Building Basics

Understanding the Matrix

Composites are a combination of cloth and resin

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COMPOSITE CONSTRUCTION has been a part of homebuilding for 25 years, but with all its variations, it can be a bit confusing. At its most basic, "composite" refers to a woven cloth or filament combined with a plastic resin to create a component that is applied over a core material like foam (used on the VariEze and called "moldless" construction) or formed with a mold (usually used by kit manufacturers).

Different materials are used to weave the cloth used in composite construction, and they range from simple fiberglass to exotic materials made of Kevlar (an aramid fiber), carbon graphite, or ceramic fibers. When combined with the appropriate resin, each cloth has particular strength attributes that make it more or less suitable for a particular application.

Because the cloth/resin composite bears all the primary flight loads imposed on the airplane, using the cloth with the correct strength, weight, and workability is essential. Composite cloth uses weaving patterns that maximize its strength in both directions (bidirectional or BID) and just one orientation (unidirectional or UND).

To give it strength in both directions, BID cloth is woven with half its fibers parallel to the selvage (the woven edge of the fabric) and the other half at a right angle to the selvage. To lay BID into compound contours (like cowlings and wheel fairings), builders can cut it on the bias, or on a 45-degree angle to the selvage.

UND cloth is woven with 95 percent of its fibers parallel to the selvage, which gives it exceptional strength in that direction but little strength at right angles to it. It's used in areas where the primary loads are imposed in one direction, such as wing skins and spar caps.

Manufacturers use two different weaving patterns. A plain weave is the familiar over-under checkerboard pattern you might remember from the pot holder you made for your mom in kindergarten. It's strong, but its tight weave makes it less pliable. The "crow foot" weave is less common, but it's desirable for high thread-count fabric that must conform to compound curves.

The beauty of composite construction is that each surface does not have to be made up of only one type of cloth. Designers can specify combinations of various cloths to create a structural sandwich. For example, you could create a spar cap of UND cloth covered with a series of BID cloth plies to create a wing control surface. Here are the types of cloth materials and resins in general use today.

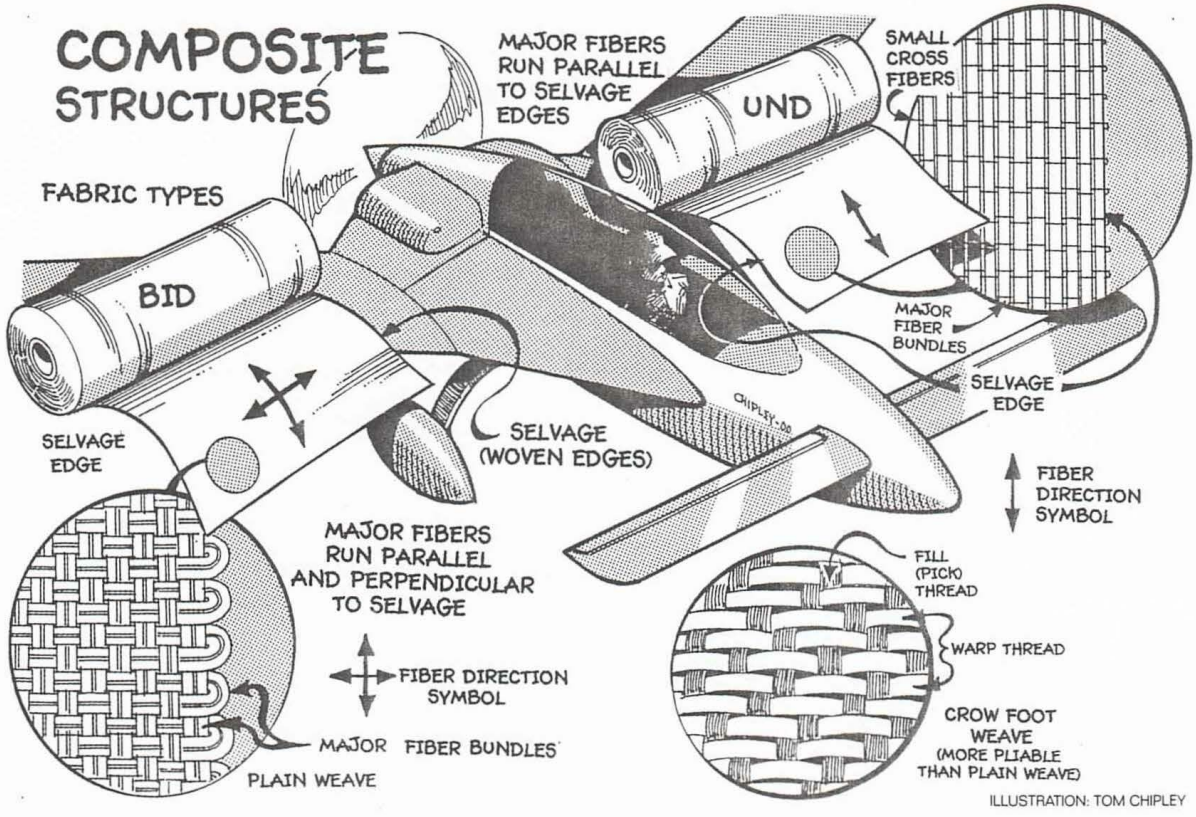

ILLUSTRATION: TOM CHIPLEY

Fiberglass, combined with epoxy resin, is the most basic of composite material. It's made of fine glass filaments gathered

into yarn that's woven into cloth of hundreds of different weights and weaving patterns. As fiberglass has been developed, it's been designated as E Glass and S Glass.

E Glass is the standard cloth used over the years to make components such as wingtips and wheel pants. S Glass is a newer fiberglass formulation that is 30 percent stronger, 15 percent stiffer, and three times more expensive than E Glass.

Kevlar, an organic aramid fiber Du Pont introduced in 1972, offers exceptional weight savings over fiberglass and has excellent durability when exposed to jet fuel, oil, water, and temperature variations. A Kevlar component weighs one-third less than an identical component made of fiberglass, but it costs much more than glass.

Kevlar can be difficult to work with. Cutting and drilling raw Kevlar and completed parts requires procedures and tools particular to the material, and builders should reserve these tools for Kevlar alone because using them on other composite materials dulls them. Manufacturers often use high-pressure water jets to drill and cut Kevlar without fraying it. A rigid backup reduces fraying when drilling and cutting Kevlar in the home workshop.

Carbon Graphite is another relatively new composite fiber, and many manufacturers have chosen it as their primary composite material because it can replace multiple layers of fiberglass and creates a lightweight panel with superior strength and durability.

Ceramic Fiber incorporates even newer technology that turns mineral fibers into cloth. When laminated, it can create components that approach the strength characteristics of S Glass, but it will withstand temperatures of nearly 3,000°F, perfect for lightweight firewalls. But it's expensive, with a square yard running around $200.

All of these fabrics are available in special tapes and strands that resemble heavy threads (often called "Tow"). These tapes and filaments can be used to strengthen structural composite components.

Resins

Fabric alone doesn't make composite material. It requires an adhesive matrix to hold the fabric in a specific shape that can accept the loads imposed on it. Epoxy resin is the most commonly used adhesive matrix, and it's mixed with a hardening agent.

By itself, epoxy is weak and heavy. The first lesson builders must learn is how to work the resin into the weave

of the fabric with a roller, brush, or squeegee to get the full benefit of its adhesive properties—without adding unnecessary weight to the component. Properly done, the resin/glass weight ratio should be less than 55 percent. Any more resin is additional weight without additional strength. In prepreg, tightly controlled production environments, manufacturers are able to approach ratios closer to 35/65 percent resin/cloth while still maintaining the strength of the part!

Many composite fabrics are available with the proper amount of catalyzed resin pre-applied to them. Called "prepreg" fabrics, they are often used in conjunction with the vacuum bagging process to create parts with a consistent distribution of mass, weight, and dimensions. Special handling requirements (like refrigeration and precise humidity control) to keep the resin from curing preclude most homebuilders from using prepreg material.

Like the fabrics they are applied to, there are different brands of epoxy resins that have different cure rates, or the time it takes the resin to harden. Early composite airplanes, like the VariEze, used Shell Epon 815 epoxy resin, followed by an RAE epoxy. With time, a number of builders developed an allergic reaction to RAE epoxy, and some of them had to abandon their projects.

To minimize the toxicity of the resins, the industry created Safe-T-Poxy in 1980, and its successor, E-Z Poxy, in 1996. Other epoxy systems have also been created for the homebuilder, many of them adapted from the marine industry.

Next month we'll address the other aspects of composite construction, including the various foams in use, vacuum bagging, tools, and finishing. EAA

Composite Safety

Working with composites exposes builders to a new set of hazards. Besides developing an allergic reaction to the chemicals, some older resins contain known carcinogens. To protect themselves, builders should wear chemical resistant gloves or barrier creams, respirators, and eye protection.

Cut and sand composite materials with care because small carbon graphite fibers, for instance, can lodge themselves in unprotected skin and cause irritation and, possibly, infection until the offending fibers are cut out. Before working with any composite material, read all accompanying literature and follow the recommended safety procedures.