Fibreglass Boat Repair & Maintenance

A guide to repair, restoration and prolonging the life of fibreglass boats with WEST SYSTEM® brand products

Contents

Fibreglass Boat Repair & Maintenance

Repairing, restoring and prolonging the life of fibreglass boats
with WEST SYSTEM ® Brand epoxy.

Catalogue No. 002-550

Published by Gougeon Brothers Inc. and Wessex Resins & Adhesives Limited

The techniques described in this manual are based on the handling characteristics and physical properties of WEST SYSTEM Epoxy products. Because physical properties of epoxy systems and epoxy brands vary considerably, using the techniques in this publication with coatings or adhesives other than WEST SYSTEM Brand products is not recommended. Please refer to the current WEST SYSTEM Technical Manual & Product Guide for complete product information and safety/handling data.

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ISBN 1-899347-25-9

(Original edition ISBN 1-878207-26-1 published by Gougeon Brothers Inc., U.S.A.)

GOUGEON ®

Section One

1 Introduction

Over the last few decades the popular perception of fibreglass boats is that they are maintenance free and far more durable than wooden boats. While fibreglass boats do, on average, require less maintenance, they are not without problems. Fibreglass boats suffer from many of the same age related problems of fatigue and moisture that have long been associated with older traditionally built wooden boats in addition to the usual damage from collisions, groundings and the forces of nature.

This manual provides repair and maintenance solutions to many of the problems which affect fibreglass boats.

1.1 Typical Fibreglass Boat Construction

A fibreglass boat is a composite structure made of many layers of various reinforcing fabrics and core materials bonded together with plastic resins. Alternatively, a fibreglass boat could be described as a plastic resin shell reinforced with various fibres or Fibre Reinforced Plastic (FRP). Most loads in the structure are carried by the fibres in the laminate. Resin and core materials support the fibres in positions to effectively carry and spread the loads. Generally, the higher the proportion of fibre to resin in a laminate, the greater its strength and stiffness.

The continuity of these resin/fibre skins is critical to the integrity of the structure. It is often necessary to cut through the skin while carrying out repairs even though the skin itself may not be damaged. Bear in mind that one objective must always be to rebuild for skin continuity. This will ensure the repaired area will return the load carrying capability of the fibres in the laminate to original or greater strength.

1.1.1 Fibreglass resins

The vast majority of fibreglass boats in use today are built with polyester resin. Modern unsaturated polyesters used in boat construction are made up of three basic components: glycol, organic acid and reactive diluents (usually styrene). If looking at uncured polyester resin under an electron microscope, thousands of chains of alternating glycol and acid units would be revealed. These chains are polyester pre-polymers. Adding a peroxide catalyst, typically MEKP, to the polyester resin mixture initiates a cross-linking reaction that causes the styrene to create bridges, linking adjacent pre-polymer chains together. As the mixture cures, more and more bridges are established and the free-flowing glycol/acid chains begin to gel, becoming a solid mass. Eventually, enough bridges are built to form a rigid, three-dimensional grid or matrix. The mix has become a solid thermoset plastic used, in this case, to hold bundles of fibres together in the shape of a boat.

1.1.2 Fibres

Fibres used in production fibreglass boats take the form of various types of fabrics, such as chopped strand mat, woven cloth, woven rovings, unidirectional, biaxial and triaxial cloth. Each fabric type offers different properties and they are often used in combination to provide specific strength or stiffness properties in different parts of a laminate. Fabric selection may also be based on handling characteristics and cost. Most fabrics are either woven or bundles of individual, continuous pultruded fibres of various synthetic plastics stitched together. The least expensive and most common fibre used in production boats is E-glass. It is widely available and used extensively for repair. Fibres may also be made of more exotic materials such as aramid or graphite. These fibres offer much higher strengths but are much more expensive and are used primarily in one-off, high-performance boats where saving weight is vital and worth the higher cost. Stitched fabrics represent a major advancement in composite technology achieving higher fibre-to-resin ratios and stiffer laminates than woven fabrics of equal weight.

1.1.3 Cores

Cores are used in laminates to increase stiffness of a panel without adding a proportional increase in weight. Doubling the thickness of a panel can result in an eight fold increase in stiffness. By laminating a lightweight core between two fibre/resin skins a great deal of stiffness can be gained with a minimum amount of added weight. The skins take the tensile and compressive loads caused by bending the panel but the “I” beam effect produced by the addition of the core allows the panel to withstand much greater bending loads. End-grained balsa is the most widely used core material in production boats. It offers low cost, good impact resistance and compressive strength to resist the collapsing of skins under load. PVC foam cores are available with a variety of characteristics. They are more expensive than balsa, but more resistant to moisture damage. Honeycomb core is an open corrugated pattern of paper or other thin material on edge. Honeycomb is often used in prefabricated panels for bulkheads and other internal components.

1.1.4 Construction methods

Generally, production fibreglass boat hulls are built in a female mould. A release agent is first applied to the surface of the mould over which the gelcoat material is applied. The gelcoat is usually a pigmented, unsaturated polyester resin and varies in thickness between 300 and 600 microns. It is designed to act as a moisture barrier for the underlying laminate in addition to providing a smooth, glossy, cosmetic finish. Subsequent layers of fabric are saturated with resin and laid up over the gelcoat. There are as many lay-up schedules as there are boats. A typical hull section might consist of the layer of gelcoat, several alternating layers of mat and woven roving and, in many cases, a core material such as end-grain balsa or foam, followed by several more alternating layers of mat and woven roving *(Figures 1-1 & 1-2)*. Hull thickness will vary from boat to boat. Older boats were often laid up with a solid glass laminate thickness of 35mm to as much as 125mm in the keel areas of the more heavily-built boats. Today, however, the trend is toward thinner, lighter laminates, making the structural integrity of each of the laminate components much more critical.

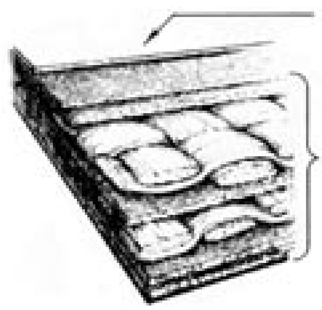

Figure 1-1 Typical **solid** (single skin) fibreglass laminate. Various reinforcing fabrics are bonded together with polyester resin.

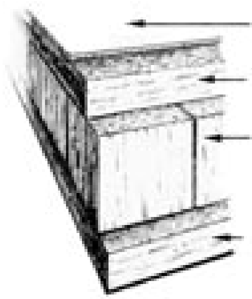

Figure 1-2 A typical **cored** laminate consists of end-grained balsa or other core material sandwiched between two resin/fibre skins.

Standard lay-up relies on gravity to hold the resin-saturated material in place until cured. However, the technique of vacuum bag laminating has advanced composite construction by allowing the builder to compress the entire wet-out laminate evenly in the mould and more accurately control the resin content and the strength-to-weight ratio of the laminate.

Although it is not often associated with fibreglass boats, wood is used extensively in fibreglass boat construction for primary and secondar`y structural members such as bulkheads, frames and stringers, core material, blocking and trim. Stringers, bulkheads and other interior fixtures are bonded in after the shell has been completed. Many fibreglass boat repairs involve wood and the problems associated with polyester resins when bonding to wood.

Terminology used to describe the structure of fibreglass boats is not always the same terminology used to describe wooden boats. Where fibreglass boat components serve the same functions as wooden boat components, their names are often the same. However, materials and manufacturing methods vary from small boat to large boat, from power to sail and from manufacturer to manufacturer. Here is a general guide to the fibreglass boat terminology used in this manual. (*Figure 1-3)*

1.1.5 Hydrolysis and gelcoat blisters

The repair procedures in this manual address problems most often associated with mechanical damage — abrasion, bending, fatigue, impact and the resulting water damage to cores or other structural components. Another common problem for fibreglass boats is chemical in nature. Hydrolysis (and its symptom, gelcoat blisters or osmosis) is widespread and a growing problem in the fibreglass boat world.

Hydrolysis is more than a cosmetic problem. Water soluble materials in a polyester resin laminate mix with moisture that has penetrated the laminate to create an acidic fluid. The fluid collects in cavities under the gelcoat layer to form blisters. This acidic mixture also attacks the polyester resin, severing the chemical bonds that hold the resin matrix together as well as the resin/fibre bond. Once hydrolysis has begun in a polyester hull, the strength is compromised and the potential for serious further hydrolysis will exist.

An owner of a boat built with polyester resin should be aware that the potential for this problem is high, especially in warmer climates. Any damage due to hydrolysis should be assessed before commencing any repairs. Although this subject is too large to be adequately addressed in this manual, hydrolysis and gelcoat blisters can be treated with WEST SYSTEM epoxy to limit further damage and to protect unaffected hulls. In many cases the use of WEST SYSTEM epoxy will restore the structural integrity of a damaged hull. Full information covering the osmosis phenomenon is provided in our manual “Gelcoat Blisters: A Guide To Osmosis Repair”, published by Gougeon Brothers Inc. and Wessex Resins & Adhesives Limited.

1.2 WEST SYSTEM epoxy for fibreglass repair

Unsaturated polyester resins perform fairly well during the construction of a structure when all the layers of resin are applied and allowed to cure together. This type of bond is considered a primary bond. However, problems can occur when trying to bond polyester resin to a cured laminate, as is necessary in every repair application. This type of bond is secondary or post-bonding.

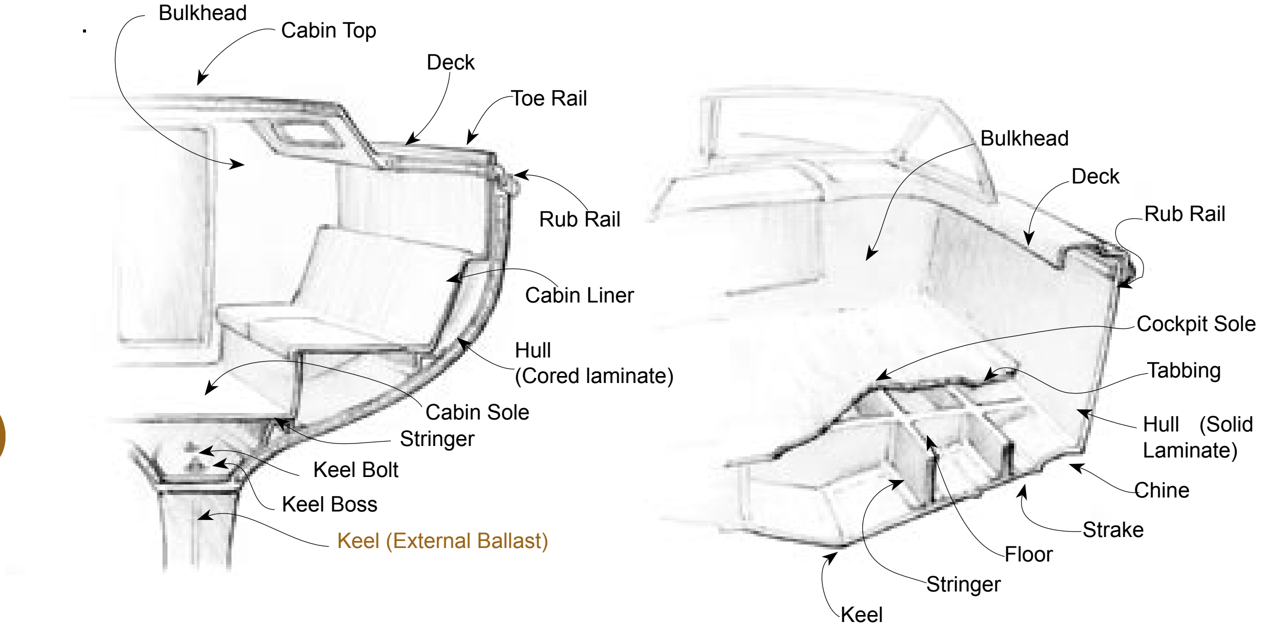

Figure 1-3 Components of typical fibreglass sail and power boats

To effectively repair damage typical of fibreglass boats, the repair material must be a superior structural adhesive, capable of bonding not only to polyester resin but also to glass fibre, wood, metal and other materials.There are several important reasons to use WEST SYSTEM epoxy rather than a polyester resin or other materials for fibreglass boat repair. Polyester resin can shrink from 5% to 8% creating stress concentrations at the repair joint. WEST SYSTEM epoxy shrinks less than 1% and is more effective as a moisture barrier. In addition, it forms a superior mechanical bond with the cured polyester and other materials in secondary bonding. Since epoxy is more durable than polyester, the epoxy repair may be actually stronger than the original structure. When considering the ease and practicality of application, availability, safety and access to technical assistance, WEST SYSTEM epoxy is an excellent choice for fibreglass boat repair. However it is stressed that osmosis is a complex problem and this manual should be fully read, understood and the instructions followed to achive the best chance of a successful repair

1.2.1 Using this manual

This manual begins with techniques for repairing common minor damage to hull and deck surfaces and progresses to more complicated structural repairs. Section 2 includes basic surface repairs and cosmetic finishing. Section 3 describes methods for repairing rotted stringers and adding reinforcing to areas of the hull or deck that are too flexible. Sections 4 and 5 deal with repairs to seriously damaged, solid and cored laminates in both hull and deck panels. The later sections include specific deck repair and modification, hardware attachment and keel and rudder repair. After the structural repairs are completed, it may be necessary to refer to Section 2 for the surface repair and cosmetic finishing.

Study and become familiar with all the steps in a procedure before beginning a repair. The procedures described in this manual assume a working knowledge of WEST SYSTEM products and the basic techniques of epoxy use. If you are unfamiliar with or have any questions about the application and handling techniques of WEST SYSTEM Brand epoxy products, read thoroughly Section 9 - *"Using WEST SYSTEM Epoxy"* -.before proceeding with repairs. The WEST SYSTEM Technical Manual & Product Guide also provides basic epoxy handling information as well as current product descriptions.

If you have additional questions after reading this data, contact our Technical Support Group for further advice:

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Section Two

2 Repairing Minor Cracks & Holes

Most of the repair work to be found on fibreglass boats is cosmetic in nature. Cracking or crazing of the gelcoat and scrapes and scratches account for much of the repair work carried out in boat yards. Permanent repairs to such damage can be made with WEST SYSTEM epoxy. When properly applied, an epoxy repair affords an extremely durable, water-resistant repair which offers an excellent base for various finishes. This section addresses the cosmetic repair of minor surface damage, cracking and panel reinforcement to reduce the cause of cracking.

2.1 Assessing damage

It is easy to account for the scrapes, scratches and cracks that result from impact but the causes of flex cracking or crazing may not be as obvious. Most cracks or crazing that appear gradually and get worse over time are the result of flexing and are frequently found in areas of solid laminate. They often appear near a bulkhead, deck to cabin curve, or window. In addition to the cosmetic surface repair, a thorough work programme will often require structural repair or reinforcing to reduce the flexing. The longer a laminate is allowed to flex, or the greater the impact, the deeper the cracks. The deeper a crack extends into the laminate, the greater the reduction in the strength of the panel. The first step in the repair is to prepare the damaged area and assess the degree of damage:

1. Examine the pattern and location of cracks to determine their cause *(Figure 2-1)*. If the pattern or location indicates flexing, examine the interior side of the panel to determine the best location for additional reinforcement. If the cracks are a result of impact, examine the panel internally to determine whether damage extends through the entire laminate.

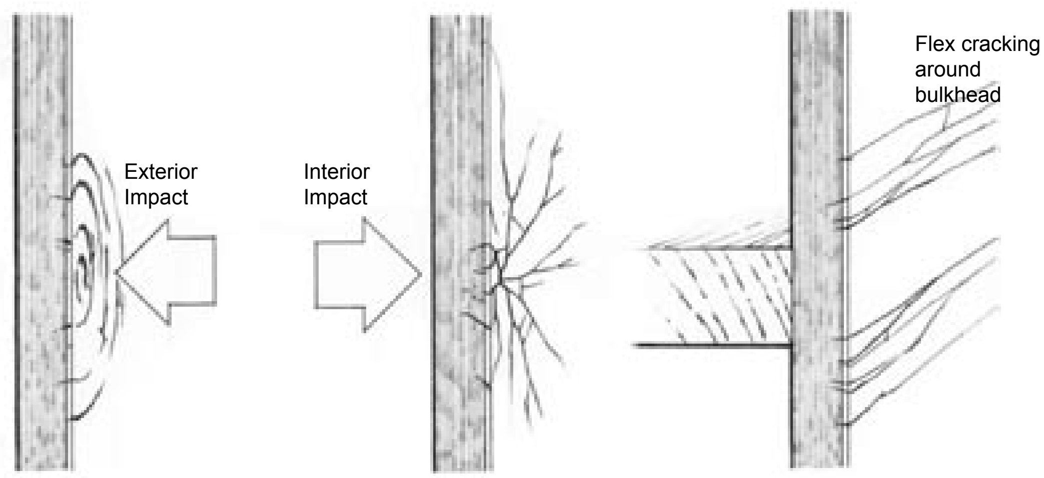

Figure 2-1 Typical types of cracks from impact or flexing. The pattern of cracking may help to determine the cause.

2. Remove any surface contaminants such as wax, oil or mould release. Wipe an area at least twice as large as the damaged area with a wax and silicone remover, or WEST SYSTEM 850 solvent. Dry the area with clean paper towels before the solvent evaporates.

3. Open the cracks for repair. Use a sharpened "V" shaped tool to scrape down to the bottom of cracks *(Figure 2-2)*. A puncture-type can opener with the tip sharpened to about 90° is ideal for the job. Bevelling the sides of the crack provides more bonding area for the repair. It may be more effective to grind out an entire area of many closely spaced or deep cracks *(Figure 2-3)*. Scrape or grind as deep as necessary to reach solid, undamaged material. The depth of the crack will determine which course of repair to follow:

a. Shallow cracks or scrapes that affect only the gelcoat layer may be repaired with the gelcoat repair technique described in Section 2.3.1. If necessary, reinforce the laminate to reduce flexing as described in Section 3.

b. Minor cracks or scrapes that run through the gelcoat into the first chopped strand mat layers of the laminate *(Figure 2-1)* should be repaired with epoxy using the procedures described below (Section 2.2). Finish with the gelcoat repair technique described later in Section 2.3.1. If necessary, reinforce the laminate to reduce flexing as described in Section 3.

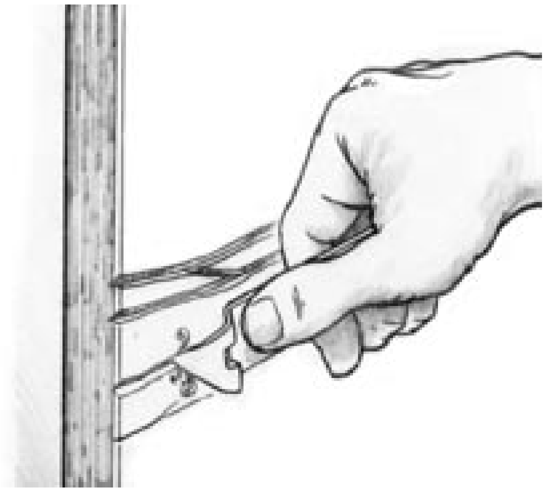

figure 2-2 Open shallow and minor cracks with a “V”-shaped scraper,such as a sharpened can opener.

Figure 2-3 Grind out an area of many closely spaced or deep cracks with a disc grinder.

a. Shallow cracks or scrapes that affect only the gelcoat layer may be repaired with the gelcoat repair technique described in Section 2.3.1. If necessary, reinforce the laminate to reduce flexing as described in Section 3.

b. Minor cracks or scrapes that run through the gelcoat into the first chopped strand mat layers of the laminate *(Figure 2-1)* should be repaired with epoxy using the procedures described below (Section 2.2). Finish with the gelcoat repair technique described later in Section 2.3.1. If necessary, reinforce the laminate to reduce flexing as described in Section 3.

c. Deep cracks extending into the woven fabric of the laminate require a structural repair before beginnin the cosmetic gelcoat repair. If the crack extends into or through the woven fabric of the skin, follow the procedures in Section 3. If a core has delaminated or is damaged from moisture penetration or impact, follow the appropriate procedure in Section 4.

2.2 Minor crack & abrasion repair

Minor cracks and scrapes that extend to the chopped strand mat layers of laminate may be repaired with WEST SYSTEM epoxy.

Scraped out damage

If cracks were exposed with a “V” shaped scraper, complete the repair as follows after preparing the damaged area as described above:

1. Feather the edges with the scraper or with 100-grit sandpaper and brush the surface free of dust and loose material.

2. Wet out the cracks with a resin/hardener mix.

3. Using 404 or 406 filler, thicken the resin/hardener mix to the consistency of peanut butter with 404 or 406 filler. Fill the cracks with the thickened epoxy mixture using the flat end of a mixing stick or a plastic squeegee. Smooth the filled epoxy mix flush with the surface and remove any excess before it begins to cure. Allow the epoxy to cure thoroughly.

4. Sand the area using 100-grit paper to remove any bumps or ridges. Finish by wet-sanding with 220-grit.

5. Finish the area with gelcoat or paint following the procedures in Section 2.3. Reinforce the laminate as necessary to reduce flexing, following the procedure in Section 3.

Ground out damage

If the damage is the result of a scrape or gouge or if cracks were exposed with a grinder, complete the repair as follows:

1. Grind a shallow, 20-to-1 slope around the damaged area. Remove any dust or loose material.

2. Wet out the repair area with a resin/hardener mix.

3. Fill the void with an epoxy/404 or 406 mix, thickened to the consistency of peanut butter. Use a plastic squeegee to shape the mix to the surface contour. Leave the mixture slightly higher than the surrounding area and remove any excess before it begins to cure. Allow the epoxy to cure thoroughly.

4. Sand the area to blend with the surrounding contour. Use 50-grit paper to remove any bumps or ridges and finish with 80-grit paper when close to the final shape.

5. Fill any remaining voids (if necessary), repeating Steps 3 and 4.

6. Apply two or three very thin coats of epoxy to seal the surface. Extend each coat slightly beyond the previous one to feather the edge. The area may be warmed with a heat lamp to speed the cure and to help the epoxy flow out. Allow the final coat to cure thoroughly.

7. Wet sand the area with 180-grit paper to prepare for the final finish.

8. Finish the area with paint or the gelcoat finishing procedure (Section 2.3.1). Reinforce the laminate as necessary to reduce flexing, following the procedure in Section 3.

2.3 Finishing

Although many types of coating systems are compatible with WEST SYSTEM epoxy and provide the necessary UV protection, we recommend polyester gelcoat for small repair areas and linear polyurethane paint for large repairs. Although gelcoat may be used over large areas, it's handling characteristics are more manageable over smaller areas and this is particularly so when it is necessary to colour match existing gelcoat. Linear polyurethane paints give extremely durable finishes and are appropriate for large complete sections like a hull or deck where colour matching is not critical. Paint application over a large area is more practical than gelcoat. These finishes are recommended for above the waterline only. Use WEST SYSTEM epoxy for all repairs and coating below the waterline, prior to applying antifouling paint.

2.3.1 Gelcoat finishes

The WEST SYSTEM epoxy is an excellent base for polyester gelcoats providing the procedure below is followed. This technique will ensure good adhesion and a good colour match for the repair. Ensure the WEST SYSTEM epoxy has thoroughly cured before applying gelcoat. Thoroughly wash the surface to remove any traces of amine blush.

1. Mask around the repair area and sand using an 80 grit paper or other suitable grinding/scraping implement.

2. Remove any small particles and dust from the area of repair and reapply masking if necessary.

3. Mix the gelcoat and catalyst following the manufacturers instructions, (normally 2% catalyst to 98% gel) then,using a clean brush, apply the gelcoat evenly. If required, re-apply gelcoat after approximately 2 hours to gain the correct film thickness. Allow to cure for 24 hours.

4. Using a sanding batten or suitable sanding block (220 grit wet and dry) lightly rub down the repair area to remove high spots. Care should be exercised not to mark the surrounding area.

5. If any low areas are visible re-apply the gelcoat following the steps above.

6. Allow the gelcoat to reach a full cure. Remove the tape and sand the tape line smooth. Start with 220-grit wet or dry paper to sand the surface fair and then use finer grades — suggested grades are 220, 380, 600 and 1000.

7. Buff the surface with a white, medium-cut rubbing compound. Exercise care when buffing to avoid overheating the surface. The excess heat can cause a stain which will be very difficult to remove. Finish with a fine compound and wax the area.

There are times when the repair will not match simply because the original gelcoat colour has faded. It may be necessary to polish the entire section of the boat to restore the original colour.

When filling small cracks or scratches that have not penetrated through to the laminate follow the steps below:

1. Remove any surface contaminants such as wax, oil or mould release. Wipe an area at least twice as large as the damaged area with a wax and silicone remover, or WEST SYSTEM 850 solvent. Dry the area with clean paper towels before the solvent evaporates.

2. Scrape out the cracks or scratches with a 90° "V" shaped scraper to expose clean gelcoat and increase the bonding area slightly. Do not scrape through the gelcoat.

3. Fill the scraped out voids with gelcoat. Mix a small batch of gelcoat without thinners. Trowel the mixture into the voids, leaving it slightly higher than the surface. Allow the gelcoat mixture to cure thoroughly. Follow steps 4 through to 7 above.

2.3.2. Paint finishes

Although almost any high-quality, marine-grade paint will suffice, we recommend using a two-part polyurethane paint system above the waterline. (Below the waterline, apply antifouling paint directly over the WEST SYSTEM epoxy surface which has thoroughly cured and has been well prepared). These paints provide ultraviolet protection, have good gloss retention and a durable, abrasion-resistant surface, provided the manufacturer's instructions are followed carefully. Polyurethanes adhere well to fibreglass surfaces bonded with both polyester and epoxy resins. Note: Ensure that all areas of 407 and 410 filled epoxy fairing compounds which have been abraded are sealed with a WEST SYSTEM resin/hardener mix

It is possible to colour match small areas, particularly if they are in fairly inconspicuous locations. However, if the repair is large or there are several smaller repairs over a large area, it may be easier to re-paint the entire hull or deck.

Polyurethanes, just like epoxies, are affected by moisture contamination and it is important to take careful note when painting - do not paint early in the morning or late in the afternoon and avoid painting in direct sunlight.

If painting the entire hull, deck or cabin top, begin by inspecting the total surface. Wipe with a silicone and wax remover, or WEST SYSTEM 850 solvent to eliminate any trace of mould release agents or wax. It may require two or three washings. Thoroughly abrade the surface to be painted by wet-sanding with 180-grit paper followed by 220-grit sandpaper. Note: Follow the paint manufacturer's recommendations for the final grit - the thinner the paint , the finer the grit. Remove all glossiness from the surface. Polyurethanes tend to highlight any surface imperfections, rather than hide them. Check for nicks, scratches or gouges and repair them as described previously.

After all repairs have been made, wash the entire painted surface with the paint manufacturer's recommended solvent. Always follow the manufacturer's mixing and application instructions to the letter. It is far better to apply two or three thin coats than one thick coat.

Section Three

3 Repairing Stringers and Floors. (Reinforcing to Improve Panel Stiffness)

Fixing damaged or delaminated stringers is one of the most common repairs associated with fibreglass boats. The usual causes of stringer failure are disintegration of the stringer core material, impact damage from slamming and grounding and fatigue from normal use. Although each repair situation has its own unique problems, the following techniques are fundamental to stringer repair. These guidelines will assist in repairing almost any damaged stringer.

3.1 Typical stringer construction

Stringers are support members bonded into boat hulls which are usually parallel to the long axis of a boat hull. Floors are support members, perpendicular to the long axis of the hull and they are fitted for a variety of reasons. They stiffen unsupported flatter hull panels in the same way that ribs or beams are used to provide the structural framework for wooden boats. They support cockpit and cabin soles and they distribute high load concentrations from engines and other mechanical systems. Often they perform several of these functions simultaneously.

Normally, in fibreglass boats, stringers (and floors) are composed of a core material onto which is bonded a resin: glass laminate. This thin laminate or skin usually extends a few centimetres on either side of the stringer and this skin extension, or tabbing, ties the stringer to the hull or bulkheads, spreading the load of the stringer over a larger area. Tabbing may be a simple piece of glass tape across the stringer/hull joint or an integral structural part of the stringer. Some cores are structural or "active" and some are "inactive", used primarily to provide a form for a structural fibreglass skin. 3

Active core stringers, with cores of solid wood or plywood, rely on the structural properties of the wood core itself to provide stiffness. Generally, higher density core materials such as wood or plywood will carry higher loads. The fibreglass skin covering an active core is primarily used to protect the wood and to attach it to the hull. It is generally thinner than the skin on an inactive core. When replacing structural cores, it is essential to use proper scarf bevels or other recognised means of piecing the new core into the old. Furthermore, it is vital to replace or repair active stringers with a core material which is similar to and at least as strong as the original construction.

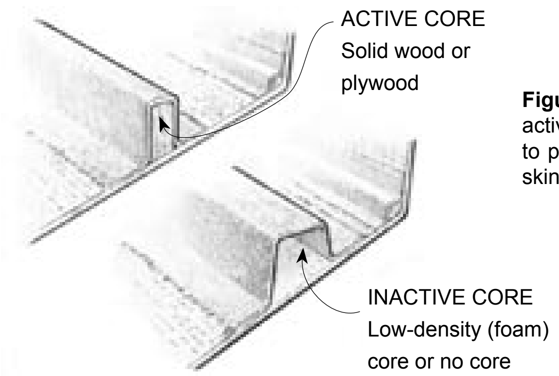

Figure 3-1 Some cores are structural, or active, and some are inactive, used primarily to provide a form for a structural fibreglass skin

Inactive core stringers rely on the geometry of the fibreglass skins to provide stiffness. The non-structural cores are primarily forms to give a profile to layers of fibreglass. Inactive cores are made of low-density foam, cardboard tube, or in the case of moulded stringers, no core at all. Moulded stringers are pre-built in a mould and "tabbed in" after the hull is built with a fairly heavy resin:glass laminate skin.

3.1.1 Assessing damaged stringers

It is essential to know the extent of the repair before work commences. Carefully inspect the area of damage because hull liners or cabin and cockpit soles may be fastened to the very stringers which are in need of repair. It is also difficult to locate damage under engines, water tanks and other equipment. It may be necessary to cut access holes in the hull liner or cabin sole to examine the area in question. Stringer damage often accompanies sole delamination - See Section 6. Fortunately, access covers can be purchased to fill the holes if there is no stringer damage to repair.

Having determined that it is necessary to cut holes in the boat, use a mirror and flashlight and look for the following:

Impact Damage — Look for obvious fractures in the stringer and for delamination of both the tabbing and the core some distance away from the impact point. Inspect the tabbing where the stringer attaches to a bulkhead or transom.

Rot damage — Wood cores rot from (a), water leaking around fasteners and, (b), water collecting where the fibreglass skin has delaminated. If possible, tap the suspected area of stringer with a small hammer - the impact of the hammer has a definite "dead" sound when the core is not firmly attached to the fibreglass.

3.2 Repairing local core damage

For small areas of rot, you may be able to simply dry the stringer and inject epoxy into the rottd area. While this is a common method of wood stringer repair, it is not nearly as effective as replacing the damaged area with new timber. Without removing the skin from the wood, it is often difficult to determine the extent of the rot and the moisture content of the core. Furthermore, the degree of penetration of the injected epoxy cannot be accurately determined so the quality of the repair is unknown. However, if this is the chosen method, we recommend the following procedure:

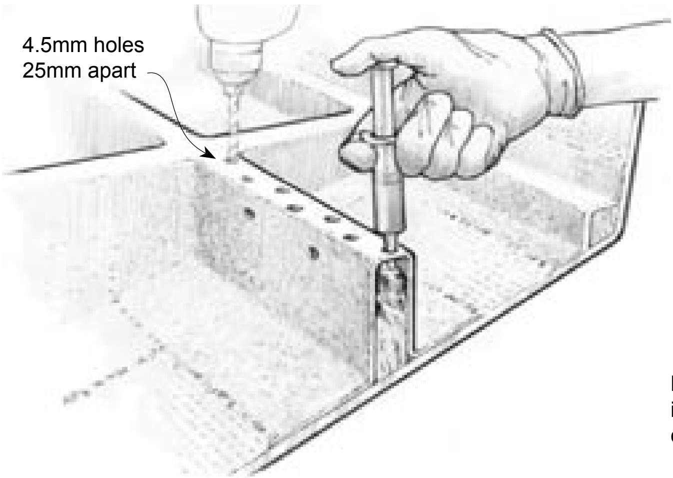

Figure 3-2 Inject or pour resin/hardener mixture into the holes when the core is dry and while the core is warm.

3

1. Drill a pattern of 4.5mm. holes over the rotted area. Space the holes 25mm. or less from centre to centre in all directions. Drill each hole deep enough to pass through the rot, into solid wood.
2. Dry the core thoroughly. If necessary, use heat guns or fans to accelerate drying.
3. Inject or pour a resin/hardener mix into the holes while the core is warm *(Figure3-2)*. Epoxy, warmed by the core, will become thinner and penetrate more deeply into the exposed end grain. 206 Slow Hardener will penetrate more deeply than 205 Fast Hardener before it begins to gel.
4. Continue to inject epoxy into the holes until the core can no longer absorb epoxy and the voids under the skin are filled.
5. If necessary, fill remaining surface voids with thickened epoxy after the injected epoxy reaches its initial cure. Use an epoxy/low-density filler mix for cosmetic fairing of the surface.
6. Apply a layer or two of glass tape or cloth over the stringer to restore stiffness if the damage and hole drilling is extensive.

3.3 Stringer repair guidelines

For more serious repairs that involve removing and replacing stringer material, try to duplicate the original construction. Unless the damage is directly attributable to an undersized stringer, assume that the stringers were structurally adequate and properly located when the boat was originally built. Making a repair that is significantly stronger than the original design can cause hard spots that may distort or crack the hull shell. A repair that is lighter than the original may fail prematurely. When removing and replacing stringer material, observe the following guidelines:

Duplicate the shape and dimensions of the original stringer. Where the stringer is supporting a cockpit sole, cabin sole or engine, the height of the repaired or replaced stringer must be the same as the original. If not, it will be extremely difficult to reinstall the equipment.

Duplicate the original core material or find an equivalent material. Use wood where wood was used, plywood to replace plywood, foam for foam, etc. Attempt to duplicate the species of wood used in the original stringer as well as the same dimensions.

Measure and duplicate the thickness of the fibreglass skin. On stringers with an inactive core or moulded stringers (with no core), watch for variations in the skin thickness. Occasionally, the laminate on the top of the stringer is thicker than the "skins" at the sides. This "cap" can significantly increase the strength and stiffness of the stringer and if the extra thickness is present, it should be duplicated.

Locate new stringers as close as possible to their original position. This is especially true of engine stringers or stringers that support other equipment.

Support the hull. If major stringer replacement is necessary, ensure the hull is well supported so the original shape is maintained. Stringers that are removed or have broken away from the hull may allow parts of the hull to sag.

3.4 Replacing active core sections

Often damage to the core of a stringer is limited to a small section and/or the stringer may be too difficult to remove. It may be possible to replace only the damaged portion, restoring the strength of the stringer while leaving it in position in the boat.

Because wood cored stringers are structural, any repairs made must be joined with a scarf. If replacing a section of plywood stringer, use a minimum of an 8-to-1 scarf bevel. For 20mm. thick plywood, this equates to a 160mm long bevel. When repairing hardwood or highly loaded core areas, use a longer (12-to-1) scarf angle. When cutting scarfs, keep in mind, the longer the scarf angle, the greater the joint surface area, the stronger the joint. All joints in fibreglass skins should have a minimum 12-to-1 bevel or overlap.

Forming the scarf bevel on the new piece of wood is fairly easy using typical cutting tools with the wood supported on a work bench. Cutting the matching bevel on the wood that remains in the stringer is not as easy. Use chisels, disc grinders, hand planes, hand saws, and any other useful tool available to cut wood and fibreglass. The surface of the bevel does not have to be perfect.

3

1. Cut out the damaged section of the existing stringer. Remove as much laminate as necessary to remove the damaged core. Trim the exposed core ends to a minimum 8-to-1 scarf angle *(Figure 3-3)*. The scarf may run vertically or horizontally.

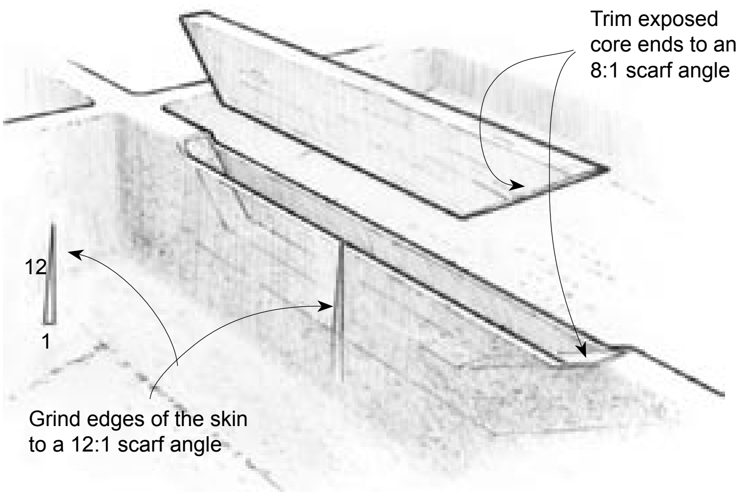

Figure 3-3 Trim a new piece of core material to fit the size and shape of the void in the existing core. The scarf may run vertically or horizontally.

2. Grind the laminate edges to 12-to-1 scarf angles to prepare for the "skin" replacement.

3. Trim a new piece of core material to fit the size and shape of the void in the existing core using the same species of wood. Cut a matching scarf angle on each end of the new core section. Dry fit and trim the new piece and existing core ends as necessary for a good fit.

4. Prepare the surfaces for bonding. All surfaces should be clean, dry and sanded.

5. Install the new core section. With a resin/hardener mix, wet out all contact surfaces of the new and existing core. Apply a liberal amount of thickened epoxy/406 mix to one side of each contact area. Depending on the fit of the new core, use enough thickened epoxy to bridge all gaps between the two surfaces.

6. Clamp the section in position. Clean up excess epoxy before it cures. Remove clamps after epoxy cures thoroughly.

7. Replace the fibreglass skin as described in Section 3.5.1.

3.5 Replacing stringers

Complete replacement of the damaged stringer may be much easier than attempting to replace a small section of the same stringer. For example, engine stringers commonly run from the transom to a bulkhead and may not run the entire length of the boat. Stringers can also be added to under-engineered panels to improve stiffness. Replace stringers as follows:

1. Mark the location of the stringer before removal. It is often critical that the stringer is replaced in exactly the same position in which it was previously located. Locate reference marks away from the repair area so they will not be disturbed when the surface is prepared prior to bonding.
2. Remove the stringer and core. Use a grinder to cut the tabbing at the core/hull joint but be sure not to cut into the hull laminate. Save any large pieces of core which are removed – these may be useful as a pattern to help fit the new core. Measure the thickness of the fibreglass skin so that it can be duplicated.
3. Using the same species of wood as the existing core, work a piece of the timber to fit the size and shape of the core in the removed stringer. See section 3.6.3 for various stringer core construction methods. Dry fit and trim the new piece for a good fit.
4. Prepare the surfaces for bonding. All surfaces should be clean, dry and sanded. Remove any traces of contamination by wiping the surface with WEST SYSTEM 850 solvent and drying with paper towels before the solvent evaporates. In areas that may be contaminated with gasoline or oil residue use a degreaser or detergent before wiping with solvent. Use a stiff nylon bristle brush on heavily textured surfaces like roving. Abrade the bonding surfaces by sanding with 50-grit paper and brush the area free of dust or loose material. Use a wire brush to abrade heavily textured surfaces. The bonding surface should appear dull. Sand the bonding surfaces of hardwood or epoxy coated stringers with 50-grit sandpaper.
5. With a resin/hardener mix, wet out all contact surfaces of the hull and core with epoxy. Apply a liberal amount of thickened epoxy/404 High-Density or 406 Colloidal Silica mixture to one side of the contact area.
6. Push the stringer in position with firm hand pressure. Thickened epoxy should squeeze out of the joint.

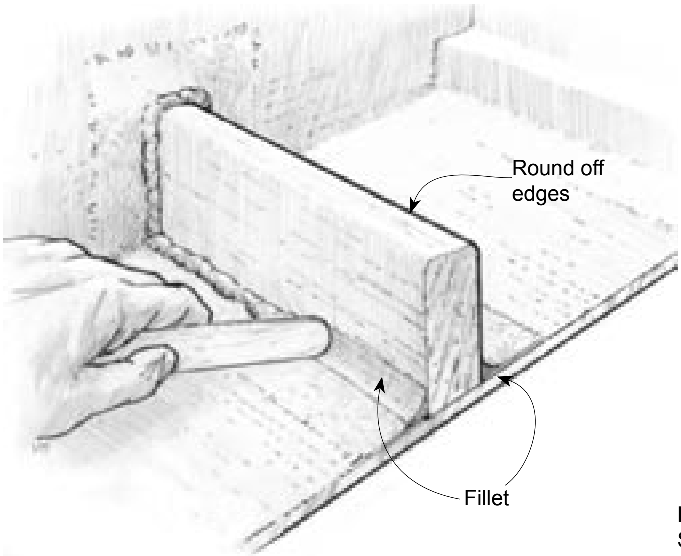

Figure 3-4 Epoxy mixture should squeeze out of the joint. Shape the squeezed out epoxy into a fillet

7. Brace or tape the stringer in position as necessary. Shape the squeezed out epoxy into a fillet and, if necessary, apply additional thickened epoxy to the joint for a smooth 12mm. radius fillet.*(Figure 3-4)* Clean up excess epoxy before it cures. Remove clamps after epoxy cures thoroughly.
8. Replace the fibreglass skin as described in section 3.5.1

3.5.1 Applying the fibreglass skin

After repairing or replacing core material, it is necessary to replace the fibreglass skin and tab the stringer to the hull. To duplicate the strength of the original skin, it is important to duplicate the thickness of the original skin and to properly prepare the surfaces for a good bond.

Preparing the fibreglass fabric

Measure the thickness of the skin on the original stringer. Keep in mind, the top skin may be thicker than the sides and the tabbing. Refer to the chart in Appendix A to determine the number of layers of a particular weight fabric necessary to achieve the required thickness.

Cut the necessary number of strips of glass fabric the same length as the stringer. Cut the first piece large enough to extend as far as the original tabbing from each side of the stringer. Cut each of the remaining pieces 25mm (12.5mm each side) narrower than the previous one. When laying out the layers of fabric, do not allow the tabbing edges to end at the same place. For stress reduction, step the edges of the fabric to create a tapered edge. If this is not done, the load the stringer is carrying will be transferred to the line on the hull's surface where the reinforcement ends and the hull may crack at that point. However, by stepping the tabbing edges, the load from the stringer is gradually distributed to the hull. Where stringers end at a bulkhead or the transom, wrap the glass tabbing onto them in the same manner.

WEST SYSTEM 739 Fabric (446g/m²) is ideal for stringer repairs as it yields about 0.5mm. per layer when hand laminating. Thus, fewer layers of cloth are required to achieve the necessary thickness and this, in turn, translates into less time and labour. However, there is nothing wrong with using a lighter fabric - it simply means more layers per unit of laminate thickness and a longer laminating period.

Preparing surfaces for bonding

Surface preparation for bonding is a critical part of any repair. The bilge of a boat can be very difficult to prepare for bonding, because it is likely to be contaminated (especially around engines) and many areas may be inaccessible.

Use a degreaser or detergent in areas that may be contaminated with gasoline or oil residue before wiping with WEST SYSTEM 850 solvent. Use a stiff brush on heavily textured surfaces such as roving. Remove any traces of contamination by wiping the surface with solvent and drying with paper towels before the solvent evaporates.

Use a 50-grit grinding disc to prepare the surface. A 50-grit disc cuts quickly with little heat build-up. If gelcoat is present and it is soundly attached, you do not need to remove it. Grind it to create a fresh, no-gloss surface. Brush the area free of dust or loose material. Use a wire brush to abrade heavily textured surfaces. The bonding surface should appear dull.

A 12-to-1 bevel must be ground into any existing fibreglass left on a stringer. The new fibreglass will run onto this bevel attaching the new material to the original material. A 12-to-1 bevel provides adequate surface area for the transfer of loads across the repair area. For example, if the skin on the original portion of the stringer is 6mm thick, the bevel must not be less than 70mm wide.

Glass cloth must not be laminated around a sharp 90° corner. It is essential to round over the top edges of the cores and fillet the core/hull and core/bulkhead inside corners a 10 mm - radius for thinner fabric, 12.5 mm radius for thicker fabric.

Applying the fibreglass skin

1. Prepare glass fabric and bonding surfaces as described above.
2. Wet out the entire bonding surface, including the stringer, with a resin/hardener mix. Mix epoxy/404 High-Density or 406 Colloidal Silica filler to the consistency of mayonnaise. Squeegee a thin layer of thickened epoxy over the exposed panel bonding area. The thickened epoxy will fill voids on the surface and provide better contact with the first layer of fabric.
3. Centre the largest piece of fabric over the stringer and reinforcement area and wet it out with the resin/hardener mix. Squeegee any excess epoxy from the surface, making sure the entire piece of fabric has been saturated.
4. Apply each successive piece of fabric in the same manner and these may be applied immediately after the previous piece or any time before the previous piece becomes tack free. The fabric edges should be stepped, *Figure 3-5)* with the last piece extending between 45mm and 60mm from each side of the stringer (depending on the number of fabric layers). Allow the lay-up to reach its initial cure.
5. Apply two or three coats of epoxy to fill the weave of the cloth. To avoid sanding between coats, apply each coat before the previous coat becomes tack free. Allow the final coat to cure thoroughly.

   Note: The final two or three coats may be tinted with WEST SYSTEM 501 to 506. If a smoother cosmetic finish is required, the lay-up may be faired and finished.

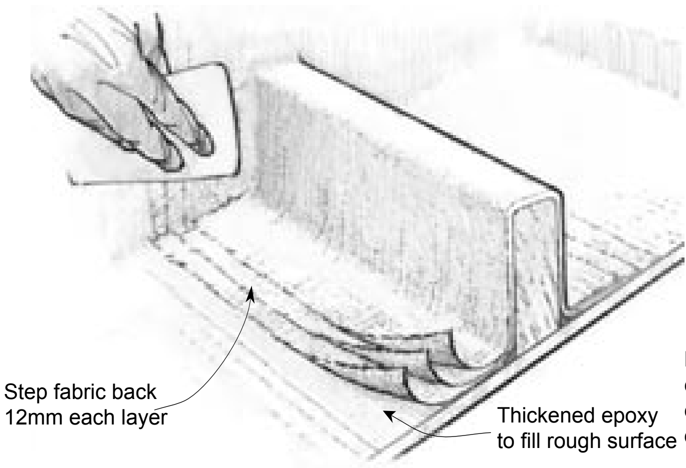

Figure 3-5 Cut each of the remaining pieces 25mm (12.5mm each side) narrower than the previous one. Squeegee any excess epoxy from the surface, but make sure the entire piece of fabric has been saturated.

When the repair is complete, there will be a little additional finishing work to do. Resin/glass repairs inevitably have some sharp edges or tiny,sharp "hairs" protruding from the laminate. These make cleaning the bilge difficult, if not dangerous. Use 80-grit sand paper to eliminate imperfections that might cut you.

Note: The application of WEST SYSTEM 775 peel ply onto the final epoxy coat would eliminate the need for this finishing work.

There are two options for final finishing:

1. Do nothing. Since most of the work is in the bilge area, it is not necessary to apply a final finish. UV degradation of the epoxy will not be a problem and in many circumstances, the appearance of the repair does not matter.
2. Paint the repair. If appearance matters, select a paint colour that matches the rest of the area and paint therepair. Proper surface preparation of the repair includes washing with water and thoroughly sanding the epoxy surface *(Final surface preparation 9.4.7*). Apply a paint primer or apply the top-coat directly to the prepared epoxy.

   As always, when installing any hardware, use epoxy to seal all drilled holes. If this step is neglected, another repair may be necessary in a few years when the core material rots!

3.6 Reinforcing to improve panel stiffness

Small cracks and flaws in panels can be a result of high-stress concentrations and flexing within a panel. A common example of this problem is hairline cracking around the perimeter of a foredeck, usually the result of the deck flexing under load. Similarly, a lightly-built hull may experience considerable flexing as it pounds through waves, resulting in cracks around bulkheads. In the flatter bow areas, panel flexing or "oil-canning" often results in gelcoat crazing. Such deflections can be controlled by reinforcing these panels using WEST SYSTEM epoxy. Panels can be reinforced by one or more of the methods detailed below. Some of these reinforcing methods can be further improved with the use of graphite fibres.

3.6.1 Reinforcing with fabric

Perhaps one of the simplest methods of reinforcing a large area, particularly the hull, is to laminate layers of resin/glass fabric to the interior surface of the hull or deck to increase the thickness of the laminate. Bonding layers of glass fabric to a panel is covered in 9.4.5 "Applying woven cloth & tape". Multiple layers of fabric may be applied one after the other or before the previous layer has become tack free Step each layer back from the previous layer (progressively smaller layers) to avoid stress concentrations at the edge of the stiffer area.

3.6.2 Reinforcing with fabric and core material

As noted in the introduction, doubling the thickness of a laminate will result in an eight fold increase in stiffness. Bonding a core material between the glass fabric and the interior of a panel is a good way to increase stiffness with a minimum amount of added weight. Either end-grained balsa or a rigid, closed-cell foam are good choices for a core material. This method of reinforcement is useful over large areas with good access to the interior side of the panel.

Stiffen a flexible panel by bonding core material and glass fabric to the inner side of the panel. Bond the core in place as follows:

1. Prepare the surface for bonding. Remove any traces of contamination by wiping the surface with WEST SYSTEM 850 solvent and drying with paper towels before the solvent evaporates. Use a degreasing agent or detergent in areas that may be contaminated with gasoline or oil residue before wiping with solvent. Use a stiff nylon bristle brush on heavily textured surfaces like roving.
2. Abrade the bonding surface by sanding with 50-grit paper and brush the area free of dust or loose material. Use a wire brush to abrade heavily textured surfaces. The bonding surface should appear dull.
3. Prepare the core material and fabric. Cut the core material to size. Round the corners and bevel the edges of the core material to reduce stress concentrations. Cut four or five pieces of glass cloth, each piece 25mm to 50mm shorter on each side than the previous one. The smallest piece of fabric should overlap the core material by 50mm on each side *(Figure 3-6*).
4. Wet out the core and panel bonding surfaces with a resin/hardener mix.

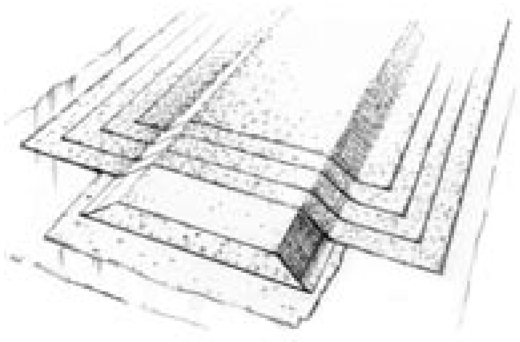

Figure 3-6 End-grained balsa or high-density foam core material is useful for reinforcing large panel areas.

5. Apply an epoxy/404 or 406 filler mixture, thickened to the consistency of mayonnaise, to the bonding surface of the core material. Place the core in position on the panel to be reinforced. Use enough clamping pressure to hold the piece in place, squeezing just a little of the mixture from the joint. Use braces and wedges to clamp the core in position. Try to achieve uniform clamping pressure and avoid any gaps between the core and the panel. Shape the excess epoxy mixture into a fillet at the core/panel joint before it hardens. Allow the epoxy to cure before removing clamping.

Bond the fibreglass fabric to the core and panel as follows:

6. Wet out the bonding surface of the core material and panel with a mixture of resin/hardener. Thicken the epoxy with 404 or 406 filler to the consistency of mayonnaise. Squeegee a thin layer of thickened epoxy over the core and exposed panel bonding area. The thickened epoxy will fill voids on the surface and provide better contact with the first layer of cloth.

7. Centre the largest piece of glass fabric over the reinforcement area and wet it out with epoxy. It may be helpful to hold the fabric in place with pieces of masking tape. Squeegee any excess epoxy from the surface, but ensure the entire piece of cloth has been saturated.

8. Apply each successive piece of cloth in the same manner. Each piece may be applied immediately after the previous piece is positioned and saturated or any time before the previous piece reaches its final cure. As already stated in paragraph 3 above,the final piece should extend at least 50mm. each side of the core

9. Allow the lay-up to reach its initial cure i.e. become touch dry and apply two or three coats of epoxy before the laminate reaches its final cure. Apply each coat before the previous coat reaches its final cure and allow the final coat to cure thoroughly. Note: The final two or three coats may be tinted with WEST SYSTEM 501 (white) or 506 (grey) pigment or with 420 Aluminum Powder (grey) or 423 Graphite Powder (black).

   If a smoother cosmetic finish is required, the lay-up may be faired and finished. Follow the fairing instructions in “Standard Techniques” – Section 9.4.4 and the finishing instructions in Section 2.3. Note: Vacuum bagging is an ideal clamping method for large bonding areas. *Refer to 002-150 VACUUM BAGGING TECHNIQUES, published by Gougeon Brothers, for detailed information on vacuum bagging.*

3.6.3 Reinforcing with stringers

One of the advantages of using wood for stringers is that most of the stiffness comes from the wood itself, so there is no need to rely on additional fibreglass fabric for strength.

Solid wood and plywood

Plywood or solid wood stringers can be cut to shape with a band or table saw. The end of each stringer should either butt into a bulkhead or a floor or should be tapered to the surface with at least a 4-to-1 slope. Failure to do this will result in hard spots, causing stress fractures or cracking.

The stringer cross sections are generally rectangular or square, although a trapezoid is a good selection if using solid wood. The trapezoid has a wide base for load distribution, narrowing at the top to offer less weight. If glass fabric is to be applied over a stringer, the trapezoid shape allows easier fabric application. *(Figure 3.7*). The upper edges should be rounded to eliminate sharp corners.

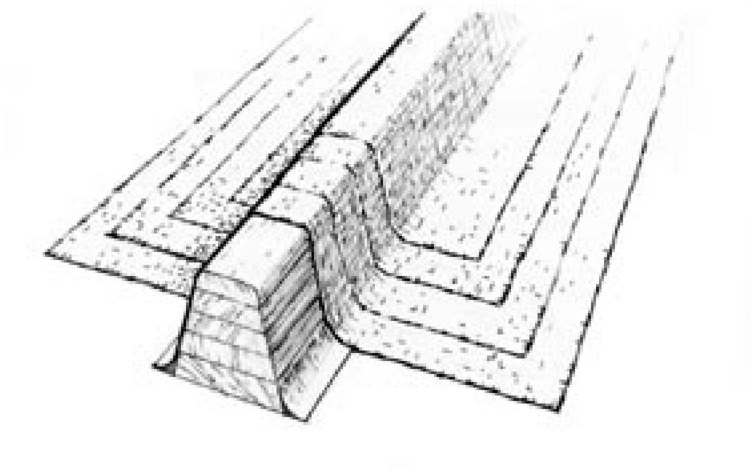

Figure 3-7 Laminated or solid wooden stringers provide effective panel reinforcement with or without the addition of glass fabric.

Install new stringers as described in section 3.5. Apply glass fabric over the stringers as described in section 3.6.

Laminated wooden stringers

Laminated stringers have structural advantages over cut stringers, especially in curved areas. Laminated stringers are made of multiple thin layers of wood and can duplicate the shape of the inner side of the panel. More of the wood grain in the stringer follows the shape of the panel, making laminated frames stronger. The new frame can be laminated in a simple jig made from a pattern or, in some cases, directly in place on the back of the panel.

When preparing wood for laminated stringers :

- Use wood strips thin enough to bend easily into the shape of the panel. Ensure that all the strips collectively can bend to shape. Thick strips want to relax or springback.
- For a curved frame with greater strength and less springback, use more, thinner strips for a given stringer thickness.
- Use full-length strips. Make the strips longer than the finished stringer to allow for trimming.
- Select wood strips that are seasoned. Ideal moisture content is between 6% and 14%.

A laminating jig will allow the new frame to be laminated in the controlled environment of the workshop. Use cardboard or other convenient material to pattern the inside face of the panel at the stringer locations. Transfer the pattern line to a laminating jig of one the types illustrated *(Figure 3-8)*. Laminate frames in a jig as follows:

1. Prepare the jig and the strips as suggested. Complete a dry run to ensure the strips bend enough and that the jig and clamps accomodate the bending of all the strips. Cover the jig with plastic to prevent the frame from bonding to the jig.
2. Wet out the strips on both sides with epoxy, except for the outer faces of the top and bottom strip.
3. Thicken the mix with 406 filler to a ketchup consistency. Apply thickened epoxy to one side of each strip and stack it in place on the jig against the previously coated strip. Ensure that one side coated with thickened epoxy faces each joint.

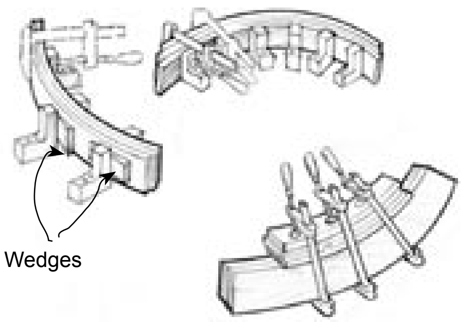

Figure 3-8 Transfer the desired stringer profile to a laminating jig.

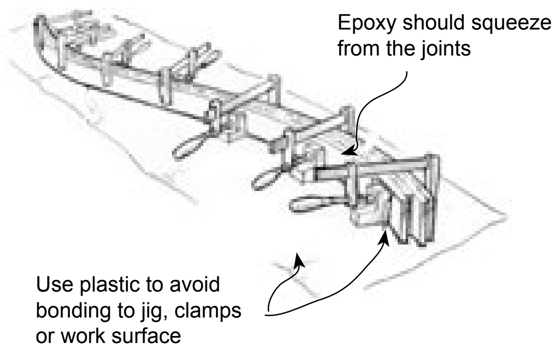

Figure 3-9 Clamp the appropriate number of coated strips into the jig. Trim the stringer to size after the epoxy is fully cured.

4. Clamp the strips in the jig until the epoxy cures *(Figure 3-9)*. Use clamps, wedges, staples or small nails to apply enough pressure to squeeze a small amount of epoxy from each joint.

5. After the epoxy has thoroughly cured remove the stringer from the jig. Allow extra cure time if the temperature is cool, especially if excessive springback Is anticipated Trim laminated stringers to final shape.

Install new stringers as described in section 3.5. Apply resin/glass fabric over the stringers as described in section 3.6. If stringers have been added to an exposed interior area, it may not be desirable or, indeed, necessary to apply a fibreglass skin. Wood stringers, especially the laminated type, can enhance the interior appearance of any boat. Visually, they are extremely attractive when varnished, while they serve their primary function of reinforcement. Should it be decided to coat the stringers, abrade the wood and fillets to prepare for bonding. Apply two or three coats of epoxy to seal the stringer. Allow the final coat to cure thoroughly.

Half-round and foam cores

Half-round or foam reinforcements with a resin/glass skin are a simple way of strengthening panels. With this method, the core material primarily serves as a former and the laminated glass fabric provides the stiffening strength.

An economical core material for this method of reinforcement is a cardboard or paper tube cut in half lengthwise. Pieces can be placed end to end to reinforce larger areas. The tube should be heavy enough to hold its shape during the lay-up and cure of the fabric laminate.

Low-density foam also makes an economical core material. Cut the foam on a table or band saw to a trapezoid shaped cross section. This cross sectional shape is more effective than the half-round cross section because it places more reinforcing fibres on top of the stringer, away from the stringer's neutral axis. Cut a 4-to-1 bevel on ends that fall in the middle of a panel. Sand a 9mm. radius on the top edges.

To bond half-round tubes - Mix epoxy/404 or 406 filler to the consistency of peanut butter and apply a 6mm bead of the thickened mix to the outlined edge of the bonding surface. Place the tube/stringer in position in the thickened epoxy beads which should hold it in place. Shape the epoxy bead on the outside of the stringer/panel joint into a fillet and, if necessary, apply additional thickened epoxy to the joint to give a smooth 12mm. radius fillet. If required, brace or tape the stringer in position until the epoxy reaches an initial cure (Figure 3-10). Laminate glass fabric as described in Section 3.6. Remember, more layers of resin/glass reinforcing are required over inactive cores. 3

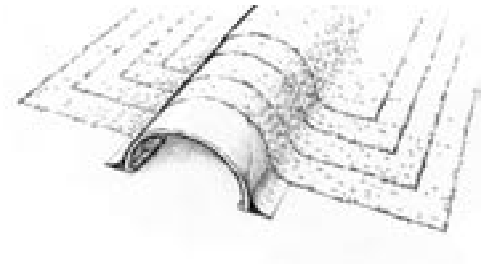

Figure 3-10. The half-round material serves as a former for the laminated glass fabric, that provides the stiffness.

3.6.4 Reinforcing with unidirectional fibres

The stiffness of reinforcement stringers can be significantly improved with little weight gain by applying unidirectional glass or carbon (graphite) fibre tape along the top side of the stringer facing away from the panel. When applied to the top of the stringer, where the tensile loads are greatest, all the fibres can be oriented parallel to the load. Carbon fibre is more costly than glass, but real savings in weight and bulk for the same amount of stiffening may offset the additional cost. Refer to "Using WEST SYSTEM Epoxy– Section 9.4.5 Applying Woven Cloth and Tape" for application procedures.

Section Four

4. Repairing Damaged Skins

Cutting through either the hull or the deck of a fibreglass boat will reveal either a non-cored (single skin) or a cored laminate (two skins sandwiching a lower density core material). Often a panel changes from cored to non-cored at corners, the ends of panels and at panel openings. Depending on the size of the boat and the location of the damage, a structural repair could involve either or both types of laminate.

Whether cored or non-cored, the structure of a fibreglass boat relies on the continuity of the fibres that run through the skins. Damage from impact, abrasion, flexing or even deterioration of the resin holding the fibres in place can reduce or eliminate the load carrying ability of these fibres. The objective of the repair procedures discussed in this section is to restore skin continuity by rebuilding the load carrying ability of the fibres through the damaged area of the skin.

Typical fibreglass skin

Below an outer layer of gelcoat and chopped-strand mat, a typical fibreglass skin consists of alternating layers of woven roving and chopped-strand mat, repeated until a required thickness is reached. In a cored panel, the schedule is similar, but the inner and outer skins are generally much thinner than a single, non-cored panel (Figure 1-1 & 1-2). Some of the newer structures being manufactured today may include layers of unidirectional or multidirectional glass, aramid or graphite fibres. The fabric is usually bonded together with an isophthalic or orthophthalic polyester resin, although vinylester resins are being used more frequently in place of polyester resins.

Restoring skin continuity

Skin continuity can be restored if enough fibres can be bonded across a damaged area to equal the strength of those that were damaged or removed. The lay-up schedule for the repair work should duplicate thickness and types of materials used in that area as closely as possible. However, heavy woven roving may be replaced by more layers of lighter weight woven or bi-directional fabrics. Although more layers may mean extra work, lighter weight fabrics are often more readily available and their tighter weave results in a higher fibre to resin ratio which can result in a repair that is actually stronger than the original panel.

As a general rule, the bonding area of the repair patch should be 12 times the thickness of the damaged skin on each side of the damage. To maintain the necessary bonding area and keep the repair flush with the surface, the edges of the repair area are bevelled to a 12-to-1 angle and each piece of repair fabric is cut progressively smaller. The bevel provides the proper bonding area but allows the patch to be bonded below the surface where it can be subsequently faired flush with the surface.

4.1 Assessing and preparing the damaged area

Begin with a thorough inspection of the damaged area to determine the depth and extent of the required repair. If accessible, examine the back of the panel. An abrasion or flex crack that extends into the roving layers will affect the strength of the skin even if the damage does not extend completely through the laminate. Cracks that are visible on the back side of a panel indicate that the fibres running through the area have lost their ability to carry their load and are structurally the same as a hole through the panel. In addition, inspect internal structural members and hardware. An impact can cause panels to flex inwards, sufficient to damage adjoining bulkheads or frames. Check for excessive flexing or panel movement. If movement is evident, reinforce the panel after the damage has been repaired as outlined in Section 3.

1. Remove all the damaged material. Use a grinder to cut down to solid laminate or a saw to enlarge a hole to solid undamaged laminate. While removing the damaged material, try to maintain a circular or oval shape. The laminate around an impact site may be structurally damaged beyond the area of visible damage. Tap around the damaged area with a small hammer or metal object. Soft or dull sounding areas indicate a void or fracture under the surface that should be exposed.

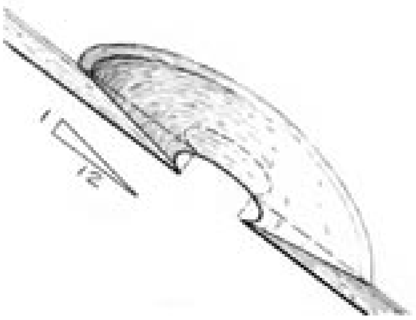

Figure 4-1 Grind a minimum 12-to-1 bevel around the edge of the excavated hole, whether the damage extends partially or completely through the skin.

2. Grind a bevel around the edge of the repair area to create a bonding area for the patch that will ensure the repair is ultimately flush with the surface of the skin. A minimum 12-to-1 bevel is required to ensure the transfer of loads across the repair area *(Figure 4-1).* For example, the hole in a 6mm. thick laminate would require the outer edge of the bevel to extend 72mm from the inside edge of the hole. If the skin is very thin, a longer bevel angle is required.

Proceed with the laminating of the repair patch as described in Section 4.3 if,

a. solid, undamaged laminate has been reached without grinding through the skin,

b. the hole through the skin of a non-cored panel is smaller than 25 mm diameter,

c. the hole through the outer skin of a cored panel reveals undamaged core material.

Provide backing to support the lay up of the repair patch as described in Section 4.2 if,

a. the hole through a non-cored panel is larger than 25 mm in diameter,

b. the hole through the inner skin of a cored panel is larger than 25 mm in diameter.

4.2 Backing support for a repair patch

If the hole through the skin is larger than 25 mm a backing will be required to support the wet fabric patch until the epoxy cures. Applying a support to the back of a panel is generally not a problem if there is access to the inside of the damaged panel. However, if the boat has a fibreglass liner or if the back of the hole is inaccessible, an alternative method must be used. Several methods for backing are suggested in this manual. Use the method or a modification of one, that is most appropriate for the particular situation. If using vacuum bagging techniques to laminate the patch, an air-tight backing is necessary for all holes.

Suggested backing supports for cored panels, with and without back access, will be discussed in Section 5. The following are suggested backing supports for non-cored panels with and without access to the back of the panel.

4.2.1 Temporary backing support – with inside access

If the hole is in an exposed interior area, the following backing method will leave the repair flush with the inner surface for easy fairing and finishing when the repair is complete.

1. Cut a piece of Styrofoam® material slightly larger than the hole to be patched. If the panel is curved more than the foam is able to deform (bend), shape the foam as necessary to match the contour of the repair area. The foam should make contact at the edges of the hole.

2. Cover the backing support with a piece of plastic and brace it against the hole from the inside. The plastic will help seal the hole and prevent the patch from bonding to the foam backing. Looking at the hole from the outside, the foam should be in contact with the edges of the opening and the plastic should be smooth and tight.

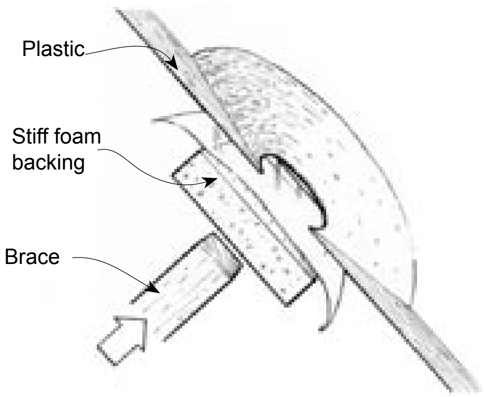

Figure 4-2 A temporary backing support should fit tight against the inside of the panel and match the panel contour.

If planning to finish the interior, cover the plastic with a piece of peel ply before placing the support over the hole - this will leave the inner surface of the patch textured and ready for finishing.

3. With the backing support in position, laminate the repair patch as described in Section 4.3. When the repair patch has cured, remove the brace and foam. Peel the plastic and peel ply from the repair area. Fair and finish the interior side of the panel as desired.

4.2.2 Backing supports–without access

If there is no access available to the inside of the panel the following method is designed to provide support for the repair patch by bonding a thin panel to the back of the panel from the outside. The backing panel will become a permanent part of the panel. Although the installation method and backing material can be altered depending on the size and curve of the repair area, the method described below can accommodate the widest range of openings. This type of backing may also be applied from the back of the panel if access and a permanent backing on the interior of the panel is acceptable.

The first part of this method describes laminating a backer to match a specific opening. The second part explains the technique of slipping the backer through the hole and bonding it in place on the back of the panel.

Laminating a backing support

1. Select and tape an area of the panel next to and several centimetres larger than the hole opening to act as a mould for the lay up of the backing. Mask the area outside the tape to protect from epoxy spillage. Apply a liberal coat of automobile paste wax or release agent to the mould area. The selected area should match the curve or contour of the repair area.

2. Cut two pieces of 200g/m² glass fabric to the size of the waxed area. Add one piece of cloth for every 300mm increase in hole diameter over 300mm. Lay the cloth on a plastic protected work table.

3. Wet-out the layers of fabric with epoxy. Pour a small amount of resin/hardener mix in the middle of the cloth. Use a squeegee to spread the epoxy over the cloth until both layers are completely saturated.

4. Place the wet-out fabric against the waxed panel *(Figure 4-3)*. Use a squeegee to smooth the cloth against the panel and remove excess epoxy. The paste wax will prevent the cloth from bonding to the panel. If the hole is in a flat or moderately curved area of the panel, the backer can be laminated on the flat table. It should be flexible enough to conform to a moderately curved panel. Allow the backer to cure thoroughly.

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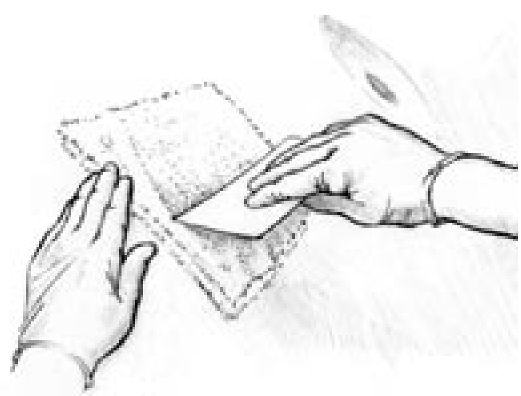

Figure 4-3. Smooth the wet-out fabric against the waxed panel to laminate a backer that matches the panel contour.

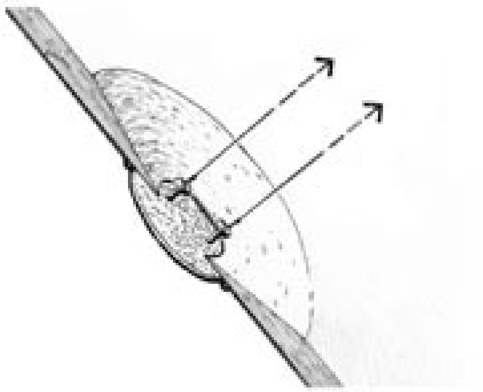

Figure 4-4. Pull the backer tight against the inside of the panel to permanently bond the backer in position.

5. Peel the cured backer laminate from the panel (or table). Using a utility knife or scissors, trim the laminated backer to the shape of the hole, 25mm larger than the hole on all sides. To help handle and hold the backer in position when bonding, screw two or more sheet metal screws into the laminate and attach a length of heavy string or wire to each screw. The string will also help retrieve the laminate if it is accidentally dropped behind the panel.

Bonding the backer in place

1. Prepare the inside of the opening for bonding. Reach through the opening and thoroughly abrade the inside edge of the hole with 50-grit sandpaper.

2. Bend the laminate slightly so that it can pass through the opening using the string to keep it from dropping.

   Note: If acceptable, grind the hole and trim the backer to an oval shape rather than a round shape. An oval shape will allow the narrower dimension of the oversized backer to pass through the wider dimension of the smaller hole without having to flex the backer.

3. Bond the backer in place with a quick setting adhesive such as G/5 Five-Minute Adhesive available from

Wessex Resins. Apply adhesive to the inside edge of the hole and to the edge of the laminate. A thickened epoxy/404 high-density filler mix is acceptable if a quick curing adhesive is not available.

4. Pull the backer into position on the inside of the panel and tie the strings to a stationary object close to the hole or a stick laid across the hole *(Figure 4-4)*. Keep enough tension on the strings to hold the backer in position and bend the backer as necessary to match the contour of the panel. Some of the epoxy mix should squeeze out of the joint. Scrape away the excess and smooth the joint before it begins to cure. Allow the epoxy to cure thoroughly before removing the screws.
5. Proceed with laminating the repair patch as described in Section 4.3.

The method described above works well on compound curved sections or corners. In smaller or flat areas, other materials e.g. a plastic laminate, can be used as a backer, as long as the patch holds the correct shape until it cures.

If intending to use vacuum bagging techniques to repair the patch, this backing method provides a good air-tight seal and should be used, even if access is available to the back of the panel. Ensure the screw holes are filled with thickened epoxy before laminating the patch. Refer to Section 4.3.3 for information on vacuum bagging for repair.

4.3 Laminating a repair patch

The new skin must be laminated to approximately the same thickness to ensure the strength of the original skin. Multiple layers of lightweight cloth will develop the same or greater strength than a single layer of heavy cloth.

The patch can be laminated by either of two methods, depending on the size of the patch. For **large areas** it is easier to handle and lay up each piece of cloth one piece at a time. For **smaller areas** it may be more convenient to wet out and lay up all of the pieces together.

4.3.1. Large area patch

1. Cut an appropriate number of glass fabric pieces the same shape as the hole. The first piece should match the outside edge of the bevel, with subsequent pieces gradually getting smaller. The final layer should match the inside edge of the bevel at the hole. The combined thickness of the layers should be slightly thinner than the original panel to allow for shaping and fairing *(Figure 4-5)*.
2. Wet out and then apply a layer of thickened epoxy to the bevelled edge of the hole and to the backing piece to fill voids and provide good contact between the surface and the first layer of cloth. Thicken the epoxy with either 404 or 406 filler to the consistency of ketchup and apply it with a disposable brush.
3. Lay the largest piece of fabric in position on the repair area. Use a squeegee to smooth the cloth and remove trapped air.

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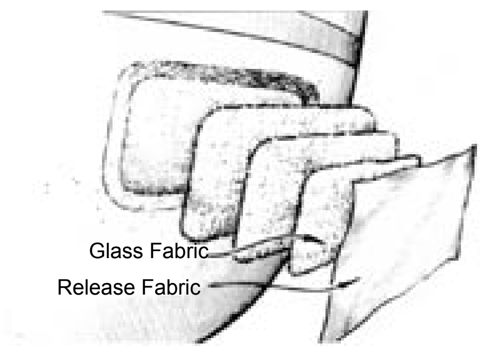

Figure 4-5 Cut an appropriate number of pieces of glass fabric. The first piece should match the outside edge of the bevel.

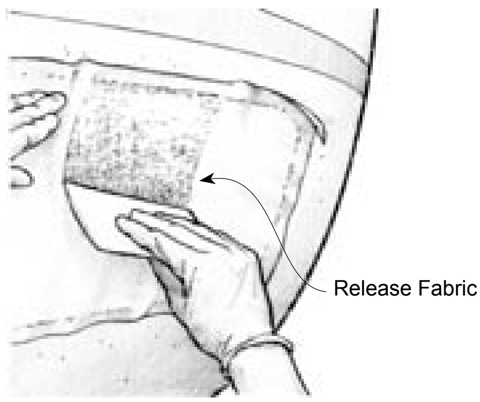

Figure 4-6 Squeegee over the release fabric with firm pressure to remove excess epoxy and smooth the patch.

4. Using a resin/hardener mix, wet out the fabric with a plastic squeegee or roller to spread the epoxy and saturate all areas of the fabric.
5. Repeat the process for each layer of fabric until the smallest piece is finally laminated in central position over the hole. By bonding the patch into place in a large-to-small-piece sequence, the possibility of sanding through any of the cloth layers when fairing the surface is eliminated.
6. Cut a piece of 775 Peel Ply several centimetres larger than the patch and smooth this release fabric in place

over the patch. Squeegee over the peel ply with firm pressure to remove excess epoxy and smooth the patch *(Figure 4-6).* Before the epoxy cures, remove the excess from the surrounding areas with a bevelled mixing stick or paper towel.

7. Allow the patch to cure thoroughly and then remove the peel ply. Release fabric will not bond to the epoxy and will leave a smooth textured finish. Sand to remove any high spots. Fair the repair as described in Section 9.4.4.*"Using WEST SYSTEM Epoxy - Fairing"*. Finish the repair as described in Section 2.3.

4.3.2. Small area patch

If the patch area is smaller than about 200 mm on each side, it may be easier to first prepare the entire patch on a piece of plastic placed on a flat surface. The patch can then be bonded into the hole cavity in one operation.

1. Cut the appropriate number of glass fabric pieces the same shape as the hole. The first piece should match the outside edge of the bevel, with subsequent pieces gradually getting smaller. The final layer should match the inside edge of the bevel. The combined thickness of the layers should be slightly thinner than the original panel to allow for shaping and fairing.

2. Cut a piece of plastic and a piece of 775 Peel Ply several centimetres larger than the patch area. Place the plastic on the working surface, followed by the peel ply.

3. Wet out each piece of fabric with a resin/hardener mix and stack the glass cloth pieces on the working surface beginning with the smallest piece and finishing with the largest. Centre each layer over the previous layer. The result will be a plug of wet-out fabric approximately the size, shape and depth of the hole *(Figure 4-7).*

4. Wet out and then apply a layer of thickened epoxy to the bevelled edge of the hole and to the backing piece to fill voids and provide good contact between the surface and the first layer of cloth. Thicken the epoxy with either 404 or 406 filler to the consistency of ketchup and apply it with a disposable brush.

Figure 4-7 Build up a plug of wet-out fabric approximately the size, shape and depth of the hole.

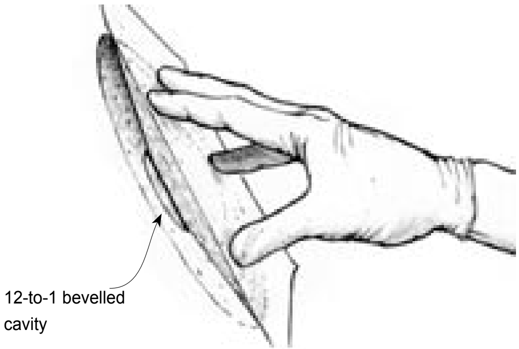

Figure 4-8 Press the wet-out patch, release fabric and plastic into the bevelled hole cavity. Squeegee over the patch to remove excess epoxy and trapped air.

5. Lift the wet-out patch, peel ply and plastic from the work surface and press it, plastic side out, into the bevelled hole cavity *(Figure 4-8)*. Squeegee over the plastic with firm pressure to remove excess epoxy, smooth the patch and release any trapped air. Before the epoxy cures, remove the excess from the surrounding areas with a bevelled mixing stick or paper towel.

6. Allow the patch to cure thoroughly and then remove the plastic and peel ply. Sand any high spots. Fair the repair as described in Section 9.4.4, *"Using WEST SYSTEM Epoxy - Fairing"*. Finish the repair as described in Section 2.3.

4.3.3. Vacuum bagging

Vacuum bagging is a clamping method that uses atmospheric pressure to apply even clamping pressure to a laminate or, in this case, the repair patch. For most repair situations, vacuum bagging is not necessary to achieve a sound repair. Vacuum bagging is useful in situations where compaction of the laminate is required, as in lightweight or high performance structures. It is also useful in situations where conventional clamping is not practical e.g. when bonding large areas of core material.

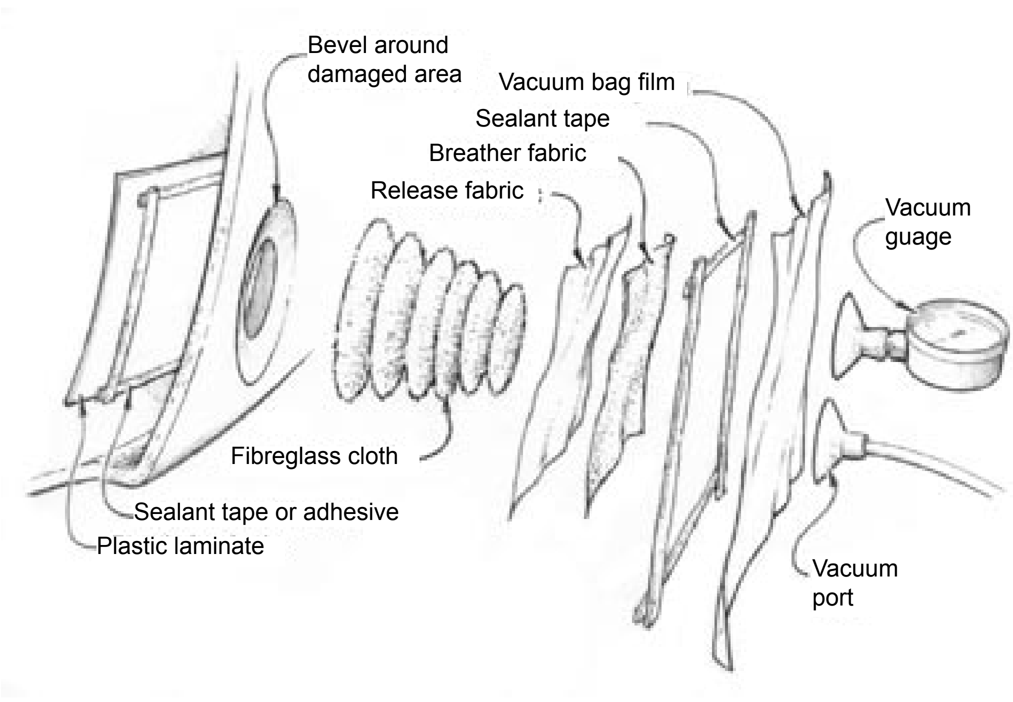

Figure 4-9 Smooth the patch and the release fabric in place. Lay the vacuuum bag material over the patch, seal the bag and attach vacuum lines.

The lay up procedures for vacuum bagging a small repair is the same as for the repair described above, except for the following steps:-

1. Prepare all vacuum bagging materials and apply a continuous strip of vacuum bag sealant around the perimeter of the repair area before mixing epoxy.
2. Laminate the repair patch following either of the above procedures.
3. After smoothing the patch and with the peel ply in place, lay the vacuum bag material over the patch *(Figure 4-9)*. With the breather fabric in place, remove the protective paper from the vacuum bag sealant and press the bag into the sealant around the perimeter. The lay-up must be airtight - seal off scored or porous core material with epoxy.
4. Attach the vacuum lines and pump. Apply vacuum pressure before the epoxy begins to cure - check for air leaks through the back patch and around the mastic sealant. Maintain vacuum pressure until the epoxy is cured. Remove the vacuum bag and release fabric. Abrade to remove any high spots. Fair the repair as described in Section 9.4.4. Finish the repair as detailed in Section 2.3.

Section Five

5 Repairing Core Related Damage

As mentioned in Section 1, the core material separating the two skins of a composite panel reduces the tensile and compressive loads on the skins and allows a structural panel to withstand greater bending loads without a proportional increase in weight. To do this, the core material must remain bonded to both skins and to resist compression loads applied by the skins when the panel bends.

The previous section provided procedures for the repair of damaged skins. This section describes how to restore the core-to-skin bond and/or the structural properties of the core. Although the skin itself may not be damaged, it may be necessary to cut or remove a portion of the skin for access to the core. Repair or replacement of core material nearly always involves some degree of skin repair — refer to the procedures in the previous section.

5.1.Types of core related damage

Core related damage can vary from a small skin delamination with little or no actual damage to either the core material or skins, to moisture related core deterioration and to collision damage that can leave a hole through both the core and the inner and outer skins. The repair procedures in this section begin with the least damage, easiest to repair:

1. **Repairing skin delamination.** Often the core is wet, but still firm and usable. A delaminated area may be several square centimetres or several square metres.
2. **Replacing damaged cores.** The skin may be intact, but moisture penetration over time may have caused the balsa core to deteriorate. An impact may puncture the outer (or inner) skin and core without affecting the other skin. Even a minor puncture can allow moisture to migrate under the skin and affect the strength of the core over a large area.
3. **Repairing transom delamination.** The plywood core may delaminate or rot as a result of moisture penetration through a crack or hole in the transom skin.
4. **Repairing holed panels.** An impact or modification can require rebuilding the entire panel structure. Impact damage can extend to both skins and core or one skin with major core damage.

The work required to repair each type of damage varies with the size of the damaged area. Often, the full extent of damage cannot be determined until a portion of the outer skin has been removed as described in Section 4.1 – "*Assessing And Preparing The Damaged Area*". After a thorough inspection and assessment of the damage, follow the procedure that is most appropriate to the situation in hand and bear in mind that the objective is to restore the structural properties of the panel by rebuilding the load carrying capability of the core and the skins to the original or greater strength.

5.2.Repairing skin delamination

Skin delamination is often first noticed when stepping on a flexible or spongy area on an otherwise firm deck. Most delamination is the result of moisture damage to the skin/core bond and usually involves panels either consisting of balsa or plywood cores. Moisture entering cracks or loose hardware can migrate much more easily through a wooden core than through a foam core but because they are much less expensive, balsa and plywood cores are more widely used in productrion boats. Often the core material will be wet or even saturated but it may still be serviceable if dried thoroughly. However, if a wooden core remains wet for a long period it will begin to deteriorate and will need replacement.

Delamination may also occur in isolated pockets as a result of inadequate core bonding during manufacture. In some cases, the core may remain dry and undamaged and simply need rebonding.

5.2.1 Assessing delamination damage

The first step in the repair is to determine the extent of delamination and the condition of the core. Subsequently follow the repair procedure most appropriate to the situation.

Locate and mark the extent of the damage by exerting pressure on the panel, checking for a soft feel and/or skin movement. Tap lightly around the suspected area with a small, hard object to reveal the area of delamination. A void under the skin will sound flat or dull, compared to a more resonant sound of a solid laminate.

When pushing against the surface, the delaminated skin will depress easily until it contacts the core. If the core is solid, the skin will appear fair when pressed against the core. If the core is damaged or deteriorated, it will be possible to push the skin below the fair surface of the deck or hull. Water or air may squeeze from a nearby crack or hardware fastener.

Determine the condition of the core material by drilling 5mm diameter inspection holes through the skin, several centimetres apart over the area delamination. Push the skin tight against the core and drill through the core without drilling into the opposite skin. Collect the core material removed by the drill. Squeeze this core material tightly between thumb and finger to determine whether the material is wet or dry and examine it for signs of decay. A wire or nail can be inserted though the hole to probe the core. If voids are apparent or the core feels soft, the core should be replaced.

5.2.2. Rebonding delaminated skin to a dry core

If the core material is firm and dry, rebond the skin by injecting epoxy between the skin and core as follows:-

1. At an angle cut the tip of a 807 WEST SYSTEM Syringe. Fill the syringe with an epoxy/404 or 406 filled mix thickened to the consistency of ketchup.

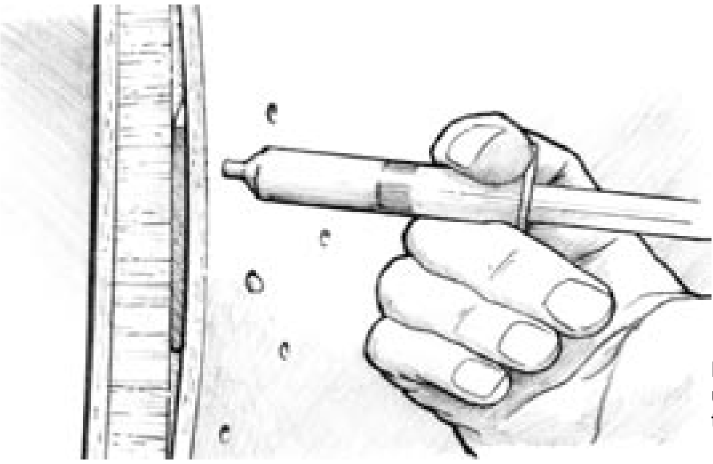

Figure 5-1 Inject epoxy under the skin using an 807 syringe with the tip cut off to match the hole diameter.

2. Inject the epoxy mixture under the skin through each of the inspection holes. The shortened tapered syringe tip should fit tightly in the inspection holes *(Figure 5-1).* Enough pressure should develop to force the epoxy several centimetres from the hole.
3. Clamp the skin to the core when enough epoxy has been injected between the core and the skin, i.e., to bridge any gaps between the skin and core. Use weights, braces or sheet metal screws through the inspection holes to hold the skin tight and fair against the core until the epoxy cures. Clean up excess epoxy before it begins to gel. Allow the epoxy to cure thoroughly before removing clamps or holding screws.
4. After removing clamps, fill any voids or screw holes in the inspection holes with a thickened epoxy/406 mix. When the epoxy has cured thoroughly, fair and finish the surface as described in Section 2.

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5.2.3. Rebonding delaminated skin to a wet core

If the core material is wet but still solid, rebond the skin after the core has been thoroughly dried. One of two methods may be used to expose the core for drying.

Pattern hole drying method

This method involves drilling a pattern of holes through the skin to expose the core to both air and heat and to allow moisture to escape. When the core is dry, epoxy is injected under the skin and the skin and core are clamped together until the epoxy cures. This method is useful if the delamination is small and is not under an area of non-skid deck.

1. Drill 5 mm diameter holes at 25mm intervals, creating a pegboard-like pattern that extends several centimetres beyond the delaminated area *(Figure 5-2)*. The holes should penetrate the fibreglass skin and the core without drilling into the opposite skin. Use a drill depth control device to prevent drilling entirely through the panel.

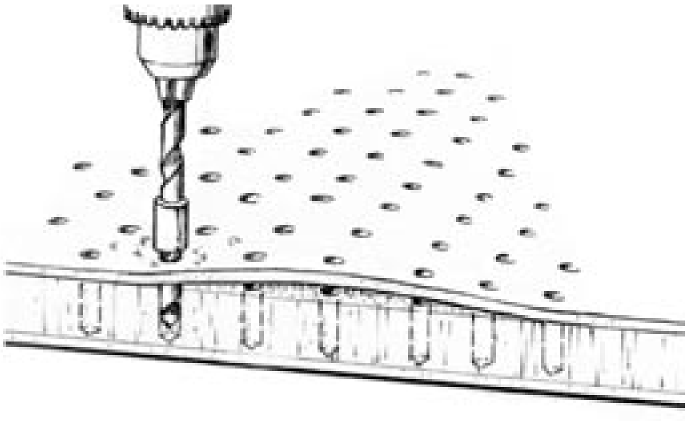

Figure 5-2 Drill a pattern of holes, 25mm apart over the area of delamination to allow the core material to dry out.

2. Dry the core thoroughly. If the core is extremely wet, start by using a high-powered shop vacuum cleaner or use vacuum bagging to draw water out of the laminate. A heat lamp or heat gun will speed the drying. Ensure the fibreglass surface or the core is not damaged by excessive heat and do not allow the surface to exeed 50°C Do not heat the surface above 50°C. The surface and core must cool to room temperature before continuing. Drill a few test holes between the existing holes to check for core dryness.

3. Cut the tip of a 807 Syringe at an angle. Fill the syringe with an epoxy/404 or 406 filled mix, thickened to the consistency of ketchup.

4. Inject the epoxy mixture under the skin through each of the holes starting in the centre of the delaminated area *(Figure 5-3)*. The shortened tapered syringe tip will fit tightly in the 5mm holes. Enough pressure should develop to force the epoxy to the surrounding holes.

5. Clamp the skin to the core when there is enough epoxy to bridge any gaps between the skin and core. Use evenly placed weights or braces covered with plastic to hold the skin tight and fair against the core. Sheet metal or drywall screws will also work. Whichever clamping method is used, do not distort the panel by applying too much pressure. It is only necessary to keep the skin fair and the skin and core in contact whilst the epoxy cures. Remove the excess epoxy before it begins to gel. Allow the epoxy to cure thoroughly before removing clamping.

6. Sand the surface and fill any remaining holes with an epoxy/407 Low-density Filler mix, thickened to the consistency of peanut butter *(Figure 5-4).* After the epoxy has cured thoroughly, sand the surface fair and finish as described in Section 2.

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For thin skins, this procedure may result in a weakened structure, making it necessary to bond several layers of 200g/m² Episize™ Glass Fabric over the repair area. Refer to Section 9.4.5 – "*Applying Woven Cloth And Tape*".

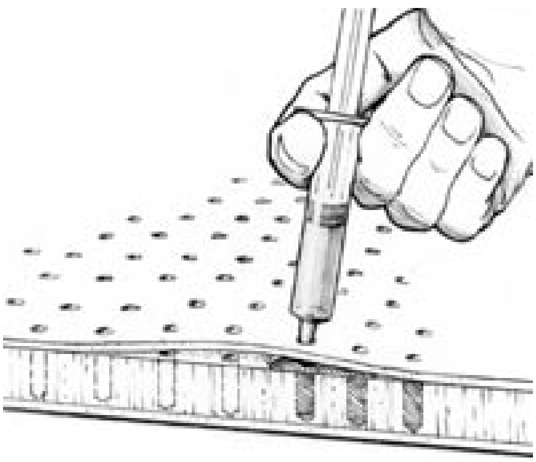

Figure 5-3 Inject the epoxy mixture under the skin through each of the holes starting in the center of the delaminated area. Fill all voids between the skin and core.

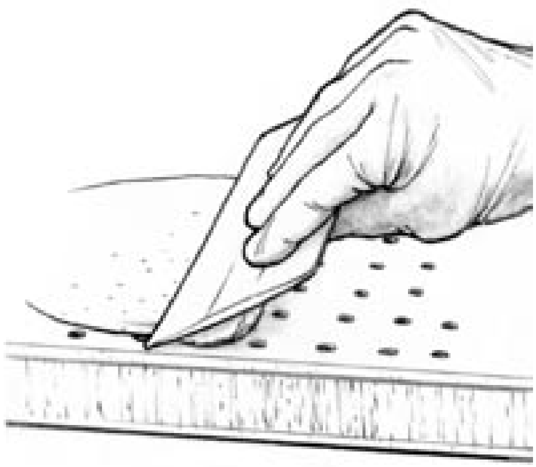

Figure 5-4 Fill any remaining voids and fair the surface with an epoxy/407 mix.

Skin removal method

This method involves removal of a section of skin to expose the core for drying. Because of the difficulty (or impossibility) of fairing and finishing a non-skid surface, it is often easier to cut and remove an entire non-skid area. After the core has dried, the skin is rebonded and then patched and refinished at the smooth areas outside the non-skid surface. Follow the procedure below in Section 5.3 – "*Replacing damaged cores*".

5.3.Replacing damaged cores

This method is used when the core is damaged and must be replaced or when a skin delamination is in a non-skid area of a deck. After the core is replaced or dried, the skin is rebonded to the core and a repair patch is laminated over the joint to restore skin continuity.

Remove the skin and replace the damaged core as follows:-

1. Cut through the skin around the area of delamination with a panel or circular saw with a carbide tipped blade or a router with a small diameter straight-fluted bit. Set the blade or bit to the depth of the skin. On smooth surfaces cut several centimetres outside the area of delamination. If the delamination is in an area of non-skid, cut in the smooth area several centimetres outside the non-skid or midway between non-skid areas.

2. Remove the skin *(Figure 5-5)*. The skin should separate easily in areas where the core is damaged or wet. In areas where the skin is well bonded to the core, use a chisel or thin blade between the skin and core to pull the skin away from the core material. Be careful not to bend the skin too much or gouge the core. Applying heat to the joint with a heat gun will also help to soften the skin/core bond but take care not to overheat the skin.

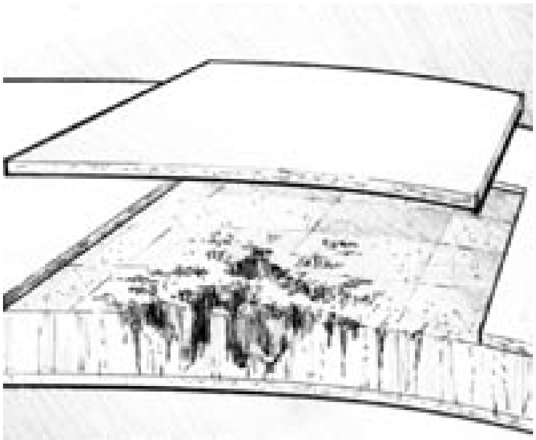

Figure 5-5 Cut through the skin only, outside the area of delamination. Carefully pull the skin away from the core material.

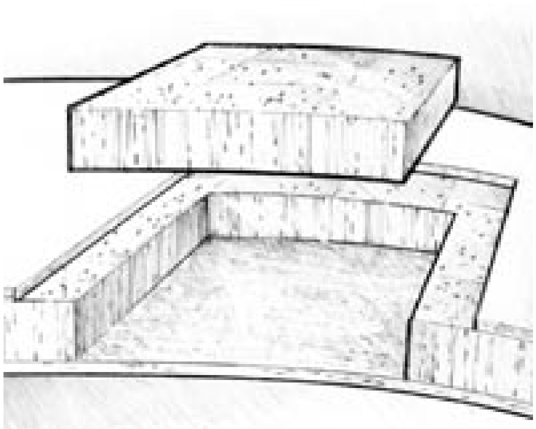

Figure 5-6 Fit a new piece of core material to match the shape, thickness and density of the damaged section that was removed.

3. Dry the core thoroughly. If the core is extremely wet, start by using a high-powered shop vacuum cleaner or use vacuum bagging to draw out the water out of the laminate. A heat lamp or heat gun will speed the drying.

Note: If the core is undamaged, do not replace the core - only rebond the skin as described in Section 5.3.1

4. Remove damaged core material. Cut around the area of damage with a utility knife. Use a chisel to remove the damaged core and shave all traces of core from the opposite skin.

5. Prepare a new piece of core material to match the shape, thickness and density of the core that was removed. Dry fit the core to ensure the new piece is the correct size, i.e., no higher than the surrounding core *(Figure 5-6)*. When replacing damaged core material, try to purchase the same material used by the builder. If that is impossible, locate a core material which is as close as possible to the original thickness and density. It is better to have a slightly thinner core material than a thicker one.

If the damaged area is smaller than about 50mm x 50mm, the area may be filled with a thick epoxy/404 or 406 filled mix.

If the damaged area is smaller than about 300mm x 300mm and the original core material is not available, use a substitute core material cut from soft woods such as pine, fir or cedar. Cut short blocks to the length of the appropriate core thickness.

6. Bond the new core material in place. Using a resin/hardener mix, wet out the bonding surfaces of the skin, existing core and new core with epoxy. Coat the bonding surfaces with an epoxy/406 filled mix, thickened to the consistency of mayonnaise. Apply enough thickened epoxy to bridge all gaps between the skin and core and between pieces of core. Press the core material firmly in position. A small amount of thickened epoxy should squeeze from the joint around the piece.

7. If necessary clamp the piece (or pieces) with plastic covered weights or braces, to hold it in place. Smooth the epoxy at the joint and remove excess epoxy before it begins to gel. Allow the epoxy to cure thoroughly before removing clamps.

5.3.1.Rebonding the skin

If the skin was damaged from an impact or abrasion or damaged during removal, laminate a new skin in place against the new core as described in Section 4.3. If the skin is reusable, rebond the skin as follows:

1. Sand the surface of the core and the inner surface of the skin that was removed. Dry fit, ensuring that the skin lays flat and fair with the adjoining skin.

2. Bond the skin to the core in its original position. Wet out the bonding surfaces of the core and skin with epoxy. Coat the bonding surface of the core with an epoxy/406 filled mix thickened to the consistency of mayonnaise. Apply enough of the thickened mixture to bridge all gaps between the skin and core. Position the skin so that the gap around the piece (the saw cut) is equal on all sides.

2. Clamp the skin in position using vacuum bagging, weights, braces or sheet metal screws. Vacuum bagging is an ideal method for providing equal clamping pressure over large areas. Follow the procedure for vacuum bagging repair patches described in Section 4.3.3. If using standard clamping, a small amount of epoxy should squeeze from the joint. Remove excess epoxy before it begins to gel. Allow the epoxy to cure thoroughly before removing vacuum pressure or clamps.

3. Grind a 12-to-1 bevel on both edges of the joint and laminate a repair patch over the joint to restore skin continuity *(Figure 5-7)*. The bevel will provide a recessed bonding area for the application of epoxy/glass fabric and allow the patch to be faired flush with the surface. The objective and procedure for patching the joint are the same as repairing damaged skins. Follow the procedure described in Section 4.3.

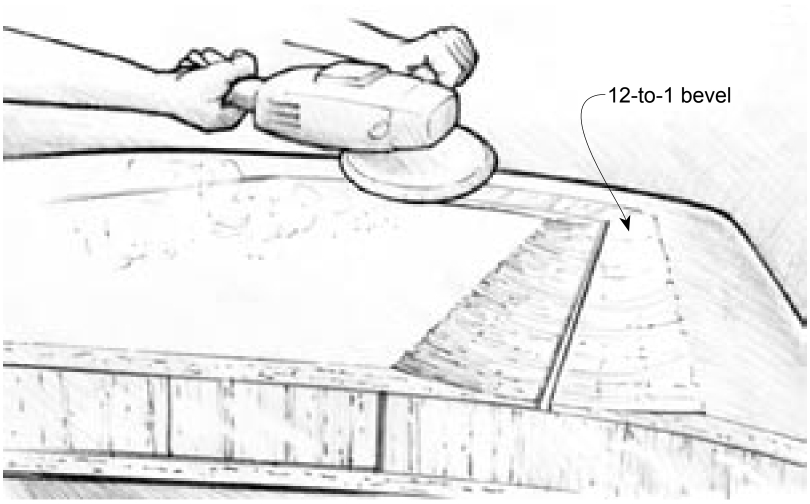

Figure 5-7 Grind a 12-to-1 bevel on the edges of the joint, so the joint repair patch can be faired flush with the surface.

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5.4.Repairing transom delamination

Removing a section of skin to expose and replace the core is a repair method often used to repair delaminated powerboat transoms. Transoms are major structural parts of fibreglass powerboats, especially outboards. They not only support the weight of the motor, they maintain the shape of the boat and are a mounting point for holdowns, towing eyes and other accessories.

Outboard motors apply a considerable load to the transom. The effect of the weight of the motor is concentrated on small areas of the skin and core when the boat is accelerated under normal operating conditions and when the boat is bouncing along on a trailer. *(Figure 5.8)*. Over time, the core is crushed and cracks develop in the skin. Moisture penetrates the plywood core, leading to delamination and eventual rot. Moisture can also penetrate the transom skin at hardware fasteners and around drain holes and I/O cutouts. These factors have a cumulative effect on structural failure.

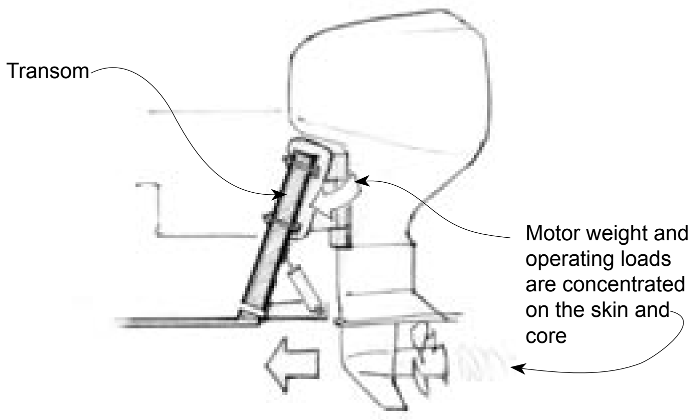


Figure 5-8 Motor loads are concentrated on the fibreglass skin and core where the mount is located. Moisture penetrates cracks in the skin, leading to delamination and eventual rot of the plywood core

Excessive motor movement may be the first sign of trouble. Tap around the suspected area lightly with a small, hard object to help reveal any areas of delamination. A void under the skin will sound flat or dull, compared to a more resonant sound of a solid laminate. Damage can be confirmed by drilling 5mm diameter inspection holes into the core at the area of suspected delamination. Examine the core material removed by the drill for signs of water or decay.

5.4.1 Planning the repair

The objective is to remove and replace the damaged core. Access to the damaged core is gained by removing the fibreglass skin from either the outside or, if possible, the inside of the transom. The design of the boat determines which method is more practical. Interior access requires much less cosmetic finishing, but stringers, soles or decks often make it impossible to remove the interior skin The following method describes accessing and removing the core from the outside. If the removed fibreglass skin is in good condition, it is usually bonded back over the new core, then structurally and cosmetically blended into the surrounding skin as described in Section 5.3.1. Support the hull to prevent sagging or distortion before removing the skin and core.

This repair is much easier if the total area affected can be confined to the transom and not extended around the corners. It is much easier to finish painting at the corner of an object, where there is a visual break, than it is to match colour and texture in the middle of an area. The following transom repair method leaves enough fibreglass around the perimeter of the transom for a proper bevel and repair patch, yet allows enough access for the damaged core to be removed and replaced. Before making a substantial cut through a structural fibreglass skin, support the hull with blocking to maintain the shape of the hull.

5

Determine the location of the cut

After removing the motor, hardware and trim, measure the fibreglass skin thickness at one of the holes through the transom. The fibreglass thickness determines the bevel length and the distance of the cut line from the corners. The bevel is at least 12 times the fibreglass thickness.

A 12-to-1 bevel allows room for multiple layers of epoxy/glass fabric across the cut line to restore strength to the fibreglass skin. If the fibreglass skin is 3.5mm thick, the width of the bevel will be at least 42mm If the fibreglass is 6.5mm thick, the cut line will need to be at least 78mm. from the corners to allow for a 78mm bevel. If the original fibreglass skin is reused, the same bevel is required on each side of the cut after the skin is rebonded to the new core.

Mark the cut line on the transom the required distance from the corners. Measure from the end of the rounded corners where they blend into the flat transom surface.

5.4.2 Removing the damaged skin and core

The skin removal method as described above for deck or hull panel delamination is essentially the same for transom delamination. The main difference is the core material. Most transom cores consist of two or more layers of marine plywood glued together. Often, if the core has been wet for a period of time, the plywood veneers will begin to delaminate and much of the veneer may have rotted away. It is not difficult to bond a new core into the transom and rebond the fibreglass skin. Remove the outer (or inner) transom skin and replace the plywood core as follows:

1. Cut through the skin at the cut line established by the bevel length. Use a panel or circular saw with a carbide tipped blade or a router with a small diameter straight-fluted bit. Set the blade or bit to the depth of the skin only.

2. Remove the skin. The skin should separate easily in areas where the core is damaged or wet. In areas where the skin is well bonded to the core, use a chisel or thin blade between the skin and core to pull the skin away from the core material. Applying heat to the joint with a heat gun will also help to soften the skin/core bond. Be careful not to overheat the skin. Avoid damaging the skin by over bending or using too much force when pulling the skin from the core. It is worth the effort if it is possible to remove the skin in one piece.

3. Inspect the condition of the plywood core material. If the plywood is sound but wet, dry it thoroughly with a heat lamp or heat gun and rebond the skin (Section 5.3.1). Fill any minor voids, delaminations or endgrain while the core is uncovered. Drying a saturated transom core may be difficult even with heaters and unless plenty of time can be allowed for drying, it is better to replace the core. However, if the plywood has deteriorated or dry rot has set in, the plywood should be replaced.

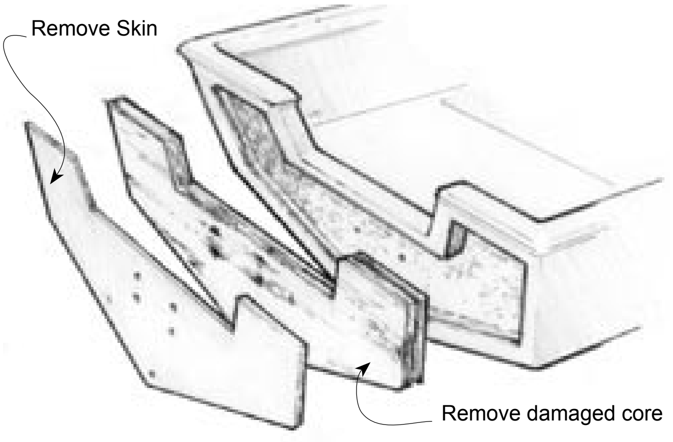


Figure 5-9 Cut through the outer skin at the perimeter of the core. Remove the skin and the core if it is delaminated or rotted.

4. Remove the damaged plywood core *(Figure 5-9)*. Use a chisel or whatever combination of tools is required to remove all damaged material. The plywood core in the perimeter and corners of the transom will be the biggest challenge. If necessary, use large drill bits to carefully weaken and remove stubborn areas. Shave all traces of the core material from the inner skin, being careful not to damage the skin. Make any necessary repairs to the inner skin. Sand the skin to prepare for bonding.

5.4.3 Preparing a new transom

Prepare a new plywood core to match the shape and thickness of the core that was removed. Try to use the same grade of plywood (or better) than was used in the original core - marine grade plywood is ideal for this repair. It is possible to use thinner sheets of the same type of plywood, laminated to equal the thickness of the original core. For example, if the core consisted of two sheets of 18mm plywood, laminate three sheets of 12mm or four sheets of 9mm to equal the original 36mm core thickness. Trim and dry fit the new pieces of core to fit the void left by the old core.

Make a template of the transom and use it to layout the plywood layers. Because the opening in the transom skin is smaller than the full sized plywood core, it is necessary to replace each layer of the core in pieces (Figure 5-10). Cut each layer into pieces small enough to fit through the opening in the transom skin. Stagger the joints in each layer by at least eight times the plywood thickness. For example, a 72mm stagger will be required between joints when using 9mm plywood. Ideally these joints are widely staggered and can also be made on a diagonal to further increase the stagger. Joints near the sides of the transom will affect strength less than joints near the middle. It is to be remembered that the cantilevered load of an outboard motor puts significant loads on the middle of the transom. If joints in the layers are scarffed with an 8:1 bevel rather than butted, joint location is not an issue.

Before mixing epoxy

- Plan all of the installation steps. The layers can be bonded in place in one continuous operation or over several sessions.
- Label the pieces and dry fit them in the transom to eliminate potential problems during assembly. The fit need not be perfect - thickened epoxy will bridge gaps.
- Use 206 Slow Hardener for extra working time. Use 209 Extra Slow Hardener when working in warm temperatures.
- Protect surrounding areas of the boat from accidental spillage of epoxy.
- Ensure all parts, tools and clamps are within easy reach. Drywall screws provide a practical clamping method for a plywood transom lay-up. Clamps, wedges or prop sticks can also be used. Bolts with nuts and oversized washers can be used in places where motor mount holes and drain holes will eventually be required.

5.4.4 Installing the new core

To accomplish the repair in manageable steps when working alone, laminate the new pieces of plywood core in place as follows:

1. Prepare all bonding surfaces. Check the condition of the inner skin and make repairs as necessary. Sand rough surfaces. Remove all loose material and dust.

2. With a resin/hardener mix, wet out the bonding surfaces of the inner fibreglass skin and the first piece of core. Apply extra epoxy to the plywood endgrain.

3. Coat the bonding surfaces of the inner skin and hull edges with an epoxy/403 or 406 filled mix, thickened to the consistency between that of ketchup and mayonnaise. Use a notched spreader to apply enough thickened epoxy to bridge all gaps between the core piece and the skin and the edge of the core and the hull. Avoid over-thickening - the epoxy needs to move under minimum pressure.

4. Place the first piece of plywood in position against the coated skin *(Figure 5-10)*. Clamp the piece in place with drywall screws (and oversized washers) through the inner skin to draw the pieces of core tight to the inner skin. Coat the screws with a mould release for easy removal. A small amount of epoxy should squeeze from the joint around the core. (Fill the screw holes with epoxy after the lay-up has cured.)

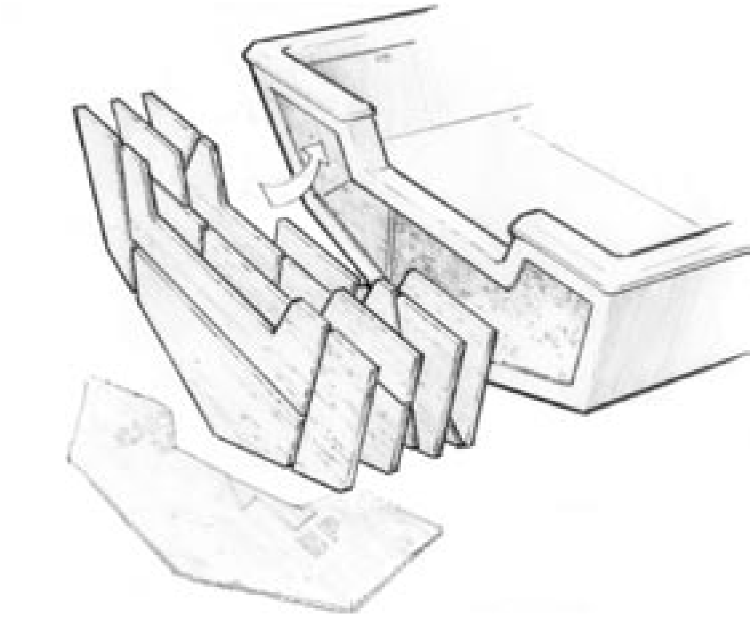


Figure 5-10 Bond a new plywood core in place. Laminate sheets of thinner plywood to equal the thickness of the old core. Trim the pieces to fit the void left by the old core using a cardboard template to layout pieces. Cut the pieces as neccessary to fit opening.

5. Repeat the process for the remaining pieces of the first layer. Fill any gaps and smooth the epoxy at the joints. Remove excess epoxy before it begins to gel. Allow the epoxy to cure thoroughly before removing screws, clamps or vacuum pressure. Once cured, a rigid base is available on which to bond or laminate the remaining plywood one layer at a time.

6. Recheck the fit of the final pieces and ensure the cured epoxy coated surfaces are well abraded prior to laminating additional plywood layers.

7. Repeat the process for each layer. Use drywall screws to draw the new layer onto to the first layer. Remove the screws and fill the holes with epoxy after the epoxy cures or, if you plan to leave the fasteners in place, ensure they are stainless, galvanized or bronze.

An alternative method is to install and clamp all the layers in place at the same time if using the 209 Extra Slow Hardener. Dry fit and label all the parts. Apply unthickened epoxy to the plywood segments - especially the end grain around the perimeter of each piece - before applying thickened epoxy. Pieces can be temporarily clamped with drywall screws. Remove and replace the screws as each layer is installed.

5.4.5 Replacing the fibreglass skin

After the core replacement is complete, the original fibreglass skin can be laminated over the new core or, if necessary, laminate a new skin.

A transom skin is often reusable except for a relatively small damaged area around the motor mount. If the damage is limited, it may be easier to repair the damage in the centre of the skin after it is rebonded, rather than laminating a new skin over the entire transom. Repair the skin using the appropriate procedure in Section 4 after the skin is replaced. Rebond the original skin as follows:

1. Abrade the bonding surfaces of the core and skin. If the skin was repaired, take care to sand flush the back side of the repair. Dry fit the skin to ensure it lays flat and fair with the adjoining skin.

2. Wet out the bonding surfaces of the core and skin with epoxy. Bond the skin to the core in its original position with the same laminating techniques used to bond the plywood core in place.

3. Clamp the skin with drywall screws driven through plywood blocks or oversized washers. Large blocks or washers spread the holding power of the screws over a larger area and prevent dimples in the fibreglass skin that would later require filling and fairing. Use pieces of plastic sheet under the washers or blocks to prevent bonding to the skin. Allow the epoxy to cure. Remove the screws and fill the holes with epoxy.

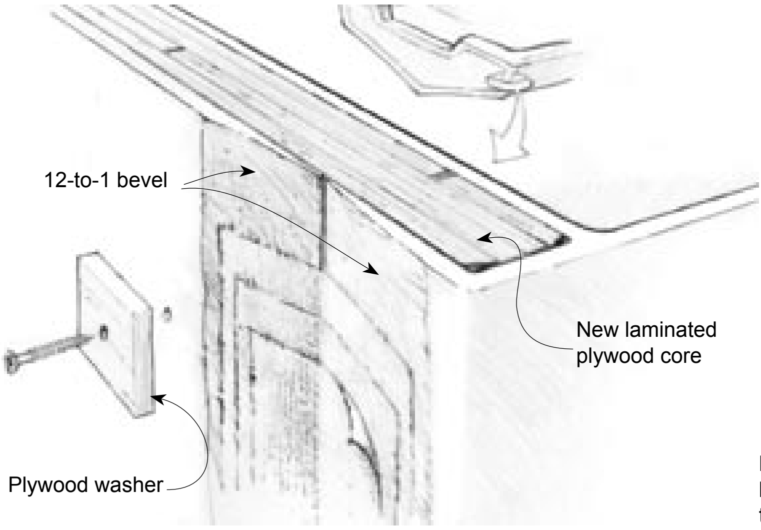


Figure 5-11 Grind a minimum 12-to-1 bevel on both sides of the joint. Laminate a repair patch over the joint to restore skin continuity.

4. Grind a minimum 12-to-1 bevel on both sides of the joint. The outside edge of the bevel should be short of the corner, as detailed earlier in Section 5.4.1 – "*Planning the repair*". Laminate a repair patch over the joint to restore skin continuity *(Figure 5-11).* The bevel will provide a recessed bonding area for the application of epoxy/glass fabric and allow the patch to be faired flush with the surface. The procedure for patching the joint are the same as repairing damaged skins. Follow the procedure described in Section 4.3. Limit the patch and finishing to the transom side of the corners.

5.4.6 Laminating a new transom skin

If the fibreglass skin is unusable, plan to laminate a new epoxy/glass skin over the core using sufficient layers to give the same thickness as the original skin.(See the fabric thickness chart in Appendix A). Glass layers can be applied immediately onto the previous lamination or while the preceeding layer is still tacky. However, if the epoxy is allowed to cure beyond the tacky stage, allow it to cure overnight, then wash the surface with water and abrade before re-starting the laminating operation. Laminate the new skin so it extends to the edge of the 12-to-1 bevel that was machined earlier on the outer edges of the transom. Install the biggest patch first with each layer being progressively smaller to fill the 12-to-1 bevel. For additional information on laminating a large new epoxy/glass skin see Section 4.3.

1. Grind a 12-to-1 bevel around the remaining edge of the transom. The outside edge of the bevel should be short of the corner, as described earlier in Section 5.4.1 – "*Planning the repair*".

2. Cut the appropriate number of fabric pieces to the size and shape of the transom. Cut the first piece 12/13mm from the outer edges of the bevel with subsequent fabric pieces smaller than the previous one. The final piece should be the same size as the inner edge of the bevel. The edges of the middle fabrics should be evenly spaced between the edges of the first and last pieces. The spacing depends on the number of laminations (equating to the laminate thickness) and the length of the bevel.

3. With a resin/hardener mix wet out the transom core and bevel. Using a plastic spreader, coat the transom core with a thin even layer of an epoxy/406 filled mix thickened to a mayonnaise consistency.

4. Wet out the cloth with epoxy on a work surface covered with plastic sheeting. Apply enough epoxy to saturate the cloth using a thin foam roller or by pouring epoxy onto the fabric and spreading with a plastic spreader.

5. Place the fabric on the transom and centre it within the edges of the bevel. Smooth the fabric into the thickened epoxy layer with a plastic spreader. Use the spreader to remove trapped air and excess epoxy and to smooth the fabric against the surface.

6. Wet out with epoxy and apply each of the remaining fabric layers, ending with the smallest piece. Apply each layer before the previous layer becomes tack free.

Smooth each layer with a plastic spreader to remove wrinkles, trapped air and excess epoxy *(Figure 5-12).*

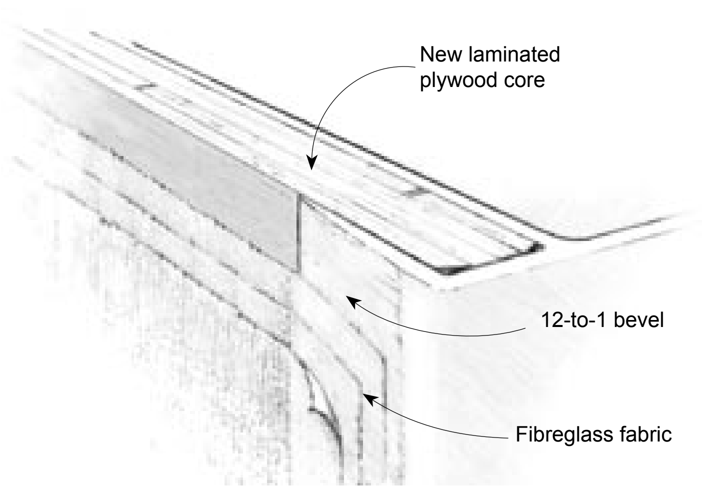


Figure 5-12 Wet out and apply each layer of fabric with epoxy, ending with the smallest piece. Smooth each layer with a plastic spreader to remove wrinkles, trapped air and excess epoxy.

7. When the laminate has reached the gel stage, apply several coats of epoxy over the fabric to fill the weave of the fabric. Use the thin foam roller to apply each coat after the previous coat reaches the gel stage and before it becomes completely tack free (to avoid sanding between coats). Allow the final coat to cure thoroughly.

8. Wash and sand the final coat after it has cured thoroughly. Sand and fair the edges of the fabric to blend with the hull surface. Any flaws or unevenness can be faired with a thickened mix of epoxy using 407 or 410 Fairing Filler. Seal filled and sanded surfaces with epoxy and wet sand to prepare the surface for paint. Be sure to coat and seal the endgrain of all holes drilled through the transom with at least three coats of epoxy This is essential - if the holes are not properly sealed, plan on replacing the core again in the future.

   If all sources of water are eliminated by sealing the wood with epoxy, the repair should be better than new and will last indefinitely. The screw holes must be coated with epoxy just prior to installing screws for motor mounts and transom hardware. Apply mould release (or vegetable oil cooking spray) to the fasteners prior to gluing them in place if these fasteners are to be removed in the future.

Replacing the core and both skins

If it is impossible to separate the skins from the core or if the skins and core are damaged beyond repair, cut the entire transom section out and bond in a new core as follows:

1. Cut away the transom by sawing through the skins and core at the perimeter of the transom. Prepare the bonding area by abrading any rough or uneven edges around the hole perimeter. Ensure the hull is supported to prevent distortion.

2. Prepare the transom core replacement as described above (5.4.3). Bond the plywood pieces together on a flat surface or a surface matching the curve of the transom. Trim the perimeter of the new core, checking the piece fits into the exact position of the old core. Ensure the hull is set up square and true before bonding the new transom in place.

3. Bond the new core in position. Using a resin/hardener mix, wet out the bonding surfaces of the new plywood core and the hull. Use particular care to thoroughly wet out the end grain of the plywood. Coat the bonding surfaces of the core and hull with an epoxy/404 filled mix thickened to the consistency of mayonnaise. Use enough of the mixture to ensure no voids remain between the two surfaces when the core is positioned.

4. Clamp or brace the core in position until the epoxy cures. Use only enough clamping pressure to restrict movement and squeeze out some of the epoxy. Remove the excess thickened epoxy or use it to fill any voids in the joint before it begins to gel. Align the core in the exact position of the old core and allow the epoxy to cure thoroughly before removing clamps.

5. Rebond reusable skins as described in Section 5.4.5 or laminate new skins following the procedures in Section 5.4.6.

5.5 Repairing holed panels

Minor impacts or abrasions can include dropping hardware or a sharp tool on the deck, rubbing against a dock or the weight of an outboard motor mount against a transom. This type of damage often results in a hole or crack through one skin and possible skin delamination around the impact. If the damaged area has been submerged or left unprotected for a period of time, water penetration can lead to further delamination and eventually rot. Most minor impact damage can be repaired with procedures previously described.

Major impact damage is often associated with collisions, groundings, natural disasters and occasionally traffic accidents. The amount of damage depends on the force of the impact and the shape of the “collision” object. In this case, the structural damage is through the core and both skins. Damage may mean a fracture that results in loss of skin continuity or a hole several feet across. There is also a strong possibility that the impact may also have caused internal structural damage to bulkheads, frames, etc. Any such damage must be repaired prior to undertaking the repair of the cored panel.

The objective in repairing holes through cored panels is to replace damaged core material and restore skin continuity to both skins. The sequence of skin and core replacement will vary depending on access to the back of the panel.

5.5.1 Repairing holes through cored panels with back access

After preparing the hole, replace the core material and laminate the inner and outer skin to the core as follows:-

1. Prepare the hole by cutting away ragged or damaged skin. Cut back to undamaged core and skin while maintaining a circular or oval hole shape. Grind a minimum 12-to-1 bevel on the edges of the inner and outer skins at the hole to provide adequate bonding surface when relaminating the skin repair patches.

For example, if the skin is 6mm thick, the bevel will extend 75mm from the edge of the hole *(Figure 5-13)*.

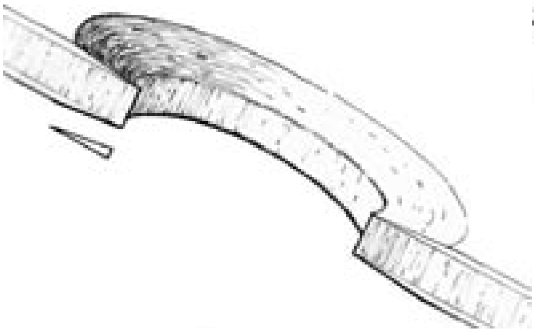


Figure 5-13 Grind a 12-to-1 bevel on the edges of the inner and outer skins.

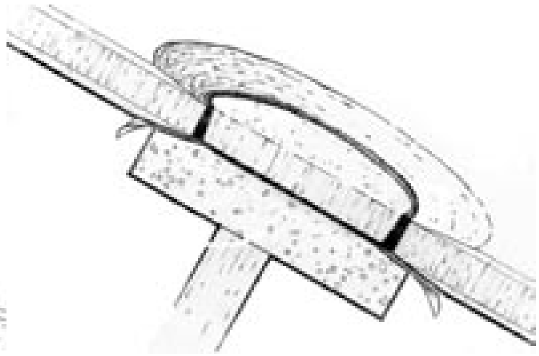


Figure 5-14 Brace a temporary backing against the back of the hole to support the new core.

2. Provide a temporary backing to support the core while bonding it in position and laminating the new outer skin patch. Cut a piece of low density insulating foam slightly larger than the hole opening. Bevel the edges of the foam so the face of the foam is flush with the inner skin/core bond line. Cover the foam with 4-6 ml plastic and brace it in position against the inner edge of the hole. If the foam is too stiff to conform to a curved panel shape when braced from the back, sand the foam to a shape that matches the panel curve *(Figure 5-14)*.

5

3. Prepare a new piece of core material to match the shape, thickness and density of the core that was removed. Dry fit the core to match the shape and contour required. When replacing damaged core material, try to purchase the same material as originally used. If this is impossible, locate a material that is as close as possible to the original thickness and density of the core.

4. Bond the core material into position. With a resin/hardener mix wet out the edges of the hole and the core material. Apply a layer of epoxy/406 filler thickened to the consistency of peanut butter to the wetted surfaces. Place the core material in position. If the epoxy mixture will not hold the core in place or if it will not conform to the panel contour, use braces to hold it in position. Smooth any excess epoxy and fill any voids in the joint before the epoxy begins to gel. Allow the epoxy to cure thoroughly.

5. Laminate a new outer skin repair patch following the procedure in Section 4.3. Finish the repair following the procedure in Section 2.

6. Remove the temporary backing support and laminate a new inner skin repair patch following the procedure in Section 4.3. Finish the repair as desired.

5.5.2 Repairing holes through cored panels without back access

The difference between repairing holes with or without back access is in the sequence of steps. Without back access it is necessary to laminate the inner skin first, replace the core, and then laminate the outer skin. Laminating the inner skin from the outside requires additional preparation, as follows:-

1. Prepare the hole by cutting away ragged or damaged skin. Cut back to undamaged core and skin, while maintaining a circular or oval hole shape.

2. Cut back the outer skin and core several centimetres from the edge of the hole in the inner skin to provide an area wide enough to grind a 12-to-1 bevel around the edge of the inner skin *(Figure 5-15).* Use a router with a straight fluted bit set to the depth of the outer skin and core to avoid cutting the inner skin. Cut back the core and outer skin 12 times the thickness of the inner skin plus about 25mm to provide room to grind the inner skin bevel. For example, if the inner skin is 6mm thick, the bevel will extend 75mm from the edge of the hole. The core and outer skin should be cut back about 100mm from the edge of the hole in the inner skin.

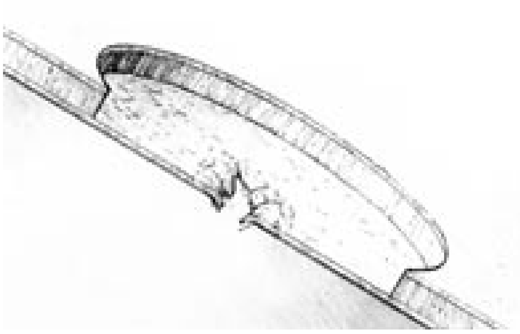


Figure 5-15 Cut back the outer skin and core several centimetres from the hole in the inner skin.

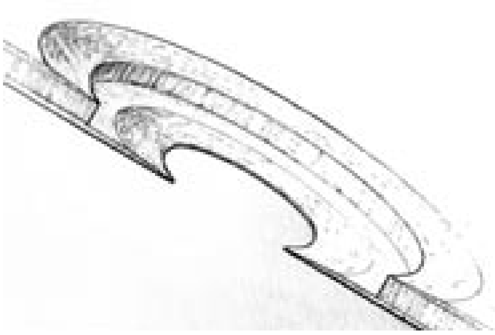


Figure 5-16 Grind a 12-to-1 bevel around the edge of the inner and outer skins.

3. Grind a minimum12-to-1 bevel around the inner edges of both skins to provide adequate bonding surface when relaminating the skin repair patches *(Figure 5-16).*

4. Bond a permanent backer to the back of the inner skin following the procedure in Section 4.2.2. The backer should match the contour of the panel.

5. Laminate a new inner skin repair patch following the procedure in Section 4.3.

6. Bond a new piece of core material in place against the new inner skin.

7. Laminate a new outer skin repair patch following the procedure in Section 4.3. Finish the outer skin following the procedures beginning in Section 2.3

The information in Sections 2, 3, 4 and 5 is intended to provide a range of repair procedures for typical cored and non-cored fibreglass structures. Individual procedures or the sequence of procedures may be altered to suit any specific situation. Remember the major objective in repairing the fibreglass structure is to restore the skin continuity and structural properties of the core to be at least equal in strength to the original.

Section Six

6. Repairing and Upgrading Soles and Decks

A common source of problems on open runabouts and pontoon boats is the cockpit sole or deck. Poorly installed soles and decks are prone to delamination and rot. The first part of this section describes how to remove and replace damaged plywood decks. The second part describes how to install a teak veneer deck that is a practical and beautiful option for finishing a deck repair.

6.1 Repairing delaminated soles and decks

On runabouts, the plywood cockpit sole is usually a layer of plywood screwed down to the top of stringers and frames and "tabbed" or joined to the hull sides with fibreglass tape along the edges of the plywood and onto the side of the hull. Some runabouts will also have a layer or two of fibreglass fabric over the top of the plywood with a non-skid pattern moulded into the surface. Many have a layer of carpet or vinyl flooring material glued onto the plywood that can trap moisture and contribute to delamination and rot.

Moisture enters the plywood endgrain along the screws holding the sole down to the framing as well as the fasteners holding the seats, coolers, and other items to the sole. (Moisture also penetrates and damages the stringers supporting the sole. See Section 3 – *"Repairing Stringers and Floors"*.) In addition, there is seldom any fibreglass or resin coating to seal the back of the plywood and, in consequence, moisture also enters the plywood from below the sole where the air is often damp and stagnant.

When the plywood begins to delaminate, the deck will feel spongy underfoot. This is an unsafe surface on which to walk and also reduces the athwartship (side to side) hull stiffness that the sole would normally provide. If not repaired, the plywood will rot. This situation can be avoided if any penetrations into the plywood are carefully sealed.

If moisture damage is particularly severe, replacing the affected plywood is often necessary. The following procedure describes sole replacement in a runabout. A pontoon deck would be repaired in a similar manner but it will usually be fastened with screws around perimeter framing.

6.1.1 Removing the damaged sole

1. Remove any equipment or hardware screwed to the sole e.g. seat bases, cooler brackets, step or ladder brackets, etc,.

2. Pull up any carpeting or covering to expose the fasteners or tabs used to hold the plywood down on top of the frame and stringer system. If there are cutouts in the sole for access to storage compartments below, carefully remove any trim around the cutout. This will be reuseable when the new sole is in place.

   Before cutting tabs or removing any of the fasteners, ensure the hull is supported so that the sides do not move when the sole is no longer providing support. In many boats, this will not be a problem but there are some hulls that will be very floppy when the sole is removed. If the new sole is installed while the hull is out of shape, the hull will stay that way.

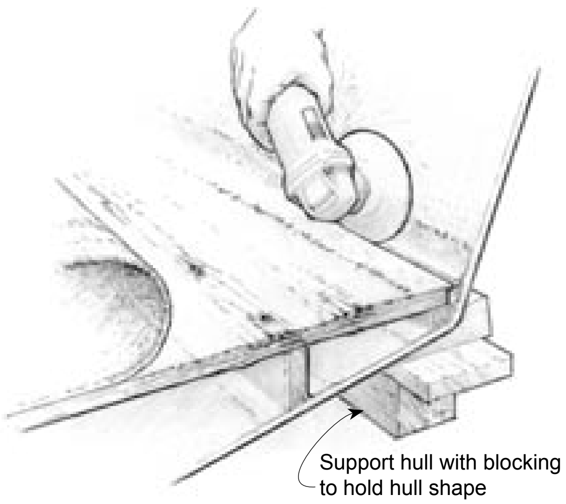


Figure 6-1 Cut through the fibreglass at the sole/hull joint if the plywood is tabbed to the hull with fibreglass tape or if the sole is covered with a layer of glasscloth. CAUTION! Do not cut into the hull laminate.

3. Cut through the fibreglass at the sole/hull joint if the plywood is tabbed to the hull with fibreglass tape or if the sole is covered with a layer of glasscloth *(Figure 6-1).* This is not a 90° joint - the hull is at an angle with the centreline. When cutting the tab, take great care not to damage the hull laminate. Remove all the fasteners. The sole may be screwed to butt blocks between plywood sections, cleats attached to the hull at the perimeter and/or stringers near the centre of the sole. Pontoon decks will be screwed or bolted around the perimeter.

4. Remove the pieces of plywood. If removed carefully, these can be used as patterns for the new sole. If only a portion of the sole is damaged, cut out that section of the sole. If there is no structural member below it to make a good joint, use cleats bonded under the edge of the remaining original deck on which to set the new plywood.

The sole may be bonded to the stringers and cleats supporting it. If necessary, cut the sole out in sections then chisel and grind away any material bonded to the tops of the stringers.

6.1.2 Installing the new sole

The moisture that damaged the plywood sole could also damage the supporting stringers and floors. It is essential to inspect and repair all damage to the structure below the sole before reinstalling the sole. If the structure is in good shape, reinstall the sole as follows:-

1. Cut out new pieces of plywood using careful measurements or patterns from the old sole. Ensure the new plywood is at least the same thickness as the original material.

2. Dry fit the sections, drill any fastener holes and then remove the section.

3. Coat the back of the plywood with two or three coats of epoxy before reinstalling to prevent moisture penetrating the bottom of the new sole. It is also extremely important to completely seal the edges of the plywood and the fastener holes.

4. Using a thickened epoxy adhesive, bond the new plywood sole to the hull, the stringers, floors and to any cleats installed to support the edges of the plywood between stringers. For partial replacement of the plywood or multiple sheets of plywood, open out the joint between plywood pieces with a grinder and join the pieces together with epoxy/glass tape to make a continuous panel.

With a pontoon deck, install the new deck by screwing the plywood to the stringers. Before inserting the screws, coat the fastener holes with epoxy to prevent moisture from penetrating into the plywood endgrain. It is advisable to coat or sheath the top side with epoxy/glass after the sole is installed.

6.1.3 Tabbing the sole to the hull

1. Use an 80-grit paper to prepare the hull surface for bonding by abrading a 10cm - 15cm wide strip on the hull above the sole.

2. Mix WEST SYSTEM epoxy and add either 406 Colloidal Silica or 407 Low Density filler to create a mix having peanut butter consistency.

3. Apply a fillet of thickened epoxy along the hull-to-sole joint. This will fill any gap between the plywood and the hull and allow the epoxy/glass tabbing to lay easily across the joint.

4, Apply 100mm wide 726 Biaxial glass tape over the fillet *(Figure 6-2)*. Wet out the tape with epoxy. If necessary apply multiple layers of tape to build up to the same thickness as the original tabbing but stagger the edges of the tabbing so they do not end in the same place on the hull side or sole. Apply the first layer of tape some 75mm up the side of the hull, the second layer 75mm out on the sole and the third layer over the centre of the corner. This creates an aggregate build up three layers thick on the corner without causing a hard spot at the edges of the tabbing. The tape can be applied over the uncured fillet or after it is thoroughly cured and sanded.

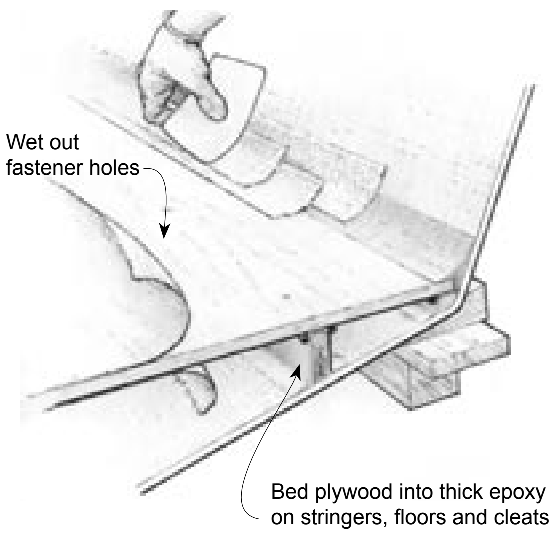


Figure 6-2 Apply epoxy/glass tape over the fillet. Stagger the edges of the tabbing when using multiple layers so they do not end in the same place on the hull side or sole.

5. Reinstall the carpeting or covering after the epoxy is cured. If painting the sole, ensure the surface is wet sanded to remove all gloss before priming and painting - the same preparation is required before installing a teak surface. When reinstalling seats and deck hardware, be sure to seal the fastener holes with epoxy. This will prevent the same type of damage from recurring.

6.2 Installing a teak deck

Installing a teak deck is a practical and beautiful option for finishing a deck or sole repair and for increasing the value of a boat. The thickness of the teak determines which of two installation methods are used. With both methods, the teak is bonded to the substrate with epoxy. Bonding with epoxy not only seals the deck with an epoxy moisture barrier but also eliminates the need for fasteners that penetrate conventional teak decks and are often a source of leaks.

Thinner teak veneers, 3mm - 6mm can be applied to decks, seats, cabin tops or hatches without adding excessive weight. When installing veneers, the gap between the strips is filled with a WEST SYSTEM epoxy/ 404/423 graphite mix to give an authentic teak deck that is both durable and low in maintenance.

Thicker teak planks, 6mm - 19mm are also bonded to the substrate but the gap between planks is filled with a flexible caulking more suited to the greater expansion and contraction of thicker timber. This is similar to traditional methods but with the advantage of a reliable moisture barrier under the teak and no fasteners penetrating the substrate.

6.2.1 Installing teak veneers

Although strips of up to 6mm thickness may be used, the effects of dimensional change can be limited by using thinner, 3mm thick strips. A 3mm thick deck will provide years of service in high-traffic areas and it will keep the additional weight of a new teak deck to a minimum. Strips should be 38mm-50mm wide, with edges planed smooth and straight. Leave the flat surfaces (top and bottom) rough sawn as the texture left by the saw improves the mechanical bonding characteristics of the strip. The remaining marks on the exposed surfaces will be sanded smooth after the new deck has been laid.

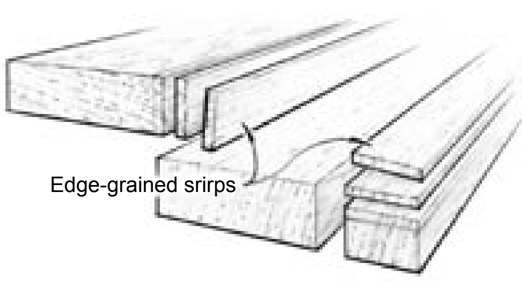


Figure 6-3 Alternate methods for cutting edge-grained deck strips from rough-sawn teak planks.

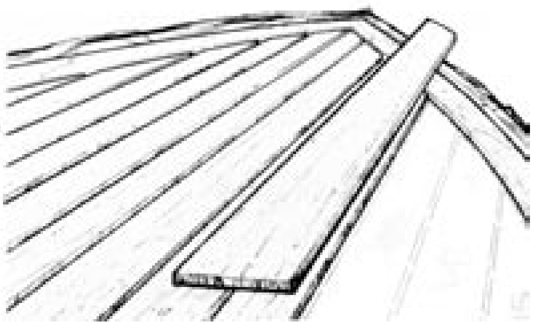


Figure 6-4 Cut and fit the teak strips. Mask off and protect surrounding surfaces.

If milling stock, select a plank width that makes the most efficient use of the raw material. Teak is generally available in 50mm thick, rough-sawn planks and it should be possible to achieve a 45mm finished dimension from these planks. Saw the stock so that the strips will be edge-grained *(Figure 6-3).* This will minimize expansion and contraction of the wood and make a more attractive, even-wearing surface than will slab-grained strips. Select wood that is well seasoned.

Make all necessary repairs to the sole or deck structure before applying teak veneer. See Section 6.1 to repair a plywood deck. See Section 5 to repair a cored fibreglass laminate deck. Install a teak deck as follows:-

1. Plan the location and pattern for the layout of the teak strips *(Figure 6-4*). Cut the strips to fit and mark them and the deck for reference as necessary. Mask off the application area and cover the surrounding area with plastic for protection against spills.

2. Prepare the bonding surfaces. Thoroughly wipe the bonding surfaces of the boat with clean acetone and dry with a paper towel. Grind non-skid areas flat and abrade smooth surfaces with 50-grit sandpaper. Remove sanding dust. If any of the bonding surfaces of the teak are smooth, abrade with 50 grit paper. Wipe the bonding surfaces of the teak strips, using paper towels with acetone, 30 minutes before bonding. This will remove the natural oil from the surface of the teak and improve epoxy penetration.

3. Place the first set of teak strips in the desired location, mark the bonding area and use the reference location points on the strips and deck. Place only the number of strips that can be applied during the open time of a batch of epoxy. The open time will vary with the resin/hardener combination in use and the ambient temperature. Begin with a small area or number of strips.

4. With a resin/hardener mix, wet out the bonding surface of the first set of teak strips and the corresponding bonding area of the deck. Remember to solvent wipe the bonding surfaces of the teak 30 minutes before the wet-out.

Thicken a resin/hardener mix to a mayonnaise consistency using 404 High-Density filler and then add enough 423 Graphite Powder to turn the mixture to an opaque black colour. Apply a heavy layer of the thickened epoxy to the wet-out deck surface, sufficient to bridge gaps between the strips and the deck and to squeeze up and fill the gap between the planks. A 809 Notched Spreader works well to apply an even layer over the deck. Ensure the reference marks remain uncovered.

5. Position the first set of strips on the deck. Use the reference marks as necessary.

6. Clamp the strips in place with #10 sheet metal screws and large washers. Place the screws and washers between the strips, 20cm. apart. Each row of screws will clamp the edges of two adjoining planks and act as spacers *(Figure 6-5, left).* Coat the screws and washers with a mould release (cooking nonstick spray) or place a small sheet of plastic under the washers to prevent bonding. Washers may also be cut from stiff plastic, thin wood lath covered with plastic or similar stock with holes drilled for the screws. Push adjoining strips tight against the screws before tightening the screws completely. Tighten the screws enough to hold the strips firmly and force some of the epoxy mixture to squeeze up between the strips.

Fill any voids between the planks with the resin/hardener/404/423 epoxy mixture and smooth the excess epoxy flush with the surface of the teak strips. Scrape up excess epoxy around the outside edges of the strips before the epoxy begins to gel.

7. Bond the remaining strips in place, several at a time, following the same procedure. Adjust the number of strips or size of the batch of epoxy as necessary. Allow the epoxy to cure thoroughly before removing clamps.

8. Remove the screws and washers within 24 hours. Tighten the screw slightly (5°) before backing it out. If there is difficulty in removing a screw, heat the head with the cutter tip of a soldering gun. While the screw is still hot, try to unscrew it again. Repeat until you are successful.

9. Fill the screw holes with the epoxy/404/423 mixture. A syringe loaded with the mix will speed the process. If the screws penetrated a panel, seal the back of the hole with duct tape before filling the hole.

10. Sand the surface level and remove saw marks from the teak surface. Use a belt sander or disc sander with 50-grit sandpaper for the initial sanding. A commercial floor sander works well for large decks. Finish with 80-grit then 120 grit sandpaper. The teak surface may be left natural or finished with a marine-grade teak oil, marine varnish or WEST SYSTEM 105 Resin/207 Hardener and a high quality two-part polyurethane varnish.

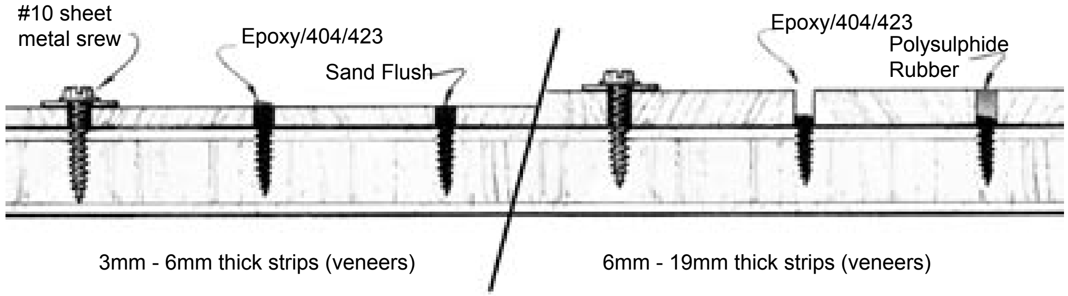


Figure 6-5 Teak veneer and teak plank installations cross section. Clamp strips in position with #10 sheet metal screws and washers. Sand the surface of veneers and planks after the epoxy cures thoroughly. Caulk the gap between planks after sanding.

6

6.2.2 Installing teak planks

An alternative method allows the use of teak strips up to 19 mm. thick. The top surface of a thick plank will expand and contract much more than the bottom, bonded surface of the plank because the moisture content varies more at the top surface. Because of this expansion differential, a more yielding material such as a flexible caulking compound is more appropriate for the upper portion of these joints. This method uses epoxy to bond planks to the substrate, but uses a flexible caulk to fill the gap between planks.

The steps for preparing and placing teak planks is the same as for installing veneers. Instead of filling the gap between strips with epoxy - as the planks are clamped down, clean excess epoxy out of the gap. Epoxy should fill no more than 1/3 of the height of the plank *(Figure 6-5, right).* After the epoxy has cured, remove the clamping screws and fill the fastener holes with epoxy as with the veneer method. Prepare the sides of the teak planks for bonding - they should be clean, dry and sanded. Mask off the gaps to make caulking neater. Fill the remaining gap between planks with a polysulphide flexible caulking compound. Sand the deck smooth after the caulking has cured.

Section Seven

7 Installing Hardware

Hardware attachment is a critical and often overlooked element in a boat's structure. Over time, high-loads and fatigue can cause hardware fasteners to loosen, not only reducing the load carrying ability of the hardware but also creating a source for leaks into the laminate. Leaks at hardware locations are the most common cause of skin delamination and core damage. Often, the first indication of loose hardware is an area of delaminated deck nearby. This section provides procedures for the repair of hardware installations with the objective of improving the load carrying ability of the hardware and eliminating hardware movement and leaks.

Standard hardware installations

Many factory hardware installations are inadequate for the loads on the hardware which is evident if the installation is loose or leaking. Hardware items attached with multiple fasteners must have all the mounting holes drilled precisely or the fasteners will not share the load equally. If not drilled accurately, the hole with the most highly-loaded fastener will elongate as the hardware is continually loaded. The hardware eventually becomes loose and the gap provides an entrance point for moisture.

The typical approach to this problem is to accept the hardware movement and to bed the hardware item in an elastic sealant material. A variety of sealants are used for this purpose, all with a very high elongation capability (usually 200% or greater) and good adhesive qualities. Unfortunately, high elongation means low load-carrying capability and the inability to prevent hardware from moving when subjected to any significant load. The sealant's job is limited to preventing water leakage. However, given sufficient time, the sealant material will break down with continual hardware movement, eventually allowing moisture to pass through into the laminate.

Improved hardware installations

To overcome the problems associated with hardware installations, Gougeon Brothers has developed an approach called hardware bonding. The principle of hardware bonding is to eliminate all hardware movement by distributing the high, single-point loads of the hardware to the largest possible area of deck or hull laminate. This is accomplished by bonding the contact surface of the hardware item to the laminate surface and all fasteners into the laminate to equalize their load carrying ability. Proper hardware bonding techniques can dramatically improve the load-carrying capacity over hardware installed by standard methods. Bonded hardware becomes an integral part of a deck or hull and can perform long term without the movement that causes water ingress.

In saltwater applications, experience has shown that bonded hardware and fasteners provide excellent resistance to corrosion attack. Where fasteners are vulnerable to flexure and saltwater attack (i.e., hollow or bridged traveller tracks, bonded U-bolts or solitary eyebolts) a small silicone sealant fillet covering the joint between the cured epoxy and the fastener will protect against moisture and salt intrusion. Of course, any exposed metal surface will be subject to the effects of saltwater corrosion and proper maintenance and cleaning procedures must be practised.

7.1.Bonding fasteners

Bonding fasteners with epoxy is the most important part of hardware bonding and improving the load bearing capacity. The techniques for bonding fasteners vary depending on the type of fastener, the substrate, the loads on the fastener and any existing damage to the substrate. This section describes simple fastener bonding methods for several situations. Section 7.2 describes more advanced fastener bonding techniques used in combination with hardware (base) bonding.

Basic fastener bonding

Normal vibration can cause hardware fasteners to loosen as fibres around the fasteners are fractured and compressed. A simple countermeasure is to:-

1. Remove the loose fastener.

2. Clean the threaded hole with a cotton swab wetted with WEST SYSTEM 850 solvent or acetone to remove any wax, oil or other contaminate.

3. Wet out the hole with epoxy using a syringe, pipe cleaner or cotton swab.

4. Reinstall the fastener. The fastener can be waxed for removal at a later date.

This technique will help retain the strength of the connection and prevent moisture penetration. Fastener connections that have lost strength or were under-engineered require a more extensive repair.

7.1.1 Bonding fasteners to non-cored panels

Hardware fasteners that are screwed into a non-cored panel without additional blocking rely entirely on the skin for holding power. If the fastener hole is stripped, the skin will provide little holding power for clamping or coping with the hardware loads.

Panels with back access

Blocking, bonded to the back of the panel, will not only provide the holding power for clamping, but will greatly increase the load carrying capability of the hardware. If access is available to the back, bond a plywood block to the inner side of the panel. The block should be thicker than the length of fasteners and cover an area beyond the perimeter of the fasteners. The larger the block, the greater the load transfer area. With the block in place, follow the basic fastener bonding procedure described above.

Panels without back access.

If a small fastener hole in a non-cored panel is stripped and there is no access to the back of the panel, the hole can be plugged to regain some holding power. This technique is not recommended for high load applications.

1. Enlarge the stripped holes to at least 6mm diameter or about twice the screw diameter.
2. Cut a cylinder or cube of flexible, open-cell foam with a cross section about twice the hole diameter.
3. Saturate the foam with epoxy and insert the foam into the hole. Work the foam through the hole with a small stick or nail. Allow the epoxy to cure thoroughly with most of the foam volume on the inside of the hole *(Figure 7-1).*

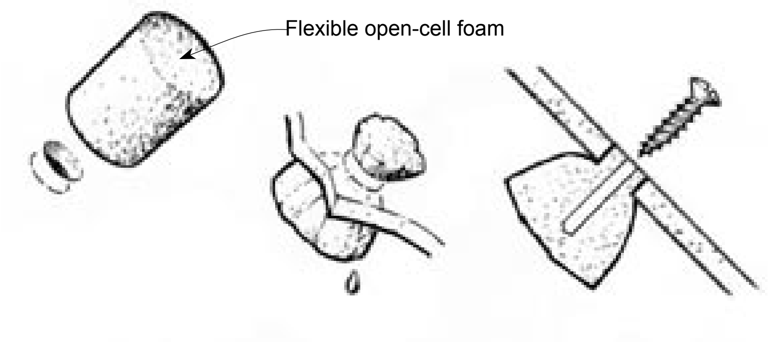


Figure 7-1 Work the foam through the hole with a small stick or nail and allow the epoxy to cure thoroughly. Grind the foam flush with the surface and redrill a pilot hole in the foam.

4. Grind the foam flush with the surface and redrill a pilot hole in the foam.
5. Wet out the pilot hole thoroughly with epoxy before reinstalling the hardware. The foam density, the depth of the plug, the amount of foam expansion in the back of the hole and the epoxy content of the foam all affect the holding power of the plug.

7.2.Bonding fasteners and hardware

Hardware can vary by size, type, number of fasteners and the size and direction of the load on the hardware. The panel may be cored or single skin, with (and often without) blocking behind it. The hardware fasteners may be through-bolted with washers or a backer plate, screwed to the skin and blocking or simply to a single skin.

The following procedures describe repairs for through-bolted fasteners and for fasteners that do not pass through the panel. These repairs combine techniques for a), advanced fastener bonding and b), bonding the hardware base. Through-bolted fasteners are used on larger or more heavily loaded hard-ware. Fasteners that are screwed to the skin and core or blocking carry less load and should be used for lighter hardware. If the hardware is screwed to a cored or non-cored panel, follow the procedure in Section 7.2.2.

Bonding to metal

WEST SYSTEM epoxy will produce excellent bonds to most metals and adhering the metal hardware base to the substrate provides additional load transfer capability to the substrate. However, careful preparation of the metal surface is essential for good adhesion. Metals must have all surface pre-treatments and contaminants e.g. rust, removed taking the surface back to the bare metal by abrading or grit blasting and then thoroughly degreasing the surface. The use of an adhesion promoter is advised on non-ferrous metal substrates. Please contact your nearest distributor, refer to the WEST SYSTEM USER MANUAL or contact our technical helpline, +44 (0)870 7701030.

7.2.1 Through-bolted fasteners–cored panels

Hardware bolted through a balsa or foam cored panel can be over-tightened or loaded sufficiently to crush the skins and core material. Replacing the core with an epoxy mixture in the immediate area of the hardware installation will allow the panel to withstand the compression loads exerted by the through-bolts and nuts of the fitting. Replacing a portion of the core with epoxy will provide better distrbution of the load and protect the core from moisture.

It is extremely useful to have an assistant on the opposite side of the panel to handle nuts, backing plates, washers and to control excess epoxy. If the hardware is through-bolted to a cored panel, prepare the panel and bond the hardware for increased load transfer as follows:

1. Remove the loose hardware and thoroughly clean dirt, paint, sealants, etc., from the hardware and the deck or hull surface. Wipe both surfaces with solvent to remove any residue or contaminants. Inspect for delamination or core damage and make the necessary core repairs before re-attaching hardware (see Section 5). Cover interior areas below the hardware location with plastic for protection from spills and dirt.

2. Clean out the fastener holes and remove a portion of the core around the hole. Redrill holes with an over-sized bit or enlarge holes with a round file to increase the bonding area. Drill through the outer skin and core only. Remove about 12mm. of core material around the hole with a bent nail or an Allen key chucked into a drill motor *(Figure 7-2).* The spinning nail or Allen key will pulverize the core material without damaging the skins, provided care is taken.

   Seal the underside of the holes with duct tape and fill the holes completely with an epoxy/404 or 406 filled mix thickened to the consistency of mayonnaise. Allow the mix to cure thoroughly.

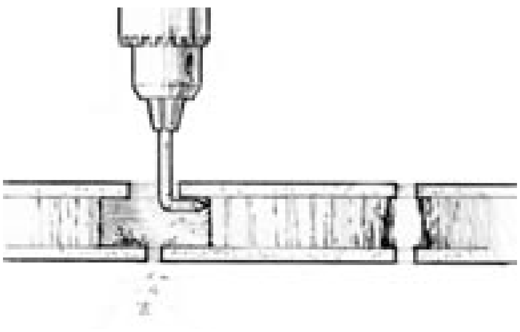


Figure 7-2 Remove about 12mm of core material around the hole with a bent nail or an Allen key chucked into a drill motor.

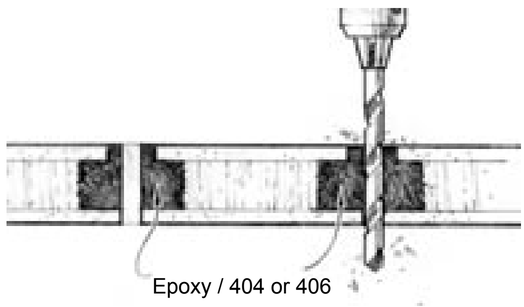


Figure 7-3 Redrill slightly oversized fastener holes through the cured epoxy

4. Temporarily place the hardware item in position and trace the outline of the base and the fastener holes with a pencil. Redrill slightly oversized fastener holes through the cured epoxy *(Figure 7-3).*

5. Mask off the outside of the marked area and cover the area beyond the tape with plastic sheeting for protection from spills.

6. With coarse sandpaper thoroughly abrade a), the surface within the masked area to provide a good mechanical key for bonding and, b), the contact surface of the hardware item to expose fresh metal. Mask off the area not to be bonded on the hardware item to prevent contamination. Re-tape the underside of the fastener holes to contain the epoxy.

7. With a resin/hardener mix, wet-out the deck surface, the inside of the fastener holes, the fastener threads and the abraded contact surface of the hardware. While the hardware contact surface is still wet, abrade the coated surface with coarse sandpaper, working the epoxy into the metal surface. This technique exposes fresh metal directly to the epoxy without any air contact and the possibility of oxidation. Insert the fasteners into the hardware.

8. Apply an epoxy/404 or 406 filled mix, thickened to a peanut butter consistency to one of the bonding surfaces – sufficient to bridge any gaps between the two surfaces. Apply the thickened mix to both the fastener threads and the inside of the fastener holes.

   Apply enough thickened epoxy to the contact surface of the backer plate to bridge gaps between the plate and the inner surface of the panel. Since the backer plate is held in compression, the bond to the inner side of the panel is not critical. However, filling the gaps between the surfaces with epoxy will provide uniform bearing against the panel.

9. Place the hardware item in position on the surface, carefully inserting the bolts through the fastener holes. Have an assistant on the inside of the panel cut an “x” through the tape over the fastener holes and guide the bolts through the slits in the tape. The tight fit of the tape around the bolts should keep most of the epoxy from squeezing out of the holes. Remove the tape after the bolts are in position.

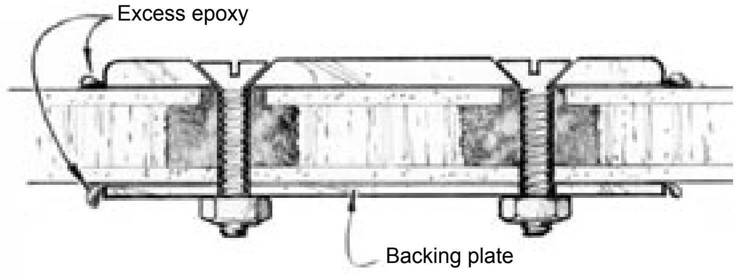


Figure 7-4 Tighten the nuts until epoxy begins to squeeze from the sides of hardware item and backing plate .

10. Place the backing plate over the bolts against the inner side of the panel. Tighten the nuts until epoxy begins to squeeze from the sides of the hardware item and backing plate *(Figure 7-4)*. Do not over-tighten the fasteners. Clean away any squeezed out epoxy mixture with a chisel-shaped mixing stick and remove the masking tape before the epoxy begins to gel. Allow the epoxy to cure at least 24 hours before applying load to the hardware. Allow more time in cool weather. Tighten the nuts completely after the epoxy cures thoroughly.

It may be advisable to re-bond the hardware using a backing plate rather than screwing into the laminate or through-bolting with washers. Often, adequate backing plates were not installed by the original manufacturer causing hardware items to over-stress a localized area. To increase the load carrying ability of the hardware and reduce stress concentrations, fabricate a plywood or metal backer and install as described above.

7.2.2 Screw type fasteners

If hardware is screwed to a cored or non-cored panel without additional blocking, the fasteners rely primarily on the skin for holding power. Bonding the fasteners in epoxy can greatly improve holding power by increasing the load transfer area around the fastener. If the hardware is screwed to a cored panel or a non-cored panel with blocking, prepare the panel and bond the hardware for increased load transfer as follows:

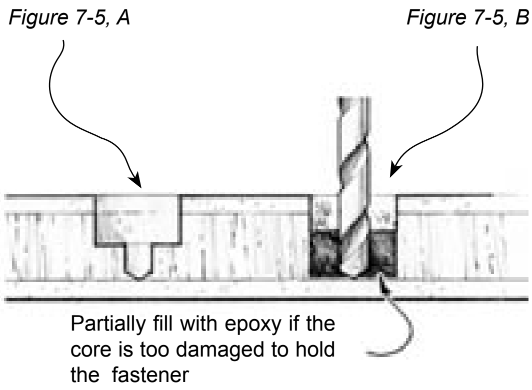
1. Remove the loose hardware and thoroughly clean dirt, paint, sealants, etc., from the hardware and the deck or hull surface. Wipe both surfaces with solvent to remove any residue or contaminants. If the panel is cored, inspect for delamination or core damage and make the necessary core repairs before re-attaching hardware (see Section 5).

2. Drill an oversized hole around each existing fastener hole to increase the skin and core area to which the epoxy can bond. This may be much larger than the fastener - twice the fastener diameter, for example. If the fastener still has holding power at the bottom of the hole, drill the oversized hole ⅔ to ¾ the depth of the fastener. This will leave material into which the bottom threads of the fastener can bite and provide some clamping pressure when the hardware is bonded in position *(Figure 7-5, A).*

In some cases (if the hardware is being mounted to a horizontal surface, for example) gravity or weight can provide enough clamping pressure to hold the hardware and the fasteners in position. In this case, drill the oversized hole to the full length of the fastener.

If it is necessary for the fasteners to provide clamping pressure (on vertical surfaces, for example) and the existing hole is stripped and has no holding power, drill the oversized hole to the full length of the fastener andfill the hole at least ¼ to ⅓ full with epoxy. If the surface is vertical or overhead, first wet out the hole with epoxy, then partially fill the hole with an epoxy/404 or 406 mixture thickened to a non-sagging consistency. After the epoxy has cured, drill a standard sized pilot hole in the epoxy to provide enough holding power for the fastener to clamp the hardware *(Figure 7-5, B)*. Place the hardware in position temporarily to locate the proper pilot hole locations.

If the loose hardware was mounted to a non-cored (single-skin) panel without blocking, see Section 7.1.1.



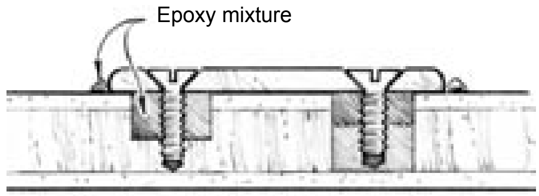


Figure 7-5 Drill an oversized hole around each existing fastener hole to increase the fastener's bonding area and a standard sized pilot hole at the bottom of the oversized hole to provide holding power for the fastener to clamp the hardware.

Figure 7-6 Tighten the fasteners until a small amount of epoxy squeezes out of the joint.

3. Temporarily place the hardware item in position and trace the outline of the base and the fastener holes with a pencil.

4. Mask off the outside of the marked area and cover the area beyond the tape with plastic sheeting for protection from spills.

5. With coarse sandpaper, thoroughly abrade a), the surface within the masked area to provide a good mechanical key for bonding and b), the contact surface of the hardware item to expose fresh metal. Mask off the area not to be bonded on the hardware item to prevent contamination.

6. With epoxy, wet-out the deck surface, the inside of the fastener holes, the fastener threads and the abraded contact surface of the hardware. While the hardware contact surface is still wet, abrade the coated surface with coarse sandpaper, working the epoxy into the metal surface. This technique exposes fresh metal directly to the epoxy without any air contact and the possibility of oxidation.

7. Apply an epoxy/404 or 406 filled mix, thickened to a peanut butter consistency, to one of the bonding surfaces. Apply enough of the mixture to bridge any gaps between the two surfaces. Inject or use a mixing stick to fill the fastener holes with the thickened mixture. Use sufficient mixture to ensure there will be no voids in the hole after inserting the fastener. Coat the fastener threads with the thickened mixture.

8. Place the hardware item in position. Insert and tighten the fasteners until a small amount of epoxy squeezes out of the joint. Do not over tighten (Figure 7-6).

If not relying on the screws to clamp the hardware in position, brace or weight the hardware until a small amount of epoxy squeezes from the joint. Ensure the fasteners are pushed tight against the hardware.

9. Clean the excess epoxy mixture that has squeezed out of the joint and remove the masking before the epoxy begins to gel.

10. Allow the epoxy to cure at least 24 hours before applying a load to the hardware. Allow more time in cool weather.

7.3 Casting epoxy bases for hardware

Occasionally, fittings must be set at specific angles to the hull or deck surfaces. Downrigger bases, lifeline stanchions, winches and turning blocks are all good examples. Traditionally, hand-carved, wedge-shaped shims have been used to achieve the proper angles with such fittings. Unfortunately, wooden shims require a great deal of time and carpentry skill. Hardware casting can save time and is easy to do - more importantly, it can result in a stronger, waterproof base. Cast the hardware at an angle to the surface as follows:

1. Prepare the bonding surfaces. Clean the substrate and hardware bonding surfaces with solvent to remove any contaminants. Abrade the deck with 50-grit sandpaper. Apply a release agent, such as an automobile wax or a non-stick cooking spray, to the base of the hardware.

2. Position the hardware. Mark the outline of the hardware and shim it to the desired angle. Mark the shim locations. Often one edge of the fitting will rest on the deck to become the zero point for the required angle.

3. With the exception of the shim locations, wet out the substrate (deck) surface using a resin/hardener mix.

4. Cast epoxy supports under the hardware (*Figure 7-7A*). Prepare a mix of epoxy/404 filler, thickened to a peanut butter consistency. Use a mixing stick to place three small "piles" of the mixture within the hardware outline, evenly spaced around the perimeter. Use sufficient epoxy to ensure there is good contact between the GRP surface and the base of the hardware when it is shimmed in the correct position. When cured, these epoxy "supports" will take the place of the temporary shims. Set the fitting in place with the temporary shims holding the hardware at the proper height and angle. The bottom of the hardware must contact all three epoxy supports. Allow the epoxy supports to cure thoroughly.

5. Tap the hardware with a mallet to break it loose and remove the temporary shims. Mask off the area around the fitting with duct tape and plastic in case of accidental epoxy spills.

6. Prepare the deck and hardware for casting the base. Wash and abrade the cured epoxy in the deck base area. Re-apply mould release to the hardware base. At this time, mask off areas of the hardware that do not need to come in contact with the epoxy. It may also be helpful to place small pieces of tape over the holes in the hardware item to prevent the epoxy mixture from oozing through them when the piece is re-positioned.

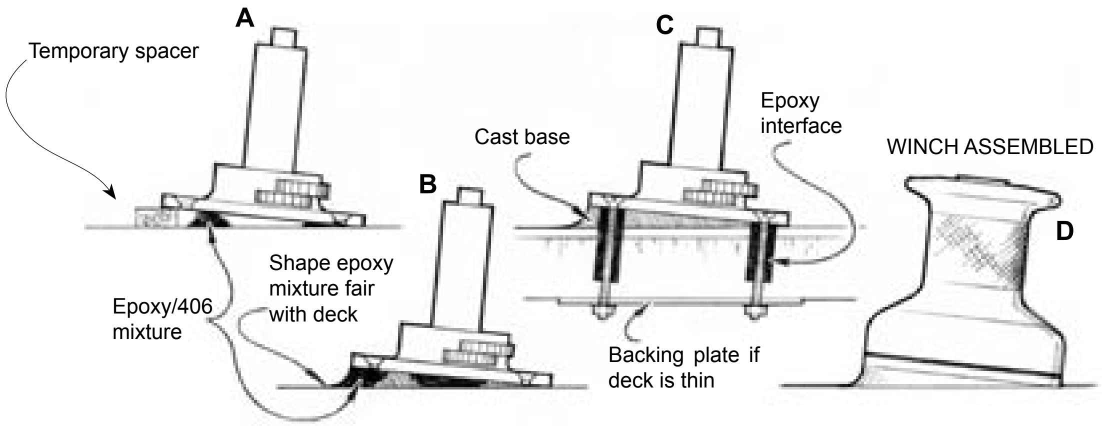


Figure 7-7 Hardware casting is a variation of hardware bonding for fittings that must be mounted at specific angles to hull or deck surfaces or mounted to curved or uneven surfaces.

7. Apply enough epoxy/404 mixture, thickened to a peanut butter consistency, to fill the entire base area. If the base to be cast is more than 12mm. thick, use 206 Slow Hardener to reduce the possibility of an exothermic heat build-up during the curing process. Build up the mixture slightly higher than the base supports, roughly forming the shape of the base. Fill all voids around the epoxy supports.

8. Reset the hardware in its proper location. Slowly press it into the correct position on top of the cast epoxy supports. Allow excess epoxy mix to squeeze out of the gap between the base of the hardware and the deck. The excess material should be sculptured to the desired shape *(Figure 7-7B)*. A standard fillet works well in this situation (Section 9.4.3). Add extra mixture if necessary for shaping or to fill any voids. Remove any excess epoxy before it cures. Allow the epoxy to cure thoroughly.

9. Tap the hardware with a mallet to remove it from the base. Clean the bottom of the hardware and the top of the cast base with solvent to remove the mould release. Abrade both bonding surfaces with 50-grit paper.

10. Sand the cast base to the desired final finish. Begin with 50-grit sandpaper or a file if the base is extremely irregular. Finish with 80-grit paper.

11. Bond the hardware to the cast base using the hardware bonding procedure in Section 7.1.1 *(Figure 7-7C)*. Drill oversized and standard pilot holes for the fasteners through the cast base. Allow to cure at least 24 hours before re-assembling or applying loads to the hardware. Allow more time in cool weather. Apply three coats of resin/hardener mixture to the base before final finishing.

7.4 Making fasteners removable

Because of the advantages gained, whenever possible, we recommend adhesive bonding of all hardware and fasteners rather than the use of removable fasteners. However, fatigue testing at Gougeon Brothers, Inc. has clearly shown that when fasteners (screws, bolts, threaded rods, etc.), are coated with a thin film of mould release before bonding there is only a 4-10% reduction in the overall fatigue strength of the fastener. This operation facilitates the easy removal of the fastener after the epoxy cures.

A thin film of mould release - paste wax, nonstick cooking spray, silicone spray or hair spray - will yield a more predictable performance than a thick film. While the reduction in strength of the fastener treated with mould release is slight, it should be taken into account when calculating hardware loads.

7.5 Removing bonded hardware

Occasionally it is necessary to remove bonded hardware items. At temperatures above 66°C, cured epoxy begins to lose its physical properties, the resin softens and the bonding strength is reduced considerably. This characteristic can be used to advantage when a piece of bonded hardware needs to be removed.

1. Remove all fasteners. If a release agent was used to bond the piece in place, the hardware will be removed without too much difficulty. If the fasteners were bonded, it will be necessary to apply heat to them, using a soldering iron. The epoxy around the fastener will soften enough to loosen the fastener when sufficient heat is conducted down the fastener.

2. Heat the fitting briefly with a propane torch. Protect the area around the fitting from heat damage by covering with water-soaked plywood. Allow the heat to conduct through the base of the hardware. A sharp rap with a mallet should be enough to dislodge the hardware. If the fitting fails to break loose the first time, don't force it!! Heat the fitting a second time with the torch and try again.

3. Replace the hardware by following the procedures in Section 7.1.1. Redrill the fastener holes in the existing epoxy as for a new installation.

Section Eight

8 Repairing Keels and Rudders

The thin foil shape that allows many keels and rudders to perform efficiently under water also makes them vulnerable to damage, especially from grounding. This section outlines procedures to repair common problems associated with keels and rudders.

Modern, self-righting sailboats have either internal or external ballast keels. An external ballast keel is a foil shaped iron or lead casting, bolted to the outside of the hull. The keel bolts pass through the skin into the hull structure. An internal ballast keel involves placing the lead casting into a moulded fibreglass hull cavity. The outer foil shape of the keel is an extension of the fibreglass hull surrounding a cast lead core.

8.1. Repairing internal ballast keels

Internally mounted ballast offers some structural advantages over external ballast, but presents some potential problems. When a boat with internal ballast is heavily grounded, the fibreglass skin takes the brunt of the collision. Unlike lead, the fibreglass laminate is not malleable, so repairs can be more complicated. Furthermore, due to the difficulty builders encounter in trying to mate the cast lead ballast with the interior of the laminated keel pocket, irregularities and voids often occur between the lead and the fibreglass laminate. If moisture finds its way into these voids, additional delamination can occur, particularly in areas where freezing temperatures can cause expanding ice to further wedge the skin from the ballast.

Although the fibreglass laminate of the keel is generally much thicker than the hull and deck laminate, the procedure for the skin repair is the same as described in Section 4. Repair grounding damage to an internally ballast keel as follows:

1. Remove all loose and damaged material to expose solid laminate in the damaged area and, if necessary, expose the lead core. Grind the edge of the laminate to a circular or oval shape and bevel the edge to a minimum 12-to-1 slope to provide a good bonding surface for the repair patch. Wear a dust mask!
2. Inspect for any voids and moisture between the laminate and the lead ballast. Tapping with a small hammer may help to reveal voids. Voids between the skin and the lead can be extensive and hold a lot of water. Often, water will drip or seep from a crack in the bottom of a keel for some time after a boat is pulled from the water. Drill 5mm holes through the laminate in areas of suspected voids. If water can be detected, drill a pattern of holes in that area to allow the void to dry. Apply moderate heat to the area to speed drying. Flushing the void with industrial methylated spirits can help to remove moisture.
3. After the laminate and voids have been thoroughly dried, fill all voids between the laminate and lead ballast with an epoxy/404 or 406 filler mixture, thickened to a ketchup consistency. Use an 807 Syringe, with the tip cut back to fit the 5mm hole and inject the mixture under pressure into the void *(Figure 8-1)*. Fill the remaining holes in the laminate with an epoxy/404 or 406 filled mix, thickened to a mayonnaise consistency. Allow the epoxy to cure thoroughly. If voids are extensive, use a clean, dry caulking tube (with the appropriate sized drilled hole in the laminate) to fill the voids. If necessary, use multiple applications to avoid excessive exothermic heat build-up when filling large volume voids.

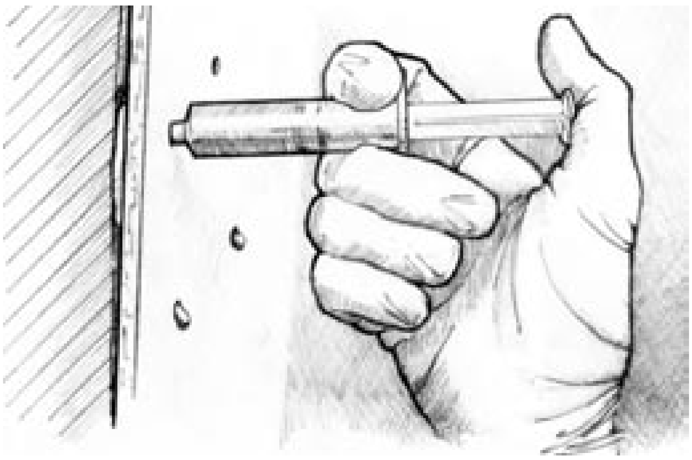


Figure 8-1 Drill 5mm holes through the laminate, in areas of suspected voids. Inject the mixture into the voids.

4. Repair the lead surface if the impact was severe enough to dent or gouge the lead. Follow the procedures outlined below.

Prepare an epoxy/406 filled mix, thickened to a mayonnaise consistency. Apply this epoxy to the remaining voids in the damaged lead ballast and spread a thin coating to the bevelled bonding surface of the laminate.

5. Before the thickened epoxy layer begins to gel, apply a repair patch to the repair area following the procedure in Section 4.3. Allow the patch to cure thoroughly. Abrade and fair the patch and apply several coats of WEST SYSTEM epoxy to the area. Wet sand the final coat after it has cured thoroughly and apply an antifouling paint in the manner prescribed by the manufacturer

8.2. Repairing external ballast keels

One of the advantages of using lead for an external keel, in addition to its high density, is its malleability. The lead will deform and thereby absorb some of the energy incurred upon impact or grounding. The ability to deform reduces the intensity of shock loads to the hull and can prevent serious structural damage to a hull. However, the deformation of the lead keel can measurably affect overall sailing performance but, fortunately, repairing this type of damage is a relatively modest project. To repair an external ballast lead keel, deformed from impact or grounding, proceed as under:

1. Ensure the damaged area of the keel is accessible when the boat is hauled from the water. Dry the keel thoroughly - a heat gun or heat lamp will speed drying.

2. Remove any loose chips of lead and/or filling materials. Scrub the repair area with a wire brush to remove any remaining surface contamination and to expose fresh lead. Wear a dust mask!

3. Forge displaced lead toward voids with a ball peen hammer. As the lead is deformed from an impact, it is common to find a bulge on one or both sides of a dent or gouge. Use repeated light taps to work the lead back to its original shape *(Figure 8-2)* - heavy blows will shear sections of lead. With experience, it will be possible to gauge the amount of force to use and how much lead can be moved before shearing occurs. Some alloys are more malleable and easier to forge than others.

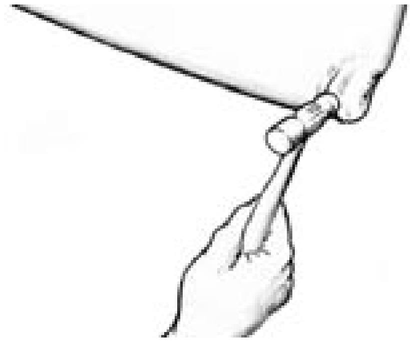


Figure 8-2 Use a ball peen hammer, with repeated light taps to work the lead bulge back to its original shape.

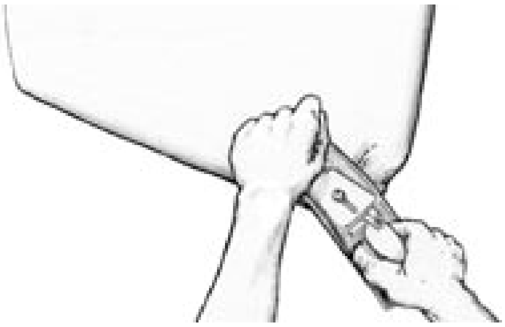


Figure 8-3 Plane or file the remainder of the bulge flush after you have forged as much as is practical.

4. Plane or file the remainder of the bulge flush after forging as much as is practical *(Figure 8-3)*. For small areas, a body file works well. When greater amounts of lead must be removed, a woodworking plane is the best tool for the job. Apply a liberal coat of petroleum jelly to the lead surface. Adjust the blade of the plane for a medium cut and ensure the blade is sharp.

Thoroughly clean the lead of any remaining petroleum jelly with solvent after the bulge has been faired. When the solvent has evaporated, scrub the surface vigorously with a wire brush to expose fresh lead.

5. Wet out the repair surface with epoxy. Brush the still-wet surface with a wire brush to expose fresh lead directly to the epoxy, thereby avoiding any air contact and the possibility of oxidation.

6. Fill the voids with an epoxy/407 low-density filler mix, thickened to a peanut butter consistency. Trowel the mixture into the voids and shape it to match the form of the keel (*Figure 8-4*). If the volume of a void is larger than a golf ball, apply the mix in several applications to avoid excessive exothermic heat build-up. Allow the epoxy to cure thoroughly.

7. Abrade the cured epoxy to the shape of the keel with a 50-grit sanding block. Fill any remaining voids with the epoxy/407 filler mix thickened to a peanut butter consistency. Sand again when cured and coat the entire repair area with three coats of WEST SYSTEM epoxy. After the final coat has thoroughly cured, abrade the surface and, following the manufacturers instruction, apply antifouling paint.

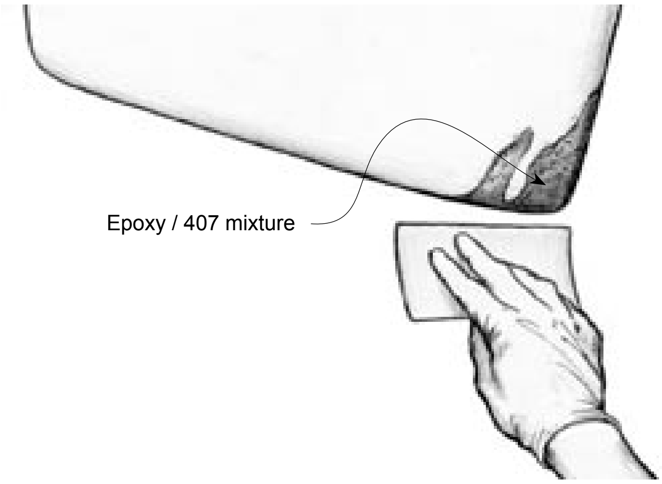


Figure 8-4 Trowel the epoxy/407 mixture into the voids and shape it to match the form of the keel.

8.3. Templating keels and rudders

Few production boats achieve the underwater shape intended by the designer but for the majority of boats (and the owners) the difference is marginal. For those interested in obtaining a little more performance from their boat, most racing classes will allow the skipper/owner to fair the hull closer to the original specification without these changes being considered "modifications".

Profile shape and section offsets are usually available from either the class association or the designer. If foil profiles are not available, you may design your own foil shape. The object of this procedure is to reshape the keel or rudder to more closely match the designed foil shape. Although the procedure describes keel templating, the same procedure applies to rudders:

1. Obtain the profiles for three locations on the keel - the root (top of the keel near the hull attachment point), the midpoint and the tip of the keel. Enlarge the profiles as necessary to full size and transfer the profiles to 12mm. plywood *(Figure 8-5).* Cut out the three templates with a band saw or sabre saw. Abrade the edges of the foil shape carefully to eliminate any bumps or unfairness. Mark the centreline of the keel on each end of the template. Seal the profile edge of the templates with a coat of epoxy and sand them smooth after the epoxy cures.

2. Prepare the keel for bonding by removing all antifouling paint. Wire brush the entire surface of external keels to remove any contamination and to expose fresh iron or lead. (Wear an appropriate dust mask, especially when abrading or wire brushing lead). Sand the surface of internal keels (or hulls) to remove loose fillers and gelcoat and expose solid fibreglass laminate. Dry the keel using a hot air gun, hair dryer or heat lamp.

   Locate and mark the centreline on the leading edge and, if necessary, the trailing edge of the keel. Mark the template locations on both sides of the keel. Check the profile of the keel with the templates to locate any high spots and to gauge how much fairing compound to apply to the low areas. Grind down or plane off excessive high spots.

3. With epoxy, wet out 50-75mm wide strips at the template locations. If working with a lead or metal keel, wire brush the surface while the epoxy is still wet to improve the bond. Allow the epoxy to gel.

8

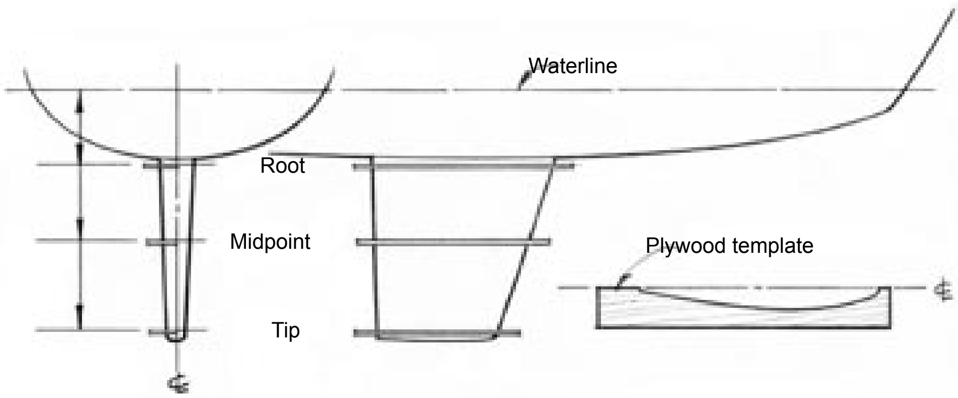


Figure 8-5 Transfer the profiles from the root, midpoint and tip of the keel to 12mm plywood.

4. To the surface at each template location, apply a 25-50mm. wide ridge of epoxy/407 or 410 filled mix, thickened to a stiff peanut butter consistency. Use a plastic squeegee to trowel on the fairing mix so that it

is slightly thicker than the required finished profile. A squeegee notched to the shape of the ridge is helpful to shape the mixture.

5. Cover the ridges with strips of 775 Release Fabric to stop the fairing mix sticking to the template. Lightly press the release fabric to the ridge but do not flatten the ridge.

6. Push the templates into the soft epoxy mix to make an impression of the exact keel profile at each template location. To gauge the depth of the impression (height of the profile), push the template into the mix until the centrelines marked on the template match the centrelines marked on the leading and trailing edges of the keel *(Figure 8-6)*. If an area of the ridge is too low to contact the template when it is properly aligned, squeeze the material under the release fabric upward so it comes in contact with the template. Carefully remove the template without disturbing the profile impression, leave the release fabric in place and allow the epoxy to thoroughly cure.

7. Remove the release fabric and mark the centre of the template impression with a permanent felt tipped marker to act as a sanding guide. Sand the ridges on each side of the template impression flush with the profile. Avoid sanding into the profile. This procedure should leave smooth bands of fairing compound at the root, midpoint and tip of the keel that will be used as profile guides to accurately apply the remaining fairing material. Use the templates to check the profiles and sand or add filler to the profile as necessary to match the template.

8. Wet out the surface between the guides with epoxy and allow the coating to gel.

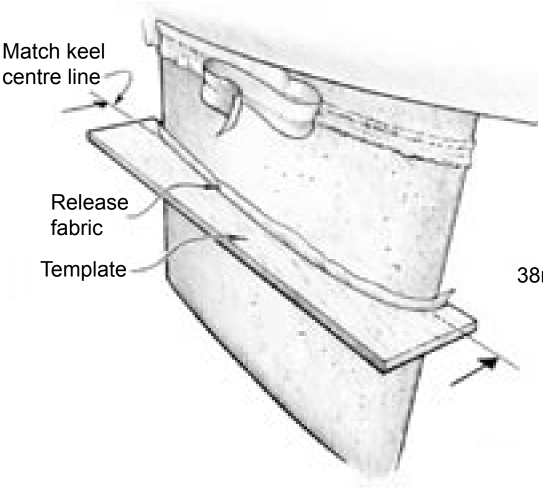


Figure 8-6 Make an impression of each template profile in the epoxy mixture. Sand the excess mixture flush with the profile after the mixture has cured.

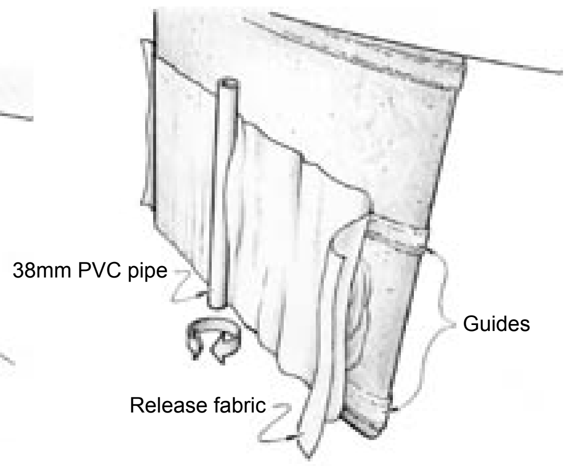


Figure 8-7 Using the cast template profiles as guides, drag a batten across the profiles to level the fresh epoxy mixture flush with the three profiles.

9. Apply a layer of the epoxy/407 or 410 fairing compound to fill the area between two of the profile guides. With a plastic squeegee or custom spreader, apply and smooth the epoxy slightly higher than the profile guides.

10. Lay a precut piece of release fabric over the fairing compound - the fabric should be large enough to cover the entire area from guide to guide. Cut a length of PVC pipe (diameter between 36-40mm) to span two of the guides and with this "tool",shape the fairing mix flush with the guides. Beginning in the middle of the foil, roll the pipe back and forth as you would a rolling pin, forcing the fairing compound under the release fabric toward the leading and trailing edges of the foil *(Figure 8-7).* Adjust the angle of the pipe as you approach the edges of the foil to finish with the pipe parallel to the leading and trailing edges. With the correct amount of fairing compound, a small amount of excess will squeeze from the leading and trailing edge. To give adequate working time in warmer temperatures, use 206 or 209 Hardener. Allow the fairing mix to cure thoroughly.

11. Remove the release fabric. Repeat the process on the remaining areas. Fill any remaining low areas using the same procedure after the fairing compound has cured but remember to abrade and wet out the surface before applying the fairing mix . Repeat as necessary until the shape and fairness of the surface is precisely as required.

12. Abrade the cured surface as necessary. Apply an epoxy barrier coat and finish as described in Section 2.3.

8.4. Repairing worn rudder bearings

Common wear points on sailboats with spade-type rudders are the bearings that support the rudder shaft. Worn bearings can result in sloppy steering and an irritating thump as the rudder shaft flops from side to side in the enlarged bearing. Worn bearings can also detract from the precise sense of feel, especially important to a helmsman if the boat is raced.

Most stock rudders simply bear on the inside of the fibreglass housing in which the metal rudder shaft turns *(Figure 8-8).* Some builders use Delrin® plastic or a similar material as an insert for lower friction and better wearing performance. But the high loads exerted by the rudder eventually wear the bearings. This section describes how to restore tight steering control by injecting a new, long-wearing epoxy/graphite bearing surface around the rudder shaft.

The amount of play in the rudder bearings is most easily detected when the boat is out of the water. Hold the bottom of the rudder blade and move it side to side. Look for excess lateral motion of the rudder blade and listen for the thump of the shaft hitting the opposite side of the bearing as the rudder is moved. Careful observation will show if the movement is coming from the lower, upper or both bearing points.

1. Lower the rudder from the boat and wipe the shaft with solvent to remove grease and oil. Inspect the shaft for roundness and straightness. IMPORTANT! If the shaft is not round or bent, you may need to take it to a machine shop to make it true. Look for burrs, rough spots or grooves. Abrade any burrs or other rough spots on the shaft with emery cloth or very fine sandpaper. The smoother the surface of the shaft, the less it will abrade the bearing surface. If scores or similar flaws are too deep to remove by sanding, fill them with an epoxy/406 Colloidal Silica mix following the procedures for bonding to metal as discussed in Section 7.

2. Wipe the upper and lower bearing surfaces with WEST SYSTEM 850 solvent or acetone to remove all traces of grease or oil. Sand the bearing surfaces with coarse sandpaper. Drill three, equally spaced 5mm diameter holes through the shaft housing *(Figure 8-9)* at the level of the bearing surfaces. These “ports” will permit injection of the thickened epoxy to form the new bearing surfaces. Cut the end of an 807 Syringe to wedge tightly into the 5mm holes. This will allow the thickened mixture to be injected under pressure into the gap between the shaft and the bearing surface.

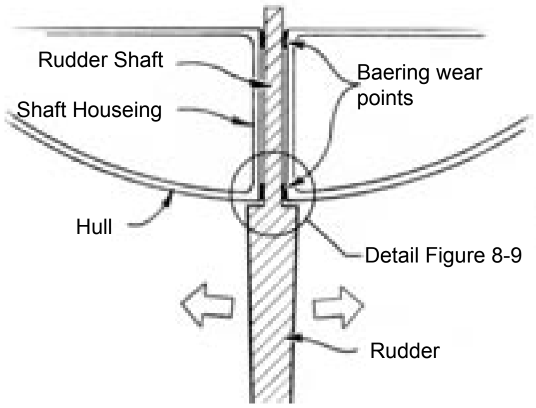


Figure 8-8 Most stock rudders simply bear on the inside of a fibreglass housing and the high loads exerted by the rudder eventually wear the bearing surfaces.

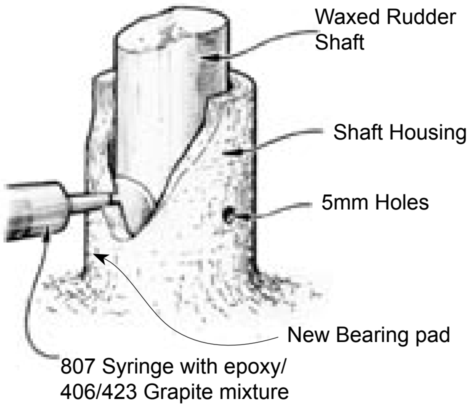


Figure 8-9 Inject enough of epoxy/406/423 mixture through the drilled 5mm. diameter ports to form a 20-25mm. diameter pad between the shaft and housing at each port.

3. Wax the shaft surface with three coats of automotive paste wax to act as a release agent and prevent the shaft from bonding to the new bearing surface.

Replace the rudder in the boat and sight the rudder to ensure it is vertical. The keel will serve as a good reference point. Brace the rudder to prevent movement.

4. Prepare a bearing mixture of epoxy using a filler blend of 50% 406 Colloidal Silica and 50% 423 Graphite Powder. The epoxy/406/423 mix should have the consistency of mayonnaise to prevent running or sagging. Load the mixture into the syringe.

5. Inject enough material through each of the three drilled ports to create a 20-25mm diameter pad between the shaft and the housing at each port. Take care not to move the rudder shaft until the mixture cures thoroughly.

6. Break the shaft free by twisting the rudder blade. If the cured bearing pads are too tight after rotating the rudder briefly (which is not typical), remove the rudder and apply a buffing compound to the rudder shaft. Re-install the rudder and work it back and forth until it turns freely in the new bearings.

Lower the rudder once more and thoroughly clean any remaining mould release or buffing compound from the shaft and bearing surfaces. Spread a thin layer of waterproof grease on the shaft and re-install the rudder.

This technique is useful for restoring a variety of bearing surfaces. The epoxy/406/423 blended silica/graphite mix provides a hard, low-friction bearing surface. The durability of the bearing depends a great deal on the smoothness of the surface sliding against it.

Section Nine

9 Using WEST SYSTEM Epoxy

This section is designed to help identify, understand and safely handle WEST SYSTEM epoxy products and to provide the basic techniques used in most repair and building operations. Please refer to the WEST SYSTEM *Technical Manual* for more complete product information.

9.1 Epoxy safety

Epoxies are safe when handled properly but the primary hazard associated with epoxy involves skin contact. WEST SYSTEM Resin may cause moderate skin irritation. WEST SYSTEM Hardeners are corrosive and may cause severe skin irritation but this irritancy is greatly reduced when they are mixed and cured in the correct ratio with 105 Resin. Nevertheless, to use WEST SYSTEM epoxies safely, you must understand their hazards and take adequate precautions to avoid them. Refer to product labels or Material Safety Data Sheets for specific product warnings and safety information.

The hazards associated with resins and hardeners also apply to the sanding dust from epoxy. We recommend that the following safeguards are strictly observed.

9.1.1. Precautions

1. Avoid contact with resin, hardeners, mixed epoxy and sanding dust from epoxy. Wear protective gloves and clothing when handling WEST SYSTEM materials. WEST SYSTEM 831 Barrier Cream provides additional protection for sensitive skin, allergies or when there is a great deal of epoxy work to be done. DO NOT use solvents to remove epoxy from the skin. Immediately after skin contact with resin, hardeners, sanding dust from epoxy and/or solvents use WEST SYSTEM 820 Resin Removing Cream for the initial clean-up, followed by a good wash with soap and water.
2. If a skin rash develops while working with epoxy, stop using the product until the rash disappears, usually three or four days later. After this period and once returning to work, improve safety precautions and prevent any further skin contact with resin, hardeners and mixed epoxy, as well as their fumes. If problems persist, consult a doctor.
3. Protect your eyes from contact with resin, hardeners, mixed epoxy, and sanding dust by wearing appropriate eye protection. If contact occurs, immediately flush the eyes with copious quantities of water under low pressure for 15 minutes. If discomfort persists, seek medical attention.
4. Avoid breathing concentrated vapours and sanding dust. Use epoxy only in areas with good ventilation. In close quarters, such as boat interiors, take special care to ventilate the area and provide a supply of fresh air. Wear a WEST SYSTEM 839 Dust Mask when sanding epoxy, taking extra care if it has cured for less than a week.
5. Avoid ingestion. Wash thoroughly after handling epoxy. AVOID EATING OR SMOKING WHEN USING EPOXIES.
6. Use extreme care with pots of mixed epoxy. Mixed epoxy generates heat, especially when a large quantity is confined in a container offering a small surface area. Place pots of mixed epoxy in a safe and ventilated area, away from workers and combustible materials. DO NOT throw epoxy waste into a bin before it has solidified and cooled.
7. KEEP RESINS, HARDENERS, FILLERS AND SOLVENTS OUT OF REACH OF CHILDREN.

9

For additional safety information or data, please contact your nearest distributor or:

WESSEX RESINS & ADHESIVES LIMITED

Cupernham House, Cupernham Lane, Romsey, Hampshire SO51 7LF.

Technical helpline +44 (0)870 7701030: techinfo@wessex-resins.com

Web Site: www.wessex-resins.com

9.1.2. Clean-up

Contain large spills with sand, clay or other inert absorbent material. Use a scraper to contain small spills and collect as much as possible. Follow up with absorbent towels

Clean resin or mixed epoxy residue with WEST SYSTEM 850 Cleaning Solvent or acetone. Follow all safety warnings on solvent containers. Clean hardener residue with warm soapy water.

Dispose of resin, hardener and empty containers safely. DO NOT dispose of either resin or hardener in a liquid state. Waste resin and hardener should be mixed and cured (in small quantities) to a non-hazardous inert solid. Dispose of the containers and any solidified mass when cooled as specified by local regulations.

9.2 Epoxy products

This section provides a short description of WEST SYSTEM resin, hardeners and fillers. Refer to the current *Technical Manual & Product Guide* for complete information on all WEST SYSTEM products

9.2.1 Resin and hardeners

Resin

105 Resin - A clear, light-amber, low-viscosity epoxy resin that can be cured in a wide temperature range to yield a high-strength, rigid solid which has excellent cohesive properties and is an outstanding bonding adhesive and moisture vapour barrier. Two types of WEST SYSTEM hardeners are formulated for use with 105 Resin. Hardeners 205 and 206 require a mixing ratio of 5 parts by weight of resin to 1 part by weight of hardener. Hardeners 207 and 209 require a 3-to-1 mixing ratio by weight, resin : hardener..

Hardeners

205 Standard Hardener - Used in the majority of situations for general bonding, barrier coating and fabric application. Formulated to cure at lower temperatures and to produce a rapid cure that develops its physical properties quickly at room temperature.

206 Slow Hardener – Again used for general bonding, barrier coating and fabric application. Formulated for a longer working and cure time or to provide adequate working time at higher temperatures.

<u>Note</u>: 205 Standard and 206 Slow Hardeners may be blended for intermediate cure times. However, it is essential to maintain the proper 5 part resin to 1 part hardener ratio.

207 Special Coating Hardener - Formulated specifically for coating and fabric application where a.clear finish is desired. Hardener 207 contains a UV stabilisation additive, but still requires long term UV protection with paint or varnish. The 105/207 mix provides good physical properties for bonding, but it is more difficult to thicken and less cost effective for this purpose than 205 or 206 hardener. 207 is a light amber colour that, when mixed with 105 resin, will tint wood slightly darker, giving a "warmer" appearance, similar to varnish. Mix ratio - 3 parts by weight of resin :1 part by weight of hardener.

209 Extra Slow Hardener - Used for general bonding, coating and fabric application when longer working times are required and in extremely warm and/or humid conditions. Provides approximately twice the pot life and working time as 206 Slow Hardener and adequate pot life up to 43°C. A mix ratio of 3:1 by weight, resin: hardener.

Hardener Selection Guide

HARDENER	RESIN/HARDENER USE	HARDENER TEMPERATURE RANGE (°C)	CURE SPEEDS at room tempurature*			MINI PUMP REQUIRED
		Room Temp 5° 10° 15° 20° 25° 30° 35°	Gel Time at (25°C) (60g mass)	Open Time at (20°C) (Thin film)	Cure to solid at (20°C) (Thin film)	
205	General bonding and coating		10-15 mins	60-70 mins	6-8 hours	301 A,B or C
206	General bonding and coating		20-25 min	90-110 mins	10-15 hours	301 A,B or C
207	Clear coating		18-23 mins	85-110 mins	10-15 hours	303 A,B or C
209	General bonding and coating		48-56 mins	200-260 mins	10-15 hours	303 A,B or C

Figure 9-1. Select a hardener for the intended use and for the cure speed best suited to the job in hand at the current ambient temperatures.

9.2.2 Fillers

Throughout this manual, we will refer to epoxy or resin/hardener mix, meaning mixed resin and hardener without fillers added; reference to thickened mix or thickened epoxy, meaning resin/hardener with at least one of six fillers added.

Fillers are used to thicken the epoxy for specific applications. They are categorized as either a), **Adhesive Fillers** - used for structural bonding or gluing and gap-filling; or b), **Fairing Fillers** - used for cosmetic surface filling. Although each filler has unique handling and cured physical characteristics that make it more suitable for some jobs than others *(Figure 9-2*), for most bonding applications any of the adhesive fillers can be used and for most surface filling, either of the fairing fillers can be used. Fillers may also be blended for intermediate characteristics.

Adhesive fillers

403 Microfibres - A fine fibre blend used to thicken epoxy for general bonding and gap filling. Epoxy/403 mixes have superior gap-filling qualities and good strength for most bonding applications while retaining wetting and penetrating capabilities. Micofibres help to ensure 100% bonding within joints by bridging gaps and works especially well with porous woods. Cures to an off-white colour.

404 High-Density Filler – Developed for maximum physical properties in hardware fastener bonding and applications where high-cyclic loads are anticipated. Can also be used for gap-filling where maximum strength is necessary. Cures to an off-white colour.

405 Filleting Blend - For use in bonding and filleting on naturally finished wood projects. A strong, wood-toned filler that mixes easily and spreads smoothly. Cures to a brown colour and can be used to tint other fillers.

406 Colloidal Silica – An extremely fine filler used for gap-filling, high-strength bonds and fillets. It is perhaps the most practical and versatile filler and is the most frequently used. Can be used alone or mixed with other fillers to improve workability and smoothness. Cures to an off-white colour.

Fairing fillers

407 Low Density Filler – A blended microballoon-based filler used to make a fairing compound that is easy to sand or carve while still being reasonably strong on a strength-to-weight basis. Cures to a reddish-brown colour.

410 Microlight™ - The ideal low-density filler for creating a light-weight, easily-worked fairing compound. Filler 410 handles well, mixes with greater ease than 407, is considerably easier to sand when cured and is more economical for large fairing jobs. Overcoating with dark coloured paints is not recommended or on surfaces subject to high temperatures. Cures to a light tan colour.

*See Appendix A for additional filler selection informatio*n.

Filler Selection Guide

USES **Resin/Hardener mixture thickness with a Filler** Use description - desired characteristics	ADHESIVE FILLERS High density / High strength ↔				FAIRING FILLERS Lowest density / Easiest sanding	
	404	**406**	**403**	**405**	**407**	**410**
Bonding Hardware - Increased fastener interface and hardware load capability - maximum strength	★★★★	★★★	★★★	★★		
General Bonding - Join parts with epoxy thickened to create a structural gap filler - strength/ gap filling	★★★	★★★	★★★	★★	★	
Bonding with Fillets - Increase joint bonding area and create a structural brace between parts - smoothness/strength	★★	★★★★	★★	★★★	★★★	
Laminating - bond layers of wood strips, veneers, planks, sheets and cores - gap filling strength	★★	★★★	★★★★	★★	★★	
Fairing - Fill low areas and voids with an easily shaped and sanded surface filler/fairing compound - sandability/gap filling					★★★	★★★★

Figure 9-2. Suitability of WEST SYSTEM fillers for various applications

9.3 Handling epoxy

This section explains the fundamentals of epoxy curing and the steps for proper dispensing, mixing, and adding fillers to ensure that every batch of epoxy cures to a useful high-strength solid.

9.3.1 Understanding the cure stages of epoxy

Mixing epoxy resin and hardener begins a chemical reaction that transforms the combined liquid ingredients to a solid. The time it takes for this transformation is the cure time. As it cures the epoxy passes from the liquid state, through a gel state, before it reaches a solid state *(Figure 9-3).*

1. Liquid - Open time

Open time (also working time or wet lay-up time) is the period after mixing that the resin/hardener mix remains a liquid and is workable and suitable for application. All assembly and clamping should take place during the open time to ensure a dependable bond.

2. Gel - Initial cure phase

After the liquid state, the epoxy mix passes into the initial cure phase (also called the green stage) when it begins to *gel*. The epoxy is no longer workable and will progress from a tacky, gel consistency to the firmness of hard rubber but it is possible to dent it with your thumb nail. The mix will become tack free about midway through the initial cure phase. While it is still tacky, a new application of epoxy will still chemically link with it, so it is possible to bond to this surface or apply another coat without sanding. However, this ability diminishes as the mix approaches the final cure phase.

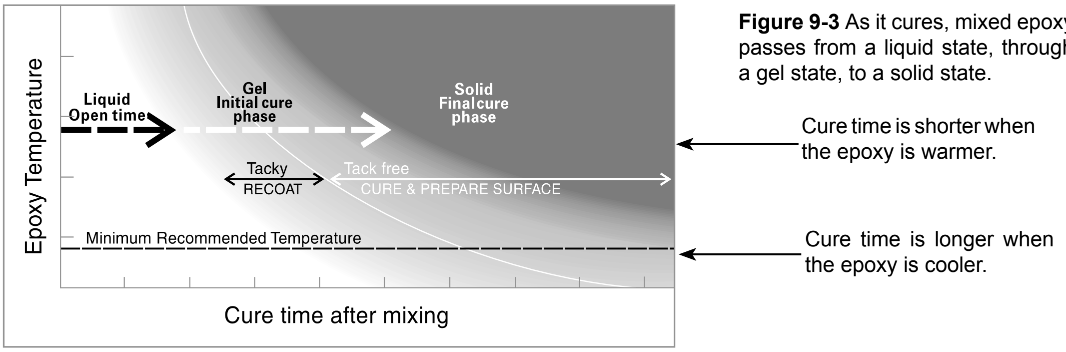


Figure 9-3 As it cures, mixed epoxy passes from a liquid state, through a gel state, to a solid state.

3. Solid - Final cure phase

The mixed epoxy finally cures to a solid state and can be dry sanded and shaped. It should not be possible to dent it with a thumbnail. At this point the epoxy has reached about 90% of its ultimate strength, so clamps can be removed. It will continue to cure over the next several days at room temperature.

A new application of epoxy will no longer chemically link to it, so the surface of the epoxy must be properly prepared and sanded before recoating to achieve a good mechanical, secondary bond. See *Surface Preparation* 9.4.1.

9.3.2 Understanding and controlling cure time

Open time and cure time govern much of the activity of building and repairing with epoxy. Open time dictates the time available for mixing, application, smoothing, shaping, assembly and clamping. Cure time dictates the period before a), removing clamps b), abrading or c), the next step in the project can be undertaken. Two factors determine the open time of an epoxy mix and overall cure time - **hardener cure speed and epoxy temperature.**

Hardener speed

Each hardener has an ideal temperature cure range *(Figure 9-1*). At any given temperature, each resin/hardener combination will go through the same cure stages but at different rates. Select the hardener that gives you adequate working time for the job in hand at the temperature and conditions under which the work is to be done. The product guide and container labels describe hardener pot lives and cure times.

Pot life is a term used to compare the cure speeds of different hardeners. It is the amount of time a specific mass of mixed resin and hardener remains a liquid at a specific temperature. e.g. a 100g mass of an epoxy mix in a standard container at 25°C is a routine quality control test procedure to record the "pot life".

Because pot life is a measure of the speed of cure of a specific mass (volume) of epoxy rather than a thin film, the pot life of a resin/hardener mix is much shorter than its open time. (*See Figure 9-1*)

9

Epoxy temperature

The warmer the temperature, the faster an epoxy mix will cure. *(Figure 9-3)*. The temperature at which epoxy cures is determined by the ambient temperature plus the exothermic heat generated by its cure.

Ambient temperature is the temperature of the air and/or the material in contact with the epoxy. Epoxy cures faster when the air temperature is warmer.

Exothermic heat is produced by the chemical reaction that cures epoxy. The amount of heat produced depends on the thickness or exposed surface area of mixed epoxy. In a thicker mass, more heat is retained, causing a faster reaction and more heat for example, a contained mass of, say, 200g in a plastic cup can generate sufficient heat to melt the cup. However, if the same quantity is spread into a thin layer, exothermic heat is dissipated and the cure time of the epoxy is determined by the ambient temperature. The thinner the layer of curing epoxy, the less it is affected by exothermic heat and the slower it cures.

Controlling cure time

In warm conditions use a slower hardener, if possible. Mix small batches that can be used quickly or pour the epoxy mix into a container with greater surface area e.g. a roller pan, thus allowing exothermic heat to dissipate and thereby extending the open time. The sooner the mix is transferred or applied (after thorough mixing), the longer the open time will be for coating, lay-up or assembly.

In cool conditions use a faster hardener or warm the mix to raise the epoxy temperature above the minimum recommended application temperature of the resin/hardener mix in use. Use a hot air gun, heat lamp or other heat source to warm the resin and hardener before mixing or after the epoxy is applied. At room temperature, additional heat can be useful when a quicker cure is desired.

CAUTION! Warming a resin/hardener mix will lower the viscosity, allowing the epoxy to run or sag more easily on vertical surfaces. However, heating epoxy applied to a porous substrate (soft wood or low density core material) may cause the substrate to "out-gas" and form bubbles in the epoxy coating. To avoid outgassing, wait until the coating has gelled before warming it. Never heat mixed epoxy in a liquid state over 49°C.

Regardless of the steps taken to control the cure time, thorough planning of the application and assembly will allow maximum use of the open time and cure time of the epoxy mix.

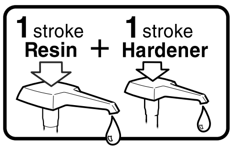
9.3.3 Dispensing and mixing

Careful measuring of the resin and hardener and thorough mixing of the blended components are essential for a proper cure. Whether the resin/hardener mix is applied as a coating or modified with fillers or additives, observing the following procedures will ensure a controlled and thorough chemical transition to a high-strength epoxy solid.

Dispense the proper proportions of resin and hardener into a clean plastic, metal or wax-free paper container. Do not use glass or foam containers because of the potential hazard of exothermic heat build-up. DO NOT attempt to alter the cure time by altering the mix ratio. An accurate ratio is essential for a proper cure and full development of physical properties.

Dispensing with Mini pumps

Most problems related to curing of epoxy can be traced to the wrong ratio of resin and hardener. To simplify metering, use WEST SYSTEM Mini Pumps to dispense the resin and hardener. Mini Pumps mount onto the resin and hardener containers and are calibrated to deliver the correct working ratio of resin to hardener.



For one full pump stroke of resin use one full pump stroke of hardener. Depress each pump head fully and allow the head to return completely to the top before beginning the next stroke *(Figure 9-4).* Partial strokes will give the wrong ratio. Read the instructions before using the pumps and verify the correct ratio before using the first mix on a project. Re-check the ratio whenever curing problems are experienced.

Dispensing without Mini Pumps - Weight/volume measure

To measure 105 Resin and 205 or 206 Hardener by weight or volume, combine 5 parts of resin with 1 part of hardener. To measure 105 Resin and 207 or 209 Hardener by volume, combine three parts resin with one part hardener (by weight, 3.5 parts resin : 1 part hardener). **Note: See Appendix A (Page 65).**

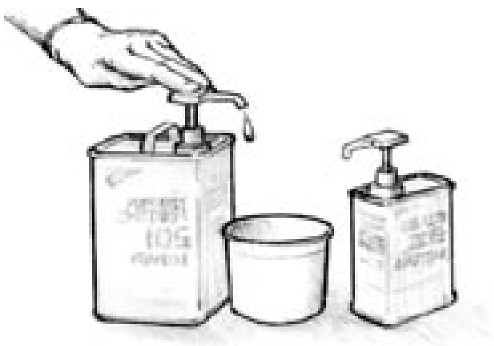


Figure 9-4 Dispense the proper proportions of resin and hardener.

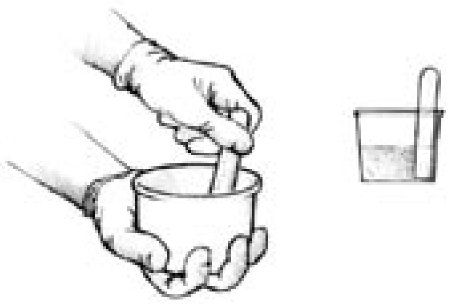


Figure 9-5 Stir resin and hardener together thoroughly, at least one minute - longer in cooler temperatures.

First time users - If using WEST SYSTEM epoxy for the first time, begin with a small test batch to get the feel for the mixing and curing process before applying a mix to your project. This will demonstrate a), The open time for the resin/hardener mix at the present ambient temperature and b), The ratio is correctly metered. Mix small batches until confident of the handling characteristics of the epoxy.

Mixing

Thoroughly blend the two ingredients together for at least one minute - longer in cooler temperatures *(Figure 9-5).* To ensure thorough mixing, scrape the sides and bottom of the pot using the flat end of the mixing stick to reach the inside corner of the pot. If using a power mixer, occasionally scrape the sides and corners of the mixing pot while mixing. If using the mix for coating, quickly pour the blend into a roller pan to extend the open time.

WARNING! Curing epoxy generates heat. Do not fill or cast layers of epoxy thicker than 10mm - thinner if enclosed by foam or other insulated material. Greater thicknesses of mixed epoxy in a plastic mixing cup will generate enough heat to melt the cup if left to stand for its full pot life. For this reason do not use foam or glass mixing containers. If a pot of mixed epoxy begins to exotherm (heat up), quickly move it outdoors. Avoid breathing the fumes. Do not dispose of the mixture until the reaction is complete and has cooled.

9.3.4 Adding fillers and additives

Fillers

After selecting an appropriate filler for the job in hand (Section 9.2.2), use it to thicken the epoxy mix to the desired consistency. The viscosity or thickness of a mix required for a particular job is controlled by the amount of filler added. There is no strict formula or measuring involved - visually judge the consistency which will be best for the job in hand. Figure 9-6 gives a general guide to the differences between unthickened epoxy and the three consistencies referred to in this manual.

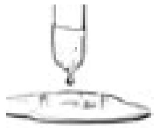
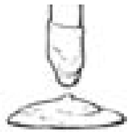
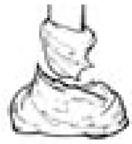
CONSISTENCY	Unthickened	Slightly thickened	Moderately thickened	Maximum thickness
	"SYRUP"	"KETCHUP"	"MAYONNAISE"	"PEANUT BUTTER"
GENERAL APPEARANCE				
CHARACTERISTICS	Drips off vertical surfaces.	Sags down vertical surfaces.	Clings to vertical surfaces. Peaks fall over.	Clings to vertical surfaces. Peaks stand up.
USES	Coating, "wetting-out" before bonding, applying fibreglass, graphite and other fabrics.	Laminating/bonding flat panels with large surface areas, injecting with syringe.	General bonding, filleting, hardware bonding.	Gap filling, filleting, fairing, bonding uneven surfaces.

Figure 9-6 Epoxy can be thickened to the exact consistency needed for a particular job. The procedures in this manual refer to four common consistencies; syrup, ketchup, mayonnaise and peanut butter.

Always add fillers in a two-step process:

1. Mix the desired quantity of resin and hardener thoroughly before adding fillers. Begin with a small batch - allow room for the filler.

2. Blend in small handfuls or scoops of the appropriate filler until the desired consistency is reached *(Figure 9-7).*

Figure 9-7 Blend in small handfuls or scoops of the appropriate filler until the desired consistency is reached.

For maximum strength, add only enough filler to completely bridge gaps between surfaces without sagging or running out of the joint or gap. Only a small amount should squeeze out of joints when clamped. For thick mixes, only fill the mixing cup 1/3 full of epoxy before adding filler. When preparing fairing compounds, stir in as much 407 or 410 as you can blend in smoothly - for easy sanding, the thicker the viscosity, the better. Ensure all the filler is thoroughly blended before the mix is applied.

Additives

Additives are used to give epoxy additional physical properties when used as a coating. Although additives are blended with mixed epoxy in the same two-step process as fillers, they are not designed to thicken the epoxy. Follow the mixing instructions on the individual additive containers.

9.3.5 Removing epoxy

Removing uncured or non-curing epoxy. Remove uncured epoxy as you would spilled resin. Scrape as much material as possible from the surface using a stiff metal or plastic scraper – if necessary, warm the epoxy to lower its viscosity. Clean the residue with WEST SYSTEM 850 solvent or acetone. Follow safety warnings on solvents and provide adequate ventilation. Allow solvents to evaporate before recoating. After recoating wood surfaces with epoxy, it is a good idea to brush the wet epoxy (in the direction of the grain) with a wire brush to improve adhesion.

Removing glasscloth applied with epoxy. Use a heat gun to heat and soften the epoxy. Start in a small area near a corner or an edge. Apply heat until you can slip a putty knife or chisel under the cloth (between 90° and 95°C). Grab the edge with a pair of pliers and pull up the cloth while heating just ahead of the separation. On large areas, use a utility knife to score the glass and remove in narrow strips. Resulting surface texture may be coated or remaining epoxy may be removed as follows:-

Removing cured epoxy coating. Use a heat gun to soften the epoxy (90°-95°C) in a small area and use a paint or cabinet scraper to remove the bulk of the coating. Sand the surface to remove the remaining material. Provide ventilation when heating epoxy.

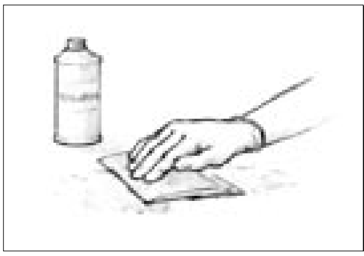
9.4 Basic techniques

The following basic techniques are common to most repair or building projects, regardless of the type of structure or material being worked upon.

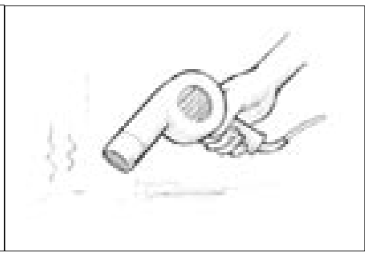
9.4.1 Surface preparation

Whether bonding, fairing or applying fabrics, the success of the application depends not only on the strength of the epoxy but also on the bond strength with which the epoxy adheres to the surface to which it is being applied. Unless bonding to partially cured epoxy, the strength of the bond relies on the ability of the epoxy to mechanically "key" into the surface. Thus, the following three steps of surface preparation are critical to any secondary bonding operation.

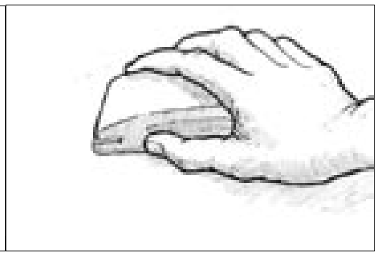
For good adhesion, bonding surfaces should be:-



CLEAN



DRY



SANDED

1. Clean

Bonding surfaces must be free of any contaminants such as grease, oil, wax or mould release. Clean contaminated surfaces with WEST SYSTEM 850 SOLVENT or acetone. Wipe the surface with paper towels before the solvent dries. Clean surfaces before sanding to avoid abrading the contaminant into the surface. Caution! Follow all safety precautions when working with solvents.

2. Dry

All bonding surfaces must be as dry as possible for good adhesion. If necessary, accelerate drying by warming the bonding surface with hot air guns, hair dryers or heat lamps. Use fans to move the air in confined or enclosed spaces. Watch for condensation when working outdoors or whenever the temperature of the work environment changes.

3. Sanded

Thoroughly abrade hardwoods and non-porous surfaces. For most surfaces, 80-grit aluminum oxide paper will provide a good mechanical key for the epoxy. Ensure the surface to be bonded is solid. Remove any flaking, chalking, blistering, or old coating before sanding. Remove all dust after sanding.

Special preparation for various materials

a). Cured epoxy - Amine blush can appear as a wax-like film on cured epoxy surfaces. It is a by-product of the curing process and is more noticeable in cool, moist conditions. Amine blush can clog sandpaper and inhibit subsequent bonding but the blush is water soluble and can be easily removed. It is not unreasonable to assume the blush has formed on any cured epoxy surface.

To remove the blush, thoroughly wash the surface with WEST SYSTEM 855 Cleaning Solution and then wash with clean water and an abrasive pad. Dry the surface with paper towels to remove the dissolved blush before it dries on the surface. After washing with the abrasive pad, the surface should appear dull. Sand any remaining glossy areas with 80-grit sandpaper.

Wet-sanding will also remove the amine blush. If a release fabric e.g peel ply, is applied over the surface of fresh epoxy, amine blush will be removed when the release fabric is peeled away and no additional sanding is required.

Epoxy surfaces that have not fully cured may be bonded to or coated ***with epoxy*** without washing or sanding. Before applying ***coatings other than epoxy*** (paints, anti-foulings, varnishes, gelcoats, etc.), allow epoxy surfaces to fully cure then wash and sand .

b). Hardwoods - Thoroughly sand with 80-grit paper

c). Teak/oily woods - Wipe the surface with acetone and when evaporated, abrade with 80-grit paper. Clean the dust from the surface and then wipe the abraded surface with acetone again - the solvent dries the oil at the surface and allows epoxy to penetrate. Ensure the solvent has evaporated before coating but apply the epoxy within 15 minutes of the acetone wipe. .

d). Porous woods - No special preparation needed but it is advisable to abrade with a medium grit paper to open the pores.

e). Steel, lead and aluminum - Remove contamination, abrade or grind to bright metal. Brush the surface clean and to avoid oxidation of the metal, coat with epoxy within 30 minutes. Abrade the coated surface with coarse sandpaper, working the fresh epoxy into the metal surface – this technique exposes the metal to the epoxy without air contact and the possibility of oxidation. Recoat or bond after the first coat gels.

f). Polyester (fibreglass) - Clean contamination with WEST SYSTEM 855 solvent, acetone or a silicone and wax remover. Thoroughly abrade with 80-grit paper to a dull finish.

9.4.2 Bonding (gluing)

This section refers to two types of bonding. Two-step bonding is the preferred method for most situations because it promotes maximum epoxy penetration into the bonding surface and prevents resin-starved joints. Single-step bonding can be used when joints have minimal loads and excess absorption into porous surfaces is not a problem.

Before mixing epoxy, ensure all parts to be bonded fit properly and that surface preparation has been completed.(See Surface Preparation - 9.4.1). Gather all clamps and tools necessary for the operation and cover any areas that need protection from spills.

Two-step bonding

1. Apply a straight resin/hardener mix to the surfaces to be joined *(Figure 9-8).* This is called wetting-out the surface(s). The epoxy is applied with a disposable brush in small or tight areas; wet out larger areas with a foam roller or by spreading the resin/hardener mix evenly over the surface with a plastic squeegee/spreader. You may proceed to step two immediately or at any time before the wet-out coat becomes completely tack free.

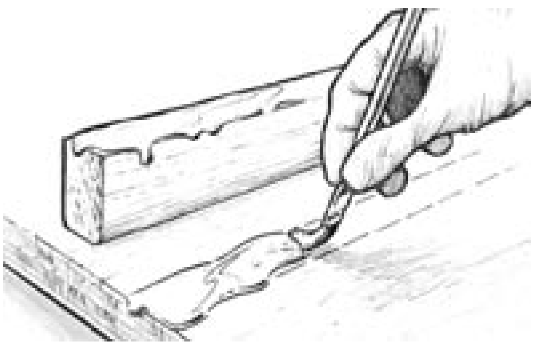


Figure 9-8 Wet out bonding surfaces with unthickened epoxy for maximum penetration and greater adhesion.

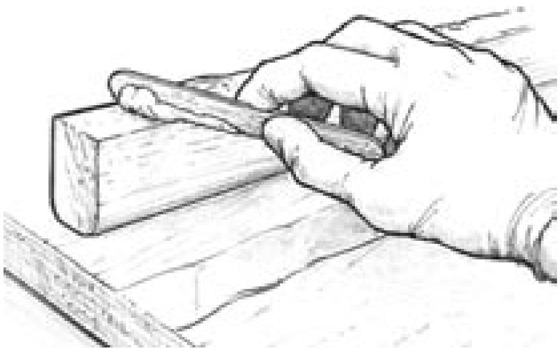


Figure 9-9 Apply enough thickened epoxy to one of the bonding surfaces so that a small amount will squeeze out of the joint when clamped with moderate pressure.

2. Modify the resin/hardener mix by stirring in the appropriate filler until it becomes thick enough to bridge any gaps between the mating surfaces and to prevent "resin-starved" joints. Apply an even coat of the thickened blend to one of the surfaces to be bonded and sufficient so that a small amount will squeeze out when the surfaces are joined together. *(Figure 9-9).*

As already stated, the thickened mix can be applied immediately over the wet-out surface or before the epoxy becomes tack free. For most small bonding operations, add the filler to the epoxy remaining in the batch that was used for the wet-out. Mix enough resin/hardener for both steps. Add the filler quickly after the surface is wet out and allow for a shorter working life of the mix.

Fully cured epoxy surfaces that have been washed and sanded do not need to be wet out.

3. Clamp components. Attach clamps as necessary to hold the components in place. Use just enough clamping pressure to squeeze a small amount of the thickened mix from the joint, indicating that the epoxy is making good contact with both mating surfaces *(Figure 9-10)*. Do not squeeze all the thickened mix from the joint by using too much clamping pressure.

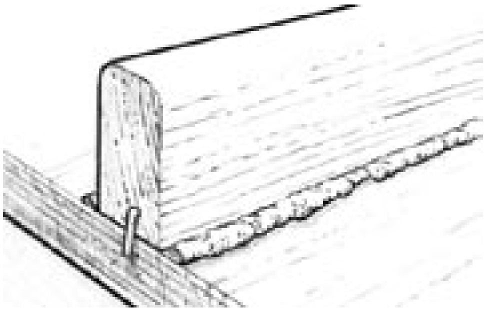


Figure 9-10 Use just enough pressure to squeeze out a small amount of thickened epoxy from the joint.

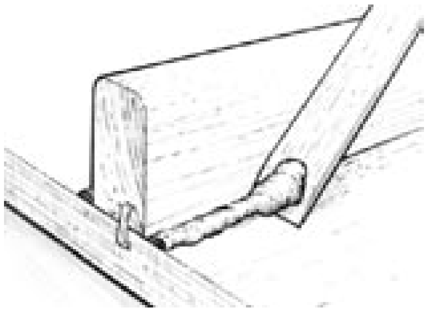


Figure 9-11 Remove excess epoxy before it begins to gel. A sharpened mixing stick makes an excellent cleanup tool.

4. Remove or shape excess adhesive that squeezes from the joint as soon as the joint is secured with clamps. A wooden mixing stick with one end sanded to a chisel edge is an ideal tool for removing the excess *(Figure 9-11).*

Single-step bonding

Single-step bonding is applying the thickened epoxy directly to the component without first wetting out the surfaces with resin/hardener. However, it is strongly recommended that the epoxy is thickened no more than is necessary to bridge gaps in the joint (the thinner the mix, the more it can penetrate the surface). This method is not used for highly-loaded joints or for bonding either end grain or other porous surfaces.

Laminating

The term “laminating” refers to the process of bonding a number of relatively thin sheets, such as plywood, veneers, fabrics or core material, to create a composite. A composite may be any number of layers of the same material or combinations of different materials. Methods of epoxy application and clamping will differ depending on the materials being laminated.

Because of large surface areas and limitations of wet lay-up time, roller application is the most common method for applying epoxy. A faster method for large surfaces is to simply pour the resin/hardener mix onto the middle of the panel/veneer/fabric and spread the epoxy evenly over the surface with a plastic spreader. Apply thickened mixes with an WEST SYSTEM 809 Notched Spreader.

Staples or screws are the most common method of clamping when there is a solid substrate on which to fasten. An even distribution of weights will suffice when laminating over a base that will not hold mechanical fixings, such as a foam or honeycomb core material.

Vacuum bagging is the ideal clamping method for laminating a wide range of materials. Using a vacuum pump and plastic sheeting, the atmosphere is used to apply perfectly even clamping pressure over all areas of a panel regardless of the size, shape or number of layers. *For detailed information on vacuum bagging, refer to 002-150 Vacuum Bagging Techniques.*

Clamping

Any method of clamping is suitable as long as the parts to be joined are held securely so that movement will not occur. Methods of clamping include spring clamps, “C” clamps and adjustable bar clamps, heavy rubber bands cut from inner tubes, nylon-reinforced packaging tape, applying weights and vacuum bagging. When placing clamps near epoxy-covered areas, use polyethylene sheeting or peel ply under the clamps so they do not inadvertently bond to the surface. Staples, nails or drywall screws are often used where conventional clamps are unsuitable. Any fasteners that need to remain should be of a non-corroding alloy such as bronze. In some cases the thickened epoxy or gravity will hold parts in position without clamps.

9.4.3 Bonding with fillets

A fillet is a cove-shaped application of thickened epoxy that bridges an inside corner joint. It is an excellent technique for bonding components because the surface area of the bond is increased and serves as a structural brace. All joints that will be covered with glasscloth will require a fillet to support the cloth at the inside corner of the joint.

The procedure for bonding with fillets is similar to normal bonding but, instead of removing the squeezed-out thickened epoxy after the components are clamped in position, the epoxy/filler blend is shaped into a fillet. For larger fillets, add more thickened mix to the joint as soon as the bonding operation is complete and before the bonding mix is fully cured or any time after the final cure, providing the exposed epoxy in the fillet area is sanded.

1. Bond parts as described in Section 9.4.2. The resin/hardener/filler mix should have the consistency of non-sagging peanut butter.

2. Shape and smooth the squeezed-out thickened epoxy into a fillet by drawing a rounded filleting tool - a mixing stick is often ideal - along the joint, dragging excess material ahead of the tool and leaving a smooth cove-shaped fillet bordered on each side by a clean margin. Remove filleting blend outside the margin and use the excess material to refill any voids *(Figure 9-12).* Smooth the fillet until satisfied with the appearance. An 804 Mixing Stick will produce a fillet with about a 10mm radius. For larger fillets, a WEST SYSTEM 808 Plastic Squeegee is recommended, cut to shape or bent to the desired radius.

   Apply additional thickened epoxy to fill voids or make larger fillets. Apply the mix along the joint line with the rounded mixing stick, using sufficient epoxy to create the desired size of fillet. For longer or multiple fillets, empty caulking gun cartridges or disposable cake decorating bags can be used. Cut the plastic tip to lay a bead of thickened epoxy large enough for the desired fillet size. Heavy duty, sealable food storage bags with one corner cut off may also be used.

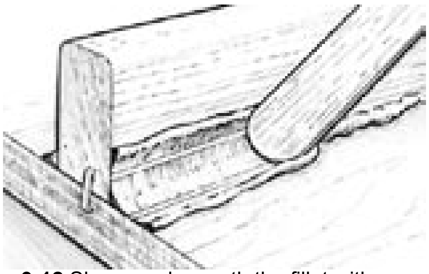


Figure 9-12 Shape and smooth the fillet with a rounded tool.

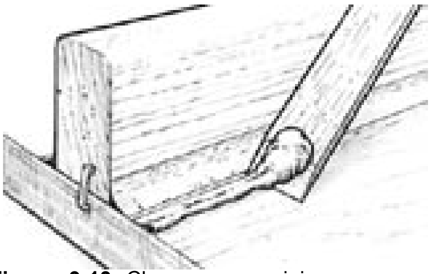


Figure 9-13 Clean up remaining excess epoxy outside of the clean margin before it cures.

3. Clean up the remaining excess material outside the margin by using a sharpened mixing stick or a putty knife *(Figure 9-13).* Glass cloth or glass tape may be applied over the fillet area before the fillet has cured (or after the fillet is cured and sanded).

4. When the fillet has cured, sand smooth with 80-grit sandpaper. Wipe the surface clean of any dust and apply two or three coats of resin/hardener over the entire fillet area before final finishing.

9.4.4 Fairing

Fairing refers to the filling and shaping of low or uneven areas so that the surface blends with the surrounding surfaces and appear “fair” to the eye and touch. After major structural repairs have been completed, final fairing can be easily accomplished with WEST SYSTEM epoxy and low-density fillers.

1. Prepare the surface as detailed for bonding (Section 9.4.1). Sand smooth any bumps or ridges on the surface and remove all dust from the area to be faired.

2. Wet out porous surfaces with resin/hardener mix *(Figure 9-14).* (If allowed to cure, wash, sand and dry before proceeding).

3. Mix resin/hardener and either 407 Low-Density or 410 Microlight™ filler to a peanut butter consistency.

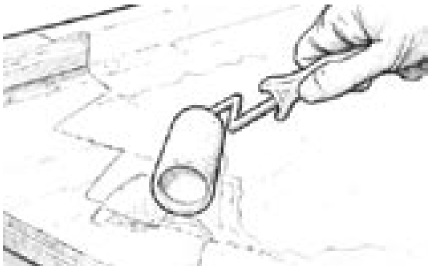


Figure 9-14 Wet out porous surfaces before applying thickened fairing compound.

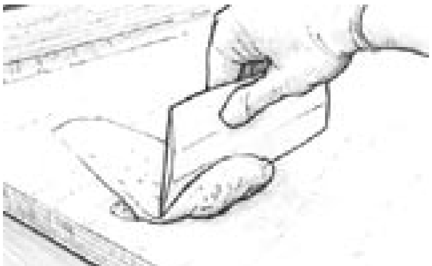


Figure 9-15 Trowel the thickened epoxy fairing compound into the voids and depressions with a plastic spreader.

4. Trowel the thickened mix onto the wetted surface with a plastic spreader, working it into all voids and depressions. Smooth the thickened epoxy to the desired shape, leaving the mix slightly higher than the surrounding area *(Figure 9-15).* Remove any excess thickened epoxy before it cures. If filling voids over 12mm deep, apply the fairing mix in several applications allowing each application to partially cure before proceeding and/or use 206 Slow Hardener or 209 Extra Slow Hardener, depending on ambient temperature.

5. Allow the final application of thickened epoxy to cure thoroughly.

6. Sand the fairing material to blend with the surrounding contour *(Figure 9-16).* Begin with 50-grit paper if it is necessary to remove a lot of fairing material. Use 80-grit paper when close to the final contour. CAUTION! Do not forget your dust mask.

Remove the sanding dust and fill any remaining voids following the same procedure.

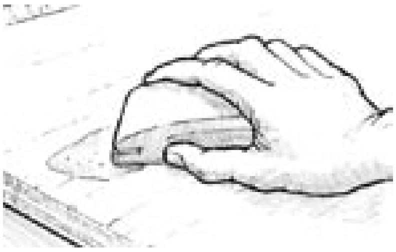


Figure 9-16 *Sand the fairing material to blend with the surrounding contour.*

7. When satisfied with the fairness, apply two or three coats of resin/hardener to the area with a disposable brush or roller. Allow the final coat to cure thoroughly before final sanding and finishing.

9.4.5 Applying woven cloth and tape

Glass cloth is applied to surfaces to provide reinforcement and/or abrasion resistance. It is usually applied after fairing and shaping are completed and before the final coating operation. It is also applied in multiple layers i.e. laminated, and in combination with other materials to build composite parts.

Glass cloth may be applied to surfaces by one of two methods to provide reinforcement and/or abrasion resistance. The "wet" method refers to the cloth being applied to a wet epoxy-coated surface. The "dry" method is to apply the cloth over a dry surface and then impregnate the glass with epoxy. The wet method is preferred whenever possible.

Wet method

By working with small quantities of mixed epoxy, it is possible to work at a comfortable pace over quite large areas to be reinforced.

1. Prepare the surface (Section 9.4.1).

2. Pre-fit and trim the cloth to size. Roll the cloth neatly so that it may be conveniently rolled back into position later.

3. Roll a heavy coat of resin/hardener mix onto the surface.

4. Unroll the glass cloth into position over the wet epoxy. Surface tension will hold most cloths in position. (If applying the cloth vertically or overhead, it is possible to wait until the epoxy becomes tacky). Work out wrinkles by lifting the edge of the cloth and smoothing from the centre with your gloved hand or a squeegee/preader. The use of a paddle roller will help to ensure thorough wetting of the cloth. If cutting a pleat or notch in the cloth to lay it flat on a compound curve or corner, make the cut with sharp scissors and temporarily overlap the edges.

5. Any areas of cloth which appear to be dry, (white in appearance), apply more epoxy with a foam roller

6. Remove the excess epoxy with a spreader/squeegee, using long overlapping strokes of uniform pressure. The object is to remove the excess epoxy that may allow the cloth to "float off" the surface but avoid creating dry spots by exerting too much pressure on the squeegee. Excess epoxy appears as a shiny area while a properly wet out surface appears evenly transparent with a smooth cloth texture. Subsequent coats of epoxy will fill the weave of the cloth.

7. Further layers of glass cloth may be applied immediately by repeating the steps above.

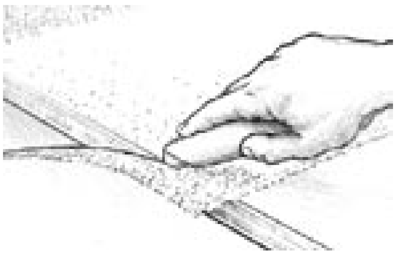


Figure 9-17 Trim excess cloth after the epoxy has begun to gel using a sharp utility knife.

8. Trim excess and overlapped cloth after the epoxy has reached initial cure. The cloth will cut easily with a sharp utility knife. *(Figure 9-17*). Trim overlapped cloth as detailed below:-

a.) Place a metal straightedge on top of and midway between the two overlapped edges.

b.) Cut through both layers of cloth with a sharp utility knife. *(Figure 9-18).*

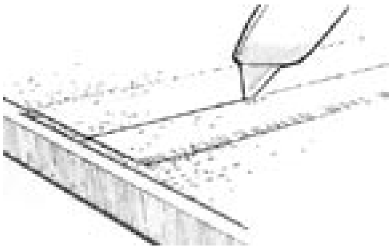


Figure 9-18 Trim overlapping fabric using a metal straightedge and a sharp utility knife, for a flush butt joint.

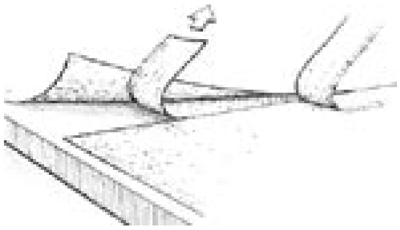


Figure 9-19 Remove the top-most trimming. Then lift the opposite cut edge to remove the overlapped trimming.

c.) Remove the top-most trimming and then lift the opposite cut edge to remove the overlapped trimming. *(Figure 9-19).*

d.) Re-wet the underside of the raised edge with epoxy and smooth into place.

The result should be a near perfect butt joint, eliminating double cloth thickness. However,a lapped joint is stronger than a butt joint, so if appearance is not important, it may be advisable to leave the overlap and fair in the unevenness after coating.

Any remaining irregularities between the cloth and substrate can be faired by using an epoxy/filler compound if the surface is to be painted. Any fairing completed after the final glass cloth layer should receive several coats of epoxy over the faired area.

9. Coat the surface to fill the weave before the wet-out becomes completely tack free *(Figure 9-20)*. Follow the procedures for epoxy barrier coating under Section 9.4.6. It will take two or three coats to completely fill the weave of the cloth and to allow for a final sanding that will not damage the cloth.

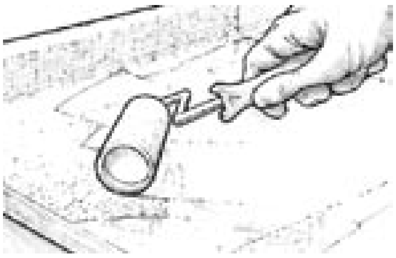


Figure 9-20 Apply the first coat of unthickened epoxy to fill the weave of the cloth before the wet-out coat becomes completely tack free.

Dry method

1. Prepare the surface as you would for bonding (Section 9.4.1).
2. Position the cloth over the surface and cut it several centimetres larger on all sides. If the surface area to be covered is larger than the cloth size, allow multiple pieces to overlap by approximately five centimetres. On sloped or vertical surfaces, it may be necessary to hold the cloth in place with masking tape or staples.
3. Mix a small quantity of epoxy (three or four pumps of both resin and hardener).
4. On horizontal surfaces pour a small pool of resin/hardener mix near the centre of the cloth but it is essential to use a roller or brush for wetting cloth on vertical surfaces.
5. Spread the epoxy over the cloth surface with an 808 Plastic Squeegee, working the epoxy gently from the pool into the dry areas *(Figure 9-21).* Use a foam roller or brush to wet out fabric on vertical surfaces. As the fabric is wet out it becomes transparent, indicating the cloth has absorbed enough epoxy. The use of a paddle roller will help to ensure thorough wetting of the cloth. If applying cloth over a porous surface, ensure that sufficient epoxy is left to absorb into both the cloth and the surface below. Dry areas will be whiter and less transparent than a properly wet out area. Try to limit the amount of squeegeeing as excessive “work” on the wet surface produces minute air bubbles which are placed in suspension in the epoxy. This is especially important if a clear finish is required.

   Continue pouring and spreading (or rolling) small batches of epoxy away from the centre towards the edges, smoothing wrinkles and positioning the cloth. Check for dry areas (especially over porous surfaces) and re-wet as necessary before proceeding to the next step. If cutting a pleat or notch in the cloth to lay flat on a compound curve or corner, make the cut with sharp scissors and overlap the edges.

9

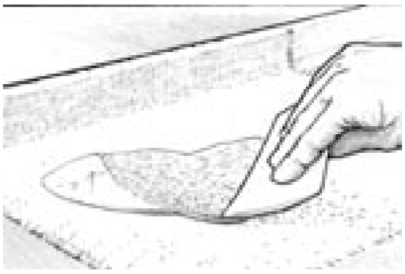


Figure 9-21 Spread the epoxy from the centre of the fabric toward the edges with a plastic spreader.

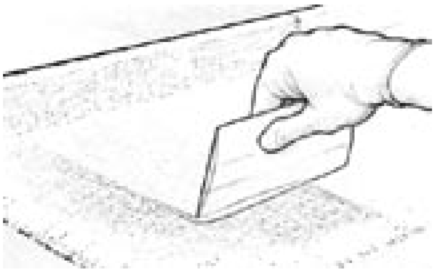


Figure 9-22 Squeegee away excess epoxy before the first batch begins to gel.

6. Squeegee away excess epoxy before the first batch begins to gel *(Figure 9-22)*. Drag the spreader over the fabric, use overlapping strokes of uniform pressure. Now refer to Steps 6, 7, 8 and 9 detailed above in the "wet method" technique to finish the procedure.

9.4.6 Epoxy barrier coating

The object is to build up an epoxy thickness that provides an effective moisture barrier and a smooth base for final finishing.

Apply a minimum of two coats of WEST SYSTEM epoxy for an effective moisture barrier. Apply three coats if sanding is to be done. Moisture protection will increase with additional coats and, in the case of osmosis repair and protection, six coats or about a thickness of 600 microns must be applied. Additives or pigments should not be added to the first coat. Do not mix thinners with WEST SYSTEM epoxy.

When coating, remember that the thinner the film thickness, the easier it is to control the uniformity of the epoxy thereby avoiding runs or sags in each coat. Disposable, thin urethane foam rollers, such as WEST SYSTEM 800 Roller Covers, allow greater control over film thickness, are less likely to cause the epoxy to exotherm and leave less stipple than thicker roller covers. Cut the covers into narrower widths to reach difficult areas or for long narrow surfaces such as stringers.

Complete all fairing and cloth application before beginning the final coating. Allow the temperature of porous surfaces to stabilize before coating otherwise, as the material warms up, air within the porous material may expand and pass from the material (outgassing) into the epoxy and leave bubbles in the cured coating.

1. Prepare the surface as necessary (Section 9.4.1).

2. Mix only as much resin/hardener as can be applied during the open time of the epoxy. Pour the mix into a roller pan as soon as it is blended thoroughly.

3. Load the roller with a moderate amount of the epoxy mix. Roll out the excess on the raised section of the roller pan to obtain a uniform coating on the roller.

4. Roll lightly and randomly over an area approximately 600mm x 600mm to transfer the epoxy evenly over the area *(Figure 9-23)*.

5. As the roller dries out, increase pressure to spread the epoxy into a thin, even film. Increase the coverage area, if necessary, to spread the film more thinly and evenly. As stated above, the thinner the film, the easier it is to keep it uniform and avoid runs or sags in each coat.

6. Finish the area with long, light, even strokes to reduce roller marks. Overlap the previously coated area to blend both areas together.

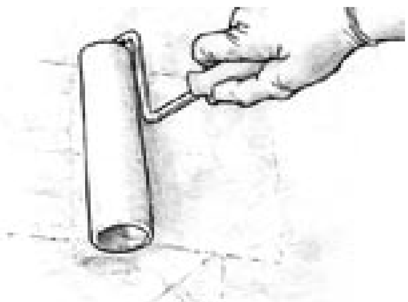


Figure 9-23 *Apply the epoxy in thin even coats using a thin foam roller.*

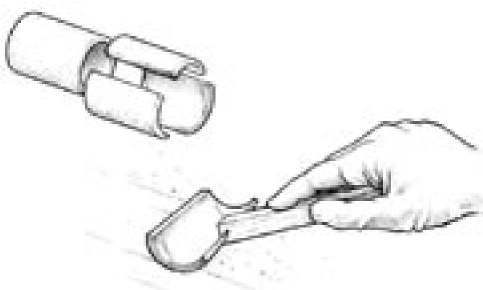


Figure 9-24 *Tip off the fresh coat of epoxy with the grain, using a foam roller brush to remove bubbles and roller marks.*

7. Coat as many of these small working areas as can be completed with each batch. If a batch begins to thicken before it can be applied, discard it and mix a fresh, smaller batch.

8. Drag a foam roller brush lightly over the fresh epoxy in long, even, overlapping strokes after each full batch is applied. Use enough pressure to smooth the stipple, but not enough to remove any of the coating *(Figure 9-24)*. Alternate the direction in which each coat is “tipped off”, 1st coat vertical, 2nd coat horizontal, 3rd coat vertical, etc. A WEST SYSTEM 800 Roller Cover can be cut into segments to make an excellent “tipping” bush.

Recoating

Apply second and subsequent coats of epoxy following the same procedures. Make sure the previous coat has cured firmly enough to support the weight of the next coat. To avoid sanding between coats, apply additional coats before the previous coat has become completely tack free and, ideally, apply all coats on the same day - See Special preparation - Cured epoxy in Section 9.4.1. After the final coat has cured overnight, wash and sand it to prepare for the final finish.

NOTE: When coating timber, the first coat of epoxy will soak into the wood causing the fibres to lift from the surface. Allow this coat to cure overnight before washing and then dry sanding. Remove all debris/dust before applying subsequent coats.

When to sand

If an impression can be made in the epoxy with the thumbnail, it is not hard enough to sand and can still be recoated without sanding. As a general time guide, if a period greater than 8 hours elapses between coating applicatiions at 18°C or if the surface feels waxy, allow the epoxy to cure overnight then wash with fresh water and sand before overcoating.

9.4.7 Final surface preparation

Correct finishing techniques will not only add beauty to the finished surface but will also protect your work from ultraviolet light which will break down the epoxy over a long period of time. The most common methods of finishing are painting or varnishing. These coating systems protect the epoxy from ultraviolet light and require proper preparation of the surface before application.

Preparation for the final finish is just as important as it is for recoating with epoxy. The surface must be clean, dry, sanded and without any amine contamination (See Section 9.4.1).

1. Allow the final epoxy coat to cure thoroughly.

2. Wash the surface with a Scotch-brite™ pad and water. Dry with paper towels.

3. Sand to a smooth finish. The amount of sanding required will depend on the smoothness with which the final epoxy coatings were applied and which finishing system has been selected.

   If there are runs or sags, begin sanding with 80-grit paper to remove the highest areas. Sand until the surface feels and looks fair. Complete sanding with the appropriate grit for the type of coating to be applied and, in general, the thinner the coating, the finer the grit. Paint adhesion relies on the mechanical grip of the paint keying into the sanding scratches in the surface of the epoxy. If a high-build or filling primer is to be applied, 80-100 grit is usually sufficient. For primers and high-solids coatings, 120-180 grit may be adequate. Finishing with 180 grit paper is often recommended for coatings with high-gloss finishes. Grits finer than this may not provide enough “tooth” for good adhesion. Always follow the paint manufacturer’s recommendations for surface preparation.

   Wet sanding is preferred by many people because it reduces sanding dust and, in addition, steps 2 and 3 above become one operation. Wet sanding is often used for final sanding after an initial machine sanding with a coarse grit.

4. When satisfied with the texture and fairness of the surface, rinse the surface with fresh water which should flow evenly without beading or fish-eyeing. If the rinse water forms into droplets or beads (a sign of contamination), wipe the area with solvent, dry with a paper towel, then wet sand again until all water droplets are eliminated.

   Proceed with your final coating after the surface has dried thoroughly. To reduce the possibility of contamination, it is advisable to begin coating within 24 hours of the final sanding. Follow the paint manufacturer’s instructions but we suggest making a test panel to evaluate the degree of surface preparation required and the compatibility of the finish system.

   When applying anti-fouling it is particularly important to seek the advice of the paint manufacturer as to the necessity of using a primer.

65 Estimating guides for WEST SYSTEM products
Appendix A

Group size quantities and coating coverage

WEST SYSTEM epoxy resin and hardeners are packaged in three “Group Sizes”. For each container size of resin, there is a corresponding sized container of hardener and a corresponding mini pump size. The three sizes are A, B or C as shown in the table.

Group Size	Resin Quantity	Hardener Quantity	Mixed Quantity surface	Coverage over a porous surface	Coverage over a non-porous
A	1kg (105)	0.2kg (205/206)	1.2kg	7.5 - 9 m^2	10 - 11.5 m^2
		0.29kg (207/209)	1.29kg	9 - 10.5 m^2	12 - 13 m^2
B	5kg (105)	1kg (205/206)	6kg	40 - 45 m^2	50 - 55 m^2
		1.45kg (207/209)	6.45kg	45 - 50 m^2	60 - 65 m^2
C	25kg (105)	5kg (205/206)	30kg	195 - 225 m^2	255 - 285 m^2
		7.2kg (207/209)	32.2kg	235 - 260 m^2	300 - 330 m^2

Fibreglass thickness per layer

Product Number	740	741	742	743	736	739	738
Fabric Type	Plain	Plain	Twill	Twill	Biaxial	Biaxial	Biaxial
Fabric Weight (g/m^2)	135	200	200	280	300	450	610
*Single Layer Thickness (mm)	0.10	0.25	0.22	0.39	0.38	0.47	0.62

***Average of multiple layers applied by hand lay-up. These values are for guidance only because of the variables incurred during laminating e.g. resin: fibre ratio.**

Filler/epoxy proportion guide

Approximate percentage by weight of filler required to be added to mixed epoxy to produce a “Ketchup”, “Mayonnaise” or “Peanut Butter” consistency for the various filler products.

FILLER	Quantity of filler required for		
	“KETCHUP” consistency	**“MAYONNAISE”** consistency	**“PEANUT BUTTER”** consistency
			
402 Milled Glass Fibre Blend	N/A	N/A	25-30%
403 Microfibres	4%	7%	16%
404 High-Density Filler	35%	45%	60%
405 Filleting Blend	15%	20%	25%
406 Colloidal Silica	3%	5%	8%
407 Low-Density Filler	20%	30%	35-40%
409 Microsphere Blend	11%	16%	25-30%
410 Microlight	7%	13%	16%

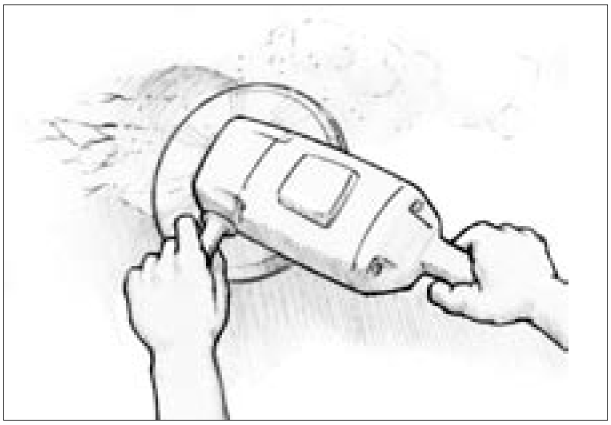
Appendix B

Tools

Most fibreglass repair procedures can be completed with a small inventory of common or readily available hand and power tools. The tools listed here are specially suited for repair procedures when working with epoxy.

Grinders

Grinding to remove damaged laminate and preparing an area for bonding is a key step in many of the procedures throughout this manual. The proper grinder can make a big difference in the quality and efficiency of these operations.

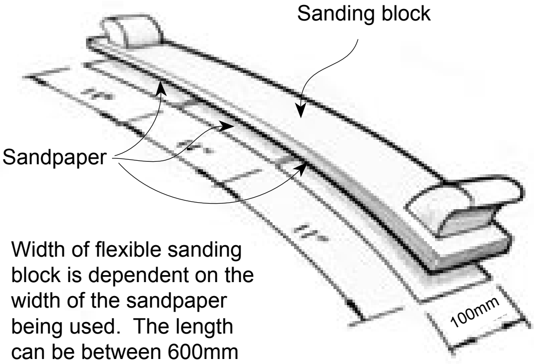


We recommend using a 180mm polisher (about 2000 RPM), with 200mm diameter, 12mm thick foam sanding pad attachment.

Use 36-50 grit paper, either self adhesive or attached with feathering disc adhesive for quick removal or general shaping. Use 80 grit for finer shaping and smoothing.

Fairing boards

A long flexible sanding block is the primary tool for overall fairing. Working on the same principle as a batten, it will bend to the overall shape of the surface, bridging the low areas and knocking down the high spots. A long fairing block can be made of 6mm to 12mm plywood, depending on the curve of the surface to be faired. The length of the block should be approximately 600 to 900mm depending on the ability of the user. The width of the block is the same as the width of the sandpaper being used - usually 100mm. The sandpaper is applied to the block using a suitable adhesive. Handles may be bonded to the ends of the block for greater control.

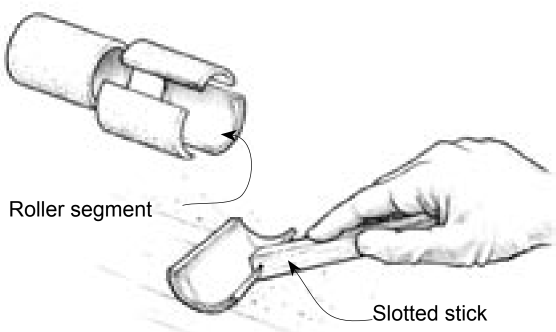


Width of flexible sanding block is dependent on the width of the sandpaper being used. The length can be between 600mm and 900mm

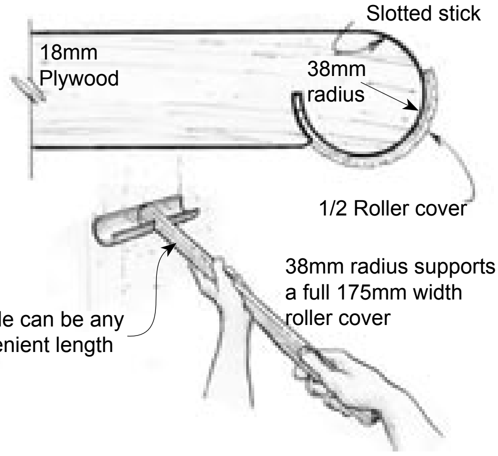
Roller cover brushes

Roller cover brushes are used to “tip off” coats of epoxy, to remove bubbles and roller marks. Drag the brush over the fresh epoxy in long, even, overlapping strokes after each batch is applied. Use enough pressure to smooth the surface, without removing epoxy.

A 88mm wide roller cover brush for small areas.



A 175mm wide roller cover brush for large areas.



B

Appendix C

Epoxy can be used under cold weather conditions, but special application techniques should be employed to achieve acceptable long-term epoxy performance. These precautions are not elaborate or difficult and do not apply to WEST SYSTEM epoxy alone - any epoxy used at low temperatures may have its capabilities and performance affected which could promote significant problems if the epoxy is used in critical marine structural situations. In fact, due to differences in formulation, not all epoxies possess the necessary characteristics to perform well when used under cold weather conditions.

Chemical characteristics

When an epoxy resin and hardener are mixed together, a chemical reaction is started which produces heat - an "exothermic reaction". The ambient temperature in which an epoxy chemical reaction takes place affects the rate or speed of this reaction. Warmer temperatures accelerate the reaction time, while cooler temperatures retard it.

If the reaction is too slow, even though the epoxy may harden, it may not cure completely and possibly never achieve its designed physical properties. This is where danger lies, for improperly cured epoxy may possess enough strength to hold a structure together, yet may fail after repeated loadings during normal operation.

Working properties

Temperature has a profound effect on the working properties of uncured epoxy. Ambient temperature changes will dramatically change the viscosity (thickness) of the epoxy. When cold, the viscosity of water varies little with temperature changes until it freezes but temperature can have an effect that is 10 times greater on epoxy molecules than on water molecules over a temperature change of 15°C. Because of this, the colder it is, the thicker the epoxy becomes, significantly reducing its flow properties. This change has three important consequences for working with epoxy under cold conditions.

a.) it is more difficult to mix the resin and hardener thoroughly. The resin flows through the dispensing pumps and out of containers with much greater difficulty and both resin and hardener are prone to clinging to the surfaces of the pumps, containers and mixing tools. Remember, because of the low temperature, the chemical reaction is much slower and compounding a less efficient exothermic reaction with the potential for incomplete and/or inaccurate mixing, is a recipe for a permanently deficient bond.

b.) the mixed epoxy is much harder to apply because the viscosity is similar to cold honey and is extremely difficult to coat and wet out surfaces.

c.) air bubbles may be introduced when mixing and remain in suspension due to the increased surface tension of the cold epoxy. This can be especially troublesome in clear-finish applications.

Cold weather techniques

Having explained that cold weather epoxy usage is both difficult and potentially dangerous, with a little advance planning and taking certain simple precautions, the problems detailed above can be addressed and their consequences avoided. The following six basic cold weather rules have been used for over 25 years and we have yet to experience a cold weather curing problem with WEST SYSTEM epoxy.

1. Use WEST SYSTEM 205 Fast Hardener.

WEST SYSTEM 205 Hardener has been designed with a chemically-activated polyamine system which exhibits a good cure at temperatures as low as 5°C. It exhibits a fast cure characteristic and offers less uncured exposure time thereby reducing the chances of incomplete cure due to cold temperatures.

2. Dispense resin and hardener in the proper mixing ratio.

All epoxies are formulated to a specific mix ratio of resin to hardener. It is important to mix epoxy in the precise ratio recommended by the manufacturer. Increasing the amount of hardener will not accelerate cure but it will seriously compromise the ultimate strength of the cured epoxy. NOTE: WEST SYSTEM Mini Pumps are designed and calibrated to dispense the correct ratio with one pump stroke of resin for every one pump stroke of hardener.

3. Warm resin and hardener before using.

As discussed above, the warmer the resin and hardener, the lower the viscosity. Thinner (lower viscosity) resin and hardener will flow through dispensing pumps better, cling less to containers and mixing equipment, and exhibit superior handling and wet-out characteristics.

The two epoxy components can be warmed using heat lamps or kept in a warm area until they are needed. Another simple method of warming the resin and hardener is to construct a small hot box out of rigid sheets of foil-backed insulation. Place a regular light bulb or an electric heating pad inside to maintain a temperature no greater than 30°C.

4. Stir the resin and hardener thoroughly.

Use extra care when mixing the resin and hardener and mix for a longer period of time than normal. Scrape the sides and bottom of the mixing container using a flat-ended mixing stick to reach the corners. Using a smaller diameter mixing pot will also improve the chemical activity because the limited surface area will not dissipate heat produced by the reaction.

5. Warm working surfaces.

Applying warmed epoxy to a cold structure will quickly retard the molecular bonding activity of the epoxy. Ensure the structure and the surrounding area is brought up to temperature. A hull, for example, which is colder than the surrounding air may exhibit condensation and this moisture could contaminate the epoxy when it is applied. Warm the structure as much as possible. This can be done by constructing tents around small areas and heating with portable heaters or warming the area with hot air guns or heat lamps. Small components or materials e.g. glass cloth, can be warmed before use in a hot box as described in Paragraph 3 above.

6. Prepare surfaces carefully between applications.

When coating under cold conditions, a thin film of epoxy does not generate much heat and this heat of reaction quickly dissipates. The rate or speed of cure is therefore extended and some reaction with moisture in the atmosphere may occur, resulting in the formation of an amine blush on the cured surface. Immediately prior to applying subsequent coatings, wash the surface with clean water, allow it to dry thoroughly and sand.

Cold weather storage

It is best to store WEST SYSTEM materials above 10°C with the container caps screwed down tightly. Storing epoxy resin in extreme cold may cause crystallization but the formation of crystals does not compromise the resin and the situation can be remedied. Heat water in a pot large enough to hold the epoxy resin container(s). Remove the lid(s) of the resin container(s) to avoid pressure build-up and place the container(s) in the hot water. Stir the epoxy with a clean stick until the liquid regains clarity and all crystals have melted. Remove from the water, replace the lid(s) tightly and invert the container(s) to melt any crystals which may be clinging to the top of the container(s). If the resin pump has crystallized, pumping warm resin through should dissolve the crystals.

Appendix D

This guide is designed to help identify and prevent potential problems associated with epoxy use. If the prevention steps described here do not resolve the problem, please call the Technical Support Helpline at WESSEX RESINS & ADHESIVES Ltd.

<table>
<tr><th>PROBLEM</th><th>POSSIBLE CAUSES</th><th>SOLUTION</th></tr>
<tr><td rowspan="4">The epoxy mixture has not cured after the recommended cure time has passed.</td><td>Off ratio – too much or too little hardener will affect the cure time and thoroughness of the cure</td><td>1. Remove epoxy. Do not apply additional material over non-curing epoxy. See removing epoxy. (page 57)
2. Check correct number of pump strokes used equal stroke of resin and hardener. DO NOT add extra hardener for faster cure!
3. Check for correct pump (5:1 or 3:1 ratio) and pump group size e.g. Group A
4. Check pump ratio (see pump instructions). See Dispensing (page 55).</td></tr>
<tr><td>Low temperature-epoxy mixtures cure slower at low temperatures</td><td>1. Allow extra curing time in cool weather.
2. Apply heat to maintain the chemical reaction and speed the cure. NOTE! Unvented kerosene or propane heaters can inhibit the cure of epoxy and contaminate epoxy surfaces.
3. Use a faster hardener, designed to cure at lower temperatures.
See understanding cure time,(page 53)</td></tr>
<tr><td>Insufficient mixing</td><td>1. Remove epoxy. Do not apply additional material over non-curing epoxy. See epoxy removal note, (page 57)
2. Mix resin and hardener together thoroughly to avoid resin rich and hardener rich areas.
3. Add fillers or additives after resin and hardener have been thoroughly mixed.
See Mixing (page 56)</td></tr>
<tr><td>Incorrect products</td><td>1. Remove epoxy. Do not apply additional material over non-curing epoxy. See epoxy removal note (page 57)
2. Check for proper resin and hardener. Resin will not cure properly with other brands of hardeners or with polyester catalysts.</td></tr>
<tr><td rowspan="5">Bond Failure</td><td>Insufficient cure</td><td>See above</td></tr>
<tr><td>Resin starved joint-epoxy has wicked into porous surfaces leaving a void at the joint.</td><td>Wet out bonding surfaces before applying thickened epoxy. Re wet very porous surfaces and end grain.
See Two-step bonding, (page 58)</td></tr>
<tr><td>Contaminated bonding surface.</td><td>Clean and sand the surface following the procedure on (page 57).
Sand wood surfaces after planing or jointing.</td></tr>
<tr><td>Bonding area too small for the load on the joint.</td><td>Increase bonding area by adding fillets, bonded fasteners or scarf joints.</td></tr>
<tr><td>Too much clamping pressure squeezed epoxy out of the joint.</td><td>Use just enough clamping pressure to squeeze a small amount of epoxy from the joint.
See clamping note , (page 59)</td></tr>
<tr><td rowspan="2">Clear Coating turned cloudy.</td><td>Moisture from condensation or very humid conditions reacts with components in uncured hardener.</td><td>1. Apply moderate heat to partially cured coating to remove moisture and complete cure. See out-gassing caution , (page 55)
2. Use 207 Hardener for clear coating applications and for bonding thin veneers where epoxy may bleed through to the surface.</td></tr>
<tr><td>Entrapped air from aggressive roller application.</td><td>1. Apply coating at warmer temperature-epoxy is thinner at warmer temperatures.
2. Apply epoxy in thin coats.
3. Apply moderate heat to release trapped air and complete cure. See out-gassing caution(page 55)</td></tr>
<tr><td>Waxy film appears on surface of cured epoxy.</td><td>Amine blush forms as a result of the curing process.</td><td>Blush formation is typical. Remove with water.
See special preparation- cured epoxy,(page 57)</td></tr>
</table>

PROBLEM	POSSIBLE CAUSES	SOLUTION
Runs or sags in coating.	Epoxy applied is too thick.	1. use 800 Roller Covers and roll the coating into a thinner film. A thin film will flow out more smoothly than a thicker film after it is tipped off with the foam roller brush. 2. Warm the epoxy to reduce viscosity or apply the coating at a warmer temperature. See Appendix C; Paragraph 3, **(page 67)**
	Coating curing too slowly.	1. Apply the coating at a warmer temperature. 2. Warm the resin and hardener before mixing to speed the cure in cool werather. 3. Switch to a faster hardener if possible. See controlling cure time, **(Page 54)**
Fairing compound (using filler/ 407 or 410 mixture) sags and is difficult to sand.	Fairing material not thick enough.	1. Add more filler to the mix until it reaches a "peanut butter" consistency-the more filler added, the stiffer it becomes and the easier it will be to sand. 2. Allow the wet-out coat to gel before applying the fairing material to vertical surfaces. See Fairing, **(Page 60)**
Paint, varnish or gelcoat will not cure over epoxy.	Epoxy not completely cured.	Allow the final epoxy coat to cure thoroughly. Allow several days if necessary for slow hardeners at cooler temperatures. Apply moderate heat to complete the cure if necessary. See controlling cure time.**(page 54)**
	Paint incompatible with epoxy.	1. Use a different type of paint. Some paints and varnishes may be incompatible with some hardeners. If unsure, test for compatibility on a coated piece scrap material. 2. Use 207 Hardener. It is compatible with most paints and varnishes.
	Epoxy surface not thoroughly prepared.	Remove the amine blush and sand the surface thoroughly before applying paints and varnishes. See Final surface preparation, **(page 64)**
Epoxy became very hot and cured too quickly.	Batch too large, or left in mixing pot too long.	1. Mix smaller batches. 2. Transfer the mix to a container with more surface are, immediately after mixing. See Understanding cure time,**(page 53)** Dispensing and mixing.**(page 55)**
	Temperature too warm for the hardener.	Use 206 Slow or 209 Extra Slow Hardener in very warm weather.
	Application too thick.	When filling large, deep areas, apply mix in several thin layers.
Bubbles formed in coating over porous material(bare wood or foam)	Air trapped in the material escapes through coating (out-gassing) as the temperature of the material rises	1. Coat the wood as its temperature is dropping-after warming the wood with heaters or during the later part of the day. 2. Apply a thinner coat, allowing air to escape easier. 3. Tips off the coating with a roller cover brush to break bubbles. See out-gassing caution,**(page 55)**
Pinholes appear in epoxy coating over abraded fibreglass or epoxy.	Surface tension causes epoxy film to pull away from pinhole before it gels.	After applying epoxy with 800 Roller Cover, force epoxy into pinholes with a stiff plastic or metal spreader held at a low or nearly flat angle. Re-coat and tip off coating after all pinholes are filled.
Fish-eyeing in coating.	Contamination of the coating or surface, application tools, or inadequate abrasion of the surfaces.	1. Ensure mixing equipment is clean. Avoid waxed mixing containers. 2. Ensure surface is properly prepared. Use correct grit paper for the coating, e.g. 80-grit for epoxy. See paint or varnish manufacturer's instructions for precise surface preparation. After surface is prepared, avoid contamination-fingerprints, exhaust fumes, rags with fabric softener (silicone). Coat within hours of preparation. After wet sanding, rinse water should sheet without beading (beading indicates contamination). If rinse water forms droplets/beads, solvent wipe and repeat operation – see 9.4.7. Final surface preparation.

D

Appendix E

Aramid Aromatic polyamide fibres offering exceptionally high specific properties. High tensile properties at a lower density give aramid fibres a distinct advantage over glass cloth, especially in pressure vessel applications. Most aramid fibre is known by the DuPont trade name Kevlar®. Kevlar comes in three grades, 29, 49 and 149. Nomex® is another popular aramid. See Kevlar & Nomex.

Biased Fabric Fabric where warp and weft fibres are oriented at an angle to the length of the fabric.

Bi-Directional or Bi-Axial Cloth with two or more layers of uni-directional fibres not interwoven but lying so the kink-free layers give high strength in two directions.

Carbon Fibre (graphite fibre) Produced from either polyacrylonitrile (PAN) or pitch precursor. A broad range of strength, modulus and strain combinations are possible. Has close to the tensile strength of Kevlar aramid but has excellent compressive and fatigue strength. The terms carbon and graphite fibres are typically used interchangeably, although graphite technically refers to fibres that are greater than 99% carbon composition versus 93 - 95% for PAN-base fibres.

Chopped Strand Mat (CSM) Made of E-glass consisting of randomly oriented fibres 0,75mm to 25mm long. Lengths up to 3mm are called milled fibres. The fibres are held together with a binder or stitched to a uni-, bi- or tri-axial fabric. CSM tends to soak up large amounts of resin, thus is heavy for relatively low strength characteristics. It serves as a veil to prevent print through and to ensure contact between heavier weaves such as woven roving.

Dynel® A modern acrylic fabric. Its low density often causes it to float in uncured resin used to bond it to substrates.

Fibre Glass One of the oldest and most common reinforcement fabrics, it remains among the strongest and lowest cost of all the fibres today. Fibres are similar to wool or cotton fibres, but formed from molten glass, drawn at high speeds into very fine fibres. Glass fibre forms include cloth, yarn, mat, milled fibres, chopped strands, roving, and woven roving. They do not burn, shrink, stretch or absorb moisture. Most common grades are E for electrical and S for high strength.

E-glass is the most commonly used glass cloth with good versatility, balance of mechanical properties and lower cost.

S-glass offers performance improvements of 20-40% over E-glass but it is 3 times more expensive.

Hybrid A cloth, woven roving or unidirectional material composed of two or more different fibres. The properties of the material are a proportional combination of the properties of the individual fibres.

Kevlar® A trade name for a DuPont aramid fibre. Yellow to gold in colour. Outstanding features are low weight, high tensile strength and modulus, impact and fatigue resistance, weave ability. Compressive strength of aramids is relatively poor as they show nonlinear plastic flow behaviour at low strain values. Aramids tend to be difficult to cut and wet-out during lamination. See aramid.

Mat A randomly distributed felt or glass fibres held together with a binder, used in reinforced plastics lay-up moulding. See CSM.

Nomex® A hexagonal, honeycomb core material manufactured of aramid material. A DuPont trade name.

Peel Ply A coated fabric to which resin does not adhere. Used in vacuum bagging to prevent the bag material from adhering to the laminate. Also used in FRP repairs to allow elimination of air, extrusion of excess resin and helps provide an uncontaminated, textured surface acceptable for secondary bonding.

Quad-Directional or Quadriaxial Cloth with four layers of uni-directional fibres not interwoven but lying so the kink-free layers give high strength in four directions.

Roving A collection of bundles of continuous filaments either as untwisted strands or as twisted yarns. They are generally wound as bands or tapes with as little twist as possible.

Spectra® A Polyethylene fibre (thermoplastic) developed in 1985 used for rope, sails and fabrics for composite construction. High strength, low stretch. Specific mechanical properties of Spectra are slightly better than Kevlar although performance at elevated temperatures falls off. A difficult material to cut and abrade. An Allied Industries trade name.

Tow An untwisted bundle of continuous filaments. Commonly used when referring to manmade fibres, particularly carbon fibres, but also glass and aramid. A tow designated as 140K has 140,000 filaments.

Tri-Directional or tri-axial Similar to bi-axial except that the fibres are oriented in three directions; about 120 degrees to each other.

Uni-Directional or mono-axial Consists of strands of fibre running in one direction only, held together by single fibres that are glued or sewn laterally. It has high directional strength, so it can be used in areas where the loads are specific.

Woven Roving Fabric Heavy fabrics woven from continuous filament in roving form. They drape well, are quickly impregnated, but with a low fibre-to -resin ratio. Priced between mats and yarn cloths.

Additional building and repair information available from WESSEX RESIN & ADHESIVES Ltd.

Publications

002-950 WEST SYSTEM® Technical Manual
The primary guide to safety, handling and the basic techniques of epoxy use. Includes a complete description of WEST SYSTEM epoxy resin, hardeners, fillers, additives, reinforcing materials, tools, supplies and publications.

002 The Gougeon Brothers on Boat Construction
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002-896 Gelcoat Blister Repair with WEST SYSTEM Brand Epoxy
A guide for repairing and preventing gelcoat blisters on fibreglass boats. Includes an analysis of the factors contributing to blister formation and steps for preparation, drying, repairing and coating for moisture protection. VHS–16 min.

002-550 Fibreglass Boat Repair & Maintenance

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