

DEPARTMENT OF TRANSPORTATION
DIVISION OF ENGINEERING SERVICES
Transportation Laboratory
5900 Folsom Blvd
Sacramento, California 95819-4612



METHOD OF TEST FOR RESISTANCE OF COMPACTED BITUMINOUS MIXTURE TO MOISTURE INDUCED DAMAGE

CAUTION: Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read “**SAFETY AND HEALTH**” in Section L of this method. It is the responsibility of the user of this method to consult and use departmental safety and health practices and to determine the applicability of regulatory limitations before any testing is performed.

A. SCOPE

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, with a freeze-thaw cycle, of compacted bituminous mixtures. The results may be used to predict long-term stripping susceptibility of the bituminous mixtures and to evaluate liquid anti-stripping additives that are added to the asphalt cement or solids that can be reduced to a fine powder, such as hydrated lime, that are added to the mineral aggregate.

B. SIGNIFICANCE AND USE

1. As noted in the scope, this method is intended to evaluate the effects of saturation and accelerated water and freeze-thaw conditioning of compacted bituminous mixtures. This method can be used to test: (a) bituminous mixtures in conjunction with mixture design testing (lab-mixed, lab-compacted); (b) bituminous mixtures produced at mixing plants (field-mixed, lab-compacted); and (c) bituminous mixture cores obtained from completed pavements of any age (field-mixed, field compacted).
2. Numerical indices of retained indirect tensile properties are obtained by

comparing the properties of laboratory specimens subjected to moisture and freeze-thaw conditioning with similar properties of dry specimens.

C. SUMMARY OF METHOD

Test specimens for each set of mix conditions, such as those prepared with untreated asphalt, asphalt treated with liquid anti-strip, or aggregate treated with lime, are prepared. Each set of specimens is divided into two subsets. One subset is tested in dry condition for indirect tensile strength. The other subset is subjected to vacuum saturation and a freeze cycle, followed by a warm water soaking cycle, before being tested for indirect tensile strength. Numerical indices of retained indirect tensile strength properties are calculated from the test data obtained on the two subsets: dry and conditioned. All test data and related information are to be recorded on Figure 1.

D. APPARATUS

1. Equipment for preparing and compacting asphalt concrete specimens from California Test 304.
2. Vacuum container (Type D or E) and vacuum pump, including manometer, from California Test 309.

3. Balance and water bath from AASHTO T 166.
4. Water bath capable of maintaining a temperature of $60 \pm 1^\circ\text{C}$.
5. Freezer maintained at $-18 \pm 3^\circ\text{C}$.
6. A supply of plastic film for wrapping specimens; heavy-duty, leak-proof plastic bags to enclose the saturated specimens; and masking tape.
7. 10 mL graduated cylinder.
8. Metal pans having a surface area of 48 400 to 64 500 square millimeters in the bottom and a depth of approximately 25 mm.
9. Forced air draft oven capable of maintaining a temperature of $60 \pm 1^\circ\text{C}$.
10. 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 50 mm per min.
11. Breaking Heads; Lottman Breaking Heads equivalent to Gilson MS-35.

E. PREPARATION OF LABORATORY-MIXED, LABORATORY-COMPACTED SPECIMENS

1. Obtain samples of the aggregate, additives (if any), and the asphalt binder that will be used on the project in accordance with California Test 125.
2. Make at least twelve asphalt concrete specimens for each test (NOTE 1). Six of the specimens are to be tested dry and the other six are to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle.

NOTE 1: It is recommended that two additional specimens be prepared. These specimens can be used to establish the compaction procedures as given in

Section E7 through E10 and the vacuum saturation technique as given in Section I.3.

3. Specimens 101.6 mm in diameter and 63.5 ± 3 mm thick are used.
4. Individually batch and mix specimens at the optimum or design binder content in accordance with California Test 304. The approximate quantity of mixture needed to batch a single specimen should be determined by the following formula:

$$\text{Mass (g)} = (G_{\text{mm}} \times 477.8) - 15 \text{ g}$$

Where:

G_{mm} = theoretical maximum specific gravity of mixture by California Test 309.

Some adjustment of mass may be required to achieve target height and voids.

5. After mixing, place the mixture in a metal pan having a surface area of 48 400 to 64 500 square millimeters in the bottom and a depth of approximately 25 mm, and cool at room temperature (NOTE 2) for 2 ± 0.5 hrs. Place the mixture in a $60 \pm 1^\circ\text{C}$ oven for 16 ± 1 hr for curing. The pans should be placed on spacers to allow air circulation under the pan if the shelves are not perforated.

NOTE 2: Room temperature for the purposes of this test method is defined as between 17°C and 28°C .

6. After curing, place the mixture in an oven at 110°C to 115°C for 2 hrs prior to compaction. Then, place the mixture in the mold and hand rod in accordance with California Test 304. *A mechanical spader shall not be used.*

7. Apply 25 tamping blows at a pressure of 1.7 MPa with the shims in place. Remove the mold and specimen from the compactor.
8. Place the mold directly on the lower platen of the compression machine (do not use a follower between the mix and platen) and apply a leveling load with a fixed head compression machine until a specimen height of 63.5 ± 3 mm is achieved, and then release the load.
9. It is recommended to scribe a mark on the metal follower 63.5 mm from each end. Place the scribed metal follower in the mold on top of the specimen. Lower the upper platen, at a rate of 6 mm per minute until the scribed mark on the follower meets the top of the mold. This leaves 63.5 mm between the follower and the lower platen. If a spherical seat or floating head is attached to the upper platen of the compression machine, it must be shimmed while applying the leveling load.
10. The mixture shall be compacted to between 6.5% and 7.5% air voids.
11. Store the test specimens in the molds at room temperature for 2 hrs before extraction.
12. After extraction from the molds, the test specimens shall be stored from 24 to 96 hrs at room temperature.

F. PREPARATION OF FIELD-MIXED, LABORATORY-COMPACTED SPECIMENS

1. Obtain samples of uncompacted field-mixed asphalt concrete in accordance with California Test 125.
2. Make at least twelve asphalt concrete specimens for each test (NOTE 1). Six of the specimens are to be tested dry and the other six are to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle.

3. Specimens 101.6 mm in diameter and 63.5 ± 3 mm thick are used.
4. Heat the field-mixed samples to approximately 93°C for workability. Thoroughly mix and quarter the sample, either by mechanical or hand quartering methods, into the amount needed to make individual specimens. The approximate quantity of asphalt concrete needed to make a single specimen should be determined by the following formula:

$$\text{Mass (g)} = (G_{\text{mm}} \times 477.8) - 15 \text{ g}$$

Where:

G_{mm} = theoretical maximum
specific gravity of mixture
by California Test 309.

Some adjustment of mass may be required to achieve target height and voids.

5. No loose mix curing as described in Section E.5 shall be performed on the field-mixed samples.
6. After sampling and quartering, place the mixture in an oven at 110°C to 115°C for 2 hrs prior to compaction. Then, place the mixture in the mold and hand rod in accordance with California Test 304. A *mechanical spader shall not be used*.
7. Compact the mixture in accordance with procedures specified in Sections E7 through E12.

G. PREPARATION OF FIELD-MIXED, FIELD-COMPACTED SPECIMENS (CORES)

1. Select locations on the completed pavement to be sampled and obtain cores. The number of cores shall be at least 12 for each test. Six of the cores are to be tested dry and the other six are to be tested after partial saturation and moisture conditioning with a freeze-thaw cycle. Obtain

additional cores to determine theoretical maximum specific gravity of the mixture (California Test 309).

2. Separate the core layers as necessary by sawing them or by other suitable means, and store the layers to be tested at room temperature (NOTE 2). The height limit for testing 101.6 mm diameter cores is 63.5 ± 10 mm and the height limit for testing 152.4 mm diameter cores is 95.25 ± 15 mm.
3. Measure and record each core diameter as *D* in Figure 1.

H. EVALUATION AND GROUPING OF TEST SPECIMENS

1. Determine theoretical maximum specific gravity of the mixture in accordance with California Test 309.
2. Determine each specimen thickness as *t* on Figure 1 in accordance with ASTM D 3549.
3. After curing the compacted specimens for 24 to 96 hrs at room temperature, determine bulk specific gravity by AASHTO T 166 Method A, saturated surface dry (SSD). Determine the specimen volume as the difference between SSD mass and mass in water and express in cubic centimeters.
4. Calculate air voids by AASHTO T 269. Multiply the specimen volume by air void content (decimal format) to determine the volume of air voids.
5. Sort specimens into two subsets of six specimens each so that average air voids contents of the two subsets are approximately equal.

I. PRECONDITIONING OF TEST SPECIMENS

1. One subset will be tested dry and the other will be preconditioned before testing.

2. The dry specimens will be stored at room temperature until testing. The specimens shall be wrapped with plastic or placed in a heavy-duty leak proof plastic bag. The specimens shall then be placed in a $25 \pm 0.5^\circ\text{C}$ distilled water bath for a minimum of 2 hrs and then tested as described in Section J.

3. The other specimens shall be conditioned as follows:

- a. Place the specimen in the vacuum container. The specimen should be supported above the container bottom by a spacer. Fill the container with distilled water at room temperature so that the specimens have at least 25 mm of water above their surface. Apply a vacuum of 13 to 67 kPa absolute pressure (254 to 660 mm of Hg partial pressure) measured at the vessel chamber, which should correlate to 13 to 67 kPa (254 to 660 mm of Hg) as measured at the pump gauge, for a short time (5 to 10 min). Time duration for vacuum shall start when the residual manometer reaches the prescribed range. Remove the vacuum and leave the specimen submerged in water for a short time (5 to 10 min).

- b. Immediately determine the bulk specific gravity by AASHTO T 166 (Method A). Compare saturated surface dry mass with dry mass in air determined in Section H.3. Calculate volume of absorbed water.

- c. Determine the degree of saturation by dividing the volume of absorbed water from Section I.3.b by the volume of air voids from Section H.4 and express the result as a percentage. If the volume of water is between 70% and 80% of the volume of air, proceed to Section I.3.d. If the volume of water is less than 70%, repeat the procedure beginning

- with Section I.3.a and using either more vacuum and/or time. If volume of water is more than 80%, specimen has been damaged and shall be discarded. Repeat the procedure, beginning with Section I.3.a using less vacuum and/or time.
- d. Moisture condition the specimen using the following procedure:
- (1) Cover each of the vacuum-saturated specimens tightly with a plastic film (Saran Wrap or equivalent). Place each wrapped specimen in a plastic bag containing 10 mL of distilled water and seal the bag. Place the plastic bags containing the specimens in a freezer at a temperature of $-18 \pm 3^{\circ}\text{C}$ for a minimum of 16 hrs. After removal from the freezer, place the specimens in a $60 \pm 1^{\circ}\text{C}$ distilled water bath for 24 ± 1 hrs. As soon as possible after placement in the bath, remove the plastic bag and film from each specimen.
 - (2) After 24 ± 1 hrs in the $60 \pm 1^{\circ}\text{C}$ water bath, remove the specimens and place them in a distilled water bath already at $25 \pm 0.5^{\circ}\text{C}$ for 2 ± 1 hrs. It may be necessary to add ice to the water bath to prevent the water temperature from rising above $25 \pm 0.5^{\circ}\text{C}$.
 - (3) Measure the thickness (mm) of the conditioned specimens prior to testing and record as 't' on Figure 1.
 - (4) Test the specimens as described in Section J.
2. Remove the specimen from the $25 \pm 0.5^{\circ}\text{C}$ water bath and immediately place between the two breaking heads 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 of 50 mm per min. (Lottman breaking heads equivalent to Gilson MS-35 shall be used to test indirect tensile strength.)
 3. Record the maximum compressive load noted on the testing machine, and continue loading until a vertical crack appears. Remove the specimen from the machine and pull apart at the crack.
 4. Visually inspect the interior surfaces of the specimen for stripping (NOTE 3), soft aggregate particles (NOTE 4) and for freshly fractured aggregate particles (NOTE 5) and record the observations on Figure 1. Conditioned specimens should be visually examined immediately after testing while still wet and again after air-drying in the laboratory. Compare the color and appearance of the asphalt binder in the conditioned specimens after drying with that of the dry specimens. If the binder appears lighter in color or duller after moisture conditioning, it may be susceptible to moisture damage.

NOTE 3. Stripping is loss of binder coating from the aggregate surfaces. Both coarse and fine aggregate particles should be visually examined.

NOTE 4. Soft aggregate particles are most easily detected in wet asphalt concrete specimens and may not be distinguishable upon drying. They are weak (deleterious) when wet but may appear hard or friable when dry. Soft particles often exhibit "halos" of absorbed binder along their edge, and may be scratched or gouged by a fingernail with relative ease when wet.

J. TESTING

1. Determine concurrently the indirect tensile strength of dry and conditioned specimens at $25 \pm 0.5^{\circ}\text{C}$.

NOTE 5. Some aggregate particles will crack or break due to the mode of loading and stress concentrations at the breaking heads. This does not mean that the aggregate is not sound or durable. Although most of the breakage occurs near the loaded edges, it is not unusual for some aggregate particles to split at the asphalt concrete specimen's diametral failure plane. Record the number of broken aggregate particles along the failure crack for information.

5. All test data and related information are to be recorded on Figure 1.

K. CALCULATIONS (see Figure 1)

1. Calculate the tensile strength as follows:

$$S_t = \frac{2000 P}{\pi t D}$$

Where:

S_t = tensile strength, kPa

P = maximum load, N

t or t' = specimen thickness, mm
(NOTE 6)

D = specimen diameter, mm

NOTE 6. Determine each specimen thickness as t as specified in Section H.2 and use to calculate dry tensile strength. Determine each conditioned specimen thickness as t' as specified in Section I.3 and use to calculate wet tensile strength.

2. Remove the high and low values for each subset. Calculate the final Tensile Strength Ratio (TSR) using the remaining values in each subset, rounded to the nearest whole number, as follows:

$$\text{Tensile Strength Ratio (TSR)} = \frac{S_2}{S_1} \times 100$$

Where:

S_1 = average tensile strength of dry subset, and

S_2 = average tensile strength of conditioned subset.

L. SAFETY AND HEALTH

Prior to handling, testing or disposing of any waste materials, testers are required to read: Part A (Section 5.0), Part B (Sections: 5.0, 6.0 and 10.0) and Part C (Section 1.0) of Caltrans Laboratory Safety Manual. Users of this method do so at their own risk.

REFERENCES:

California Test 125, 304, 309
AASHTO Designations: T 166, T 167,
T 245, T 269, T 283
ASTM Designations: D 3549

End of Text

(California Test 371 contains 7 pages)

RESISTANCE TO COMPACTED BITUMINOUS MIXTURE TO MOISTURE DAMAGE

Project:	Mix:
Plant:	Dosage %:
Additive:	Tester:
Date Tested:	
Sample ID	
Diameter, mm	D
Thickness, mm	t
Dry Mass in Air, g	A
S.S.D. Mass, g	B
Mass in Water, g	C
Volume (B-C), cc	E
Bulk Sp. Gr. (A/E)	F
Max Sp. Gr.	G
% Air Voids [100(G-F)/G]	H
Volume Air Voids (H*E/100), cc	I
Load (Dry), N	P
Saturation	
Absolute Pressure: Hg @ Manometer	
Absolute Pressure: Hg @ Pump	
Time, Minutes	
Moisture Conditioned, One Freeze Thaw Cycle	
S.S.D. Mass, g	B'
Mass in Water, g	C'
Volume (B'-C'), cc	E'
Volume Absorbed Water (B'-A), cc	J'
% Saturation (100*J'/I)	S'
% Swell [100(E'-E)/E]	W'
Thickness, mm	t'
Load (Wet), N	P'
Dry Strength (2000*P/rr**D), kPa	S _d
Wet Strength (2000*P'/rr**D), kPa	S _w
Visual Moisture Damage (Yes/No)	
Aggregate Break Damage (Number of particles)	
Soft Aggregate (Number of particles)	

Initial Tensile Strength Values		Final Tensile Strength Values	
	Dry (S _d) ¹	Dry (S _d) ²	Wet (S _w) ²
1			
2			
3			
4			
5		S ₁	S ₂
6			

Tensile Strength Ratio S₂/S₁*100= _____ %

Conversions:
PSI to kPa, Multiply psi by 6.895
lb_f to N, Multiply lb_f by 4.448

¹The high and low tensile strength values from each "Initial Tensile Strength Values" sub-set shall not be used for the purposes of the "Tensile Strength Average".
²The remaining four tensile strength values from each sub-set shall be used for the final tensile strength values.

OBSERVATIONS/ REMARKS

Figure 1