Standard Method of Test for

Determining Asphalt Binder Bond Strength by Means of the Bitumen Bond Strength (BBS) Test

AASHTO Designation: TP-XX-11

1. SCOPE

1.1 This test method quantifies the tensile force needed to remove a pullout stub adhered to a solid substrate with asphalt binder (bitumen). Samples are prepared at controlled environmental (i.e., temperature and humidity) and moisture conditions. After conditioning, a pneumatic load is applied to a pullout stub until failure using an ASTM D 4145 Type IV adhesion tester. The pullout tension at failure is used to describe the adhesive properties of the asphalt binder and compatibility between aggregates and asphalt binders.

1.2 The values stated in SI units are to be regarded as the standard.

1.3 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety concerns 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:*

- D 140, Practice for Sampling Bituminous Materials
- D 977, Specification for Emulsified Asphalt
- D 2397, Specification for Cationic Emulsified Asphalt
- D 4541, Pull-Off Strength of Coatings Using Portable Adhesion Testers
- E 77, Inspection and Verification of Thermometers
- E 145, Gravity-Convection and Forced-Ventilation Ovens

2.2 *AASHTO Standards:*

- M 140, Standard Specification for Emulsified Asphalt
- M 208, Standard Specification for Cationic Emulsified Asphalt
- T 40, Standard Method of Test for Sampling Bituminous Materials

3. TERMINOLOGY

3.1 *Definitions:*

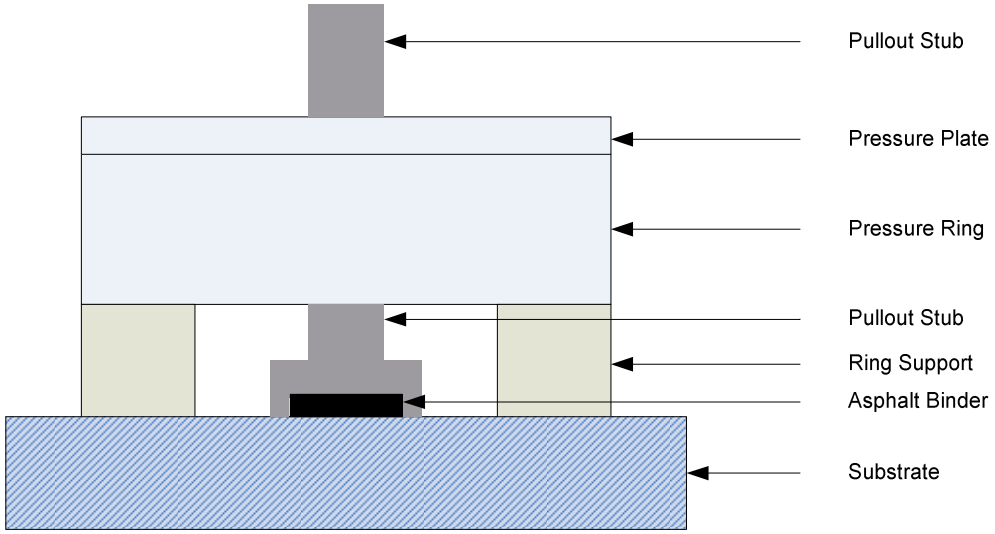
3.1.1 *Adhesion*—Bond strength between the substrate and asphalt binder.

3.1.2 *Cohesion*—Bond strength within the asphalt binder.

3.1.3 *Saturated Surface Dry (SSD) Condition*—In the SSD condition, the void structure of the aggregate is filled with moisture, while the main surface area of the aggregate particles remains dry.

4. SUMMARY OF METHOD

4.1 The adhesion tester applies a pneumatic load via a pressure ring to a pullout stub fixed to a rigid substrate with asphalt binder, as shown in Figure 1. The binder is adhered to the substrate and subjected to differing curing conditions. For curing emulsified binders, fixed levels of temperature and humidity are used. Moisture conditioning is possible for hot-applied binders to evaluate the effects of moisture damage. Recording the applied stress on the binder sample over time allows for calculation of load to failure and loading rate. The surface of the substrate is visually examined to determine the type of failure mode.



Scale is approximate.

Figure 1—Schematic Representation of the Testing Assembly for the Bitumen Bond Strength Test

5. SIGNIFICANCE AND USE

5.1 Pullout tensile strength values measured over a range of environmental conditions and curing times provide information related to the adhesive and cohesive behavior of hot-applied and emulsified asphalt binders.

5.2 Evaluation of pullout tensile strength on different aggregate substrates allows for assessment of asphalt-aggregate compatibility.

5.2.1 For emulsified binders, comparison of materials based on curing rate and ultimate tensile strength is possible.

5.2.2 For hot-applied binders, moisture damage evaluation is possible by observing the decrease in pullout tensile strength due to moisture conditioning.

6. APPARATUS

6.1 *Molds*—For emulsified binders, use a silicone mold measuring approximately 40 mm on each side with a 20 mm diameter hole and 0.8 mm thickness. The mold has no backing and is used to contain the emulsion on the aggregate surface. For hot-applied binders, use a silicone mold measuring approximately 40 mm on each side with a 10 mm diameter cavity with 2.0 mm depth. This mold is similar to the molds used to prepare Dynamic Shear Rheometer (DSR) test samples. Figure 2 depicts diagrams of both mold types.

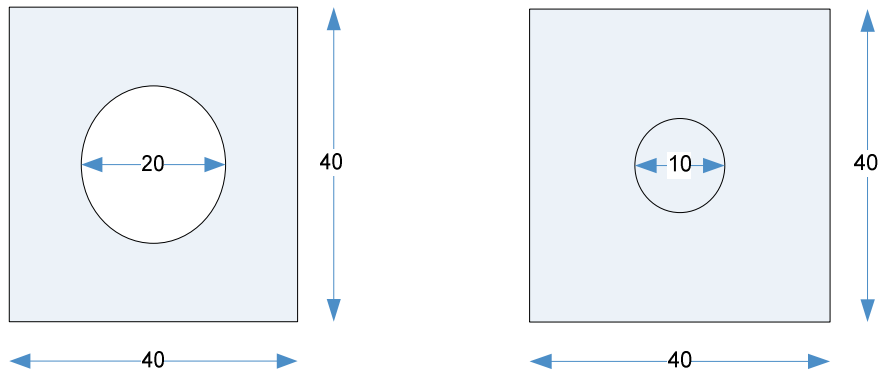


Figure 2—Mold Dimensions (mm) for Emulsified Binders (left) and Hot-Applied Binders (right)

6.2 *Base Plate*—A solid aggregate substrate, aggregate composite, or glass plate of sufficient thickness is used. Recommended minimum thicknesses are 20 mm and 5 mm for the aggregate and glass substrates, respectively. The base plate must be uniformly flat to ensure that asphalt binder does not flow beneath the mold, and to reduce the possibility of eccentric loading during testing.

6.3 *Testing Machine*—Use a Type IV adhesion tester as defined in ASTM D 4541 for all tests. Such a device must consist of, at minimum, a control module, pressure ring, pressure plate, and data acquisition software. While different loading fixtures are

available, a pressure plate of 57 mm diameter is recommended for hot-applied and emulsified binders. Figure 3 depicts an example of the testing machine.

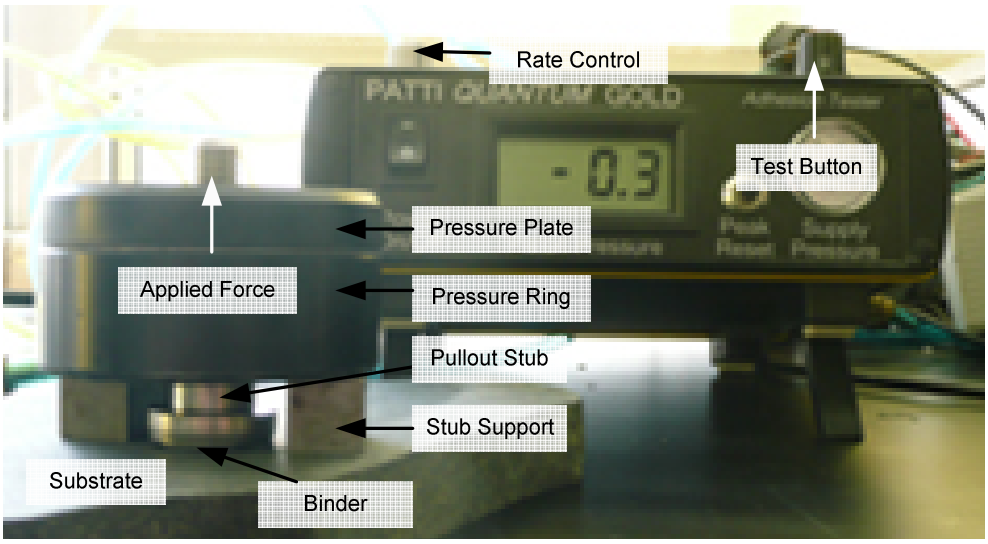


Figure 3—General Representation of Bitumen Bond Strength Test Apparatus

6.4 *Air Supply*—Capable of producing a consistent air pressure of at least 0.7 MPa as read on the supply gauge. Self-contained air cylinders, shop (bottled) air, or air from an automatic pump may be used.

6.5 *Pullout Stubs*—Stainless steel or any other machineable material, with dimensions as shown in Figure 4. Beveled stub edges minimize the amount of binder trapped between the stub edge and substrate and ensure a uniform binder film thickness.

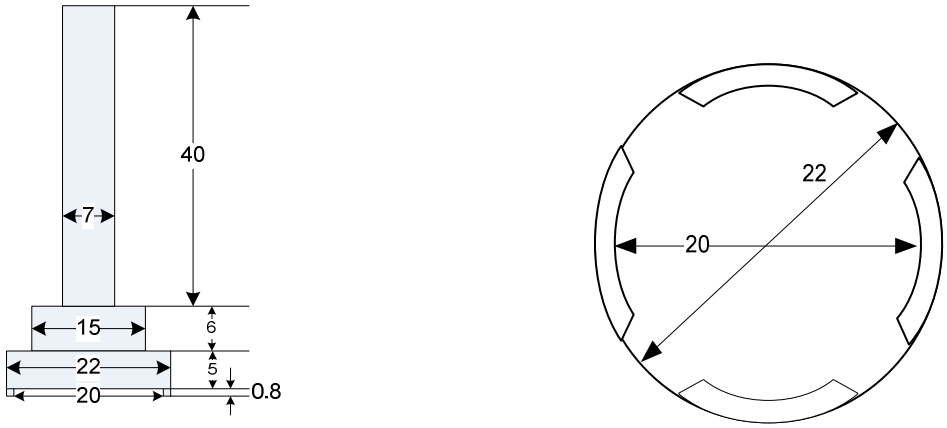


Figure 4—Pullout Stub Dimensions (mm) for Bitumen Bond Strength Test

6.6 *Ring Support*—Provides support to the pressure ring and pressure plate. The ring support (e.g., a shaft collar) has minimum dimensions of 12.5 mm height and 25.4 mm inside diameter.

6.7 *Forced Draft Oven*—Capable of maintaining temperatures of at least 150 ± 3°C for preparing all aggregate and binder samples. Use two temperature-controlled ovens of Type IIA or IIB as defined in ASTM E 145 to accommodate different heating conditions required in the sample preparation process.

6.8 *Environmental Chamber*—Capable of maintaining temperatures between 15°C and 75°C ± 1°C, and relative humidity between 20 percent and 80 percent ± 1 percent, for curing all emulsion samples.

6.9 *Thermometer*—For tests performed at 25°C, use ASTM Thermometer No. 17C (17F) to measure the temperature of the aggregate surface prior to testing. For tests performed at other temperatures, use ASTM thermometers of an appropriate range and accuracy equal to that of the No. 17 thermometer. Since the accuracy of test results depends upon closely controlled temperature conditions, calibrate thermometers in accordance with ASTM E 77. Thermometric devices with the same accuracy as ASTM thermometers may also be used.

6.10 *Container*—Any suitable container may be used to hold the hot-applied asphalt binder while being melted. For emulsified binders, the suitable container may be plastic, non-metal, or epoxy-lined, if metal.

6.11 *Ultrasonic Cleaner*—To remove residual particles from substrate surfaces prior to testing, use an ultrasonic cleaner that is capable of maintaining a bath temperature of 60°C ± 1°C, with a sufficiently large tank to allow for complete submersion of substrates.

7. SAFETY PRECAUTIONS

7.1 Observe standard laboratory safety precautions when preparing and testing hot-applied binders and emulsified binders.

8. CALIBRATION OF TESTING EQUIPMENT

8.1 Check the data acquisition capabilities of the test system to ensure that activation of the pressure ring produces a real-time transient plot of pullout tension.

8.2 Verify the operating condition of all physical components in the testing system (i.e., air supply, pressure ring, software, and connections) prior to testing.

8.3 Calibrate the testing system prior to initial use and as often as necessary per the manufacturer's recommendation and instructions.

9. AGGREGATE TEST SPECIMENS

9.1 *Solid Aggregate Substrates*—Cut aggregate substrates from either quarried rocks or cored rock samples using standard rock saws such that plate faces are parallel. Lap all substrates using a 280-grit silicon carbide material on a standard lapidary wheel to remove saw marks and ensure a consistent surface roughness. Once cut and lapped, clean samples for 60 minutes in an ultrasonic cleaner containing distilled water at a temperature

of 60°C ± 1°C to remove residual particles on the plate surface. Limit the re-use of the same solid aggregate substrate to five times per cut surface.

9.2 *Composite Substrates*— Composite substrates contain aggregate chips and a rapid-setting cement compound. Prepare composite substrates by casting samples in Portland cement concrete cylinder molds measuring 152 mm in diameter and 354 mm in height. Cut, lap, and clean the composite substrates according to the procedures provided in Section 9.1 for aggregate substrates. Limit the re-use of the same composite substrate to five times per cut surface.

9.3 *Hot Mix Asphalt Concrete (HMAC) Substrates*—HMAC samples obtained from field sites are not used as a substrate due to deviations in surface roughness, which does not allow for uniform binder film thickness. For laboratory HMAC specimens prepared using a Superpave gyratory compactor, lapping HMAC surfaces will damage lapidary equipment and is not recommended.

10. HOT-APPLIED BINDERS

10.1 *Sample Preparation:*

10.1.1 Obtain a representative sample of the material for testing using procedures specified in AASHTO T 40 (ASTM D 140). Handle materials with clean laboratory gloves throughout the test procedure to prevent contamination of testing surfaces.

10.1.2 Place substrates and pullout stubs in the first forced draft oven at 150 ± 2°C for a minimum of 30 minutes to remove residual moisture from the substrate surface and to pre-heat pullout stubs for application.

10.1.3 Remove substrates from the first forced draft oven and place them in a second forced draft oven at 60 ± 2°C for a minimum of 30 minutes to achieve the application temperature.

10.1.4 While substrates reach the application temperature, heat the hot-applied binder in an appropriate container to 150 ± 2°C in the first forced draft oven.

10.1.5 Upon reaching the application temperature, pour molten binder into mold cavities. The binder will slightly overfill the mold. Cool the sample and mold for 15 minutes in laboratory conditions. Trim samples to a weight of 0.4 ± 0.05 g while the binder remains in the mold, and allow samples to cool for an additional 20 minutes.

Note: If samples are not easily removed from the molds, refrigerate the samples for an additional 10 to 15 minutes before removing.

10.1.6 Remove pullout stubs from the first forced draft oven and place the de-molded asphalt binder samples onto the stub surface. Apply the heated pullout stub and binder sample to the substrate surface. Position binder samples on the substrate to allow for placement of multiple applications and for sufficient clearance of the testing apparatus. Maintain a distance between the centers of two stub shafts of at least 38 mm. Refrain from placing stubs on previous areas of application.

10.1.7 Firmly press each pullout stub to the substrate surface, adhering the stub to the substrate with asphalt binder. After stub application, screw a weight of approximately 50 ± 1.0 g onto the stub to maintain full contact between the stub and substrate. Expect excess binder to flow out of the pullout stub channels. Avoid twisting the pullout stub during application to reduce air entrapment between the binder sample and substrate surface.

10.1.8 Allow dry samples to acclimate to lab conditions for 24 hours before testing.

10.1.9 To assess moisture damage of wet-conditioned samples, allow samples to acclimate to lab conditions for 1 hour before wet conditioning. Place samples in a submerged environment of 40 ± 2°C for a predetermined conditioning interval. Water or a combination of water and de-icing agents may be used for wet conditioning.

10.1.10 After conditioning, allow wet-conditioned samples to acclimate to lab conditions for 1 hour before testing.

10.2 *Test Procedure:*

10.2.1 Record the temperature of the substrate surface before testing samples.

10.2.2 Place the ring support concentrically around the stub, which is adhered to the substrate with binder, to reduce the possibility of eccentric loading.

10.2.3 Place the pressure ring around the pullout stub and rest on the ring support. Do not disturb the stub to prevent inducing premature stresses or strains in the sample.

10.2.4 Screw the pressure plate onto the pullout stub, taking care not to rotate the stub, until the pressure plate touches the pressure ring.

10.2.5 Unscrew the pressure plate one quarter of a turn (approximately 90°) to ensure a small gap between the pressure plate and the pressure ring.

10.2.6 Test the samples using the adhesion testing device in accordance with the manufacturer's recommendations. Record environmental conditions (i.e., temperature and humidity) for all tests.

10.2.7 Record the maximum pullout tension and observe the failure mode. If the binder detaches from the substrate completely, the failure is adhesive. If the binder remains adhered to the substrate, the failure is cohesive. A combination of adhesive and cohesive failure occurs when binder is partially removed from the substrate. See Figure 5 for examples of cohesive and combined failure modes.

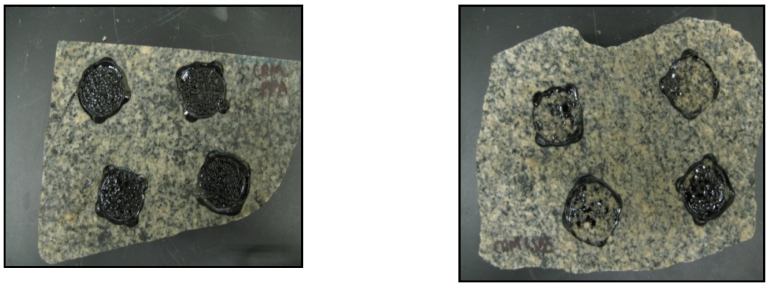


Figure 5—Cohesive Failure (left and Combination Failure (right) in Aggregate-Binder Systems

10.2.8 Repeat the test procedure for a minimum of three samples at each set of experimental conditions.

11. EMULSIFIED BINDERS

11.1 *Sample Preparation:*

11.1.1 Obtain a representative sample of the material for testing using procedures specified in AASHTO M 140 (ASTM D 977) for emulsified binders in general and AASHTO M 208 for cationic emulsified binders.

11.1.2 Heat emulsified binder in a suitable container to an application temperature of 60 ± 2°C in the first forced draft oven. Heat the sample for no longer than 2 hours to avoid premature breaking.

11.1.3 Simultaneously heat the substrate to an application temperature of 25 ± 2°C in a second forced draft oven.

11.1.4 If moisture conditioning substrates, submerge the substrates in a bath of heated distilled water to achieve the SSD condition while preheating to the application temperature.

11.1.5 Place molds without backing on the substrate surface and weigh the substrate with the molds in place on a bench scale. Position the molds on the substrate to allow for placement of multiple applications and for sufficient clearance of the testing apparatus, as seen in Figure 6. Maintain a distance of at least 38 mm between the centers of any two samples.

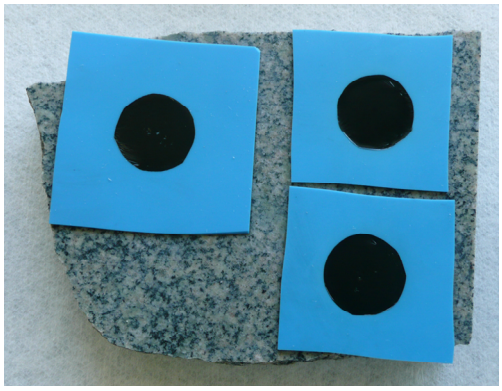


Figure 6 – Multiple Test Samples Placed on the Substrate Surface Form the Substrate-Binder Assembly

11.1.6 Fill each mold with 0.4 ± 0.05 g liquid emulsion using a graduated eyedropper to ensure a consistent sample size. The mold will be slightly overfilled.

11.1.7 Cure the substrate-binder assembly under controlled conditions in an environmental chamber for 2, 6 or 24 hours. Curing conditions can be varied to represent expected field conditions.

11.1.8 While the substrate-binder assembly cures, heat pullout stubs to 60 ± 2°C in a forced draft oven.

11.1.9 After curing, remove the substrate-binder assembly from the environmental chamber. Remove the silicone molds encircling the cured binder and immediately place the heated pullout stubs on the binder samples.

11.1.10 Firmly press each pullout stub to the substrate surface, adhering the stub to the substrate with binder. Screw a weight of 50 ± 1.0 g onto the stub to maintain full contact between the stub and substrate. Expect excess binder to flow out of the pullout stub channels. Avoid twisting the pullout stub during application to reduce air entrapment between the binder sample and substrate surface.

11.1.11 Return the testing assembly to a forced draft oven set at 25°C ± 2°C for approximately 1 hour to allow the samples to acclimate to testing conditions.

11.2 *Test Procedure:*

11.2.1 Record the temperature of the substrate surface before testing samples.

11.2.2 Place the ring support concentrically around the stub, which is now adhered to the substrate with binder, to reduce the possibility of eccentric loading.

11.2.3 Place the pressure ring around the pullout stub and rest on the ring support. Do not disturb the stub by inducing premature stresses or strains in the sample.

11.2.4 Screw the pressure plate onto the pullout stub, taking care not to rotate the stub, until the pressure plate touches the pressure ring.

11.2.5 Unscrew the pressure plate one quarter of a turn (approximately 90°) to ensure a small gap between the pressure plate and the pressure ring.

11.2.6 Test the samples using the adhesion testing device in accordance with the manufacturer's recommendations. Record conditions (i.e., temperature and humidity) for all tests.

11.2.7 Record the maximum pullout tension and observe the failure mode. If the binder detaches from the substrate completely, the failure is adhesive. If the binder remains adhered to the substrate, the failure is cohesive. A combination of adhesive and cohesive failure occurs when binder is partially removed from the substrate. See Figure 5 for examples of cohesive and combined failure modes.

11.2.8 Repeat the test procedure for a minimum of three samples at each set of experimental conditions.

12. REPORT

12.1 Obtain the pullout tensile stress directly from the graphical computer interface and report to the nearest 0.7 kPa. Note environmental conditions (i.e., temperature and humidity) and curing times for each test.

12.2 Find the arithmetic mean for each set of samples tested. Test a minimum of three samples at each set of experimental conditions.

12.3 Determine the loading rate by calculating the slope of the line between the initial pullout tensile stress and the final failure stress. Calculate the slope of the line between 20 percent and 80 percent of the maximum stress.

12.4 Document the failure mode as cohesive, adhesive or a combination of failure modes by visual observation or photo analysis. Reject samples that exhibit failure between the pullout stub surface and asphalt binder, observed as inadequate stub coverage.

13. PRECISION AND BIAS

13.1 Precision and bias has yet to be established for this test method.