ACPA TEST METHOD

Standard Method of Test for Dowel Bars for Concrete Street and Highway Pavement

ACPA T 253-23a

October 12, 2023

INTRODUCTION AND BACKGROUND

This document provides a revised, alternative version of the American Association of State Highway and Transportation Officials (AASHTO) Test Method (AASHTO T 253-02 (2016)). It was developed to provide a specification that could be applied to the evaluation of structural and durability characteristics of the wide range of dowel materials and installation configurations now available; AASHTO T 253 is directly applicable only to epoxy-coated steel dowels, and it was developed specifically for 1.25-inch diameter dowels with then-standard length and spacing.

The need for this specification was first documented by the National Concrete Consortium around 2015, which provided funding for the development and validation of an updated load-deflection test procedure for dowel groups at joints (rather than the single dowel test included in AASHTO T 253). A group of stakeholders representing state highway agencies, dowel manufacturers, and the paving industry oversaw and guided the test program. The American Concrete Pavement Association (ACPA) donated staff/consultant time to perform test reporting and specification development. ACPA also agreed to publish the completed new specifications online.

The group determined at the start that the best way to expedite acceptance of a specification that included the new load-deflection test procedure would be to maintain the general format, content, and scope of the existing AASHTO specifications (rather than to start from scratch and produce something completely new). It was recognized that the constraint of working within the existing AASHTO specification framework meant that the new specification would not reflect all desired changes, but that agency and manufacturer needs would be best served by first implementing the new load-deflection procedure and then later following up with additional changes.

The specification presented here represents the achievement of that goal. The primary change is the replacement/update of the load-deflection test procedure. Other changes made throughout the document were made mainly to address differences in testing different types of materials and coating systems, and to standardize requirements for concrete materials and lubricants used in testing.

Consistent with the AASHTO T 253 and M 254 documents, the new specifications mainly describe testing procedures (T 253) and the types of physical and mechanical properties for dowels that can be included by specifiers in purchasing dowels (M 254). The only test result requirements included in AASHTO M 254 are for load-deflection (limited to 0.25mm or 0.01 inches [incorrectly stated as 0.1 inches in AASHTO M

254]) and pullout (limited to 3000 lbf or 1360 kg [an incorrect conversion of force to mass in AASHTO M 254]). Those same limits are cited in the new specification (along with guidance for modifying load-deflection limits for varying dowel size, pavement type, and structural/environmental considerations.

No limits or criteria are provided for tests of corrosion resistance, coating durability, etc., as there are none in the current AASHTO specifications. Further, there are no definitions of (or guidance on defining) structural or corrosion resistance requirements for categorizing dowels as being "good," "better," or "best" for highway paving applications. It was the consensus of the oversight group that: 1) it was most important to standardize the test protocols so that agencies could determine their own limits for different pavement applications in different climates; and 2) the inclusion of such requirements would impede the adoption of the new specification, which would be counter-productive to opening the market to competition from new and innovative dowel products with the potential to improve pavement performance and extend service life.

It is recognized that there is a strong need to provide specifying agencies with guidance on setting or modifying limits for all the tests included in these specifications. The development of that guidance should be undertaken immediately, but should not impede the adoption of these specifications, which reference long-established standard test procedures, material standards and specifications produced by AASHTO, American Society of Testing Materials (ASTM) and several other entities. It also includes numerous footnotes that provide added details concerning the reasoning and considerations behind certain specification features, as well as choices and important references for clarity to the specification reader.

APPLICABILITY

This specification is directly applicable to dowel bars intended for use in conventional and long-life pavements for an array of projects, including: highways, streets, roads, and private or commercial parking facilities that require dowel bars. This specification was not developed for airport or industrial facility applications but may be adapted for use on these type of facilities.

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TEST METHOD

1. SCOPE

1.1. These methods are designed to test the qualifications of concrete pavement dowel bars to withstand the effects of weathering, deicing chemicals, and the abrading and loading stresses experienced in field joints.

1.2. The units of measure to be used shall be either SI units or inch-pound units (shown in parentheses in this standard) depending on the units used in the applicable material specification.

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

2. REFERENCED DOCUMENTS AND TESTING STANDARDS

2.1. AASHTO Standards:

R39	Making and Curing Concrete Test Specimens in the Laboratory
T106M/T106	Compressive Strength of Hydraulic Cement Mortar (Using 50-mm or 2-in. Cube Specimens)
T253-02 (2016)	Standard Method of Test for Coated Dowel Bars
M254-06 (2015)	Standard Specification for Corrosion-Resistant Coated Dowel Bars
M334 (2017)	Standard Specification for Uncoated, Corrosion-Resistant, Deformed and Plain Chromium Alloy, Billet-Steel Bars for Concrete Reinforcement and Dowels
T 373M/T 373	Standard Specification for Comparative Qualitative Corrosion Characterization of Steel Bars Used for Concrete Reinforcement (Linear Polarization Resistance and Potentiodynamic Polarization Tests)

2.2. ASTM Standards:

C33-07	Standard Specification for Concrete Aggregates
C150-07	Standard Specification for Portland Cement
D570-98 (2018)	Standard Test Method for Water Absorption of Plastics
C595-08a	Standard Specification for Blended Hydraulic Cements
D1474/D1474M	Standard Test Methods for Indentation Hardness of Organic Coatings
D7091	Standard Practice for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to Ferrous Metals and Nonmagnetic, Nonconductive Coatings Applied to Non-Ferrous Metals
D7913/D7913M	Standard Test Method for Bond Strength of Fiber-Reinforced Polymer Matrix Composite Bars to Concrete by Pullout Testing
G8	Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
G14	Standard Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)

3. MATERIALS AND APPARATUS

3.1. The concrete mix design and constituents shall comply with the following:

3.1.1. Type I, Type II or Type I/II cement conforming to ASTM C150/C150M or Type IL blended cement conforming to ASTM C595.

3.1.2. Coarse and fine aggregate conforming with ASTM C33, with coarse aggregate meeting Grading 57 or 67 and conforming to Class 4S (ASTM C33, Table 4).

Note 1: Grading 57 coarse aggregate may contain particles too large to produce uniform concrete properties in small pullout test specimens; Grading 67 may be preferred for such applications.

3.1.3. Air-entrained concrete proportioned using ACI 211.1 procedures using 307 ± 3 kg cement/m^3 of concrete (517 ± 5 lb/yd^3) to produce concrete with 90 ± 15mm (3½ ± ½ in.) slump and 6.0 ± 1.0 percent air content.

3.2. Suitable containers, molds, and miscellaneous concrete mixing equipment necessary for mixing and casting the simulated doweled joints for load, pullout, and corrosion tests to meet conditions stated in AASHTO R 39.

3.3. An abradometer capable of operating at 60 to 70 double-strokes per minute using 100-mm (4-in.) long strokes.

3.4. Load test frame capable of operating accurately in the 0- to 90-kN (0 to 20,000 lbf) range and capable of controlled load and strain rate loading.

3.5. Suitable hold-down devices for positioning and holding specimens in place during tests.

3.6. Freeze–thaw equipment of sufficient capacity and capabilities to handle the pullout and corrosion–abrasion test specimens.

3.7. Sufficient quantities of chemical to maintain solution levels for corrosion tests.

4. PREPARATION OF SAMPLES

4.1. The dowels for deflection tests may be in support baskets or loose. Loose dowels shall be used for all other tests.

4.2. Dowels that will be embedded in concrete for testing (e.g., under sections 5 and 6 below) shall be coated with SAE 30 oil prior to casting in concrete unless the dowel bar manufacturer demonstrates that dowel pull-out forces without the use of an approved debonding material are less than 13.3 kN (3000 lbf), as determined using Section 6 of this specification. Oil coating of the dowel shall be accomplished by briefly submerging or dipping the dowel in a reservoir of clean oil (or by brush-coating the lateral surface of the dowel with a heavy coat of oil) and then standing the dowel on end for approximately 15 minutes to allow

excess oil to drain from the surface.

Note 2: The use of SAE 30 oil is intended to be a standard, readily available debonding agent for tests performed on embedded dowel specimens under this specification only. The use of SAE 30 oil herein should not be construed as a recommendation or endorsement of its use over approved products in agency pavement specifications.

4.3. Dowels that are to be tested without embedment in concrete shall not be coated with debonding material prior to testing.

4.4. Prepared dowels shall be properly positioned in the appropriate molds specified for the various tests and cast in concrete.

5. LOAD-DEFLECTION TEST PROCEDURE

5.1. Dowels (with or without basket assemblies) will be used in load-deflection tests conducted in accordance with the following procedures.

5.2. Dowels shall be cast into a single concrete test specimen in a manner to simulate two 1200-mm- (48-in-) long highway contraction joints in a concrete pavement wheel path (see Figure 1). The number and spacing of dowels in each contraction joint will be determined by the dowel manufacturer to provide the purchaser-specified load transfer system capabilities. The contraction joints are to be formed by dividing the mold into three sections with sheets of suitable material measuring 9.5 mm ($^3/_8$ in.) thick that have been fabricated to allow the installation of dowels at appropriate locations. The plastic concrete shall be consolidated by vibration.

5.3. The concrete test specimens shall be made and cured in accordance with AASHTO R 39. Specimens shall be moist-cured for a total of 14 days. Specimen forms (including joint forming materials) must be removed prior to testing.

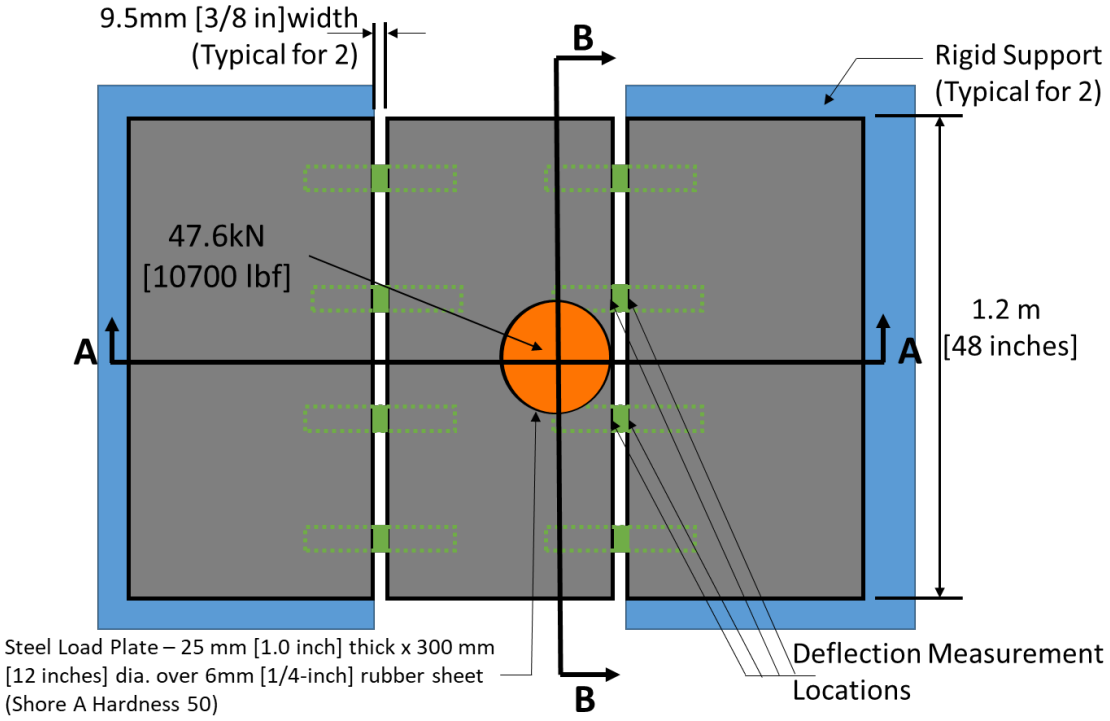
5.4. On completion of curing, the specimen shall be placed in a testing machine, instrumented, and prepared for load-deflection testing, as illustrated in Figure 1. The end sections shall be prevented from rotating with using suitable hold-down devices. Deflection measuring devices shall be accurate to 2.5 microns [0.0001 inch].

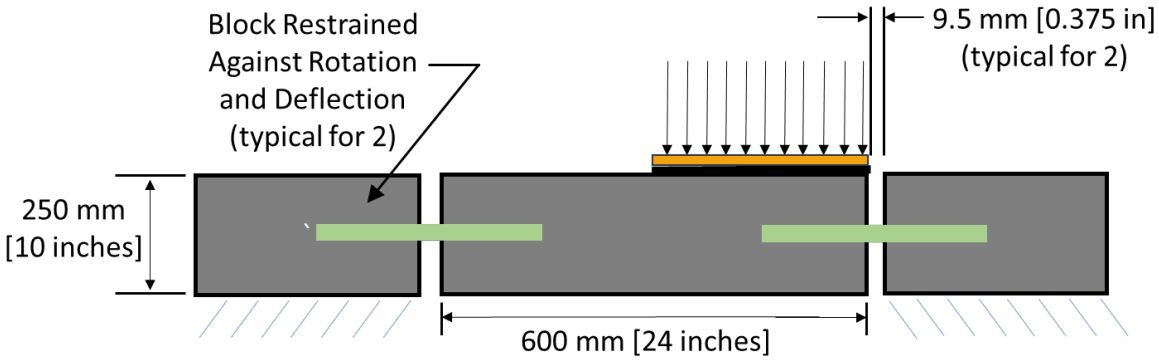
5.5. Apply a preload at a rate of 8.9 kN/min [2000 lbf/min] ($\pm$ 1.8 kN/min [400 lbf/min]) until a load of 4.4 kN (1000 lbf) is obtained. Remove the preload at the same rate. Then “zero” the load measuring devices just prior to the start of testing.

5.6. Apply load at the rate of 8.9 kN/min [2000 lbf/min] ($\pm$ 1.8 kN/min [400 lbf/min]) until the specified load (typically 47.6 kN (10,700 lbf)) is obtained. Immediately measure relative deflections across the joint at locations 15 cm (6 in) on either side of the center of the load plate. [Optional Sustained Load Procedure: Hold the load for 10 minutes and repeat the measurements.] Remove the load at the same rate used for loading and immediately measure residual relative deflections at the same two locations.

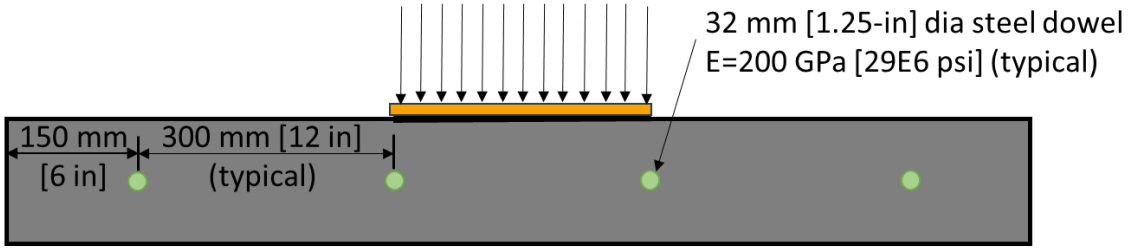
5.7. Reposition the load to the center of the other joint and repeat sections 5.5 and 5.6.

5.8. Report all measured deflections. Calculate and report all relative deflections (difference in deflection across the transverse joint at each measurement location). Report the average and standard deviation of the relative deflection for all load positions at each load level.





Section A-A



Section B-B
(Typical for Common Steel Dowel Layout)

Figure 1. Load-Deflection Test Schematic

5.9. Alternative Dynamic Load-Deflection Test. Some state highway agencies have standardized and adopted a dynamic load test for dowel load transfer systems. This test is described, along with representative dowel acceptance criteria, in Annex A. It subjects dowel load transfer systems to 10 million cycles of simulated vehicle loading and is an acceptable alternative to the load-deflection test described above.

Note 3: The dynamic test may provide a better indication of long-term dowel behavior than does the static test, but it is generally more costly and time-consuming. It also produces measures of relative deflection at a single location (versus 4 locations for the static test described above); the results of a single measure of relative deflection must be evaluated with greater consideration of the potential variability of test results.

6. PULLOUT TEST PROCEDURE

6.1. Three dowels shall be tested in accordance with the following procedures.

6.2. Each dowel shall be cast into a separate concrete cylinder or block. The length of dowel embedment shall be ½ the overall design length of the dowels in service (e.g., 225 mm [9 inches] embedment for dowels with 450 mm [18-inch] design length). Overall dowel test specimen length must be sufficient to allow required dowel embedment and enough unembedded dowel length for installing or attaching grips for pullout loading.

Note 4: ASTM D7913/D7913M describes procedures for determining the pullout strength of GFRP reinforcing bars. It includes installing steel anchors to apply pullout loads without damaging the GFRP at the gripping locations. Similar procedures should be considered for performing pullout tests of GFRP dowels, except that embedment length should be as described in section 6.2 above.

6.3 The specimen moulds shall provide a minimum of 50 mm [2 inches] clear distance between the dowel and mould sides along the entire length of the embedded portion of the dowel, and a minimum of 50 mm (2 inches) of cover over the embedded end of the dowel. Care shall be taken to ensure that each dowel is positioned along the centerline axis of the concrete cylinder or block. The concrete shall be properly consolidated.

6.4. Cure the molded specimens in accordance with AASHTO R 39. Remove the moulds from the specimens after the first 24 h of a 48-h moist-curing period.

6.5. After 48±2 hours of curing, place the concrete cylinder or block in the testing machine and apply a tensile load parallel to the axis of the dowel. The testing machine shall be adjusted to a free-running speed of 0.76 mm/min (0.030 in./min) prior to performing this test and this setting shall be maintained during the test. Record the maximum pullout tensile load for the first 12.7 mm (0.5 in.) of movement for each of the three

test specimens.

6.6. Optional Pullout Test after Salt and Freeze-Thaw Exposure. The specifying agency may opt to require additional pullout testing, as described herein.

6.6.1. After the first 12.7 mm (0.5 in.) of movement of the dowels, the test specimens will be further cured as before for an additional 12 days. Then the test specimens will be placed in a 10 percent (by mass) sodium chloride solution in such a manner as to inundate half of the cross-sectional perimeter of the dowels. The sodium chloride solution will be maintained at this level and will be replaced with fresh solution every seven days. The partially submerged specimens will be subjected to 50 cycles of freezing and thawing consisting of freezing in air for 16 h at a temperature of −28.9 ± 1.7°C (−20 ± 3°F) and thawing in air for 8 h at a temperature of 22.8 ± 1.7°C (73 ± 3°F).

6.6.2. On completion of the freeze–thaw cycling, the test specimens will again be placed in the testing machine and the pullout load redetermined by pulling the dowels out an additional 12.7 mm (0.5 in.) at the rate specified in Section 6.4. Again record the maximum tensile load for each of the specimens.

6.6.3. After the total 25.4-mm (1-in.) movement of the dowel, remove the concrete by breaking it away from the dowel. Examine the dowel and the concrete–dowel interface and report any evidence of corrosion, tearing, and perforation.

Note 5: The optional salt and freeze-thaw exposure pullout test is a part of AASHTO T253 but has rarely been required or performed in practice. It appears to be based on experimental work performed at the Portland Cement Association in the 1960s (reference PCA publication MS 237.01P). This procedure extends the duration of pullout testing from approximately 2 days to approximately 64 days (time of specimen casting to test completion).

7. ABRASION-CORROSION TEST PROCEDURE

7.1. Three dowel bars shall be subjected to testing in accordance with the following procedures. Type A dowels shall be subjected only to the corrosion portion of the test. Type B dowels shall be subjected only to the abrasion portion of the test. Types C and D dowels shall be subjected to both abrasion and corrosion portions of the test.

Note 6: The corrosion test described below was developed for use with epoxy-coated dowels after performing a standard abrasion effort that might result in partial exposure of the steel dowel. Applying this aggressive corrosion test to completely uncoated metallic dowels (i.e., Type A dowels) may produce results that are useful only for determining relative corrosion resistance of one uncoated metal type to another uncoated metal type; the results may not be directly comparable with results of abrasion-corrosion testing of coated dowels.

An alternate test of the corrosion resistance of uncoated metallic dowels might be AASHTO T373 "Standard Test Method for Comparative Qualitative Characterization of Steel Bars Used for Concrete Reinforcement (Linear Polarization Resistance and Potentiodynamic Polarization Tests)." It is not

known whether the test result limits proposed in AASHTO T373 are as appropriate for dowel applications at open joints as they are for reinforcing steel embedded in concrete.

7.2. Abrasion resistance of the dowels will be determined using an abradometer.

7.2.1. The abrading block is a 100-mm (4-in) long mortar block made of portland cement and Ottawa sand (proportioned as described in AASHTO T 106M/T 106) cast to fit over an area of about 3300 mm^2 (5.15 in^2) of the test dowel surface.

Note 7: For non-cylindrical dowels, the abrasion test shall be performed on the intended bearing surface of the dowel (e.g., perpendicular to the major axis for elliptical dowels, on the flat bearing surface of plate dowels, etc.). The mortar block abrader shall be shaped to provide uniform contact with the dowel over the specified area, regardless of dowel shape and size.

7.2.2. The test load is 2500 g (5.5 lbf) and is comprised of the abrading block, the abrading assembly, and added mass, as required.

7.2.3. The specimens shall be mounted in the abradometer and secured so that they cannot translate or rotate during testing.

7.2.4. The abradometer shall be operated at 60 to 70 double-strokes per minute using a 100-mm (4-inch) long stroke. A "double-stroke" is defined as a cycle of abrading block movement that begins at one end of the range of motion, proceeds to the other end, and returns to the starting point.

7.2.5. Each dowel shall be tested for a total of 10,000 double-strokes.

Note 8: ASTM A775 and A934 require that conforming epoxy coatings are subjected to abrasion testing using a Taber abraser (ASTM D4060). This requirement is separate from the requirements of this specification.

7.3. On completion of the abrading, the dowels will be examined for wear, perforation, and/or wrinkling.

7.4. Determine loss of thickness due to abrasion at the location of maximum wear using ASTM D7091 procedures. A minimum of five readings shall be taken in both the abraded and unabraded portions of the dowel. The average of at least five readings shall determine the layer thickness in each portion of the dowel. Report thickness loss/wear as an absolute value and as a percentage of the original layer thickness (as a percentage of unabraded dowel diameter for Type B dowels).

7.5. For Type A dowels, determine the average thickness or diameter of each of three unabraded, uncorroded dowels perpendicular to the intended dowel bearing surface to the nearest 0.025mm [0.001 inch] as the average of at least five measurements obtained at random locations.

7.6. Partially submerge unabraded Type A dowels and abraded Type C and D dowels in a 10

percent (by mass) sodium chloride solution to a depth that immerses one half of the abraded area of Type C and D dowels (or one half of the dowel length for Type A dowels) and exposes the upper half of the dowel to the atmosphere. Maintain the sodium chloride solution at this level for the seven-week duration of the test, replacing the solution with fresh solution once each week.

7.7. After seven weeks, remove the dowels and thoroughly examine them for evidence of steel corrosion under five-power magnification. Without removing or disturbing areas of corrosion, measure and report the dowel thickness or diameter across the most corroded bearing areas (average of at least five measurements). For type C and D dowels, also measure and report the dowel thickness or diameter across the least corroded unabraded bearing areas (average of at least five measurements).

7.8. For Type A dowels, compute and report the percentage of expansion due to corrosion as:

$$\%\ Expansion = 100\ \text{x}\frac{\text{Average Corroded Area Thickness or Diameter} - \text{Average Pretest Thickness or Diameter}}{\text{Average Pretest Thickness or Diameter}}$$

8.9. For Type C and D dowels, compute and report the percentage of expansion due to corrosion as:

$$\%\ Expansion = 100\ \text{x}\frac{\text{Average Corroded Area Thickness or Diameter} - \text{Average Uncorroded Area Thickness or Diameter}}{\text{Nominal Thickness or Diameter of Steel Core}}$$

8. CHEMICAL RESISTANCE TEST PROCEDURE (Type D2 only)

8.1. Twenty-four seven-inch dowel bar specimens will be subjected to chemical resistance testing in accordance with ASTM G20 with the following modifications:

8.2. Six dowel samples (three with intentional holidays and three without holidays) shall be tested by immersion for 45 days in each of the following four reagents: distilled water, an aqueous solution of 3 molar $CaCl_2$, an aqueous solution of 3 molar NaOH, and a solution saturated with $Ca(OH)_2$. Testing shall be conducted at a temperature of 23.9 ± 1.7°C (75 ± 3°F).

Note 9: ASTM G20 requires testing 12 seven-inch-long specimens (6 with intentional holidays, 6 without) for each reagent used; 4 samples (2 with holidays, 2 without) are removed and examined/tested at 30-, 60- and 90-day intervals.

ASTM A775 and A934 include the ASTM G20 chemical resistance test as part of mandatory information contained in Annex section A1.3.2 (same section for A775 and A934) and call for the use of the four reagents: distilled water, 3M $CaCl_2$, 3M NaOH, and saturated $Ca(OH)_2$ solution.

AASHTO T253-02 (2016) calls for testing three dowel bars for 45 days only and using the same

reagents considered in ASTM A775 and A934.

The specification provided here was developed to be consistent with the perceived intent of AASHTO T253-02 (2016) to provide three replicate specimens in each reagent, while conforming to ASTM G20 requirements for using specimens with and without holidays.

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9. CATHODIC DISBONDING TEST PROCEDURE (Type D2 Only)

9.1. Three coated dowel bars shall be tested to determine their resistance to cathodic disbonding using the test procedure described in section A1.3.3 of the Annex to ASTM A775 except that the cathode shall be a 250-mm (10-in) long section of coated dowel bar.

Note 10: ASTM G8 describes a test performed on 762-mm (30-in) minimum length pipe specimen with one or three test holes or holidays drilled through the coating. The holidays are a minimum of 6.4mm (1/4 in) diameter. Three electrolytes are used: sodium chloride, sodium sulfate, and sodium carbonate (1 percent by mass solutions of each). For Method A, a magnesium alloy anode is used to create a solution potential of -1.45 to -1.55 V with respect to a $CuCuSO_4$ reference electrode. The test duration is 30 days. Method B additionally monitors the progress of the test electrically.

ASTM A775 mandatory information in Annex A1.3.3 generally follows ASTM G8 procedures except: 1) the test specimen is a 250-mm (10-in) coated reinforcing bar; 2) the anode is a 150-mm (6-in) platinum electrode with 1.6mm (0.06 in) diameter or platinized wire with 3.2mm (0.125 in) nominal diameter; 3) a calomel (mercury chloride) electrode is used rather than copper-copper-sulfate; 4) the electrolyte is 3 percent NaCl by mass in distilled water; 5) drilled coating defects are 3mm (0.12 in) diameter; 6) the potential of -1.5 V is impressed and a 10-ohm shunt resister is used; 7) the test duration is 168 hours (1 week). Average disbondment radius is limited to 4 mm (0.16 in).

ASTM A934 mandatory information in Annex A1.3.3 Test B is essentially the same as the one presented in ASTM A775 except that the specimen length is 200mm (8 in) and the average disbondment radius is limited to 2mm (0.08 in). ASTM A934 Test A follows ASTM G42 procedures and is structured similarly to ASTM A775 and ASTM A934 Test B except that the applied voltage is -3V, the test duration is 24 hours, and the average disbondment radius is limited to 6mm (0.24 in).

AASHTO T253-02 (2016) purports to follow ASTM G8 Method A except: 1) the cathode and anode are dowels of the same material with the same coating; 2) the electrolyte is an aqueous solution of 7 percent mass NaCl; 3) the applied voltage potential is -2 V; 4) a single 6.4mm (1/4-inch) diameter holiday is made at the middle of the immersed depth of both the cathode and anode; and 5) the test duration is 30 days.

The test proposed here generally follows the ASTM A775 Annex A1.3.3 test.

Note 11: The coating hardness test procedure previously included in AASHTO T253 has been deleted.

This test is not a part of either ASTM A775 or A934, and the related ASTM standard (D1474) describes it as a method for determining "indentation hardness of organic materials such as dried paint, varnish and lacquer coatings applied to an acceptable plan, rigid surface, for example metal or glass." The test was considered not directly applicable to epoxy-coated pavement dowel systems and unlikely to provide information not provided by other tests in this current specification (e.g., the coating impact resistance test below).

10. COATING IMPACT RESISTANCE TEST PROCEDURE (Type D Dowels Only)

10.1. Impact resistance testing shall be performed according to the procedures described in ASTM A775 Annex Section A1.3.9 with modifications described herein.

10.2. A minimum of three tests will be performed on one or more dowels. When more than one test is performed on a single dowel, test locations on the dowel shall be chosen at random while maintaining a distance of at least 76.2 mm (3 in) between adjacent points of impact, and a distance of at least 38 mm (1.5 in) from the dowel ends.

10.3. The test impact force shall be 9 J (80 in.-lb) and shall be achieved using a 1.8-kg (4-lb) tup at 23.9 ± 1.7°C (75 ± 3°F) unless applicable coating specifications require differently (see note 10).

Note 12: ASTM G14 describes a test performed on 406.4-mm (16-in) long pieces of epoxy-coated pipe with outside diameter 60.325 mm (2.375 in). The impact "tup" has a fixed weight of 1.361 kg (3.00 lb) with a 15.875-mm (5/8-in) diameter hemispherical impact head. The test is performed by dropping the tup onto the specimen from various heights through a tube and determining the maximum height/impact energy that produces no detectable coating breaks using a holiday detector. An equation is provided for determining impact strength of the coating.

ASTM A775 mandatory information in Annex A1.3.9 describes a test of epoxy-coated rebar using a test apparatus similar to that described in ASTM G14, except that the tup mass is 1.8 kg (4 lb) and testing is performed at a single energy level of 9 N-m (80 in-lb). The acceptance criterion is that "no shattering, cracking, or bond loss of the coating shall occur except at the impact area, that is, the area permanently deformed by the tup."

ASTM A934 mandatory information in Annex A1.3.9 also describes a test of epoxy-coated rebar using a test apparatus similar to that described in ASTM G14. No tup mass is prescribed and testing is performed at a single energy level of 4.5 N-m (40 in-lb) – half that of ASTM A775. The acceptance criterion is the same as for ASTM A775.

AASHTO T253-02 (2016) is essentially the same as ASTM A775 Annex A1.3.9.

The test proposed here generally follows the procedure described in ASTM A775 Annex A1.3.9 test, with modifications for clarity and application to dowel bars rather than deformed bars.

Note 13: For example, ASTM A934 specifies an impact energy of 4.5 N-m (40 in-lb) rather than 9 N-m (80 in-lb).

11. REPORTING

The report shall show all temperature, load, and miscellaneous data pertinent to the test conditions, including the following:

11.1. Load-Deflection Test

11.1.1 For standard test (static double-shear test): Measured deflections and calculated relative deflections at each load position at each load level and hold time (if optional sustained load procedure is performed), average and standard deviation of relative deflections at each load level and hold time (if optional sustained load procedure is performed).

11.1.2 For alternate dynamic test: as described in Annex A.

11.2. Pullout test - Maximum kilonewton (lbf) load for pullout of each specimen after 48-h curing period and after the optional subsequent 50-cycle freeze–thaw procedure, if used.

11.3. Corrosion-Abrasion Test – Report thickness abrasion loss/wear as absolute and percentage values. Report absolute and percentage increases in dowel thickness or expansion after corrosion testing.

11.4. Chemical Resistance Test – Report duration of immersion, outside diameter of test specimen, initial thickness of coating, general appearance of specimen after immersion, immersion area in square millimeters [square inches], and disbonded area after immersion (square millimeters [square inches]).

11.5. Cathodic Disbonding Test – Report individual and average coating disbondment radii, measured from the edge of the intentional coating defect, for three bars.

11.6. Coating Impact Resistance Test – Report maximum, minimum and average measured coating thickness, impact energy used, and evidence of coating shattering, cracking, or bond loss within and outside of the impact area at each test location.

Revisions since Sept 10 version:

- *Update all publication dates to Oct 12, 2023*
- *Correct Kevin McMullen affiliation on page 3*
- *Page 4 – Add ASTM C33, C150, C595, D7913; delete ASTM D4476*
- *Corrected Section B-B Drawing on page 7*
- *Modifications to Section 6.2 (and addition of Note 4, renumbering subsequent notes) to provide additional information on required length of dowel test specimens for pullout testing – ½ design dowel length plus enough unembedded length to accommodate grips or anchors, with reference to ASTM D7913 procedures for pullout testing of GFRP rebar.*
- *Minor editorial modifications.*
- *Removed "Draft" watermark.*

ANNEX A – Alternative Dynamic Load-Deflection Test

Some highway agencies have adopted a dynamic load-deflection test procedure for evaluating alternative dowel load transfer systems. The test method formalized by the Pennsylvania Department of Transportation (and presented herein) is representative of the approach used by most of these agencies.

While the test methods used by these agencies are very similar, acceptance criteria vary. Example acceptance criteria are provided in this Annex following the test procedure description.

LABORATORY TESTING SECTION

Method of Test for

DETERMINING STRUCTURAL ADEQUACY OF DOWEL BARS USED IN CONCRETE PAVEMENT

1. SCOPE

1.1 This method describes a testing protocol to determine the structural adequacy of dowel bars that provide force transfer in plain cement concrete pavements.

2. OUTLINE OF METHOD

2.1 The determination of structural adequacy of dowel bars entails the construction of a test specimen and loading of a test specimen to simulate the stress conditions that are encountered by a load transfer unit (dowels) in a plain cement concrete pavement.

3. APPARATUS

3.1 Slab Support System - The slab support system can be comprised of natural soils or an artificial foundation (e.g., steel beams and plate under one or more layers of engineered vibration isolation padding or other material). In either case, the actual or simulated foundation stiffness (k-value: modulus of subgrade reaction) is 200 pounds per square inch/inch (± 50 pounds per square inch/inch).

3.2 Repeated loads are to be applied using one of the following techniques:

3.2.1 Use an actual rolling 9,000-pound single wheel load, operated linearly over the test specimen and centered over a line located 6 inches from the edge of the slab and crossing the transverse joint at a speed of 35 to 45 miles per hour.

3.2.2 Use a system of hydraulic actuators and 12-inch diameter load plates with rubber pads (similar to a falling weight deflectometer load plate) positioned with the plate centers 6 inches from the edge of the slab and 7.125 inches on either side of the center of the transverse joint (see Figures 1 and 2). The actuator system shall be operated in a manner that simulates the passage of a 9,000-pound wheel load (at a simulated speed of 35 to 45 miles per hour) using a load-controlled wave-form similar to the one shown in Figure 3. Figure 3 shows haversine waveforms that range (nominally) from 500 pounds to 9,500 pounds and are 90 degrees out of phase with each other. The duration of the complete load cycle is 0.2 seconds and corresponds to a simulated vehicle speed of about 40 miles per hour.

3.3 Mount Linear Variable Differential Transformers (LVDTs) 1 inch on either side of the transverse joint and ½ inch from the edge of the slab, as shown in Figures 1 and 4, to measure vertical movements of the slabs on each side of the joint.

3.4 Use data recording equipment with a sufficient number of channels and appropriate data sampling rates for accurately monitoring and measuring applied loads and LVDT measures (joint movements) throughout the test.

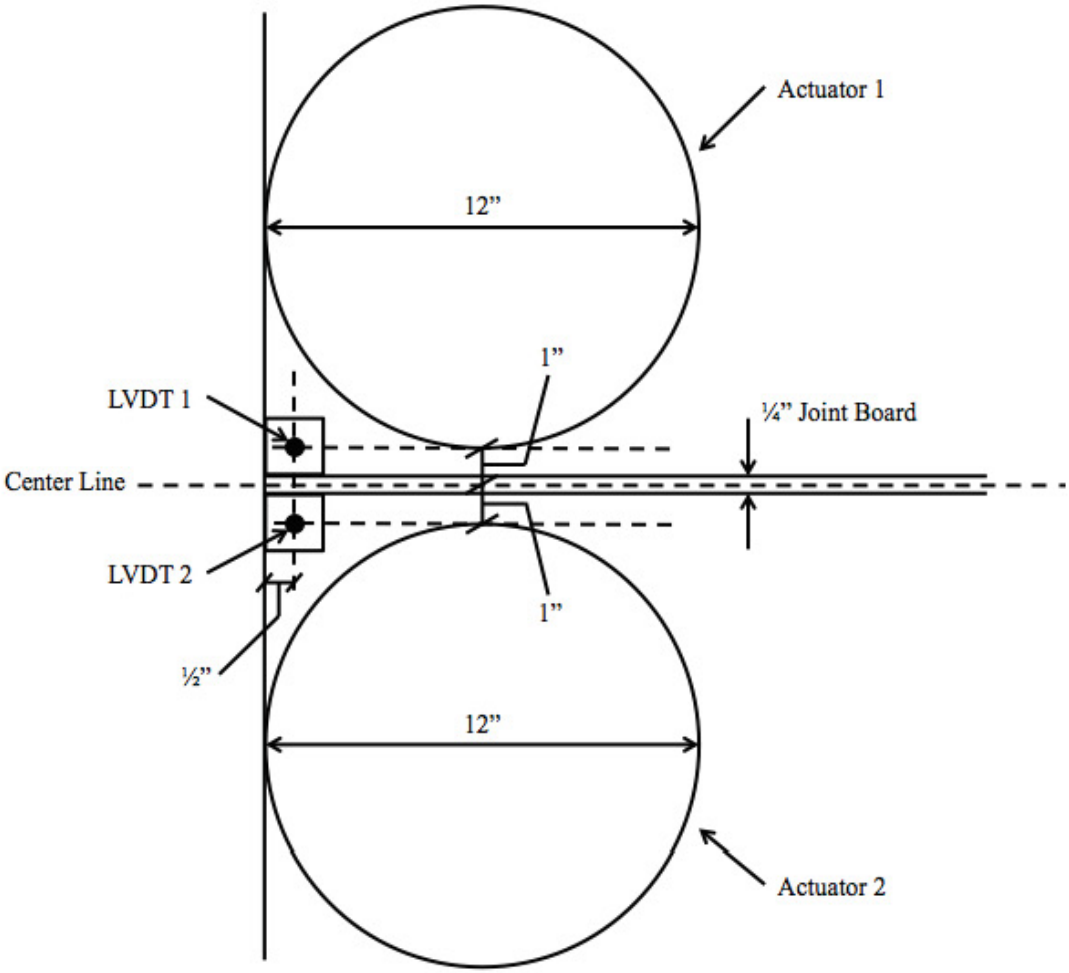

Figure 1. Schematic showing location of LVDTs relative to joint and actuator load plates (Source: J. Vandenbossche, Univ. of Pittsburgh, 2017).

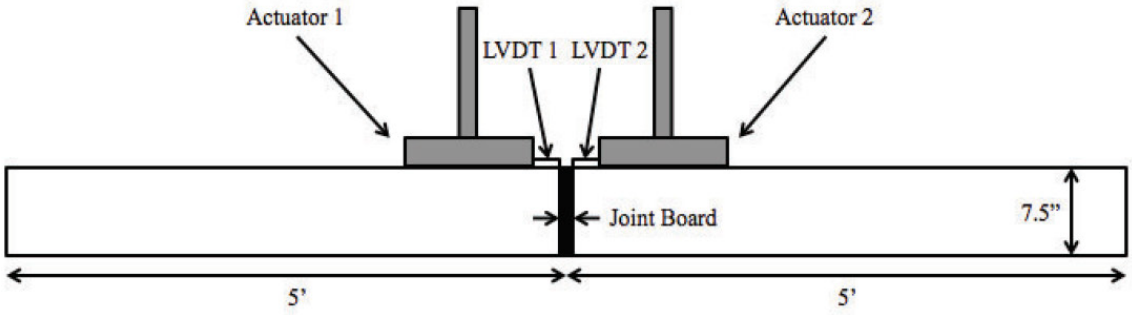

Figure 2. Schematic showing location of LVDTs relative to joint and actuator load plates (Source: J. Vandenbossche, Univ. of Pittsburgh, 2017).

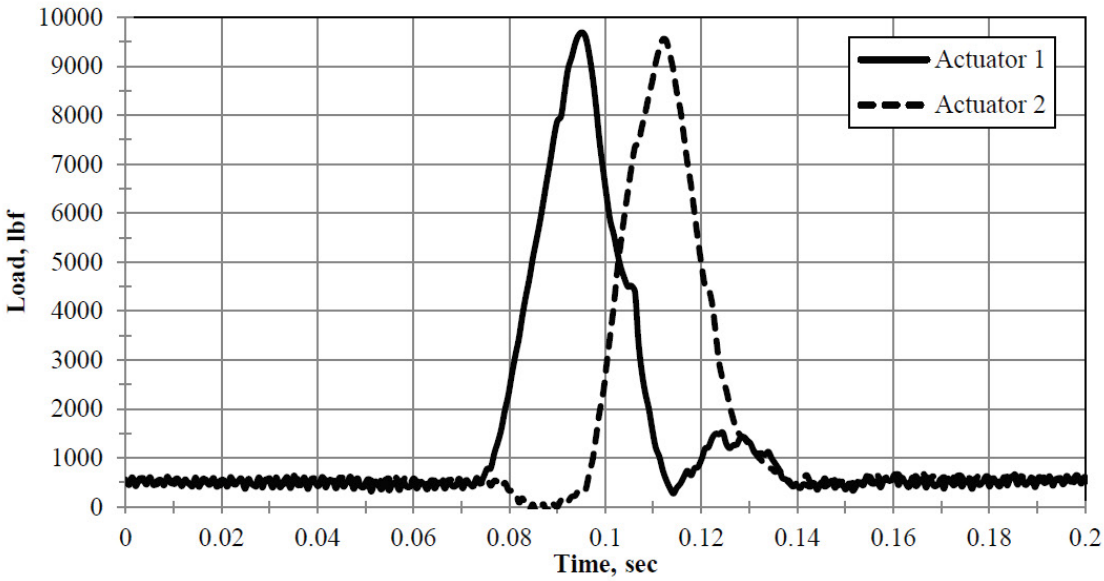

Figure 3. Target actuator loading profiles from University of Pittsburgh ALF (Vandenbossche and Li, 2015).

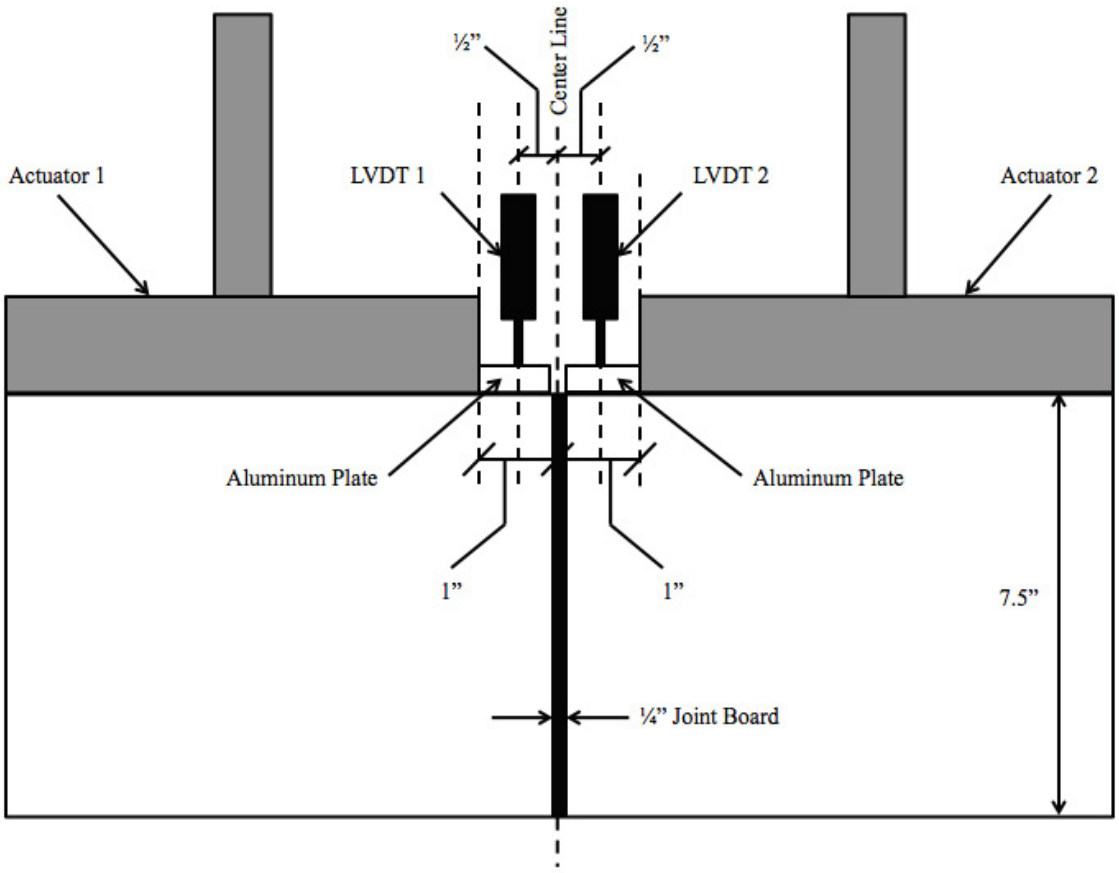

Figure 4. Schematic showing location of LVDTs relative to joint and actuator load plates (Source: J. Vandenbossche, Univ. of Pittsburgh, 2017).

4. TEST SPECIMEN PREPARATION

4.1 The concrete test specimen shall be 7.5 inches thick, at least 6 feet wide (1/2 typical lane width) and at least 10 feet long with a ¼-inch wide transverse joint containing the subject load transfer devices formed full depth (to ensure that all joint load transfer capacity is due to the load transfer device, without contribution of aggregate interlock) at a minimum distance of 5 feet from either end of the specimen similar to Figures 5 and 6. The specimen detail represents 1/6-panels (and the included transverse joint) of two adjacent 12-foot wide by 15-foot long jointed plain concrete pavement slabs.

4.2 Prior to installation in the test specimen, measure the cross-sectional dimensions of each load transfer device (dowel bar) to the nearest 0.001 inch in at least the vertical and horizontal directions at locations that correspond to the joint face (one each side of the joint) and at distances of ½ inch and 1 inch away from the joint face on each side. (See Table 1 below) The measurement locations should be marked with a punch or other durable mark to allow post-test measures to be performed at the same locations.

4.3 Load transfer devices shall be installed through precisely drilled, cut holes, or slots in the transverse joint forming material according to the load transfer device size, spacing, and locations that are proposed for system approval. For many cylindrical metallic dowels, this will be mid-depth installation on 12-inch centers, with the first dowel located 6 inches from the edge of the specimen as shown in Figure 5. The load transfer devices must be supported and secured to ensure proper positioning and alignment during specimen fabrication.

4.4 The concrete mixture shall achieve a minimum compressive strength of 4,000 pounds per square inch at 28 days.

4.5 The concrete should be placed and the slab consolidated (taking care not to disturb the load transfer system) and finished with at least the level of care used in the field. A troweled surface is desirable for the load plates and LVDT contact points.

4.6 Cure the prepared specimen for 21 days using wet burlap or other appropriate paving curing technique. Air cure the specimen for an additional 7 days.

4.7 The test specimen may be cast directly on the test stand or platform, or can be cast off-site and placed on the test stand or platform using an appropriate bedding technique to achieve complete and uniform support of the specimen. The precast pavement industry can provide guidance on appropriate bedding materials and techniques.

4.8 All side and bottom forms (if used) must be removed prior to testing.

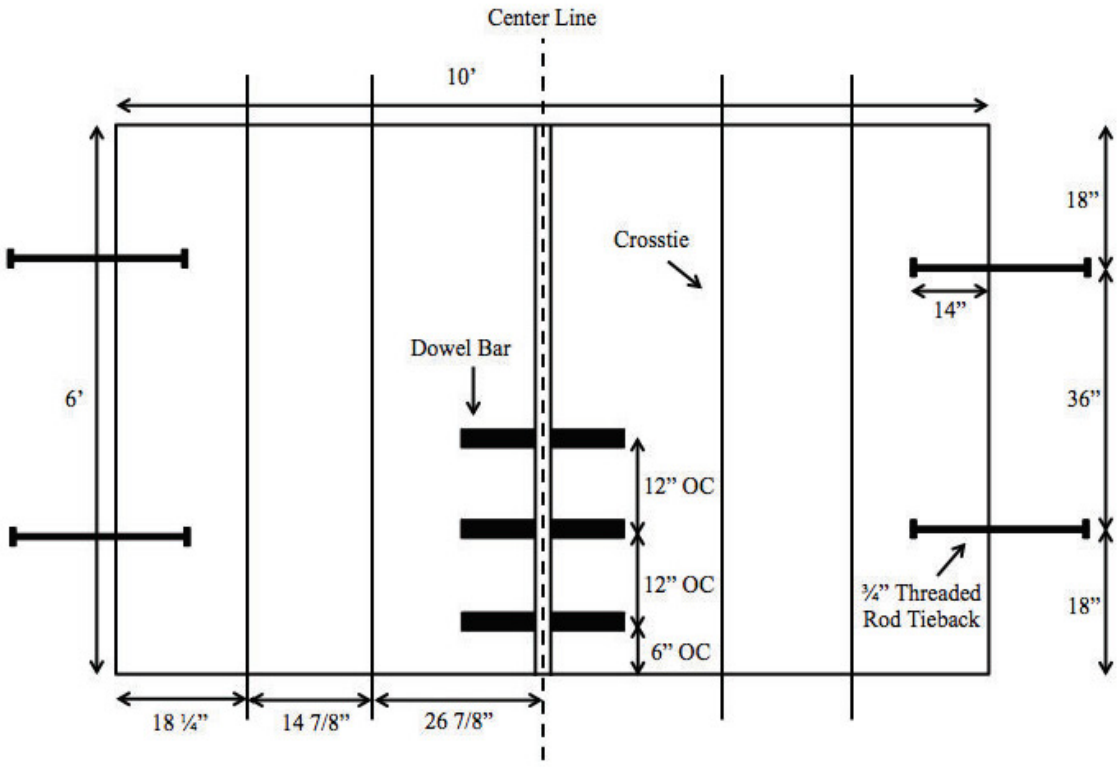

Figure 5. Plan view schematic of test specimen layout (Source: J. Vandenbossche, Univ. of Pittsburgh)

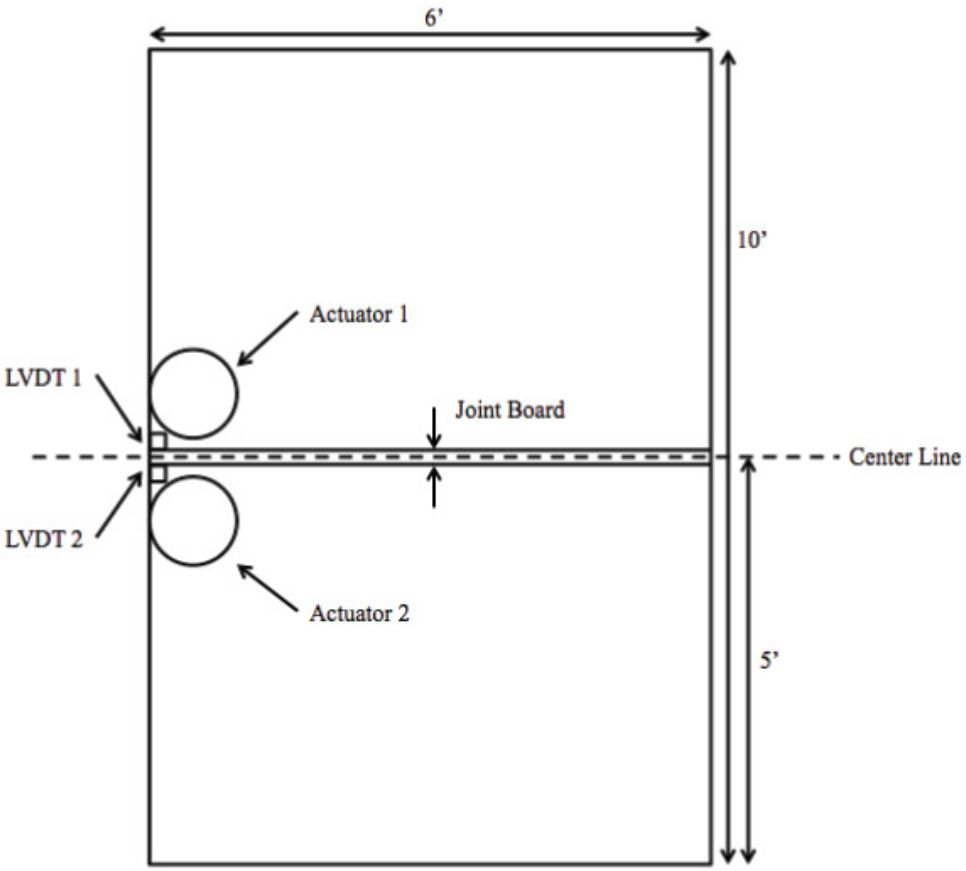

Figure 6. Schematic showing location of LVDTs relative to joint and actuator load plates (Source: J. Vandenbossche, Univ. of Pittsburgh, 2017).

Dowel	Angle from Vertical	Approach Side			Leave Side		
		Before	After	Difference	Before	After	Difference
1	0						
	36						
	72						
	108						
	144						
2	0						
	36						
	72						
	108						
	144						
3	0						
	36						
	72						
	108						
	144						

Table 1. Measured dowel diameter (inches) at locations one-quarter inch on either side of the joint, before and after testing. (Source: J. Vandenbossche, Univ. of Pittsburgh, 2017).

5. PROCEDURE

5.1 Obtain diameter cross-sectional measurements of load transfer dowels. (See Table 1 above)

5.1.1 Prior to installation of the load transfer dowel specimens into the concrete forms, measure the cross-sectional dimension of each load transfer dowel as described in Section 4.2.

5.1.2 Upon completion of the load-related portion of the test, carefully remove the load transfer devices, taking care not to damage them, and obtain cross-section measures at the same locations they were obtained prior to testing. Use photographs to document the condition of the load transfer devices.

5.2 Dynamic load testing should begin 28 days after the specimen is cast.

5.3 Obtain and record dynamic and static deflection and load measurements when the test begins and at the following load cycle counts (as a minimum): 1,000, 5,000, 10,000, 20,000, 50,000, 100,000, 250,000, 500,000, 1,000,000, 1,500,000 and every 500,000 thereafter to 10,000,000 load cycles. Obtain measurements of relative deflection when either side of the joint is fully loaded.

6. REPORTING

6.1 Present all load testing data (for both static and dynamic load measures) in tabular form showing peak load on the approach side with associated LVDT differential deflection measures and peak load on the leave side with associated LVDT differential deflection measures for each designated load cycle count. (The differential deflection is the absolute difference in deflection between the loaded and unloaded sides of the joint)

6.2 Prepare graphs showing relative deflection data gathered from the LVDTs vs. log (cumulative load cycles) for both approach side loading and leave side loading.

6.3 Prepare graphs of load transfer efficiency (unloaded side deflection/loaded side deflection) versus log (cumulative load cycles) for both approach and leave side loading.

6.4 Prepare a table of "before" and "after" diameter at each location on each dowel and identify any locations where the dimensional change is greater than 0.1%. (See Table 1 above)

Example Acceptance Criteria for Dynamic Load-Deflection Testing of Alternative Dowels

From Pennsylvania DOT Publication 408/2020 (Specifications), Section 705.3f:

"Submit structural adequacy testing according to PTM No. 642 showing a maximum Linear Variable Differential Transformers (LVDT) differential deflection for dynamic and static loading, for both the approach and leave sides of the joint of not more than 7.5 mils at 1 million cycles and not greater than a 2.5-mil increase in the LVDT differential deflection at 10 million cycles from the corresponding 1 million cycle LVDT deflection. The differential deflection is the absolute difference in deflection between the loaded and unloaded sides of the joint."

From Minnesota DOT High-Performance Dowel Bar Approval Procedure (February 2, 2018):

"Differential Deflection (DD) using an accelerated loading frame which repeatedly applies approximately 10 million load cycles of simulated heavy vehicle loads (9000-lb single wheel passage)."

"Differential Deflection (DD) ≤ 10 mils with a flat DD trend after 10M load cycles"