

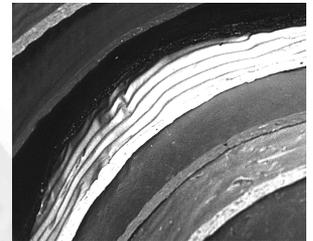


# > structural thermoset compounds and their primary applications

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Markets such as Automotive, Military, Industrial, Electrical, Sports, and Safety are relying increasingly on structural thermoset SMC (sheet molding compound) and structural thermoset BMC (bulk molding compound) to address growing demands for high-performance materials that exhibit both high mechanical strength and low density. Due to the intrinsic limitations of metals and thermoplastics, many designers turn to structural thermoset compounds to provide greater strength, lower coefficients of thermal expansion, and better corrosion resistance than other commonly used materials, while increasing design flexibility and manufacturing efficiency. The strong molecular bonds inherent in thermosets impart a tight web of inner connectivity that allows these materials to maintain excellent structural properties during prolonged exposure to extreme chemical and temperature profiles.

This paper takes an in-depth look at structural thermoset compounds and why structural thermoset SMC is the optimal material for an ever increasing market for high-performance applications. The paper will cover the basic chemistry of thermosets and will detail the unique properties of structural thermosets. The specific characteristics of the two predominant thermoset formulations -- SMC and BMC -- will also be covered, including an examination of the key properties of structural thermoset SMC and BMC that are prompting design engineers and molders to convert their product designs from metal and thermoplastics to structural thermosets. These advantages are highlighted in a discussion of current and potential uses for structural thermoset SMC and BMC. The paper also explains how certain additives imbue thermosets with special properties that allow them to meet specific needs that are not addressed by other materials.



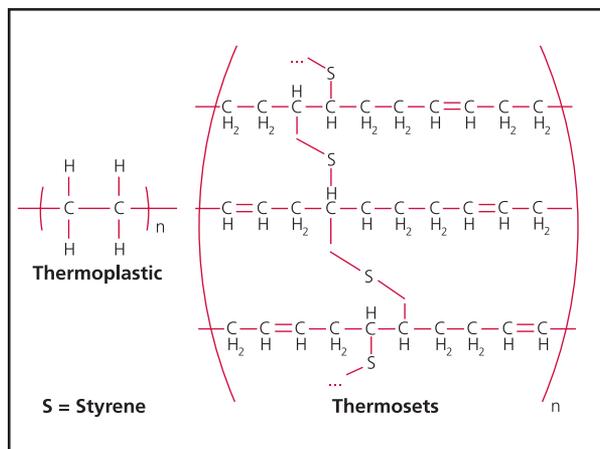
**Thermoset compounds** — properties of BMC and SMC can be altered to create custom formulations. Fiber type, length, and mix proportion help determine properties such as strength and rigidity...

## > thermoset basics

Structural thermosets are distinguished from standard thermosets by the use of more specialized resins combined with higher levels of reinforcement (glass, carbon, aramid, etc.). This combination allows structural thermosets to satisfy unique performance requirements. The added reinforcement provides additional strength and stiffness, while the special resin formulation protects the fibers and helps the thermoset compound achieve its overall properties. These properties can be changed by varying the type and quantity of its ingredients. For example, fiber type, length, and mix proportion would change its flow, strength, and rigidity; varying resin concentration and type would affect the overall strength along with the heat/corrosion resistance of the compound.

Exposure to thermal energy during the molding process for structural thermoset compounds causes the formation of three-dimensional covalent bonds between the polymer molecules. This process, known as cross-linking, is irreversible. Therefore, cross-linked materials cannot be melted and reshaped. The term “thermoset” accurately describes this chemistry. Cross-linking creates a rigid 3D molecular structure that allows thermosets to maintain the desired physical and electrical properties during prolonged exposure to a variety of conditions such as high temperatures. This distinguishes thermosets from thermoplastics, which are generally unsuitable for high-temperature environments because they can be melted after solidification. Thermosets have the advantage of high heat distortion temperatures (HDT) and glass transition temperatures (Tg) that literally melt most thermoplastics.

Three of the most common thermoset resins are polyester, vinyl ester, and epoxy. Each of these resins has its own price and performance characteristics, so selection is based on functional and cost requirements of the application. For example, design engineers might choose vinyl ester resin for corrosion-resistant products, epoxy for high-strength applications, and polyester when good overall performance and cost are the driving factors.



**Figure 1. Depiction of thermoplastic monomer bond and thermoset crosslinked covalent bond.**

As for reinforcement, many types of reinforcement fiber can be used for structural thermosets, depending on the molding process and the product’s strength requirements. Glass reinforcement options include chopped-strand, mat with random fiber orientation, light textile fabrics, heavy woven materials, knitted materials, and uni-directional fabrics. Carbon fiber reinforcement is used for applications that require exceptional strength coupled with severe weight restrictions.



**Figure 2. IDI BMC can be molded in a variety of colors.**

## > structural thermoset SMC and BMC

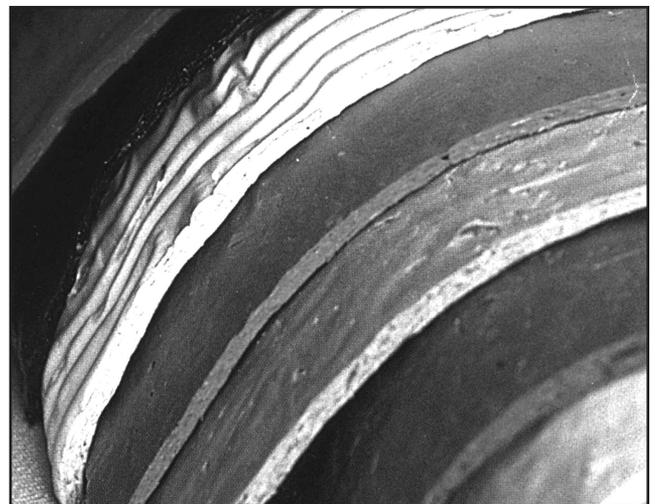
SMC is the primary format for structural thermoset compounds, though some applications require BMC. SMC is a cost-effective, lower weight alternative to many metals. Standard SMC contains 10-30% reinforcement, while structural grades are typically in the 40-65% range. This reinforcement normally consists of chopped-strand glass fibers measuring 1/2-2 inches (12.7mm – 50.8mm) long. For most structural compounds, the fiber level exceeds 40%, due to the type of applications in which they are found.

Structural thermoset SMC manufacturing is a continuous process that combines a viscous paste and glass fiber on a specialized machine that features a continuous web. Custom paste that contains the resin and special additives is poured onto a carrier film, then cut glass fibers are added, along with a second layer of film. This applied paste and glass between a top and bottom carrier film produces a thin “sandwich” that is run through a series of serpentine rollers. The serpentine action and resulting pressure allow the paste to “wet out” the glass fibers. The SMC is then packaged in continuous lengths, 12 to 60 inches wide either on rolls or soft-folded into large, flat containers for handling and thickening. For many applications, the rolls or containers hold in excess of 1,000 pounds.

The packaged SMC is matured for a specific period of time (usually 48 hours, depending on the formulation) in a controlled temperature and humidity environment before it is shipped to the customer. This maturation step is critical since the material increases in viscosity over time. Proper maturation allows the finished SMC product to easily peel from the carrier film, facilitating handling at the customer site. Because of this, it is important to tightly control the amount of water and chemical thickeners (metal oxides, metal hydroxides, isocyanates, etc.) added to the paste during manufacturing. Since maturation is an on-going chemical reaction, it is also important to know the optimum molding viscosity window for the best molding performance. Typically, an SMC should be molded within 30 days of manufacture unless it is stored below 75°F. Many molders of structural thermoset SMC store their material at sub-zero Celsius temperatures to extend the product's shelf life. Though it can be used in transfer and injection molding

processes, structural thermoset SMC is best suited for compression molding. Structural SMC can be molded into complex shapes in processes that generate little scrap. With its excellent surface appearance and mechanical properties, structural SMC is used as a replacement for sheet metal for heat shields, skid plates, sports equipment, high-strength electrical components, prosthetics, watercraft, and a host of other high-performance products. Due to its ease of handling and sheet size, structural thermoset SMC is often the only choice for larger parts.

For structural thermoset BMC, a resin, fiber reinforcement, and several other ingredients blend to form a viscous, putty-like material. By weight, structural BMC normally includes 5-25 percent reinforcement, which usually consists of chopped-strand glass fibers measuring 1/32 -1/2 inch (.75 -12.7mm) in length. BMC is suitable for compression, transfer, or injection molding. When BMC is injection molded, cycles can be as fast as 10 seconds per millimeter of part thickness. Depending on the application and specific formulation, structural BMC provides tight dimensional control, flame and track resistance, superior dielectric strength, corrosion and stain resistance, excellent mechanical properties, minimal shrink, and color stability. Available in numerous colors, BMC also provides surfaces receptive to powder coating, paint, and other coating processes.



**Figure 3. IDI SMC can be formulated with 10 – 60 percent glass content depending on the physical requirements of the application.**

**Thermoset compounds** — improving the design, manufacture, and performance of a wide variety of products...

## > applications for structural thermoset compounds

The advantages of structural thermoset compounds make them an attractive alternative to metals and thermoplastics in a variety of industries. At present, the primary markets for SMC thermoset compounds are:

### **Military & Aerospace**

Commercial and military aircraft benefit from structural compounds in weight, cost, and cycle time reduction, FST retardance, and prevention of galvanic corrosion. Applications include military radomes, ammo handling guides and containers, helicopter components, rifle hand guards and other weapons components.

### **Transportation**

A large and growing number of exterior automotive components are now made of structural compounds instead of metals. Thermoset SMC is also gaining popularity among designers of interior vehicle components. The reasons include:



**Figure 4.** Heavy truck valve cover molded with IDI SMC.

- **Weight:** compounds are 25-35 percent lighter than steel parts of equal strength;
- **Dimensional stability:** SMC has a low CLTE and holds up well to engine heat and scorching summer temperatures, making it suitable for vehicle hoods, deck lids, and roof panels;
- **Memory:** while metal panels permanently deform on impact, SMC panels deform and spring back to their original shape;

- **Cycle time:** by reducing the number of parts in finished assemblies, thermosets shorten design and production time, which is critical in this highly competitive market.
- **Thermal resistance:** Ability to withstand high temperatures while still maintaining strength is ideal for heat shields and skid plates.

### **Safety**

Thermoset structural compounds are temperature resistant, fire retardant, and provide a high strength-to-weight ratio, which are critical considerations in the Safety market. Applications include



**Figure 5.** Fireman's Helmet molded with IDI SMC

firemen's helmets, firefighting equipment components, composite toe caps, and bump caps.

### **Medical**

X-ray equipment components, instrumentation covers and bases, biohazard receptacles, and prosthetics are just a few of the many medical applications that benefit from the use of structural compounds. Corrosion resistance, antimicrobial properties, dimensional control, thermal insulation, and dielectric strength make these high-performance materials ideal for the Medical market.

### Electrical

Structural compounds hold up well during electrical arcing or tracking, with no significant changes to shape or performance. Parts molded from thermoplastic materials, on the other hand, will often carbonize or melt. Thermoset compounds offer comparative tracking index values in excess of 600 volts and dielectric strength of over 15 kilovolts per millimeter. In the electrical industry, SMC and BMC are used for parts with track resistance greater than 600 minutes and arc resistance greater than 180 seconds.



**Figure 6.**  
*Electrical enclosures molded with IDI SMC.*

### Industrial

Excellent load bearing capabilities, as well as corrosion resistance and dielectric strength make thermoset compounds the right choice for heavy industrial applications, such as load bearings, valve bodies, and downhole plugs, and components for the oil and gas industry.

### Alternative Energy

Each year, the fuel cell industry uses large quantities of thermoset compounds to make bipolar plates. They provide heat and corrosion resistance without the shrink or excessive stress that might compromise a thin thermoplastic part. SMC and BMC are also suitable for solar power tiles and wind turbines. These applications require materials that won't warp or deteriorate during long-term exposure to the sun and other natural elements.

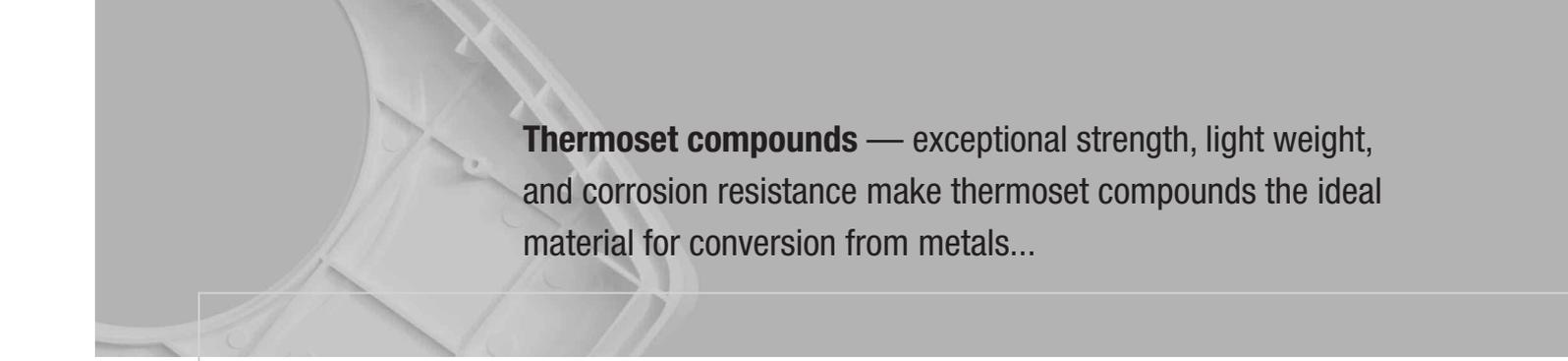
### Marine

Structural compounds provide all the necessary material properties for the Marine Market, including corrosion resistance and a high strength-to-weight ratio. Applications include gimbal rings and cowlings, out drive gimbal housing, and power boat seat shells.

## Structural Thermoset - BMC/SMC Market Applications

Markets	Applications	Defining Properties
Military & Aerospace	Military aviation, radomes Military aviation, rotary aircraft components Military aviation, ammunition cartridge handling guides Munitions Containers Weapon Components	high temperature resistance, fire retardant, high strength-to-weight ratio, design flexibility, corrosion resistance, durable, high impact resistance, excellent memory characteristics, radar absorption, light weight
Transportation	Automotive, fuel vapor canister bracket Automotive, heat shield Automotive, radiator bracket Automotive, sun roof drainage channel Automotive, body shield Automotive, leaf spring Automotive, skip plate Rail, switchgear Rail, window casing	high temperature resistance, fire retardant, high strength-to-weight ratio, dimensional stability, high impact resistance, parts consolidation, reduced tooling costs, design flexibility, paintable surfaces, dielectric strength, corrosion resistance, moisture resistance
Safety	Firemen's helmets Firefighting equipment Composite toe cap Bump cap	high temperature resistance, fire retardant, high strength-to-weight ratio, low smoke and toxicity generation, dimensional stability, high impact resistance, corrosion resistant, electrical insulation, RFI/EMI/ESD resistance, molded-in color
Medical	X-ray equipment components Prosthetics	corrosion resistance, dielectric strength, molded-in color, excellent cosmetic appearance, antimicrobial properties, high temperature resistance, fire retardant, dimensional stability, x-ray transparency or opaqueness, thermal insulation
Electrical	Switchgear	corrosion resistance, high strength, high temperature resistance, dielectric strength
Industrial	Drive equipment coupling Load bearings Springs Valve bodies Circular saws	corrosion resistance, high strength-to-weight ratio, high temperature resistance, dielectric strength, dimensional control, UV stability, non-sparking
Alternative Energy	Solar, power tiles Wind, turbine blades Fuel cell, bipolar plates, end panels	corrosion resistance, UV stability, high temperature resistance, high tensile strength, dielectric strength, high strength-to-weight ratio, consolidation of parts, paintable surface or molded-in color, design flexibility, fire retardant, low specific gravity, structural rigidity, moisture resistant
Marine	Out drive Gimbal housing Gimbal rings and cowlings Power boat seat shells Personal watercraft longerons (internal stringers)	corrosion resistance, high strength-to-weight ratio, low water absorption

**Figure 7.** Some common market applications for IDI BMC & SMC.



**Thermoset compounds** — exceptional strength, light weight, and corrosion resistance make thermoset compounds the ideal material for conversion from metals...

## > advantages of structural thermoset compounds

Structural thermoset compounds have a number of critical advantages over commonly used materials that are causing design engineers and molders to convert their product designs to SMC and BMC. By evaluating the attributes of structural compounds early in the design process, custom formulations can be created that take advantage of key material properties for a specific application. Core advantages include:

### **Tensile and Flexural Strength**

Structural thermoset compounds offer higher tensile and flexural strength per unit weight than most metals. With the high loadings of fiber, the structural thermosets yield functional strength that allows them to replace many traditional materials. When compared to thermoplastics such as polycarbonate/ABS, PPO/Nylon 6, and polycarbonate/PBT, a structural thermoset made with SMC has significantly higher flexural and tensile strength. When it comes to high Modulus (Flex and Tensile), a structural thermoset made with SMC will usually yield much higher values than thermoplastics.

Thermoset compounds can be comprised of many different resins and reinforcement combinations. Therefore, unlike other materials, they can be custom designed to meet the strength requirements of a particular application. Unlike metals, which have equal strength in all directions, thermosets are anisotropic and can be custom tailored to provide extra strength in a specific direction. If a thermoset part has to resist bending in one direction, most of the fiber can be oriented at 90 degrees to the bending force to produce a stiff structure in the desired direction. Thanks to their molecular structure, thermosets maintain excellent strength and other physical properties during prolonged exposure to extreme temperatures.

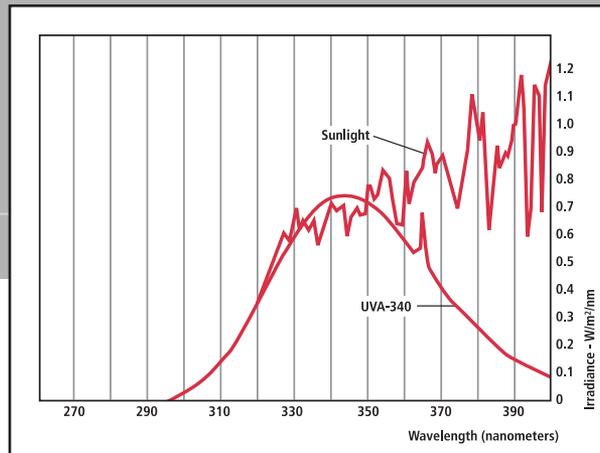
By contrast, when metals and thermoplastics are exposed to high temperatures, they may bend under the weight of applied loads. In addition, thermoplastics become brittle at low temperatures. Some highly engineered thermoplastics offer physical properties close to those of structural compounds, but these materials are very expensive and cannot replace SMC in many applications.

### **Dimensional Stability**

Besides strength, the cross-linked molecules in structural thermoset compounds provide dimensional stability in high-temperature environments. A thermoset part is far less susceptible to relaxation or creep failure than one made of thermoplastic. The ability to increase fiber content reduces structural variations and makes structural thermosets ideal for low shrink applications. The dimensional difference between structural thermosets and thermoplastics can be seen during tensile and flexural tests at elevated temperatures. In these tests, thermoplastics may stretch several inches, while thermoset compounds stretch just thousandths of an inch. In addition, tensile loads applied in high-temperature environments cause molded holes in thermoplastic parts to elongate over time. Under the same circumstances, however, holes in a thermoset compound part retain their original shape.

A structural thermoset has a shrinkage range from 0.2 percent down to zero and, if needed, a thermoset material can expand to be larger than the tool after cooling. Minimal shrinkage helps to ensure close tolerances in molded parts, which often eliminates the need for secondary operations, such as drilling or machining. For many applications, structural compounds mimic the coefficient of linear thermal expansion (CLTE) of metals, allowing for many types of materials to work together with thermoset compounds in a single application.

**Figure 8. The deterioration of durable materials exposed outdoors is primarily caused by the short wavelength UV portion of sunlight.**



### Corrosion Resistance

Unlike common metals, SMC won't rust or corrode when used outdoors or in harsh environments. The material provides long-term resistance to both chemicals and extreme temperatures. A good example of this can be found in chemical manufacturing plants where thermoset ductwork has been in service for more than 25 years. Thermoset compounds have also seen long service life in underground chemical storage systems. The corrosion resistant properties of SMC make it ideal for applications that are subject to strict sanitary requirements. Frequent exposure to harsh cleaning chemicals will not corrode the material, promoting sanitary operation.

In contrast, thermoplastics can be weakened by corrosive substances and environments. And metals are notoriously susceptible to corrosion caused by water and common chemicals. Metals used in corrosive environments must first be coated, or must be an expensive corrosion-resistant alloy.

### UV Resistance

Constant and prolonged exposure to ultraviolet (UV) radiation from direct sunlight can cause a number of problems for common materials. These include pigmentation fading, discoloration, and uneven coloration, as well as chalking (a scaly white surface) and reduced material strength. With thermoset compounds, the right choice of resin, filler, glass, and pigment reduces material degradation. Most of the sun's damaging energy occurs at wavelengths between 370 nm down to the exact solar cut-off of 295 nm. With the proper formulation technology, a compound can now perform at levels much higher than previous generations.

### Cost-effective Alternatives

Thermoset compounds have a very long life span. Many compound structures built in the 1950s are still in use. In addition, thermoset compounds feature low maintenance requirements. Thermoset compounds also reduce manufacturing costs by enabling part consolidation and virtually eliminating final finishing and coloring.

In metal manufacturing, complex designs may require multi-piece parts. The pieces of such a part are made in a series of progressive dies or costly stamping stations, and then assembled to create the final product. But by using SMC or BMC, complex parts can be made as a single piece in a single step. A simpler process translates into faster, more efficient production, with fewer secondary operations, fewer errors, and lower costs. At the end of the manufacturing process, parts made from thermoset compound are essentially ready to ship to the customer. They require very little final finishing, if any, and benefit from molded-in color and an attractive, durable surface.

### Design Flexibility

Thermoset compounds give designers more freedom than they have with metals. Normal compound molding processes allow for complex shapes and intricate details that are impractical or even impossible to produce from metals. And unlike metals, compounds allow for a wide range of material combinations. Various resin and reinforcement options can be tried to give unique properties to certain products. In some cases, structural compounds can be molded on the most basic of systems for R&D and prototyping purposes.

With more than 35 years of leadership experience, IDI works closely with customers to identify the optimal thermoset molding compound for each application....



## > conclusion

Structural thermoset compounds improve the design, manufacture, and durability of a vast number of products, causing many design engineers and molders to convert their products from metals to structural SMC and BMC materials. Consisting of fiber-reinforced polymer(s) with cross-linked molecules, structural thermosets offer a number of advantages over metals and thermoplastics, including higher strength per unit weight, better dimensional stability and corrosion resistance, greater design flexibility, and lower cost. Because the properties of a structural thermoset can be altered by varying the type and quantity of its ingredients, custom formulations can be created specifically tailored to the requirements of an application. Firmly established in a number of industries, structural thermoset compounds are finding their way into new applications as more design engineers discover the benefits of these high-performance, cost-effective materials.



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