V. Superpave Mixtures

Superpave asphalt mixture requirements were developed from both previously established criteria, and new criteria that were developed in conjunction with new compaction equipment. The objectives of this section will be to:

- describe the Superpave Gyratory Compactor
- review the Superpave mixture criteria, including mixture compaction requirements and mixture volumetric criteria
- describe the moisture sensitivity test and criteria

ASPHALT MIXTURE TESTS

Superpave Gyratory Compaction

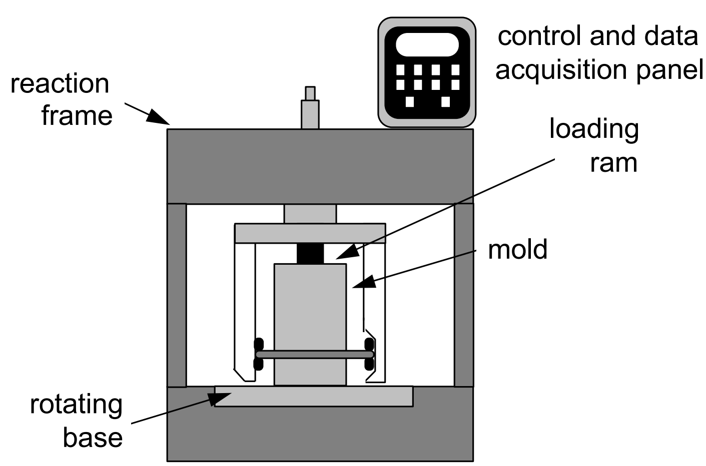
SHRP researchers had several goals in selecting a method of laboratory compaction. Most important, they desired a device that would realistically compact trial mix specimens to densities achieved under actual pavement climate and loading conditions. The device needed to be capable of accommodating large aggregates. Furthermore, it was desired that the device afford a measure of compactability so that potential tender mixture behavior and similar compaction problems could be identified. A high priority for SHRP researchers was a device that was well suited to mixing facility quality control and quality assurance operations. No compactor in current use achieved all these goals. Consequently, a new compactor was developed, the Superpave Gyratory Compactor (SGC).

The basis for the SGC was a large Texas gyratory compactor modified to use the compaction principles of a French gyratory compactor. The Texas device accomplished the goals of achieving realistic specimen densification and it was reasonably portable. Its 6-inch sample diameter (ultimately 150 mm on an SGC) could accommodate mixtures containing aggregate up to 50 mm maximum (37.5 nominal) size. SHRP researchers modified the Texas device by lowering its angle and speed of gyration and adding real time specimen height recordation.

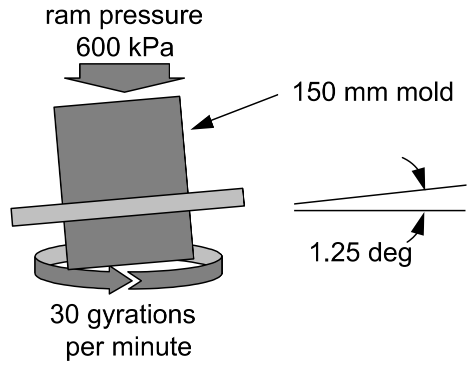
Test Equipment

The SGC is a mechanical device comprised of the following system of components:

- reaction frame, rotating base, and motor,
- loading system, loading ram, and pressure gauge,
- height measuring and recordation system, and
- mold and base plate.

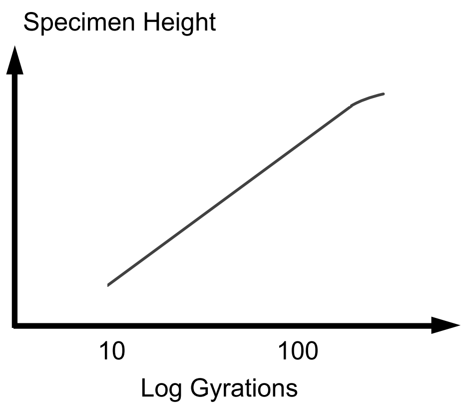


The reaction frame provides a stiff structure against which the loading ram can push when compacting specimens. The base of the SGC rotates and is affixed to the loading frame. It supports the mold while compaction occurs. The SGC uses a mold with an inside diameter of 150 mm and a nominal height of at least 250 mm. A base plate fits in the bottom of the mold to afford specimen confinement during compaction. Reaction bearings are used to position the mold at a compaction angle of 1.25 degrees, which is the compaction angle of the SGC. An electric motor drives the rotating base at a constant speed of 30 revolutions per minute.



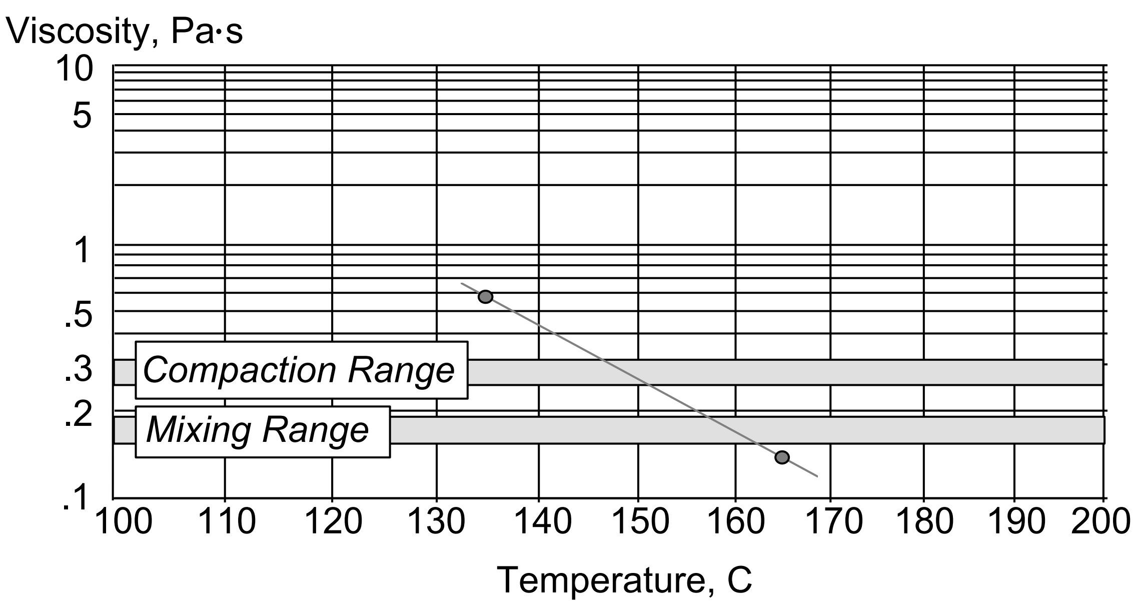
A hydraulic or mechanical system applies a load to the loading ram, which imparts 600 kPa compaction pressure to the specimen. The loading ram diameter nominally matches the inside diameter of the mold, which is 150 mm. A pressure gauge measures the ram pressure during compaction. As the specimen densifies during compaction, the pressure gauge and loading ram maintain compaction pressure.

Specimen height measurement is an important function of the SGC. Using the mass of material placed in the mold, the diameter of the mold, and the specimen height, an estimate of specimen density can be made at any time throughout the compaction process. Specimen density is computed by dividing the mass by the volume of the specimen. The specimen volume is calculated as the volume of a smooth-sided cylinder with a diameter of 150 mm and the measured height. Height is recorded by measuring the position of the ram before and during the test. The vertical change in ram position equals the change in specimen height. The specimen height signal is connected to a personal computer, printer, or other device to record height (i.e., density) measurements throughout the compaction process. By this method, a compaction characteristic is developed as the specimen is compacted.



Specimen Preparation

To normalize the effect of the binder, compaction specimens require mixing and compaction under equiviscous temperature conditions corresponding to 0.170 ± 20 Pa·s and 0.280 ± 30 Pa·s, respectively, as determined from the temperature-viscosity characteristics for the asphalt binder. If the temperature-viscosity plot produces a mixing temperature higher than 170°C, it may indicate that the asphalt is modified. Because of their distinctive characteristics, modified asphalts can frequently be mixed and compacted at higher viscosities (lower temperatures) than the shaded ranges shown above. It should be noted that temperatures above 177°C may lead to binder thermal degradation and should not be used. The binder supplier should always be consulted for recommendations of the optimum laboratory and field mixing and compaction temperatures for modified binders. Users may defer to the manufacturer's recommendations for all PG binder grades.



Mixing is accomplished using a mechanical mixer. After mixing, loose test specimens are subjected to conditioning as specified in AASHTO PP-2, "Standard Practice for Mixture Conditioning of Hot Mix Asphalt". For volumetric mix design, the mixture is conditioned for 2 hours at the specified compaction temperature. During short term aging, loose mix specimens are required to be spread into a thickness resulting in 21 to 22 kg per square meter and stirred every hour to ensure uniform aging. The compaction molds and base plates should also be placed in an oven at 135°C for at least 30 to 45 minutes prior to use.

Three specimen sizes are used. If specimens are to be used for volumetric determinations only, use sufficient mix to arrive at a specimen 115 mm ± 5 mm height. This requires approximately 4500 grams of mixture. In this case, the test specimen produced is tested without trimming. Alternatively, to produce specimens for performance testing, approximately 5500 grams of mixture is used to fabricate a specimen that is 150 mm in diameter by approximately 135 mm height. In this case, specimens will have to be trimmed to 50 mm before testing in the SST or IDT. At least one loose sample should remain uncompacted to obtain a maximum theoretical specific gravity using AASHTO T 209. For performing moisture sensitivity tests (AASHTO T283), test specimens are fabricated to a height of 95 mm, which requires approximately 3500 grams of mixture.

Overview of Procedure

After short term aging the loose test specimens are ready for compacting. The compactor is initiated by turning on its main power. The vertical pressure should be set at 600 kPa (± 18 kPa). The gyration counter should be zeroed and set to stop when the desired number of gyrations is achieved. Three gyration levels are of interest:

- design number of gyrations (N_{design} or N_{des}).
- initial number of gyrations ($N_{initial}$, or N_{ini}), and
- maximum number of gyrations ($N_{maximum}$ or N_{max}).

Test specimens are compacted using Ndes gyrations. The relationship between N_{des}, N_{max}, and N_{ini} are:

$$\text{Log}_{10} N_{max} = 1.10 \times \text{Log}_{10} N_{des}$$

$$\text{Log}_{10} N_{ini} = 0.45 \times \text{Log}_{10} N_{des}$$

The design number of gyrations (N_{des}) ranges from 50 to 125 and is a function of the traffic level. The range of values for N_{des}, N_{max}, and N_{ini} are shown:

Superpave Design Gyratory Compactive Effort

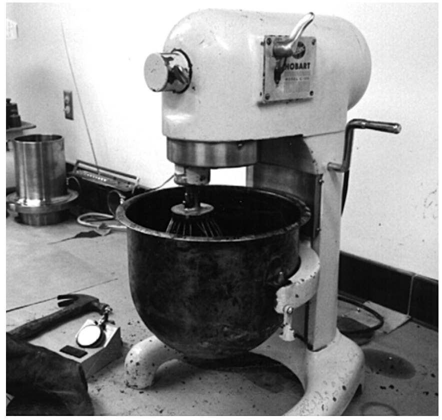
Design ESALs (millions)	Compaction Parameters		
	$N_{initial}$	N_{design}	$N_{maximum}$
< 0.3	6	50	75
0.3 to < 3	7	75	115
3 to < 10	8	100	160
$\geq$ 30	9	125	205

After the base plate is in place, a paper disk is placed on top of the plate and the mold is charged in a single lift. The top of the uncompacted specimen should be slightly rounded. A paper disk is placed on top of the mixture.

The mold is placed in the compactor and centered under the ram. The ram is then lowered until it contacts the mixture and the resisting pressure is 600 kPa (± 18 kPa). The angle of gyration (1.25° ± 0.02°) is then applied and the compaction process begins.

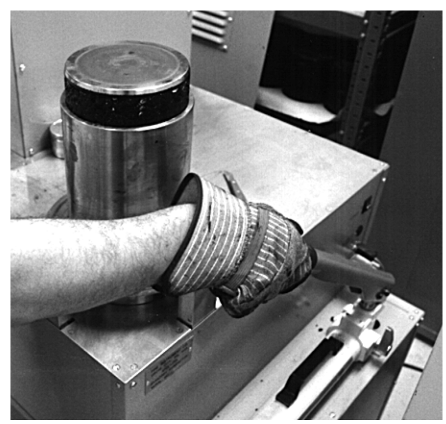
When N_{des} has been reached, the compactor automatically stops. After the angle and pressure are released, the mold containing the compacted specimen is then removed. After a suitable cooling period, the specimen is extruded from the mold.

The bulk specific gravity of test specimens should be measured using AASHTO T 166. Maximum theoretical specific gravity should be measured using AASHTO T 209.


PINE
Instrument Company
Grove City, PA 16127
SPECIMEN DIA: 150mm
PRESSURE: 0.60MPa
SET GYRATIONS: 152
SPEC. HT.: 122.5 mm
GYRATORY COMPACTOR
MACHINE READY
DOOR OPEN
ENTER
PAGE
SELECT
ROTATE
RAM
ANGLE
START
STOP

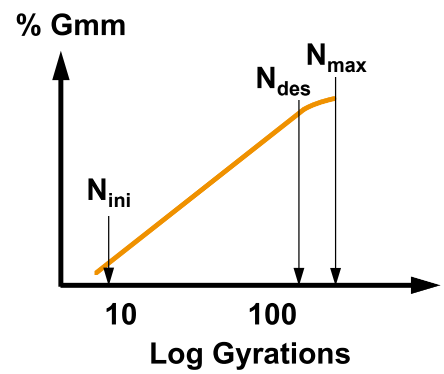


Data Presentation

Superpave gyratory compaction data is analyzed by computing the percent of maximum theoretical specific gravity for each desired gyration. This example specimen compaction information illustrates this analysis:

Specimen No. 1: Total Mass = 4869 g		
No. of Gyrations	Height, mm	% G_{mm}
8 (N_{ini})	134.2	84.4
25	126.6	89.5
50	122.4	92.6
75	120.1	94.3
100 (N_{des})	118.6	95.5
G_{mb}	2.360	
G_{mm}	2.471	



Project conditions for this mixture are such that N_{des} = 100, N_{ini} = 8, and N_{max} gyrations. During compaction, the height is measured after each gyration and recorded for the number of gyrations shown in the first column. After compaction, the specimen is removed from the cylinder and, after cooling, the G_{mb} is measured. G_{mb} is then divided by G_{mm} to determine the % G_{mm} @ N_{des}. The % G_{mm} at any number of gyrations (N_x) is then calculated by multiplying % G_{mm} @ N_{des} by the ratio of the heights at N_{des} and N_x. The calculations for this example are illustrated here:

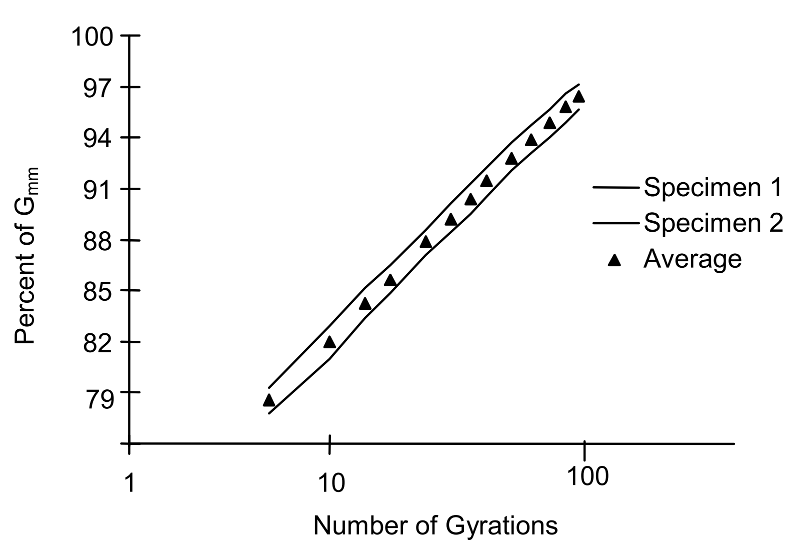
G_{mb} = 2.360 G_{mm} = 2.471

% G_{mm} @ N_{des} = G_{mb} ÷ G_{mm} = 2.360 ÷ 2.471 x 100% = 95.5%

% G_{mm} @ N_x = % G_{mm} @ N_{des} x (H_{des} ÷ H_x)

For N = 50, % G_{mm} @ N_{50} = % G_{mm} @ N_{des} x (H_{des} ÷ H_{50}) = 95.5 x (118.6 ÷ 122.4) = 92.6%.

If this example had been for a mix design, a companion specimen would have been compacted and average percent G_{mm} values resulting from the two specimens would have been used for further analysis. A compaction characteristic curve for this example showing two specimens and an average is shown:



ASPHALT MIXTURE REQUIREMENTS

Asphalt mixture design requirements in Superpave consist of:

- mixture volumetric requirements,
- dust proportion, and
- moisture susceptibility.

Specified values for these parameters are applied during mixture design.

Mixture Volumetric Requirements

Mixture volumetric requirements consist of air voids, voids in the mineral aggregate, voids filled with asphalt, and the mixture density during compaction at N_{ini} and N_{max}. Air void content is an important property because it is used as the basis for asphalt binder content selection. In Superpave, the **design air void content is four percent**.

VOIDS IN THE MINERAL AGGREGATE

Superpave defines voids in the mineral aggregate (VMA) as the sum of the volume of air voids and effective (i.e., unabsorbed) binder in a compacted sample. It represents the void space between aggregate particles. The goal is to furnish enough space for the asphalt binder so it can provide adequate adhesion to bind the aggregates, but without bleeding when the temperatures rise and the asphalt expands. Specified minimum values for VMA at the design air void content of four percent are a function of nominal maximum aggregate size.

Superpave VMA Requirements	
Nominal Maximum Aggregate Size	Minimum VMA, %
9.5 mm	15.0
12.5 mm	14.0
19 mm	13.0
25 mm	12.0
37.5 mm	11.0

VOIDS FILLED WITH ASPHALT

Voids filled with asphalt (VFA) is defined as the percentage of the VMA containing asphalt binder. Consequently, VFA is the volume of effective asphalt binder expressed as a percentage of the VMA. Although VFA, VMA and air voids are all interrelated and only two of the values are necessary to solve for the other, including the VFA criteria helps prevent the design of mixes with marginally acceptable VMA. The main effect of the VFA criteria is to limit maximum levels of VMA, and, subsequently, maximum levels of asphalt content. The acceptable range of VFA at four percent air voids is a function of traffic level.

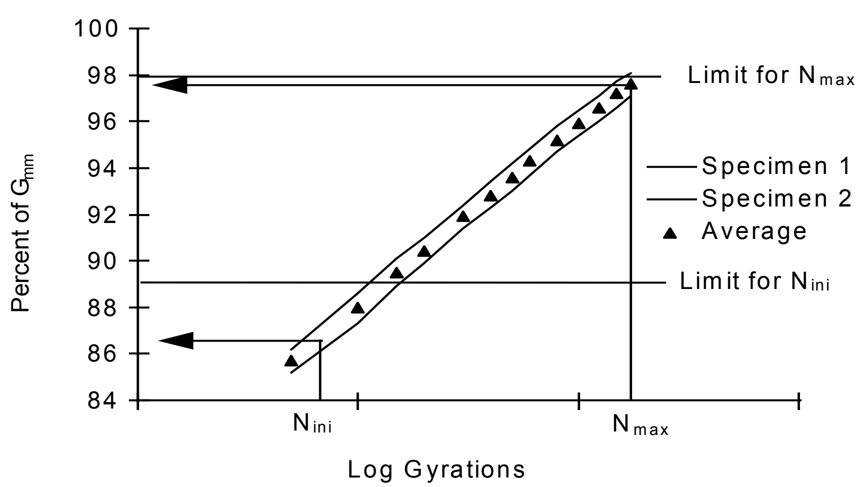
Superpave VFA Requirements

Design ESALs (million)	Design VFA, %
< 0.3	70 - 80
0.3 to < 3	65 - 78
3 to < 10	65 - 75
10 to < 30	65 - 75
≥ 30	65 - 75

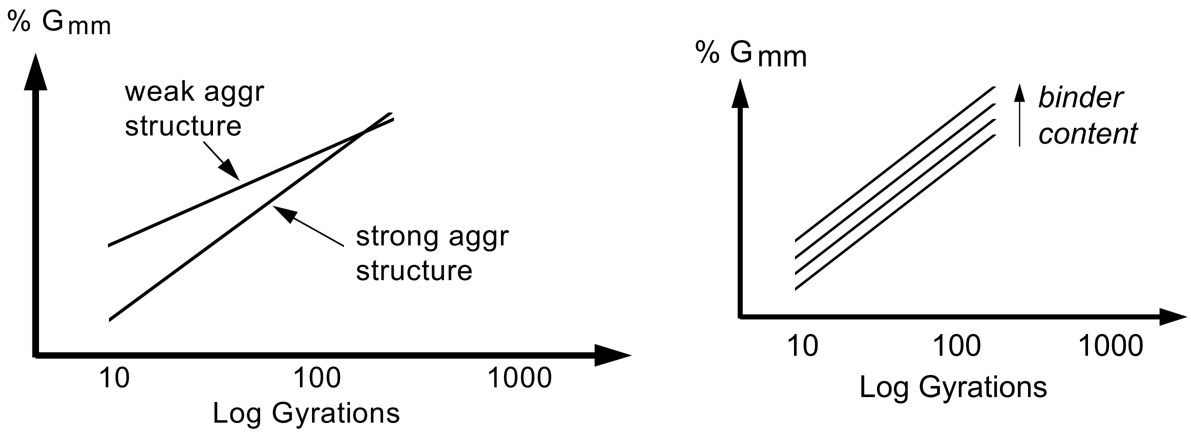
- For 9.5-mm nominal size mixtures, the VFA shall be 73% to 76% for design traffic levels ≥ 3 million ESALs.
- For 25-mm mixtures, the VFA lower limit shall be 67% for < 0.3 million ESALS.
- For 37.5-mm mixtures, the VFA lower limit shall be 64% for all design traffic levels.

DENSITY REQUIREMENTS

During the trial blend step of the mix design process, samples are compacted to the specified number of gyrations, N_{des}. Superpave specifies density criteria at N_{ini} and N_{max}. The compaction characteristic curve shown illustrates the limits of 89 percent maximum density (for selected traffic levels) and 98% (for all traffic levels) at N_{max}. N_{ini} can be evaluated from the trial blend compaction data. After the design aggregate structure has been selected, two additional specimens are compacted to N_{max} to determine the percent of maximum density.



The compaction characteristic curve developed during gyratory compaction provides information about the relative strength of aggregate structures and binder contents. At the same asphalt content, weaker aggregate structures will have flatter slopes and higher density than stronger aggregate structures. For the same aggregate structure, an increase in binder content will produce a mixture with increased density



Specifying a maximum value of percent density N_{ini} prevents design of a mixture that has a weak aggregate structure and low internal friction, indicators of a tender mix. Specifying a maximum value of percent density at N_{max} prevents design of a mixture that will compact excessively under the design traffic, become plastic, and produce permanent deformation. Since N_{max} represents a compactive effort that would be equivalent to traffic much greater than the design traffic, excessive compaction under traffic will not occur.

Dust Proportion

Another mixture requirement is the dust proportion. This is computed as the ratio of the percentage by weight of aggregate finer than the 0.075 mm sieve to the effective asphalt content expressed as a percent by weight of total mix. Effective asphalt content is the total asphalt used in the mixture less the percentage of absorbed asphalt. Dust proportion is used during the mixture design phase as a design criterion. An acceptable dust proportion is in the range from 0.6 to 1.6, inclusive for all mixtures. Low dust proportion values are indicative of mixtures that may be unstable, and high dust proportion values indicate mixtures that lack sufficient durability.

MOISTURE SUSCEPTIBILITY

The adhesion between the asphalt and aggregate is an important, yet complex and not well understood, property that helps ensure good pavement performance. The loss of bond, or stripping, caused by the presence of moisture between the asphalt and aggregate is a problem in some areas and can be severe in some cases. Many factors such as aggregate characteristics, asphalt characteristics, environment, traffic, construction practices and drainage can contribute to stripping.

The moisture susceptibility test used to evaluate HMA for stripping is AASHTO T 283, *"Resistance of Compacted Bituminous Mixtures to Moisture Induced Damage."* This test is not a performance based test but serves two purposes. First, it identifies whether a combination of asphalt binder and aggregate is moisture susceptible. Second, it measures the effectiveness of anti-stripping additives.

In the test, two subsets of test specimens are produced. Specimens are compacted to a specimen height of 95 mm and to achieve an air void content in the range from six to eight percent with a target value of seven percent. Test specimens should be sorted so that each subset has the same air void content. One subset is moisture conditioned by vacuum saturation to a constant degree of saturation in the range from 55 to 80 percent. This is followed by an optional freeze cycle. The final conditioning step is a hot water soak. After conditioning both subsets are tested for indirect tensile strength. The test result reported is the ratio of tensile strength of the conditioned subset to that of the unconditioned subset. This ratio is called the "tensile strength ratio" or TSR. This table outlines the current test parameters in AASHTO T 283:

Test Parameter	Test Requirement
Short-Term Aging	Loose mix[1]: 16 hrs at 60° C Compacted mix: 72-96 hrs at 25° C
Air Voids Compacted Specimens	6 to 8 %
Sample Grouping	Average air voids of two subsets should be equal
Saturation	55 to 80 %
Swell Determination	None
Freeze	Minimum 16 hrs at -18° C (optional)
Hot Water Soak	24 hrs at 60° C
Strength Property	Indirect tensile strength
Loading Rate	51 mm/min at 25° C
Precision Statement	None

[1] Short-term aging protocol of AASHTO T 283 does not match short-term aging protocol of Superpave. Suggest using T283 procedure of 16 hours at 60° C.

Superpave requires a minimum TSR of 80 percent. Lower values are indicative of mixtures that may exhibit stripping problems after construction.