket and record the mass. For automatic ovens (method A), enter the mass and the correction factor into the oven controls. Test the sample as described above for calibration.

The automatic ovens (method A) will display and/or printout the corrected asphalt content. For the manual ovens (method B), the apparent asphalt content is determined the same way as for calibration, then the correction factor is added to the result to produce the final reported asphalt content. The correction factor is normally a negative number. If moisture is present in the sample, subtract the percent moisture from the corrected asphalt content to get the final reported asphalt content.

Asphalt Placed in Basket

Basket Placed in Oven

Report the asphalt content by ignition to two decimal places.

Example

Correction factor determination:
where: Percent asphalt in the calibration sample (P_b) = 5.00%
Original dry mass of the calibration sample = 2507.5 g
Final mass of burned off calibration sample = 2370.7 g

$$\frac{(2507.5\&2370.7)}{2507.5}100 \text{ ' } 5.46\%$$

Apparent percent asphalt = 5.46%
Correction factor = 5.00 - 5.46 = -0.46

Corrected asphalt content determination:
where: Original dry mass of the test sample = 2512.4 g
Final mass of burned off test sample = 2379.5 g

$$\frac{(2512.4\&2379.5)}{2512.4}100 \text{ \& } 0.46 \text{ ' } 4.83\%$$

Corrected asphalt content = 4.83%

Note: *Follow the rounding rules specified by your state.*

RESISTANCE OF COMPACTED BITUMINOUS MIXTURE TO MOISTURE INDUCED DAMAGE

AASHTO T 283

Developed by
FHWA Multi-Regional Asphalt Training & Certification Group
1999

NOTE

Successful completion of the following training materials, including examination and performance evaluation are prerequisites for this training package.

- AASHTO T 168, Sampling Bituminous Paving Mixtures
- AASHTO TP 4, Standard Method for Preparing and Determining the Density of Hot Mix Asphalt (HMA) by Means of the SHRP Gyratory Compactor.
- AASHTO T 209, Maximum Specific Gravity of Bituminous Paving Mixtures.
- AASHTO T 166, Bulk Specific Gravity of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens.

GLOSSARY

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

Steel loading strips: square or rectangular steel bars long enough to cover the full thickness of the specimen with one side curved to match the side of the specimen. For 101.6 mm (4 in.) specimens, the strips shall be 12.7 mm (0.5 in.) wide, and for 152.4 mm (6 in.) specimens, the strips shall be 19.05 mm (0.75 in.) wide.

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

Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

Bituminous mixtures made from certain materials may be sensitive to the presence of water in the finished pavement. Water will cause the asphalt to stop sticking to the aggregate. Since the asphalt is the "glue" that holds the pavement together, rapid failure of the pavement can be expected if the asphalt cannot stick to the aggregate. This is often referred to as stripping. To help prevent stripping, additives such as hydrated lime or liquid anti-stripping chemicals may be required. AASHTO T 283 is a test method that can be used to determine if the materials used are subject to stripping and can also be used to evaluate the effectiveness of additives.

The test is performed by compacting specimens to an air void level of six to eight percent. Three specimens are selected as a control and tested without moisture conditioning, and three more are selected to be conditioned by saturating with water. The specimens are then tested for indirect tensile strength by loading the specimens at a constant rate and measuring the force required to break the specimen. The tensile strength of the conditioned specimens is compared to the control specimens to determine the tensile strength ratio (TSR). This test may also be performed on cores taken from finished pavement.

Common Testing Errors

- Voids in the conditioned specimens not the same as the unconditioned ones.
- Conditioned specimens not properly saturated with water.
- Conditioned specimens not soaked for 24 hours in a water bath at 60 ± 1EC (140 ± 1.8EF)

TEST METHODOLOGY

Apparatus

- Vacuum container for saturating specimens
- Balance and water bath from T 166
- Water bath able to maintain 60 ± 1EC (140 ± 1.8EF)
- Aluminum pans (cake pans)
- Loading jack and force measuring device
- Loading strips with a curved face to match the side of the specimen (optional)
- Forced air oven able to maintain 60 ± 1EC (140 ± 1.8EF)
- Freezer able to maintain -18 ± 3EC (0 ± 5EF) (optional)
- Plastic wrap and heavy-duty leak proof plastic bags
- 10 mL graduated cylinder (optional)

Sample Preparation

If pavement cores are to be tested, a minimum of six cores is required. Separate the cores into two sets of three so that each set has approximately the same average voids.

For laboratory-batched mixtures, 101.6 mm (4 in.) diameter and 63.5 mm (2.5 in.) thick specimens are normally used, but larger specimens may be used. Larger diameter specimens should be used if there is 25.0 mm (1 in.) aggregate or larger in the mixture. Mix enough material to produce at least eight specimens at the asphalt content recommended for the mixture. Extra mixture will be needed for trials to establish the compaction required and for determining the maximum specific gravity of the mixture, if these values are not known. *(Note: When specimens other than 101.6 mm (4 in.) diameter and 63.5 mm (2.5 in.) thick are used, test results may not agree with results from standard size specimens.)*

After mixing, place the mixture in the aluminum pans and spread it to about 25 mm (1 in.) thick. Allow the mix to cool to room temperature for 2 ± 0.5 hours. Then put the mixture in the 60EC (140EF)

oven for 16 hours to cure. After curing, put the mixture in an oven at 135EC (275EF) for 2 hours before compacting the specimens. Compact the specimens to 7 ± 1.0 percent air voids.

Some experimentation will be needed to find the correct compactive effort that will yield the desired voids. When using the SHRP gyratory compactor, the height needed can be calculated from one trial specimen. Other compactors may require several trials before the correct compactive effort can be established. After removing the specimens from the molds, store them at room temperature for 72 to 96 hours.

Determine the maximum specific gravity of the mixture. Measure the thickness and determine the bulk specific gravity of each specimen. Calculate the air voids of each specimen. Sort the specimens into two groups of three so that each group has about the same average voids. One set will be stored at room temperature until tested, the other set will be conditioned before testing. The unconditioned control set should be sealed in plastic wrap or a plastic bag.

Moisture Conditioning

Put the specimens to be conditioned into the vacuum container and fill with distilled water so that at least 25 mm (1 in.) of water is covering them. Apply a partial vacuum to the container for about 5 to 10 minutes. Release the vacuum and allow the specimens to sit submerged in the water for another 5 to 10 minutes. Determine the bulk specific gravity of the saturated specimens. Compare the saturated surface dry (SSD) mass of the saturated specimens to the original SSD mass of the specimens before saturation. The difference will be the volume of absorbed water. Compare the volume of absorbed water to the original volume of air voids to determine the amount of saturation. The volume of absorbed water needs to be between 55 to 80 percent of the original volume of air voids. If the volume of absorbed water is less than 55 percent, repeat the vacuum saturation procedure. If the volume of absorbed water is greater than 80 percent, the specimens have been damaged and must be discarded and replaced.

If the optional freeze cycle is required, wrap the saturated specimens tightly with plastic wrap and place in a plastic bag with 10 mL of water and seal the bag. Place the bag in the freezer for at least 16 hours. Remove the bags from the freezer and place in the water bath at 60 ± 1EC (140 ±1.8EF) for 24 ± 1 hours. As soon as possible after putting in the bath, remove the plastic bag and plastic wrap from the specimens.

If no freeze cycle is required, place the saturated specimens directly into the 60EC water bath for the 24 ± 1 hours of conditioning.

Test Procedure

After the 24-hour soak, remove the specimens and place in a water bath at 25 ± 0.5EC (77 ± 1EF)

for 2 ±1 hours. The bath should return to 25EC within 15 minutes after the warm specimens are placed in the bath. The unconditioned specimens, still sealed in plastic, also need to be placed in the 25EC bath for at least 2 hours.

Remove the specimen from the bath and place it on its side between the bearing plates of the testing machine. It is recommended that steel loading strips be placed between the specimen and the bearing plates as this will simplify the calculation of the tensile strength.

Apply the load to the specimen by forcing the bearing plates together at a constant rate of 50 mm (2 in.) per minute.

If steel loading strips are used, record the maximum load, then continue to load the specimen until it cracks. Stop the machine, remove the specimen and break it apart at the crack. Look at the inside of the specimen and estimate the percent of stripped aggregate. Record the observations.

If steel loading strips are not used, stop the machine when the maximum load is observed. Record the maximum load. Remove the specimen from the machine and measure and record the width of the flattened area on each side of the specimen. Return the specimen to the machine and continue loading until the specimen cracks. Stop the machine, remove the specimen and break it apart at the crack. Look at the inside of the specimen and estimate the percent of stripped aggregate. Record the observations.

Calculations

If steel loading strips are used, calculate the tensile strength using the following equation:

$$S_t = \frac{2P}{\pi t D}$$

where:

S_t = tensile strength, Pa (psi)
P = maximum load, Newtons (pounds)
t = specimen thickness, mm (inches)
D = specimen diameter, mm (inches)

If steel loading strips are not used, calculate the tensile strength using one of the following equations:

$$S_t = \frac{S_{10}P}{44000\ t}$$

where:

S_t = tensile strength, Pa
S_{10} = maximum tensile stress corresponding to the width of the flattened area from table 1
P = maximum load, Newtons
t = specimen thickness, mm

Or in U.S. Customary Units:

$$S_t = \frac{S_{10}P}{10000\ t}$$

where:

S_t = tensile strength, psi
S_{10} = maximum tensile stress corresponding to the width of the flattened area from Table 1
P = maximum load, pounds
t = specimen thickness, inches

The tensile strength ratio (TSR) is calculated by dividing the average tensile strength of the conditioned specimens by the average tensile strength of the unconditioned control specimens.

A TSR value of at least 80 percent is normally required as evidence that the mixture will not be subject to stripping.

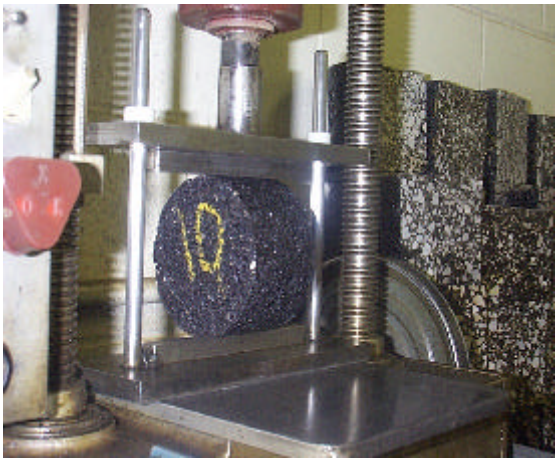
TABLE 1

Width of Flattened Area in Millimeters (inches)	Maximum Tensile Stress, S_{10}, kPa (psi)
0.0 (0.0)	11307 (1640)
2.5 (0.1)	11232 (1629)
5.0 (0.2)	11163 (1619)
7.6 (0.3)	11073 (1606)
10.2 (0.4)	10997 (1595)
12.7 (0.5)	10832 (1571)
15.2 (0.6)	10618 (1540)
17.8 (0.7)	10397 (1508)
20.3 (0.8)	10135 (1470)
22.9 (0.9)	9915 (1438)
25.4 (1.0)	9687 (1405)

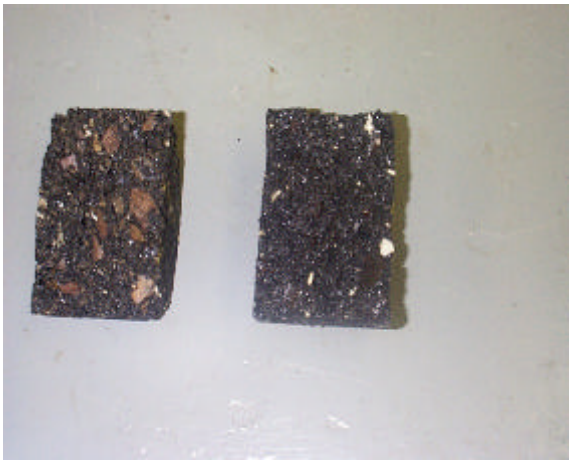
T  **ESTING SPECIMENS**

Specimen in Vacuum Container

Specimen in Bath



Specimen in Testing Frame



Broken Core