An Evaluation of Stiffener Attachment Methods

Abstract:

This paper summarizes an independent 3rd party analysis of stiffener attachment with welds, liquid adhesives, and acrylic foam tapes in industry-accepted ASTM test methods for evaluating the performance of architectural panels. Six metal panels were assembled and underwent several sequences of architectural tests to demonstrate differences in performance between each attachment method mentioned. Each attachment passed the industry-accepted tests with some differences observed in rigidity and panel deflection. With this information, fabricators can look to optimize panel performance, assembly processes and panel aesthetics.

Introduction:

3M™ VHB™ Tapes have been used worldwide in a variety of demanding applications since 1980. One common application across many industries is the attachment of stiffeners to panels. Stiffeners are applied to panels to provide extra support, reducing panel deflection as well as allowing for the use of lighter gauge metal panels while maintaining rigidity. These attachments are commonly seen in applications such as metal enclosures, HVAC units, architectural metal panels, commercial doors, metal office furniture and more.

Stiffeners come in many different form factors and materials that provide different levels of rigidity, process complexity, and determine final-product cost. There are multiple methods used to attach stiffeners to panels for the end-use application. The attachment method can be chosen for its ease of use, final aesthetic, stress-resistance capability, process flexibility, end-use environment, and more. Some of the most common methods include:

Attachment Method	Key Characteristics	Product(s) Tested
Stitch Welding	• "Gold Standard" for attachment strength, but requires experienced, skilled labor • Intense heat disfigures substrates and may require re-work	N/A
Rigid Structural Adhesive	• 1000+ psi overlap shear strength • Liquid-applied adhesives require clamping/fixturing until cured	3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS
Flexible Adhesive Sealant	• Allow greater movement between parts compared to rigid attachment • Liquid-applied adhesives require clamping/fixturing until cured	DOWSIL™ 795 Building Sealant
Acrylic Foam Tape	• Best ease of use • Provide immediate handling strength • Limited gap-filling capability	3M™ VHB™ Tape 4956 (G16F) 3M™ VHB™ Tape GPH-160GF 3M™ VHB™ Tape RP+160GF 3M™ VHB™ Tape 4991B (B90F)

Table 1: Stiffener Attachment Methods

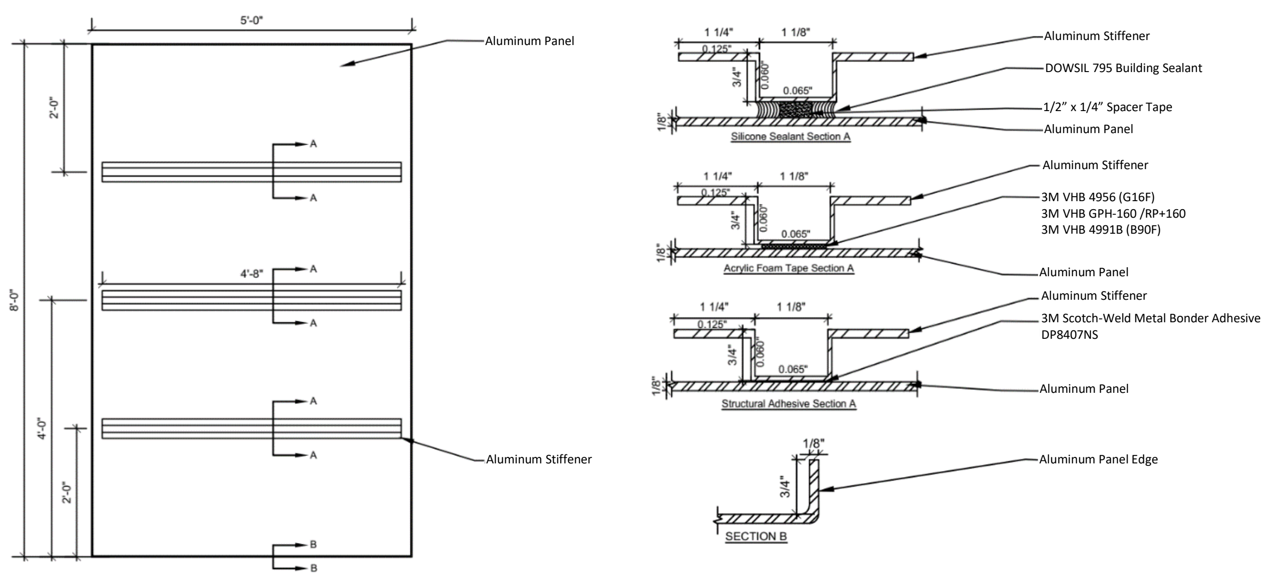
The ASTM test methods used in this study are trusted to determine suitability for high-risk attachment of stiffeners and panels to building exteriors and are relevant to other markets as they test structural integrity across varying stress loading, pressure cycling, and environmental conditions.

Center panel deflection was measured during wind load structural testing to determine the ability of each stiffener attachment method to meet the L/60 criterion for aluminum wall panels according to the International Building Code (IBC) Section 1604 Deflection Limits. “L” is the longest panel dimension.

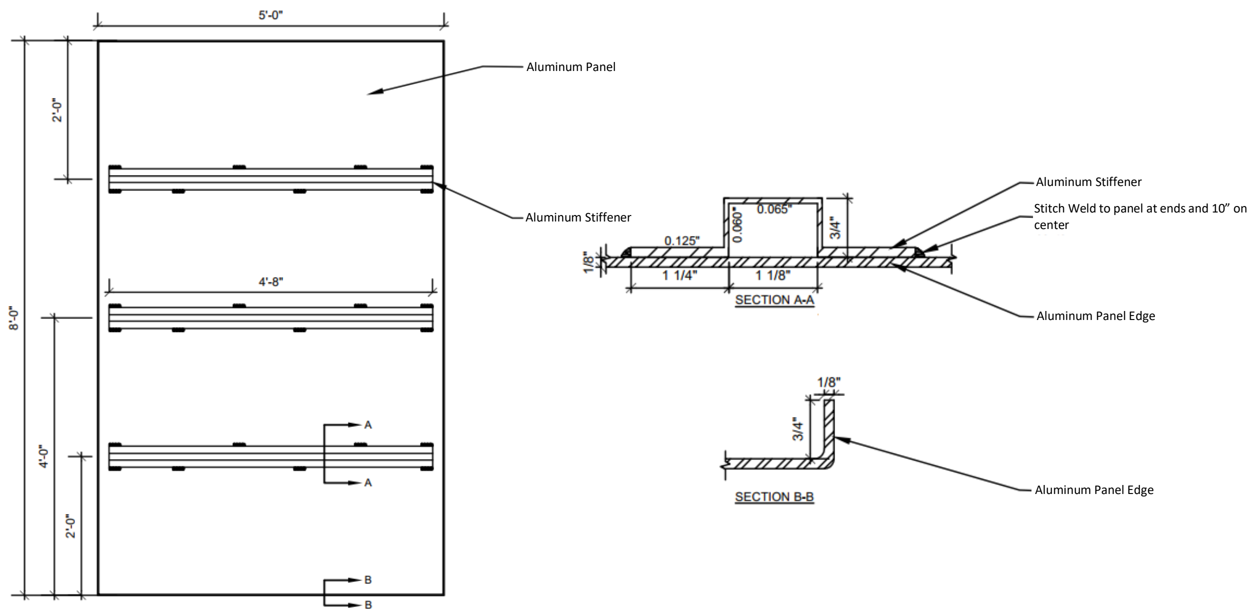
Assembly:

Six different panel assemblies were fabricated to evaluate the different stiffener attachment methods as described in the Introduction section. 1/8” (3.2 mm) thick panels were constructed of 3003 aluminum alloy with attached 3003 aluminum alloy hat channel stiffeners, both mill finish. Each panel had 3/4” (19 mm) return legs folded 90° towards the back of the panel on all four sides. Panel dimensions were 60” (1524 mm) wide x 96” (2438 mm) tall. Three 56” (1422 mm) long stiffeners spanning the 60” (1524 mm) panel length at 2’ (610 mm) on center spacing were secured with the six different attachment methods on each panel. Each panel had only one attachment method for all three stiffeners.

All stiffeners were attached with the top of the hat adhered to the back side of the panel except for the stitch-welded stiffeners which had the two flanges down against the back side of the panel. Additional panel and stiffener dimensions and attachment methods are shown in the drawings below.



Figures 1 – 5: Bonded Panel Dimensions and Stiffener Attachment Methods



Figures 6-8: Welded Panel Dimensions and Stiffener Attachment Method

Test Methods:

Each panel construction was subjected to four different ASTM test methods, in the order summarized below. Full test method descriptions can be found in the appendix.

ASTM E2264-05(2013)
Panels are set in an environmental chamber and exposed to temperature cycling. Extreme hot and cold temperatures induce expansion and contraction in materials that could lead to attachment failure.

ASTM E330/E330M-14
Panels were tested with incrementally increasing positive and negative loads equal to a sustained wind speed of 220 mph (355 km/h). These sustained wind loads test the strength and rigidity of each attachment method.

ASTM E1886-13a,
Lumber projectiles were launched at two panel locations and were analyzed for any damage or separation.

ASTM E1996-14a
Panels were then subjected to positive and negative pressure cycling to simulate a hurricane event and assessed for further damage to the attachments.

Results:

Welding:
The stitch-welded stiffeners passed the L/60 deflection criterion for stiffening performance up to ±40 psf (±1.9 kPa) and was just slightly over at +80 psf (+3.8 kPa). This was the only panel to show no signs of attachment failure through the entire testing process. These results point to the continued trust in weld performance seen in industry. However, there are a few pitfalls when it comes to the use of welding. Welding (especially stitch-welding) requires trained, skilled labor to implement, with most employers preferring certified technicians. These skilled laborers come at greater cost and can be in short supply.

Welding also limits the potential materials that can be used for joining. Aluminum and steel welding require different equipment, and dissimilar metals cannot be welded due to galvanic corrosion.

One other pitfall with welding is the final aesthetics of the attachment. Metal welding requires intense localized heat to melt the parts together and cause the fusion needed to give the levels of expected strength. These extreme temperature levels affect the surrounding areas, causing the thermal distortion seen in the panels below:

Figure 9: Welded Panel - Faceside

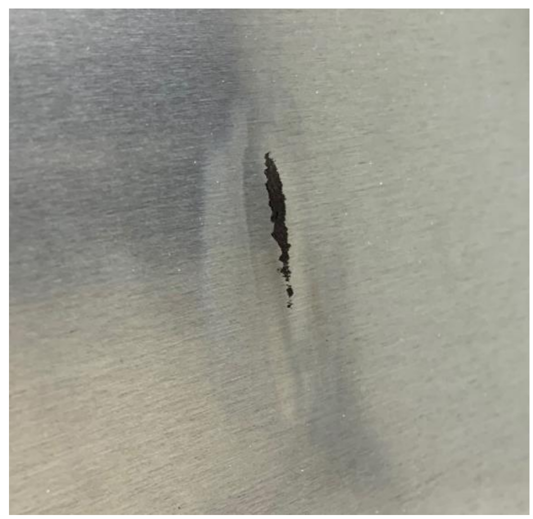


Figure 10: Visible Weld Mark

When end-use aesthetics are vital, refinishing is the only remedy. Refinishing can be a tedious process of grinding down the welded areas with increasingly finer abrasives to flatten the area and smooth out the appearance. Panels requiring coatings can also need further re-work with fillers to create a pristine finish. These fillers typically have limited durability compared to the original material and require further labor. Aesthetics as seen in the pictures above and the process steps to remove weld marks are what limit welding use in many metal panel applications.

Structural Adhesive:

Structural adhesives are the strongest adhesive option on the market and come closest to competing with the strength of welds. 3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS showed good performance in the series of ASTM tests. The stiffeners bonded with the rigid, liquid-applied adhesive passed each of the structural wind loads tests and the L/60 deflection criterion at both ±40 (±1.9 kPa) and ±80 psf (±3.8 kPa) loads. This was also the only attachment solution to pass the more strenuous L/120 criterion in any of the tests, passing at ±40 psf load. However, in impact testing, the center stiffener attached with the structural adhesive de-bonded from the panel. This perhaps illustrates some of the strengths and weaknesses of rigid liquid adhesive attachment. A rigid attachment provides great levels of strength and minimizes deflection but has little flexibility. Therefore, the adhesive cannot absorb much load and transfers the load to the second substrate.

Most structural adhesives are two-part chemistries that require mixing prior to application. Once mixed, the adhesives have a set work life – the time between dispensing and needing to fixture the second part. Once fixtured, the adhesives gain strength relatively quickly, typically reaching handling strength (>50 psi (0.345 MPa)) in under an hour with longer time to reach full cure. However, these time constraints and fixturing requirements can create logistical issues as parts must be staged and sit idle before they reach handling strength and full cure. Some liquid-applied adhesives also have a strong odor associated with them depending on adhesive chemistry.

Once cured, structural adhesives have overlap shear strengths greater than 1000 psi (6.9 MPa) and are quite environmentally stable. This attachment method relies on chemical and physical interactions with the substrate surfaces, which means there is less damage to the substrate when compared with mechanical attachments like rivets, screws, or welding. As the substrates are not inherently damaged while being attached, these panels also have a good, relatively smooth aesthetic. However, during the curing process the adhesive can shrink, which may "telegraph" through thinner panels and be visible to the end user.

Silicone Sealant

Structural silicone sealants like Dowsil 795 Building Sealant have been trusted in the commercial construction industry for decades. These silicone sealants come in one or two-part chemistries and are highly resistant to weathering when cured. In the stiffener-to-panel testing, the panel constructed with the Dowsil sealant passed all tests and the L/60 deflection criterion up to ±40 psf (±1.9 kPa). After the impact testing and pressure cycling, the sealant only showed small signs of cohesive failure at the stiffener end.

These types of sealants are different from rigid structural in a variety of ways. A few of these major differences are surface preparation, bond thickness, cure time, flexibility, and strength. Acrylic structural adhesives (e.g., Scotch-Weld DP8407NS) are known for their ability to bond to bare metals with minimal surface preparation – even if the metal is oily. In contrast, the Dowsil sealant required an adhesion promoter for bonding to the mill finish aluminum.

The bond thickness for each liquid applied adhesive needed to be designed differently as well. Rigid structural adhesives are designed for thinner bonds, with shear strength maximized at ~0.010" (0.25 mm) and with no need for an additional spacer (e.g., spacer tape) to maintain the glue line thickness. At greater bond thickness, a rigid structural adhesive's shear strength will diminish, but peel strength will increase. Typically, these bonds are thinner than 1/8" (3.18 mm). When using liquid-applied sealants, standard bond thickness in the construction industry is considerably greater at 1/4" (6.4 mm) or more. To obtain a constant thickness across the sealant bond, 1/4" (6.4 mm) thick spacer tape was applied prior to application. As the sealant is a 1-part chemistry that requires moisture to cure, its cure time is also far longer – requiring 7-14 days at 77°F (25°C) and 50% RH to cure and 14-21 days before reaching full adhesion. In contrast, the two-part acrylic structural adhesive reaches handling strength in 22-26 minutes, structural strength at 28-32 minutes, and full cure at 1 day.

In use, sealants are designed to be more flexible than the rigid structural adhesive tested. This flexibility gives the sealant the ability to move with substrate thermal expansion and contraction or other outside forces, which helps to protect the bond area from failure. With this flexibility also comes an understandable drop in overlap shear strength when compared to rigid structural adhesives. Published data sheet values of the Dowsil sealant show a tension adhesion strength of 45 psi (0.310 MPa) at 25% extension and 60 psi (0.414 MPa) at 50% extension, whereas the DP8407NS publishes a tensile strength of 2400 psi (16.5 MPa).

Acrylic Foam Tape

Acrylic foam tapes like 3M™ VHB™ Tapes are fully cured, pressure-sensitive adhesives, and have been used for stiffener bonding since the early 1980s. Three different VHB tapes were tested:

1. 3M™ VHB™ Tape 4956 or G16F (0.062" (1.6 mm) thickness) – Trusted bonding solution used for architectural panel bonding for many years
2. 3M™ VHB™ Tape GPH-160GF/RP+160GF (0.062" (1.6 mm) thickness) – Greatest temperature resistance (450°F (230°C)) in VHB portfolio and can withstand powder coating and liquid paint bake cycle processes
3. 3M™ VHB™ Tape 4991B or B90F (0.090" (2.3 mm) thickness) – Thicker tape used on larger rigid panels like plate aluminum or stainless steel

Each of the three tape solutions passed the entire testing cycle along with the other bonding solutions. The tapes also performed well when compared to the L/60 criterion – VHB GPH-160/RP+160GF and VHB 4956 (G16F) both passed at the ±40 and ±80 psf (±1.9 and ±3.8 kPa) loadings, matching the deflection results of the rigid structural adhesive. VHB 4991B (B90F) met the deflection criterion up to ±40 psf, matching the results of the flexible silicone sealant. Similar to the silicone sealant, each VHB tape also showed small signs of cohesive failure at the stiffener ends that were impacted in the missile testing.

Acrylic foam tapes are perhaps the easiest of the bonding solutions tested to apply. The tape does require moderate levels of surface preparation which includes cleaning and may require a primer depending on the bonding surface, but its fully cured construction means that the tape has immediate handling strength. There is no clamping or fixturing necessary. Once pressure (3M suggests 15 psi (103 kPa)) has been applied to both sides of the tape, the bond is instantly at 30-40% of its final bond strength. This immediate strength allows end users to move the product around the manufacturing floor instantly without needing a staging area to wait for a liquid adhesive to cure. Unskilled labor can also be used to apply tape, whereas stitch welding typically requires a certified welder. Tape application can also be semi- or fully automated further enhancing the manufacturing process.

These tapes adhere to the substrates through the process of electrostatic adhesion and viscous flow. This means that they do not damage the substrates during attachment like the process of welding does. As there is no heat involved and no chemical reactions taking place, tapes allow for the smoothest aesthetic of the attachment methods tested.

When comparing published tensile and shear strength of attachment methods, acrylic foam tapes will be closest to the silicone sealant. Each of the three tapes tested have published tensile strength of 70 psi (480 kPa) or greater, and dynamic overlap shear strength of 65 psi (450 kPa) or greater. This said, acrylic foam tapes are viscoelastic materials, which give them unique properties compared to other attachment methods. Their strength is highly dependent on the rate that a stress is applied – the tape will behave more stiffly and have greater strength as a fast-acting force like wind load or impact is applied. Conversely, they will behave softer and have less strength when a slow-acting force like gravity is applied. This means that tapes can be a weaker option when being asked to hold larger static loads (dead load). 3M publishes a static load design guideline of 0.25 psi (1.7 kPa) and a dynamic load design guideline of 12 psi (85 kPa). While viscoelasticity makes these materials weaker against large static loads, it also brings some benefit because of the stress relaxation which acts to protect the bond. The acrylic foam tapes tested were far thinner bonding options compared to the silicone sealant, but because of their viscoelastic properties can allow a similar amount of movement between attached materials by allowing up to 300% shear strain according to 3M.

Conclusion:

After 4 different ASTM tests were run sequentially, each set of panels and attached stiffeners likely saw greater stresses in a condensed time period than many real applications will see in their lifetime. None of the stiffeners failed when subjected to pressures equivalent of 220 mph (355 km/h) sustained wind speeds, and there was only one failure during missile impact testing. The entire application process, labor, cost and aesthetics should be assessed alongside the stiffener performance to determine an appropriate stiffener attachment method. Acrylic foam tapes offer the greatest process flexibility through ease of use and immediate handling strength and have the most aesthetically pleasing result, whereas welding and rigid structural adhesives have more complicated or less efficient processes but provide the greatest shear strength performance when needed for an application.

From a panel deflection viewpoint, the two thinnest acrylic foam tapes (3M™ VHB™ Tape 4956 (G16F) and 3M™ VHB™ Tape GPH-160GF/RP+-160GF) and the rigid structural adhesive (3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS) outperformed all the other attachment methods by passing the L/60 criterion up to 80 psf (3.8 kPa) while the other attachment methods only passed up to 40 psf (1.9 kPa).

Tables 2 and 3 offer simplified summaries of the testing and process information.

Attachment Method	Load	Impact	Process	Shear Strength	Aesthetics
Stitch Welding	+++	+++	++	+++	+
Rigid Structural Adhesive	+++	+	+	+++	++
Flexible Adhesive Sealant	+++	++	+	+	++
Acrylic Foam Tape	+++	++	+++	+	+++

Table 2 Results Comparison Table

Attachment Method	Load	Impact	Process	Shear Strength	Aesthetics
Stitch Welding	Passed all tests. Passed L/60 deflection criterion at 40 loading	Passed missile impact test. No failures	Minimal surface preparation. Requires skilled labor to apply.	1000+ psi when correctly applied	Least Attractive, requires refinishing for smooth appearance
Rigid Structural Adhesive	Passed all tests. Passed L/60 deflection criterion up to 80 psf loading. Passed L/120 criterion up to 40 psf	Passed missile impact test. Complete de-bond of center stiffener. Cohesive failure at bottom stiffener end closest to corner impact	Minimal surface preparation. Easy, fast application. Needs fixturing. 1 day for full cure	1000+ psi when correctly applied	Smooth look. Potential for dimpling, waviness, or read-through. Thinnest bond line
Flexible Adhesive Sealant	Passed all tests. Passed L/60 deflection criterion up to 40 psf loading.	Passed missile impact test. Minimal cohesive failure at center stiffener end.	Medium surface preparation. Requires spacer tape and sealant. Needs fixturing and 7-21 days for full cure	45-60 psi ultimate strength	Smooth look. Potential for dimpling, waviness, or read-through. Thickest bond line
Acrylic Foam Tape	Passed all tests. 1/16” (1.6 mm) calipers passed L/60 deflection criterion up to 80 psf loading. 0.090” (2.3 mm) caliper passed up to 40 psf.	Passed missile impact test. Minimal cohesive failure at bottom stiffener ends closest to corner impact.	Medium surface preparation. Easy, fast application. Immediate handling strength	65+ psi ultimate dynamic strength.	Smoothest look

Table 3 Results Comparison Table

Technical Information: The technical information, guidance, and other statements contained in this document or otherwise provided by 3M are based upon records, tests, or experience that 3M believes to be reliable, but the accuracy, completeness, and representative nature of such information is not guaranteed. Such information is intended for people with knowledge and technical skills sufficient to assess and apply their own informed judgment to the information. No license under any 3M or third-party intellectual property rights is granted or implied with this information.

Product Selection and Use: Many factors beyond 3M's control and uniquely within user's knowledge and control can affect the use and performance of a 3M product in a particular application. As a result, customer is solely responsible for evaluating the product and determining whether it is appropriate and suitable for customer's application, including conducting a workplace hazard assessment and reviewing all applicable regulations and standards (*e.g.*, OSHA, ANSI, etc.). Failure to properly evaluate, select, and use a 3M product in accordance with all applicable instructions and with appropriate safety equipment, or to meet all applicable safety regulations, may result in injury, sickness, death, and/or harm to property.

Warranty, Limited Remedy, and Disclaimer: Unless a different warranty is specifically stated on the applicable 3M product packaging or product literature (in which case such warranty governs), 3M warrants that each 3M product meets the applicable 3M product specification at the time 3M ships the product. 3M MAKES NO OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR ARISING OUT OF A COURSE OF DEALING, CUSTOM, OR USAGE OF TRADE. If a 3M product does not conform to this warranty, then the sole and exclusive remedy is, at 3M's option, replacement or repair of the 3M product or refund of the purchase price. Warranty claims must be made within one (1) year from the date of 3M's shipment.

Limitation of Liability: Except for the limited remedy stated above, and except to the extent prohibited by applicable law, 3M will not be liable for any loss or damage arising from or related to the 3M product, whether direct, indirect, special, incidental, or consequential (including, but not limited to, lost profits or business opportunity), regardless of the legal or equitable theory asserted, including, but not limited to, warranty, contract, negligence, or strict liability.

Disclaimer: 3M industrial and occupational products are intended, labeled, and packaged for sale to trained industrial and occupational customers for workplace use. Unless specifically stated otherwise on the applicable product packaging or literature, these products are not intended, labeled, or packaged for sale to or use by consumers (e.g., for home, personal, primary or secondary school, recreational/sporting, or other uses not described in the applicable product packaging or literature), and must be selected and used in compliance with applicable health and safety regulations and standards (e.g., U.S. OSHA, ANSI), as well as all product literature, user instructions, warnings, and other limitations, and the user must take any action required under any recall, field action or other product use notice. Misuse of 3M industrial and occupational products may result in injury, sickness, death, or property damage. For help with product selection and use, consult your on-site safety professional, industrial hygienist, or other subject matter expert. For additional product information, visit www.3M.com.[[1]]

Industrial Adhesives and Tapes Division
3M Center, Building 225-3S-06
St. Paul, MN 55144-1000
800-362-3550 • 877-369-2923 (Fax)
www.3M.com/VHB

Appendix:

ASTM E2264-05(2013), *Standard Practice for Determining the Effects of Temperature Cycling on Fenestration Products*
Panels were set in an environmental chamber and subjected to fourteen 12-hour cycles between -33°F ± 5°F to 180°F ±5°F (-36°C ±3°C. to 82°C ±3°C). Each panel was then assessed for any warping or attachment failures.

ASTM E330/E330M-14*, Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference*
Panels were tested with loads increasing incrementally up to a maximum of 120 psf (5.7 kPa). The panels were subjected to both positive wind loads (inward acting – the most severe direction for stiffener attachment) and negative wind loads (outward acting). Each panel was subjected to loads of ±40, ±80, and ±120 psf (±1.9, ±3.8, and ±5.8 kPa). Pressure loads were held for 10 seconds according to the test method with the exception of the peak pressure (±120 psf (5.8 kPa)) which was held for 1 minute. The 120 psf (5.8 kPa) load is equal to a sustained wind speed of 220 mph (355 km/h). All tests were run at 70°F (21°C). Panel deflection at the center of the central stiffener and at the middle of the panel between stiffeners was measured. The L/60 deflection limit for the panels in this test was 1.6" (40.6 mm).

ASTM E1886-13a, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*
A 9.1 lb (4.1 kg) lumber projectile, 8' (2.4 m) in length was launched at a velocity between 50-51 fps (~15.4 m/s) at two locations on each panel – one center impact and one corner impact, as shown in the drawing below. After each impact, attachment methods were analyzed for any damage or separation.

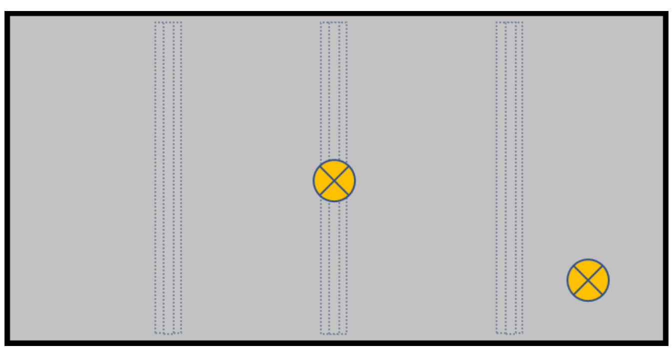


Figure 11: Impact Locations

ASTM E1996-14a, *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*
After impact testing, panels were then subjected to positive and negative hurricane pressure cycling and assessed for further damage to the attachment regions.

intertek
Total Quality. Assured.

3M COMPANY
TEST REPORT

SCOPE OF WORK
THERMAL CYCLE, STRUCTURAL, IMPACT, AND PRESSURE CYCLE TESTING ON ALUMINUM PANELS WITH STIFFENERS

REPORT NUMBER
L6017.01-201-44 R0

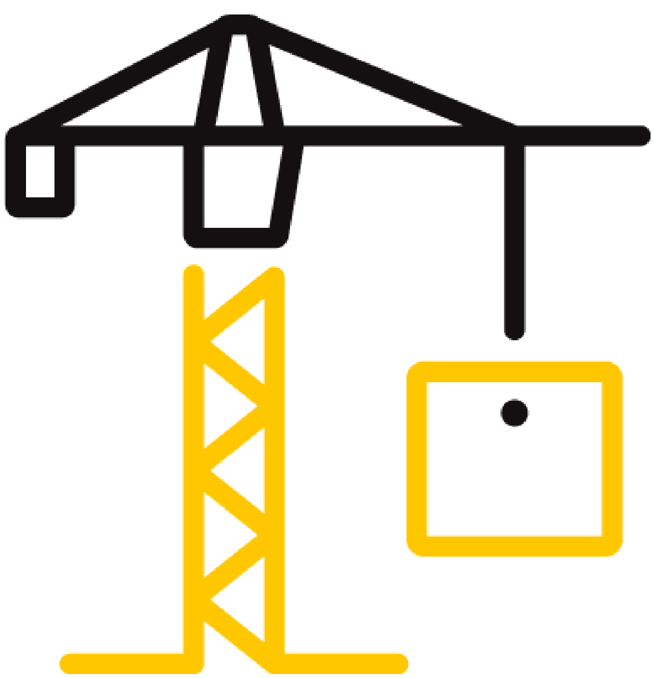
TEST DATES
12/15/20 - 12/16/20

ISSUE DATE
12/21/20

RECORD RETENTION END DATE
12/16/24

PAGES
25

DOCUMENT CONTROL NUMBER
ATI 00479 (07/24/17)
RT-R-AMER-Test-2805



REPORT ISSUED TO

3M COMPANY
230-2S-29
St. Paul, MN 55144

SECTION 1
SCOPE

Intertek Building & Construction (B&C) was contracted by 3M Company to perform testing in accordance with ASTM E2264, ASTM E330, E1886, E1996 on aluminum panels with stiffeners attached by various means. Results obtained are tested values and were secured by using the designated test method(s). Testing was conducted at Intertek Inc. test facility in Fridley, MN.

This report does not constitute certification of this product nor an opinion or endorsement by this laboratory.

SECTION 2
SUMMARY OF TESTS AND TEST CONDITIONS

TEST	TEST CONDITIONS
Thermal Cycling	Fourteen 12 hr cycles: -33°F ± 5°F to 180°F ± 5°F
Design Pressure	±3840 Pa (±80.0 psf)
Uniform Load Structural Test Pressure	±5760 Pa (±120.0 psf)
Missile Impacts	Missile Level D, Wind Zone 4
Cyclic Structural Loading	±3840 Pa (±80.0 psf)

For INTERTEK B&C:

COMPLETED BY:	Karl Lips	**REVIEWED BY:**	Daniel Johnson
TITLE:	Senior Technician – B&C	**TITLE:**	Director, Regional Operations
SIGNATURE:	Digitally Signed by: Karl Lips-Eakins	**SIGNATURE:**	Digitally Signed by: Daniel A. Johnson
DATE:	12/21/20	**DATE:**	12/21/20

KL: daj/wma

SECTION 3
TEST METHOD(S)

The specimens were evaluated in accordance with the following:

ASTM E2264-05(2013), *Standard Practice for Determining the Effects of Temperature Cycling on Fenestration Products*

ASTM E330/E330M-14, *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference*

ASTM E1886-13a, *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*

ASTM E1996-14a, *Standard Specification for Performance of Exterior Windows, Curtain Walls, Doors, and Impact Protective Systems Impacted by Windborne Debris in Hurricanes*

SECTION 4
MATERIAL SOURCE/INSTALLATION

Test specimens were provided by the client. The specimen was installed into a Spruce-Pine-Fir wood buck.

LOCATION	ANCHOR DESCRIPTION	ANCHOR LOCATION
Panel perimeter	Aluminum bracket, spaced 6" on center	Each bracket secured to panel return legs with two #10 x 3/4" Tek screws and secured to wood buck with one 2" pole barn screw.

SECTION 5
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Steve Austin	3M Company
Reese Weber	3M Company
Anthony Gavin	Intertek B&C
Karl Lips	Intertek B&C

SECTION 6
TEST SPECIMEN DESCRIPTION

Panel Sizes:

OVERALL AREA:	WIDTH		HEIGHT	
3.7 m² (40.0 ft²)	millimeters	inches	millimeters	inches
Overall Size	1524	60	2438	96

Panel Construction:

PANEL MEMBER	MATERIAL	DESCRIPTION
Panel	Aluminum	1/8" thick aluminum panel with a 3/4" 90° return leg folded towards the back of the panel around the entire perimeter.
Stiffener Reinforcements	Aluminum	1/8" thick x 56" long hat channel profiles - applied with the top of the hat channel stiffeners in contact with the back of the aluminum panel except for the stitch-welded stiffeners which had the two bottom flanges in contact with the back of the aluminum panel. Three stiffeners applied to the back of each panel at 2' on center spacing spanning the 60" panel length.

Reinforcement Attachment:

SPECIMEN #	DESCRIPTION
DOWSIL™ 795 Building Sealant	Structural silicone sealant.1/2" wide x 1/4" thick spacer tape placed down the center of the hat channel and panel. Remaining space on each side of the spacer tape filled in with silicone sealant (~3/8" to 1/2" of sealant on each side). Allowed to cure 21 days before testing.
3M™ VHB™ Tape GPH-160GF	3M VHB variant. 1" wide x 1/16" thick. Tape applied down the entire length on the top side of the hat channels (i.e., 1" wide tape per stiffener).
3M™ VHB™ Tape 4956(G16F)	3M VHB variant. 1" wide x 1/16" thick. Tape applied down the entire length on the top side of the hat channels (i.e., 1" wide tape per stiffener).
3M™ VHB Tape 4991B	3M VHB variant. 1" wide x 0.090" thick. Tape applied down the entire length on the top side of the hat channels (i.e., 1"wide tape per stiffener).
3M™ Scotch-Weld™ Metal Bonder Acrylic Adhesive DP8407NS	3M structural adhesive applied between hat channel and panel in an "S" pattern. Allowed to cure 14 days before testing.
Stitch-Weld	Hat channel stitch-welded to panel at ends and 10" on center.

SECTION 7
TEST RESULTS

Thermal cycling: Panels were set in an environmental chamber and subjected to fourteen 12 hr cycles: -33°F ± 5°F to 180°F ± 5°F per ASTM 2264.

SPECIMEN #	OBSERVATIONS
Dowsil 795	No warping of stiffeners or panel. No adhesion/cohesion failures observed.
VHB GPH-160	No warping of stiffeners or panel. No adhesion/cohesion failures observed.
VHB 4956 (G16F)	No warping of stiffeners or panel. No adhesion/cohesion failures observed.
VHB 4991B	No warping of stiffeners or panel. No adhesion/cohesion failures observed.
Scotch-Weld DP8407	No warping of stiffeners or panel. No adhesion/cohesion failures observed.
Stitch-Weld	No warping of stiffeners or panel. No cracks or breaks in welds observed.

Structural Test: The temperature during ASTM E330 structural load testing was 21°C (70°F). The results are tabulated as follows:

Test Specimen #1: Dowsil 795

TITLE OF TEST	Center of Stiffener	Mid-Panel Between Stiffeners	NOTE
Uniform Load, per ASTM E330			
+1920 Pa (+40.0 psf)	1.10"	1.06"	
-1920 Pa (-40.0 psf)	1.06"	1.00"	
+3840 Pa (+80.0 psf)	1.66"	1.60"	
-3840 Pa (-80.0 psf)	1.59"	1.51"	
+5760 Pa (+120.0 psf)	2.05"	1.97"	
-5760 Pa (-120.0 psf)	1.94"	1.84"	
Permanent Set after loading, per ASTM E330	0.14" 0.20"	0.14" 0.18"	

Test Specimen #2: VHB GPH-160

TITLE OF TEST	Center of Stiffener	Mid-Panel Between Stiffeners	NOTE
Uniform Load, per ASTM E330 +1920 Pa (+40.0 psf) -1920 Pa (-40.0 psf) +3840 Pa (+80.0 psf) -3840 Pa (-80.0 psf) +5760 Pa (+120.0 psf) -5760 Pa (-120.0 psf)	 1.02" 0.91" 1.44" 1.30" 1.68" 1.55"	 0.99" 0.89" 1.37" 1.26" 1.61" 1.50"	
Permanent Set after loading, per ASTM E330	0.09" 0.14"	0.09" 0.14"	

Test Specimen #3: VHB 4956 (G16F)

TITLE OF TEST	Center of Stiffener	Mid-Panel Between Stiffeners	NOTE
Uniform Load, per ASTM E330 +1920 Pa (+40.0 psf) -1920 Pa (-40.0 psf) +3840 Pa (+80.0 psf) -3840 Pa (-80.0 psf) +5760 Pa (+120.0 psf) -5760 Pa (-120.0 psf)	 1.04" 0.85" 1.47" 1.21" 1.70" 1.47"	 0.97" 0.85" 1.38" 1.20" 1.59" 1.44"	
Permanent Set after loading, per ASTM E330	0.11" 0.12"	0.10" 0.12"	

Test Specimen #4: VHB 4991B

TITLE OF TEST	Center of Stiffener	Mid-Panel Between Stiffeners	NOTE
Uniform Load, per ASTM E330 +1920 Pa (+40.0 psf) -1920 Pa (-40.0 psf) +3840 Pa (+80.0 psf) -3840 Pa (-80.0 psf) +5760 Pa (+120.0 psf) -5760 Pa (-120.0 psf)	 1.19" 0.99" 1.80" 1.52" 2.21" 1.91"	 1.11" 1.00" 1.69" 1.50 2.08" 1.88"	
Permanent Set after loading, per ASTM E330	0.05" 0.25"	0.06" 0.25"	

Test Specimen #5: Scotch-Weld DP8407

TITLE OF TEST	Center of Stiffener	Mid-Panel Between Stiffeners	NOTE
Uniform Load, per ASTM E330 +1920 Pa (+40.0 psf) -1920 Pa (-40.0 psf) +3840 Pa (+80.0 psf) -3840 Pa (-80.0 psf) +5760 Pa (+120.0 psf) -5760 Pa (-120.0 psf)	 0.63" 0.53" 1.11" 0.90" 1.71" 1.20"	 0.68" 0.54 1.14" 0.88" 1.67" 1.16"	 1
Permanent Set after loading, per ASTM E330	0.03" 0.09"	0.03" 0.08"	

Test Specimen #6: Stitch-Weld

TITLE OF TEST	Center of Stiffener	Mid-Panel Between Stiffeners	NOTE
Uniform Load, per ASTM E330 +1920 Pa (+40.0 psf) -1920 Pa (-40.0 psf) +3840 Pa (+80.0 psf) -3840 Pa (-80.0 psf) +5760 Pa (+120.0 psf) -5760 Pa (-120.0 psf)	 1.16" 0.69" 1.64" 1.03" 1.92" 1.28"	 1.18" 0.69" 1.60" 1.01" 1.85" 1.24"	
Permanent Set after loading, per ASTM E330	0.03" 0.13"	0.03" 0.13"	

Note 1: Left side, as viewed from interior, of stiffeners separated from panel at ~100 psf. Length of separation was approximately 6".

ASTM E1886, *LARGE OR SMALL MISSILE IMPACT*

Conditioning Temperature: 21°C (70°F)
Missile Weight: 4127 g (9.1 lbs)
Missile Length: 2.4 m (96")
Muzzle Distance from Test Specimen: 5.2 m (17')

Test Specimen #1: Orientation within ±5° of horizontal

IMPACT	#1	#2
MISSILE VELOCITY	15.5 m/s (50.8 fps)	15.3 m/s (50.3 fps)
IMPACT AREA	Center of panel	Lower right corner of panel
OBSERVATIONS	Missile hit target area	Missile hit target area
RESULTS	Pass	Pass

Test Specimen #2: Orientation within ±5° of horizontal

IMPACT	#1	#2
MISSILE VELOCITY	15.5 m/s (50.8 fps)	15.3 m/s (50.1 fps)
IMPACT AREA	Center of panel	Lower right corner of panel
OBSERVATIONS	Missile hit target area	Missile hit target area
RESULTS	Pass	Pass

Test Specimen #3: Orientation within ±5° of horizontal

IMPACT	#1	#2
MISSILE VELOCITY	15.4 m/s (50.6 fps)	15.4 m/s (50.6 fps)
IMPACT AREA	Center of panel	Lower right corner of panel
OBSERVATIONS	Missile hit target area	Missile hit target area
RESULTS	Pass	Pass

ASTM E1886, *LARGE OR SMALL MISSILE IMPACT*

Conditioning Temperature: 21°C (70°F)
Missile Weight: 4127 g (9.1 lbs)
Missile Length: 2.4 m (96")
Muzzle Distance from Test Specimen: 5.2 m (17')

Test Specimen #4: Orientation within ±5° of horizontal

IMPACT	#1	#2
MISSILE VELOCITY	15.5 m/s (50.9 fps)	15.5 m/s (50.8 fps)
IMPACT AREA	Center of panel	Lower right corner of panel
OBSERVATIONS	Missile hit target area	Missile hit target area
RESULTS	Pass	Pass

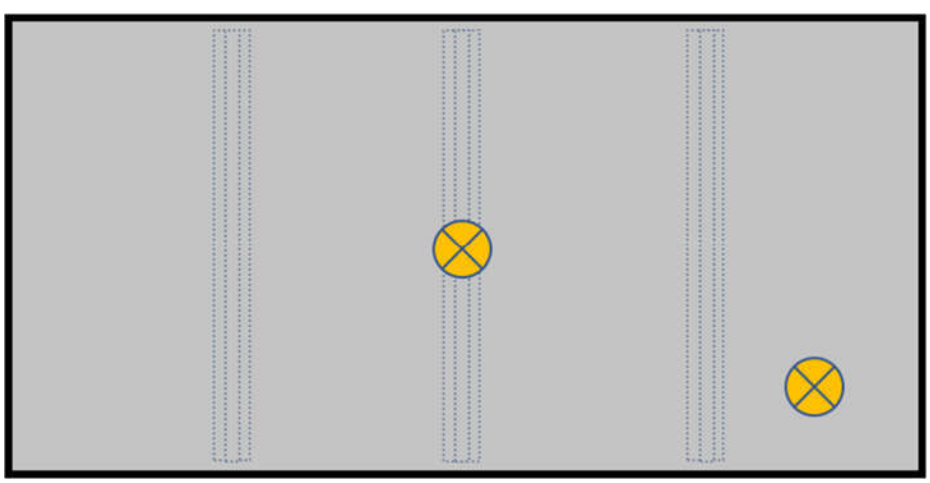
Test Specimen #5: Orientation within ±5° of horizontal

IMPACT	#1	#2
MISSILE VELOCITY	15.4 m/s (50.6 fps)	15.5 m/s (50.8 fps)
IMPACT AREA	Center of panel	Lower right corner of panel
OBSERVATIONS	Missile hit target area; Center stiffener completely separated from panel when impacted.	Missile hit target area
RESULTS	Pass	Pass

Test Specimen #6 Orientation within ±5° of horizontal

IMPACT	#1	#2
MISSILE VELOCITY	15.5 m/s (50.8 fps)	15.4 m/s (50.5 fps)
IMPACT AREA	Center of panel	Lower right corner of panel
OBSERVATIONS	Missile hit target area	Missile hit target area
RESULTS	Pass	Pass

Impact locations on each specimen



ASTM E1886, AIR PRESSURE CYCLING

Test Specimen #1: Dowsil 795
Design Pressure: ±3840 Pa (±80.0 psf)

Positive Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
768 to 1920 (16.0 to 40.0)	3500	3.24	1.63	1.79	0.10	
0 to 2304 (0 to 48.0)	300	2.61	1.70	1.86	0.11	
1920 to 3072 (40.0 to 64.0)	600	2.96	1.92	2.06	0.13	
1152 to 3840 (24.0 to 80.0)	100	4.11	2.09	2.22	0.14	
0 to 4992 (0 to 104.0)	1	1.00	2.33	2.44	0.14	

Negative Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
1152 to 3840 (24.0 to 80.0)	50	4.27	1.65	1.45	0.10	
1920 to 3072 (40.0 to 64.0)	1050	2.65	1.49	1.32	0.10	
0 to 2304 (0 to 48.0)	50	4.00	1.30	1.15	0.10	
768 to 1920 (16.0 to 40.0)	3350	3.14	1.19	1.05	0.10	
0 to 4992 (0 to 104.0)	1	1.00	1.88	1.67	0.12	

Result: Pass

ASTM E1886, AIR PRESSURE CYCLING

Test Specimen #2: VHB GPH-160
Design Pressure: ±3840 Pa (±80.0 psf)

Positive Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
768 to 1920 (16.0 to 40.0)	3500	3.24	1.69	1.91	0.32	
0 to 2304 (0 to 48.0)	300	2.61	1.77	1.98	0.34	
1920 to 3072 (40.0 to 64.0)	600	2.96	1.99	2.20	0.42	
1152 to 3840 (24.0 to 80.0)	100	4.11	2.17	2.36	0.49	
0 to 4992 (0 to 104.0)	1	1.00	2.41	2.59	0.57	

Negative Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
1152 to 3840 (24.0 to 80.0)	50	4.27	1.60	1.35	0.32	
1920 to 3072 (40.0 to 64.0)	1050	2.65	1.44	1.21	0.28	
0 to 2304 (0 to 48.0)	50	4.00	1.24	1.02	0.24	
768 to 1920 (16.0 to 40.0)	3350	3.14	1.13	0.92	0.21	
0 to 4992 (0 to 104.0)	1	1.00	1.83	1.57	0.41	

Result: Pass

ASTM E1886, AIR PRESSURE CYCLING

Test Specimen #3: VHB 4956 (G16F)
Design Pressure: ±3840 Pa (±80.0 psf)

Positive Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
768 to 1920 (16.0 to 40.0)	3500	3.24	1.76	1.94	0.36	
0 to 2304 (0 to 48.0)	300	2.61	1.84	2.01	0.39	
1920 to 3072 (40.0 to 64.0)	600	2.96	2.07	2.23	0.48	
1152 to 3840 (24.0 to 80.0)	100	4.11	2.25	2.39	0.55	
0 to 4992 (0 to 104.0)	1	1.00	2.49	2.61	0.64	

Negative Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
1152 to 3840 (24.0 to 80.0)	50	4.27	1.54	1.36	0.36	
1920 to 3072 (40.0 to 64.0)	1050	2.65	1.39	1.22	0.32	
0 to 2304 (0 to 48.0)	50	4.00	1.19	1.04	0.27	
768 to 1920 (16.0 to 40.0)	3350	3.14	1.08	0.94	0.24	
0 to 4992 (0 to 104.0)	1	1.00	1.77	1.58	0.47	

Result: Pass

ASTM E1886, AIR PRESSURE CYCLING

Test Specimen #4: VHB 4991B
Design Pressure: ±3840 Pa (±80.0 psf)

Positive Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
768 to 1920 (16.0 to 40.0)	3500	3.24	1.76	1.88	0.08	
0 to 2304 (0 to 48.0)	300	2.61	1.85	1.96	0.08	
1920 to 3072 (40.0 to 64.0)	600	2.96	2.09	2.19	0.10	
1152 to 3840 (24.0 to 80.0)	100	4.11	2.28	2.36	0.11	
0 to 4992 (0 to 104.0)	1	1.00	2.51	2.59	0.13	

Negative Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
1152 to 3840 (24.0 to 80.0)	50	4.27	1.47	1.34	0.04	
1920 to 3072 (40.0 to 64.0)	1050	2.65	1.33	1.21	0.04	
0 to 2304 (0 to 48.0)	50	4.00	1.11	1.02	0.04	
768 to 1920 (16.0 to 40.0)	3350	3.14	1.02	0.93	0.04	
0 to 4992 (0 to 104.0)	1	1.00	1.68	1.53	0.04	

Result: Pass

ASTM E1886, AIR PRESSURE CYCLING

Test Specimen #5: Scotch-Weld DP8407
Design Pressure: ±3840 Pa (±80.0 psf)

Positive Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
768 to 1920 (16.0 to 40.0)	3500	3.24	1.30	1.19	0.20	Center stiffener absent for all positive pressure cycling
0 to 2304 (0 to 48.0)	300	2.61	1.39	1.28	0.22	
1920 to 3072 (40.0 to 64.0)	600	2.96	1.60	1.48	0.29	
1152 to 3840 (24.0 to 80.0)	100	4.11	1.78	1.65	0.35	
0 to 4992 (0 to 104.0)	1	1.00	2.02	1.89	0.44	

Negative Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
1152 to 3840 (24.0 to 80.0)	50	4.27	2.06	2.11	0.30	Center stiffener absent for all negative pressure cycling
1920 to 3072 (40.0 to 64.0)	1050	2.65	1.92	1.98	0.27	
0 to 2304 (0 to 48.0)	50	4.00	1.72	1.79	0.22	
768 to 1920 (16.0 to 40.0)	3350	3.14	1.62	1.70	0.21	
0 to 4992 (0 to 104.0)	1	1.00	2.26	2.31	0.35	

Result: Pass

ASTM E1886, AIR PRESSURE CYCLING

Test Specimen #6: Stitch-Weld
Design Pressure: ±3840 Pa (±80.0 psf)

Positive Pressure

PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
768 to 1920 (16.0 to 40.0)	3500	3.24	1.42	1.80	0.26	
0 to 2304 (0 to 48.0)	300	2.61	1.53	1.90	0.29	
1920 to 3072 (40.0 to 64.0)	600	2.96	1.77	2.13	0.37	
1152 to 3840 (24.0 to 80.0)	100	4.11	1.97	2.32	0.44	
0 to 4992 (0 to 104.0)	1	1.00	2.23	2.57	0.54	

Negative Pressure

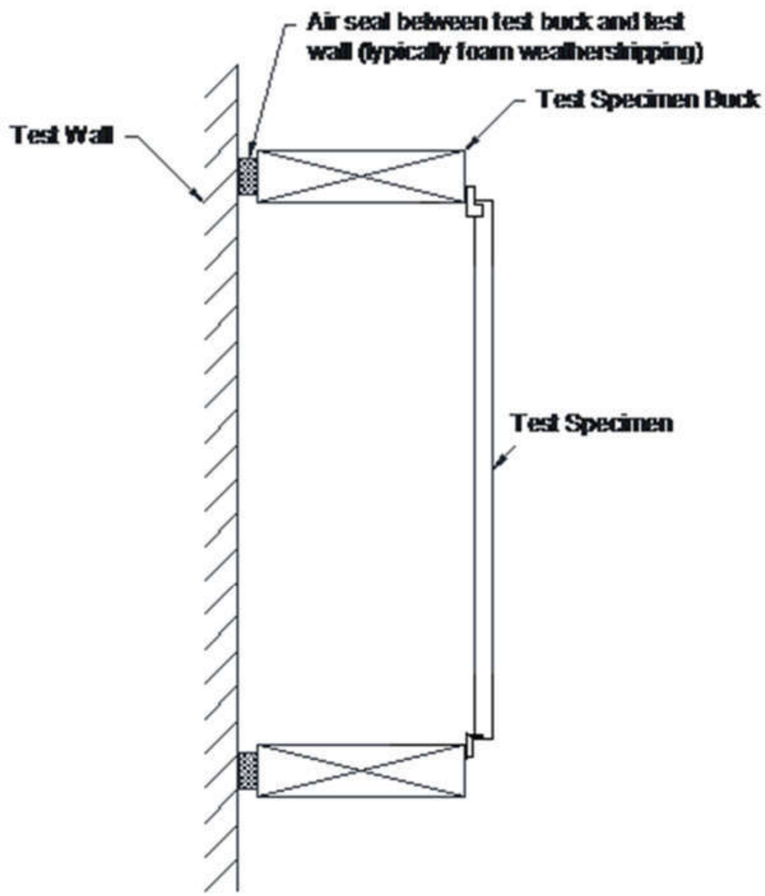
PRESSURE RANGE Pa (psf)	NUMBER OF CYCLES	AVERAGE CYCLE TIME (seconds)	DEFLECTIONS			OBSERVATIONS
			1	2	3	
1152 to 3840 (24.0 to 80.0)	50	4.27	1.66	1.29	0.34	
1920 to 3072 (40.0 to 64.0)	1050	2.65	1.50	1.15	0.30	
0 to 2304 (0 to 48.0)	50	4.00	1.29	0.96	0.24	
768 to 1920 (16.0 to 40.0)	3350	3.14	1.18	0.88	0.22	
0 to 4992 (0 to 104.0)	1	1.00	1.88	1.49	0.42	

Result: Pass

SECTION 8

LOCATION OF AIR SEAL

The air seal between the test specimen and the test wall is detailed below. The seal is made of foam weatherstripping and is attached to the edge of the test specimen buck. The test specimen buck is placed against the test wall and clamped in place, compressing the weatherstripping and creating a seal.

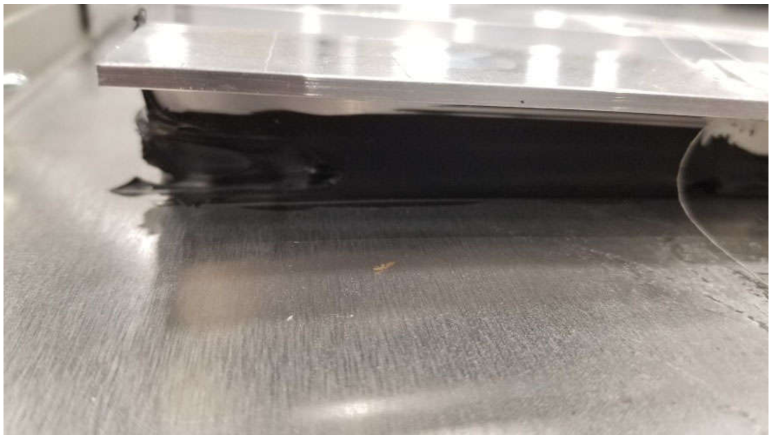


SECTION 9
PHOTOGRAPHS

Aluminum brackets attached to panel with #10 x 3/4" Tek screws

Panels installed onto wood buck and test wall

Specimen #1: Dowsil 795
Stiffener end, closest to corner impact

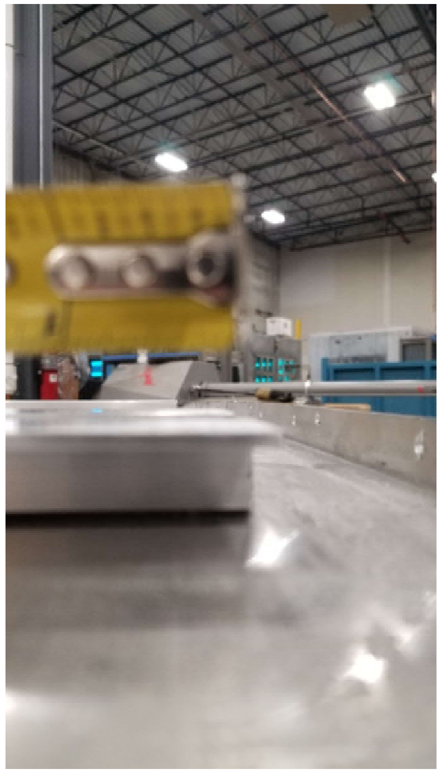


Specimen #1: Dowsil 795
Middle stiffener, end opposite of corner impact. 1.25" separation, sealant run short of the ends.

Specimen #2: VHB GPH-160
End of bottom stiffener closest to corner impact. Cohesive separation.

Specimen #2: VHB GPH-160
Stiffener end, opposite of corner impact.

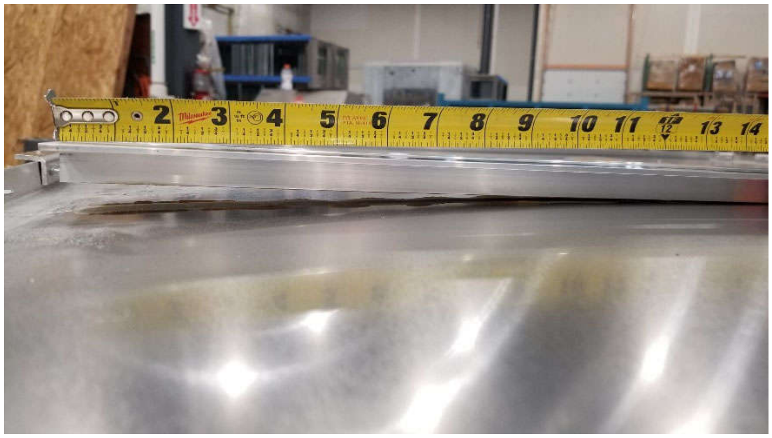
Specimen #3: VHB 4956-G16F
End of bottom stiffener closest to corner impact. Cohesive separation.



Specimen #3: VHB 4956-G16F
Stiffener end, opposite of corner impact.

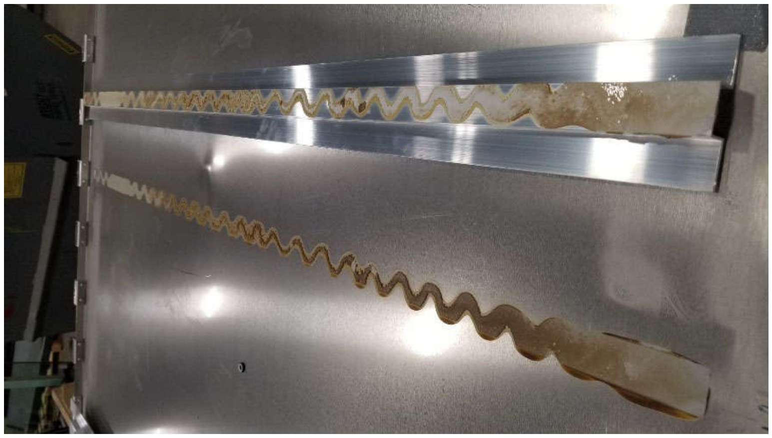
Specimen #4: VHB 4991B
End of bottom stiffener closest to corner impact. Cohesive separation.


Specimen #4: VHB 4991B
Stiffener end, opposite of corner impact.

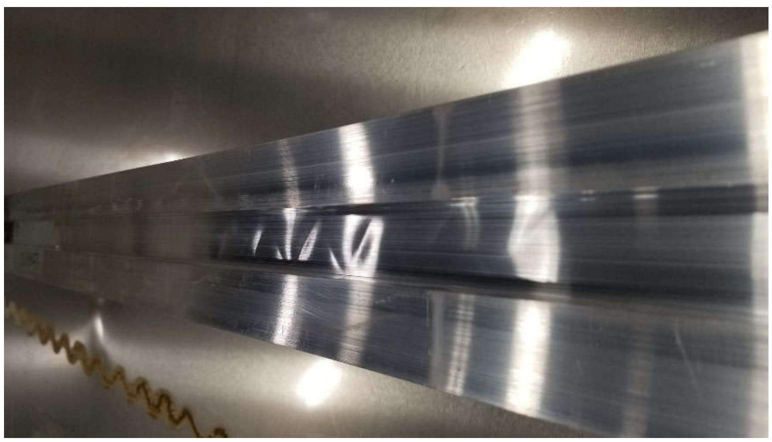


Specimen #5: Scotch-Weld DP8407
End of bottom stiffener closest to corner impact. Cohesive separation.

Specimen #5: Scotch-Weld DP8407
Stiffener end, opposite of corner impact.



Specimen #5: Scotch-Weld DP8407
Stiffener fail from impact



Specimen #5: Scotch-Weld DP8407
Adhesive held strong enough to pull indentations through hat channel

Specimen #6: Stitch-Weld
End of bottom stiffener closest to corner impact.

Specimen #6: Stitch-Weld
Typical weld spacing. No failures.

SECTION 10
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	12/21/20	N/A	Original Report Issue