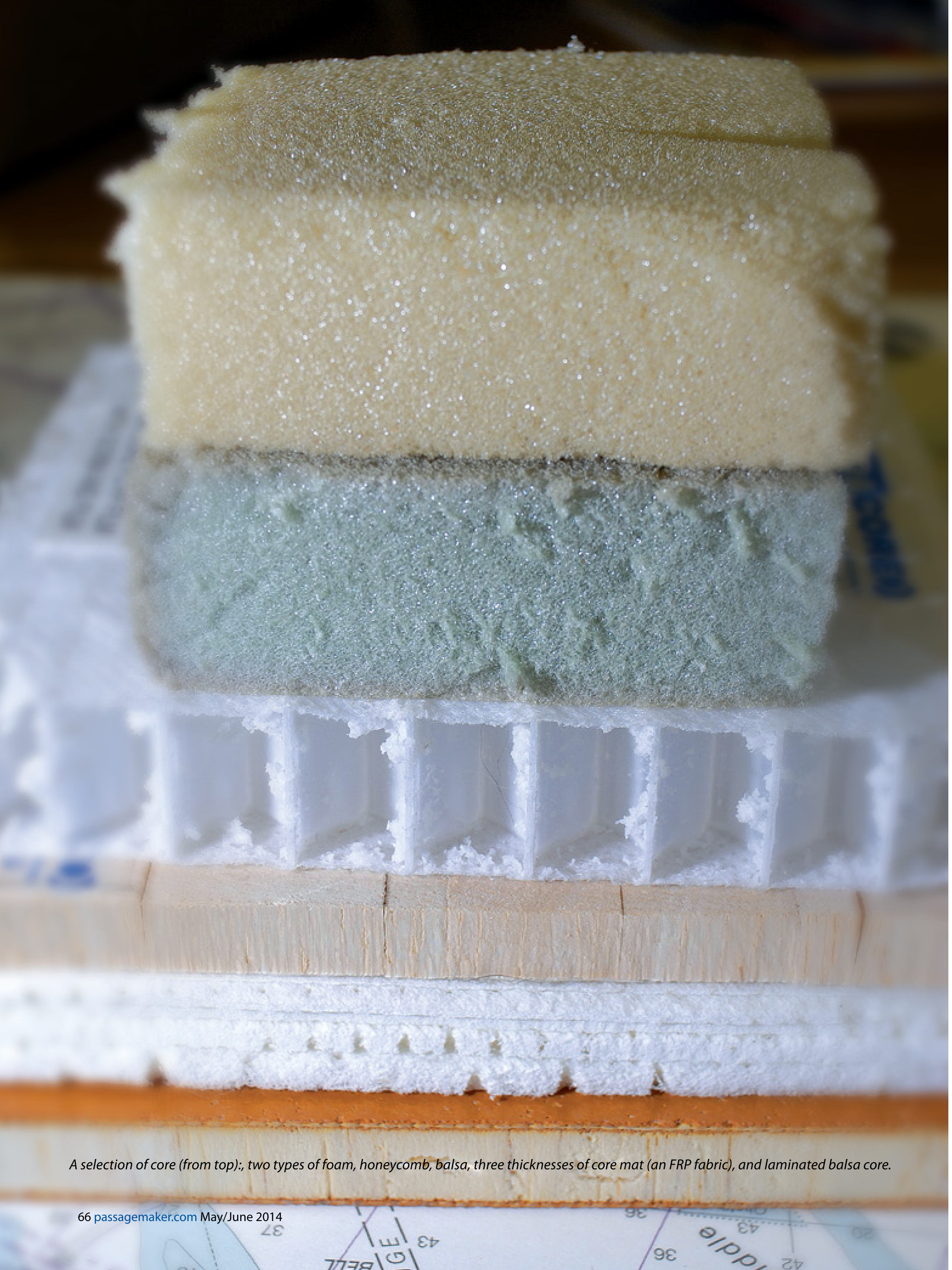

A selection of core (from top):, two types of foam, honeycomb, balsa, three thicknesses of core mat (an FRP fabric), and laminated balsa core.

Steve D'Antonio

CORE VALUES

DONE RIGHT, CORING IS A GOOD THING; DONE WRONG, IT'S A NIGHTMARE WAITING TO HAPPEN.

By Steve D'Antonio

I hear it all too often. "Oh, it's strong. It's solid fiberglass, not core," or "It's only cored above the waterline. The bottom is solid fiberglass," as if "core" were a dirty word, something to be avoided. In fact, nothing could be further from the truth. The cored composite, or sandwich, construction technique has been used, albeit not without problems, in the marine industry for more than a half-century and extensively since World War II by manufacturers of aircraft, railway stock, trucks and wind turbines, among others.

Coreing sandwiched by two skins of fiberglass laminate is often likened to a girder or I-beam, a design acknowledged as being exceptionally strong for its weight. Viewing a cored laminate in section–looking at the side of the hole-saw plug that is the result of a transducer or thruster installation, for instance–the skins are represented by the horizontal top and bottom panels, with the core material as the vertical section of the "I".

Fiberglass, known in the industry as FRP, or fiber-reinforced plastic, is a composite material made up of resin, polyester, vinyl ester or epoxy, the plastic, which is reinforced with a fabric made up of fine filaments of glass and occasionally carbon or Kevlar–the fiber.

The inner and outer skins absorb loads that are both tensile and compressive (pulling and pushing). Provided the core material is resistant to shear (movement in the same plane but in opposite directions–i.e., the skins being slid in differing directions), compression or crushing, and the skins are well bonded to the core, this makes for an extremely strong structure. However, based on the tales of woe that doggedly seem to follow this construction technique, one might ask, is it worth the trouble, and how might that trouble be avoided?

WHY CORE?

Why use core at all? Isn't solid fiberglass, or solid anything, for that matter, always better? The short answer to this question is that there is no short answer to this question. One thing is clear, though, the benefits of cored construction are undeniable and can make for stronger, lighter, stiffer and longer-lasting structures.

For things that move or are propelled–boats, aircraft, etc.–the strength-to-weight ratio becomes an important focus, as does a seagoing vessel's center of gravity. Stiffness is a structure's ability to withstand stress and resist distortion. Typically, the stiffer the better; however, some distortion can enable a structure to absorb shock loads without fracturing, provided the design and construction take this into account. Strength, on the other hand, is often equated with load-carrying ability, which should match–and exceed, to a degree–a design's intended use, with a margin for occasional use outside those bounds.

Center of gravity becomes an issue where roll characteristics and stability are concerned. Generally speaking, a vessel with more weight in the superstructure and decks, will roll more deeply, albeit more slowly, than the same vessel with less weight aloft, which may require the use of additional ballast.

Boatbuilders have known of this phenomenon for centuries, and with the advent of fiberglass boatbuilding, they soon realized that cored construction in cabins and decks reduced weight in these areas, thereby lowering the center of gravity. You would be hard-pressed to find an FRP vessel today that doesn't use cored construction in cabins, cabin tops, decks, and even topsides .

Reducing weight through the use of cored structures may also reduce the cost of maerials. Cored structures use less resin, a petrochemical product that becomes more expensive

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every year. Many early adopters of cored construction did so during the oil embargoes of the 1970s, when the price of resin rose exponentially. In the process, many also discovered that the boats they were building, both power and sail, were now lighter and potentially faster. If the vessel is of the planing or semi-planing variety, every pound saved helps the builder and designer achieve better fuel economy. A lightweight boat needs less powerful engines, which reduces fuel consumption, which permits smaller tanks, which further reduces the boat's full-load displacement–and the cycle continues.

In addition to their structural stiffness and strength attributes, most cored laminates are good insulators, helping to keep a vessel's cabin temperature reasonable. Hulls that are cored above the waterline, especially those painted in dark colors, offer superior thermal insulating characteristics, which often have a noticeable effect on the efficiency and frequency with which a vessel's air conditioning system operates. In addition, cored structures, including those used within a vessel for bulkheads, help to reduce noise and vibration.

Things get a bit more complicated when the subject of coring below the waterline arises. The primary concern is that a small hole, leak or breach of any sort in the bottom will allow water to migrate into and saturate the core, which can add significant weight and result in a loss of stiffness and strength, along with diminishing the vessel's value. It's also worth pointing out that all cored structures are subject to such a saturation risk, including decks and cabins. Rainwater can be just as damaging, and in some cases more so above the waterline than, seawater penetrating a cored bottom. The heightened concern where the bottom is concerned, however, is not entirely unwarranted. While water may penetrate the deck or cabin core when it rains, the cored bottom of a vessel that is afloat is always ripe for water entry.

IT DOES WORK

The first high-profile vessel built with an entirely (balsa) cored hull, is still sailing today, and doing so competitively. The sloop *Red Jacket*, designed by Cuthbertson and Cassian (which would eventually become the well-known C&C Yachts) and built by Eric Bruckmann in 1966, turned the boatbuilding industry on its ear as she went on to win many races.

Today, a handful of cruising powerboat builders use all-cored hulls, notably Marlow Yachts and MJM Yachts. The latter boast that the 40z, a fully planing design, is one of only two such 40-foot vessels in the world certified to meet the Category A Ocean standard of the International Organization for Standardization (ISO). The other is the solid-bottom Nordhavn 40. That's no small matter. The Ocean A category is ISO's most rigorous standard, it's defined as the "Category of boats considered suitable for seas of up to 7 meters (23 feet) significant wave height and winds of Beaufort Force 9 (41–47 knots) or less."

Do a cored structure and bottom play a role in this small vessel's ability to meet rigorous ISO (and CE) standards? Once again, there's no short answer to questions of this sort. Doubtless, many factors in MJM's design and construction are salient; however, I believe the proper and appropriate use of core, both above and below the waterline, is highly relevant to the vessel's ability to withstand these conditions. There is yet another value added to the MJM 40's super-light, all-cored design. She achieves an impressive 1.6nm/gallon, at 25 knots, a statistic that would not be possible unless the hull was fully cored.

CONSTRUCTION

The aviation industry remains the largest user of cored composite construction. That's a fortunate happenstance for the marine industry, because aviation has resources that far exceed those of recreational-boat-builders. As a result, the marine industry benefits from trickle-down technology. Today it's not unusual to see boatbuilding and custom composite shops carrying out work for both industries. Some of the most advanced cored composite structures in the world are used on commercial and military aircraft for the same reasons they are used on boats–they are strong, stiff and lightweight.

While there are many variations on this theme, building cored composite vessels is relatively straightforward. The process begins with an outer skin laminate of resin and fiber reinforcement applied to the inside of a female mold.

Steve D'Antonio

THE MOSQUITO LED THE WAY

The famed British de Havilland Mosquito, among World War II's fastest aircraft, was one of the first successful uses of a composite structure. Made of balsa core sandwiched between skins of Canadian birch plywood (the plywood was made in the U.S., using balsa wood from Ecuador, from where it continues to be sourced to this day for boatbuilding applications), glued together with a phenolic-based resin, it flew into history as the "Wooden Wonder." The cored plywood made for a stiff, strong and very light aircraft that caused the enemy no end of frustration, thanks to its agility and alacrity.

De Havilland pursued the wood composite design, in the face of strong skepticism from the RAF, for two reasons: There were many furniture makers in Britain whose skills were being underutilized by the war effort, and both steel and aluminum were in short supply.

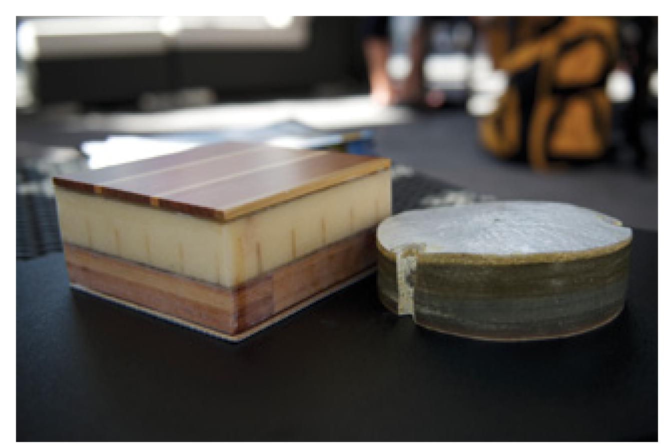
The equally famed Catalina PBY flying boat, built by Consolidated Aircraft in the U.S., used a core structure that more closely resembled the one used today, balsa surrounded by aluminum rather than FRP skins, with one notable difference, the grain of the balsa was long, using plank-like strips.

Successive layers are built up, following a naval architect's or boatbuilder's laminate schedule, using specific types or weaves and weights of fabric. Once the outer skin is complete, the core material is ready to be applied.

There are countless varieties, material types and configurations of core material. These include end-grain balsa (Alcan Baltek is the largest and oldest supplier of balsa core; their products helped build the Mosquito), the most common organic core material; linear and cross-linked polyvinyl chloride, or PVC, which is among the most popular of the synthetic foam cores; styrene acrylonitrile, or SAN foam (marketed as Core-Cell); polyurethane, or PU; and polystyrene, or PS, to name a few. Then there are the honeycomb cores, of which there is an equally dizzying variety.

Today's recreational-boat builders rely primarily on balsa, PVC or SAN foam core and honeycomb cored panels for interior construction, each with its own unique strengths and weaknesses. Balsa provides extremely good strength and stiffness-to-weight ratio, and of course it's light. The most significant difference between balsa core and ordinary wood is the orientation of the grain. Balsa core is used in an end-grain configuration, in small blocks that vary in size and thickness depending upon the application and structural requirements.

At top left, repairs to a hull show good technique because water damage was contained, compared to the bad installation below it. Bottom right, builders at boat shows often show core cut-outs like these.



Mark Fusco

Early balsa-cored vessels and aircraft used long-grain strips, or planks. These were strong, but they had two inherent weaknesses. One, long-timber grains effectively act as water conduits; get them wet at one end, and they are soon wet for the entire length, due to capillary action. If the sandwich skin were pierced in one place, an entire section of cored structure could become wet very quickly, which could add weight and lead to structural failure, as the skins could separate from the wet and decaying core.

Two, in the long-grain format, the wood's resistance to compression is comparatively low. You can test this yourself with a wood ruler; it's relatively easy to bend longitudinally, but try distorting or compressing it end to end–it's virtually impossible. End-grain balsa's ability to resist compression is multiplied many times over. Even with advances in synthetic core materials, it remains among the strongest of options.

Originally called Contourkore, the end-grain concept was pioneered by Everett Pearson of Pearson Yachts of Bristol, Rhode Island, and Belcobalsa (later Baltek) in 1963. Pearson was building his popular Triton sailboat using balsa planks. In order to stop water from traveling along the grain, Pearson began cutting the balsa into short blocks and placing them side by side in the laminate. This concept quickly took hold and is now the standard approach.

Balsa, PVC, SAN or other materials, are typically provided in 2-x-4-foot sheets, attached on one side to a thin fabric called scrim. Because the scrim is only attached to one side of the blocks, the sheet can be placed over an irregularly shaped surface.The core sheet is placed scrim side down over convex surfaces and face up over concave surfaces. The surface is prepared by applying a final resin-rich laminate, into which the core sheet is placed. In lieu of the resin-rich laminate, a proprietary core-bonding product may be applied to the FRP surface.

It is critically important that the surfaces over which cores are applied be absolutely clean and free of oil, grease, moisture or dust. Even oil and moisture from a misplaced sweaty palm can lead to delamination issues. The core material, particularly balsa, must be primed with cured resin so that it does not wick the resin from the bonding surface, leading to a dry bond and delamination. Many cores are available in a pre-primed condition to speed this process. Gaps between the core blocks must be filled completely, or as completely as possible, with resin or bonding material. A common and insidious problem, the failure to fill the gaps, or kerfs, between the core blocks, leads to a structure that is not as strong or as stiff as it should be. These gaps can act as a path through which water can flow, a phenomenon called channeling, in the event of a breach in the laminate.

For laminates applied by hand, proper training, good technique and attention to detail by laminators ensures that kerfs and other voids are filled. When done properly, cored composite structures that use resin infusion (a process wherein a vacuum draws resin through the glass fabric and core at once, rather than relying on technicians to do it) ensures that channels and gaps are completely filled, avoiding this issue. After the layer of core is applied and all kerfs and voids are filled, the multilayer inner skin is applied.

At this point, some builders choose to vacuum bag the laminate. Vacuum bagging, which differs from resin infusion, creates a vacuum within the laminate, applying many thousands of pounds of atmospheric pressure. This compresses the laminate, removing trapped air. Air voids are areas where resin and fabric or core fails to make contact, thus failing to add strength to the structure. In addition, vacuum bagging compresses the layers of glass fabric, improving their ability to absorb and withstand loading. Finally, reducing the amount of air within a laminate reduces the amount of water vapor it can retain. Water trapped within a laminate at the time of construction can lead to delamination and other issues.

The finished product, the I-beam, is strong, stiff and light, offering builder and user an enviable strength-to-weight ratio, with all the associated benefits of efficiency, fuel economy and durability.

PROBLEMS AND FAILURES

Having inspected, repaired and supervised the repair of hundreds of cored vessels, I'm firmly convinced that the bad rap core gets is the result of a select few factors. The first is poor execution or compromised build quality. Boatbuilders are the first line of defense when it comes to preventing core problems. The second involves work performed on the vessel after it is in service by equipment contractors, boatyards and repair personnel.

Boatbuilders must be conscientious about the type of core material they use and how it is installed. Balsa core, as desirable as it may be for its strength and light weight, does have one primary weakness–it is susceptible to water absorption and the decay that often follows. The dreaded brown stains running out of penetrations for hardware indicate that water has migrated into the core, the repairs for which are nearly always costly. I've seen this occur on vessels that were less than a year old. This is entirely avoidable.

The problem is not the choice of balsa core, per se. When properly installed, balsa cannot absorb water, and if water does reach a single block or section of blocks, it should not migrate unless voids or channels are present. Closed-cell PVC or SAN foams are significantly more resistant to this phenomenon, in that if water does reach them, there is no risk of decay. The use of closed-cell foam, however, does not preclude the admonition regarding the avoidance of voids or channels. Every effort must be made to prevent them from occurring.

Boatbuilders must be very careful about installing stanchions, cleats, seacocks, rudder and shaft logs, struts and windlasses, as well as small items like light fixtures, deck hatch hinges and latches and pad eyes. Bedding compound or sealant must never be relied upon as the sole means of preventing water from reaching core material. In each and every case where fasteners or hardware penetrate a cored

Core Values *continues on page 94*

WHAT ABOUT PLYWOOD?

No discourse on cored composite construction would be complete without mention of plywood. In the early years of fiberglass boatbuilding, plywood was regarded as an effective core material, particularly in decks and cabin tops. It's lighter than fiberglass of equal dimensions and quality, void-free grades are strong and long lasting, and it's comparatively inexpensive. Many vessels, large and small, power and sail, were built using plywood core, and many of those vessels are still cruising successfully today.

Steve D'Antonio

Plywood does have some drawbacks, though, which is why its popularity as a core material, especially in exterior applications, has waned in recent years. Chief among these drawbacks is its long-grain structure. Unlike balsa core, plywood is laminated with the grain oriented longitudinally, which makes it susceptible to water migration via capillary action. While not as profound as ordinary dimensional, solid lumber, plywood will absorb water readily.

Eventually the plies will delaminate, forfeiting much of their stiffness in the process. Ultimately, the plywood will decay. Like other core material, especially wood core, plywood will remain sound as long as it remains dry. Because it will absorb water and is compressible, it requires the same closeout technique as any other core material. In addition, while it is lighter than solid fiberglass, plywood is substantially heavier than all other common core materials—balsa, foam, etc.—making it less attractive in that respect.

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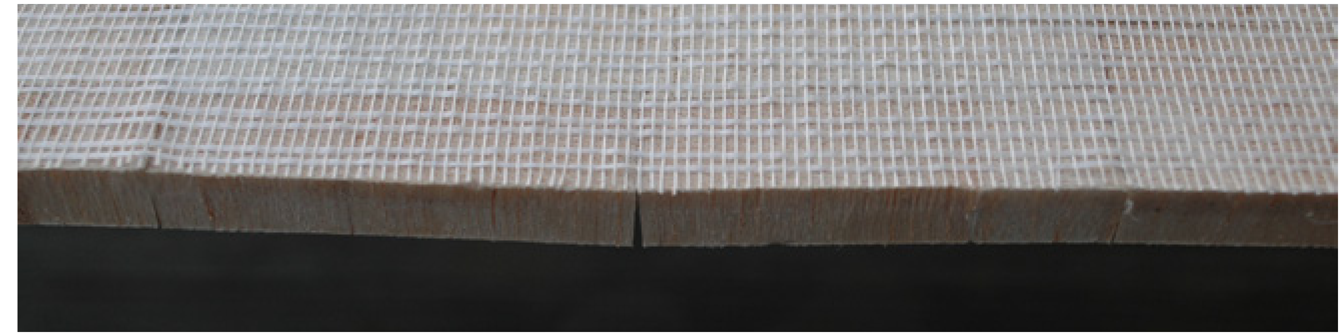
structure, the core must either not be present in this area (the builder, knowing where this gear is to be installed opts to laminate with either solid fiberglass or proprietary high density, nonporous, incompressible core material), or the core must be removed or reefed out, and the void backfilled with a thickened resin mixture.

This approach virtually guarantees that if–nay, when–water migrates past the bedding compound, it can't penetrate the core. It also means that the fasteners, when tightened, can't compress and crush the core. The latter phenomenon is evinced by a depression that can be seen around hardware, which forms a catch basin for water, dramatically increasing the likelihood of water making its way to the core. The failure to exclude core, and its subsequent compression, also serves to weaken the installation, which, if it's a highly loaded part, such as a cleat, can lead to dangerous failure.

From an aftermarket perspective, core trouble often begins when uninitiated installers fail to observe proper hardware installation technique, what's known in the industry as core closeout. Among the most common offenders are electronics, crane and davit installations (including dinghy chocks), life rafts and canvas tops that require drilling and cutting through cored cabin tops and sides, as well as decks and masts.

For vessels with a cored bottom, installation of transducers and aftermarket through-hulls for water makers

or air-conditioning systems present similar issues, albeit with potentially more dire consequences. I've encountered vessels whose cored bottoms were almost entirely saturated as a result of the incorrect installation of a single transducer.These failures are entirely avoidable if those carrying out the work remove or reef out the core and backfill with thickened epoxy. In all but a few cases, painting exposed core with fiberglass or epoxy resin is not an acceptable approach. The result is too thin and too delicate, and it does nothing to prevent the core from being compressed.



Above is a pre-laminated area of solid FRP in a cored hull, ready for a seacock. At left an installer reefs core out of a deck for back filling to create a hard spot at which to attach hardware.

Steve D'Antonio

In the case of installations involving flanges that are screwed into place–an antenna base or port light, for instance–it's important that the closeout, the epoxy mixture, captures the surrounding flange fasteners as well as the primary hole onto or through which the hardware is installed.

TRUST BUT VERIFY

If you are considering the purchase of a new boat, ask the dealer, salesman or builder to explain how hardware is installed in cored structures above and below the waterline. If you own a vessel and you are a do-it-yourselfer, be certain you fully understand the core closeout technique before installing any hardware.

If you contract with others to carry out work that involves penetrating the core, before allowing them to proceed, ask for a clear description of their installation approach. Simply ask, "How do you ensure water will not get to the core?" If the response is something along the lines of, "We use lots of sealant," you have the choice of educating them on the proper technique or looking elsewhere for those experienced in proper core closeout.

On a final note, you should expect to pay more for vessels whose builders install and close out core properly; the same is true for aftermarket installers. Drilling or cutting holes and loading them up with sealant is much quicker than laminating in place solid fiberglass or high density core, or reefing and backfilling.