Colorado Procedure – Laboratory 5109-16

Standard Method of Test for

Resistance of Compacted Bituminous Mixture to Moisture Induced Damage

(This is based upon AASHTO T 283-02. AASHTO T 283-07 or any subsequent revision may not be used in-place of this procedure.)

1. SCOPE

1.1 This method covers preparation of specimens and measurement of the change of diametral tensile strength resulting from the effects of saturation and accelerated water conditioning of compacted bituminous mixtures in the laboratory. The results may be used to predict long-term stripping susceptibility of the bituminous mixtures, and evaluating liquid anti-stripping additives, which are added to the asphalt cement or pulverulent solids, such as hydrated lime, which are added to the mineral aggregate.

1.2 This method is also referred to as the Lottman.

2. REFERENCED DOCUMENTS

2.1 *AASHTO Standards*:

- M 156 Requirements for Mixing Plants for Hot Mixed, Hot-Laid Bituminous Paving Mixtures
- T 166 Bulk Specific Gravity (Gmb) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens
- T 167 Compressive Strength of Hot Mix Asphalt
- T 168 Sampling Bituminous Paving Mixtures
- T 209 Theoretical Maximum Specific Gravity (Gmm) and Density of Hot Mix Asphalt (HMA)
- T 245 Resistance to Plastic Flow of Asphalt Mixtures Using Marshall Apparatus
- T 246 Resistance to Deformation and Cohesion of Hot Mix Asphalt (HMA) by Means of Hveem Apparatus
- T 247 Preparation of Test Specimens of Hot Mix Asphalt (HMA) by Means of California Kneading Compactor
- T 269 Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

2.2 *ASTM Standards*:

- D 3387 Test Method for Compaction and Shear Properties of Bituminous Mixtures by Means of the U.S. Corps of Engineers Gyratory Testing Machine (GTM)
- D 3549 Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
- D 4013 Practice for Preparation of Test Specimens of Bituminous Mixtures by Means of Gyratory Shear Compactor

2.3 *Colorado Procedures:*

CP 44 Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface- Dry Specimens
CP 51 Determining the Maximum Specific Gravity of HMA
CP-L 5115 Standard Method for Preparing and Determining the Density of Bituminous Mixture Test Specimens Compacted by the Superpave Gyratory Compactor

3. SIGNIFICANCE AND USE

3.1 As noted in the scope, this method is intended to evaluate the effects of saturation and accelerated water conditioning of compacted bituminous mixtures in the laboratory. This method can be used (a) to test bituminous mixtures in conjunction with mixture design testing and (b) to test bituminous mixtures produced at mixing plants.

3.2 Numerical indices of retained indirect tensile properties are obtained by comparing the retained indirect properties of saturated, accelerated water-conditioned laboratory specimens with the similar properties of dry specimens.

4. SUMMARY OF METHOD

4.1 Test specimens of laboratory produced material are tested using the proposed asphalt binder at the optimum asphalt cement content (see Note 1). Each set of specimens is divided into subsets. One subset is tested in dry condition for indirect tensile strength. The other subset is subjected to vacuum saturation followed by a freeze and warm water soaking cycle and then tested for indirect tensile strength. Numerical indices of retained indirect tensile strength properties are computed from the test data obtained on the two subsets: dry and conditioned.

5. APPARATUS

5.1 *Superpave Gyratory Compactor* - as per CP-L 5115.

5.2 *Vacuum Container*:

5.2.1 The vacuum container must be capable of withstanding the full vacuum applied, and each must be equipped with the fittings and other accessories required by the test procedure being employed.

5.2.2 A metal or plastic bowl with a diameter and height sufficient to cover the samples with water when the vacuum is applied. The capacity of the vacuum container should be between 2000 and 10,000 mL. The size selected depends on the minimum sample size requirements given in Section 6.1. Avoid using too small of a sample in a large container.

5.3 *Balance and water bath* - (from T 166).

5.3.1 *Water bath:*

5.3.1.1 *Water bath* - Capable of maintaining a temperature of 140°F ± 1.0° (60°C ± 0.5°).

5.3.1.2 *Water bath* - Capable of maintaining a temperature of 77°F ± 1.0° (25°C ± 0.5°).

5.4 *Freezer* - Maintained at -2.5°F ± 7.5° (-19°C ± 4°).

5.5 *Plastic film (Plastic Wrap or equivalent*) for sample wrapping.

5.6 Heavy-duty leak proof *plastic bags or leak proof container* to enclose the saturated specimens, and *masking tape*.

5.7 *Aluminum or steel pans* - having a surface area of 40-100 square inches (250-640 cm^2) in the bottom and a depth of approximately 1 to 3 inches (25 mm to 75 mm).

5.8 *Forced air draft oven* - capable of maintaining a temperature of 140°F ± 1.8° (60°C ± 1°).

5.9 *Loading jack and ring dynamometer* -from AASHTO T 245, or a mechanical or hydraulic testing machine from AASHTO T 167 to provide a range of accurately controllable rates of vertical deformation including 5.1 and 50.8 mm (0.2 and 2 inches) per minute.

5.10 *Loading Strips* - Steel loading strips with a concave surface having a radius of curvature equal to the nominal radius of the test specimen. For specimens 100 mm (3.937 inches) in diameter the loading strips shall be 12.7 mm (0.5 inches) wide, and for specimens 150 mm (5.906 inches) in diameter the loading strips shall be 19.05 mm (0.75 inches) wide. The length of the loading strips shall exceed the thickness of the specimens. The edges of the loading strips shall be rounded by grinding.

5.11 *Vacuum Measurement Device* - Mercury manometer or digital vacuum gauge is to be connected in line with the vacuum vessel. The digital vacuum gauge shall have been initially NIST traceable. If a digital vacuum gauge is used or the mercury manometer is suspected of being inaccurate, then once a year they shall be certified. The mercury manometer shall be free of air bubbles to obtain the correct reading.

5.12 *Bleeder Valve* - attached to the vacuum train to facilitate adjustment of the vacuum being applied to the vacuum container.

5.13 *Low Temperature Oven* - capable of maintaining a temperature of 77°F ± 1.0°(25°C ± 0.5°)

5.14 *Vacuum Pump*—Capable of evacuating air from the vacuum container to a residual pressure of a minimum of 4.0 kPa (30 mm Hg).

5.14.1 When a vacuum pump is used, a suitable trap of one or more filter flasks, or equivalent, shall be installed between the vacuum vessel and vacuum source to reduce the amount of water vapor entering the vacuum pump.

6. PREPARATION OF LABORATORY MIXED AND FIELD PRODUCED TEST SPECIMENS

6.1 Specimens approximately 100 mm (3.937 inches) in diameter and approximately 63.5 mm (2.5 inches)) thick are normally used. Specimens of other dimensions may be used if desired and should be used if the aggregate present is larger than 1 inch (25.4 mm), and is not permitted to be scalped out. Table 1 in CP-L 5115 can be used to determine the approximate sample size to be adjusted in Section 6.4.

6.2 *Laboratory Mixed Material* - After mixing, the mixture shall be placed in an aluminum or steel pan and cooled at room temperature for 2 ± 0.5 hours. Then the mixture shall be placed in a 140°F ± 1.8° (60°C ± 1°) oven for 20 ± 4 hours, followed by 2.5 ± 0.5 hours at the compaction temperature of the binder in CP-L 5115 for short-term aging. The pans should be placed on spacers to allow air circulation under the pan if the shelves are not perforated. This short-term aging procedure is used for laboratory mixed samples only. Field produced material is not short-term aged before the compaction procedure.

6.3 Lottman specimens shall have the same mix compaction temperature specifications and mold temperature specifications as volumetric specimens (CP-L 5115). For Lottman specimens (CP-L 5109), enter the final sample height (corrected if necessary to achieve the desired sample air voids) into the compactor control panel. Variations in sample heights and/or weight, which result in Lottman specimens having 7 ± 1.0 percent air voids, are permitted.

6.3.1 The suggested calculation to determine Lottman height is as follows:

$$\frac{(\textbf{Ave. Bulk SpG @ N(des) x Ave. Ht. @ N(des)})}{(\textbf{0.925 x Rice})}$$

6.4 Reduce field produced sample to the proper sample weight as per CP 55. Adjustment of sample voids may be done by adjusting sample weights. If a sample has a sample weight of 1150 grams and a specific gravity of 94.5% of the theoretical maximum specific gravity (Rice value) (with 5.5% air voids) and the target specific gravity is 93% of the theoretical maximum specific gravity (with 7% air voids), the sample weight may be reduced according to the formula: target sample weight = (1150 x 93%) / 94.5%. The target sample weight would be approximately 1132 grams.

6.5 Samples shall be placed in an oven at the compaction temperature for the specified time in CP-L 5115 before compaction begins. Both Laboratory and Field produced samples shall be compacted to 7 ± 1.0 percent air voids (calculated in Subsection 7.4). This level of voids can be obtained as specified in CP-L 5115.

6.6 After extraction from the molds, the specimens should not be tested until they reach room temperature.

7. EVALUATION OF TEST SPECIMENS AND GROUPING

7.1 Determine theoretical maximum specific gravity of mixture by CP 51.

7.2 Determine specimen thickness by CP-L 5115.

7.3 Determine bulk specific gravity by CP 44. Express volume of specimens in cubic centimeters.

7.4 Calculate air voids using the formula:

$$\mathbf{V_a = 100\left[1 - \left(\frac{G_{mb}}{G_{mm}}\right)\right]}$$

Where:

V_a = air voids content (percent),
G_{mb} = bulk specific gravity of compacted sample,
G_{mm} = theoretical maximum specific gravity of mixture.

7.5 Sort specimens into two subsets of three specimens each so that average air voids of the two subsets are approximately equal.

8. MOISTURE CONDITIONING OF TEST SPECIMENS (5 Minute Saturation Method)

8.1 The dry subset shall be conditioned as follows:

8.1.1 The dry specimens shall be wrapped in plastic film (Plastic Wrap or equivalent) and placed in a heavy duty, leak proof plastic bag or placed unwrapped in a leak proof container. The dry specimens shall be placed in the 77°F ± 1.0° (25°± 0.5°C) water bath with the conditioned specimens for 3.5 ± 0.5 hour for 100 mm (3.937 inches) diameter specimens. 150 mm (5.906 inches) diameter specimens shall remain in the 77°F ± 1° (25°C ± 0.5°) water bath for 6 ± 2 hours , and then tested as described in Section 9. It is critical that the dry specimens remain dry if this method is used.
Alternatively, the dry specimens may remain unwrapped and stored in a low temperature oven capable of holding a temperature of 77°F ± 1.0° (25°C ± 0.5°) until tested as described in Section 9.

8.2 The moisture conditioned subset shall be conditioned as follows:

8.2.1 Place the moisture conditioned specimens in the vacuum container which is supported above the container bottom by a spacer or with the specimen being placed on its side. Fill the container with potable water at room temperature so that the specimens have at least one inch of water above their surface. Apply a vacuum of 28 ± 2 mm of Hg for a period of 5 ± 0.25 minutes. The vacuum shall be monitored using a mercury manometer or digital vacuum gauge and adjusted using a bleeder valve. Begin timing the vacuum application when the applied vacuum reaches the specified level. After the 5 ± 0.25 minutes, slowly remove the vacuum and leave the specimen submerged in water for a short time (greater than 5 seconds).

NOTE 1: If calculating saturation and/or swell, then as soon as possible after removing the specimen from the water, determine bulk specific gravity of the saturated specimen by CP 44. Calculate the level of saturation and swell as defined in Section 12.

8.2.2 Place the specimens under water for one second then wrap the wet, vacuum saturated specimens tightly with a plastic film (Plastic Wrap or equivalent). Place each wrapped specimen in a plastic bag and seal the bag or place it in a leak proof container.

8.2.3 Place the plastic bag or container containing the specimen in a freezer at -2.5°F ± 7.5° (-19°C ± 4°) for a minimum of 16 hours for 100 mm (3.937 inches) diameter specimens. 150 mm (5.906 inches) diameter specimens shall remain in the freezer for a minimum of 40 hours.

8.2.4 After removal from the freezer, place the moisture conditioned specimens into a 140°F ± 1.0° (60°C ± 0.5°) water bath for 24 ± 1 hour. As soon as possible after placement in the water bath or, if possible, before placement in the water bath, remove the specimens from the container or plastic bag and remove the plastic film from the specimens.

8.2.5 After 24 ± 1 hours in the 140°F ± 1.0° (60°C ± 0.5°) water bath, remove the specimens and place them in a water bath already at 77°F ± 1° (25°C ± 0.5°) for 3.5 ± 0.5 hour for 100 mm (3.937 inches)diameter specimens. 150 mm diameter specimens shall remain in the 77°F ± 1° (25°C ± 0.5°) bath for 6 ± 2 hours. It may be necessary to add ice to the water bath to prevent the water temperature from rising above 77°F ± 1° (25°C ± 0.5°). Not more than 15 minutes should be required for the water bath to reach 77°F ± 1° (25°C ± 0.5°). Test the specimens as described in Section 9.

9. TESTING

9.1 Determine the indirect tensile strength (PEAK or MAX LOAD) of dry and conditioned specimens at 77°F ± 1° (25°C ± 0.5°).

9.2 Remove each specimen from the 77°F ± 1° (25°C ± 0.5°) water bath or low temperature oven (dry sample only) and place between the two steel loading strips. Place the specimen and loading strips between the two bearing plates in the testing machine. Care must be taken so that the load will be applied along the diameter of the specimen. Apply the load to the specimen, by means of the constant rate of movement of the testing machine head, at 0.2 inches per minute.

9.3 Record the maximum compressive strength noted on the testing machine (PEAK or MAX LOAD). If desired, continue loading until a vertical crack appears. Remove the specimen from the machine and pull it apart at the crack. Inspect the interior surface for stripping and record the observations

9.4 Repeat steps 9.2 - 9.4 for each of the dry and moisture conditioned specimens.

10. CALCULATIONS

10.1 Calculate the tensile strength as follows:

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

Where:
S_t = tensile strength, psi,
P = maximum load, pounds,
t = specimen thickness (height), inches, to 0.01 of an inch,
D = specimen diameter, 3.937 inches for 100 mm molds or 5.906 inches for 150 mm molds.

10.2 Express the numerical index or resistance of asphalt mixtures to the detrimental effect of water as the ratio of the original strength that is retained after the freeze-warm water conditioning.

Calculate Percent Tensile Strength Retained (%TSR) as follows:

$$\%\boldsymbol{TSR} = (\boldsymbol{S_2 \,/\, S_1})\,\mathbf{100}$$

Where:
S_1 = average tensile strength of dry subset,
S_2 = average tensile strength of moisture conditioned subset

11. REPORT

11.1 Average % Voids

11.2 Dry Average Tensile Strength (S_1)

11.3 Wet Average Tensile Strength (S_2)

11.4 Percent Tensile Strength Retained (TSR)

12. ADDITIONAL TESTING FOR INFORMATION ONLY

12.1 Calculate % Saturation and Swell, as soon as possible after removing the conditioned specimens from the vacuum container in Section 8.2.1. Determine saturated samples surface dry weight (B_{sat}) and mass of the saturated sample, in water (C_{sat}) by CP 44. Calculate the level of saturation and percent swell as defined in Section 12.2 and 12.3 respectively. After recording the weights, place the specimens under water for one second and continue to Subsection 8.3.2.

12.2 Calculate the level of saturation as follows:

$$\mathbf{s} = \frac{\mathbf{B_{sat} - A}}{\mathbf{(B - C)x}\left[\mathbf{1} - \left[\frac{\mathbf{A}}{\mathbf{Gx(B - C)}}\right]\right]}\mathbf{x100}$$

Where:
s = level of saturation (%),
A = mass in grams of the dry sample in air,
B = mass in grams of the surface-dry sample in air,
B_{sat} = mass in grams of the surface-dry sample, in air, after saturation,
C = mass in grams of the sample, in water,
G = maximum specific gravity by CP 51.

12.3 Calculate the Percent Swell as follows:

$$\%\ \mathbf{swell} = \frac{\mathbf{(B_{sat} - C_{sat}) - (B - C)}}{\mathbf{(B - C)}}\ \mathbf{x\ 100}$$

Where:
B = mass in grams of the surface-dry sample in air,
B_{sat} = mass in grams of the surface-dry sample, in air, after saturation,
C = mass in grams of the sample, in water
C_{sat} = same as C except that the sample has been saturate