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Structural Bonding: The Hidden Costs of “Instant” Assembly

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To manufacturers, time is money. Their ultimate goal is to make the manufacturing processes better, faster and more cost effective while preserving the integrity of the assembly process and the quality of the end product.

For a range of structural assembly applications, traditional fastening methods like rivets, screws, welds and double sided tapes offer manufacturers and assemblers one major benefit – instant fixture. Some manufacturers actually avoid using liquid adhesives because of the time required for an adhesive to fixture before the assembly can be moved on to the next processing step.

While liquid adhesives are available in a range of technologies with widely varying cure times from seconds to hours, they all require a cure process. This article will explain the costs associated with adhesive assembly and compare them to the overall costs of instant assembly techniques. Although unknown to many, instant assembly methods involve hidden costs -- for example, skilled labor required for welding, labor and time needed to apply screws or rivets, and the surface preparation and scrap associated with double-sided tapes.

Assembly Methods

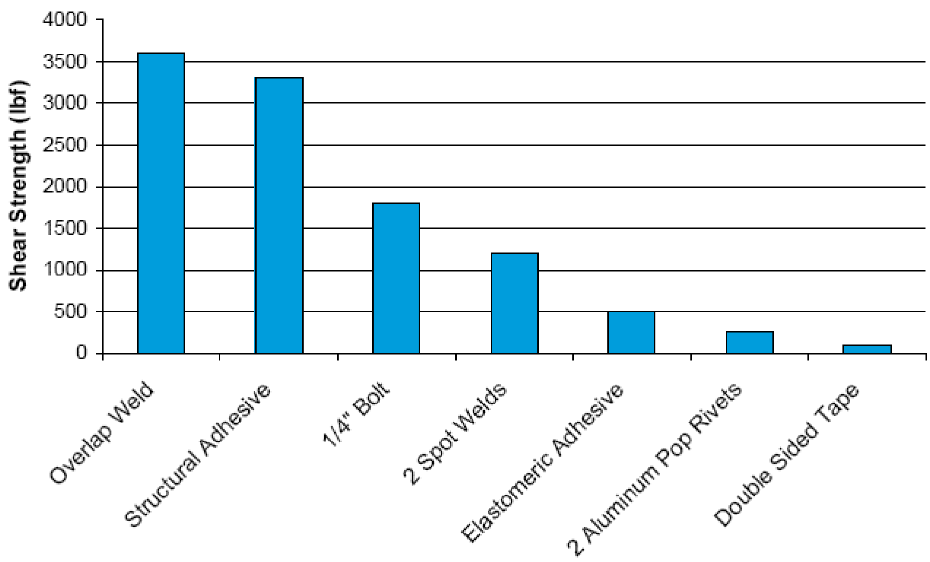
Four major assembly methods exist in today's manufacturing environment:

- Thermal methods such as spot- or overlap-welding*
- Mechanical fasteners such as bolts, screws, or rivets*
- Double-sided tapes*
- Liquid adhesives

** - Considered "Instant" assembly methods*

The first three assembly methods on the list above are considered "instant" assembly methods. All four of these methods are used with varying degrees of effectiveness depending on the final application, end use requirements, and environmental constraints such as weather, moisture, salt or chemicals. Figure 1 shows an overview of the shear strength performance over a one square inch fastening area for these assembly methods.

FIGURE 1: Shear Strength for Various Assembly Methods



As shown in this figure, overlap welds and structural adhesives are the strongest assembly methods available. Strength drops off dramatically using bolts, spot welds, flexible adhesives, pop rivets and double-sided adhesive tape. For some applications double-sided tape may provide adequate strength, but for all applications a blend of adequate strength and lowest overall cost is the target.

In many industries, structural adhesives are replacing or augmenting instant assembly methods because they can lower production costs, improve product performance and aesthetics, and reduce overall assembly time requirements.

Adhesives offer many benefits over mechanical and thermal methods of assembly. Adhesives distribute stress load evenly over a broad area, reducing stress on a joint. Adhesives are applied inside the joint and are nearly invisible within the assembly. They can resist flex and vibrational stresses, and will form a seal as well as a bond to protect joints from corrosion. Some adhesives can fill large gaps. They join irregularly shaped surfaces more easily than mechanical or thermal fastening, minimally increase the weight of an assembly, create virtually no change in part dimensions or geometry, and quickly and easily bond dissimilar substrates and heat sensitive materials.

Since adhesives are liquids prior to curing, application and assembly can be easily automated. By using the proper equipment to dispense the appropriate amount of adhesive and cure it completely, manufacturers can achieve a very strong end product that has an aesthetically pleasing, neat appearance. Bonding requires fewer skilled workers and can be up to twenty times faster than welding. Structural adhesives do not distort metals or require rework of the metal after application, a significant advantage over the grinding and abrading required to generate a smooth welded finish.

Adhesives do have several limitations. They must achieve handling strength prior to moving an assembly, a process that can take from seconds to hours. While the adhesive is achieving fixture or handling strength, temporary mechanical fasteners can be used to provide support and move the assembly process forward. Adhesives cannot be easily disassembled for rework, repair or upgrades, and add to the number of chemicals used within the plant environment.

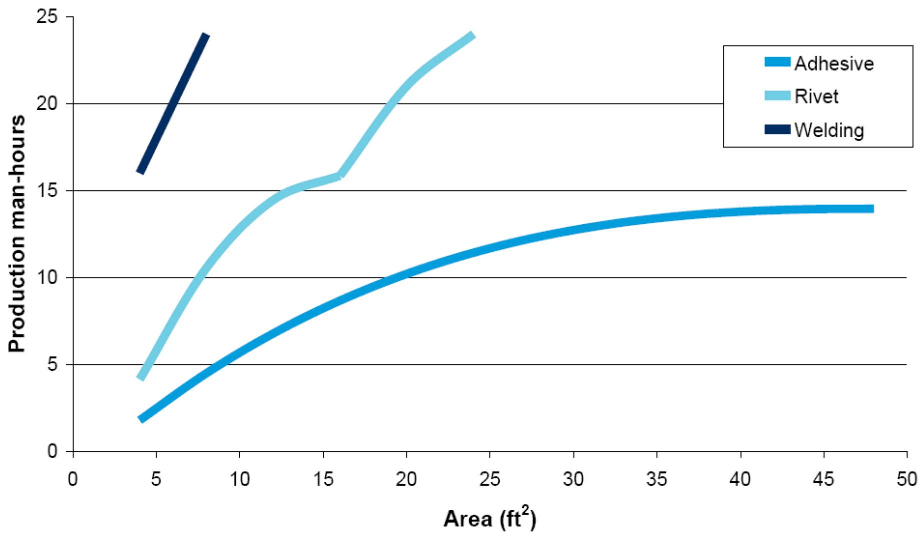
The True Costs of Thermal Joining

Once a welding process is completed, the resulting assembly is immediately at full strength. Thermal joining is widely acknowledged as an expensive assembly process that requires specialized, skilled labor and extensive time depending upon the size of the weld area. In addition, manufacturers must also consider other costs involved such as equipment, filler metals, gas, energy, and the time it takes to complete the welding process.

Welded joints are often non-uniform and lack the clean aesthetics desired for high end applications. When welding is completed, most joints must be cleaned up, a time-consuming process where weld seams are ground and polished to meet aesthetic requirements. To reduce the time involved with welding, manufacturers may choose stitch or spot welds, but will sacrifice some strength and still must invest the time in cleanup. Welded parts are also very difficult to disassemble.

Figure 2 compares man-hours per square foot involved with three assembly methods: welding, mechanical fastening and liquid structural adhesives. This graph shows that both welding and mechanical fastening are manual processes where man-hours dramatically increase as square footage increases. In short, the more area that needs to be covered, the longer and more costly these processes are.

FIGURE 2: Man-hours vs. Assembled Area for Various Fastening Methods



SOURCE: Cagle, C.V., Adhesive Bonding Techniques and Applications, 1968

As adhesives can be easily applied using automated equipment, application time levels off when larger areas are bonded. Adhesives must be applied in the correct location and in sufficient amounts to fill gaps between the bonded surfaces. Labor and clean up are minimal, and adhesives deliver nearly the same bond strength as overlap welding and substantially greater strength than mechanical fasteners.
As shown in Figure 1, adhesives perform very similarly to welds, with less than a 10% difference in shear strength performance and in many cases offer a significant cost advantage by eliminating the need for highly specialized labor and costly rework.

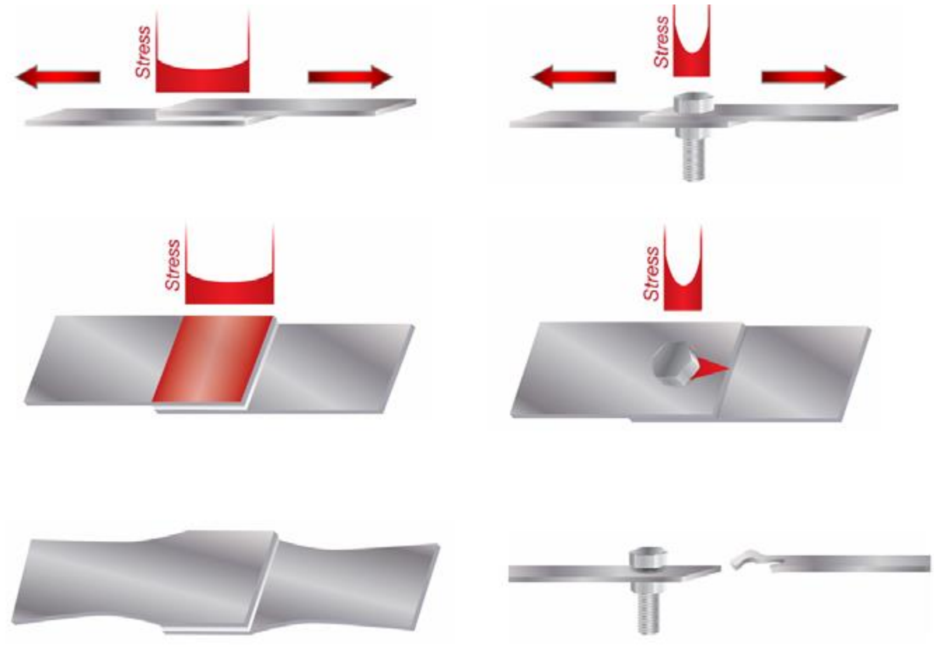
The True Costs of Mechanical Fastening

Assembly with mechanical fasteners such as bolts, rivets and screws is also considered to be immediate. However, all mechanical methods of assembly are expensive, requiring labor to drill holes and insert fasteners. Manufacturers must keep an extensive inventory of fasteners on hand, and assembly with fasteners is time consuming.

Fasteners do not distribute load over the full area of attachment; rather, they concentrate stress at the fastener site. This concentrated stress often results in substrate failure just above the fastener hole or failure of the fastener itself. Both fasteners and thermal joining can cause premature joint failure and may have difficulty withstanding stresses caused by flex or vibration.

Figure 3 illustrates distribution of stress, often an overlooked concept in the fundamental design process.

Figure 3: Distribution of Shear Stress on a Bonded (left) vs. Bolted (right) Joint



On the left had side is the bonded joint with the red arrows representing the shear force applied. The leading edge of the joint has slightly elevated stress than the middle but the overall force is distributed across the entire bond area, spreading out the load. In many cases this can lead to “necking” or stretching of the substrate as illustrated in the bottom left image. On the right hand side is the bolted joint, again with the shear stress represented by the red arrows. In this instance the entire force applied to the joint is concentrated on the bolt. This concentration of stress leads to failure of the joint at approximately half the final strength of the bonded assembly. In addition, the holes drilled for fasteners can create leak paths, a starting point for corrosion. The fasteners may detract from the visual aesthetics of the end product as they are very difficult to cover up.

The True Costs of Double-Sided Tapes

While double-sided adhesive tapes are not considered a high strength assembly method, they do deliver an instant bond. Application of double sided adhesives tape is a multi-step process, as illustrated in Table 1, which compares the processing steps required for liquid adhesives and double-sided tapes.

Table 1 – Typical Suggested Application Steps

Adhesives	Double Sided Tape
1. Clean the substrate using solvents or IPA*	1. Clean the substrate using solvents or IPA
2. Wipe dry*	2. Wipe dry
3. Apply adhesive	3. Cut tape to appropriate length
4. Mate surfaces and clamp until fixtured	4. Apply tape to panel surface

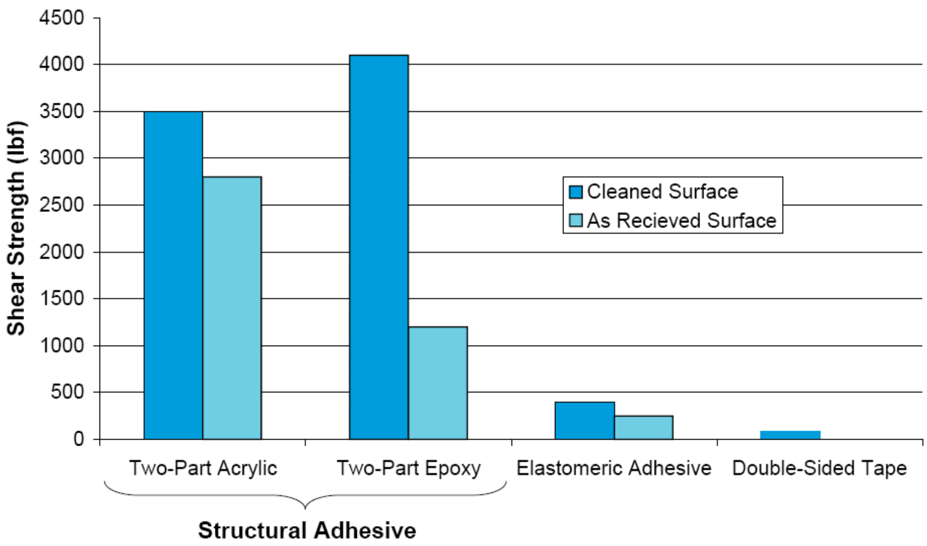
	5. Peel backing from tape and mate the two surfaces
	6. Roll the finished joint ensuring you apply 15 psi of pressure to the double sided tape

** - Can be skipped based on strength evaluation on as received parts*

As illustrated in Table 1, double-sided tape application requires two additional processing steps and takes approximately 20% more time than liquid adhesive application.

Double-sided tapes require complete removal of surface contaminants if performance is not to suffer. Figure 4 illustrates the effect of surface contamination on performance for structural adhesives, flexible adhesives and double-sided tapes. While contamination does result in a drop in strength with structural adhesives, they drastically outperform double-sided tapes even on clean surfaces. Double sided tapes display a complete performance failure when used on oily surfaces.

FIGURE 4: Shear Strength on Cleaned vs. As Received Steel

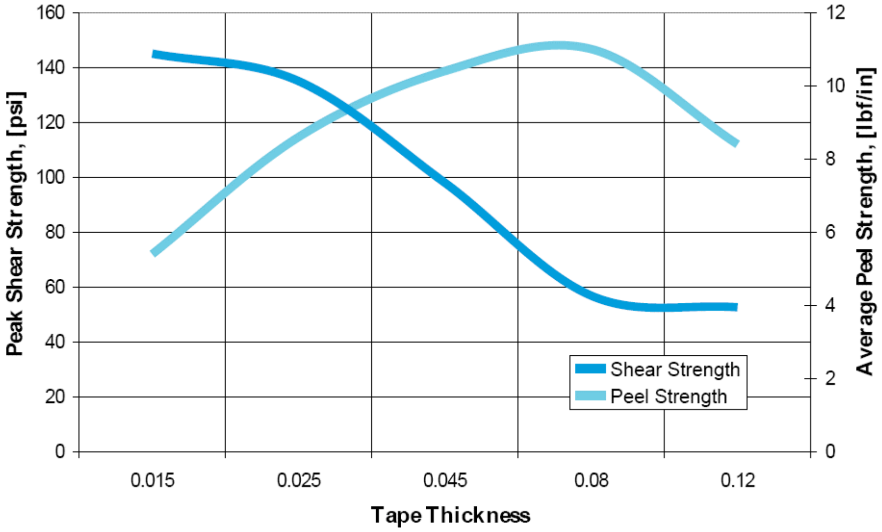


All of the three liquid adhesives tested were able to penetrate through the oils and contamination to some extent and gain adhesion to the substrate. The double-sided tape, however, is separated from the substrate by the contamination and completely loses all shear strength. Tapes absolutely require thorough surface cleaning, a step that contributes added time and cost to their use while in some cases adhesives can be used on as received parts if the small drop in performance is not critical for the desired application.

Once applied, double-sided tape cannot be adjusted. If adjustments are necessary, the user must completely re-work the part. Liquid structural adhesives are available with a variety of “work life” options that allow the manufacturer to adjust the assembly for a specified period of time. Assemblies manufactured with most liquid structural adhesives must be clamped until work life ends and the fixture time is reached. When clamping is not feasible, there are liquid adhesives that are thick enough to hold parts together at the time of assembly. These products allow the functional benefit of instant fixture while allowing repositioning.

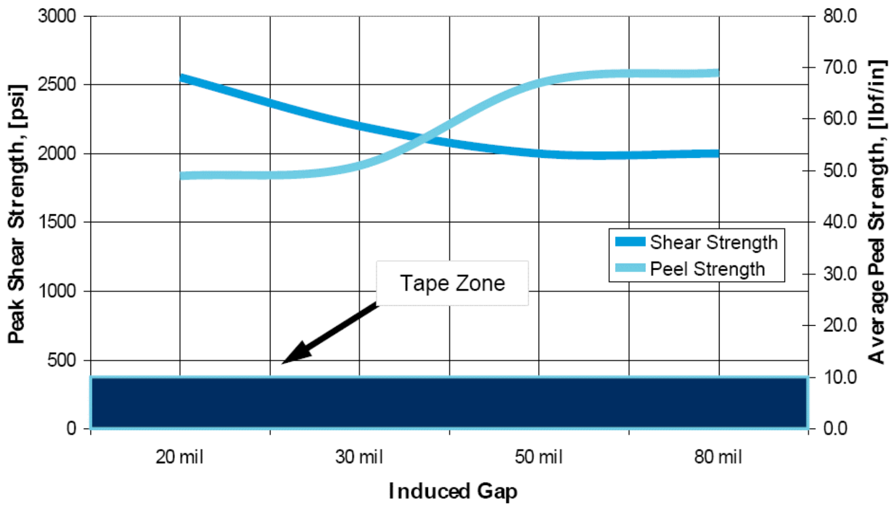
For filling large gaps, tapes are offered in a variety of thicknesses and can be an effective assembly option if gap width is consistent. As gap increases, the shear strength of a double sided tape can drop more than 50%, but peel strength can increase by approximately 100%. In order to maximize shear and peel strength, Figure 5 shows that tape thickness should be approximately 0.030”.

Figure 5: Effect of Varying Tape Thickness on Shear and Peel Strength of Double-Sided Tape



Liquid structural adhesives have a similar relationship which can be seen in figure 6, but the drop in shear strength with widening gaps is not as drastic (approximately 15%). Liquid adhesives offer an 80% increase in peel strength as gap increases, and shear strength is almost 20 times greater. The peel strength values were 10 times higher in some cases. Since structural adhesives are so strong, the effect of gap is not a major consideration when designing an

Figure 6: Effect of Varying Induced Gap on Shear and Peel Strength of Structural Adhesives



assembly but should be considered more carefully when using double-sided tapes.

Double-sided tapes require significant surface preparation and labor in order to obtain consistent adhesion. Even with this surface preparation, double-sided tapes have the lowest strength of any assembly method evaluated.

Current Assembly Applications with Structural Adhesives

Structural adhesives are excellent alternatives for bonding metal, plastics, and composites. Recent advances in structural adhesive technology have dramatically expanded the scope of potential bonding applications to include even hard-to-bond substrates such as galvanized steel and polyolefins like polyethylene and polypropylene.

On specialty vehicles such as trailers, truck bodies, buses and construction equipment, structural adhesives are used to assemble frames, panels, booms, and cabs made of metal, plastic and composites. In moist end use environments such as tubs and spas, these adhesives attach galvanized steel frames to fiberglass and ABS tubs. Commercial furniture manufacturers bond plain, painted or powder coated metals and plastics in chair, desk, and cabinet assembly. On signs and displays exposed to environmental elements, adhesives attach metals, plastics and composites, creating a unique appearance for the customer.

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