Structural Adhesive Bonding

This guide is an attempt to highlight the factors, discipline and detail that should be followed to ensure the highest level of performance when using LORD® Structural Adhesives.

LORD Structural Adhesives Chemistries

In general, acrylics excel at bonding unprepared metals, composites and thermoplastics. Urethanes offer resiliency and flexibility, and are candidates for joining composites, thermoplastics, natural materials and prepared metals. Epoxies give the highest strengths when bonding prepared metals, composites, thermoplastics and natural substrates such as wood.

Structural adhesives are thermoset polymers. They will not melt or change with environmental exposure, temperature or time. Acrylics and epoxies can withstand temperatures from -40°F to +400°F. Most urethanes are good up to 250°F with a low end slightly better than the others. Exposure to water, humidity, oil, gasoline, solvents, and other environmental factors won't weaken bond strength in properly designed joints.

Packaging

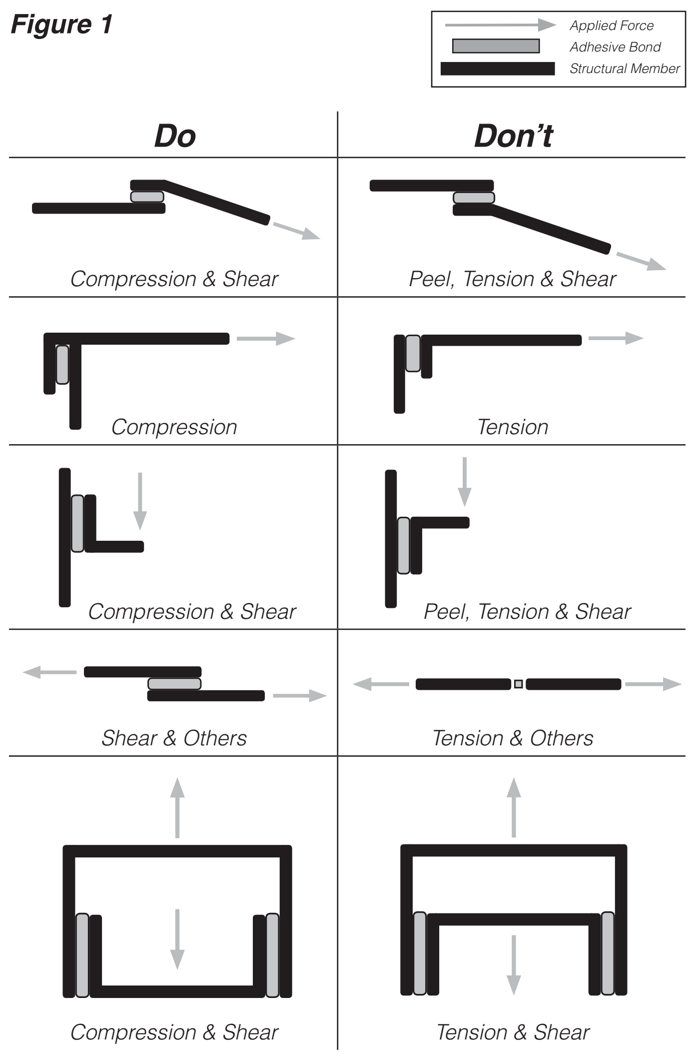
LORD Structural Adhesives are formulated to improve manufacturing processes and final products for a variety of composite, metal and plastic assemblies. For your convenience, LORD adhesives are available in convenience cartridge packaging to bulk packaging that includes gallons, pails, drums and totes for high volume applications. For higher volume production, LORD can provide Systems Engineering Expertise:

- Production process design and optimization
- Fixturing and joint design
- Meter mix dispense expertise

General Guidelines for Adhesive-Bonded Joint Design

Joint configuration should be designed so that the basic stress is primarily shear, tensile or compressive with cleavage and peel stresses minimized on the bond line. Joints should be designed so that all of the bonded area equally shares the load. Illustrations provided depict both recommended joint design alternatives and joint designs to be avoided (refer to Figure 1).

Figure 1



Lap Joints

Lap joints are the most practical design and applicable in bonding thin materials. Lap joints are used to enhance joint strength by reducing its potential to peel stress.

Butt Joints

In tension, the straight butt joint is impractical for load bearing assemblies. To minimize this stress, the angle design applies compression. Compressive loading will not affect the joint unless bucking of the vertical component occurs.

Substrate Surface Preparation

The amount of surface preparation required for good bonding will depend upon both the substrate and the adhesive that is used. In general, obvious dirt and loose particles should be removed from the bond surface with a clean, dry rag. Using compressed shop air to blow off parts is not recommended, since shop air usually contains water from condensation and oil from the compressor that can contaminate the bond surface. Avoid handling the bond area after the surface has been prepared. Dirty hands/gloves, soap, mold release, grease, etc. can contaminate the surface and potentially lead to poor adhesion.

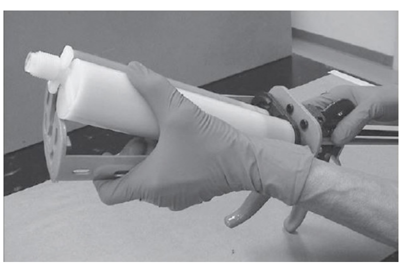
Prior to adhesive application, remove soils, greases, oils, dust, mold release agents, rust and other contaminants from substrate surface with the use of a vapor-free solvent, such as MEK, acetone or isopropyl alcohol.

- Plastics – Clean the surface with a dry rag or dampened solvent rag.
- Metals – Prime, paint or grit blast, followed by solvent wash for optimum bond performance.

Preparing Convenience Cartridges for Use - Purge and Run Adhesive

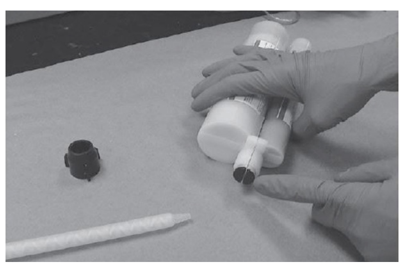
Below are best practices on preparing two-part adhesive and seam sealer cartridges for optimum bonding results (refer to Figures 2-7). The static mix tip may generally be left attached to the cartridge if the entire cartridge is not used. The cured adhesive in the tip will act as a cap. However, it is possible in some cases that mixed, cured adhesive will block the nose of the cartridge, so best practice is to remove the static mix tip and replace the original plastic plug(s) — taking care to match the proper sides — for longer-term storage.

Figure 2



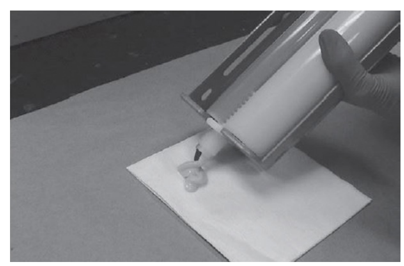
Insert the cartridge into the dispensing gun with the proper mix ratio set up.

Figure 3



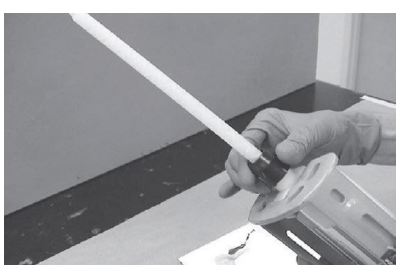
Remove any caps and plugs.

Figure 4



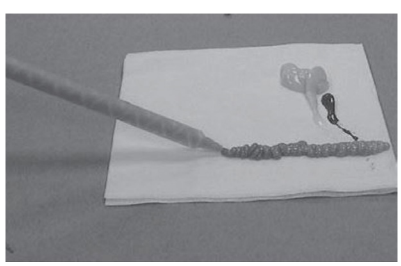
Level the plungers by applying pressure to the gun until both sides of the material flow through the openings in the cartridge.

Figure 5



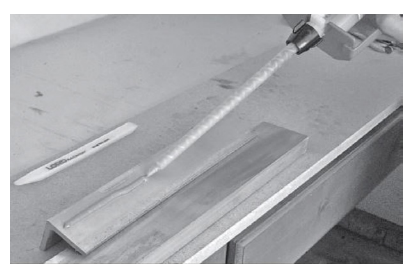
Attach the mix tip.

Figure 6



Apply pressure to the gun, forcing the material through the mix tip. Run out a mixer's length of adhesive on scrap material to ensure a complete mix.

Figure 7



Position and dispense adhesive.

Preparing Bond Area

Structural adhesives work best at a very thin, controlled bond thickness (10 to 20 mils), and they sometimes contain glass bead "spacers" to set this bond gap. Prior to dispensing the bead, attempt to remove any scrap material from the substrate such as protruding burrs, welds, or other irregularities that would prevent the two bonding surfaces from lying flat on top of one another. Apply adhesive in a continuous bead in the desired locations, taking care that the dispensed pattern will not cause air to be trapped in the bondline when the substrates are mated. A single adhesive bead dispensed in the center of the bond area is generally preferred.

Estimating Material Coverage

The bead diameter should be predetermined based upon the desired final bondline width and thickness. Table 1 can be used as a guide for sizing the adhesive bead diameter.

Note: These bead diameters will yield an excess of 10 percent in case of irregularities in the surface.

Engagement area is critical to adhesive performance, so it is important to apply enough adhesive to fill the designed joint. Insufficient adhesive quantity, or introduction of air into the adhesive, will cause a reduction in bond strength and a characteristic pattern known as "spider webbing" (the pattern is visible when parts are disassembled). This problem can also be caused by insufficient or ineffective clamping, as detailed in the section following.

Refer to Table 2 for estimated linear foot coverage based on cartridge size and bead diameter.

Figure 8

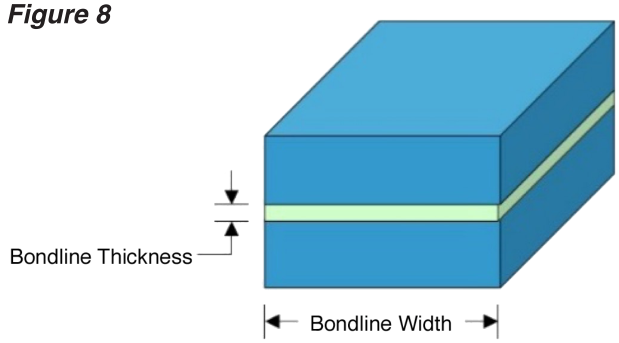


Table 1 – Bead Diameter Estimator – inches (cm)

Required Bead Diameter: Use the table below to determine the required bead diameter from the dimensions of the adhesive joint.

		Bondline Width - in (cm)					
		0.25 (0.6)	**0.50 (1.8)**	**1.0 (2.5)**	**2.0 (5.1)**	**4.0 (10.2)**	**8.0 (20.3)**
Bondline Thickness in (mm)	**0.01 (0.25)**	0.01 (0.25)	0.08 (0.20)	0.11 (0.29)	0.16 (0.41)	0.23 (0.57)	0.32 (0.81)
	0.02 (0.5)	0.02 (0.5)	0.11 (0.29)	0.16 (0.41)	0.23 (0.57)	0.32 (0.81)	0.45 (1.15)
	0.04 (1.0)	0.04 (1.0)	0.16 (0.41)	0.23 (0.57)	0.32 (0.81)	0.45 (1.15)	0.64 (1.62)
	0.08 (2.0)	0.08 (2.0)	0.23 (0.57)	0.32 (0.81)	0.45 (1.15)	0.64 (1.62)	0.90 (2.29)

Table 2 – Bead Length Estimator – feet (m)

Linear Coverage: Use the table below to determine the length of adhesive bead that can be obtained from a cartridge of adhesives.

		Bead Diameter - in (cm)					
		0.125 (0.30)	**0.188 (0.48)**	**0.250 (0.60)**	**0.313 (0.80)**	**0.375 (0.95)**	**0.500 (1.30)**
Cartridge Volume mL	**40**	17 (5.00)	7.4 (2.20)	4.1 (1.30)	2.7 (0.80)	1.8 (0.60)	1.0 (0.30)
	50	21 (6.30)	9.2 (2.80)	5.2 (1.60)	3.3 (1.00)	2.3 (0.70)	1.3 (0.40)
	200	83 (25.20)	37 (11.20)	21 (6.30)	13 (4.00)	9 (2.80)	5.2 (1.60)
	375	155 (47.20)	69 (21.00)	39 (11.80)	25 (7.60)	17 (5.20)	10 (3.10)
	400	166 (50.40)	74 (22.40)	41 (12.60)	27 (8.10)	18 (5.60)	10 (3.10)
	485	201 (61.10)	89 (27.20)	50 (15.30)	32 (9.80)	22 (6.80)	13 (3.80)
	600	249 (75.60)	111 (33.60)	62 (18.70)	40 (12.10)	28 (8.40)	16 (4.70)

Open Time/Working Time

Open Time is the amount of time from when the adhesive starts to travel down the static mix tip until the parts must be mated in order to deliver the specified bonding performance. Working Time is often used synonymously with Open Time, but working time can also refer to the time after the substrates are mated and can still be (slightly) re-positioned relative to each other.

It is important to work quickly to mate parts before the adhesive Open Time expires. Knowledge of the estimated Open Time or Working Time is particularly important when bonding large parts that have long adhesive bead lengths, and during periods of higher than normal temperatures within the production facility. Higher temperatures will generally reduce Open Times due to acceleration of the cure. In general, Open Time can be estimated by the hardness of the dispensed adhesive bead. If the adhesive bead cannot be readily compressed and spread, it has most likely passed beyond its Open Time. However, epoxy adhesives can have an additional condition referred to as “blushing,” which can limit their Open Time without any indication of bead hardening. When the working time is exceeded, the adhesive will no longer wet out on one of the surfaces to be bonded. This will generally cause a reduced bond strength and be visible as a shiny, very smooth surface on the adhesive after disassembling the bonded parts, in contrast to the rough surface generated with good, cohesive failure. The technical data sheet for each adhesive should contain specific information related to Open Time/Work Time.

Positioning Parts

Place parts in position as gently as possible, watching that the mating process works to eliminate trapping air in the bondline. Avoid applying pressure initially, allowing the clamping system to do this work. After a part has been mated and needs to be moved or repositioned, it is CRITICAL that the substrates are not pulled apart during the manipulation. This introduces air gaps into the adhesive that significantly weaken the bond, and may even prevent the adhesive from curing completely. If a part needs minor repositioning, ALWAYS SLIDE the part to the new position. If a part needs major repositioning, it may be better to separate the substrates, remove the adhesive, and begin the bonding process anew. Sliding the part over a long distance may scrape all of the adhesive out from the intended bond area and result in poor bonding.

Clamping Parts

Parts should be positioned and clamped within the working time of the adhesive. Apply uniform pressure to the joint as soon as possible after mating the parts, spreading the adhesive bead and compressing it to the desired thickness. While clamping, special care should be taken to avoid “levering” the parts, causing the bond to separate on the opposite end. Uniform pressure (pressure spread out over the length of the bondline) is very important, especially when working with thin gauge or non-uniform parts. Effective methods for applying uniform pressure can include:

- Pre-built fixtures, which provide the most reproducible results.
- Multiple clamps or weights on spreader bars, which can be used on large parts when fixturing is not available. A spreader bar is a stiff material, often steel or aluminum channel or angle, which is clamped at several locations over the bondline
- Standalone clamps or weights may be used on small parts, or when the mated parts are stiff enough to not need spreader bars.

Immediately after the parts are positioned correctly, they must be weighted with even pressure until handling strength is achieved. Some of the means typically used to accomplish this are clamps, boards/stiffeners, weights, mechanical fasteners or braces.

- Maintain even pressure across the assembly (refer to Figure 9). Avoid applying pressure in areas that allow the assembly to “bow.”
- Boards can be used to apply even pressure across the bondline on flat assemblies (refer to Figure 10). Weight bonded assemblies with sand bags, bean bags or other formable materials to distribute weight evenly.
- Mechanical fasteners (screws, rivets, bolts) can be used to fixture particularly difficult-to-clamp areas and can be removed after handling strength is achieved (refer to Figure 11).
- Braces can be used to hold odd-shapes in place while curing (refer to Figure 12).

Clamping Time

Bonded parts should remain clamped until the Handling Time of the adhesive has passed. Handling Time is an estimate of the amount of time required from when the adhesive starts to travel down the static mixing tip until the adhesive has cured enough to ensure the bonded parts will not shift when handled (roughly 50-100 psi bond strength). Handling Time is usually dependent upon cure temperature, and can also vary based upon factors such as the amount of adhesive applied, the bondline thickness, the type of substrates being bonded, and environmental factors such as humidity. The technical data sheet for each adhesive contains specific information related to Handling Time.

Figure 9 – Clamps

Figure 10 – Boards & Stiffeners

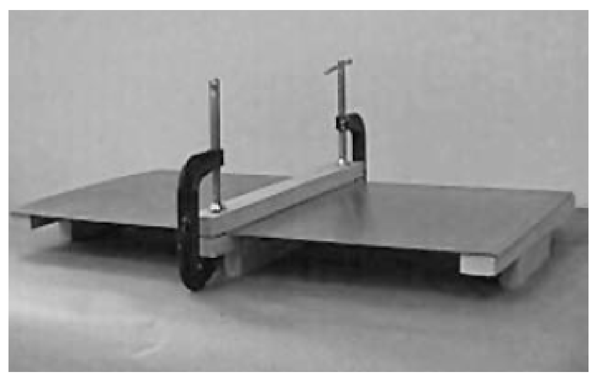
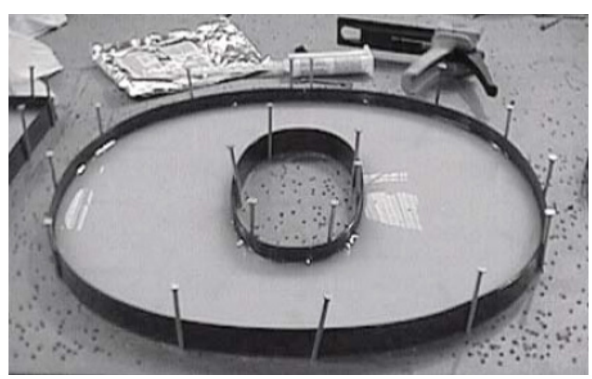


Figure 11 – Mechanical Fasteners

Figure 12 – Braces



De-roping Adhesive

Excess adhesive that is squeezed out at the seams between mated parts may be removed (after it has gelled or partially cured at room temperature) by scraping it off with a putty knife. This de-roping process can also be used with a heat curing process, scraping off the excess adhesive while it is still hot enough to remain soft. Solvents such as isopropyl alcohol or acetone can be used to remove smears or adhesive residue left behind by the de-roping process.

Adhesive Removal

If substrates are accidentally pulled apart or need major repositioning after the adhesive is applied, the adhesive should be removed and the bonding process restarted. The process for doing this is outlined to the right.

1. Use a plastic putty knife to scrape off the adhesive. If this proves difficult because the adhesive has begun to cure, a heat gun can be used to soften the adhesive while scraping.
2. Wipe off the bond area using a clean cloth and isopropyl alcohol solvent. Acetone can be used as an alternative solvent, and can sometimes be more effective in removing adhesive residue.
3. Repeat the bonding process.

Bonded Part Removal

If for some reason, bonded parts must be separated after the adhesive has fully cured, a heat gun may be used to soften the adhesive. It may be helpful to remember that adhesives are generally stronger in tension or shear, and parts can be separated more easily if pulled apart with a peel load.

Ideal Failure

When bonded parts are separated, the residue pattern from failure of the cured adhesive, in addition to the bond strength, can be used to diagnose the quality of the bond. The preferred method of failure for adhesive joints is cohesive failure (COH), which can be identified by the residue of adhesive left on both substrates. Cohesive failure mode indicates excellent adhesion to the substrates, with the residue divided evenly (COH) or unevenly (Thin Layer Cohesive, or TLC) between the failed surfaces. This can be contrasted with undesirable adhesive failure (ADH), which is characterized by a clean, usually shiny surface exposed on one of the two separated substrates. The ability to gain both high strength and ideal failure mode will depend upon appropriately matching the correct adhesive with the substrate to be bonded, and following the user guidelines detailed above.

Powder Coating after Bonding with LORD Acrylic Adhesives

Note: Clamp or fixture the assembly prior to powder coating to avoid slippage during the powder coating process. The assembly should remain fixtured until the adhesive returns to room temperature and re-hardens.

The LORD® 400, Maxlok™, and 800 series acrylic adhesives have excellent heat resistance characteristics up to 400°F (204°C), thus reducing the concern of possible degradation of the cured adhesive during the high heat associated with the powder coating process.

LORD acrylic adhesives will not degrade at the higher temperatures associated with powder coating. However, the hot tear strengths will be very low, causing the assembly to possibly sag and slide apart — especially if the assemblies are heavy. The lower strength values make it essential that the assembly is properly fixtured or placed to avoid slippage of the bonded pieces.

Spot welds or other type of mechanical fixturing are frequently used in the industry to aid in holding the assembly in place. The area to be bonded can also be masked off the assembly prior to powder coating with bonding done after the process.

The integrity of the bond will remain unchanged after powder coating, and greater strength is often seen after exposure to heat once the assemblies have been returned to ambient temperature.

To request the complete instructions, LORD Technical Tips: Powder Coating after Bonding with LORD Acrylic

How to Avoid Bondline Read-Through

Read-through is a condition where you can see the footprint of the adhesive through the material. This is caused by shrinkage that results in a pull on the bonded materials. Read-through can occur on surfaces that are high gloss, high polish or have a mirrored finish. Thin gauge metals less than 0.030 inches are more susceptible to read-through.

LORD 810/20GB Low Read-Through (LRT) acrylic adhesive is a flexible adhesive system specifically designed for bonding metals, such as aluminum, galvanized steel and CRS, and engineered plastics, such as PC-ABS and ASA. LORD 810/20GB adhesive delivers fast cure speed and strong bonding with minimal bondline read-through (BLRT).

The following are some application tips to help you avoid read-through:

- Maintain a thin and consistent bondline of 0.010 inches (10 mils)
- Remove squeeze out
- Weight the bondline appropriately to ensure full surface contact between the materials being bonded, thereby avoiding gaps in the bondline