



Standard Practice for Classifying Failure Modes in Fiber-Reinforced-Plastic (FRP) Joints¹

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1. Scope

1.1 This practice covers the method of classifying, identifying, and characterizing the failure modes in adhesively bonded fiber-reinforced-plastic (FRP) joints. The FRP used in developing this practice consists of glass fibers in a thermoset-polyester-resin matrix, commonly referred to as sheet-molding compound, or SMC.

1.2 One objective of this practice is to present comprehensive definitions of possible failure modes to serve as a guide for contracts, drawings, product specifications, and product performance.

NOTE 1—Figures 2 through 11 referred to in the practice are contained in the ASTM adjunct, Color Photographs of Failure Modes.²

Fig. 2—Side-by Side Comparison of Failure Modes

Fig. 3—Adhesive Failure

Fig. 4—Cohesive Failure

Fig. 5—Thin-Layer Cohesive Failure

Fig. 6—Fiber-Tear Failure

Fig. 7—Light-Fiber-Tear Failure

Fig. 8—Stock-Break Failure

Fig. 9—Mixed Failure—40 % Fiber-Tear Failure, 60 % Light-Fiber-Tear Fiber

Fig. 10—Mixed Failure—32 % Adhesive Failure, 68 % Fiber-Tear Failure

Fig. 11—Mixed Failure—20 % Adhesive Failure, 60 % Light-Fiber-Tear Failure, 20 % Fiber-Tear Failure

NOTE 2—This practice may be used to describe the failure modes generated from testing, using procedures such as Test Methods D 3163, D 3164, D 3165, D 3807, D 5041, D 5868, and SAE J1525.

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

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

2. Referenced Documents

2.1 ASTM Standards:

D 907 Terminology of Adhesives³

D 3163 Test Method for Determining the Strength of Adhesively Bonded Rigid Plastic Lap-Shear Joints in Shear by Tension Loading³

D 3164 Test Method for Determining the Strength of Adhesively Bonded Plastic Lap-Shear Joints in Shear by Tension Loading³

D 3165 Test Method for Strength Properties of Adhesives in Shear by Tension Loading of Single-Lap-Joint Laminated Assemblies³

D 3807 Test Method for Strength Properties of Adhesives in Cleavage/Peel by Tension Loading (Engineering Plastics-to-Engineering-Plastics)³

D 5041 Test Method for Fracture Strength in Cleavage of Adhesives in Bonded Joints³

D 5868 Test Method for Lap Shear Adhesion for Fiber Reinforced Plastic (FRP) Bonding³

2.2 SAE Standard:

SAE J1525 SAE Recommended Practice—Lap Shear Test for Automotive-Type Adhesives for Fiber Reinforced Plastic (FRP) Bonding⁴

2.3 ASTM Adjuncts:

Color Photographs of Failure Modes²

3. Terminology

3.1 Definitions:

3.1.1 Definitions may not appear outside of this practice unless the following delimiting phrase is included: “*relating to testing FRP bonded joints and ASTM Practice D 5573.*”

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *failure-mode classification, n*—relating to testing FRP bonded joints, a classification that includes the seven classes of failure modes identified here: (1) adhesive failure, (2) cohesive failure, (3) thin-layer cohesive failure, (4) fiber-tear failure, (5) light-fiber-tear failure, (6) stock-break failure, and (7) mixed failure (see 3.2.1.2 through 3.2.1.10).

3.2.1.1 *Discussion*—Failure of a tested specimen is seldom confined to a single mode, but rather is a combination of two or more of the first six modes, such combination designated as *mixed failure*. Whenever possible, *mixed failure* should always

¹ This practice is under the jurisdiction of ASTM Committee D-14 on Adhesives and is the direct responsibility of Subcommittee D14.40 on Adhesives for Plastics.

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² Available from ASTM Headquarters, Request ADJ5573.

³ *Annual Book of ASTM Standards*, Vol 15.06.

⁴ Available from Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

be reported citing the class of failure present and the percent of each class.

3.2.1.2 *adhesive failure, ADH (or A), n*—rupture of the adhesively bonded joint, such that the separation appears to be at the adhesive-adherend interface. (Sometimes referred to as *interfacial failure*.) (See Fig. 1, Fig. 2, and Fig. 3.)

3.2.1.3 *Discussion*—After failure, the FRP and adhesive surfaces may have a shiny appearance and there is no evidence that any adhesive or FRP, or both, have transferred to the other surface.

3.2.1.4 *cohesive failure, COH (or C), n*—rupture of an adhesively bonded joint, such that the separation is within the adhesive. (See Fig. 1, Fig. 2, and Fig. 4.)

3.2.1.5 *Discussion*—This term has also been used to describe a failure within the FRP substrate. This usage is being discouraged.

3.2.1.6 *thin-layer cohesive failure, TLC, n*—failure similar to *cohesive failure*, except that the failure is very close to the adhesive-substrate interface, characterized by a "light dusting" of adhesive on one substrate surface and a thick layer of adhesive left on the other. (Sometimes referred to as *interphase failure*.) (See Fig. 1, Fig. 2, and Fig. 5.)

3.2.1.7 *fiber-tear failure, FT, n*—in an adhesively bonded joint, failure occurring exclusively within the FRP matrix, characterized by the appearance of reinforcing fibers on both ruptured surfaces. (See Fig. 1, Fig. 2, and Fig. 6.)

3.2.1.8 *interphase failure, n*—see *thin-layer cohesive failure*.

3.2.1.9 *interfacial failure, n*—See *adhesive failure*.

3.2.1.10 *light-fiber-tear failure, LFT, n*—failure occurring within the FRP substrate, near the surface, characterized by a thin layer of the FRP resin matrix visible on the adhesive, with few or no glass fibers transferred from the substrate to the adhesive. (See Fig. 1, Fig. 2, and Fig. 7.)

3.2.1.11 *stock-break failure, SB, n*—a break of the FRP substrate outside the adhesively bonded-joint region, often occurring near it. (See Fig. 1, Fig. 2, and Fig. 8.)

3.2.1.12 *mixed failure, n*—any combination of two or more of the six classes of failure mode defined in 3.2.1.2, 3.2.1.4, 3.2.1.6, 3.2.1.7, 3.2.1.10, and 3.2.1.11. (See Fig. 1, Fig. 2, Fig. 9, Fig. 10, and Fig. 11.)

3.3 *Abbreviations:*

- 3.3.1 *ADH (or A)*—adhesive failure.
- 3.3.2 *COH (or C)*—cohesive failure.
- 3.3.3 *TLC*—thin-layer cohesive failure.
- 3.3.4 *FRP*—fiber-reinforced plastic.
- 3.3.5 *FT*—fiber-tear failure.
- 3.3.6 *LFT*—light-fiber-tear failure.
- 3.3.7 *SB*—stock-break failure.

4. **Significance and Use**

4.1 This practice provides a simple means of classifying failure modes for adhesively bonded FRP joints.

4.2 Each failure mode classification is based solely on a visual observation of the failure surface without the aid of a microscope or other means to magnify the surface.

4.3 Except for the line-drawing representations given, this practice does not contain descriptions of failure modes possible when using adhesion promoters. However, similar analogies to the failure modes described herein can be made.

4.4 This practice does not address the acceptability of any specific failure mode.

5. **Interferences**

5.1 When classifying the failure modes of FRP adhesively bonded joints, it is essential that the analysis be conducted on specimens tested by only one test method. There is no guarantee that the failure modes of FRP adhesively bonded joints will be the same when tested by different test methods.

6. **Test Specimens**

6.1 Prepare test specimens in accordance with the specified test method to be used in evaluating the adhesively bonded FRP joint. (Refer to 2.1.)

7. **Procedure**

7.1 Condition and test specimens as specified in the selected test method.

7.2 Classify the failure mode for each specimen by using the photographic standards shown in Figs. 2 through 11.

7.2.1 For examples exhibiting more than one failure mode, determine the percentages of each. (See Fig. 7, Fig. 8, and Fig. 9.)

7.2.2 For increased accuracy, use a grid drawn on a clear film placed over failure surface. Count squares of each type of failure mode and calculate percentage.

NOTE 3—For photographs in the adjunct, percentages were calculated using a 5 by 5 square grid, resulting in the accuracy of $\pm 4\%$.

8. **Report**

8.1 Report the following information:

- 8.1.1 Test method used, and
- 8.1.2 *Failure Mode Classification*—This should include percentages when more than one failure mode occurs.

NOTE 4—Include all pertinent data in accordance with the test method used.

9. **Precision and Bias**

9.1 This practice yields essentially qualitative comparison data to classify failure modes of bonded assemblies. Precision,

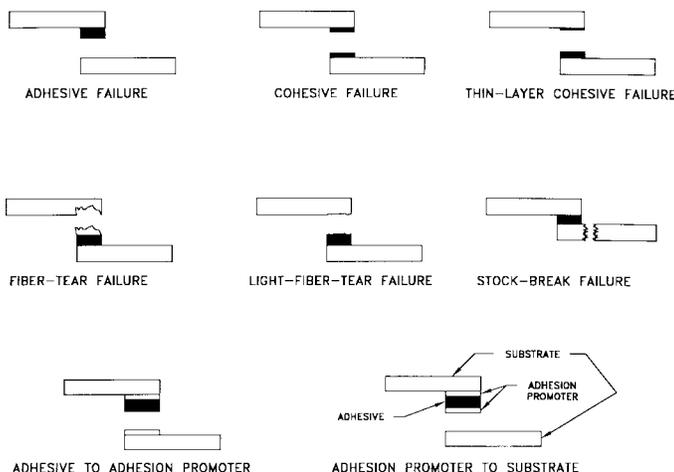


FIG. 1 Sketches Representing Failure Modes

as normally expressed for quantitative measurement test methods is not directly applicable.

10. Keywords

10.1 adhesive bond; failure mode; fiber-reinforced plastic; FRP; practice

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