

**Standard Test Method for
Thermal Stress Restrained Specimen
Tensile Strength**

AASHTO Designation: TP10-93^{1,2} (Reapproved 1996)

1. Scope

1.1 This method determines the tensile strength and temperature at fracture of field or laboratory compacted bituminous mixtures by measuring the tensile load in a specimen which is cooled at a constant rate while being restrained from contraction.

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

2. Referenced Documents

2.1 AASHTO Standards

- M231 Specification for Standard Masses and Balances Used in the Testing of Highway Materials
- PP3 Preparation of Asphalt Concrete Specimens by Means of the Rolling Wheel Compactor

2.2 ASTM Standards

- D3202 Standard Practice for Preparation of Bituminous Mixture Beam Specimens by Means of California Kneading Compactor
- D3665 Practice for Random Sampling of Construction Materials.

3. Summary of Test Method

3.1 A compacted bituminous mixture specimen, either beam or core of specified dimensions, is affixed at the ends to the platens of a test system and enclosed in an environmental chamber. An initial tensile load is applied to the specimen and the specimen is cooled

at a given rate. Thermal contraction on the long axis of the specimen is monitored electronically and the initial length of the specimen is reestablished by automatic adjustment of the platens on an incremental basis to the original position. This process continues until tensile fracture of the specimen occurs.

4. Significance and Use

4.1 The thermal stress restrained specimen test provides data that allows the temperature vs stress relationship to be determined for bituminous mixture pavement materials. The derived information can be used in pavement design and structural analysis to reduce thermal cracking and improve life cycle performance of bituminous mixture pavements.

5. Apparatus

5.1 Test System - A closed-loop test system, as described in Annex 1, capable of cooling a bituminous mixture specimen at a constant rate while restraining the specimen from contraction and periodically measuring the tensile load and the specimen temperature from the beginning of the test to specimen failure.

5.2 Specimen Alignment Stand - A device similar to the device shown in Figure 1 for providing the concentric and perpendicular alignment of the platens and the specimen, and to secure the specimen and platens while the epoxy cures.

5.3 Invar Rods - Two invar rods 6 ± 1 mm (0.25 ± 0.03 in.) in diameter and 300 ± 10 mm (12 ± 0.5 in.) in length

5.4 Specimen Platens - Two specimen platens 150 ± 3 mm (6 ± 0.1 in.) in diameter and 50 ± 3 mm (2 ± 0.1 in.) thick

¹ This standard is based on SHRP Product 1021.

² Approved in October 1993, this provisional standard was first published in January 1994. Reconfirmed in January 2001.

5.5 Threaded Rods - Two threaded rods M6 x 1 (1/4-20 UNC), 450 ± 10 mm (18 ± 0.5 in.) in length, with 2 nuts each.

5.6 Balance - A balance meeting the requirements of M231, Class G2

5.7 Miscellaneous Apparatus - Plumb bob, spatula (for proportioning and mixing epoxy components), metal pans and gloves,

6. Materials

6.1 Epoxy - Thermoset DC-80 or equivalent.

6.2 Miscellaneous Materials - Modeling clay, duct tape, epoxy solvent, 240-grit sandpaper.

7. Hazards

7.1 Follow the safety requirements listed in the manufacturer's safety information sheet when using epoxy and/or epoxy solvents.

8. Test Specimens

8.1 Compacted Bituminous Mixture Specimens - Obtain specimens from a larger sample of asphalt concrete which has been taken from an existing pavement or prepared in the laboratory by coring or by sawing on all sides with a diamond blade. When the larger samples are taken from existing pavement, obtain them in accordance with ASTM D3665. When the larger samples are compacted in the laboratory prepare them in accordance with PP3 or ASTM D3202. Cored specimens, after coring, shall be 60 ± 5 mm (2.5 ± 0.19 in.) in diameter and 250 ± 5 mm (10 ± 0.25 in.) in length. Beam specimens, after sawing, shall be 50 ± 5 mm (2.0 ± 0.15 in.) square and 250 ± 5 mm (10.0 ± 0.25 in.) in length.

8.2 Measurement of Cores - Determine the diameter of cores by obtaining six measurements taken at approximately 30° intervals around the circumference of the core at the middle of the specimen length. Record the six measurements to the nearest 0.01 mm (0.001 in.). Average the six measurements and record the result to the nearest 0.1 mm (0.01 in.). Use the average to determine the cross-sectional area of the core, and record the average cross-sectional area to the nearest 5 mm² (0.01 in²).

8.3 Measurement of Beams - Determine the cross-sectional area of beams by measuring each width dimension of the specimen at the middle of the specimen length and at points on each side of the middle point. Record the width measurements to the nearest 0.01 mm (0.001 in.). Average the three measurements for each width dimension and record the result to the nearest 0.1 mm (0.01 in.). Multiply the average width dimensions and record the average cross-sectional area obtained to the nearest 5 mm² (0.01 in.²).

9. Preparation of Apparatus and Specimen

9.1 Specimen Platen Preparation and Specimen Alignment - Clean the platens with epoxy solvent. Sand the platen surface with a piece of 240-grit sandpaper to completely remove any epoxy or specimen-end residue remaining from prior tests and to provide a rough surface for epoxy adhesion.

9.2 Using an ink marker, trace diametral lines across the top face of the bottom platen such that they connect the alignment holes on opposite sides of the platen. Also trace lines longitudinally along each side of the specimen such that each line divides the side by its midpoint. Lines on the specimen and platen will be used to provide concentric alignment. (Figure 2)

9.3 Screw the specimen platens into the alignment stand. Adjust the position of the platens to a length approximately 20 mm (1 in.) longer than the specimen length. Insert the threaded rods into holes on opposite sides of platens but do not tighten yet. Use the plumb bob to line up the holes between the top and bottom platens.

Note 1 -- Alignment is critical to obtaining meaningful test results. Therefore, the alignment device aligns the platens and specimen, and supports the specimen in a level position.

9.4 Epoxy Preparation - Follow the mixing, proportioning, applying, and curing instructions supplied by the manufacturer for the epoxy being used. If Thermoset DC-80 made by Meyer Plastics, Inc., obtain 50 ± 5 grams each of epoxy resin and epoxy hardener in a container suitable for mixing. Thoroughly mix the two epoxy components at a 1:1 ratio until a uniform color and consistency results.

9.5 Attaching Specimen to Platens - Apply a 3 to 6 mm (0.125 to 0.25 in.) thick film of epoxy over a 50 ± 3 mm (2 ± 0.125 in.) diameter area on both the top and bottom platens in the specimen alignment stand. Place the specimen between the platens and carefully lower the top platen so that the specimen ends, epoxy and platens are in contact.

9.6 Check the alignment of the specimen by comparing the marked lines on the sides of the specimen to the marked lines on the bottom platen. Rotate the specimen, if necessary, to achieve concentric alignment.

9.7 Equally apply the remaining epoxy to the intersecting surfaces between the specimen sides and the platen faces, being careful not to disturb the position of the specimen. Build up the epoxy approximately 20 mm (1 in.) along the sides of the specimen (relative to the platen face). (Figure 3)

Note 2 -- The build-up of epoxy is necessary to provide adequate adhesion between the specimen and the platen such that failure occurs in the middle portion of the specimen rather than at the specimen/platen interface.

9.7 Recheck the alignment of the specimen by comparing the marked lines on the sides of the specimen to the marked lines on the bottom platen. Rotate the specimen, if necessary, to achieve concentric alignment.

10. Conditioning

10.1 Leave the specimen in the alignment stand for 4 to 24 hours in a $23 \pm 2^\circ\text{C}$ environment to allow the epoxy to harden.

10.2 Specimen Pre-Cooling - After the epoxy has cured, tighten the nuts on the threaded rods with fingers only. Remove the specimen/platen assembly from the alignment stand and screw a clevis eyelet into the top platen. Hang the specimen/platen assembly from the eyelet in a $5 \pm 2^\circ\text{C}$ environment for 6 ± 0.5 hours prior to testing.

11. Preparation of Apparatus

11.1 Connect the specimen/platen assembly to the top U-joint clevis by inserting the eyelet between the

clevis opening, aligning the holes, and inserting a pin through the holes. Screw another eyelet into the bottom platen and similarly connect the bottom eyelet to the bottom U-joint clevis. (Figure 4)

11.2 Attach the two clamps used to secure the linear variable differential transformers (LVDT's) to the bottom platen with nuts and screws.

11.3 Attach the thermistors to the specimen with modeling clay. Place one thermistor each at the bottom end, the center, and the top end of the specimen, each on a different side of the specimen. The thermistors are used to measure the temperature of the specimen surface.

11.4 Attach the cable of the resistance temperature device (RTD) to the middle portion of the specimen on a free side. Secure the cable with duct tape. The RTD is used in monitoring and controlling the environmental cabinet temperature.

11.5 Attach the two clamps used to secure the invar rods to the top platen with nuts and screws.

11.6 Insert the LVDT's into the bottom clamps and the invar rods into the top clamps. Make sure each rod and LVDT pair are aligned properly. Adjust the clamps to obtain proper alignment. After aligning the rod and LVDT, secure the clamps to the platens and secure the invar rod in the top clamp.

11.7 Adjust the position of the LVDT in the bottom clamp such that its voltage output is near zero. This adjustment is necessary to ensure that the LVDT operates in its linear range during the test.

11.8 Sufficiently loosen the threaded rods attached on opposite sides of the platens until all stresses generated during the test are fully transmitted through the specimen. Close and secure the environmental cabinet door, and begin the test procedure.

12. Procedure

12.1 Start the flow of liquid nitrogen to cool the environmental cabinet to 5°C . When the average surface temperature is $5 \pm 1^\circ\text{C}$ apply the initial tensile load to the specimen.

12.2 Apply an initial tensile load of 50 ± 5 N (10 ± 1 lbs.) to the specimen by manually turning the hand-crank on the step-motor to raise the top platen.

12.3 Start cooling the cabinet at a rate of $10 \pm 1^\circ\text{C}$ per hour.

12.4 Automatically record the environmental cabinet temperature, specimen temperature, elapsed time, specimen displacement and load as the test progresses.

12.5 Continue the test until the specimen fails and record the specimen temperature and load at failure and the time to failure.

13. Calculations

13.1 Calculate the fracture strength as follows:

$$\text{Fracture Stress} = P_{\text{ult}}/A$$

where: P_{ult} = ultimate tensile load at fracture in Newtons (pounds)

A = average cross-sectional area of specimen in mm^2 (in.^2)

13.2 Calculate the slope of the thermally induced stress curve as follows:

$$\text{Slope} = \delta S / \delta T$$

where: δS = average change in stress along the linear portion of the curve just prior to failure, in pascals (psi), (Figure 5)

δT = average change in temperature along the linear portion of the curve just prior to failure, in $^\circ\text{C}$ (Figure 5)

14. Report

14.1 Test Specimen Description - bitumen type, bitumen content, aggregate gradation, and air void percentage of the test specimen

14.2 Time to failure, nearest 0.1 hour

14.3 Specimen temperature at failure (average of the 3 thermistor readings), nearest 0.1°C

14.4 Average cross-sectional area of the specimen, nearest 5 mm^2 (0.01 in.^2) (Section 8.2)

14.5 Ultimate load at failure (maximum tensile load), nearest 5 N (1 lb_f)

14.6 Fracture strength, nearest 5 kPa (1 psi) (Section 13.1)

14.7 Slope of the thermally induced stress curve, nearest $100 \text{ Pa}/^\circ\text{C}$ ($0.1 \text{ psi}/^\circ\text{C}$) (Section 13.2)

14.8 Failure Description - location of break along specimen length, nature of break (angular, flat, broken aggregate, etc.)

15. Precision and Bias

15.1 Precision - The work necessary to determine the precision of this test has not yet been performed.

15.2 Bias - No justifiable statement can be made on the bias of this test method because there is no reference value available.