Standard Specification for
Dowel Bars for Concrete Street and Highway Pavement

ACPA M254-21a[1]
August 1, 2021

This document provides an alternative and revised version of the American Association of State Highway and Transportation Officials (AASHTO) Specification (AASHTO M 254-06 (2019)). The intent of this specification is to broaden the applicability of the current M254 standard for new and alternative dowel materials and configurations available for use in concrete pavements.

This document references appropriate material standards, test methods and specifications of AASHTO, American Society of Testing Materials (ASTM) and several other entities. Footnotes accompany some provisions. These added details describe the reasoning and considerations behind certain features, as well as choices and important references for clarity to the specification reader.

CONTRIBUTORS

The following individuals contributed their expertise, experiences and efforts to create this guideline:

Snyder, Mark (lead author)	PAVEMENT ENGINEERING & RESEARCH CONSULTANTS, LLC
Al Saddawi, Bassam "Ben"	COMMERCIAL METALS CORP.
Barragan, Bryan	OWENS CORNING
Eder, Glenn	AMERICAN HIGHWAY
Fannin, Neal	PENNSYLVANIA DEPARTMENT OF TRANSPORTATION
Ferrebee, Eric	AMERICAN CONCRETE PAVEMENT ASSOCIATION
Gremel, Douglas	OWENS CORNING
Masten, Maria	MINNESOTA DEPARTMENT OF TRANSPORTATION
Mather, Mike	ARTAZN
McMullen, Kevin	WISCONSIN CONCRETE PAVEMENT ASSOCIATION
Mu, Feng	PNA CONSTRUCTION
Schenk, Chris	O-DOWEL, INC
Trautman, Brett	MISSOURI DEPARTMENT OF TRANSPORTATION
Voigt, Gerald F.	AMERICAN CONCRETE PAVEMENT ASSOCIATION
Zaun, Brad	MASTER DOWEL

[1] Changes made from last version: 1) Elimination of UV exposure test of epoxy and FRP coatings and FRP dowels; 2) Addition of general requirement for protection of dowels from exposure after production (section 3.8); 3) Update of load-deflection test loads based on lab test results and analyses (Snyder, 2021); and 4) Update of reference list.

GUIDE SPECIFICATION

1. SCOPE OF THIS GUIDELINE

1.1. This specification covers the materials, manufacture, and supply of dowel bars for use in conventional and long-life concrete street and highway pavements.

1.2. Dowels are categorized according to primary material type (metallic or nonmetallic) and the type of corrosion protection coating used (e.g., none, metallic, or nonmetallic) – regardless of whether solid or tubular - using the following type designations:

Type A – The dowel comprises a single uncoated metallic material (e.g., carbon steel, low-carbon chromium steel, stainless steel, or other metallic alloys).

Type B – The dowel comprises a single uncoated non-metallic material (e.g., FRP).

Type C – The dowel has a metallic core and is coated, clad or sleeved with a different metallic material (e.g., stainless steel or zinc alloy cladding/sleeving of a carbon steel core).

Type D – The dowel has a metallic core and is coated, clad or sleeved with a non-metallic material (e.g., epoxy-coated, plastic/polyethylene-coated and FRP-clad carbon steel dowels).

1.3. 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.

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

2. REFERENCE DOCUMENTS AND TESTING STANDARDS

2.1. AASHTO Standards

M 254-06 (2019)	Standard Specification for Corrosion-Resistant Coated Dowel Bars
M255M/M 255 (2019)	Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality, Mechanical Properties
M 334M/334 (2017)	Standard Specification for Uncoated, Corrosion-Resistant, Deformed and Plain Chromium Alloy, Billet-Steel Bars for Concrete Reinforcement and Dowels
T 253-02 (2016)	Standard Method of Test for Coated Dowel Bars

2.2. ASTM Standards

A249/A249M – 18a	Standard Specification for Welded Austenitic Steel Boiler, Superheater, Heat-Exchanger, and Condenser Tubes

A276/A276M – 17	Standard Specification for Stainless Steel Bars and Shapes
A312/A312M – 18a	Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
A513/A513M-19	Standard Specification for Electric-Resistance-Welded Carbon and Alloy Steel Mechanical Tubing
A615/A615M-18e1	Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement
A653/A653M – 19a	Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
A775/A775M-17	Standard Specification for Epoxy-Coated Steel Reinforcing Bars
A934/A934M-16	Standard Specification for Epoxy-Coated Prefabricated Steel Reinforcing Bars
A1035/A1035M – 16b	Standard Specification for Deformed and Plain, Low-Carbon, Chromium, Steel Bars for Concrete Reinforcement
A1055/A1055M – 16	Standard Specification for Zinc and Epoxy Dual-Coated Steel Reinforcing Bars
A1078/A1078-19	Standard Specification for Epoxy-Coated Steel Dowels for Concrete Pavement
B69-16	Standard Specification for Rolled Zinc
D4476 /D4476M-14	Standard Test Method for Flexural Properties of Fiber Reinforced Pultruded Plastic Rods
D6272-17	Standard Test Method for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials by Four-Point Bending
D7091-13	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
D7705/D 7705M-12 (2019)	Standard Test Method for Alkali Resistance of Fiber Reinforced Polymer (FRP) Matrix Composite Bars used in Concrete Construction
D7957/D7957M[2]	Standard Specification for Solid Round Glass Fiber Reinforced Polymer Bars for Concrete Reinforcement (under review)
G8-96 (2010)	Standard Test Methods for Cathodic Disbonding of Pipeline Coatings
G12	Standard Test Method for Nondestructive Measurement of Film Thickness of Pipeline Coatings on Steel (Withdrawn 2013)
G14-04 (2018)	Standard Test Method for Impact Resistance of Pipeline Coatings (Falling Weight Test)
G20-10 (2015)	Standard Test Method for Chemical Resistance of Pipeline Coatings
G62-14	Standard Test Methods for Holiday Detection in Pipeline Coatings
G155-13	Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials

[2] At the time of this writing, a new standard titled "Standard Specification for Solid Round Glass Fiber Reinforced Polymer Dowel Bars for Load Transfer Between Concrete Slabs" is in development and will soon supersede D7957/D7957M for reference in this document.

2.3. Other Standards

ACPA T 253-21	Standard Method of Test for Dowel Bars for Concrete Pavement
AWWA C213-07	Fusion-Bonded Epoxy Coating for Interior and Exterior of Steel Water Pipeline (American Water Works Association)
CSA-Z245.20	Plant-applied External Fusion Bond Epoxy Coating [Abrasion-Resistant Overcoat] for Steel Pipe (CSA Group, formerly the Canadian Standards Association)
SSPC-PA 2	Measurement of Dry Coating Thickness with Magnetic Gages (Society for Protective Coatings)

3. GENERAL REQUIREMENTS

3.1. The processing facilities of the manufacturer and the fabricator shall be open to inspection by the purchaser’s agent at all times during the manufacture and fabrication of the product.

3.2. All dowels considered for a specific project shall meet or exceed applicable physical requirements established by the purchasing agency with respect to the properties and tests described in Section 6 of this specification. The frequency of required qualification testing by the manufacturer will be determined by the purchasing agency.

3.3. All dowel bars shall be coated with an appropriate and approved bond-breaking material prior to installation in concrete pavement unless the dowel bar manufacturer demonstrates that dowel pull-out forces, as determined using Section 6 of ACPA T 253-21, meet the requirements of Section 6.5.2 below without the use of an approved bond-breaking material.

3.4. The coating, cladding, or surface finish of all dowel bars shall resist wear (due to abrasion resulting from joint movements) that would reduce corrosion resistance, increase joint restraint or reduce structural capacity to unacceptable levels. See Section 6.5.3 below.

3.5. Any dowel coating, cladding, or surface finish shall be continuous and uniform over the lateral surface of the dowel.

3.6. In the event there is any change in material composition or dimensions of the dowels or dowel assembly from those of the qualified dowel system, the purchasing agency may require that any or all parts of the dowels and assembly be subjected to partial or complete testing by the manufacturer for re-qualification.

3.7. Dowel bar samples (including dowels in basket assemblies) shall be made available to the purchasing agency upon request in sufficient quantities for verification testing by the purchasing agency at the agency’s expense. See note 1. When fixed basket assemblies are being used, a complete assembly with dowels shall be included in the sample upon request by the purchasing agency.

Note 1: The minimum number of dowel samples to be provided will depend upon which tests the purchasing agency will conduct and the number of spare or alternate dowels requested for additional or replacement tests. Refer to ACPA T253-21 for the minimum number of dowels required for each test.

3.8. After manufacture and prior to installation, store dowels in conditions that do not promote corrosion or other degradation of the dowel or dowel coating. Avoid long-term outdoor storage of dowels. If circumstances require that dowels be stored outdoors for more than two months, implement protective storage measures to protect the dowels from sunlight, salt spray, and weather exposure. Dowels stored in potentially corrosive environments may require protection sooner. Dowels and basket assembly protection may be accomplished by covering with opaque polyethylene sheeting or other suitable opaque protective materials. For stacked or palleted products, cover the entire stack or pallet on top and around all sides. Secure the covering adequately and allow air circulation around the bars to minimize condensation under the covering. If dowels are stored outdoors without cover, record the date on which the dowels are placed outdoors on identification tags on the bundles.

4. MATERIALS

The materials used to construct the dowel bar shall meet the following requirements:

4.1 *Type A* - The dowel structure shall comprise a single metallic material meeting the requirements of AASHTO M 255M/M 255, AASHTO M 334, ASTM A276, ASTM A312, or ASTM A1035 (CS, CM and CL). The grade shall be as specified by the purchasing agency.

4.2. *Type B* - The dowel structure shall comprise a single nonmetallic material meeting the requirements of ASTM D7957/D7957M[3] or as specified by the purchasing agency.

4.3. *Type C* - The core material shall be made of steel meeting the requirements of AASHTO M 255, AASHTO M 334, ASTM A513, or ASTM A615; the grade shall be as specified by the purchasing agency. The corrosion protection coating shall be made of metallic material meeting the requirements of ASTM A249, ASTM A276 or ASTM A312 for stainless steel coatings, ASTM A1035 (CS, CM and CL) for low-carbon chromium coatings, ASTM B69 for rolled zinc coating, or ASTM A653 for hot-dip galvanizing.

4.4. *Type D* - The core material shall be made of steel meeting the requirements of AASHTO M 255, AASHTO M 334, ASTM A276, ASTM A312, ASTM A513, ASTM A615, or ASTM A1035 (CS, CM and CL). The grade shall be as specified by the purchasing agency.

4.4.1. Type D1 shall have corrosion protection coatings comprising a mechanically bonded cladding nonmetallic material (e.g., FRP) meeting the requirements of ASTM D4476, D6272, or as specified by the purchasing agency.

4.4.2. Type D2 shall meet the requirements of ASTM A1078/A1078M, and have

[3] Replace with ASTMD75XX/D79XXM "Standard Specification for Solid Round Glass Fiber Reinforced Polymer Dowel Bars for Load Transfer Between Concrete Slabs" once it is released.

corrosion protection coatings comprising one or more thin layers of epoxy, plastic or similar materials of primarily organic composition (with the exception of the pigment, which may or may not be present, and which may have an inorganic composition). Epoxy coating systems shall meet the material requirements (but not the thickness requirements) of ASTM A775, A934, and/or CSA-Z245.20 and shall be produced by a certified plant. The requirements for other organic coating systems shall be as specified by the purchasing agency.

5. DIMENSIONS

5.1 Dowel bar dimensions shall be specified by the purchasing agency. All dimensions are as measured prior to the application of any coating or cladding materials, except for Type D1 for which diameter is measured for the metallic core dowel before application of the nonmetallic cladding and overall dowel diameter is measured after application of the nonmetallic cladding.

5.1.1. For solid cylindrical dowels, specified dimensions shall include the minimum required dowel length and the minimum dowel diameter. For Type D1 dowels the minimum diameter of both the core dowel and the finished dowel must be specified.

5.1.2. For solid elliptical dowels, specified dimensions shall include the minimum required dowel length and the minimum required lengths of the ellipsis section axes.

5.1.3. For tube and pipe dowel systems, specified dimensions shall include the minimum required dowel length, the minimum required wall thickness and minimum required outside diameter.

5.1.4. For plate dowel systems, specified dimensions shall include the minimum required and maximum allowable plate thicknesses and all other dimensions required to accurately define the plate shape.

5.1.5. For dowels that are not cylindrical (round), not solid, or which contain non-steel structural elements, the purchasing agency shall also call out the required structural or behavioral equivalency (i.e., minimum stiffness [EI] or maximum deflection under specified conditions) of solid steel cylindrical dowel (e.g., 1.25-inch diameter round steel equivalent).

5.2. For Type C and D systems, the non-abraded minimum thickness of coated systems shall be sufficient to resist corrosion and impact damage when tested in accordance with ACPA T253-21.

5.2.1. Coating thickness shall be determined according to ASTM D7091, or by measuring with high-precision calipers after cutting the bar across its section or stripping the coating from the bar.

5.3. Dowels shall be supplied to the testing laboratory and contractor in lengths (and in support assemblies or baskets, if appropriate), as specified by the purchasing agency.

Note 2: Agencies may need to specify additional dimensional limits and requirements (e.g., maximum allowable diameter) to ensure compatibility of dowels with chairs, expansion caps, dowel bar insertion equipment, etc.

6. PHYSICAL REQUIREMENTS

6.1. Dowels shall be cut to length by suitable means without deforming the bar, and the ends of cut dowels shall be free of burrs and projections.

6.1.1. The purchasing agency may specify that the dowel ends be coated or covered with epoxy or another barrier material to prevent corrosion, concrete intrusion in tubular dowels, or other concerns.

6.2. Dowel coatings shall be free of contamination, perforations, cracks, and “holidays” (i.e., visible “pinholes” or other coating defects that expose the underlying metal).

6.2.1. Type D2 only – Check for holidays using a device meeting the requirements of ASTM G62. On average, there shall not be more than three holidays per meter (one holiday per foot) on a coated steel dowel bar. The average applies to the full production length of a bar.

6.3. Any dowel or coating damage that results from welding or mechanical fixation to baskets or supports shall not extend more than 25.4 mm (1 in) from the weld or point of fixation.

6.4. Welds and other mechanical devices used to attach dowels to basket or support assemblies shall be sufficiently strong to hold the dowels in position during transport, handling and installation, as well as during concrete placement and paving.

6.5. Test procedures as stated herein and described in ACPA T 253-21 shall apply to all types of dowels except as noted or as waived by the purchasing agency. When applicable (and not waived by the purchasing agency), dowel bars shall meet the following requirements:

6.5.1. **Load Deflection**

6.5.1.1. Relative deflection shall be measured at the four corner locations for each test specimen after the 21.3-kN (4800-lb) load is applied and held at each corner. Optionally, the purchasing agency can specify the measurement of relative deflections at each corner location after the 32-kN (7,200-lb) load is applied and held. In either case, the average of four measurements will be reported for evaluation. The purchasing agency will specify the maximum allowable relative deflection based on project requirements.

Note 3: Laboratory testing and finite element analyses indicate that the relative deflection for the ACPA T253-21 load deflection test with 21.3-kN (4,800-lb) load should be similar to the relative deflection for the standard AASHTO T 253 load deflection test for 32-mm (1.25-in) diameter, 450-mm

(18-in) long solid steel cylindrical dowels; therefore, a similar relative deflection limit of 0.25 mm (10 mils) may be appropriate. Snyder (2021) describes the laboratory testing and analyses that were performed in support of the development of the load-deflection test described herein and in ACPA T253 Section 5.

Note 4: Laboratory testing indicates that increasing the load for the standard AASHTO T253 load-deflection test by 50 percent (from 17.8kN [4000 lbs] to 26.7 kN [6000 lbs] increases relative deflection by about 50 percent. These results were obtained for 32mm [1.25-in] diameter, 450-mm (18-in) long solid steel cylindrical dowels. Increasing the load for the ACPA T253 load-deflection test by 50 percent (from 21.3 kN [4800 lbs] to 32 kN [7,200 lbs]) should also result in relative deflections that are about 50 percent higher. Snyder (2021) describes the laboratory testing and analyses that were performed in support of the development of the load-deflection test described herein and in ACPA T253 Section 5.

Note 5: Agencies should select the maximum allowable relative deflection value with consideration of the test load magnitude (i.e., 21.3 kN [4,800 lb] or 32 kN [7,200 lbs]) and the diameter of structurally equivalent cylindrical steel dowels spaced at 30 cm [12 inches] for the designed load transfer system. For example, 38-mm (1.5-inch) cylindrical steel dowels will have lower relative deflections than standard 32-mm (1.25-inch) cylindrical steel dowels; the maximum allowable relative deflection should be lower for the larger dowels if dowel spacing is held constant, and the maximum allowable deflection for any dowel (regardless of shape or composition) intended to be structurally equivalent to the larger dowel should be evaluated using the same maximum allowable relative deflection as the larger dowel. Similarly, cylindrical steel dowels smaller than 32 mm (1.25 inches) diameter will have higher relative deflections than standard 32-mm (1.25-in) dowels; the maximum allowable relative deflection should be higher for the smaller dowels if dowel spacing is held constant, and the maximum allowable deflection for any dowel (regardless of shape or composition) intended to be structurally equivalent to the smaller dowel should be evaluated using the same maximum allowable relative deflection as the smaller dowel.

Note 6: The purchasing agency may select higher or lower relative deflection acceptance values for any given dowel load transfer system depending on project site conditions and pavement functional classifications. For example, more stringent (lower) deflection criteria (indicating stiffer dowel systems) may be appropriate to reduce risk of unacceptable performance for high-volume, heavily trafficked facilities than for streets and local roads. Similarly, less stringent (higher) deflection criteria (indicating more flexible dowel systems) may be appropriate in some cases (e.g., projects with few heavy loads or having stronger foundations that are rarely

saturated or are insensitive to moisture).

6.5.1.2. (Optional Alternative to 6.5.1.1) Some state highway agencies have standardized and adopted a dynamic load test for dowel load transfer systems. This test, which is described with representative dowel acceptance criteria in Annex A of ACPA T 253-21, subjects dowel load transfer systems to 10 million cycles of simulated vehicle loading and is an acceptable alternative to the load-deflection test described under 6.5.1.1. Acceptance criteria for dynamic load testing should be established by the agency and may be different from those established for the static load-deflection test.

Note 7: The dynamic test may provide a better indication of long-term dowel behavior than does the static test, but is generally more costly and time-consuming. It also produces a single measure of relative deflection at a single location (versus replicate measures at 4 locations for the static test described in 6.5.1.1); the results of a single measure of relative deflection must be evaluated with consideration of the potential variability of test results.

6.5.1.3 (Optional Analytical Alternative to Load-Deflection Testing) – Agencies may allow the use of analytical tools to assess the structural equivalence or adequacy of some dowel systems, thereby avoiding the need for the time-consuming and expensive laboratory tests described in 6.5.1.1 and 6.5.1.2.

Note 8: Analytical evaluation of the structural behavior of individual dowels under static loads (e.g., AASHTO T 253 Load-Deflection Testing) can be performed with reasonable confidence when dowel size, shape, coating, and core materials are similar (e.g., comparing cylindrical metallic dowels with identical dimensions but different elastic modulus values, such as might be found in carbon steel and stainless steel). In such cases, critical performance indicators, such as Friberg's dowel-concrete bearing stress and dowel deflection, can be estimated and compared using equations found in many pavement engineering texts. Similarly, the same equations can be used to evaluate or assess the impact of small changes in dowel diameter (e.g., increasing from 32 mm [1.25 in] to 38 mm [1.50 in]) when dowel length, shape and material type are constant). Bearing stress limits can be established based on joint faulting models found in literature (e.g., Darter, et al. 1985) or those incorporated in AASHTOWare Pavement ME Design, or can be limited using the following 1956 ACI 325 equation:

$$f_b < f'_c(4 - b)/3$$

where fb = maximum allowable bearing stress, f'c = 28-day compressive strength of concrete and b = dowel diameter, inches.

Note 9: Analytical tools may not provide adequate indications of structural and

behavioral equivalence when dowel shapes, spacing, and/or properties vary greatly or beyond the limits of applicability of the available tools (e.g., bearing stress equations, some FEA programs, etc.). For example, it may be difficult to accurately predict the behavior of tubular FRP dowels or steel plate dowels relative to that of conventional cylindrical steel dowels using available and accepted analytical tools. The tests described in 6.5.1.1 and 6.5.1.2 may provide more useful and reliable information for determining the structural equivalency of such systems.

6.5.1.4. After completion of the load-deflection test, dowels shall be retrieved from the test specimen and inspected for evidence of structural distress and damage to any coating or cladding (if present).

6.5.2. **Pullout** – When tested in accordance with the provisions of ACPA T 253-21, the pullout load shall not exceed 13.4 kN (3000 lb) for any specimen, and no specimen shall show any surface tears or perforation due to the pullout testing.

6.5.3. **Abrasion** – When subjected to abradometer testing in accordance with the provisions of Section 8 of ACPA T 253-21, the abrasion of any dowel surface or coating shall not exceed the limits specified by the purchasing agency.

Note 10: AASHTO M254-06 stipulates that no tested specimen shall exhibit wear depth exceeding 70 percent of the original coating (epoxy) thickness. This limit ensures some residual protection of the metallic dowel core.

Abrasion limits for uncoated dowels (e.g., Types A and B) or Types C and D dowels with thick protective layers should be established with consideration of the impact of reduced dowel diameter on dowel looseness and loss of load transfer. For example, a 70 percent reduction in thickness of a typical 10-mil layer of epoxy due to abrasion would result in a maximum reduction in dowel diameter of 14 mils over the life of the dowel (assuming field wear on both top and bottom of the dowel). The same 70 percent reduction in thickness for a 40-mil protective layer would result in a 56-mil reduction in dowel diameter, which may result in unacceptable relative deflections and loss of joint load transfer.

6.5.4. **Corrosion** – After being subjected to the corrosion-abrasion test procedures described in Section 8 of ACPA T 253-21, no evidence of steel corrosion or steel corrosion products shall be apparent on lateral surfaces (i.e., excluding dowel ends) of any of the tested dowel specimens when viewed under five-power magnification.

6.5.4.1. Uncoated dowels conforming to AASHTO M 255 or ASTM A615 are not considered to be corrosion-resistant and are exempt from this test and requirement.

6.5.4.2. The agency shall establish limits on percent expansion of Types A, C and D dowels due to the corrosion test, as defined and described in ACPA T 253-21.

6.5.4.3. For Type C dowels with zinc-based coating or cladding covered under ASTM A653 or ASTM B69, corrosion resistance will be determined by the purchasing agency.

6.5.5. **Chemical Resistance** (Dowel type D2 only) – Surface coatings shall not blister, soften, disbond, develop holidays, or exhibit undercutting at the drilled holes when tested in accordance with Section 8 of ACPA T 253-21.

6.5.6. **Cathodic Disbonding** (Dowel type D2 only) – Test in accordance with Section 10 of ACPA T 253-21. No film failure shall take place within the first hour of testing. Film failure is indicated by the evolution of hydrogen gas at the cathode, or the appearance of steel corrosion products at the anodes; hydrogen evolution or steel corrosion products observed at the intentionally cut 6.4-mm (1/4-in) holes are not a basis for rejection. The average disbondment radius after testing is limited to 4mm (0.16 in).

6.5.7. **Coating Impact Resistance** (Dowel type D2 only) – When tested in accordance with Section 10 of ACPA T 253-21, no shattering or disbonding of the coating shall occur expect at the impact area (i.e., the area permanently deformed by the tup).

7. DOCUMENTATION

7.1. Tests performed according to this specification shall be the responsibility of the manufacturers and/or coating applicator and may be performed at an accredited laboratory approved by the purchasing agency. Upon completion of the tests, all tested specimens shall be properly labeled as to test procedure performed, and be made available to the purchasing agency upon request.

7.2. The laboratory facilities and procedure must be open to observation by the purchaser while tests are underway. The purchasing agency reserves the right to check any or all parts of the required test in the agency laboratory or a laboratory of their choice.

7.3. For dowel Types C and D:

7.3.1. The coated dowel manufacturer and/or coating applicator shall provide certified copies of test reports to the purchasing agency showing all test data.

7.3.2. For the purpose of identification, the manufacturer or applicator shall provide certification showing the generic type of coating or surface material along with the type and percentages of any components used.

7.3.3. The coating/cladding applicator is defined as a company that applies the coating/cladding layer to the dowel bars.

7.4. Rechecks of the dowels may be made at the discretion of the purchasing agency. The purchasing agency may delete any of the above specified test procedures during rechecks of any previously approved product.

8. REFERENCES

ACI (1956). Report of ACI Committee 325 (Concrete Pavements). American Concrete Institute. Detroit, MI.

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Snyder, M. B. (2021). Development of an Improved Protocol for Structural Evaluation of Dowel Load Transfer Systems for Concrete Pavements. Final Report to National Concrete Consortium. American Concrete Pavement Association. Rosemont, IL. 2021