

WHITE PAPER

# STRUCTURAL BONDING

## Replacing Traditional Forms of Fasteners



Steve Schneider  
*Engineering Sales Representative*  
Ellsworth Adhesives

Industries around the world are catching on to the improvements offered by modern structural-grade adhesives. Consider the aerospace industry, which for generations relied on mechanical fasteners to keep together the machines that kept us in the air. Rivets became such a recognizable part of airplane manufacture that an entire war effort was characterized by Rosie the Riveter. The aerospace industry has long since moved away from riveted airplane wings, and it continues to eliminate mechanical fasteners and welding whenever possible.

So too has the automotive industry. Adhesives have been replacing mechanical hardware and welding in automobiles for years, and manufacturers will integrate more adhesives in years to come. Not only are planes and automobiles completed more quickly and more efficiently, but adhesives are a lightweight alternative that improves fuel economy as well as vehicle appearance.

Current structural adhesive bonding techniques have overtaken traditional assembly methods, like rivets and welding, in some of the most critical and sensitive applications because adhesives create a stronger and more durable assembly, offer significant process efficiencies, can bond a variety of dissimilar substrates, and are more aesthetically pleasing. Materials like glass and ceramic can't be welded and are too brittle for mechanical fastening, but are perfectly compatible with adhesive chemistries. Today, there are one or two structural adhesives in nearly every consumer product. From beginning to end, structural adhesives have aided some of the most innovative and sophisticated OEMs to simplify product lines, maximize process efficiency, and elevate finished product quality.

## Stronger Than Hardware, Better Than Welds

Not only does a structural adhesive bonding solution exist for almost every assembly, but they are stronger and more reliable than mechanical fastening, especially in the long run.

Adhesives maintain a supple bond that deflects with a substrate. This comes from the material's low modulus of elasticity that results in lower stiffness or greater deformation for a given amount of strain. Adhesives with a high elongation have good flexibility or ductility. As long as the joint is flexed within its elastic limit, it will always rebound to its cured structure, which is essential for structural applications. Adhesives are also more resistant to the effects of vibration—welded and fastened joints are unforgiving in comparison. Threadlockers are commonly used on nuts and bolts for assemblies that experience vibration, proving that adhesives play a critical role in most dynamic assemblies. Adhesives don't require the same precautions, preparation, or finishing as welding requires, and they don't have the torque concerns that afflict fasteners.

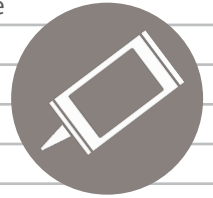
Adhesive deflection also plays a role in thermal expansion. Substrates with mismatched coefficients of thermal expansion (CTEs) can buckle, as hardware and welds permanently fix substrate locations. However, joints created via adhesives compensate for discrepant CTEs and are more forgiving than welded, brazed, soldered, or fastened joints. In some instances adhesives can match the CTEs of substrates. An adhesive with a lower modulus of elasticity and higher elongation will accommodate greater CTE mismatches. A low modulus of elasticity also reduces internal stress in the cured adhesive, and therefore reduces damaging inherent friction and heat as well.

Adhesives distribute stress better than welding and hardware. Welds concentrate loads near material seams and are also subject to internal

## Fastener Comparison Chart

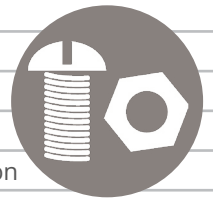
### Adhesives

- + Strong; stress distributed across adhesive area
- + Low modulus of elasticity
- + Protects against galvanic corrosion
- + Doesn't oxidize
- + Bonds dissimilar materials
- + Stable across wide temperature range
- + Vibration resistant
- + Accommodates thermal expansion
- + Hermetic seal
- + Attractive; no seams or protrusions
- Rework is difficult, if not impossible
- Adequate bonding surfaces necessary
- Chemically active



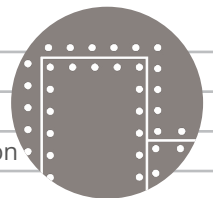
### Bolts

- + Quick
- + Bonds dissimilar materials
- + Removable
- Stress concentrated at fastener location
- Bolt head protrudes or needs recess
- Subject to fretting and fretting fatigue damage
- Requires torque measurement



### Rivets

- + Quick
- + Bonds dissimilar materials
- Stress concentrated at fastener location
- Thermal expansion mismatches
- Rivets protrude from material surface
- Difficult to remove



### Welds

- + Strong
- + Bonds instantly
- + Hermetic seal
- Only for compatible metals
- Requires preparation/finishing
- Processing hazards (metal fumes, eye damage, burns)
- Increased susceptibility to corrosion or stress cracking



stresses and defects that cause welded joints to fatigue quickly. Welding and fasteners can create local stress concentrations, such as machining burrs or notches and weld pores or inclusions that are detrimental to bond strength. Threaded hardware needs substrates to provide a reciprocating clamp force, but this isn't possible with all materials. Fastening hardware that is over or under-torqued will place too much stress on the loadbearing sections of the fasteners and will eventually lead to joint failure. Loosened fasteners can result in fretting and fatigue issues due to joint sliding or movement. Adhesives allocate stress across a larger surface area, the entire adhesive bond joint surface.



Corrosion of a nut and bolt

In addition, adhesives don't oxidize in the presence of moisture like many types of welds and hardware. Dissimilar metals bonded with structural adhesives are much less susceptible to galvanic corrosion than substrates joined by welding. Adhesives provide a highly durable and accommodating bond. Structurally-bonded components often last for 20 to 30 years or more.

### Chemistries of Structural Adhesives

Three styles of adhesive are generally used for structural bonding applications: epoxies, acrylics, and urethanes. Adhesive selection depends on what materials are to be bonded, operating environment and process specifications.

#### Epoxy Adhesives


Epoxies are excellent for bonding similar materials, especially woods, metals, glass, ceramics, hard rubbers, and some plastics. Manipulating the epoxy catalyst can provide an adhesive with excellent temperature resistance—certain epoxies maintain bond integrity at temperatures up to 200 °C. Epoxies are also quite strong (some of them boasting shear strength rates in excess of 5,000 psi) and chemically -resistant. They are an effective way of repairing holes or cracks in metal, glass, and plastic components. Available as one- or two-part resin systems, epoxies take notoriously long to fix and cure, but cure times can be reduced by choosing a heat or UV-curing

### Epoxies


Excellent at bonding similar substrates

Bonds woods, metals & glass


Comes in 1 or 2 part systems



Stronger Bond



Temperature Resistance



Slow Cure

### Acrylics

Bonds similar & dissimilar substrates

Difficulty bonding plastics

Easy-to-use & minimal prep



Weaker Bond



Chemical Resistance




Fast Cure


### Urethanes

Bonds similar & dissimilar substrates including plastics


Difficult to integrate into assembly process



Stronger Bond



Vibration Resistance



Slow Cure



epoxy. Due to potential resin mixing and lengthy cure times, epoxies can be difficult to implement in time-sensitive processes.

### *Acrylic Adhesives*

Acrylics excel at bonding both similar and dissimilar substrates, though they do have difficulty bonding plastics. Acrylics are easily integrated into volume manufacturing, require no mixing and minimal surface preparation, fixate in as little as thirty minutes, and cure in an hour or less. Acrylics can even bond oily or dirty materials, eliminating extensive cleaning and surface preparation, though proper cleaning and surface preparation is still recommended for the optimal bonding strength. Acrylics are not as strong or heat resistant as epoxies; shear strengths top out around 3,500 psi, while service temperature maximums are lower than 100 °C. Acrylics are also not as flexible as epoxies or urethanes, meaning acrylic bonds are more vulnerable to dynamic loads.

### *Urethane Adhesives*

Urethanes are proficient at bonding plastics and dissimilar materials, including metal-to-plastic and metal-to-glass, and can be engineered to provide exceptional durability. Urethane structural bonds are flexible and resilient to vibration, shock, and impact. Such adhesives come in a variety of shear strengths, even up to 5,000 psi. However, urethanes are not easy to integrate into complex processing lines, as they take a long time to fixate (up to 72 hours). Some may take a full week to cure due to lethargic cross-linking reactions. Care needs to be taken in storing and applying urethanes, as moisture and humidity cause the adhesive to harden.

## **Versatile Advantages**

The preeminent advantage of structural adhesive bonding is its ability to bond both high-surface energy substrates (e.g. metals, oxides, ceramics) and low-surface-energy substrates (e.g. rubbers, plastics, composites). Epoxies are best for similar or nearly identical high-surface-energy materials, while urethanes excel at bonding unlike materials. Acrylics supply bonding solutions for any remaining challenges. Acrylics can even bond extremely low-surface-energy materials including many grades of polypropylene and polyethylene. Henkel Loctite's 3035 polyolefin bonder is an example of a high-performance structural adhesive that bonds low-surface-energy materials.

Process engineers appreciate the efficiencies offered by structural adhesives. They are easy to apply to substrates and consume less time than installing fasteners or creating welds. The process can save time by enlisting custom packaging solutions to eliminate on-floor mixing and measuring, which reduces time and increases productivity.



The use of structural adhesives in truck trailer assembly allows for a lighter, customizable, more aesthetically pleasing trailer.



Adhesives also require minimal preparation when dealing with metal or plastic substrates. Surface cleaning is as simple as a wipe with isopropyl alcohol. Aluminum oxidizes rapidly, but a chromate primer or anodization can prevent corrosion. Hard-to-bond plastics can have their wettability improved by a primer, plasma or corona flame treatment, or by simple abrasion.

Also notable are the improved aesthetics and decreased noise offered by structural adhesives. Instead of protruding hardware, surface recesses to hide fastener heads, or seams from welding, structural bonds provide clean lines that are easy to paint or decal over. Fastened or welded materials also have a tendency to rattle, a non-issue with adhesives.

The disadvantages of structural adhesives are limited. Structural bonds are meant to be permanent, so reworking cured assemblies is nearly impossible, but there are exceptions. Most adhesives emit vapors, so ventilation or respiratory protection is required. Some products may irritate the skin and demand careful application techniques. But there is no risk of burns, like with welding, or getting items caught in machinery, as with fasteners.

Addressing structural challenges begins with an understanding of the options available for fastening composite, metal and plastic assemblies, and considering alternate manufacturing methods. Compared to traditional rivets and welds, structural adhesives eliminate the costs related to metal preparation and finishing operations, providing efficiencies in the manufacturing process.



Structural adhesive bonding can be found in many applications such as automotive (including RV & bus), shipping container, door, window & architectural cladding assembly.

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