



# Standard Specification for Structural Paste Adhesive for Sandwich Panel Repair<sup>1</sup>

This standard is issued under the fixed designation E 1555; 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 approval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This specification defines those characteristics that are required of adhesives to be used in the repair of sandwich panels for durable, rigidwall, relocatable structures.

1.1.1 This specification covers two-part epoxy adhesive suitable for bonding aluminum alloy facings to nonmetallic core and core to core in the repair of durable rigidwall relocatable structures. The adhesive shall be suitable for forming bonds that will withstand exposure to temperatures from  $-54$  to  $93^{\circ}\text{C}$  ( $-65$  to  $199^{\circ}\text{F}$ ) and high relative humidity and will also withstand the combinations of stress, temperature, and relative humidity that are expected to be encountered in service. The adhesive shall also be suitable for the bonding of panel inserts and edge attachments.

1.2 The values stated in SI units are to be regarded as the standard where only SI units are given, or where SI units are given first followed by inch-pound units; where inch-pound units are given first followed by SI units, the inch-pound units are to be regarded as the standard.

1.3 The following safety hazards caveat pertains only to the test methods described in this specification. *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:

- B 209 Specification for Aluminum and Aluminum-Alloy Sheet and Plate<sup>2</sup>
- D 1002 Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)<sup>3</sup>
- D 1781 Test Method for Climbing Drum Peel for Adhesives<sup>3</sup>
- D 2919 Test Method for Determining Durability of Adhe-

- sive Joints Stressed in Shear by Tension Loading<sup>3</sup>
- E 4 Practices for Force Verification of Testing Machines<sup>4</sup>
- E 864 Practice for Surface Preparation of Aluminum Alloys to Be Adhesively Bonded in Honeycomb Shelter Panels<sup>5</sup>
- E 1091 Specification for Nonmetallic Honeycomb Core for Use in Shelter Panels<sup>5</sup>

### 2.2 Federal Specifications:<sup>6</sup>

- QQ-A-250/8d Aluminum Alloy 5052 H34 Plate and Sheet
- QQ-A-250/11d Aluminum Alloy 6061 T6 Plate and Sheet
- MIL-STD-401 Sandwich Constructions and Core Materials; General Test Methods

## 3. Material

3.1 The adhesive shall be a two-part thermosetting epoxy paste containing no asbestos and when tested using the test methods described in Section 6, shall meet the requirements of Section 4. The adhesive shall not have a deleterious effect on the components being bonded over the range of temperatures at which the adhesive will be used.

## 4. Physical Requirements

### 4.1 Working Characteristics:

4.1.1 *Application*—The adhesive shall be suitable for application to facings and core materials. The adhesive shall not drip and shall not develop an overall average sag of 6.3 mm (0.25 in.) or more when tested in accordance with the procedures described in 6.7.

4.1.2 *Adhesive Life*—The adhesive, when mixed in 1-qt kit quantities in a standard quart paint can, allowed to sit for 30 min at  $23 \pm 3^{\circ}\text{C}$  ( $73.4 \pm 5.4^{\circ}\text{F}$ ), and then used to prepare test specimens as prescribed in 6.1-6.3, shall still be able to deliver the lap shear property levels listed in Table 1 for the  $23^{\circ}\text{C}$  temperature test condition.

4.1.3 The adhesive, when mixed in a quart kit and allowed to stand in ambient still air, shall not, as a result of an exothermic reaction, heat itself to a temperature of  $49^{\circ}\text{C}$  ( $120^{\circ}\text{F}$ ) or above. This shall be performed in a chemical fume hood so that heat and any potentially toxic fumes that may be released as a result of exothermic reaction are controlled. A

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 02.02.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 15.06.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 03.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 04.11.

<sup>6</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094, Attn: NPODS.

**TABLE 1 Tensile Lap Shear (Test Method D 1002)**

Test Condition <sup>A</sup>		Number of Specimens to be Tested	Average Must Exceed		Minimum Must Exceed <sup>B</sup>	
°C	(°F)		MPa	(psi)	MPa	(psi)
-54 ± 3	(-65 ± 5)	6	13.8	(2000)	11.7	(1700)
23 ± 3	(73 ± 5)	6	17.9	(2600)	15.2	(2200)
60 ± 3	(140 ± 5)	6	16.5	(2400)	14.1	(2050)
93 ± 3	(199 ± 5)	6	10.3	(1500)	8.6	(1250)
60 ± 3	(140 ± 5)	6	8.3	(1200)	7.0	(1020)

<sup>A</sup> After 30 day exposure to 60 ± 3°C (140 ± 5°F) and 95 to 100 % relative humidity.

<sup>B</sup> All specimens tested must exceed these minimum values.

preliminary test, using a pint kit, shall be conducted to determine if a potential problem exists.

4.1.4 *Curing*—The adhesive shall be capable of curing at 23 ± 3°C (73.4 ± 5.4°F) in 7 days, or for no longer than 3 h at a temperature of 60 to 66°C (140 to 150.8°F), with a curing pressure not to exceed 14 psig. In a 23 ± 3°C (73.4 ± 5.4°F) cure, the curing pressure shall also be a maximum of 14 psig and shall only be required during the first 24 h of cure. In a 23 ± 3°C (73.4 ± 5.4°F) cure, the adhesive shall be capable of developing 3.45 MPa (500 psi) lap shear strength, when tested at 23°C temperature, within the first 24 h of cure.

4.1.5 *Mix Ratio*—The mix ratio for the two parts of the adhesive shall be defined by the manufacturer but shall be in the range from 10:1 to 1:1 by weight.

4.2 *Storage Life*—The storage life of the two parts of the adhesive, from date of shipment, when stored in airtight containers at 23 ± 3°C (73.4 ± 5.4°F), shall be at least 12 months. The adhesive shall be considered to have met this storage life requirement if all the characteristics described in 4.1 and 4.3 are met by the adhesive after the 12-month storage period described above.

4.3 *Mechanical Properties*—The mechanical properties of the adhesive, when cured for 3 h at 63 ± 3°C (145.4 ± 5.4°F) or 7 days at 23 ± 3°C (73.4 ± 5.4°F) at a cure pressure not to exceed 14 psig, shall meet the requirements of Tables 1-4.

## 5. Significance and Use

5.1 Adhesives used in the repair of sandwich panels for durable, rigidwall, relocatable structures must have a combination of mechanical property levels and environmental resistance that will ensure long-term durability of the adhesive bonds when exposed to severe climatic exposures. In addition, these adhesives must have processability characteristics that permit their use in a variety of repair scenarios and environments.

5.2 This specification defines those characteristics that are required of adhesives to be used in the repair of sandwich panels for durable, rigidwall, relocatable structures.

**TABLE 2 Flatwise Tension (Specification E 1091)**

Test Condition		Number of Specimens to be Tested	Average Must Exceed		Minimum Must Exceed <sup>A</sup>	
°C	(°F)		MPa	(psi)	MPa	(psi)
-54 ± 3	(-65 ± 5)	6	2.11	(306)	1.79	(260)
23 ± 3	(73 ± 5)	6	2.11	(306)	1.79	(260)
60 ± 3	(140 ± 5)	6	1.56	(226)	1.33	(192)

<sup>A</sup> All specimens tested must exceed these minimum values.

**TABLE 3 Climbing Drum Peel (Method D 1781)**

Test Condition		Number of Specimens to be Tested	Average Must Exceed		Minimum Must Exceed <sup>A</sup>	
°C	(°F)		N-m/m	(in.-lb/in.)	N-m/m	(in.-lb/in.)
-54 ± 3	(-65 ± 5)	6	18	(4.04)	15.3	(3.4)
23 ± 3	(73 ± 5)	6	36	(8.08)	30.6	(6.8)
60 ± 3	(140 ± 5)	6	24	(6.06)	22.7	(5.1)

<sup>A</sup> All specimens tested must exceed these minimum values.

**TABLE 4 Durability Test (Test Method D 2919)**

Test Condition	Number of Specimens to be Tested	Applied Stress		Average Time to Failure to Exceed
		MPa	(psi)	
60 ± 3°C (140 ± 5°F) and 95 to 100 % R.H.	6	8.3	(1200)	400 h
	6	11.0	(1600)	50 h

## 6. Test Methods

6.1 *Preparation of Test Specimens*—The adherends shall be either 6061 T6 or 5052 H34 aluminum alloy (Federal Specification QQ-A-250/11d or QQ-A 250/8d, respectively or Specification B 209) and shall be cleaned as prescribed in Practice E 864.

6.2 *Apparatus*—The testing machine shall conform to the requirements of Practices E 4. The load range shall be selected so that the maximum loads for each type of test conducted falls between 15 and 85 % of the full-scale capacity. Autographic equipment, or equipment that will produce equivalent accuracy, shall be used to record loads.

6.3 *Lap-Shear Strength*—The lap shear tests shall be performed in accordance with Test Method D 1002 and at the test conditions listed in Table 1. In all tests the test chamber shall be stabilized at the test temperature for 45 min prior to the test and before the specimens are placed in it.

6.3.1 *Reduced and Elevated Temperature Tests*—For the test to be conducted on specimens that have not been humidity-aged, bring the specimens to the test temperature, as indicated by a thermocouple at the bond area, and stabilize for 10 min just prior to test.

6.3.2 *Elevated Temperature Test after Humidity Aging*—The specimen shall be maintained in the humid environment until immediately before insertion into the test chamber. The specimen shall be inserted into the test chamber and the chamber temperature returned to the test temperature as rapidly as possible to minimize specimen dryout. Based on the thermocouple located at the bond area, commence the test 2 min after the thermocouple returns to the test temperature.

6.4 *Flatwise Tensile Strength*—Sandwich specimens shall be prepared using nonmetallic honeycomb core meeting the requirements of Specification E 1091, Type IV. The specimens shall have an area of 58 cm<sup>2</sup> (9 in.<sup>2</sup>) and be tested in accordance with the requirements in MIL-STD-401. The facing skins shall be a minimum of 0.51 mm (0.020 in.) thick. The adhesive layer between the facing skins and the honeycomb core shall be uniformly applied at a rate of 0.0488 gm/cm<sup>2</sup> (0.1 lb/ft<sup>2</sup>).

6.4.1 *Reduced and Elevated Temperature Tests*—Stabilize the chamber used to test the specimens at the test temperature for 45 min prior to the test and before the specimens are placed in it. Bring the specimens to the required test temperature, as

indicated by a thermocouple at the bond area, and stabilize for 10 min just prior to test.

**6.5 Climbing Drum Peel Strength**—Sandwich specimens shall be prepared using nonmetallic honeycomb core meeting the requirements of Specification E 1091, Type IV. The specimens shall be of the dimensions specified and tested in accordance with the requirements in Method D 1781. The peeling face skin shall be 6061 T6 or 5052 H34 aluminum alloy, 0.51 mm (0.020 in.) thick. The adhesive is to be uniformly applied on each skin of the sandwich construction at a rate of 0.0488 gm/cm<sup>2</sup> (0.1 lb/ft<sup>2</sup>).

**6.5.1 Reduced and Elevated Temperature Tests**—Repeat 6.4.1.

**6.6 Dead Load Stress Durability**—Test the specimens in accordance with Test Method D 2919. Maintain the conditions of the test chamber at 60 ± 3°C (140 ± 5.4°F) and 95 to 100 % relative humidity.

**6.7 Sag**—Sag shall be defined as the average length of the adhesive flow line maxima down a vertical plate when tested at 23 ± 3°C (73.9 ± 5.4°F) in the manner described below.

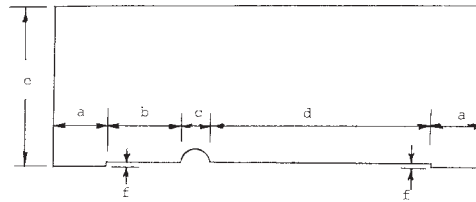
**6.7.1 Materials Required**—The following materials are required to carry out the sag test:

**6.7.1.1 Aluminum test panel** conforming to dimensions shown in Fig. 1a, solvent cleaned, and having lightly scribed lines located as shown in Fig. 1a,

**6.7.1.2 Aluminum screeding templates**, conforming to dimensions shown in Fig. 2, and

**6.7.1.3 Notched rack** to hold test panels in vertical position.

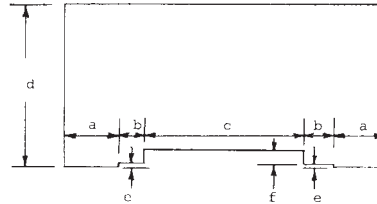
**6.7.2 Application of Adhesive to Test Panel**—Using a suitable applicator, apply 3 g of freshly mixed adhesive to the



Dimensions:

- |                                 |  |
|---------------------------------|--|
| a = 2.54 cm (1 in.) (suggested) | d = 10.16 cm (4 in.)                                     |
| b = 3.81 cm (1.5 in.)           | e = 7.62 cm (3 in.) (suggested)                          |
| c = 0.87 cm (11/32 in.) dia.    | f = 0.05 cm (0.02 in.) less than thickness of test panel |

(a) Horizontal Screeding Template, 0.062 in. Thick



Dimensions:

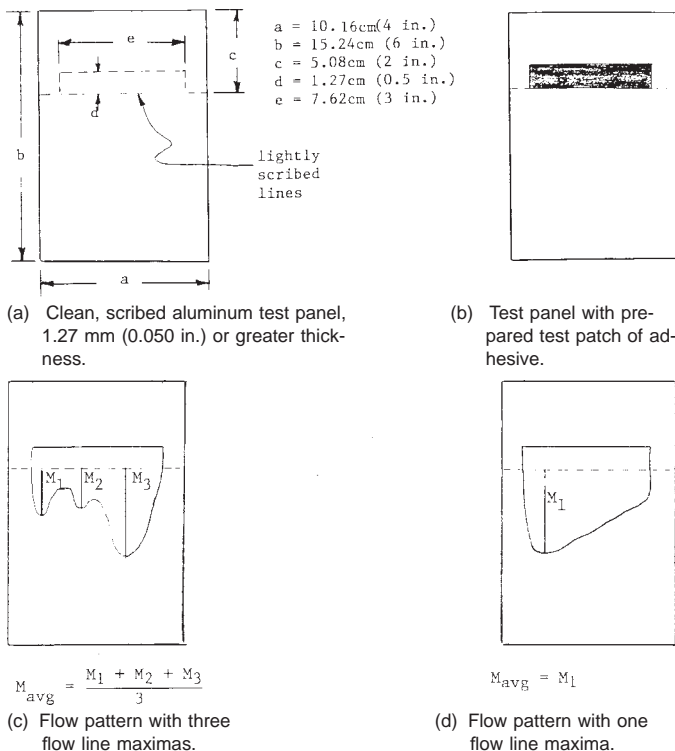
- |                                     |  |
|-------------------------------------|--|
| a = 2.54 cm (1 in.) (suggested)     | d = 7.62 cm (3 in.) (suggested)                          |
| b = 1.27 cm (0.5 in.)               | e = 0.05 cm (0.02 in.) less than thickness of test panel |
| c = 7.62 ± 0.13 cm (3.0 ± 0.05 in.) | f = 0.435 cm (11/64 in.)                                 |

(b) Vertical Screeding Template, 0.062 in., Thick

**FIG. 2 Screeding Templates for Preparation of Test Patch on Sag Specimen**

rectangular area of the aluminum test panel outlined by the light scribe lines. Spread this uniformly over the rectangular area, ensuring that the adhesive extends to or slightly beyond the edges of the rectangle. Avoid incorporating voids into this adhesive test patch. Draw the vertical screeding template, illustrated in Fig. 2b, across the length of the test panel one time in a bottom to top direction. The purpose of this is to leave an adhesive test patch with uniform thickness and well-defined side edges. If adhesive smears are left on the test panel after this step, these shall be ignored as long as the side edges of the test patch are well-defined. When required to generate well-defined edges, this step shall be repeated a second time. Next draw the horizontal screeding template, illustrated in Fig. 2a, across the width of the test panel one time. The purpose of this is to establish well-defined upper and lower edges with as little, and preferably no, adhesive left on the test panel below the scribe line. Perform this one time, ignoring any adhesive that has been pulled off the exit side of the adhesive test patch. Do not use solvent to clean adhesive smears off of the test panel, since this will influence sag.

**6.7.3 Test**—Place the test panel in a notched rack capable of holding the test panel in a vertical position (to within 2° of true vertical). The notched rack shall not interfere with flow of the adhesive down the test panel. A satisfactory rack has been made from metal channel. Maintain the test panel in the vertical position at 23 ± 3°C (73.4 ± 5.4°F) until the adhesive hardens and no longer flows. Measure and record the length of each flow line maxima of the adhesive from the full-width scribe line to the point at which the flow stops below the line. Calculate the average length of these flow line maxima, as



**FIG. 1 Illustration of Sag Test Specimen**

illustrated in Fig. 1c. If there is only one maxima, as illustrated in Fig. 1d, it is considered the average. Repeat the test twice to obtain a total of three  $M_{avg}$  values and calculate SAG as shown in 6.7.4. In order for a test to be considered valid, the sag test panels must be fully prepared and placed in the vertical holding rack not later than 15 min after mixing of the two adhesive components has been completed.

6.7.4 *Pass/Fail Criterion*—SAG shall be computed in accordance with the following equation and meet the requirement stated in 4.1.1:

$$SAG = \frac{M_{avg,1} + M_{avg,2} + M_{avg,3}}{3} \quad (1)$$

## 7. Inspection

7.1 *Responsibility for Inspection*—Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier is permitted to use any facility suitable for the performance of inspection requirements specified herein unless disapproved by the purchaser. The purchaser has the right to perform any of the inspections set forth in the specification where such inspections are required to ensure compliance with the requirements.

7.2 *Classification of Inspection*—The inspection requirements specified herein are classified as follows:

### 7.2.1 *Qualification Inspection:*

7.2.1.1 *Qualification Test*—Unless otherwise specified by the purchaser (see 7.1), adhesives that have not passed the qualification tests, or that have previously passed the tests but have subsequently been modified in any manner, must be tested against this specification and shown to meet its requirements.

7.2.1.2 *Instruction Sheet and MSDS*—A Material Safety Data Sheet (MSDS) and a dated, coded, and titled instruction sheet that outlines instructions for use of the adhesive in bonding metal facings to paper or foam cores; and metal components shall be supplied by the manufacturer. These documents shall be forwarded with the test report (7.2.1.3) when requesting qualification. In addition, a copy of the instruction sheet shall accompany each shipment of the adhesive. At the option of the purchaser, qualification tests are to be repeated at any time on material previously found satisfactory.

7.2.1.3 *Test Report*—In addition to the adhesive sample submitted for qualification, the manufacturer shall furnish a dated, traceable report giving previously determined results of all tests listed in Section 6. The individual and average values for the tests shall be reported. The test report shall cover all the

requirements of Section 4. The type of core, surface preparation (including cleaning and primer, if required), assembly condition, pressure, temperature, and time of curing used in the preparation of the test panels shall be reported. The report shall certify that the preparation of the adhesive and test specimens conformed to the description given in the instruction sheet. The manufacturer shall supply equivalent data for Table 1 after cures of 24 h and 7 days at room temperature.

### 7.2.2 *Quality Conformance Inspection:*

7.2.2.1 *Tests*—Samples of each lot of adhesive delivered on contract or order shall be subjected to the following quality conformance tests. Test reports, in duplicate, shall be furnished for all quality conformance tests specified in this specification, and shall be signed by an authorized representative of the laboratory making the tests. Acceptance or approval of material during the course of manufacture shall not be construed as a guarantee of the acceptance of the finished products.

7.2.2.2 *Shear Strength (Acceptance)*—Shear strength of specimens that have not been humidity aged shall be measured at  $23 \pm 3^\circ\text{C}$  ( $73 \pm 5^\circ\text{F}$ ),  $60 \pm 3^\circ\text{C}$  ( $140 \pm 5^\circ\text{F}$ ), and  $93 \pm 3^\circ\text{F}$  ( $199 \pm 5^\circ\text{F}$ ) using either 5052 H34 or 6061 T6 aluminum alloy. The number of specimens, test procedure, cure of adhesive, and surface preparation shall be in accordance with Table 1, 4.1, and Section 6.

## 8. Packaging and Package Marking

8.1 Packaging shall be in accordance with the supplier's and applicable regulations. The product shall be clearly and legibly labeled with the following information:

- 8.1.1 Specification number,
- 8.1.2 Date of manufacture (month and year),
- 8.1.3 Manufacturer's name and address,
- 8.1.4 Manufacturer's product trade name,
- 8.1.5 Manufacturer's product type designation,
- 8.1.6 Manufacturer's batch/lot designation,
- 8.1.7 Contract number,
- 8.1.8 Date of shipment,
- 8.1.9 Expiration date,
- 8.1.10 Manufacturer's recommended storage temperature range,
- 8.1.11 Quantity contained, and
- 8.1.12 Manufacturer's certification that the batch and lot meet the requirements of this specification.

## 9. Keywords

9.1 adhesive; epoxy; paste; properties; repair; sandwich; structure.

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