Structural adhesives offer high strength, creep resistance, and reduced weight as reasons for replacing mechanical or fusion fastening.

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From automotive bumpers to disk drive components, bicycle frames to air/fuel breather valves, plastic railings to refrigeration coils, structural adhesives are available for thousands of manufacturing applications. With ongoing advances in adhesive formulation, designers in every industry have diverse options for bonding metal, composites, plastics, rubber, glass, and more. A wide choice of epoxies, acrylics, and urethanes enable design engineers to more easily achieve the right balance of strength, heat resistance, and productivity.

This article describes epoxy, acrylic, and urethane structural adhesives, including their strength, heat properties, creep resistance, and the most appropriate applications.

Advantages of structural adhesives
In general, these structural adhesives have enough cohesive strength and creep resistance to permanently bond high-strength materials, and they have the potential to replace mechanical and fusion fastening in many applications. Practical bond strength is at least 1000 psi in overlap shear at 75°F (24°C). (Less than 1000 psi in overlap shear is generally considered too low for structural bonding.)

Beyond having the load-bearing strength to do the job, structural adhesives offer other styling, performance, and production reasons for replacing mechanical or fusion fastening.

- **Distribute stress over the entire bonded area:** The concentrated stress of rivets, bolts, spot welds, and similar fastening techniques is eliminated. A design engineer can specify lighter, thinner materials without sacrificing strength.
- **Bond dissimilar materials:** Laminates of dissimilar material can often produce combinations superior in strength and performance to either material alone. Adhesive flexibility compensates for different coefficients of expansion between substrates such as aluminum and glass, for example. Adhesives also provide a film barrier to reduce or prevent bimetallic corrosion between different metals.
- **Maintain the integrity of assembled substrates:** Mechanical fastener holes are eliminated, as are surface marks from spot welding and brazing. With this virtually invisible fastening, an engineer has greater design latitude, cleaner lines for improved end-user appeal, and less machining or finishing.
- **Maximize fatigue resistance:** Adhesive flexibility permits high extension and recovery under repeated loading. Energy absorption properties provide up to 20 times the fatigue resistance of riveted or spot-welded assemblies.
- **Bond and seal against the environment:** Structural adhesives fill voids and gaps and can effectively bond many loose-fitting parts. Continuous contact between mating surfaces effectively seals against many contaminants.
- **Reduce cost and increase production:** Several factors combine for savings and productivity: reduced material requirements, weight reduction, fewer assembly and finishing steps, minimal training. With modern adhesives, usually no solvents need to be vented.

Choosing the right adhesive
Taking full advantage of structural adhesives requires consideration of the substrate, the part design, production requirements, and end-use environment. You also need an understanding of the various types of adhesives and their characteristics. The first question to ask is, "What can structural adhesives do for me?" If you find satisfactory an-
When to select an epoxy

Comprising the largest family of structural adhesives, epoxy resin typically provides the highest strength and elevated-temperature resistance of all structural adhesives. You can select pastes or films with a wide range of application options to help match the adhesive to a manufacturing process. For example, epoxy formulations are available to fit into an existing paint/bake cycle or into an ambient temperature multi-station operation.

- **Epoxy paste adhesives** include one-part heat curing and two-part room-temperature curing formulations. One-part heat curing epoxies provide higher overlap shear strength and temperature resistance than typically possible with room-temperature-curing epoxies. One formulation, for example, exhibits shear strength of 5000 psi at room temperature. With another formulation, shear strength is 1200 psi at 350°F (177°C).

  While the adhesive cures, parts must be held with clamps, pressure pads, or other fixturing methods to apply constant and uniform pressure. Curing time ranges from 30 to 120 minutes in hot air ovens, or with heated platens, UV lamps, or other heat sources.

  Two-part room-temperature curing epoxies eliminate ovens and heaters and offer a worklife ranging from 4 to 120 minutes. For curing, a base resin and curing agent are precisely weighed and mixed just prior to application. These epoxies may be applied with spatulas, brushes, or high-volume meter/mix dispensing equipment. As a convenient alternative, many two-part epoxies are available in dual-chamber cartridges for economical hand-held applicators, which simultaneously mix, meter, and dispense the epoxy through a disposable mixing nozzle.

  Two-part epoxies have evolved over three distinct generations, from brittle to flexible to toughened. A toughened epoxy provides greater flexibility than a one-part epoxy adhesive, resulting in very high shear and peel strength combinations. For example, one epoxy provides 4500 psi in overlap shear with a peel strength of 60 pounds per inch width (psiw) on aluminum. In another typical example, toughened epoxy bonds the ABS components of an automobile breather valve. The bond at the inlet port seals in the high pressure air/fuel mixture.

  Recent advances in toughened two-part epoxies have increased worklife options to as long as six hours, with the option to heat cure at any time during the worklife. For assembly of sophisticated electronics, where outgassing and corrosion are concerns, special “clean” epoxy adhesives produce far lower levels of ionic and outgassing impurities than typical epoxies for industrial applications.

- **Epoxy film adhesives** offer several advantages over pastes. Adhesive films can be die-cut into precise shapes that facilitate bonding of complex parts. This keeps the adhesive in the immediate bonding area for clean application and less waste, and thickness is uniform throughout the joint for an even and secure bond line. In general, epoxy film adhesives also offer the best combination of shear and peel strength, as well as shock and fatigue resistance. However, all require fixturing and heat curing.

When to select an acrylic

Consider acrylic for the widest range of substrates, including hard-to-bond plastics and oily metals. Compared with epoxy and urethane, acrylic adhesives have the advantage of curing faster, and they provide high-strength bonds without the surface preparation needed for other adhesives. Depending on formulation and substrate, shear strength reaches 4200 psi, and peel strength reaches 35 psiw.

Acrylics are available as reduction-oxidation (redox) activated and cyanoacrylate adhesives. The oldest redox activated adhesive is the anaerobic adhesive that cures in the absence of oxygen. Thread locking for a nut and bolt is a typical application. Recent advances involve redox couples, more commonly known as two-part formulations.

Low surface-energy plastics, including many grades of polypropylene, polyethylene, and TPOs, are increasingly both popular and problematic for industrial designers. Popular, because of their unique properties and cost saving possibilities. Problematic, because of the challenges in bonding the materials either to themselves or to other surfaces. Some of the latest advances in this arena are acrylic adhesives that bond low surface-energy (LSE) plastics with little or no surface preparation or cleaning required.

Among the most recent advances in acrylic technology are 3M Scotch-Weld Structural Plastic Adhesives DP-8005 and DP-8010. These readily bond polypropylene, TPOs, and other difficult-to-bond low surface energy plastics. They provide high shear and peel strengths while reducing the surface preparation time and cost of traditional adhesives.

Low-odor formulations have also been devel-
oped without compromising performance characteristics. As an example, one low-odor product bonds metal hinges into metal frames of awnings without surface preparation. Handling strength develops in ten minutes, and full cure is in six hours, with overlap shear strength of 4200 psi at 75°F (24°C).

Another problem of acrylic resin for some applications is very low viscosity. However, new formulations are now available with additives to help control flow.

Cyanoacrylate adhesives are unique acrylic formulations with extremely fast reactivity, for almost immediate cures. For many applications, these clear one-part adhesives reach handling strength at room temperature in five to ten seconds, and 80% of full strength in an hour. The adhesives can bond many plastics, rubber, metal, and other materials with tensile strength up to 5000 psi. Some formulations work on problem surfaces where other adhesives may fail, such as bonding EPDM rubber gaskets to metal. Others resist fuels and chemical exposure at temperatures from -40°F to 200°F (-40°C to 93°C), and some feature extended cure rates, providing the ability to reposition the parts.

However, these adhesives do have limitations, such as poor resistance to temperatures over 200°F (93°C), and limited moisture resistance when bonding metals. In addition, porous surfaces must be primed before attempting a bond.

When to select a urethane

Lower cost, two-part structural urethane adhesives are durable and highly elastic for applications requiring energy absorption and flexibility. These properties make them suitable for bonding many dissimilar materials, because they compensate for contraction and expansion between surfaces such as concrete and metal. Overlap shear strength can reach 2500 psi with 25 psiw, but strength usually decreases at elevated temperatures. Applications range from bonding large panels subjected to flexing, to repairing conveyor belts and cracked concrete. Open times from 15 seconds to 60 minutes are available, depending on the specific formulation.

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