Designation: D7460 – 08

Standard Test Method for
Determining Fatigue Failure of Compacted Asphalt Concrete Subjected to Repeated Flexural Bending[1]

This standard is issued under the fixed designation D7460; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method provides procedures for determining a unique failure point for estimating the fatigue life of 380 mm (14.96 in.) long by 50 mm (1.97 in.) thick by 63 mm (2.48 in.) wide asphalt concrete beam specimens sawed from laboratory or field compacted asphalt concrete, which are subjected to repeated flexural bending.

1.2 The between-laboratory reproducibility of this test method is being determined and will be available on or before June 2013. Therefore, this test method should not be used for acceptance or rejection of a material for purchasing purposes.

1.3 The text of this standard references notes and footnotes which provide explanatory material. These notes and footnotes (excluding those in tables and figures) shall not be considered as requirements of the standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, 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 *ASTM Standards:*[2]
D75 Practice for Sampling Aggregates
D140 Practice for Sampling Bituminous Materials
D979 Practice for Sampling Bituminous Paving Mixtures
D2041 Test Method for Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures
D3203 Test Method for Percent Air Voids in Compacted Dense and Open Bituminous Paving Mixtures
D3549 Test Method for Thickness or Height of Compacted Bituminous Paving Mixture Specimens
D3666 Specification for Minimum Requirements for Agencies Testing and Inspecting Road and Paving Materials

D5361 Practice for Sampling Compacted Bituminous Mixtures for Laboratory Testing
E29 Practice for Using Significant Digits in Test Data to Determine Conformance with Specifications

2.2 *AASHTO Standards:*[3]
T 321 Standard Method of Test for Determining the Fatigue Life of Compacted Hot-Mix Asphalt (HMA) Subjected to Repeated Flexural Bending
PP 3 Preparing Hot-Mix Asphalt (HMA) Specimens by Means of the Rolling Wheel Compactor
R 30 Standard Practice for Mixture Conditioning of Hot-Mix Asphalt (HMA)

3. Terminology

3.1 *Definitions:*

3.1.1 *beam modulus*—Flexural Beam Stiffness, as determined in 10.1.3.

3.1.2 *failure point*—the number of cycles to failure, N_f, which corresponds to the maximum or peak Normalized Modulus × Cycles (Fig. 13) when plotted versus Number of Cycles.

3.1.3 *initial beam modulus*—Flexural Beam Stiffness determined at approximately 50 load cycles.

3.1.4 *normalized modulus × cycles*—see Rowe and Bouldin (**1**):[4]

$$\frac{(\text{Beam Stiffness} \times \text{Cycle Number})}{(\text{Initial Beam Modulus} \times \text{Cycle of Initial Beam Modulus})}$$

4. Summary of Test Method

4.1 The four-point flexural bending test method is conducted on compacted beam specimens to evaluate the fatigue properties of an asphalt concrete mixture. A cyclic haversine (displaced sine wave with full amplitude on tension side of zero) displacement is applied at the central H-frame third points of a beam specimen, while the outer third points are held in an articulating fixed position. The frequency rate ranges from 5 to 10 Hz. This produces a constant bending moment

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over the center third (L/3) span (118.5 to 119 mm (4.66 to 4.69 in.)) between the H-frame contact points on the beam specimen. The level of desired strain is pre-calculated and an input for the displacement control. The deflection at the mid-length position (L/2) of a beam specimen is regulated by the closed loop control system.

5. Significance and Use

5.1 The laboratory fatigue life determined by this standard for beam specimens have been used to estimate the fatigue life of asphalt concrete pavement layers under repeated traffic loading. Although the field performance of asphalt concrete is impacted by many factors (traffic variation, speed, and wander; climate variation; rest periods between loads; aging; etc.), it has been more accurately predicted when laboratory properties are known along with an estimate of the strain level induced at the layer depth by the traffic wheel load traveling over the pavement.

NOTE 1—The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of Specification D3666 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Specification D3666 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of Specification D3666 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.

6. Apparatus

6.1 *Test System*—The test system shall consist of a load frame, an environmental chamber (temperature control system) and a closed loop control and data acquisition system. The test system shall meet the minimum requirements specified in Table 1. This standard specifically describes the systems of two primary suppliers (Cox and Sons, Inc. [Cox] and Industrial Process Controls, Ltd. [IPC]); however, other similar equipment could also be used.

6.1.1 *Loading Device*—The test system shall include a closed-loop, computer controlled loading component which, during each load cycle in response to commands from the data processing and control component, adjusts and applies a load such that the specimen experiences a constant level of displace-

ment (and resulting strain) during each load cycle. The loading device shall be capable of *(1)* providing cyclic haversine (= SIN^2(degrees/2)) loading at a frequency range of 5 to 10 Hz, *(2)* subjecting specimens to 4-point bending with free rotation and horizontal translation at all load and reaction points, and *(3)* forcing the specimen back to its original position (that is, zero deflection) at the end of each loading cycle. Fig. 1 illustrates the haversine waveform. Figs. 2 and 3 show the movements of the Cox and IPC loading devices, respectively; the Cox device loads in a downward direction and the IPC loads in an upward direction. The early version of the IPC device does not have free translation at the inner clamps; however, the newer model allows free rotation and translation at all four clamps.

6.1.2 *Environmental Chamber (Temperature Control System)*—The environmental chamber shall enclose the entire specimen and maintain the specimen at the desired test temperature. The temperature shall be within ±0.5°C (±0.9°F) throughout the conditioning and testing times. An environmental chamber is not required if the temperature of the surrounding environment can be maintained within the specified limits.

6.1.3 *Control and Data Acquisition System*—During each load cycle the control and data acquisition system shall be capable of measuring the displacement of the beam specimen, and adjusting the load applied by the loading device such that the specimen experiences a constant level of displacement on each load cycle. In addition, it shall be capable of recording load cycles, applied loads, beam displacements, and temperature while computing and recording the maximum tensile stress, maximum tensile strain, phase angle, and stiffness at load cycle intervals specified by the user.

6.2 *Miscellaneous Apparatus and Materials*—For the Cox device, an aluminum, wedge-shaped target for connecting the displacement sensor to the neutral axis of the specimen and cyanoacrylate (super glue) or equivalent is needed for attaching the target to the specimen. With both the Cox and the IPC equipment, an alignment fixture and a solid aluminum beam are needed for setting the proper clamp spacing and a saw suitable for cutting the beams with parallel faces to the proper tolerance.

7. Hazards

7.1 Observe standard laboratory safety precautions when preparing and testing asphalt concrete specimens.

8. Sampling and Test Specimen Preparation

8.1 *Laboratory-Mixed and Compacted Specimens*—Sample asphalt binder in accordance with Practice D140 and sample aggregate in accordance with Practice D75. If a complete fatigue curve is desired, prepare nine replicate asphalt concrete beam specimens, from slab(s) or beam(s) compacted in accordance with AASHTO PP 3. Otherwise, prepare as many specimens as desired for individual beam test results. Laboratory prepared mixtures are typically conditioned with a short-term aging process, such as defined in AASHTO R 30. Test at least six replicate asphalt concrete beam specimens at different strain levels in order to develop a fatigue curve, as shown in Fig. 4. The extra specimens may also be tested as desired, if the data appears to include an outlier, or if a beam failure occurs

TABLE 1 Test System Minimum Requirements

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Load Measurement and Control	Range: 0 to 5 kN (0 to 1124 lbf) Resolution: 2.5 N (0.56 lbf) Accuracy: 5 N (1 lbf)
Displacement Measurement and Control	Range: 0 to 5 mm (0 to 0.2 in.) Resolution: 2.5 µm (9.8×10^5 in.) Accuracy: 5 µm (2.0×10^4 in.)
Frequency Measurement and Control	Range: 5 to 10 Hz Resolution: 0.005 Hz Accuracy: 0.01 Hz
Temperature Measurement and Control	Resolution: ±0.25°C (±0.45°F) Accuracy: ±0.5°C (±0.9°F)
Displacement Sensor	Linear Variable Differential Transducer (LVDT), Extensometer, or similar device
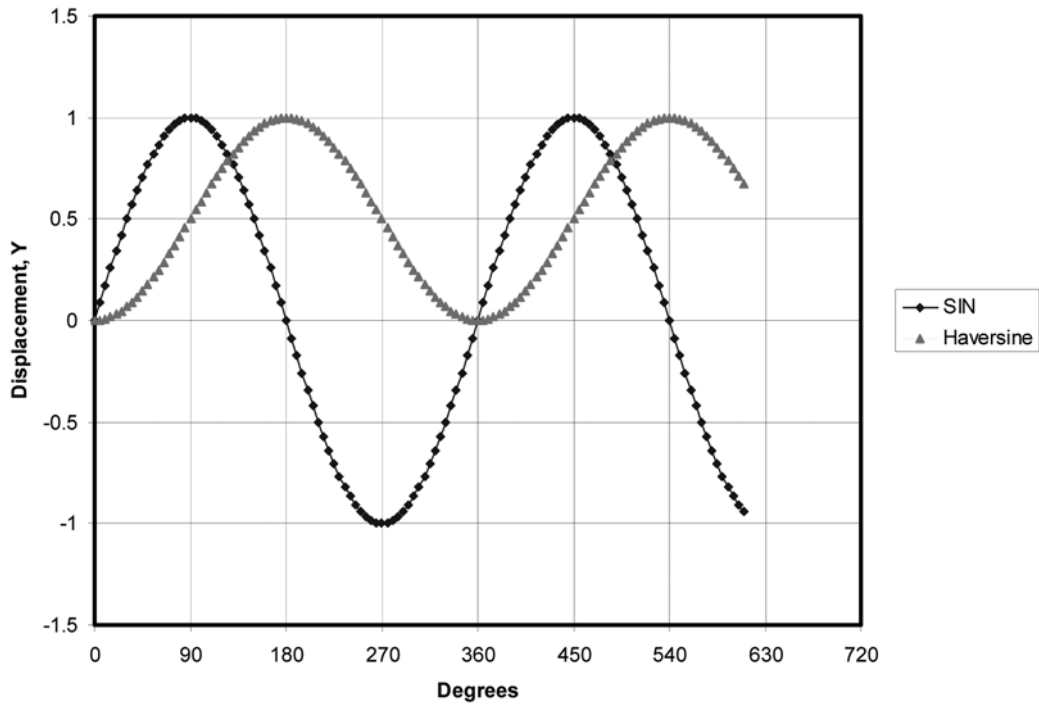
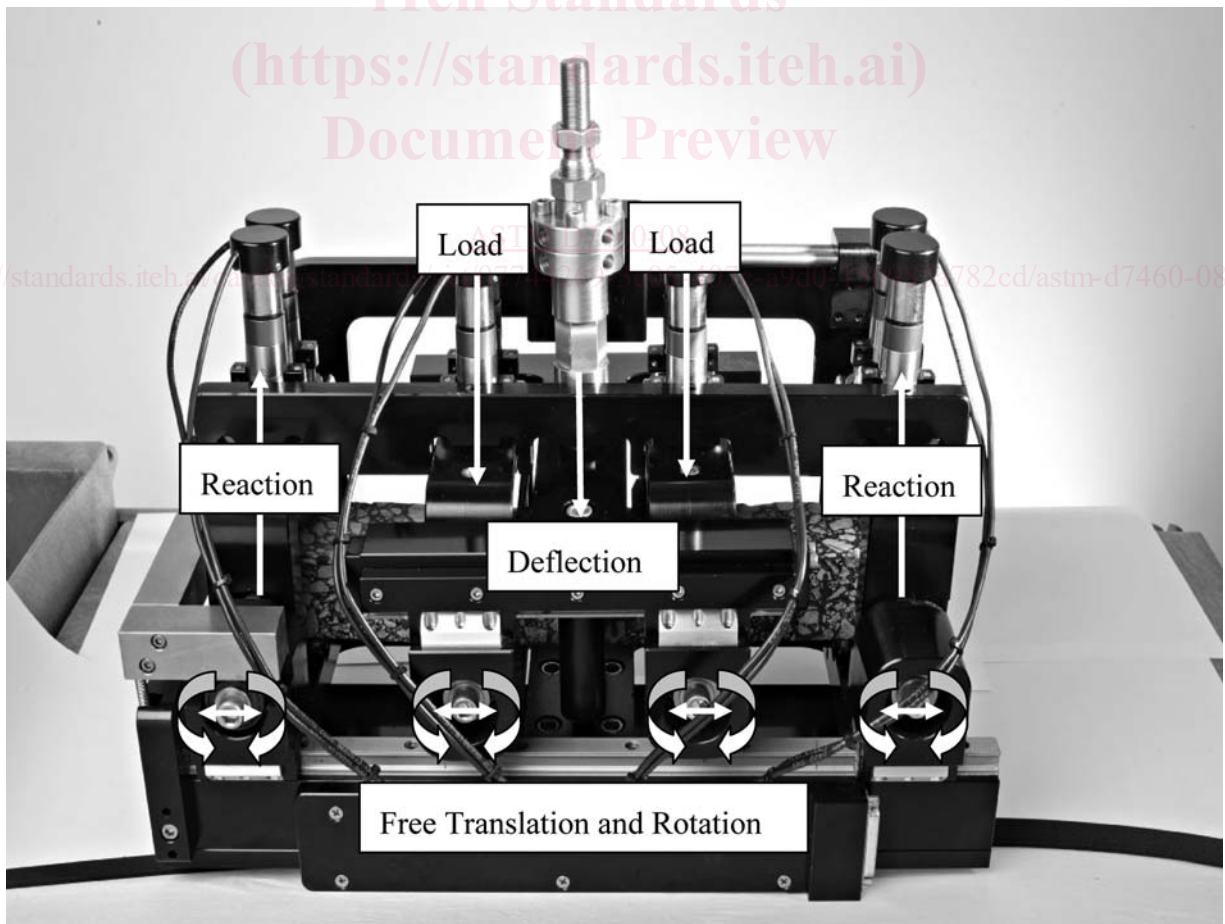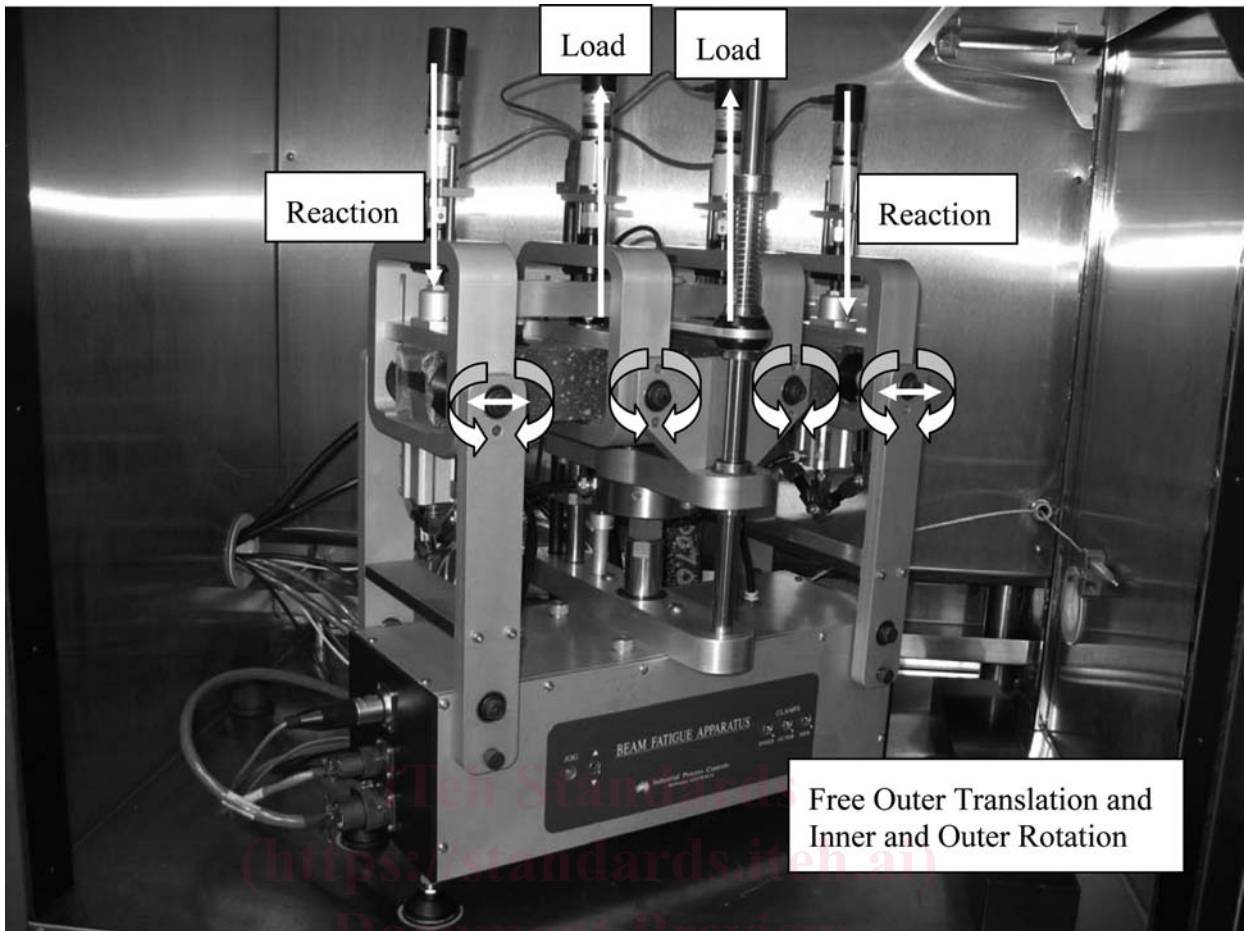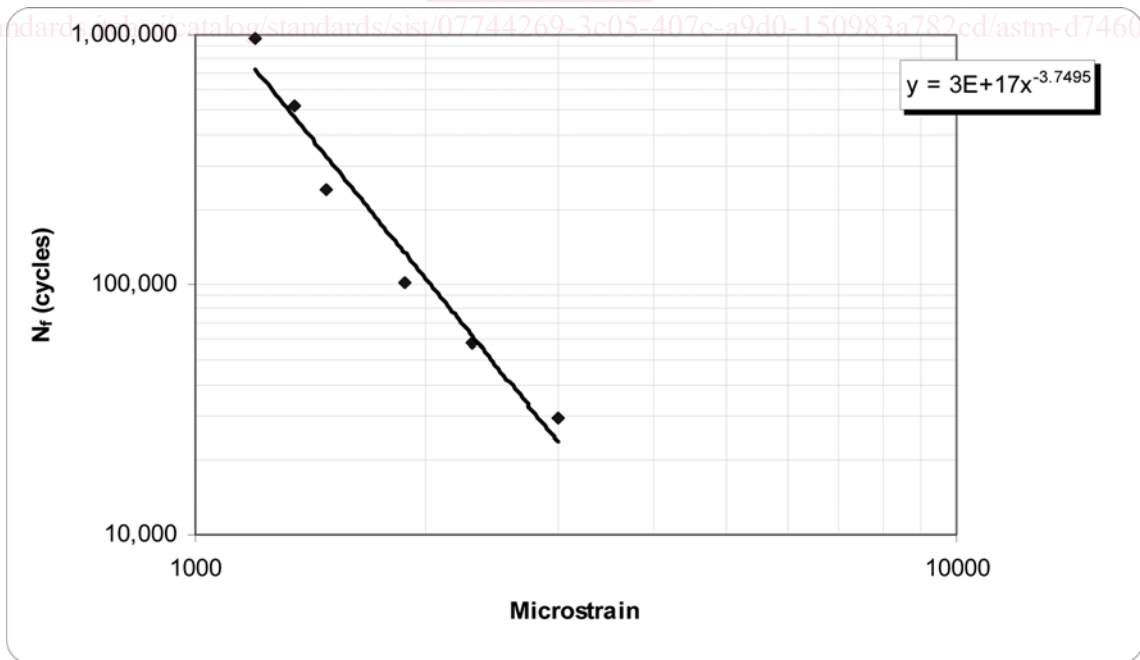**FIG. 1 Illustration of Haversine Wave Form Relative to Sine Wave**

FIG. 2 Load and Freedom Characteristics of Fatigue Test Apparatus (Cox)

NOTE 1—Early model shown; the newer model allows free rotation and translation at all four clamps.
FIG. 3 Load and Freedom Characteristics of IPC Fatigue Test Apparatus

NOTE—Strain levels should be adjusted for the material.
FIG. 4 Example Fatigue Curve

directly at a clamp. A linear relationship on a log-log plot exists between N_f and the level of strain (με, microstrain = strain $\times$ 10^6).

Note 2—The type of compaction device (linear kneading, rolling wheel, vibratory) may influence the test results, relative to representing actual construction.

Note 3—Normally test specimens are compacted using a standard compactive effort. However, the standard compactive effort may not reproduce the air voids of roadway specimens measured according to Test Method D3203. If specimens are to be compacted to a target air void content, the compactive effort should be determined experimentally.

8.2 *Plant-Mixed, Laboratory Compacted Specimens*— Obtain asphalt concrete samples in accordance with Practice D979. If a complete fatigue curve is desired, prepare nine replicate asphalt concrete beam specimens, from slab(s) or beam(s) compacted in accordance with AASHTO PP 3. Otherwise, prepare as many specimens as desired for individual beam test results. See Notes 2 and 3. Test at least six replicate asphalt concrete beam specimens at different strain levels in order to develop a fatigue curve, as shown in Fig. 4. The extra specimens may also be tested as desired, if the data appears to include an outlier, or if a beam failure occurs directly at a clamp.

8.3 *Roadway Specimens*—Obtain compacted asphalt concrete samples from the roadway in accordance with Practice D5361.

8.4 *Specimen Trimming*—Saw at least 6 mm from all sides of each compacted specimen to provide smooth, parallel (saw-cut) surfaces for mounting the measurement gages. The final required dimensions of the test specimen, after sawing, are 380 ± 6 mm (14.96 ± 0.24 in.) in length, 50 ± 2 mm (1.96 ± 0.08 in.) in height, and 63 ± 2 mm (2.48 ± 0.08 in.) in width. To minimize specimen variability, it is recommended that the beams be immediately labeled to ensure consistent orientation (top and sides) during testing, relative to the compaction process.

8.5 *Specimen Storage*—The specimens should be stored on a 12.7 mm (½ in.) steel plate with a flatness of 0.127 mm (0.005 in.) across the surface of the plate from end to end. This flat surface keeps the beam specimens from being pre-strained before testing. Limit stacking of specimens to two high on storage racks.

9. Procedure

9.1 *Fixture Alignment*—A solid aluminum beam, having dimensions specified in 8.4 with tolerances to a flatness of 0.051 mm (0.002 in.) across the length of the aluminum beam (measured using a straight edge and feeler gauges), is used to ensure proper alignment of the beam fixture prior to testing. Insert the aluminum beam into the fixture, clamping the side clamps on the outside frame first. Clamp the top clamps on the outside frames followed by the top clamps on the inside frames. Place the actuator in load control and remove the load. Verify that the clamps are fully seated on the aluminum beam. On the Cox frame, apply the side clamps to the inside frames. After returning to displacement control, adjust the load to the positive side of zero; make a note of the actuator displacement sensor location and start cycling from this position. Once this zero load position is located and used as a guide, the bottom of

all the clamps will be aligned. If the top and bottom sides of the beam test specimen are not parallel, it should not be an issue with the clamping. The saw cuts are typically straight on all sides of the beam even if these are not parallel to each other; the top clamps will compensate for the lack of parallelism, since the clamps are all independent of each other. The Cox fixture is designed to use the 3.175 mm (⅛ in.) tensile bar coupler for facilitating 360° movement without creating an eccentric moment, as shown in Fig. 5. The two spent 3.175 mm (⅛ in.) tensile bars pictured on the right-hand side of Fig. 5 show the deformation that can occur due to years of fatigue testing; any shortening of the shaft changes the stroke location. If the fixture uses this type of coupler, this initial sensor location should be checked after every seven testing days to evaluate the condition of the coupler. If the fixture is hard coupled, as with the IPC device, this alignment check can be performed less frequently.

9.2 *Specimen Measurement*—Measure the height and width of the specimen to the nearest 0.01 mm (3.94 $\times$ 10⁻⁴ in.) at three or more different points along the middle 100 mm (3.94 in.) of the specimen length in accordance with applicable sections of Test Method D3549, Determine the average of the measurements for each dimension and record the averages to the nearest 0.1 mm (0.004 in).

9.3 *Attaching the Target to the Neutral Axis of Specimen (Required with the Cox Fixture)*—Locate the center of a specimen on one of its 50 mm (1.97 in.) high lengthwise sides (i.e., mid-height and mid-length of the beam). Apply cyanoacrylate (super glue) or equivalent in a circle around this point and place the target on the glue such that the top of the target is at the center point of the beam. Allow the glue to cure before moving the specimen. Fig. 6 illustrates the target attached to the neutral axis of the specimen.

9.4 Place the specimen on a stiff flat surface in an environment holding the desired test temperature for two hours to ensure that the specimen has equilibrated to the desired test temperature prior to beginning the test. Based on past experience, approximately 1.5 to 2 hours is sufficient to equilibrate the temperature of a beam that was stored near room temperature to its testing environment. The temperature shall be within ±0.5°C (±0.9°F) throughout the conditioning and testing times.

Note 4—A common temperature used for this test method is 20°C (68°F), since it is near the critical temperature level for most of the U.S. Another method that has been used to determine the effective test temperature for equivalent pavement fatigue damage is the following equation developed during the Strategic Highway Research Program (SHRP):

$$T_{eff.Fatigue} = 0.8(MAPT) - 2.7 \quad (1)$$

where:
MAPT = mean annual pavement temperature (°C),
MAPT = $T_{20mm} = T_{air} - 0.00618(lat^2) + 0.2289(lat)$
$+ 42.2(0.9545) - 17.78,$ (2)
T_{20mm} = temperature at 20 mm depth from pavement surface (°C),
T_{air} = mean annual air temperature (°C), and
lat = latitude of project location (degrees).

9.5 Open the clamps and slide the specimen into position (Figs. 7-10). With both the Cox and the IPC equipment, use the
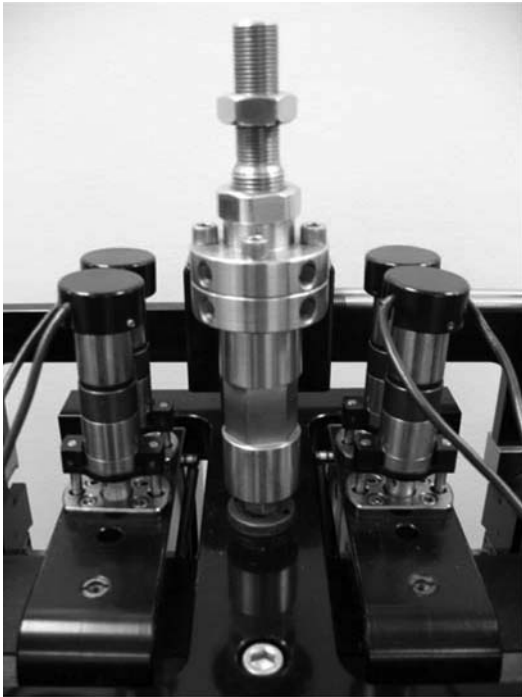
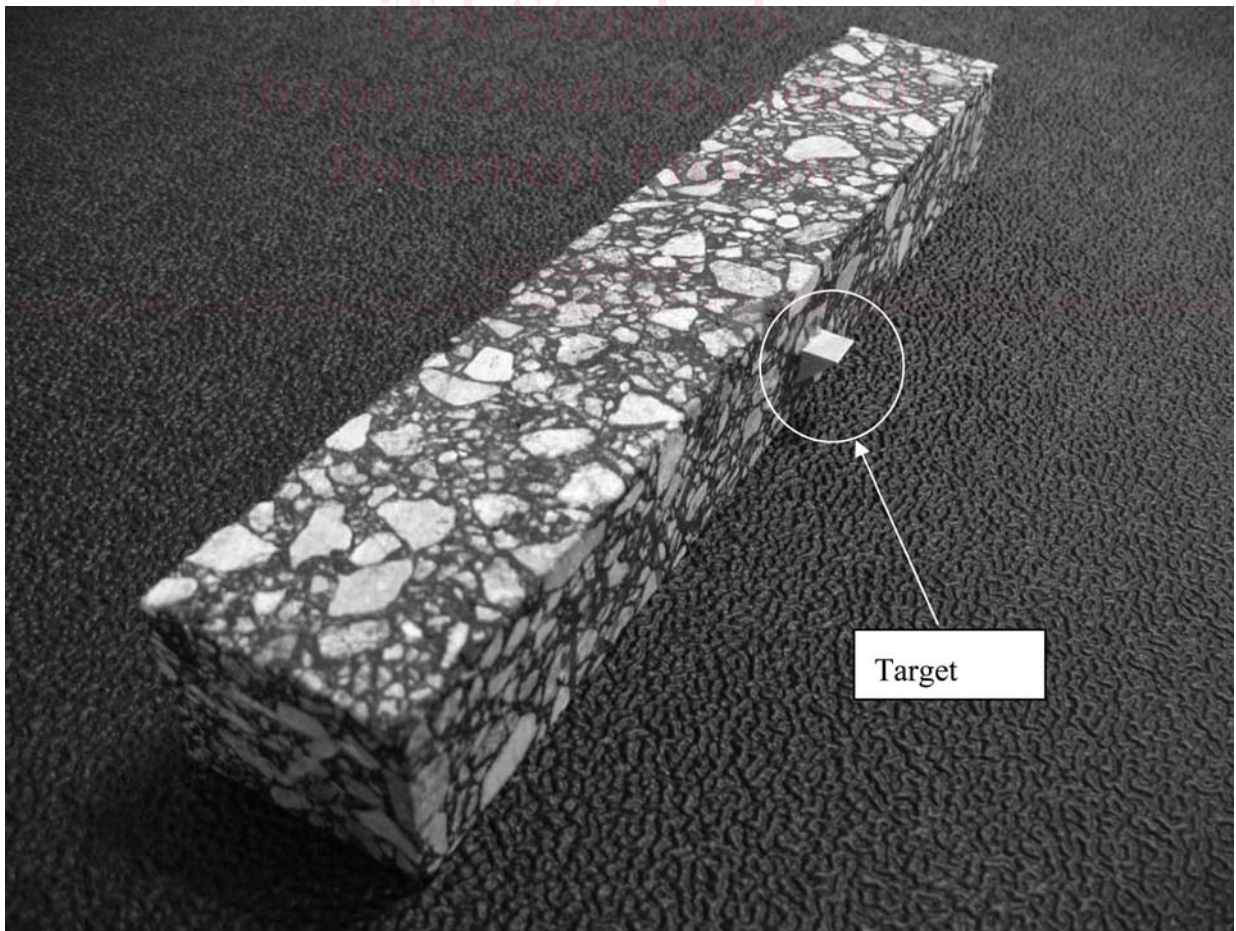FIG. 5 Tensile Bar Coupler Connecting the Actuator to the H-frame (Inner Clamps)

FIG. 6 Target Attached to the Beam Neutral Axis (Mid-Height, Mid-Length) (Cox)