

An Evaluation of Stiffener Attachment Methods

Steve Austin, Senior Application Engineering Specialist, 3M Company, St. Paul, MN

Reese Weber, Senior Application Engineer, 3M Company, St. Paul, MN

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Abstract

Stiffeners are commonly applied to metal or composite panels to provide extra support, reducing panel deflection as well as allowing for the use of lighter gauge panels while maintaining rigidity. Stiffener profiles are commonly seen in applications such as architectural metal panels, commercial doors, HVAC units, metal office furniture, metal enclosures and more. This paper summarizes an independent 3rd party analysis of stiffener attachment methods with welds, liquid adhesives, and pressure sensitive 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 method passed the industry-accepted tests with notable differences observed in rigidity and panel deflection. With this information, fabricators can look to optimize panel performance, assembly processes and panel aesthetics.

Introduction

Pressure sensitive acrylic foam tapes (AFT) 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 architectural metal panels, metal enclosures, HVAC units, 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 based on ease of use, final aesthetic, stress-resistance capability, process flexibility, end-use environment, and more. The most common methods for stiffener attachment are included in the following table along with the different methods of attachment evaluated in this study.

Attachment Method	Key Characteristics	Product(s) Tested
Stitch Welding	<ul style="list-style-type: none"> • "Gold Standard" for attachment strength, but requires experienced, skilled labor • Intense heat disfigures substrates and often requires re-work on opposite side 	N/A
Rigid Structural Adhesive	<ul style="list-style-type: none"> • 1000 PSI overlap shear strength • Liquid-applied adhesives require clamping/fixturing until cured 	Structural Acrylic Adhesive
Flexible Adhesive Sealant	<ul style="list-style-type: none"> • Allows greater movement between parts compared to rigid attachment • Liquid-applied adhesives require clamping/fixturing until cured 	One-part Neutral Cure Silicone Sealant
Acrylic Foam Tape	<ul style="list-style-type: none"> • Best ease of use • Provides immediate handling strength • Limited gap filling capability 	AFT 1 (1.6 mm thick) AFT 2 (1.6 mm thick) AFT 3 (2.3 mm thick)

Table 1: Stiffener Attachment Methods

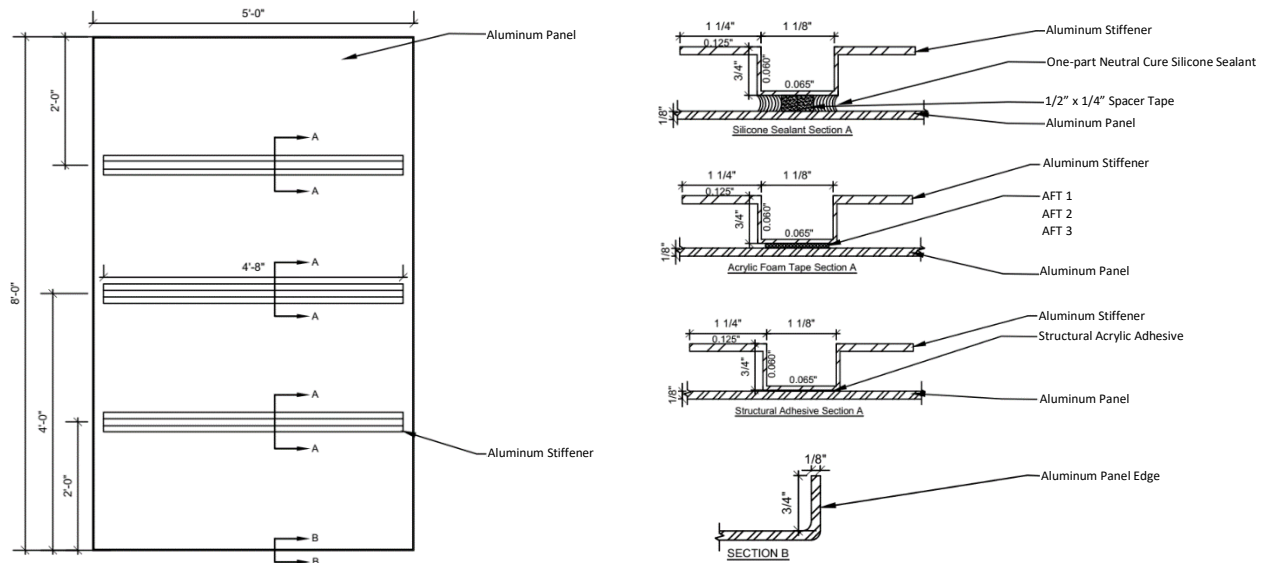
The ASTM test methods used in this study are trusted to determine suitability for high-risk attachment of stiffeners and panels to building exteriors and are relevant to other markets as they test structural integrity across varying stress loading, pressure cycling, and environmental conditions.

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.

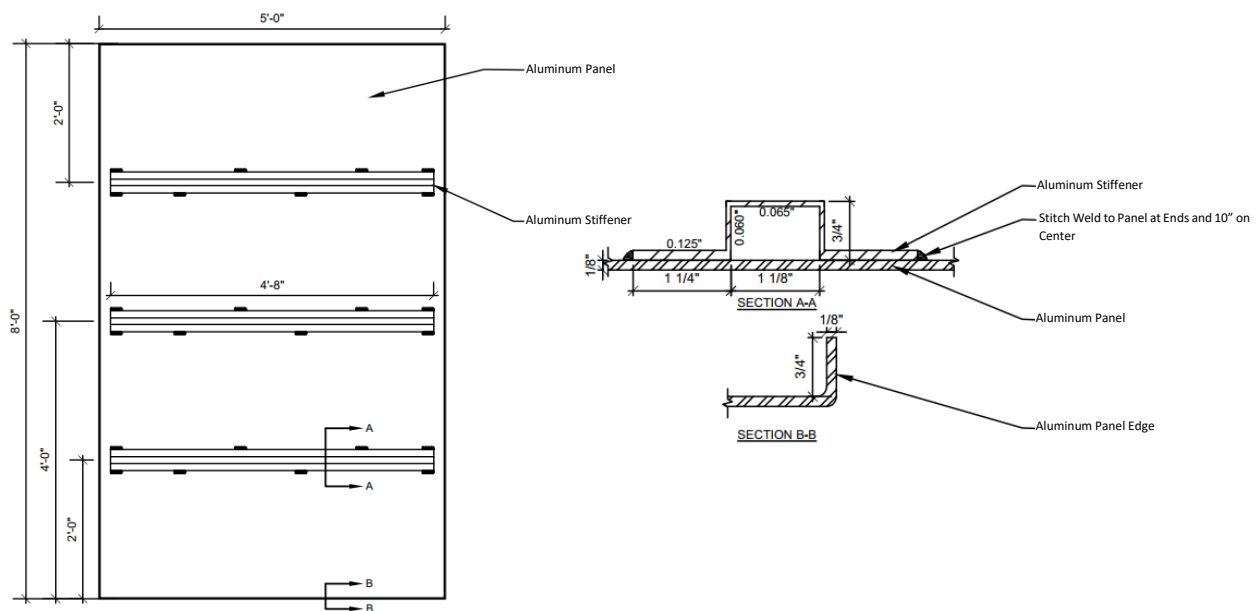
Assembly

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 on the ASTM International website.

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

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 Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference

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 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

Lumber projectiles were launched at two panel locations and were analyzed for any stiffener damage or separation.

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

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

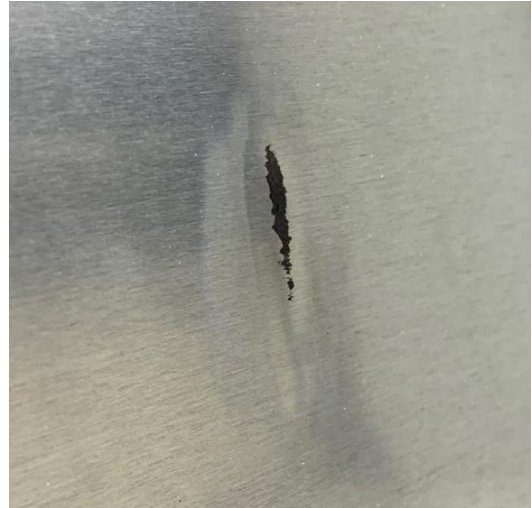


Figure 10: Visible Weld Mark

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 also 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. The structural acrylic adhesive 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 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 one-part neutral cure silicone 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 a rigid structural adhesive in a variety of ways. A few of these major differences are surface preparation, bond thickness, cure time, flexibility, and strength. Acrylic structural adhesives are known for their ability to bond to bare metals with minimal surface preparation – even if the metal is oily. In contrast, the silicone 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, a 1/4” (6.4 mm) thick spacer tape was applied prior to application. As the sealant is a one-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 one-part neutral cure silicone 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 structural acrylic adhesive publishes a tensile strength of 2400 psi (16.5 MPa).

Acrylic Foam Tape

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

1. AFT 1 (0.062" (1.6 mm) thickness) – Trusted bonding solution used for architectural panel bonding for many years
2. AFT 2 (0.062" (1.6 mm) thickness) – Greatest temperature resistance (450°F (230°C)) in acrylic foam tape portfolio and can withstand powder coating and liquid paint bake cycle processes
3. AFT 3 (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: The 0.062" (1.6 mm) thick tapes (AFT1 and AFT 2) both passed at the +40 and +80 psf (+1.9 and +3.8 kPa) loadings, matching the deflection results of the rigid structural adhesive. The 0.090" (2.3 mm) thick tape (AFT 3) met the deflection criterion up to +40 psf, matching the results of the flexible silicone sealant. Similar to the silicone sealant, each acrylic foam 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 a moderate level 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 (manufacturer suggests 15 psi (103 kPa)) has been applied to both sides of the tape, adhesion 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 or sealant 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 pressure sensitive adhesive 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 are closest to the silicone sealant. Each of the three tapes tested have a 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 the 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 used to hold larger static loads (dead load). The manufacturer 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 service life. 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. Pressure sensitive 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 (AFT 1 and AFT 2) and the rigid structural acrylic adhesive 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