FREE

EPOXYWORKS®

BUILDING, RESTORATION & REPAIR with EPOXY

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In This Issue

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The Great Lakes Boat Building School is Growing

By Matt Edmondson
Lead Instructor at GLBBS

LEFT: *Aerial shot of the Great Lakes Boat Building School, Cedarville, Michigan.*

Epoxyworks last highlighted the Great Lakes Boat Building School (GLBBS) in its Spring 2014 and Spring 2015 issues. The school has come a long way since then. Let's take a look at what's changed and glimpse into its exciting future.

Located in Cedarville in Michigan's Upper Peninsula, GLBBS has been training wooden boatbuilders since 2004 and is the only fully accredited marine trades institute in the Great Lakes. Recently, the school expanded to offer two full-time, year-long programs: the Comprehensive Career Boatbuilding program (CCBB) and the Marine Service Technology (MST) program in partnership with Mercury Marine and the American Boat & Yacht Council (ABYC). Through these two programs, GLBBS has graduated more than 200 students into the marine industry as boatbuilders and service technicians.

The foundation of GLBBS's success has been its 12-month, three-semester boatbuilding program. It encompasses the three main areas of wooden boat work: traditional construction, wood composite construction, and restoration. In the first semester students learn traditional boatbuilding techniques, how to work with hand tools and identify and select types of wood, and they build small projects such as the classic step stool and oar. Central to the CCBB program is the Indian River Skiff, a small lapstrake rowboat built in the Indian River, Michigan area in the 1920s. Students learn to take measurements from the boat and then develop a set of plans and patterns for the hull. They break into teams to build three of these boats using lapstrake, cedar strip, and fiberglass construction methods.

Semester two focuses on how to build wooden boats the modern way using products like WEST SYSTEM® Epoxy and reinforcing fabrics to ultimately build a lighter and stiffer boat than traditional planking would allow. Students also learn how to repair a wood composite laminate using WEST SYSTEM Epoxy by building a vacuum-bagged hull panel, creating impact damage, and then working to repair the panel with a patch of wood and fiberglass.

The third semester revolves around boat restoration. Students have restored a 1947 Chris Craft Deluxe and a 15" Lyman. The restoration projects currently underway are a 1959 Century Nordic, a 1939 Chris Craft, and a Concordia-built beetle cat. The goal of the restoration segment of the program is to introduce students to the many ways to solve the problems that arise with old, broken boats and to showcase some of the techniques and philosophies that drive decisions on reconstruction methods.

The MST program is focused on training entry-level technicians to enter the workforce with a solid base of general marine industry technical knowledge. Also broken into three semesters over 12 months, the MST program starts with fundamentals. While the MST program is primarily mechanical and electrical, students learn boat construction types, including fiberglass, aluminum, and wood. Each student learns to perform multiple fiberglass repair scenarios using WEST SYSTEM Epoxy, create cored laminates, bond hardware, and how to vacuum bag and infuse laminates. Some highlights of the MST program's composites section are infusing a 12' Wee Lassie canoe and creating a carbon fiber air vent using PRO-SET® Epoxy and vacuum bagging.

Both programs teach career skills and evaluate students every two weeks on their soft skills. Resume workshops, field trips, and mock interviews help to give each student the best possible opportunity for a job after graduation.

Most exciting is the goal to double the student body of GLBBS to 50 students over the next five years. The current facility at GLBBS only supports 24. We launched a capital campaign in the summer of 2021 with the goal of matching 20% of the funds for a federal grant. It would allow us to break ground on a new 10,000 square foot facility, expanding our shop space, classrooms, student center, and waterfront. The new facility would house our growing programs and provide space for additional programming in the future.

SCAN ME

For more information on the Great Lakes Boat Building School, scan this tag or go to **glbbs.edu**

TOP: *GLBBS students infusing a canoe.*

MIDDLE: *Carbon fiber air vent created by the GLBBS students.*

BOTTOM: *Indian River Skiff, a small lapstrake rowboat.*

Balsa Core Alternatives

By Greg Bull—GBI Technical Advisor

ABOVE: *Measuring the four replacement core samples.*

When you need to repair your fiberglass boat's balsa core but don't have any replacement core material on hand, what can you use as an alternative? I tested some different replacement core options to see how they'd perform in flexibility and strength alongside original balsa core in a fiberglass laminate.

One popular core material is vertical grain balsa but, if it stays wet for too long, it can start to rot. This may make a soft or spongy spot you can feel if you step on it. If the softened balsa core is near or under a winch, stopper, cleat, or stantion base, you may not notice a problem until the object shifts position when it is under a load. It can be scary to see movement in a part of your boat that's supposed to be stable.

If you need to replace core material in a small area under a winch, stopper, cleat, or stantion base, it's best if you can complete the repair from inside the boat to eliminate the exterior cosmetic finishing work. Let's say we have opened the repair area, removed the damaged core, and now have a small area in need of repair. My definition of a small repair area is anything less than 1 sq. ft. If you don't already have balsa core on hand, buying standard 2'x4' end grain balsa core sheets can be expensive and is far more material than you actually need. We'll consider some inexpensive alternatives to balsa core.

Plywood as a Core Replacement

The simplest core replacement material is a piece of exterior grade or marine plywood. In most cases, this will work fine. Just keep in mind that plywood is stiffer than balsa core, so it won't move or flex like the original core material. This difference in stiffness could cause cracking around the repaired area.

We chose to do this as a shop floor test, to show how you can learn a lot from simple tests. This test only gives a basic comparison of the properties. To obtain specific strength and other engineering data, we would use our MTS® test machines in the GBI laboratory.

Plywood's stiffness may prevent it from conforming to the surface. After all, boat surfaces are rarely flat. A simple way to improve flexibility is to cut the plywood core piece into several smaller pieces, such as 1" or 2" squares or 1"-wide strips. Balsa core comes with a scrim material on one side that holds the small balsa blocks together and lets them conform to the surface shape. Cutting plywood in this way can mimic scrimmed balsa core's flexibility.

Using Dimensional Lumber to Replace the Core

Dimensional lumber (such as a pine 2x4) can also work as core material if you cut it into sections of ¼", ⅜", ½", or any custom thickness you might need. You can arrange these vertical grain cuttings into a grid pattern to replace the missing core and conform to the surface. Use the same approach as described for plywood core replacement above to imitate the flexibility of balsa core.

Replacing Core with Epoxy

We don't recommend replacing core material with thickened WEST SYSTEM® Epoxy alone for a couple of reasons. Epoxy will create a hard spot in the repair area, resulting in stiffness and cracking similar to what can happen when solid plywood is used. You should avoid any core replacement material with different flexibility from the original core material.

If you're trying to replace a thick core with epoxy, another problem you may run into is uncontrolled exotherm. Filling a large void with thickened epoxy all at once may generate enough heat to damage the surrounding laminate.

Testing for Flexibility

To see how different core materials would behave in a laminate, I performed some simple shop tests on four 54"x1½" sample panels I made. These were simple shop tests that compare samples to each other and don't involve ASTM standards. They're easy to replicate at home when you want to determine the best materials for a repair.

I started with a control sample panel of ¾" balsa core laminated with one layer of 737 17 oz. Biaxial Fabric on each side. The other three panels were also balsa laminated with 737 Biaxial Fabric, but I made them with a 1' section of replacement core material in the center. The alternate core materials in these panels were:

- End grain pine cut ¾" thick from a 2x4 and bonded with unthickened WEST SYSTEM Epoxy.
- ¾" plywood and bonded with thickened epoxy.
- Thickened WEST SYSTEM Epoxy alone.

As expected, the balsa cored control sample deflected the most, a full 1½" with 5 lbs. of weight on the center of the test piece. It formed a nice gentle curve as I applied the weight. The end grain pine cut from a 2x4 to mimic balsa core was only a little stiffer, deflecting a full 1½" with 8 lbs. of weight. It also had a nice fair curve to it all through the transition from one coring material to the next. Bonding it with unthickened epoxy left some air gaps between the pieces of end grain pine, making it similar to the balsa core in the control sample panel.

I tested the panel with the ¾" plywood replacement section next. With 8 lbs. added pressure it deflected only ⅞". The plywood stayed fairly straight or flat across the 1' section then bent up right after the joint between the plywood and balsa core. The panel with the replacement core of ¾" thickened epoxy performed similar to the plywood but was slightly stiffer, bending only ¾" with 8 lbs. on it. It was also very flat through the one-foot area than bent up quickly at the edge of the balsa core.

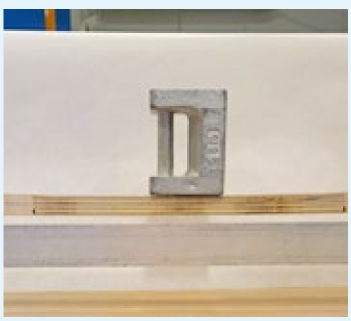
I had expected the thickened epoxy and solid plywood sample to be stiffer than the balsa cored control sample, and it was. What surprised me a little was how closely the end grain pine set in unthickened epoxy performed in the bending test compared to the balsa core control sample.

Four test samples.

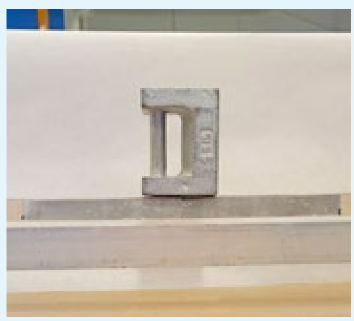
Testing for Flexibility

The balsa cored control sample deflected the most.

The end grain pine repair was only a little stiffer.



The plywood repair stayed flat across its one-foot section and bent upward at the joint.



Epoxy filled core repair performed similar to the plywood but was slightly stiffer.

Breaking the Samples

In stressing the samples to their breaking point, I saw a more pronounced flat spot where the different cores materials met, with a sharp bend at the edge of the balsa core. This was also where the breaks occurred. I did this test by supporting the sample panels 5" in from each end, then used a ratchet strap to pull down on the center of each panel.

The control sample panel with the all-balsa core just folded and cracked in half when it broke, because of the concentrated area of bending or loading. The others all broke at the edge where the balsa core met the alternate core material and fractured the fiberglass on top in compression.

Another sample panel that broke at the repair joint was the one with thickened WEST SYSTEM Epoxy as the core replacement. Its fiberglass and balsa core fractured right at the transition from epoxy to balsa core. This break happened exactly where I thought it would; I just imagined it was going to be a more dramatic break than it actually was.

This test only creates a point load and doesn't mimic a distributed load that a hull bottom would be subjected to. For small areas of core replacement, dissimilar materials can be acceptable but it is important to understand how they will perform. Replacing a section of damaged core with materials similar to the original core will prevent hard spots and offer the best results.

Close-up of the epoxy filled repair. Its fiberglass and balsa core fractured right at the transition from epoxy to balsa core.

Breaking the Samples

The balsa cored control sample cracked in half when it broke.

The pine repair broke where the balsa core met the pine.

The plywood repair broke where the balsa and plywood met.

The epoxy filled repair broke most dramatically, again at the repair joint.

The fiberglass fractured in compression at the transition from epoxy to balsa core in the epoxy-filled repair.

BO-PEEP II

75-YEAR REFIT

By Ronald Lane

The motor yacht *Bo-Peep II* is a 55' bridge deck cruiser designed by Hacker-Fermann Naval Architects Co. of Detroit, Michigan. In 2001, *BO-PEEP* underwent a major refit with extensive use of WEST SYSTEM® Epoxy. Two decades later, the benefits of this approach are apparent in hull longevity and strength; dry bottom blanks, frames, and keel; a dry bilge; dry bronze thru-hull fittings, hardware fasteners staying put; shorter shipyard haul-outs; and the propeller shaft remaining properly aligned. We no longer have rotted planks or loosened fasteners to replace, seams to caulk, or corrosions headaches.

Built by Defoe Boat and Motor Works in Bay City, Michigan in 1926, *Bo-Peep II* has been in my wife Gene's family since 1951. This mahogany boat was the second of four 55' motor yachts Defoe built from this design. With her original name unchanged, *Bo-Peep II* has been documented by the USCG (U.S. Coast Guard) since its launch in 1926.

My father-in-law, Louis Bonner, bought *Bo-Peep II* in 1951 and over the years made several modifications to the boat. By the time he passed it on to his daughter Gene in 1989, the boat needed some repairs including refastening. Of the repairs we had done at that time and since, the repairs made with WEST SYSTEM Epoxy held up best. This work was completed by shipwright Rick Ryan, who was very knowledgeable about boat repairs because his family owned several marine-related businesses.

Gene and I married in 1993. We moved *Bo-Peep II* from Houston to Seattle by truck in 1997 because we wanted to explore one of the best places in the world for our type of cruising. We hauled out the boat in late 2000 for routine hull maintenance and to correct a laundry list of problems that a surveyor had identified:

- Weakened wood in a wet area of the hull, "tired" transom planks and rot in the structural framing.
- The stem knee, which hadn't been replaced since the Fifties or Sixties, needed attention.
- The upper keel, keelson, and lower frames in the bilge were rotting.
- Several of the original steam bent oak frames had been broken by lift straps when the boat was unloaded after the move in 1997.
- The original iron bolt fasteners in the bilge stringers and floors were not holding due to galvanic corrosion. Some were totally consumed by corrosion.
- Checks in the aged original white oak keel also needed attention again.

1989 keel check with epoxy repairs still good.

These defects were mainly the result of poor performed repairs. The era of the previous repairs could be identified by shipwright techniques and material types. But the repairs Rick Ryan had made in 1989 with WEST SYSTEM Epoxy were still holding strong in 2000.

The joints repaired with WEST SYSTEM Epoxy were mechanically sound. The old wood repaired with epoxy didn't break, but the wood that wasn't epoxied broke. The plank seams that were filled with thickened epoxy remained watertight.

The lift operator in Seattle broke a plank next to the aft strut by raising the boat before the hold down chain was removed. The plank split, but the epoxy-bonded seam didn't release: the plank leaked, the seam didn't.

The planks were fastened with silicon bronze screws embedded in epoxy. During their removal more than a decade later there was no evidence of corrosion. The screws were epoxy bonded so securely that removing them from the frames required a mini torch. The epoxy used to repair checks, knotholes, and other defects in the keel remained sound with no deterioration. Most of these repairs were made by injecting epoxy into the void with a caulking gun.

I was impressed by the strength of the epoxy on some marginal wood repaired in 1989. I called Rick Ryan in Houston for more details about how he'd used WEST SYSTEM Epoxy. He said he'd used the *Wooden Boat Restoration & Repair manual* and made a few phone calls to GBI Technical Support.

We considered our choices: Continue the ongoing patchwork of "repairs as needed" requiring more frequent trips to the shipyard, or replace all the bad parts with new ones. We chose the second option, which gave us the opportunity to inspect parts of Bo Peep II not seen up close since 1926.

We based our 2001, 75-year refit plan on the knowledge of Rick's prior repairs. However, Rick Ryan had made his repairs without the luxury of extensive disassembly and had to inject the epoxy with a caulking gun in several places. Removing the keel required a lot more disassembly and made it obvious that most of the wet area of the hull needed replacing. Many of the epoxy repairs were crosscut through during the keel removal, giving us a closer look at the original epoxy repair. Realizing that the epoxy had saved "that old wood" gave us a lot of confidence in using it on new wood.

The refit plan was to epoxy coat any wood that might be exposed to water. The number of coats would vary depending whether the wood was likely to be occasionally exposed to moisture, or be submerged (such as outer keel and planks). Our concept was to replace the old, tired wood with new wood using exactly the same methods and sizes used by Defoe Shipyard during the boat's construction. We would simply seal the new wood with epoxy and use epoxy thickened with 404 High-Density Filler to bond the joints.

We stayed with the traditional planking except we coated the planks with epoxy, substituted silicone bronze screw fasteners embedded in epoxy in place of the original rivets, and bonded the seams with thickened epoxy. This approach strayed a bit from Rick Ryan's previous repairs and the *Wooden Boat Restoration & Repair* manual.

A CLOSER LOOK

We shored up the boat under the hull for support. Initially, we removed the garboard, first, and second strake planks before starting the first stage of the rib repair. Using a chainsaw, we cut out the keel in 2' sections, and then installed a plywood mock-up of the new keel.

With every rib in the boat inspected, we used mahogany laminate strips and epoxy to repair the ribs. We used laminations to repair the bilge stringers where they were inaccessible under the bulkheads. Longer, accessible stringer sections were repaired with new boards and long scarf joints with epoxy. Where stringers had oversized holes caused by bolt corrosion, we double plugged the holes with epoxy and installed a new silicon bronze bolt.

We installed the new Angélique wood keel in two sections with a very long, epoxied scarf joint. Six coats of 105/205 were applied to the keel before assembly in the boat.

All old wood floor timbers were replaced with new mahogany.

We removed the entire old bow stem and fabricated a new stem assembly (knee, apron, and cutwater) with strips of Angélique curved over a form and bonded with epoxy.

The entire transom was removed and rebuilt. The new transom framing wood is Angélique. The outer planking is steam bent Honduran mahogany. The transom assembly is put together with silicon bronze fasteners and epoxy.

The old planks that Rick had repaired with epoxy had to be cut out in sections between frames. They were rip-cut near the silicon bronze screws and chisel cut from around the screws. We heated the screws with a mini torch to release the epoxy and backed them out with vice-grips. The holes were "pin plugged" with mahogany and epoxy.

After installing the new keel, we removed and replaced all the old bottom planks that the surveyor had identified. The new mahogany planks were shaped, dry fit and pre-drilled, then removed and epoxy coated. We wet them out with epoxy, and then liberally applied epoxy thickened with 404 High-Density Filler to both mating surfaces. The excess was squeezed out to eliminate air pockets.

When new 1½"-thick planks surrounded an older thinner plank, the thin plank was "capped." A layer of epoxy with 404 High-Density Filler was spread on the old plank and then faired to match the thickness of the new plank.

Twenty years after BO-PEEP II's 75-year refit, here are some of the many benefits of using WEST SYSTEM epoxy:

- *Greater hull longevity and strength*
- *Dry bottom planks, frames, and keel*
- *A dry bilge*
- *Dry bronze thru-hull fittings, screw fasteners, bolt fasteners, and wood*
- *Shorter shipyard haul-outs*
- *No "soak-swelling" the hull planks after a haul out*
- *Propeller shaft stays properly aligned*

No more replacing rotten planks, no more replacing fasteners, no more caulking the seams, and no more corrosion headaches.

Restoring BO-PEEP II's Tender

The original wooden tender for the ***BO-PEEP II*** was also built by Defoe Boat and Motor Works of Bay City, Michigan in 1926. This tender needed a few repairs. Satisfied with the performance of the repairs done on ***BO PEEP II*** with WEST SYSTEM® Epoxy back 2001, I decided to use WEST SYSTEM in restoring the original tender in 2014.

01

On the truck to Seattle, *BO-PEEP* II's tender had suffered split planks in both bilge turns. The planks were also checked and had long gaps, rendering the tender unseaworthy. I made a uniform cut in each long split to clean out the damaged wood and inserted double overlapping graving pieces (sometimes called a Dutchman) with WEST SYSTEM 105 Resin®/205 Fast Hardener® thickened with 404 High-Density Filler.

02

The original iron bolt in the oak stem had corroded and rotted the wood causing more small checks in the area. I carefully cut out the bad wood with a drill and chisel. Only a small amount of good wood remained, leaving the mortise in an irregular in shape. I used several small blocks of wood like a three-dimensional jigsaw puzzle to fill this void. When the thickened epoxy cured, I shaped the repair and installed a 316L stainless steel bolt.

03

There were small checks in the planks joining the transom and keel. The keel had minor grounding damage. I simply reefed the checks slightly with my pocketknife and filled them with WEST SYSTEM 105/205 thickened with 404 filler.

04

I used WEST SYSTEM 105/205 to wet out the wood, then added 404 filler to install graving pieces and fills. I used 105/207 on the exterior hull to seal the wood, and then varnished it.

The thin varnish on the outside hull was sanded off very easily. I used a furniture touch up pen to darken all the white epoxy lines in my repairs. Then I applied two coats of 105/207. After this cured, I applied three coats of varnish. On the interior hull, I repainted the bilge its original color and applied several fresh coats of tung oil, which was the original treatment.

HOME REPAIR PROJECTS

WITH WEST SYSTEM® EPOXY

By Don Gutzmer
GBI Technical Advisor

As a homeowner, I like to apply my WEST SYSTEM® Epoxy skills and expertise to basic household repairs. There are always repairs and improvements needed around my house, and keeping WEST SYSTEM Epoxy on hand helps to solve many of my personal DIY challenges. Great resources for tackling home repairs can be found in back issues of *Epoxyworks*. I'll list some of the home repair and improvement articles that I have found especially helpful.

Fiberglass Tub and Shower Repair

Retired Technical Advisor Tom Pawlak explains how to use WEST SYSTEM Epoxy to repair a fiberglass tub or shower. He offers two repair approaches, one for when the backside of the tub or shower is available and the other for when it is not. Tom also explains how to determine laminate thickness with different weights of fiberglass cloth and provides examples of options for finishing your fiberglass tub or shower repair.

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SCAN FOR MORE INFO

A Quick Architectural Fix

Repairing rotted wood trim with WEST SYSTEM Epoxy is pretty simple when you follow the steps Mike Barker lays out. Step-by-step photos with detailed descriptions reveal the quickest, easiest way to fix rotting wood trim.

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SCAN FOR MORE INFO

Epoxied Porch, Columns, and Railings

If something needs repairing, Tom Pawlak is your guy! This time, he shows us how he used WEST SYSTEM Epoxy to coat the columns and railing on the deck of his covered front porch. He also gives tips on using epoxy to keep pesky insects from taking up residence inside hollow porch columns.

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SCAN FOR MORE INFO

G/flex Does It

Long-time WEST SYSTEM Epoxy expert and friend Hugh Horton explains why he chose G/flex for his bathroom floor repair. With G/flex and fiberglass cloth, he created a custom shower pan and sealed the perimeter in the bathroom of an American with Disabilities Act (ADA) home. The project required special attention to ADA rules.

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SCAN FOR MORE INFO

A Pine and Epoxy Fence, Age 20

Grace Ombry designed a picket fence and her husband built it. She explains how they used WEST SYSTEM Epoxy on the posts, stringers, and pickets to minimize the risk of wood rot, helping the fence to withstand years of wet Michigan weather.

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SCAN FOR MORE INFO

WEST SYSTEM Epoxy's Other Uses, Suggestions for Household Repair

This 16-page manual, no longer in print, is still available as a free download on the WEST SYSTEM website.

It covers a variety of repair topics including:

- Sealing & Protecting Surfaces
- Repairing Rot Damaged Wood
- Joining and Joint Repair
- Bonding Hardware & Reinforcing Structures
- Tile, Masonry, Metal and Plastic Repair

westsystem.com

SCAN FOR MORE INFO

Wet Rudder Repair

By Terry Monville—GBI Technical Advisor

My friend Chris bought a 33' fiberglass sailboat, a Cal 33, to use as his family cruiser. Because it was an older boat, he knew he had a few projects ahead—including drying out the rudder. Here in Michigan, we haul our boats out of the water for the winter and it gives us a chance to do repairs and inspect under the waterline.

After hauling out the boat and storing it in the barn for the winter, Chris asked me to advise him on repairing the rudder.

We found two smaller delaminated spots on one side of the rudder and a sizeable one on the other, along with a 6" crack near the rudder shaft. After drilling a few ⅜" drainage holes through the fiberglass skin and into the foam core, we saw that it was still in good shape even though the foam was wet.

TOP:
Cal 33 fiberglass sailboat.

BOTTOM:
The cracked fiberglass rudder.

A Temporary Fix

With the boat already in the barn and not blocked high enough for us to remove the rudder, we made a plan to do a temporary fix to get through the next sailing season, then could wait until the next fall to complete permanent repairs.

Over that winter, I had Chris use heat lamps whenever he was at the boat in order to help dry the rudder as much as possible. In the spring, we chamfered the ⅜" drainage holes and sanded the chamfer with 80-grit sandpaper. We then filled the holes with WEST SYSTEM® Six10® Thickened Epoxy Adhesive and smoothed it with an 808 Plastic Spreader. The next day, we sanded the cured epoxy and painted the rudder.

Getting the rudder completely dry was not the plan because we knew it would absorb more water over the summer, but we did it to prevent further damage during the winter freeze. Rudders can hold enough water to make them crack open from the ice expansion in cold weather.

Identifying Delaminated Areas

The next fall we took the rudder off the boat and brought it into the Gougeon tech shop. First, we sounded out the areas of delamination. For this high-tech operation, we used the handle end of a screwdriver and a felt tip marker to mark delaminated areas. I followed the marker lines to cut and remove the delaminated fiberglass skin with an oscillating saw. I also drilled out some of the drying holes we'd temporarily filled to get through the summer sailing season.

Scan the QR Code to download the WEST SYSTEM *Fiberglass Boat Repair & Maintenance Manual* and learn how to repair cracks, holes, damaged skins, cores, keels, rudders, and gelcoat, as well as how to install hardware and teak veneer decks.

Fiberglass removed from a section of the rudder.

The rudder was wet, but not as bad as I thought it would be. It still had water in it, but it wasn't running out like it had the year before.

Drying Out the Rudder

The most basic way to dry out a rudder is to drill a hole in the bottom and let gravity do its job. This works well for draining most of the water and should reduce moisture content enough to prevent ice from cracking the rudder open during the cold months. If you store the boat outdoors, a good method to dry the rudder is to tape a black plastic bag over the rudder. On sunny days this will increase the temperature of the rudder to help it dry. This works great in temperatures around 25°F (-3.8°C). The added heat brings the wet rudder above freezing to provide it with extra days of drying.

Taking the rudder off the boat and bringing it into a temperature-controlled environment, like a basement or heated workshop, is another good way to dry it out. Warm, dry air will help the moisture evaporate. If there is damage or delamination to be repaired, remove the fiberglass skin to expose the foam core. The more exposed the core is, the faster the rudder will dry. A heat lamp warming the area will also help.

The most efficient way to dry a rudder is to vacuum bag it. This works best with the rudder off the boat and placed in a controlled environment. This is how I dried Chris's rudder. At a vacuum pressure of 29 inches of mercury (Hg), water boils at only 76°F (24°C). This lets you boil the water out of the rudder without causing damage from excessive heat. It still takes some time, and I had to open the vacuum bag (which is like a big envelope) to dry out the breather fabric a couple of times. After the bulk of the water was out of the rudder, I added a heat lamp because our shop was at 72°F (22°C) and I was only pulling a vacuum of 27 Hg. At 27 inches Hg, the boiling point moves up to about 120°F (49°C), which is still cool enough to prevent damaging the rudder laminate. Drying the rudder this way removed all but the last little bit of moisture. For more about vacuum bagging, see "Vacuum Bagging Basics" by Rachael Geerts in *Epoxyworks 49*.

The moisture meter indicated the bottom of the rudder was still wet, so I removed some of the fiberglass in areas where the readings were still high. It turned out that the high moisture readings were from the laminate. The foam core was now mostly dried. Ideally, I'd want the moisture meter to read 0 but a reading anywhere in the green is good.

I didn't remove the bottom paint and what looked like one coat of VC Tar2™ osmosis protection primer before trying to dry the rudder. When I did sand down to the gel coat, I found that the rudder had a few gel coat blisters, which we would need to sand open and fill with thickened epoxy after the laminate was dried. This would account for the moisture reading in the laminate.

With the rudder dry, it was time to put it back together. In some cases, you can reuse fiberglass skin that was previously removed. We outline this procedure in our *Fiberglass Boat Repair & Maintenance* manual in section 5.2.1 "Re-bonding the skin." However, the skin I'd removed from Chris's rudder was deformed and couldn't be saved, so I had to replace the fiberglass laminate.

Replacing the Fiberglass Laminate

In order to calculate the thickness of the fiberglass replacement laminate, we first needed to measure the original laminate thickness. Grinding back the fiberglass that was still attached to the rudder allowed us to count the number of layers. We measured the laminate with vernier calipers and it was 0.070" (0.0625" is 1⁄16"). Taking off a little for the gelcoat makes it an easy number to work with.

For a typical fiberglass repair, you taper back the existing fiberglass 12 times the thickness (12:1 taper). In this case, the 1⁄16" would be 12⁄16" (¾") all the way around. It's not a bad idea to taper more than 12 times on thin skin laminates. You want a nice even taper over ¾".

Determining the Number of Fiberglass Layers

Once we knew the laminate thickness, we had to determine how to match that thickness for our laminate repair. How many layers of a given weight of fiberglass would we need?

It's not surprising that different weights of fiberglass cloth have different thicknesses. But even the same weight of fiberglass can vary in thickness depending on the amount of epoxy applied to the cloth. For example, saturated or laminated, 10 oz. fiberglass can range from 0.0014" to 0.0019" thick. The range in thickness adds a degree of difficulty to calculating the number of layers of fiberglass required to match the thickness of an existing laminate. For example, 10 oz. fiberglass that's 0.0014" would reach a laminate thickness of 0.056" with four layers. But if the 10 oz. fiberglass you had on hand was actually 0.0019" thick, it would reach a total thickness of 0.057" with only three layers laminated.

Using fabric weight alone to determine the number of layers means estimating the repair laminate thickness. The result may be a laminate that's too thin, requiring you to buy and apply additional fiberglass. Or the laminate could be too thick and need to be sanded down, turning the epoxy and fiberglass you paid for into sanding dust, not to mention the "fun" of sanding fiberglass.

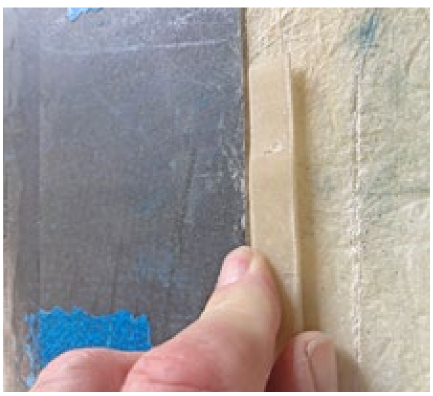
The method I used to determine the fiberglass weight and layers is simpler and more reliable. I made a laminate thickness gauge.

Making a Laminate Thickness Gauge

A laminate thickness gauge is a strip of a specific weight of fiberglass laminated in graduating layers that takes the guesswork out of comparing laminate thicknesses. To make mine, I used scraps of fiberglass cloth I had on hand. I began by cutting a few strips of fiberglass into graduating lengths. I used WEST SYSTEM 105 Resin® and 205 Fast Hardener® to lay up the fiberglass strips, one layer at a time. I started with the longest strip and left a 1" drop-off between layers. My gauge had four layers but I could have added as many as six. You can also make separate laminate thickness gauges for each weight of fiberglass you have on hand, making it easier to explore all of your laminate options.

Thickness gauge from the side.

Once the laminate thickness gauge had cured, I simply held it near the edge of the repair area to compare it to the thickness of the original laminate.



Thickness gauge.

The variance in thickness at different levels of the gauge reflects both the fabric thickness and how you laid up the laminate, making these gauges especially accurate. You can laminate the repair area in the same way you laminated the gauge to reach the same thickness results. Using my laminate thickness gauge, I decided that two layers of 17 oz. 737 Biaxial Fabric would be closest to the original laminate thickness. Any low areas could be filled with WEST SYSTEM Epoxy and 407 Low-Density filler. High spots would be minimal and easily sanded fair.

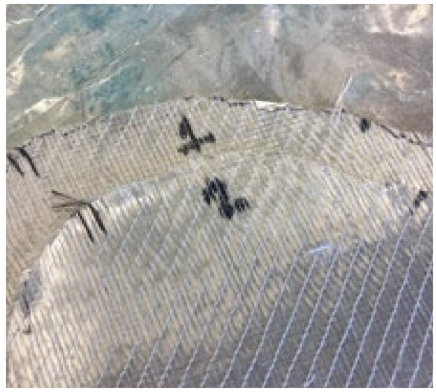
Estimating the Amount of Epoxy Needed

At two layers, I calculated we'd need 1 sq. yd. of 737 Biaxial Fabric to make the repairs. The type of laminate I wanted to create doesn't call for filling the fiberglass weave, so we needed only 1 oz. of WEST SYSTEM Epoxy per oz. of fabric. Since 737 Biaxial Fabric weighs 17 oz. per sq. yd., 17 oz. of mixed epoxy resin and hardener was enough to get the job done. I added 15% to this calculation to account for waste, bringing us up to 19.55 oz. of epoxy. An A kit of 105 Resin® and 205 Fast Hardener® or 206 Slow Hardener® contains 38.4 fl. oz. of epoxy—enough to complete this repair with plenty epoxy left over to do the fairing.

The coverage quantity chart available at westsystem.com and in the WEST SYSTEM *User Manual & Product Guide* is a good reference for determining how much epoxy you'll need when laminating fiberglass. Because the figures on the chart pertain to filling the fiberglass weave and I didn't intend to do that, my epoxy coverage calculation was considerably lower.

Cutting the Fiberglass

To cut the fiberglass to the correct size and shape, I laid clear plastic over the repair area and used a felt tip marker to trace the outline of the repair area. This is very effective when doing a repair around a corner, such as the leading edge of the rudder or the chine of a powerboat. Cutting the plastic on the line, I now had patterns for cutting my fiberglass. You can also lay these patterns out on your fiberglass to determine the most efficient way to cut it, minimizing fiberglass waste.



Alignment marks.

Using the felt tip marker, I traced the pattern on the fiberglass and cut it out. I used the same pattern for the second layer on this project and cut inside the line a little to make the piece smaller. For repair with numerous graduated layers, you can draw each size on the pattern and cut it back for each fiberglass layer.

We traced the pattern on the fiberglass before cutting it out.

For large or complicated repairs, it's good to number your layers of fiberglass. Use alignment marks to ensure you've placed the fiberglass in the right spot when you lay it on the repair area.

Fiberglass in place with release fabric.

Laminating

The repair area should be clean and dry, and any exposed foam should be hand sanded with 80-grit sandpaper. The fiberglass around the edge should already be ground back at a 12:1 taper.

Coat the repair area with a mix of 105 Resin and 205 or 206 Hardener thickened to a catsup consistency with 406 Colloidal Silica filler. This will fill small holes and imperfections while helping prevent air voids under the first layer of fiberglass.

Starting with the largest piece of fiberglass, position the fabric on the repair area. Use a plastic spreader to smooth the cloth and remove trapped air. Wet out the fabric with unthickened epoxy using a plastic spreader or foam roller to spread the epoxy, saturating all areas of the fiberglass. Repeat for each layer of fiberglass until you have bonded the smallest piece in place last, centered over the repair area. Bonding the patch into place in a large-to-small-piece sequence eliminates the possibility of sanding through any of the fiberglass layers while fairing the surface.

It's a good idea to apply 879 Release Fabric over the final layer of fiberglass. Cut the release fabric several inches larger than the repair area and smooth it in place over the patch. To remove excess epoxy and smooth the patch, drag a plastic spreader over the release fabric, pressing firmly. Before the epoxy cures, use a beveled mixing stick or a paper towel to remove any excess epoxy from the surrounding areas. Allow the patch to cure thoroughly.

TOP: *The rudder shaft before and after repair.*
RIGHT: *The finished rudder after repair.*

Final Finishing and Inspection

Remove the release fabric. Release fabric will not bond to WEST SYSTEM Epoxy and will leave an evenly textured surface. Release fabric will also remove any amine blush, a waxy byproduct of the epoxy curing process. Sand the repair area to remove any high spots. Fair the repair as described in section 14 of *Fiberglass Boat Repair & Maintenance*, then finish it as described in section 15.1.

Another area of concern was around the rudder shaft, the most common place I have found rudders to leak. On Chris's rudder, the water intrusion was from a failed repair near the top of the rudder shaft. I should also note that this rudder was used in freshwater. Saltwater is much more corrosive, and further inspection should be done on saltwater rudder shafts. Areas of core foam can be removed down to the shaft to check for corrosion.

With the rudder removed from the boat, it was a great time to inspect areas rarely seen. We found a small gap where the rudder tube was bonded to the hull. We cleaned the void area with a rotary tool then injected Six10 Thickened Epoxy Adhesive into the void.

A new rudder would have cost around $3,500. These repairs were completed for under $300. The dried and repaired the rudder is as good as new and ready to tackle whatever the Great Lakes has to throw at it.

ALUMINUM MAST STEP REPAIR ON A FARRIER TRIMARAN

By Don Gutzmer—GBI Technical Advisor

I received a call from a friend of mine who owns a 2004 Farrier F33RX folding trimaran, the 33' *Nelda Ray*. This sailboat is a frequent competitor in regattas on the Great Lakes. The aluminum mast step was compressing the deck and causing laminate failure. I told my friend I'd figure out what went wrong and then fix it so it would never happen again. I'll outline the process I used to make this successful repair.

Before I started the repair, I covered the boat inside and out with a layer of 5-mil plastic sheeting in order to keep things clean. I left exposed only the areas that needed surface preparation. I used painter's tape to seal the plastic film along the edges. Working as neatly and cleanly as possible helps me to manage my time and make repairs efficiently.

The first step in this repair was to find out why the laminate had been compressed to the point of failure. To investigate, I removed the aluminum mast brackets from the mast step and examined how the deck was constructed. Using a router with a plunge tip bit cutter, I removed a portion of the deck but left the inner fiberglass skin intact. This made the problem easy to see: the laminate damage occurred because the load was too great for the core.

The deck had been fabricated with a few layers of lightweight fiberglass over high-density foam core, with minimal layers of fiberglass inside of the hull. The high loads from the mast bearing down on the aluminum mast step had compressed the foam core, leading to fatigue damage over the years.

I devised a two-part repair plan that would prevent this failure from reoccurring. The first part required increasing the compression strength of the core. The second part was to strengthen the supporting structure to redistribute loads to the hull.

I began the first phase of the repair by bonding a ⅝"-thick Garolite® G-10 panel (approximately the size I'd removed with the router) in place of the high-density foam core. G-10 is a high-pressure fiberglass laminate that's manufactured by stacking multiple layers of glass cloth, soaking them in epoxy, and compressing them under heat until the epoxy cures. You might ask "Why use G-10 Garolite® when you could make a fiberglass panel with WEST SYSTEM® Epoxy?" One reason is that I had a time constraint so it was more efficient to order a prefabricated panel. G-10 offered all the attributes I needed for the application, including excellent mechanical properties.

To prevent stress concentrations on 90-degree angles, I rounded the corners of the G-10 panel and sanded with 80-grit to prepare for epoxy. For bonding the G-10, I chose Six10® Thickened Epoxy Adhesive because of its gel consistency and toughness when cured. The Six10® was applied to the bottom of the G-10 panel to adhere to the inner fiberglass laminate.

After the Six10® cured, I used a grinder to taper a 12:1 bevel around the perimeter of the outer fiberglass skin on the deck. In order to replace the damaged laminate, I cut five patches of 1708 biaxial fiberglass cloth in graduating sizes. I used WEST SYSTEM® 105 Resin and 206 Slow Hardener® to apply these patches. I made each fiberglass patch ½" smaller in all directions. I wet out the patches with epoxy and applied the largest patch first, followed by four consecutively smaller patches to match the original thickness. I then applied 2-3 fill coats of epoxy.

After the epoxy cured, I sanded the surface smooth with 80-grit. Next, I mixed a fairing compound consisting of WEST SYSTEM® 105/206 thickened with 407 Low-Density filler. Using a plastic spreader, I applied the fairing compound and filled in any low spots. When it cured, I sanded it with 220-grit to prepare for primer. To match the original gray paint on the deck, I carefully mixed black and white paint to reach the correct shade of gray.

Phase two was to reinforce the inside of the hull to redistribute the loads from the aluminum mast brackets. To do this, I would need four more pieces of G-10. Two panels would attach to the underside of the deck on each side of the daggerboard case and the others would adhere vertically to the daggerboard case. Then the panels would be covered with multiple layers of fiberglass cloth.

To prepare the G-10 panels, I ground a taper on one side of all four pieces to minimize stress concentration and allow the fiberglass to transition smoothly onto underside of the deck and the daggerboard case. Using an orbital sander with 80-grit, I also removed the paint from the underside of the deck and the daggerboard case where I planned to bond the G-10 panels.

With Six10 Adhesive, I epoxied a G-10 panel to the underside of the deck on each side of the daggerboard case. I positioned wooden prop sticks to help hold the panels in place until the epoxy cured. The other panels were butted underneath to better transfer the loads from the deck into the daggerboard case. Once that cured, I used Six10 to create a fillet where the two panels butted together.

The final step was applying four layers of 1708 Biaxial Cloth over the panels. Applying witness marks to the fabric with a felt tip pen helped me place it exactly where it belonged. After fairing the surface with epoxy thickened with low-density fillers, I sanded it smooth and painted it with a flat white paint.

Over a three-week period, there were many starts and stops to complete this project. My friend had a tight deadline for an upcoming race. Working evenings to meet the deadline, it took me about 45 hours to complete these repairs. My friend was very happy with the finished repair and said it looked great. He also mentioned, with the mast step repaired, he could now put on enough tension to properly tune the rig (which he was not able to do before, due to the damage.)

Following my repair, Team *Nelda Ray* successfully competed with 93 other boats in the 34th Harvest Moon Regatta. This 150-mile race goes from Galveston to Port Aransas, Texas. *Nelda Ray*'s crew took line honors and was awarded the Mayor's Trophy. They went on to take 1st place in the Multihull Gold Division of the 53rd Wurstfest Regatta hosted by the Canyon Lake Yacht Club in Texas.

Jobs like repairing *Nelda Ray* improve my ability to troubleshoot and give me more experience with WEST SYSTEM products. This in turn allows me to provide better technical support to our WEST SYSTEM customers.

SCAN ME

Watch our boat repair videos. Scan this tag or go to **youtube.com/WestSystemEpoxy**

A CLOSER LOOK

01

The aluminum mounting brackets on the mast step.

02

The aluminum brackets were removed to evaluate the damage.

03

A router was the best tool for removing the high-density foam core.

04

To make room for the G-10 panel, I removed the high-density foam with a router.

The fiberglass laminate was beveled around the perimeter of the cutout area. The foam was removed under the G-10 panel although some foam remained when this image was taken.

Thin cardboard was used to make a template for cutting the G-10 panels.

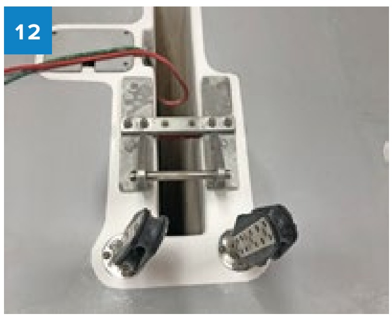
⅝" G-10 panels were bonded to the deck with Six10 Thickened Epoxy Adhesive.

Four layers of 1708 biaxial cloth was applied over the G-10 panels.

WEST SYSTEM 105/206 thickened with 407 Low-Density filler was used to fair the repair with the existing deck.

The 105/206/407 fairing compound cured, sanded smooth and ready for paint.

The repair area was taped off before applying white paint.



The paint, color-matched to the deck color with pigment.

80-grit was used to sand away the paint on the daggerboard case.

The G-10 panel bonded to the underside of the deck and the ¼" thick fiberglass panel bonded to the daggerboard case. Prop sticks helped to hold the panel into position until the Six10 cured.

Four layers of 1708 were applied over the panels with 105/206.

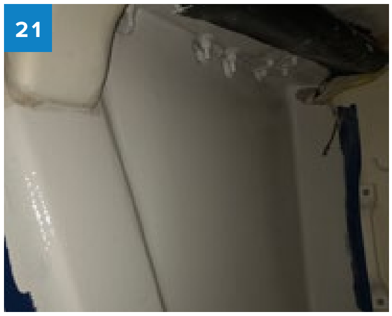
The surface was faired with 407 Low-Density and 410 Microlight® filler.

Applying the finishing touch-ups with 407 Low-Density filler to the starboard side.

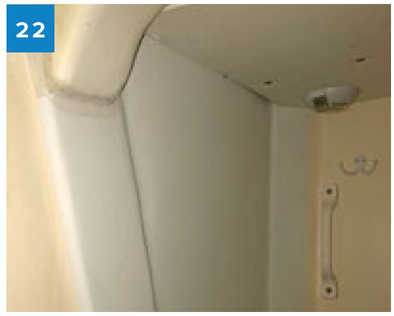
The surface was painted with flat white paint to finish the repair.

The repair finished with paint.

The port side G-10 panel was bonded underneath the deck with Six10.



The daggerboard case getting a coat of paint to finish the repair.



The finished repair after the painter's tape was removed.

Team Nelda Ray successfully competed with 93 other boats in the 34th Harvest Moon Regatta. This 150-mile race goes from Galveston to Port Aransas, Texas. Nelda Ray's crew took line honors and was awarded the Mayor's Trophy (1st Multihull to finish).

SPRAYING EPOXY
(PLEASE DON'T)

By Rachael Geerts—GBI Composite Materials Engineer

Every year we get questions regarding how to spray WEST SYSTEM® Epoxy. Some people want to know how to thin epoxy so it comes out of a spray gun better while others want to know what Personal Protective Equipment (PPE) is required for spraying epoxy safely. We give them all the same answer: Don't do it! In short, epoxy is extremely hazardous when sprayed.

Why You Shouldn't Spray Epoxy

To spray epoxy it must be atomized. This means the tiny epoxy molecules will be airborne. You might be saying to yourself, "Of course the particles of epoxy have to be small enough to be airborne Rachael, that's the definition of spraying it." Consider other materials you are used to spraying: hairspray, sunscreen, bug spray, just to name a few. Yet, how much of these relatively less hazardous aerosols do you really want to inhale?

To make matters worse, in order to reduce the viscosity of the epoxy enough for a spray gun to atomize it, you must thin the epoxy with a solvent. In general, we don't recommend thinning the epoxy with solvents as they can decrease the cured properties. In high enough loadings, solvents can affect every stage of the epoxy curing process.

No Sufficient Protection

To play devil's advocate, let's say you thinned the epoxy with a low loading of a common solvent. Now, you not only have to concern yourself with the health and safety effects of the atomized epoxy, but also those of atomized solvent. "That's okay Rachael, I've worked with other fiberglass resins that I've sprayed so I know I have to wear a mask." A mask, even an N-95 or a full face mask, isn't going to protect you from atomized epoxy. Also, a mask only theoretically prevents you from inhaling the epoxy; it doesn't prevent absorbing epoxy through your skin.

Perhaps you could find a pressurized suit with air provided (not generated, provided) from an outside source. That would help you in the immediate application but then you also have to understand how solvents affect the epoxy's curing reaction time.

Beware the Green Stage

The epoxy curing reaction is very slow compared to polyester, vinyl ester, or the glues used in spray tack and hairspray. WEST SYSTEM 105 Resin® with 205 Fast Hardener® takes about 60 minutes to gel in a thin film (~1⁄16" or ~63 mils thick). That means for at least 60 minutes, atomized epoxy that hasn't yet reached the tacky state can float around the room. Then there are another 6-8 hours during which the epoxy is trying to cure to a solid-state we call the green stage. It's when epoxy has enough cross-link density to become solid but is still reacting chemically. The 6-8 hour mark is when the green stage begins, assuming your solvent hasn't affected that too much, not when the green stage ends. The epoxy could stay green for hours to days later. Walking into the shop while atomized epoxy is in the green stage can kick up these tiny particles. Without a pressurized suit with an external air source hooked up, these epoxy particles pose serious health effects including skin sensitization, respiratory tract irritation or burns, or, as if those weren't enough, chemical pneumonia.

Overspray of Atomized Epoxy

If you have ever spray-painted something then you know how much overspray there can be, and that's with a product designed to settle to the surface within 5 or 10 minutes of spraying it. Think of how far small, atomized epoxy particles can travel with that nice summer breeze blowing through the shop, or through the heating system when you're working in the garage or the basement in the winter.

For the sake of this example, let's limit the overspray radius to six feet. Now when the epoxy has cured, everything within six feet of the edge of your project is coated with a thin layer of epoxy.

We appreciate our customers and want you to be successful. Contracting chemical pneumonia or having everything in your shop coated with epoxy is not "success" in our book.

The Good News

You don't need to spray epoxy to get a solid repair or a great-looking part. Just visit westsystem.com and follow our tips on how to properly apply epoxy. Still have questions? Call our Technical Staff weekdays from 9:00 AM to 5:00 PM EST at 886-937-8797 (toll-free).

PROTECTION FOR AGING THRESHOLDS

By Colin A.M. Duncan

I frequently use WEST SYSTEM® Epoxy to make exterior repairs on our very old house, which is part stone and part wood. The stone sections date from 1842 and the "newer" wooden parts from 1908.

The fir thresholds at the south and east entrances to the elevated kitchen were easily damaged and heavily worn. One day, I had the bright idea to apply a lick of WEST SYSTEM Epoxy to seal the kitchen thresholds and protect them from further wear.

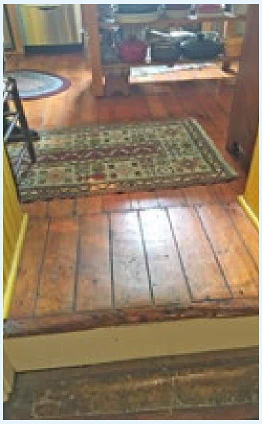
I also put a thick coat of pigmented epoxy on the front door threshold when we installed a replica period door. The front door threshold is made of tougher wood. With its epoxy coat, it endures the passage of bicycles several times a day, as well as occasional suitcases, clumsy and/or elderly relatives, winter road sand and grit, garden dirt, and so on.

There are no detectable scratches in the wood on any of the epoxy-coated thresholds despite a lot of traffic over several years.

I first used WEST SYSTEM Epoxy in 1976 when building my wooden Flying Dutchman, which is still sailing. I've been active in the DN iceboat fleet for 10 years and own one of Jan Gougeon's DN masts made for him by Ron Sherry. At the raffle at the 2020 DN North American Championships in Montana, I was delighted to win a blue WEST SYSTEM flag. I display it from time to time when on the water, whether frozen or liquid.

TOP: *Colin's front door threshold, protected by epoxy.*

BOTTOM: *The Kitchen threshold, repaired.*



YELLOW GLUE VS EPOXY

Rachael Geerts—GBI Composites Materials Engineer

When should you use yellow glue (also called wood glue or carpenter's glue) and when should you use WEST SYSTEM® Epoxy? This is a common question epoxy users ask, especially when trying to choose the best adhesive for their woodworking projects. Let's look at when one is a better choice than the other, and why.

Cost

Most people notice right off the bat that there is a price gap between the two products. Yellow glues are typically inexpensive while epoxies are more costly. This is a good time to mention that you get what you pay for. Yellow glue is great for many applications but does have its limitations.

Material

This article will only apply to wood applications because yellow glue is inappropriate for work with other materials. When gluing a hem on your dress slacks, you wouldn't consider using epoxy instead of fabric glue. That being said, the type of wood you are working with could make a difference in which adhesive you may be able to use. Nice dry pieces of mahogany or pine could be bonded with either WEST SYSTEM Epoxy or yellow glue. However, if you are trying to bond oily woods like teak or ipe then WEST SYSTEM Epoxy's toughness can help you achieve a stronger bond.

Ease of Use

It is important to define each adhesive type. Yellow glue can be identified as an aliphatic resin suspended in water. When the water evaporates it leaves behind intertwined polymer chains that bond the two pieces of wood together. This style of resin is a one-part that allows for easy clean-up with water.

All WEST SYSTEM Epoxies are 2-part systems. When you mix the epoxy resin with the hardener at the proper ratio, the two components react, chemically joining and building the polymer network that adheres the pieces of wood together. While epoxies require measuring and mixing (as opposed to one-part glues), they form a stronger polymer network.

Epoxy can't be cleaned up with water once it is cured but that's a good thing. The last thing you want is to put your boat in the water and have the glue joints start dissolving. Since epoxy can't be easily cleaned up once cured, we recommend making epoxy joints as neat as possible before the epoxy cures. Scraping off excess epoxy from your project with a mixing stick and cleaning your tools with solvent before the epoxy cures can save you a big headache later.

Joinery, Gap Filling Properties, and Shrinkage

The tightness or fit of the joint you want will make a difference in the adhesive you should select. Yellow glue works very well when you have seamless joints and the pieces of wood fit together perfectly. Woodworkers commonly use joinery techniques like biscuit joints, mortise and tenon joints, and tongue and groove joints to increase the bonding area of yellow glue while maintaining very tight and sometimes almost imperceptible joints. Also, yellow glue contains a lot of water that evaporates as the glue dries, so it shrinks quite a bit.

Conversely, WEST SYSTEM Epoxy does not shrink when it cures which makes it great for applications where a perfect fit and/or high clamping pressure is not possible. In fact, epoxy can fail prematurely in very tight-fitting joints or where high clamping pressure creates an epoxy starved joint. We recommend a bond line thickness of approximately 0.01" (0.25 mm) but epoxy can be used in bond line thicknesses up to ¼" (6.35 mm). It is important to note that in thick applications epoxy can generate a lot of heat, which is called uncontrolled exotherm. Contact our technical department if you have questions about the amount of heat generated in a thick (greater than ¼") bond line application.

You can improve epoxy's gap filling properties in adhesive applications by adding one of our four WEST SYSTEM adhesive fillers: 403 Microfibers, 404-High-Density, 405 Filleting Blend, or 406 Colloidal Silica. These fillers increase the epoxy's viscosity, ensuring continuous contact between bonding surfaces and resulting in a strong bond. Another option is to select a prethickened epoxy like Six10® Thickened Epoxy Adhesive or G/flex® 655 Thickened Epoxy Adhesive.

For best results when joining wood with epoxy and fillers, we recommend two-step bonding. This calls for coating the bonding surface with unthickened epoxy before adding thickened epoxy to fill gaps.

Moisture Content

You should understand the moisture content of the wood you are bonding. What is its moisture content during the bonding application and what is the expected moisture exposure of the finished piece? Since common yellow glue is a polymer suspended in water, the wood you plan to bond should be dry in order for the glue to dry properly.

Many woodworking sites recommend a moisture content between 8 and 12%. This is similar to what we recommend for making structural wood bonds with our 105 System. One of our specialty epoxies, G/Flex 655 Thickened Epoxy Adhesive, excels here as it can achieve a structural bond to wood that has up to 18% moisture content. G/flex 655 can even be used to make temporary repairs on damp or wet wood. Once the wood is glued together, you still need to think about the environment your project will be exposed to. There is a good reason boat builders use WEST SYSTEM Epoxy! It offers excellent moisture resistance once cured. Three to five coats of 105 Resin®-based epoxy can dimensionally stabilize wood by sealing it so the moisture content doesn't change.

Again, since yellow glue is a polymer suspended in water, it generally won't hold up well in damp or wet environments.

Want to learn more about achieving a good bond? Scan the QR Code to learn tips for best results when clamping epoxy joints from GBI Technical Advisor Don Gutzmer.

Strength

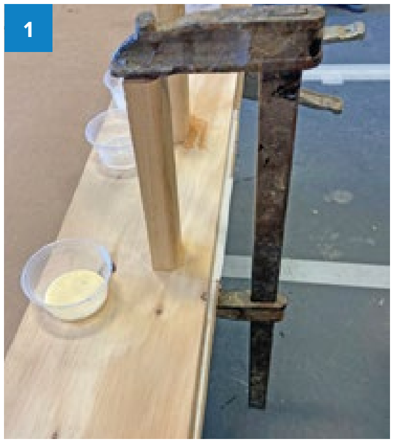
Finally, take into account how strong you need the bond to be. As you can see from images 1 and 2, we did a simple test by bonding pieces of end-grain pine to exterior grade plywood, one with yellow glue and the other with WEST SYSTEM Epoxy. After allowing both adhesives to dry/cure for 24 hours, we used a hammer to break the pine away from the plywood. As you can see from images 3 and 4, both adhesives pulled apart the wood fibers in the veneers of the plywood. This type of failure is commonly referred to as failing the wood (since the glue joint hasn't failed and still has wood on both sides). The epoxy did fail the wood more evenly in the bonding area and through one additional ply of the plywood than the yellow glue. That being said, it was the plywood that failed in both applications, so yellow glue can definitely hold its own.

I wanted to see if I could make the pieces of pine fail so I glued them down again, this time horizontally on the face grain. This increased the bonding surface area. After another 24-hour dry/cure time, I use a sledgehammer. As you can see in images 5 and 6, the bond is still fully intact. You can modify this test to account for the other wood varieties, moisture content, and other conditions previously discussed in this article to see how well each adhesive will hold up in your project.

The Best of Both Worlds

It's important to note that the only strength described here is adhesive strength. WEST SYSTEM Epoxy has great strength on its own, far above yellow glue's inherent strength. However, for applications where you are only concerned with adhesive strength and moisture isn't an issue, either system can work very well. You can also glue pieces of wood together with yellow glue and, once it is fully dried, prep and seal the wood with epoxy. Particularly for non-marine applications or non-oily woods, this approach can offer you the best of both worlds.

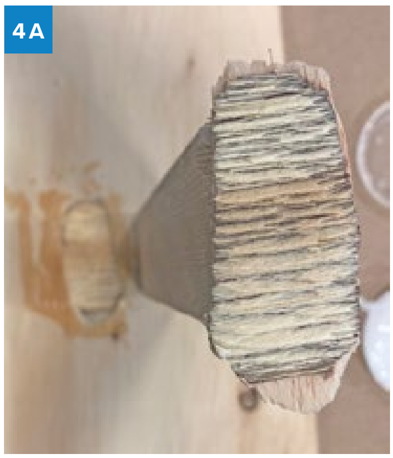
There are many aspects of your woodworking project to consider when selecting an adhesive. We've highlighted cost, material, ease of use, fit, moisture, and strength of yellow glue and WEST SYSTEM Epoxy. These are important considerations in selecting the appropriate adhesive for your next woodworking project.

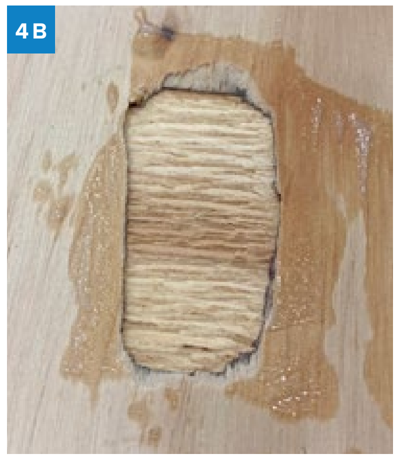


Pine glued vertically to plywood with yellow glue.

Pine glued vertically to plywood with WEST SYSTEM Epoxy.

The broken or "failed" surface of the plywood glued with yellow glue.





The broken (failed) surface from the plywood glued with WEST SYSTEM 105 Resin® and 207 Special Clear Hardener® thickened with 406 Colloidal Silica Filler.

Pine still glued horizontally on plywood with yellow glue after removal attempt.

Pine still glued horizontally on plywood with epoxy after removal attempt.

For information about WEST SYSTEM® products or technical information for a building or repair project, Gougeon Brothers offers a range of detailed publications that can help you get started. These publications are available at your local WEST SYSTEM dealer or by contacting Gougeon Brothers. They are also available as **free downloadable PDFs at westsystem.com.**

How-to Publications

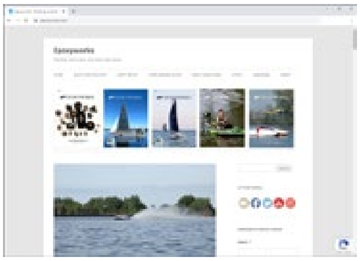
002 **The Gougeon Brothers on Boat Construction**
A must for anyone building a wooden boat or working with wood and WEST SYSTEM Epoxy. Fully illustrated composite construction techniques, materials, lofting, safety, and tools. 5th Edition, revised in 2005.

002-970 **Wooden Boat Restoration & Repair**
Illustrated guide to restore the structure, improve the appearance, reduce the maintenance and prolong the life of wooden boats with WEST SYSTEM Epoxy. Includes dry rot repair, structural framework repair, hull and deck planking repair, and hardware installation with epoxy.

002-550 **Fiberglass Boat Repair & Maintenance**
Illustrated guide to repair fiberglass boats with WEST SYSTEM Epoxy. Procedures for structural reinforcement, deck and hull repair, hardware installation, keel repair, and teak deck installation. Also, procedures for gelcoat blister diagnosis, prevention and repair, and final fairing and finishing.

Look for Epoxyworks Online

If you are a new subscriber to *Epoxyworks* or haven't diligently saved every issue, you can find back issues at epoxyworks.com. You can also click on the "*Epoxyworks*" logo on the westsystem.com homepage.



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Readers' Projects

Alan Bergen built this Bear Mountain resolute kayak using 6 oz glass on the hull, 4 oz glass on the deck, WEST SYSTEM 105 Resin® and 207 Special Clear Hardener®. The trim is walnut and pine.

James Albert at Alché Design Co. in Mount Pleasant, Brampton, Ontario, built these live edge charcuterie boards.

Kevin Triplett of Boston, Massachusetts designed and built this kayak using WEST SYSTEM 105 Resin, 207 Special Clear Hardener, and 403 Microfiber Filler.

Custom knife with glow-in-the-dark scales, designed and built by Felicia at Scissortail Bladeworks in Catoosa, Oklahoma. The handle was made with WEST SYSTEM G/flex® 650 Toughened Epoxy.

Share your work and fuel your creativity

Submit your projects at info@epoxyworks.com

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