INTERNATIONAL

Designation: D7234 – 22

Standard Test Method for Pull-Off Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers[1]

This standard is issued under the fixed designation D7234; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers procedures for evaluating the pull-off strength of a coating on concrete. Pull-Off strength of coatings for other rigid substrates is described in Test Method D4541. The test determines the greatest perpendicular force (in tension) that a surface area can bear before a plug of material is detached. Failure will occur along the weakest plane within the system comprised of the loading fixture, glue, coating system, and substrate, and will be exposed by the fracture surface.

1.2 This test method uses a class of apparatus known as portable pull-off adhesion testers.[2] They are capable of applying a concentric load and counter load to a single surface so that coatings can be tested even though only one side is accessible. Measurements are limited by the strength of adhesion bonds between the loading fixture, coating system and the substrate or the cohesive strengths of the glue, coating layers, and substrate.

1.3 This test method is suitable for both laboratory and field testing.

1.4 Pull-off strength measurements depend upon both material and instrumental parameters. There are different instruments used that comply with this test method. The specific instrument used should be identified when reporting results. This test is destructive and spot repairs may be necessary.

1.5 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

1.6 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[3]

C1583 Test Method for Tensile Strength of Concrete Surfaces and the Bond Strength or Tensile Strength of Concrete Repair and Overlay Materials by Direct Tension (Pull-off Method)

D16 Terminology for Paint, Related Coatings, Materials, and Applications

D2651 Guide for Preparation of Metal Surfaces for Adhesive Bonding

D3933 Guide for Preparation of Aluminum Surfaces for Structural Adhesives Bonding (Phosphoric Acid Anodizing)

D4541 Test Method for Pull-Off Strength of Coatings Using Portable Adhesion Testers

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E178 Practice for Dealing With Outlying Observations

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

3. Terminology

3.1 The terms and definitions in Terminology D16 apply to this test method.

3.2 *Definitions:*

3.2.1 *concrete, n—with respect to this test method*, refers to all forms of concrete including masonry units.

3.2.2 *glue, n—with respect to this test method*, glue refers to the material that bonds the bottom of the loading fixture to the top surface of the coating to be tested.

[1] This test method is under the jurisdiction of ASTM Committee D01 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.46 on Industrial Protective Coatings.

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[2] The term adhesion tester may be somewhat of a misnomer, but its adoption by two manufacturers and at least two patents indicates continued usage.

[3] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

3.2.3 *loading fixture, n*—(also referred to as dollies or studs) a metal structure that is flat on one end for bonding to the coating surface and shaped on the other end for attachment to the adhesion tester and is used to determine the pull-off strength of coatings.

3.2.4 *portable pull-off adhesion testers, n*—instruments that are capable of applying a concentric load and counter load to a single surface so that coatings can be tested even though only one side is accessible.

4. Summary of Test Method

4.1 The general pull-off test is performed by scoring through the coating down to the surface of the concrete substrate at a diameter equal to the diameter of the loading fixture (dolly, stud), and securing the loading fixture normal (perpendicular) to the surface of the coating with a glue. After the glue is cured, a testing apparatus is attached to the loading fixture and aligned to apply tension normal to the test surface. The force applied to the loading fixture is then uniformly increased and monitored until a plug of material is detached. When a plug of material is detached, the exposed surface represents the plane of limiting strength within the system. The nature of the failure is qualified in accordance with the percent of adhesive and cohesive failures, and the actual interfaces and layers involved. The pull-off strength is computed based on the maximum indicated load, the instrument calibration data, and the surface area stressed. Pull-off strength results obtained using different devices may be different because the results depend on instrumental parameters.

5. Significance and Use

5.1 The pull-off strength and mode of failure of a coating from a concrete substrate are important performance properties that are used in specifications. This test method serves as a means for uniformly preparing and testing coated surfaces, and evaluating and reporting the results.

5.2 Variations in strength results obtained using different instruments, different substrates, or different loading fixtures with the same coating are possible. Therefore, it is recommended that the specific test instrument and loading fixture be mutually agreed upon between the interested parties.

5.3 It is recommended that the coating be sufficiently cured to ensure cohesive strength and adhesion. This required minimum cure time before testing should be provided by the coating manufacturer, and may require an extension due to atmospheric conditions on site (for example, low temperature, and low or high humidity).

5.4 This test method may be adapted to determine surface strength of uncoated concrete (see X2.1). Test Method C1583 is also suitable for that determination.

5.5 The objective of this method is to determine the adhesion of a coating to concrete (or adapted for surface strength as stated in 5.4) and will result in failure in the coating or near the substrate surface. If evaluating the cohesive strength of the substrate or cementitious surfacers is the purpose of the testing, or if the substrate or cementitious surfacers have low strength, then Test Method C1583 may be more suitable.

6. Apparatus

6.1 *Adhesion Tester,* including the components and accessories described in 6.1.1 – 6.1.5.

6.1.1 *Loading Fixtures,* having a flat surface on one end that can be adhered to the coating and a means of attachment to the tester on the other end. The bonding surface may be round, square or rectangular. The round loading fixtures are usually 50 mm (2.0 in.) in diameter but may range from 20 mm (0.75 in.) to 75 mm (3.0 in.) in diameter.

6.1.2 *Detaching Assembly,* having a central grip for engaging the loading fixture.

6.1.3 *Base,* on the detaching assembly, for uniformly pressing against the coating surface around the fixture either directly, or by way of an intermediate bearing ring. A means of aligning the base is needed so that the resultant force is normal to the surface.

6.1.4 *Force Applicator,* means of moving the grip away from the base in as smooth and continuous a manner as possible so that a torsion free, co-axial (opposing pull of the grip and push of the base along the same axis) force results between them.

6.1.5 *Force Indicator and Calibration Information,* for determining the actual force delivered to the loading fixture. The force indicator shall be verified to be within ±5 % of the force measured by a calibrated testing machine at a frequency determined by the user, typically once a year.

6.2 *Timer,* or means of limiting the rate of stress to less than or equal to 0.2 MPa/s (30 psi/s) so that the maximum stress (failure) is obtained in about 5 to 30 s.

6.3 *Solvent,* or other means for cleaning the loading fixture surface.

6.4 *Fine Sandpaper,* or other means of cleaning or preparing the coating that will not alter its integrity.

6.5 *Glue,* for securing the fixture to the coating that does not affect the coating properties. Two-component epoxies and acrylics[4] have been found to be the most versatile.

6.6 *Mechanical Clamps,* if needed, for holding the fixture in place while the glue cures.

6.7 *Cotton Swabs,* or other means for removing excess glue.

6.8 *Core Bit with Drill Press or Hand Drill,* and means to ensure that the scoring is normal to the coating for the procedures that use a round loading fixture. The core bit inside diameter should equal the diameter of the loading fixture. If a core bit with an inside diameter equal to the diameter of the loading fixture is not available, the closest size available should be used. The diameter of the scored area should be measured and recorded for performing the calculations. The core bit or saw blades should be diamond tipped and, when required to minimize heat and suppress dust, supplemented with water

[4] The sole source of supply of the acrylics known to the committee at this time is Versiloc 201 and 204 with accelerator, available from Lord Corp., Industrial Adhesive Div., 2000 W. Grandview Blvd., P.O. Box 10038, Erie, PA 16514. If you are aware of alternative suppliers, please provide this information to ASTM International Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee,[1] which you may attend.

lubrication. For the test procedures that use a square or rectangular loading fixture, a circular saw is required instead of a core bit and drill. Alternately, for thin or elastomeric coatings, a sharp knife or hole saw may be sufficient to score around the loading fixture.

7. Test Preparation

7.1 The method for selecting the coating sites to be prepared for testing depends upon the objectives of the test and agreements between the contracting parties. There are, however, a few physical restrictions imposed by the general method and apparatus. The following requirements apply to all sites:

7.1.1 The selected test area must be a flat surface large enough to accommodate the specified number of replicate tests. The surface may have any orientation with reference to gravitational pull. Each test site must be separated by at least the distance needed to accommodate the detaching apparatus. The size of a test site is essentially that of the secured loading fixture. At least three replications are required in order to statistically characterize the test area.

7.1.2 The selected test areas must also have enough perpendicular and radial clearance to accommodate the apparatus, and be flat enough to permit alignment. It should be noted that measurements close to an edge may not be representative of the coating as a whole.

7.2 Scoring the coating down to the surface of the substrate is required for all coatings thicker than 0.5 mm (20 mils) and for all reinforced or elastomeric coatings. While scoring is recommended for coatings thinner than 0.5 mm (20 mils), the test may be performed without scoring, but the results should note this exception. Scoring shall be performed in a manner that ensures the cut is made normal to the coating surface and in a manner that does not twist or torque the test area and minimizes heat generated and edge damage or microcracks to the coating and the concrete substrate. For thick coatings it is recommended to cool the coating and substrate during the cutting process with water lubrication. If any defects of the coating due to the scoring are observed, the test location shall be discarded and not recorded in the results. When using a round loading fixture, scoring shall be performed before the loading fixture is attached (see Fig. 1). When using square or rectangular loading fixtures, scoring is typically performed after the loading fixture is attached (see Fig. 2).

NOTE 1—Since it is difficult to score the coating precisely "down to the surface of the substrate," especially for thicker coatings, it is acceptable to allow a range. This range for the whole circumference or edge should, at the top end, ensure touching the surface of the substrate, and at the bottom end, be no more than 3 mm (⅛ in.) below the substrate surface. In cases where the substrate is very rough, the surface of the substrate would be the lowest depth of continuous substrate with this same tolerance.

NOTE 2—(For concrete surfacers/patching materials under coatings.) It is common in recoating projects to apply a "surfacer" or patching material to the concrete substrate to repair or level, or both, the concrete prior to recoating. This surfacer/patching material layer can range in thickness from very thin (essentially immeasurable on top of the remaining concrete), up to 12 mm or more in small repair pockets. It is the option of the specifier of the project to define the surfacer/patching material as either part of the coating system (where the underlying concrete would be the substrate) or as the substrate itself. This distinction would be relevant in determining the depth of scoring as detailed in 7.2.

NOTE 3—For vertical and overhead surfaces it is recommended to use an attached template to ensure scoring is performed with a tool secured and guided in a perpendicular angle.

7.3 Clean the surfaces in a manner that will not affect integrity of the coating or leave a residue. Clean the loading fixture surface as indicated by the apparatus manufacturer. Failures at the fixture-glue interface can often be avoided by treating the fixture surfaces in accordance with an appropriate

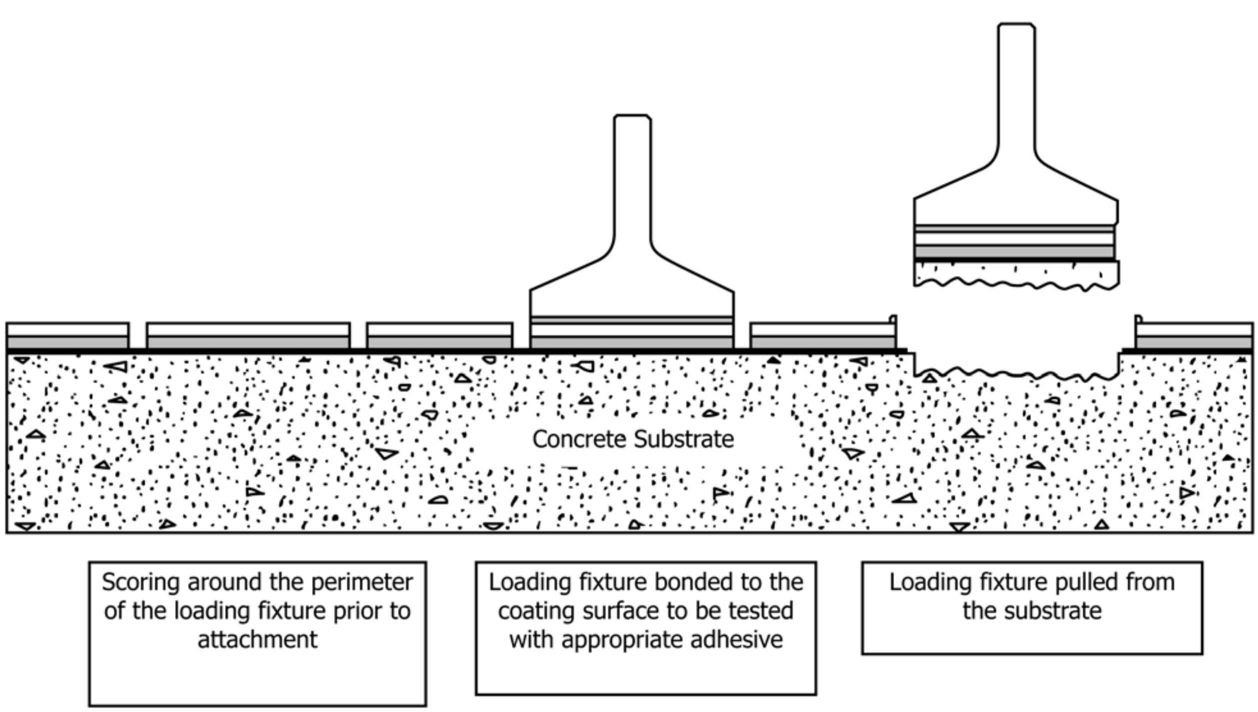

FIG. 1 Scoring Around the Loading Fixture Prior to Attachment of the Fixture (Round Loading Fixtures)

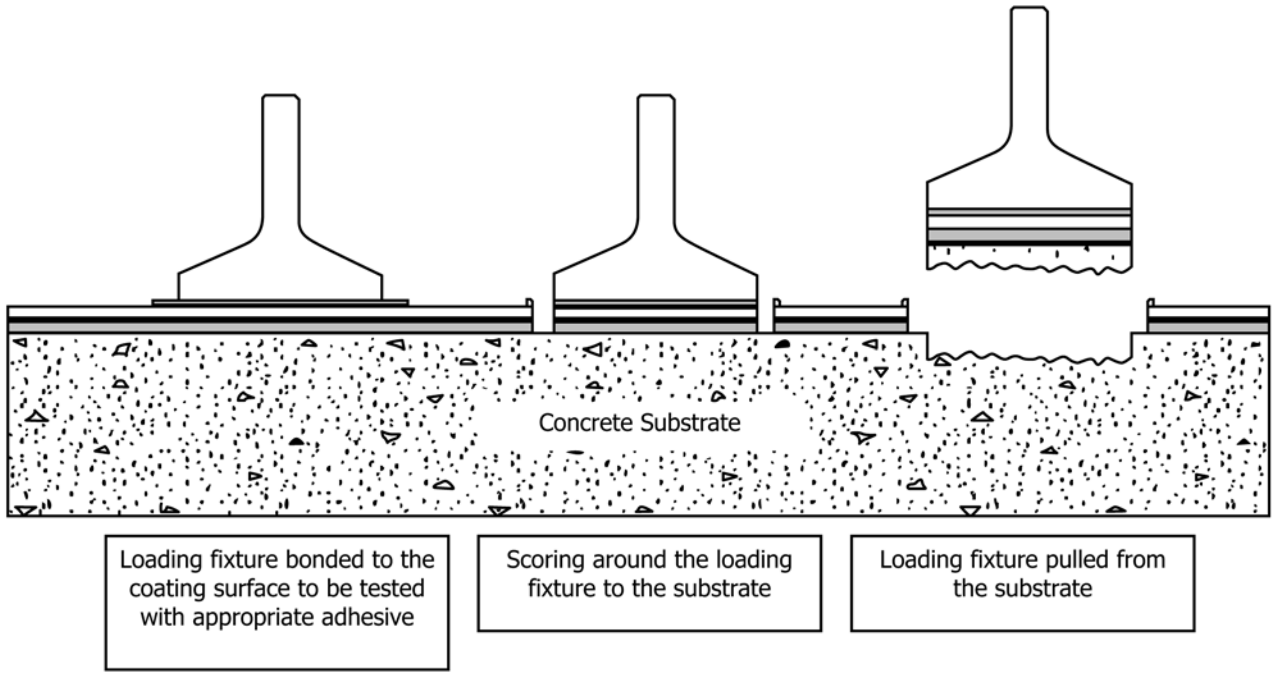

FIG. 2 Scoring Around the Loading Fixture After Attachment of the Fixture (Square or Rectangular Fixtures)

ASTM standard practice for preparing metal surfaces for adhesive bonding. Fingerprints, moisture, and oxides tend to be the primary contaminants.

NOTE 4—Guides D2651 and D3933 are typical of well-proven methods for improving adhesive bond strengths to metal surfaces.

7.4 Prepare the glue in accordance with the glue manufacturer's recommendations. Apply the glue to the fixture or the surface to be tested, or both, using a method recommended by the glue manufacturer. Be certain to apply the glue across the entire surface. Position fixture on the surface to be tested centered directly over the scored section with the fixture outer sides lined up with the inside circumference of the scored section. Carefully remove the excess glue from around the fixture. (**Warning—**Movement, especially twisting, can cause tiny bubbles to coalesce into large holidays that constitute stress discontinuities during testing.)

NOTE 5—Adding about 1 % of #5 glass beads to the glue assists in even alignment of the test fixture to the surface.

7.5 Based on the glue manufacturer's recommendations and the anticipated environmental conditions, allow enough time for the glue to set up and reach the recommended cure. During the glue set and early cure stage, a constant contact pressure should be maintained on the fixture. Mechanical clamping systems work well, but systems relying on tack, such as masking tape, should be used with care to ensure that they do not relax with time and allow air to intrude between the fixture and the test area.

7.6 Note the temperature and relative humidity during the time of test.

8. Test Procedure

8.1 Select an adhesion tester having a force calibration spanning the range of expected values along with its compatible loading fixture. Mid-range measurements are usually the best, but read the manufacturer's operating instructions before proceeding.

8.2 If a bearing ring or comparable device is to be used, place it concentrically around the loading fixture on the coating surface. If shims are required when a bearing ring is employed, place them between the tester base and bearing ring rather than on the coating surface.

8.3 Carefully connect the central grip of the detaching assembly to the loading fixture without bumping, bending, or otherwise prestressing the sample and connect the detaching assembly to its control mechanism, if necessary. For nonhorizontal surfaces, support the detaching assembly so that its weight does not contribute to the force exerted in the test.

8.4 Align the device according to the manufacturer's instructions and set the force indicator to zero.

NOTE 6—Proper alignment is critical. If alignment is required, use the procedure recommended by the manufacturer of the adhesion tester.

8.5 Increase the load to the fixture in as smooth and continuous a manner as possible, at a uniform rate of less than or equal to 0.2 MPa/s (30 psi/s) so that failure occurs or the maximum stress is reached before 30 s.

8.6 Record the force attained at failure.

8.7 When the plug of material is detached, label and store the fixture for qualification of the failed surface in accordance with 9.3.

8.8 Report any departures from the procedure such as possible misalignment, hesitations in the force application, etc.

9. Calculation and Interpretation of Results

9.1 If provided by the manufacturer, use the instrument calibration factors to convert the indicated force for each test into the actual force applied.

9.2 Either use the calibration chart supplied by the manufacturer or compute the relative stress applied to each coating sample as follows:

$$X = \frac{4F}{\pi d^2} \quad (1)$$

where:

X = pull-off strength achieved at failure in MPa (psi).
F = Maximum force applied to the test surface at failure and as determined in 9.1 in N(lb_f), and
d = diameter of the loading fixture in mm (in.).

NOTE 7—d should be the inside diameter of the scored sample if this does not equal the diameter of the loading fixture.

9.3 Estimate the percent of adhesive and cohesive failures in accordance to their respective areas and location within the test system comprised of substrate, coating and glue layers. A convenient scheme that describes the total test system is outlined in 9.3.1 – 9.3.4.

9.3.1 Describe the specimen as substrate *A, B, C,* upon which successive coating layers *D, E, F*, etc., have been applied, including the glue, *Y*, that secures the fixture, *Z*, to the top coat.

9.3.2 Designate cohesive substrate failures by the quantity and type of substrate removed (see Fig. 3).

9.3.3 Designate cohesive coating failures by the layers within which they occur as *D, E, F,* etc., and the percentage of each.

9.3.4 Designate adhesive failures by the interfaces at which they occur as *A/B, B/C, C/D*, etc., and the percent of each.

9.4 A result that is very different from most of the results may be caused by a mistake in recording or calculating, among other things. If either of these is not the cause, then examine the experimental circumstances surrounding this run. If an irregular result can be attributed to an experimental cause, drop this result from the analysis. However, do not discard a result unless there are valid nonstatistical reasons for doing so or unless the result is a statistical outlier. Valid nonstatistical reasons for dropping results include alignment of the apparatus that is not normal to the surface, poor definition of the area stressed due to improper application of the glue, poorly defined glue lines and boundaries, holidays in the glue caused by voids or inclusions, improperly prepared surfaces, and sliding or

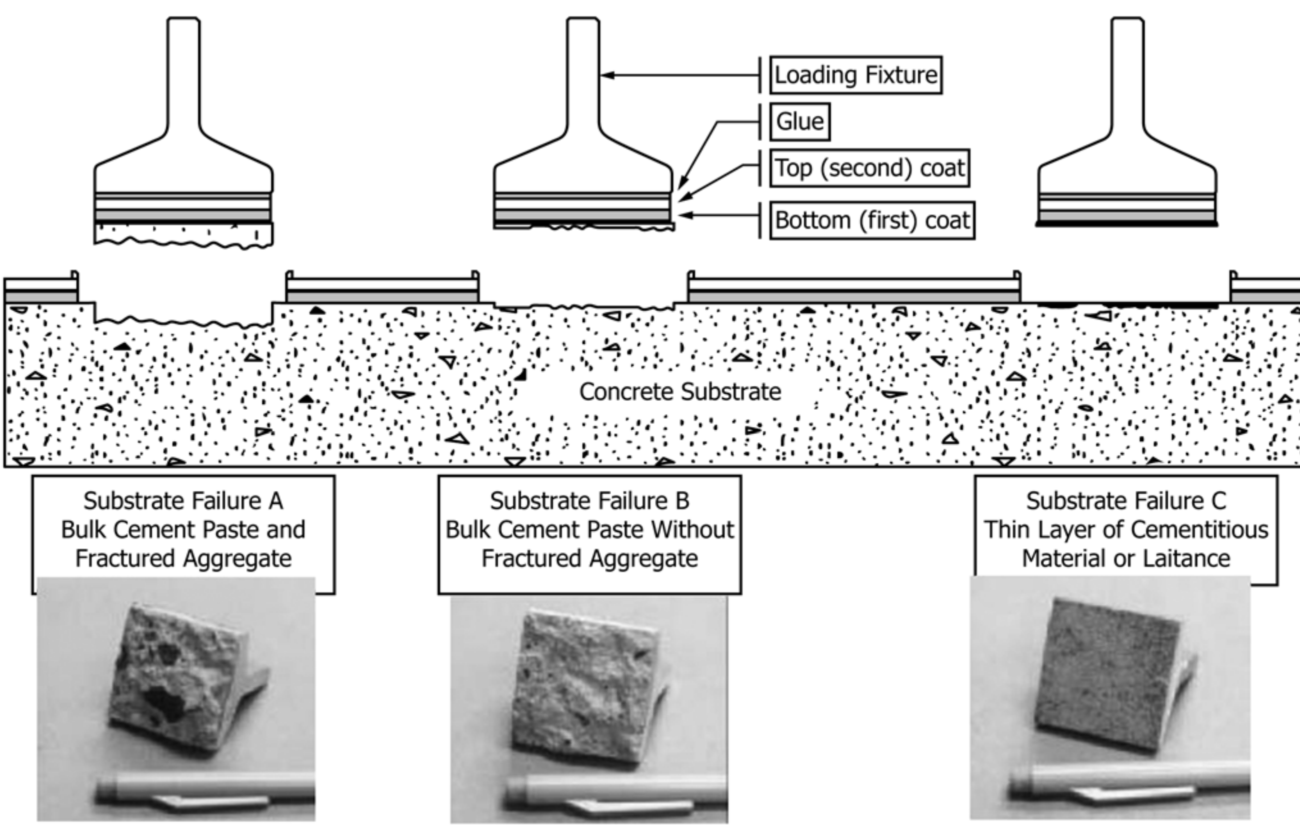

FIG. 3 Substrate Failure Classification

twisting the fixture during the initial cure. Dixon's test, as described in Practice E178, may be used to detect outliers.

9.5 Disregard any test where glue failure (between the glue, *Y*, and the loading fixture, *Z* or the coating surface) represents more than 25 % of the area.

10. Report

10.1 Report the following information:

10.1.1 Brief description of the general nature of the test, such as, field or laboratory testing, generic type of coating, etc.

10.1.2 Temperature and relative humidity and any other pertinent environmental conditions during the test period.

10.1.3 Description of the apparatus used, including: apparatus manufacturer and model number, loading fixture type and dimensions, and bearing ring type and dimensions.

10.1.4 Description of the test system, if possible, by the indexing scheme outlined in 9.3 including: product identity and generic type for each coat including primers and any other information supplied, including cure time and conditions, the substrate identity (thickness, type, orientation, etc.), and the glue used. Substrate surface preparation details including cleaning agents, if known and relevant may also be included.

10.1.5 Test results, including:

10.1.5.1 Date, test location, testing agent, and total number of test results per location.

10.1.5.2 Report all values computed in 9.2 along with the nature and location of the failures as specified in 9.3. Report the average % for each mode of failure, and the average pull-off strength for each predominant mode of failure, rounded to the nearest 0.1 MPa (10 psi). Optionally, report the diameter (and calculated surface area) or the coating thickness, or both, at each test and average coating thickness for all test specimens in the location.

10.1.5.3 If corrections of the results have been made, or if certain values have been omitted such as the lowest or highest values or others, reasons for the adjustments and criteria used.

10.1.5.4 For any test where scoring was not employed, indicate it by placing a footnote superscript beside each data point affected and a footnote to that effect at the bottom of each page on which such data appears. Note any other deviations from the procedure.

11. Precision and Bias

11.1 The precision of this test method is based on an interlaboratory study of Test Method D7234, Standard Test Method for Pull-Off Adhesion Strength of Coatings on Concrete Using Portable Pull-Off Adhesion Testers, conducted in 2011. Six analysts, using seven different instruments, tested samples of two coatings prepared on the same substrate. Every analyst reported three test results for each instrument/coating combination in this study. While the test results are representative of individual determinations, the data was combined for analysis in two ways (instruments 1 to 7 considered separately, and instruments 1 to 5 combined, as 1 to 5 all used 50 mm dollies and were drilled and prepared the same way). Practice E691 was followed for the study design; the details are given in ASTM Research Report No. RR:D01-1163.[5]

11.1.1 *Repeatability Limit (r)*—Two test results obtained within one laboratory shall be judged not equivalent if they differ by more than the "*r*" value for that material; "*r*" is the interval representing the critical difference between two test results for the same substrate and the same coating at the same intended applied coating weight, obtained by the same operator using the same equipment on the same day in the same laboratory.

11.1.1.1 Repeatability limits are listed in Table 1 and Table 2.

11.1.2 *Reproducibility Limit (R)*—Two test results shall be judged not equivalent if they differ by more than the "*R*" value for that material; "*R*" is the interval representing the critical difference between two test results for the same substrate and

[5] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D01-1163. Contact ASTM Customer Service at service@astm.org.

TABLE 1 Pull-Off Strength Measurements for Instruments 1 to 7 Separately, in MPa (psi)

Coating – Instrument	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit (2σ)	Reproducibility Limit (2σ)
	$\bar{X}$	s_r	S_R	r	R
1–1	1.86 (270.1)	0.30 (44.0)	0.43 (62.5)	0.61 (87.9)	0.86 (125.1)
1–2	1.51 (219.7)	0.31 (44.7)	0.32 (46.9)	0.62 (89.3)	0.65 (93.7)
1–3	1.68 (243.7)	0.22 (32.4)	0.46 (67.0)	0.45 (64.7)	0.92 (133.9)
1–4	1.87 (271.4)	0.42 (60.9)	0.42 (60.9)	0.84 (121.7)	0.84 (121.7)
1–5	1.82 (264.4)	0.36 (52.9)	0.43 (63.0)	0.73 (105.9)	0.87 (126.1)
1–6	2.02 (293.3)	0.31 (44.7)	0.35 (50.4)	0.62 (89.4)	0.69 (100.7)
1–7	1.26 (182.5)	0.25 (35.8)	0.32 (46.0)	0.49 (71.6)	0.63 (91.9)
2–1	2.52 (365.3)	0.33 (47.4)	0.42 (61.4)	0.65 (94.9)	0.85 (122.7)
2–2	2.10 (303.9)	0.21 (30.5)	0.26 (37.4)	0.42 (61.0)	0.52 (74.8)
2–3	2.76 (399.8)	0.27 (38.8)	0.43 (61.9)	0.53 (77.5)	0.85 (123.8)
2–4	2.79 (404.4)	0.40 (58.3)	0.40 (58.3)	0.80 (116.6)	0.80 (116.6)
2–5	2.49 (361.4)	0.37 (53.2)	0.39 (57.0)	0.73 (106.4)	0.79 (114.0)
2–6	3.16 (457.8)	0.52 (75.0)	0.52 (75.0)	1.03 (150.0)	1.03 (150.0)
2–7	1.57 (228.3)	0.44 (64.0)	0.60 (87.4)	0.88 (128.1)	1.21 (174.9)

[A] The average of the laboratories' calculate averages.

TABLE 2 Pull-Off Strength Measurements for Instruments 1 to 5 Combined, in MPa (psi)

Material	Average[A]	Repeatability Standard Deviation	Reproducibility Standard Deviation	Repeatability Limit (2σ)	Reproducibility Limit (2σ)
	$\bar{X}$	s_r	S_R	r	R
Coating 1	1.75 (253.9)	0.37 (53.5)	0.42 (60.9)	0.74 (107.0)	0.84 (121.8)
Coating 2	2.53 (367.0)	0.42 (61.3)	0.45 (64.9)	0.85 (122.7)	0.89 (129.8)

[A] The average of the laboratories' calculated averages.

the same coating at the same intended applied coating weight, obtained by different operators using different equipment in different laboratories.

11.1.2.1 Reproducibility limits are listed in Table 1 and Table 2.

11.1.3 The above terms (repeatability limit and reproducibility limit) are used as specified in Practice E177.

11.1.4 Any judgment in accordance with statements 11.1.1 and 11.1.2 would have an approximate 95 % probability of being correct.

11.2 *Bias*—At the time of the study, there was no accepted reference material suitable for determining the bias for this test method, therefore no statement on bias is being made.

11.3 The precision statement was determined through statistical examination of 252 results, from a total of six analysts, using seven instruments, on two coatings.

11.3.1 Coatings used in the study:

11.3.1.1 *Coating 1*—Zero VOC Acrylic Latex Paint (two coats, each applied at 0.25 mm wet film thickness to give a total of 0.2 mm dry film thickness).

11.3.1.2 *Coating 2*—Troweled Flooring System (6 mm thick 100 % solids, amine cured epoxy, silica filled mortar/screed over 0.1 mm WFT/DFT 100 % solids, amine cured epoxy primer.

11.3.2 *Mode of Failure*—In this ILS, all individual results were above 75 % substrate failure (in fact 90 % of the results were 100 % substrate failure) so any variability in the failure mode was ignored in the analysis.

11.3.3 While there are numerous variables for each test result, in this study a number of the items were kept constant for all the tests performed here; all labs used the same location and concrete (note, all testers came to the same location as testing was performed on a single poured concrete slab, not blocks of concrete); same coatings (since this was one continuous slab, the coatings were also continuous); same loading fixture glue (2K fast set, amine cured epoxy); same drill press and core bits (for the five instruments only); and, the same instrument for each of the different instruments noted.

11.3.4 Variability in these results is due to natural variability in the following items and procedures; the concrete (despite being from the same pour, concrete varies in strength every inch), the drilling procedure (despite using the same press and bits), the glue application and loading fixture attachment procedure, and the loading rate of the instrument (which, except for one of the instruments, is regulated by the operator).

12. Keywords

12.1 adhesion; coatings; concrete; field; paint; portable; pull-off adhesion strength; tensile test

APPENDIXES

(Nonmandatory Information)

X1. INTERPRETATION OF RESULTS

X1.1 Mode of Failure

X1.1.1 *General Failure Modes*—The mode of failure is usually categorized as either substrate failure (cohesive failure in the substrate, see Fig. 3), adhesive failure between the coating system and the substrate (see Fig. X1.1), adhesive failure between the layers in the coating system (see Fig. X1.1), cohesive failure in the coating system (see Fig. X1.1), or adhesive failure of the loading fixture glue (see Fig. X1.1). This explanation is necessary as the mode of failure is as important as the resulting value for determining the integrity of coatings on concrete.

X1.1.1.1 *Substrate Failure*—This is the preferred mode of failure for coatings on concrete. The value obtained in this failure mode is primarily dependent on the tensile strength of the concrete at or close to the surface. Low values in this failure mode point to a deficiency in the concrete.

X1.1.1.2 *Adhesive Failure Between the Coating System and the Substrate*—This is not the preferred mode of failure for coatings on concrete, especially when low pull-off strength values are obtained. This mode of failure is usually due to insufficient surface preparation of the concrete, contamination on the concrete surface, or incompatibility between the coating and the concrete. One exception is elastomeric coatings, which occasionally fail in this mode (see X1.3).

X1.1.1.3 *Adhesive Failure Between the Layers in the Coating System*—This is not the preferred mode of failure for coatings on concrete, especially when low pull-off strength values are obtained.

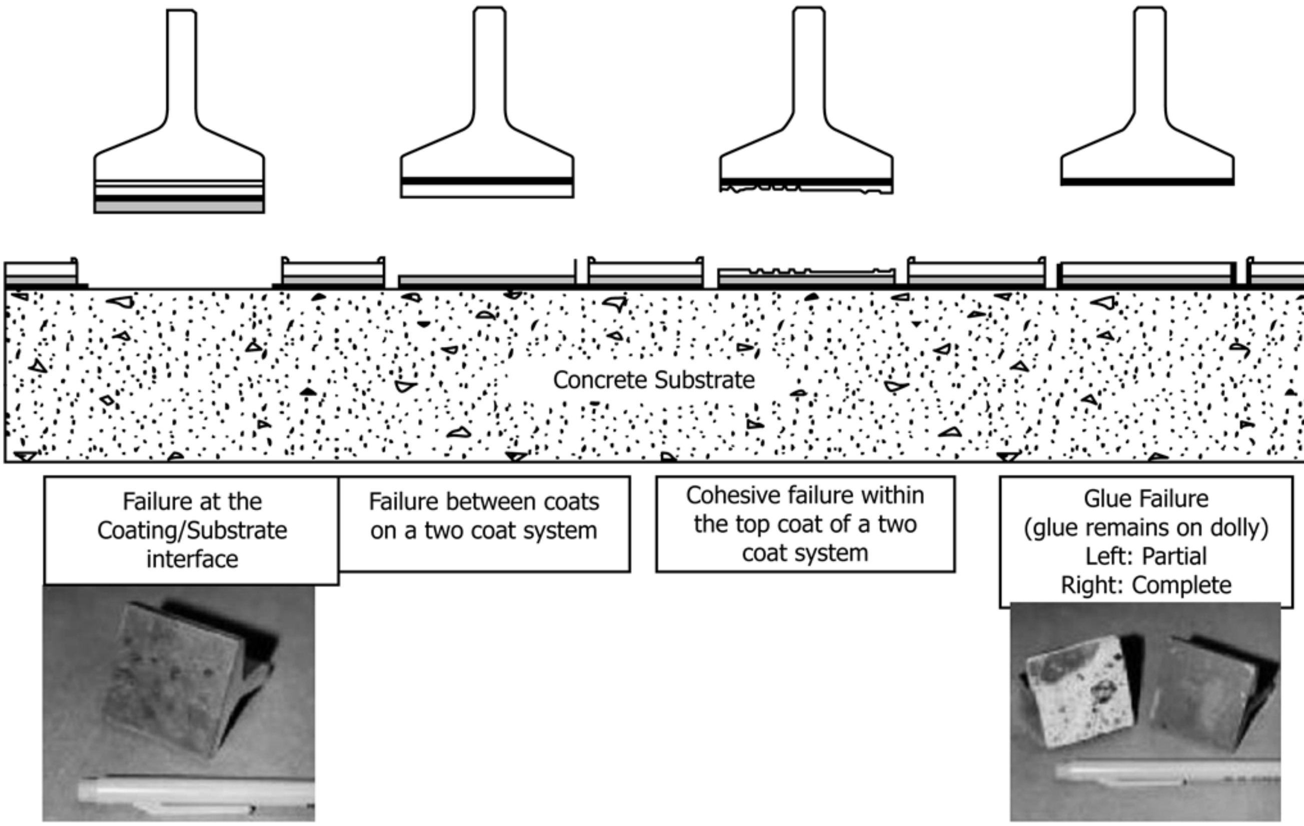

FIG. X1.1 Other Failure Modes

X1.1.1.4 *Cohesive Failure in the Coating System*—This is not the expected mode of failure for high modulus coatings on concrete.

X1.1.1.5 *Adhesive Failure of the Loading Fixture Glue*—As stated in 9.5, when this mode of failure accounts for 25 % or more of the failure surface, the results are disregarded as failure in this mode indicates that the result is not a measure of the adhesion of the system to the substrate. Additional specimens may be needed if the number of tests does not meet the requirements stated in 7.1.1.

X1.2 Effect of Not Scoring

X1.2.1 In cases where the specimen is not scored prior to testing, depending on the properties of the coating and the concrete, the effective test area may not be able to be specifically defined. This may result in test values that are higher than results from scored specimens on the same sample (see Fig. X1.2).

X1.3 Elastomeric Coatings

X1.3.1 *Interpretation of Results*—In cases where elastomeric coatings are applied directly onto concrete or onto a non-elastic primer, the elastomeric coating may show an adhesive failure between the elastomer and the primer or the substrate. If the test value is low in this failure mode then the interpretation in X1.1.1.2 may be valid, however, if the test value is high in this failure mode, this may not indicate a deficiency in the adhesion of this coating. The reason is that when subjected to pull-off load, the elastomer will elongate, and if the elongation or strain is sufficient, then the failure can be induced by a simulated peel-type load starting at the edges of the cut sample. This phenomena is exacerbated by low modulus elastomers, scoring techniques, low loading rates, and loading at angles not exactly perpendicular to the coating.

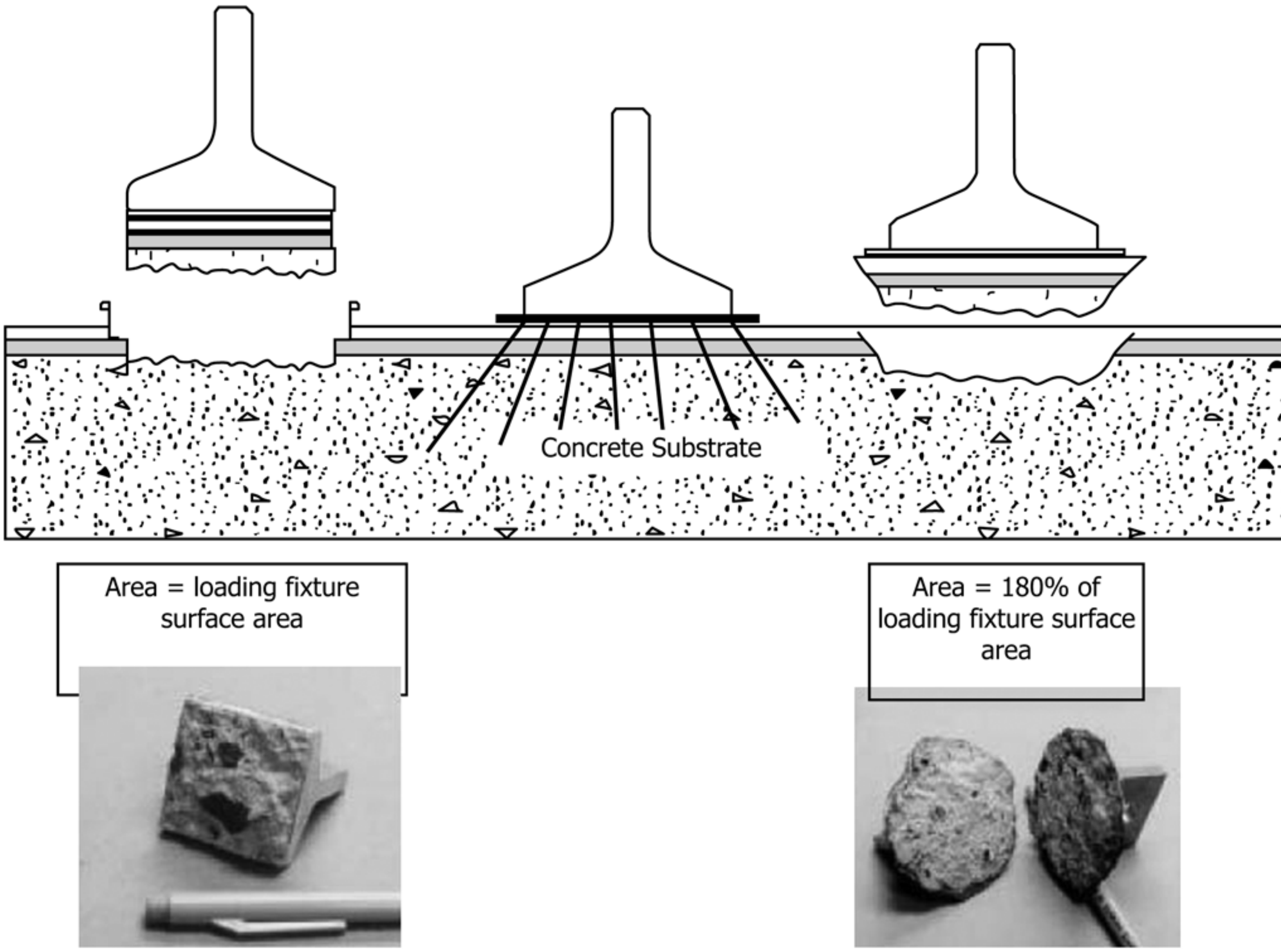

FIG. X1.2 Effect of Not Scoring Around the Loading Fixture Prior to Pulling

X2. CONCRETE SURFACE STRENGTH

X2.1 This method may be adapted to quantify concrete surface strength or qualify the concrete surface properties, or both, prior to the application of a coating system to that concrete. This analysis may be required for various reasons, including ensuring the adequacy of concrete surface preparation prior to coating installation, Currently, there is no test method specifically to perform this task before the coating is installed, with the only other relevant method, Test Method C1583 requiring scoring "at least 10 mm" into the concrete which precludes direct analysis of the concrete surface and introducing other variables. The test method to quantify concrete surface strength would follow the method described in Sections 7 and 8 above, except that scoring would not be necessary and surface preparation of the substrate should duplicate that required for the coating system to be applied. The results and report would follow Sections 9 and 10 above, except that the coating is absent so all failure is in the concrete substrate (with the same qualifications for glue failure).