Food and Agriculture Organization of the United Nations

Fibreglass-reinforced plastic (FRP) boat repair in the tropics

A practical guide

BOBP

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Contents

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This 2023 revision incorporates improved practices and knowledge. A section on damage assessment and repair options has been added and more information on materials and FRP repair techniques. This revision was prepared by Derrick Menezes with contributions from Raymon van Anrooy, Daniel Davy, Michael Allan Savins (FAO); P Krishnan and S Jayaraj (BOBP-IGO) and T Ravikumar (Tamil Nadu Dr. J. Jayalalithaa Fisheries University).

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Introduction

Every fibreglass reinforced plastic (FRP) boat gets some damage sooner or later. The damage is often caused by wear and tear. Damage to the FRP can also be the result of accidents, bad handling of the boat or poor construction of the boat. Most small damage, such as scratches, cracks or punctures can be repaired easily.

This practical guide aims to help fishers to carry out simple repairs of their FRP boats. Timely maintenance and repair will make an FRP boat last longer and will support the safety of fishers at sea.

Many fishers do not have access to a boat yard or skilled FRP boat builders for the repair of their boats. This practical guide shows how to carry out small FRP repairs. It also advises when a skilled FRP expert should be contacted instead.

Common challenges to FRP boat repairs are:

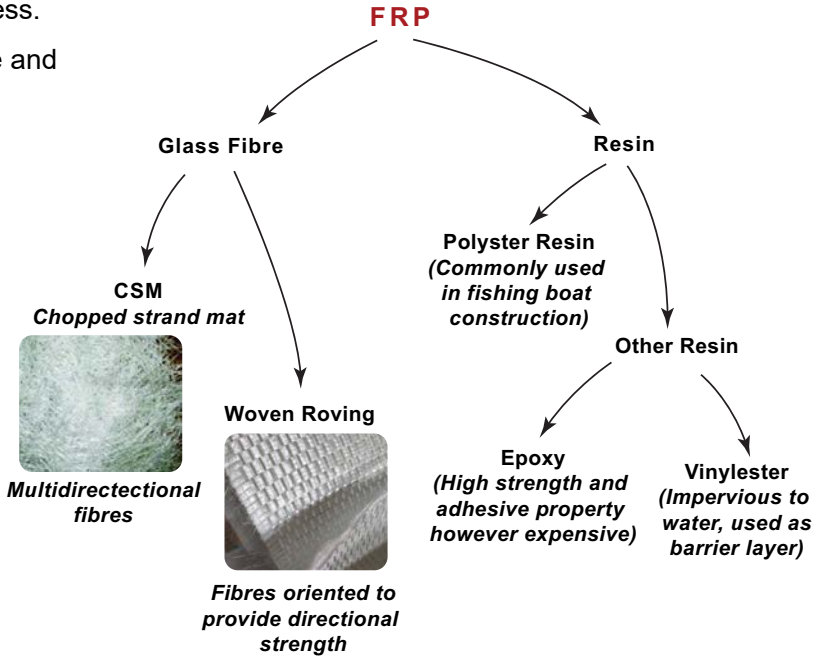
- poor working conditions, such as on the beach;
- incorrect handling of FRP materials;
- improper lamination methods;
- lack of personal safety and protection;
- inadequate storage of dangerous and highly inflammable materials; and
- careless waste disposal.

This practical guide gives advice on how to deal with these challenges when repairing small damage to FRP boats.

2. What is Fibreglass Reinforced Plastic (FRP)?

When fibreglass is impregnated with a resin it cures into a solid laminate with strength and stiffness.

FRP is a strong material, durable, affordable and light in weight. It's highly suitable for boats.



Components of a fibreglass structure

List of raw materials for repair work

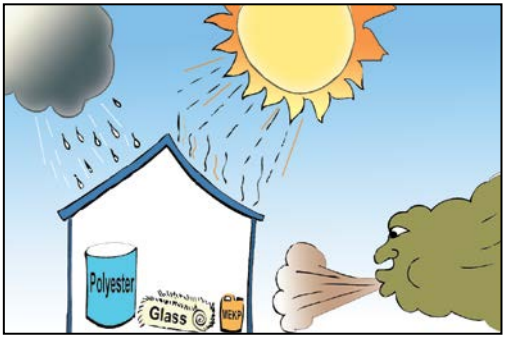
<table>
<tr><th>Sl. No</th><th>Name</th><th>Material pictures</th><th>Use</th></tr>
<tr><td>1.</td><td>Polyester Resin
Check label for the manufacture date and batch certificate</td><td> 
</td><td>General repair
Storage guide
<table>
<tr><th>Temp ^{0}C</th><th>Shelf life</th></tr>
<tr><td>18-25</td><td>6 months</td></tr>
<tr><td>25-32</td><td>4-5 months</td></tr>
<tr><td>>32</td><td>3 months</td></tr>
</table></td></tr>
<tr><td>2.</td><td>Hardener - MEKP (methyl ethyl ketone peroxide)</td><td> 
</td><td>To be used with resin</td></tr>
<tr><td>3.</td><td>Gelcoat
Check label for the manufacture and batch certificate</td><td> 
</td><td>For outer surface repair</td></tr>
<tr><td>4.</td><td>Wax</td><td>  </td><td>Use to make top coat</td></tr>
</table>

5.	Styrene liquid solvent		For cleaning and activating surfaces before lamination
6.	Vinyl ester resin		Has the properties of high resistance to both water absorption and chemicals. Used as a barrier layer in the boat hull and fuel tanks.
7.	Epoxy resins		Has high adhesive strength. Used where high strength is required during construction or repairs.
8.	Woven roving mat *Check label for quality certificate*		Used for directional strength on stringers and frames
9.	Chopped strand mat *Check label for quality certificate*		Used for general repair

3. Handling of FRP materials

- FRP materials should be protected from sun, wind and rain.
- Always check details of the materials and date of manufacture.
- Fibreglass must be kept dry and clean.
- All polyester-related materials should be stored in dark and cool place.
- Proper mixing of gelcoat and resins before use is important. Follow the correct mixing ratios.
- Mix the catalyst well through the resin.

Caution: The hardener and catalyst must be stored separately.



4. The work area

- Protect the work area from sun, wind, rain, dust and sand.
- A simple shelter is ideal. A temporary shelter can be constructed using canvas or tarpaulin sheets.
- Protective clothes should be worn while working with FRP.

5. Tools

- Brushes for applying gelcoat and polyester resin into tight corners.
- Resin rollers of different sizes and resistant to styrene solvents.
- Compacting rollers to be applied firmly for removal of air bubbles.
- Disc grinders for sanding away damaged FRP.
- Sandpaper of 40 grit and higher.
- A cutting disc for grinding cured FRP laminate.

6. Damage assessment and repair options

Before starting the repair work, it is important to assess the type and cause of damage to the FRP.

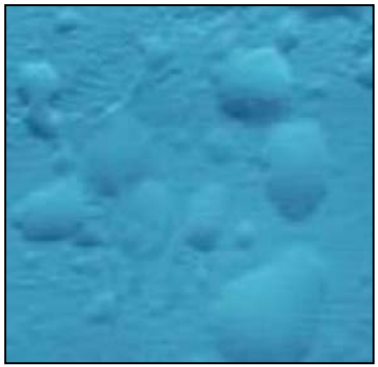
Types of damage can include for instance delamination, blisters, material fatigue, frame-, bottom-, and surface damage, structural stress, and osmosis.

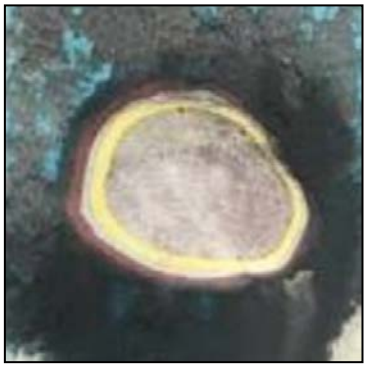
Delamination

- Delamination occurs due to water in the hull.
- Entry of water destroys the resin.
- This causes separation of layers: delamination.
- To repair remove damaged layers.

Blisters

- Blisters are bubbles and bumps due to trapped water or air droplets.
- They break to expose the laminate to water.
- This will allow water to penetrate the FRP.
- Immediate repair prevents further damage.
- To repair remove damaged material and apply a new gelcoat.



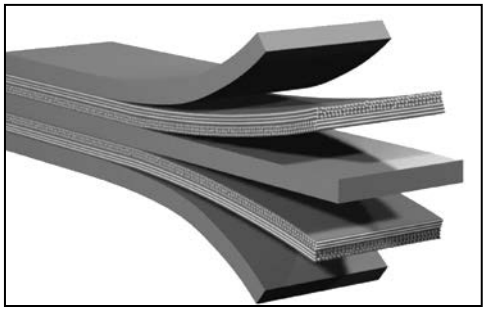


Fatigue

- Due to waves and vibration surface cracks appear in the hull.
- Early repair will increase the life span of the boat.
- To prevent fatigue it is important to use sufficient glass mat in all areas.

Warping

- Warping of fibreglass occurs due to continuous exposure to the sun.
- Results in separation of the layers; delamination.
- Use of canopies or temporary shades prevents warping.



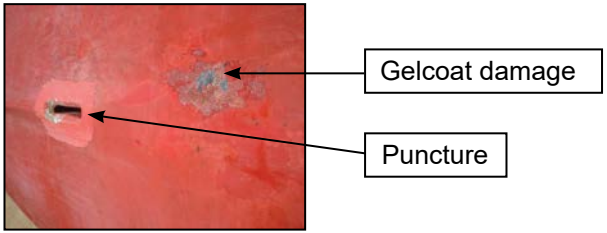
Stringer and frame damage

- Due to wear and tear, the stringers and frames require regular maintenance.
- Where a stringer passes through a transverse frame, there should be sufficient depth of frame kept (50 to 60 percent).
- Repair by cutting out and grinding the damaged areas.
- Rebuild with FRP.

Surface damage

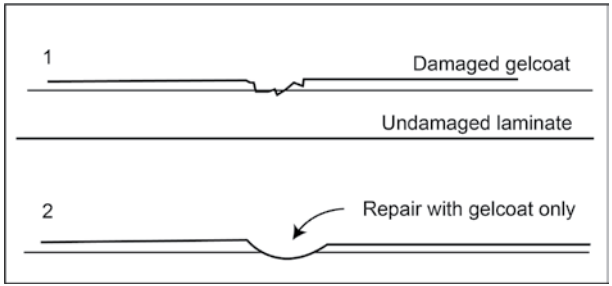
- Due to wear and tear, small damage appears.
- Regular checking, maintenance and repairs are needed.

Minor damage on the gunwale



Abrasion of gelcoat and shallow damage

Repairs to small cracks or abrasions with no damage to the fibreglass below can be fixed by repairing only the gelcoat.



Major Damage

- Any cracks and breakages that go completely through the FRP are major damage.
- Major damage needs skilled FRP workers.

Topside damage

Frame damage

Osmosis

- Caused by water in the laminate and breakdown of polyester resin.
- This can be seen by the dark spots and white pockets on the laminate.
- Repaired by grinding out the damage, drying the surface thoroughly and application of gelcoat.

Hull side damage

- Inadequate laminate thickness is a structural failure. This boat is beyond repair and should be replaced for safety reasons.

Stress damage

- Connections between the FRP structure and fixed parts of other materials can cause FRP stress, weakness and cracks.
- Areas surrounding connections between posts and FRP structure should be reinforced.
- This spreads forces evenly through the structure.

Bottom damage

- The bottom of a boat is subject to severe wear and tear due to abrasion resulting in cracks, holes and delamination.
- Strips of FRP laminates could be glued on for additional stiffness and to reduce abrasion.
- A metal keel shoe could also be used.

Operational damage

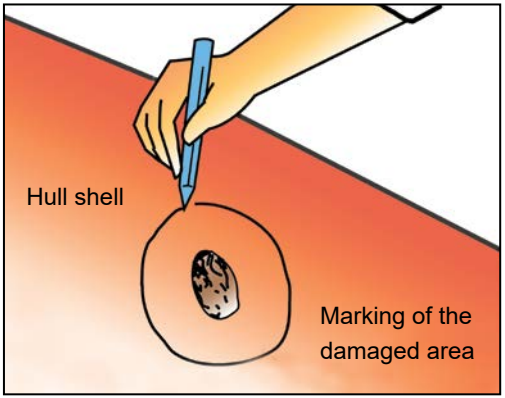
- Wear and tear and absorption of water affect the lifespan of an FRP boat.
- Regular inspection of the surface reveals cosmetic or more serious structural damage.
- A boat left constantly in the water absorbs water into the polyester laminate.
- Gelcoat or topcoat does not stop water absorption.
- Water in the laminate reduces the stiffness of the hull over a period of 5—15 years due to hydrolysis, which is the breakdown of resin.

7. FRP repair steps

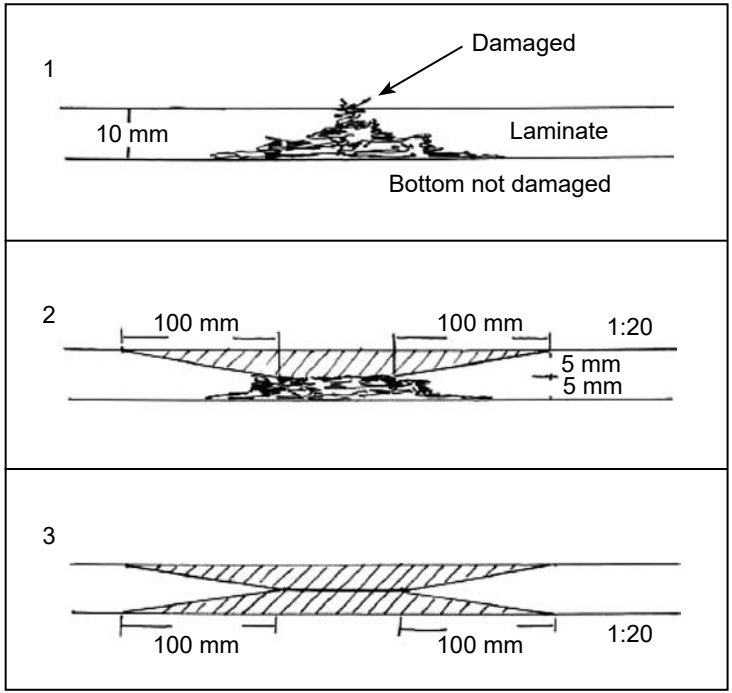
Step 1: Pre repairs

- Place the boat with the damaged side up to dry out.
- Check for water in the hull and delamination damage.
- Check the condition of wood beneath layers of fibreglass by tapping with a hard object.
- A hollow sound indicates a poor condition of the wood beneath the FRP.

Step 2: Repair basics for laminate damage



Mark the area on the surface of the laminate to be ground.



1. This damage does not penetrate through the laminate to the other side.
2. The ground area should be 20 cm wide if it is 1 cm deep (1:20).
3. Damage with complete penetration through the laminate.

Step 3: Preparation for repair

- Clean the surface with solvent before grinding.
- This removes any oil, silicon and dust.

Step 4: Grinding

- Start with 40 grit paper, or rougher, for removing damage.
- Use higher grit (120 to 600) papers for a smooth finish.
- Either hand grind or use a disc grinder.
- Make sure to remove all old resin until you expose the glass fibres.

Step 5: Fibreglass

- For simple repair work, choose chopped strand mat (CSM).
- While repairing increase the size of each layer from bottom to top.
- Tear the CSM to leave a tapered edge.

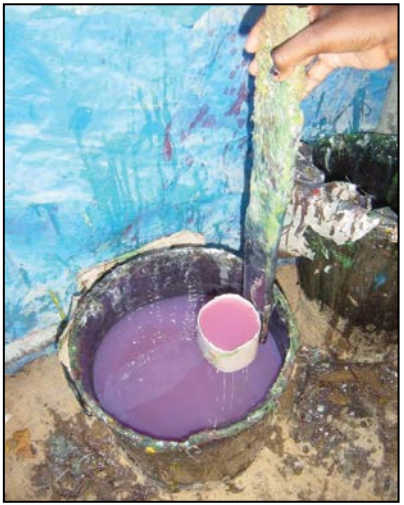
Step 6: Hardener

- Syringes can be used to measure small quantities of hardener.

Practical tips

- A handy tool for measuring hardener is a bottle cap on a piece of steel wire.
- A typical bottle cap will hold 5 ml of hardener, required for 500 grams of resin.

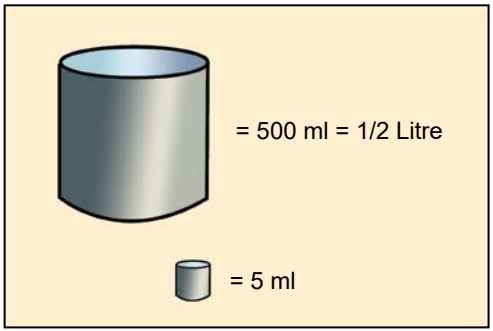
- Resin and hardener should be mixed thoroughly.



Step 7: Mixing the resin and hardener

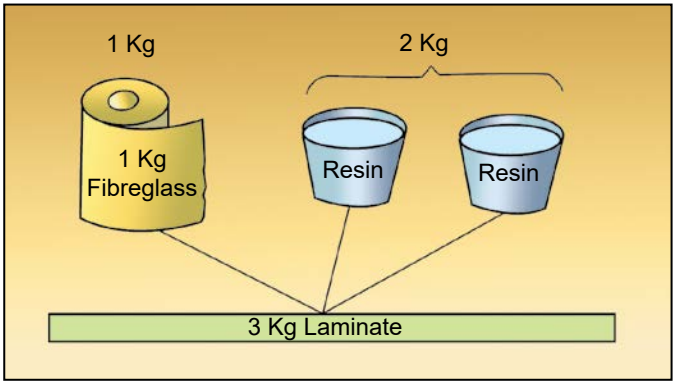
- The correct mix of hardener to resin is 1 percent, however 0.8 percent will normally also work in the tropics.

Resin	½ kg	1 kg	5 kgs
Hardener	5 ml	10 ml	50 ml



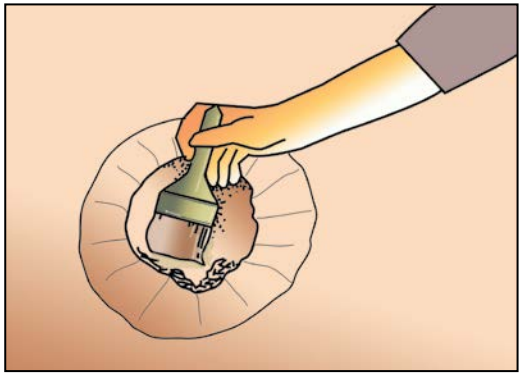
Note: Fibreglass and resin

- This is the correct amount of polyester resin to fibreglass.
- For example, 1 kg of fibreglass mat requires 2 kgs of polyester resin.



Step 8: Resin application

- A coat of resin should always be applied before laying down the fibreglass mat.



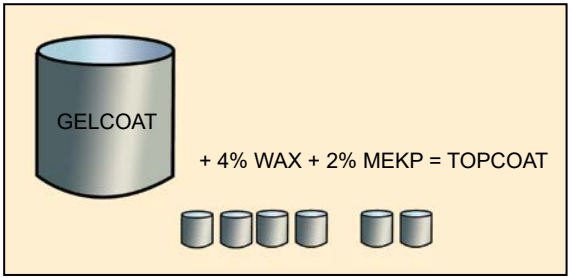
- Another coat of resin should be applied over the fibreglass mat.

Step 9: Compacting the resin and fibreglass layers together

- A metal roller is used to remove any air bubbles and to compact the resin and fibreglass layers.

Step 10: Preparation of topcoat

- The topcoat can be prepared by mixing gelcoat, paraffin wax and hardener in the percentages shown in the figure.
- 1kg gelcoat requires 40 grams wax and 20 grams MEKP (methyl ethyl ketone peroxide) hardener.
- A colour pigment can be added to the topcoat.



Gelcoat	1000 grams	5 kgs	10 kgs
Wax	40 grams	200 grams	400 grams
MEKP	20 grams	100 grams	200 grams

Step 11: Top coating

- A topcoat is applied on the repaired laminate.
- The purpose of the wax in the topcoat is to ensure proper hardening and a smooth finish.

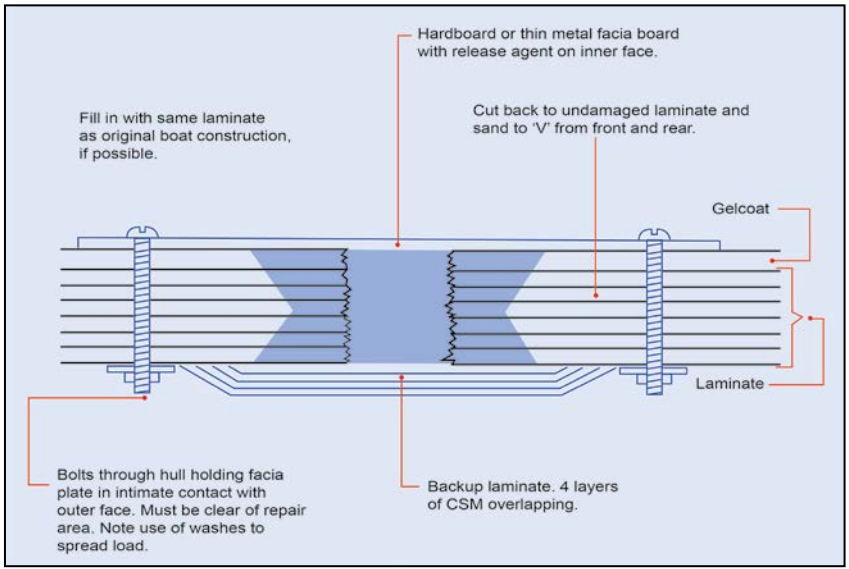
Step 12: Finishing the surface

- Hand sand with smooth grit paper and polish to finish the surface.

8. FRP repair methods and procedures

Hairline fracture and grazes

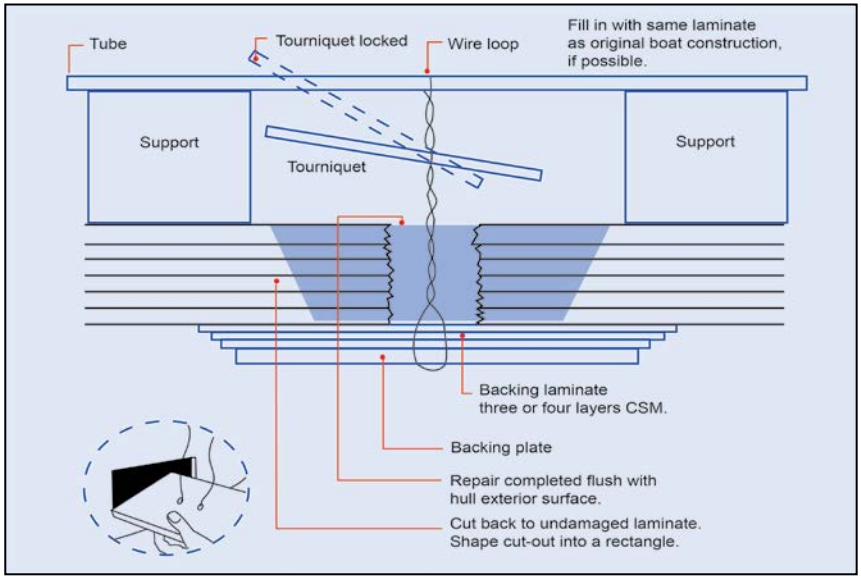
- Enlarge the hairline fracture into a V-shaped groove, using the corner of a chisel or a file.
- The groove must be deep enough to penetrate the gelcoat completely and expose the main laminate beneath.
- Prepare and activate a small quantity of resin.
- A polyester filler powder is best for this type of repair.
- Work this into the groove using a broad knife until it is slightly more than the external surface.
- Leave the repair to cure completely (2-4 hours).
- Smoothen the surface with roughness 320 wet-and-dry sandpaper on a rubber block.
- Rub lightly in one direction only to prevent the area surrounding the repair from becoming depressed.



Damage accessible from both sides

Punctures

- Punctures may or may not be accessible from both sides.
- Different methods are needed for each case.
- After placement of backing plate and laminate follow same steps as above for hairline fracture and grazes.



Repairing a puncture with only outside access

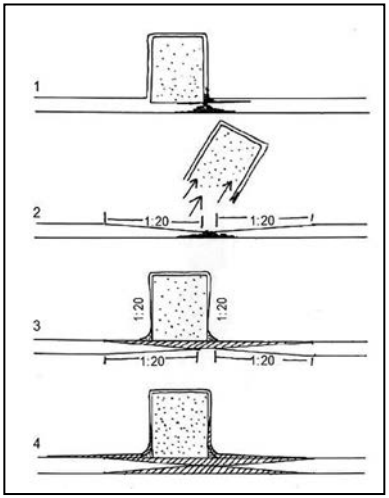
Repair of stringers and frames

The section view on the right shows the cross-section of structural damage to the frame of an FRP boat and the proper method of repair.

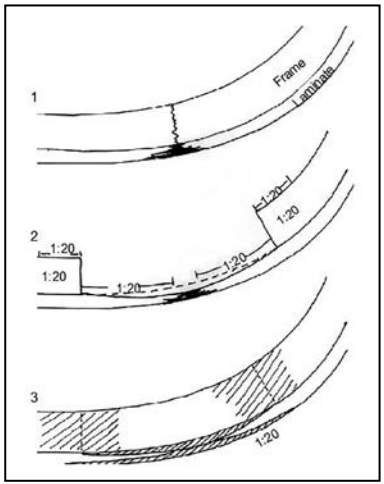
1. A fracture in the outer skin has penetrated the whole laminate and caused delamination in the framework.
2. For the repair to be effective, the wooden frame must be cut and removed.
3. Next, the hull laminate must be repaired as described earlier.
4. The damaged frame must be flat and bonded down with polyester putty and finished with a radius.

All lamination work on the frame is best done with fabrics of 450 g/m² and lighter CSM.

Add unidirectional fibres along the top of the frame to increase strength.



Section view



Side view

Example: Practical steps for common structural FRP repairs

Step 1: Damage assessment

- This picture shows a typical fatigue fracture inside the transom of a boat powered by an outboard engine.
- In this case, an attempt was made to repair the crack, however putty and gelcoat cannot mend structural damage.

Step 2: Surface preparation

- Prior to grinding, all surface contamination such as oil and silicone should be washed off and removed with a solvent. For grinding, 40-grit sandpaper is a good choice.
- In the example shown here, grinding has uncovered deep delamination.
- To ensure lasting repair, the full extent of the delaminated fibreglass must first be removed.

Step 3: Choice of repair materials

- Grinding shows that the area to repair is usually larger than estimated.
- For example, in this boat tiny cracks in the gelcoat were visible on only one side of the transom but grinding revealed that the delamination occurred on both sides.
- Based on the type of damage, appropriate repair materials need to be chosen.

Choosing a resin for structural repairs

Type of resin	Qualities	Considerations
Polyester resin	Chemical bonding – low adhesion	Standard boat building material Low cost
Vinyl ester resin	Chemical bonding – watertight	Used as single outer barrier layer under gel coat Slightly more expensive than polyester
Epoxy resin	High strength bond and high adhesion	High performance applications Ideal for emergency repairs Expensive

Caution: Avoid using fast curing epoxy for structural repairs. A thorough cleaning and preparation of the bonding surfaces are very important to achieve good adhesion.

Choosing a fibreglass mat for structural repairs

- The choice of a fibreglass mat should preferably match the original construction and thickness.
- Use of a lighter weight mat makes better surface contact.
- Build up to original thickness is a good practice.
- Laminate overbuild at one point creates stress and weakness in the structure.
- Epoxy resin is often the best choice for repair due to its high adhesion qualities.

Step 4: Surface preparation

Caution: Use of putty for structural repairs should be avoided.

- Do not clean a freshly sanded area with solvent.
- If cleaning with solvent is necessary, lightly grind with clean sandpaper, wash and allow to dry.
- Prior to lamination, activate the surface with the styrene (the base solvent of polyester resin).

- In the picture, the laminating has been completed and the surface has been ground.

Important

Check the water content of the laminate!

Too much water in the laminate will cause failure.

Step 5: Finishing

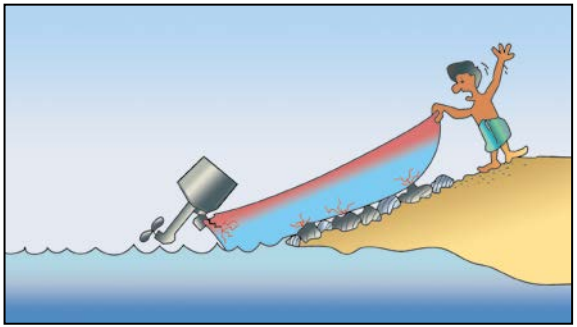
- A gelcoat should be applied and sanded and polished (when dry) for a glossy finish.
- It is good practice to use an aluminum plate for the transom to distribute the engine weight.

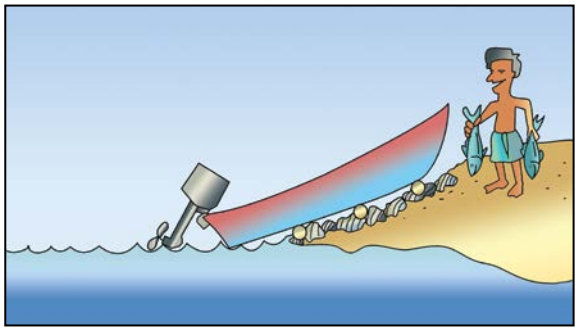
- This picture shows the completion of the repair.

No shortcuts should be taken if the repair is meant to last!

9. Damage prevention

Do not pull your boat up on a rocky shore without protection!



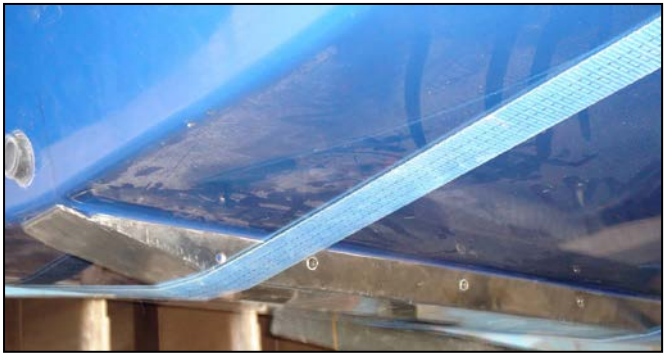


PVC pipes can be used instead of wooden runners.

- Gunwales can be protected with and extra layer of FRP or PVC pipes to reduce damage.
- The protected gunwales make deploying and recovery of nets easier.

A keel shoe flat bar tends to separate as in the pic below.

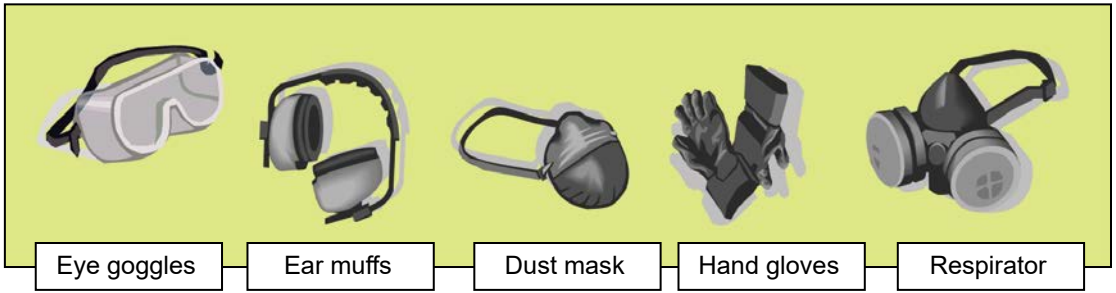
A stainless steel channel stays free of damage and is therefore preferred.



Protect the boat with fenders or tyres in a crowded harbour
to avoid impact with other boats.

10. Occupational health and safety

- Always use eye protection when working with FRP. Chemical hazards can be an eye irritant. Liquids can be severely corrosive and airborne particulate matter can damage the eyes.
- Always use a respirator and/or dust mask when working with FRP to protect from hazardous fumes and FRP grinding dust.
- Always use proper gloves when working with FRP repair work to protect skin from hazardous liquids, solvents, and cuts.
- Always use ear protection when working with noisy machinery during FRP repair work.
- Use protective clothing to protect your skin.



- Workshop cleanliness is important for the health of workers and to prevent contamination of raw materials.
- Waste material, dust, sand and other contaminants should be removed immediately.

- The workshop should be as free as possible from dust and fumes.
- This allows comfortable and safe working conditions.
- Styrene fumes are heavier than air. Ventilation at a lower level will allow these fumes to escape.

11. Environmental issues

- Fibreglass is non-biodegradable.
- Solvents and other materials are hazardous chemicals.
- Store fibreglass waste carefully before disposal.
- Fibreglass waste should be disposed in a landfill, or handed over to local authorities for disposal.

Caution:

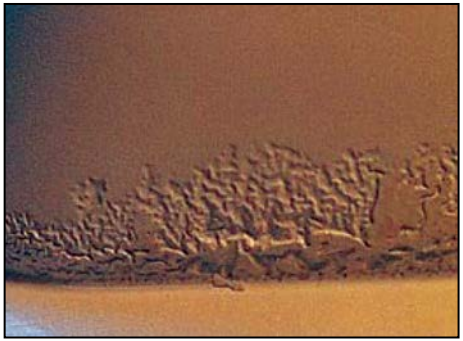
Fibreglass waste should not be burnt under any circumstances, as the fumes are highly toxic.

Stored waste must be handled carefully as it has a fire risk.

Annex I – Information for skilled FRP workers

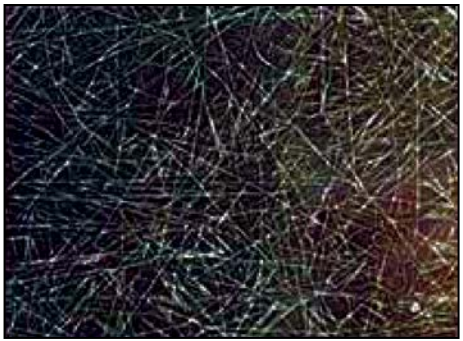
Manufacturing defects and repairs
Wrinkling or "alligatoring" is a gelcoat fault caused by:

- insufficient catalyst in the gelcoat;
- the gelcoat is too thin; and
- the next layer has been applied too soon.



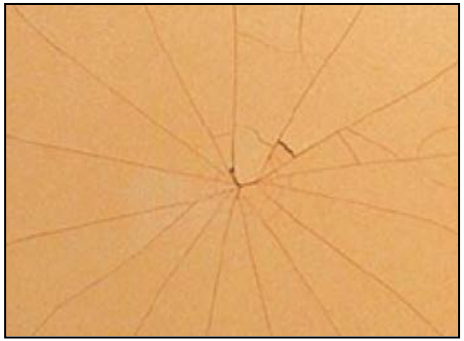
Fibre pattern is a result of:

- the gelcoat too thin; and
- high heat because of bulk curing.



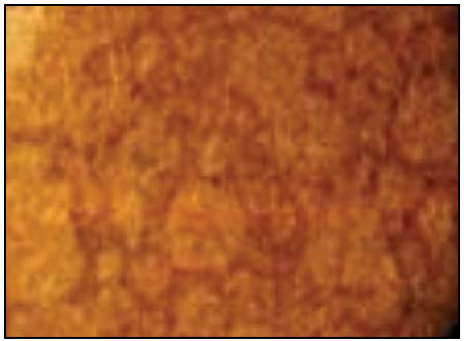
Star crazing is caused by:

- the gelcoat is too thick;
- impact from behind the laminate; and
- a crack pattern has been transferred from the mould.



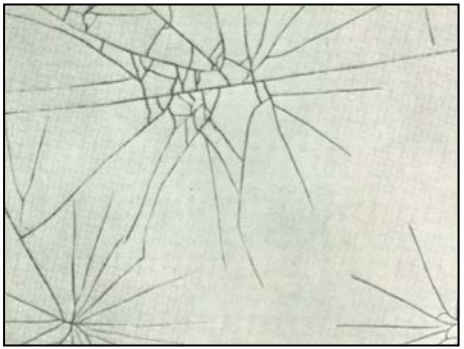
Blisters are caused by:

- moisture or water trapped in the FRP laminate; and
- the gelcoat has cured too fast.

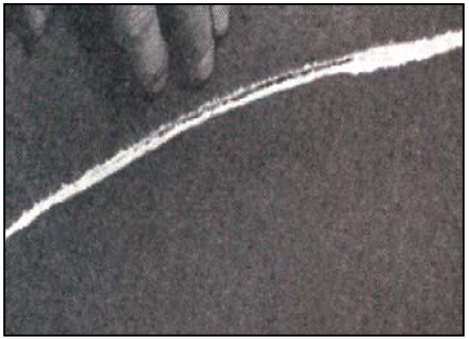


Damage

- Hull damage depends on type of the accident.
- Minor hairline cracks of the gelcoat and grazes are often caused by a sharp object.
- Collision impact can cause through-hull punctures or impact cracks.



Hairline cracks and grazes.



Severe grazing caused by scratching.

Annex II – Further readings and links

Anmarkrud, T. 2009. *Fishing boat construction: 4. Building an undecked fibreglass reinforced plastic boat.* FAO Fisheries and Aquaculture Technical Paper. No. 507. Rome, FAO. 2009. 70p. (available in English, French and Spanish languages at: https://www.fao.org/publications/card/en/c/6e38a2e5-b953-5243-a79c-b3de1494b24d/)

Coackley, N. 1991. *Fishing boat construction: 2. Building a fiberglass fishing boat.* FAO Fisheries Technical Paper 321. Rome. FAO. 84 pp. (available at https://www.fao.org/3/t0530e/T0530E.pdf)

FAO/ILO/IMO. 2012. *Safety Recommendations for Decked Fishing Vessels of Less than 12 metres in Length and Undecked Fishing Vessels.* Rome, FAO. 254 pp (available in 10 languages at https://www.fao.org/documents/card/en/c/3d78177f-bfeb-5566-ae97-a4cb55984b4f/)

Gulbrandsen, O. 2004. *Fishing boat designs: 2. V-bottom boats of planked and plywood construction*. FAO Fisheries Technical paper 134 rev.2. Rome. FAO. 64 pp. (available at: https://www.fao.org/3/y5649e/y5649e00.htm)

This practical guide to fibreglass reinforced plastic (FRP) boat repair in the tropics aims to help fishers to carry out simple repairs of FRP boats. Timely maintenance and repair will make an FRP boat last longer and will support the safety of fishers at sea. Every FRP boat gets some damage sooner or later. Most damage is small and can be repaired easily.

This guide gives advice on how to recognize specific damage, what materials and tools are needed to repair FRP, what repair techniques to use, the steps to follow and how to prevent boat damage.

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