



Marine Composites

Webb Institute
Senior Elective

Repair Procedures

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Ship Structural Failures

Mine Counter Measure Ship Collision with Dock



Christian Berggreen, Technical University of Denmark, 2008



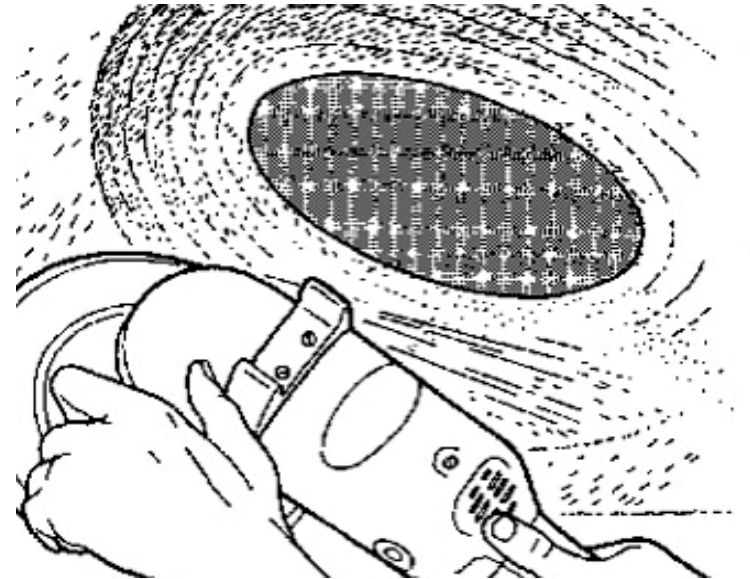
Damage Assessment

Damages can be found either by visual inspection, probing, or hammer sounding of the structure. Damage can be found from indicators such as the following:

- Cracked or chipped paint or abrasion of the surface
- Distortion of a structure or support member
- Unusual build-up or presence of moisture, oil, or rust
- Structure that appears blistered or bubbled and feels soft to the touch
- Surface and penetrating cracks, open fractures, and exposed fibers
- Gouges
- Debonding of joints



Grind Laminate to Determine Extent of Damage





Resin Repair Selection

Laminate	Original process used	Repair resin options	**Typical repair process options
Epoxy	Pre Preg	Epoxy	Pre Preg, Wet vacuum bag, Infusion
	Wet vacuum bag	Epoxy	Wet vacuum bag, Infusion
	Infused	Epoxy	Infusion, Wet vacuum bag
	Hand lay up	Epoxy	Hand Layup
Vinyl ester (VE)	Infused	VE, Epoxy	Infusion, Wet vac bag (if epoxy)
	Hand lay up	VE, Epoxy	Hand lay up
Polyester (PE)	Infused	PE*, VE, Epoxy	Infusion, Wet vac bag (if epoxy)
	Hand lay up	PE*, VE, Epoxy	Hand lay up
* Ideally only use polyester for repair if same exact resin is used as in original laminate. Otherwise use VE or Epoxy.			
**Default to original designer/builder or laminate engineer recommendations if available.			

Meade Gougeon, "Fiberglass Repair Tips," U.S. Sailing, 2013



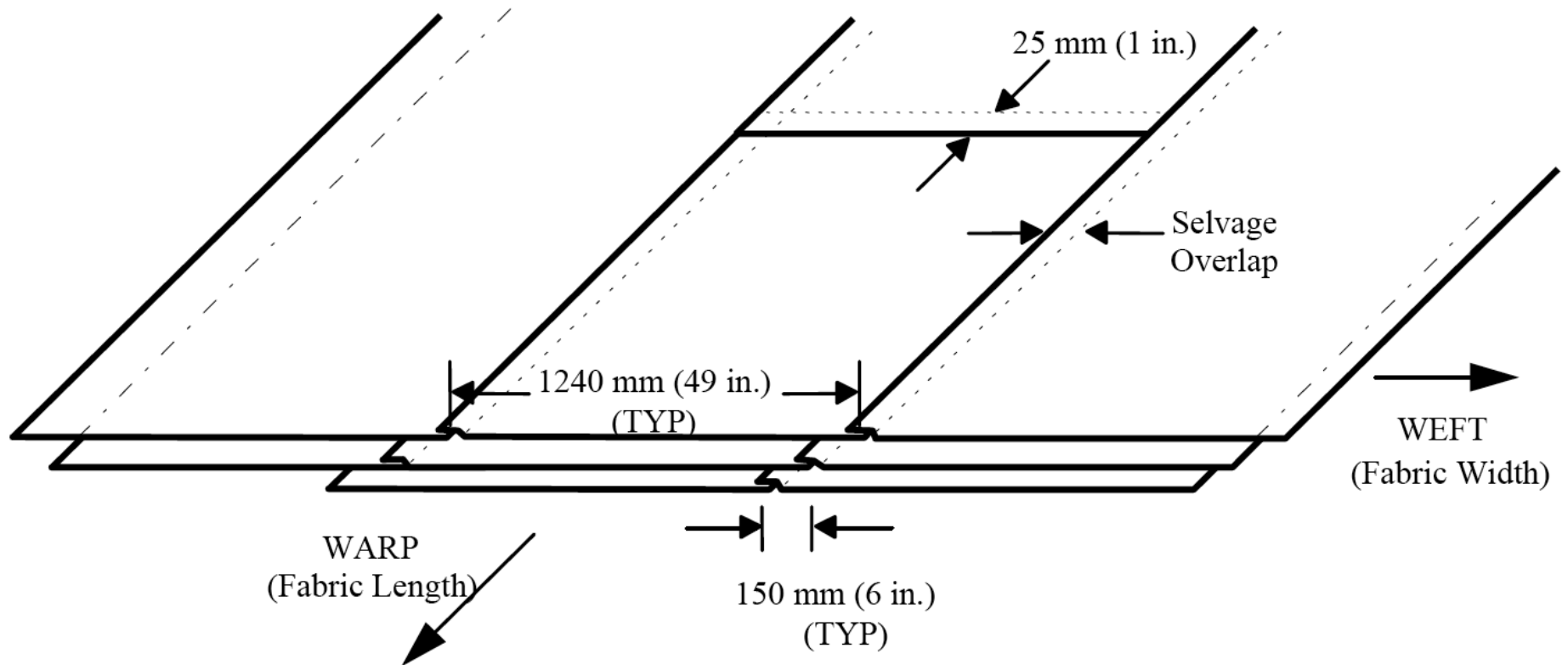
Recreational Boat Repair Guidelines

Depth of defect	Repair
Less than 1/32 inch	gel repair
Less than 1/16 inch	putty
Greater the 1/16 inch	laminare





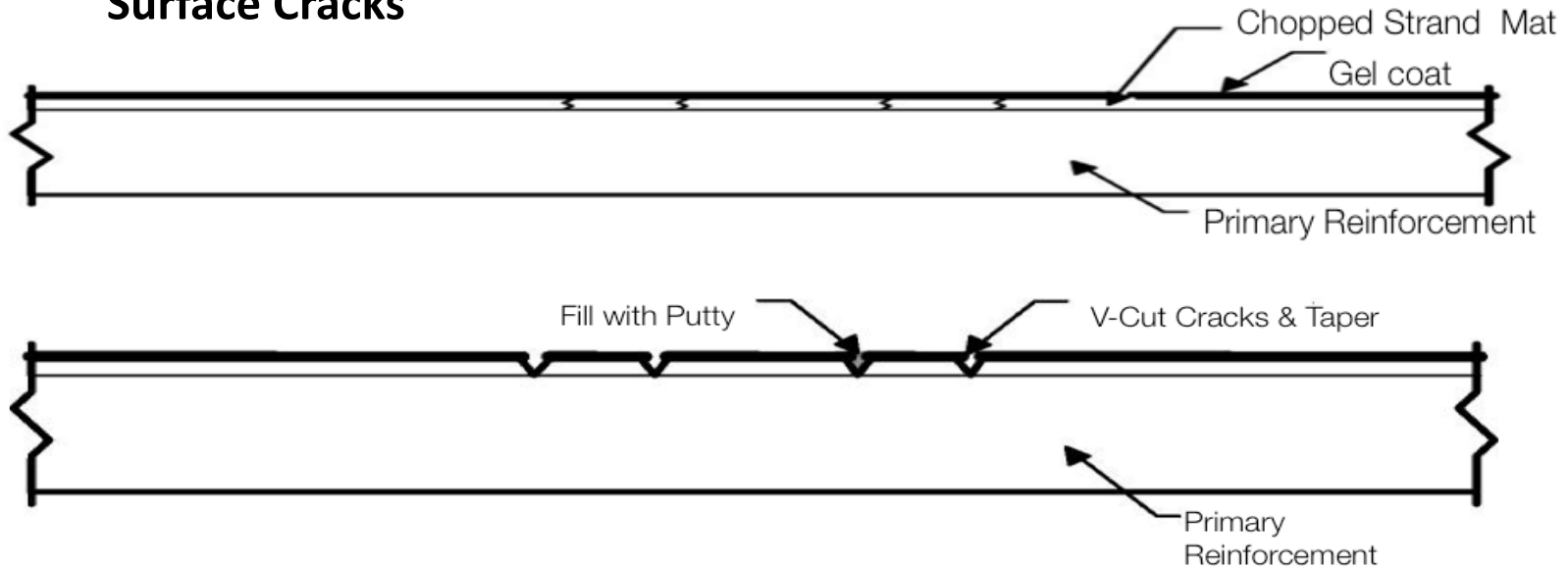
Ply Overlap Requirements



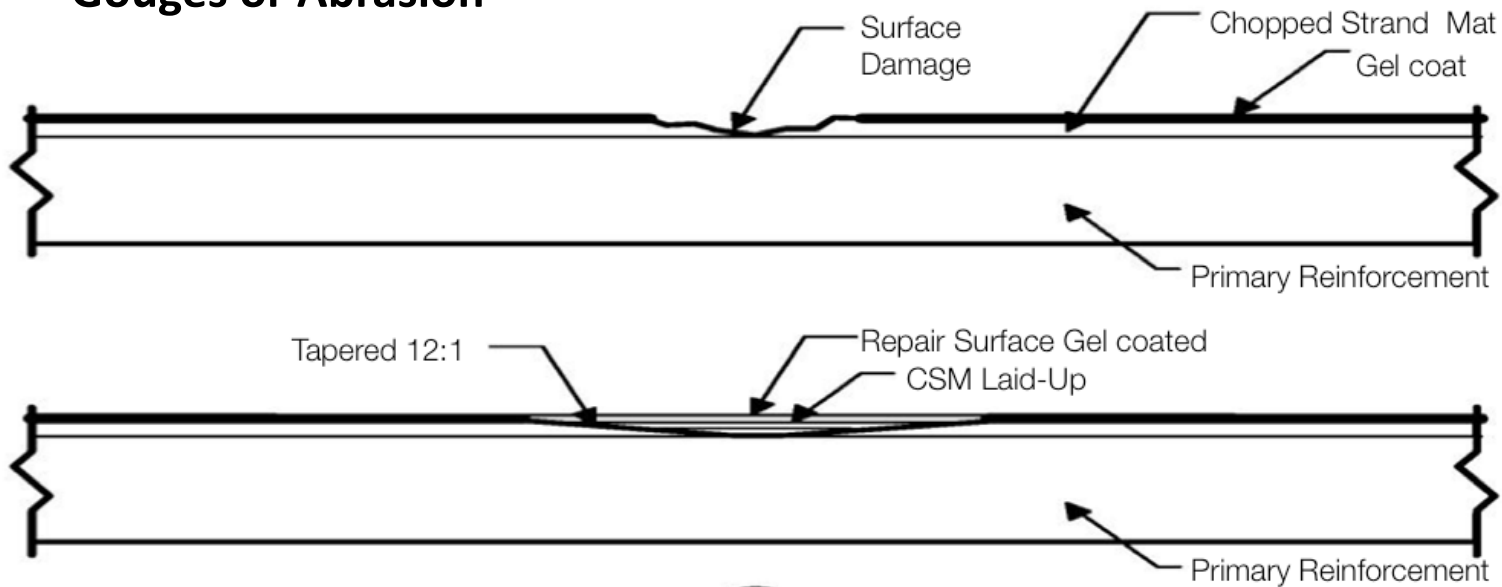


Surface Damage Repair

Surface Cracks

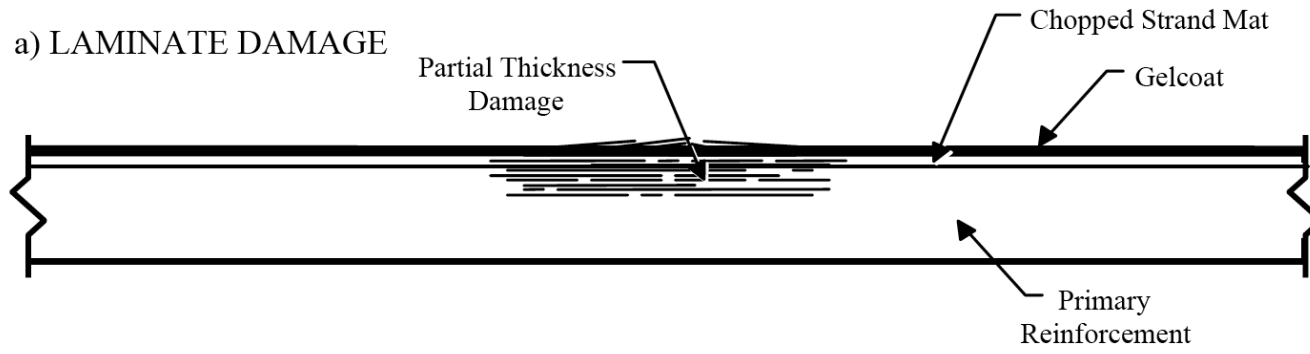


Gouges or Abrasion

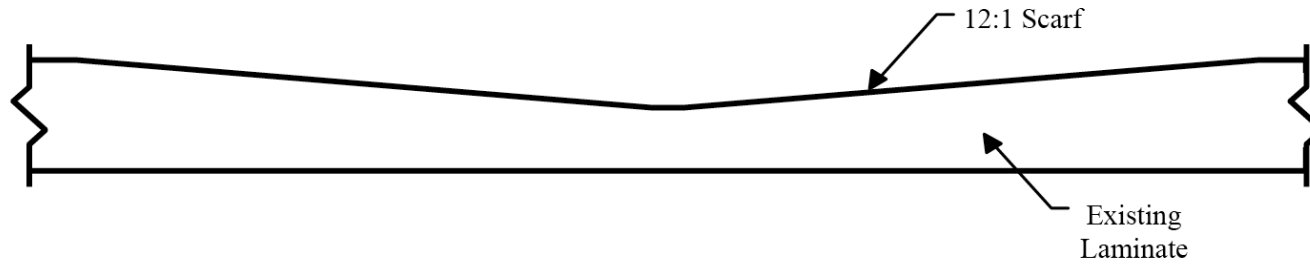




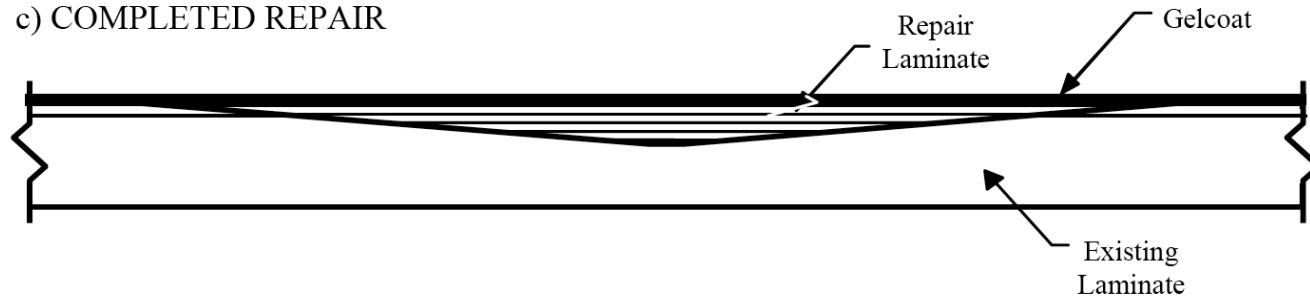
Partially Through Thickness Damage Repair



b) DAMAGE REMOVED, SURFACE PREPARED



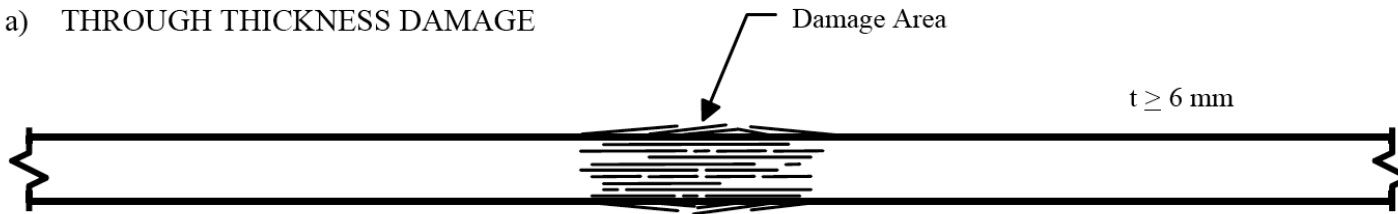
c) COMPLETED REPAIR



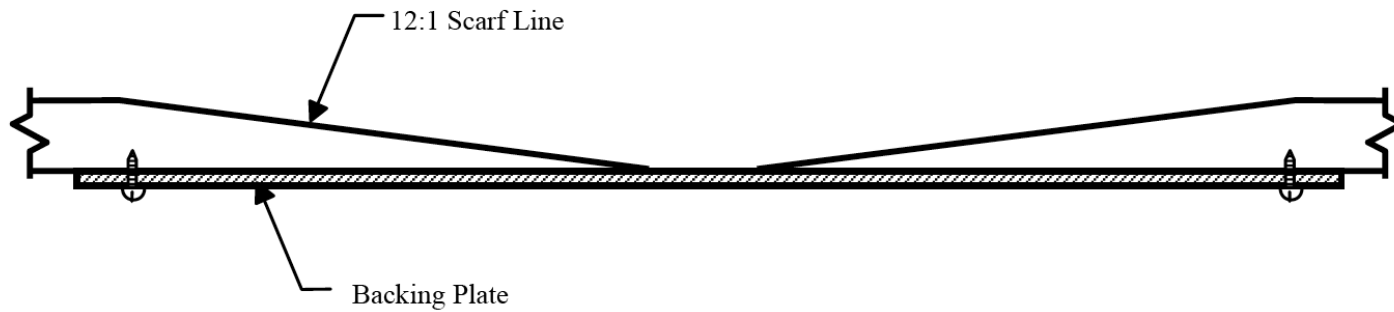


Single Sided Scarf Repair on Solid Laminate

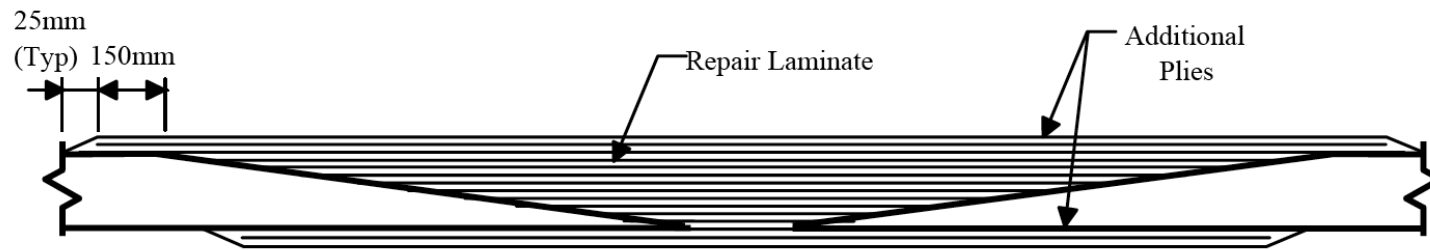
a) THROUGH THICKNESS DAMAGE



b) BACKING PLATE INSTALLATION



c) COMPLETED REPAIR





Scarf Joint Preparation

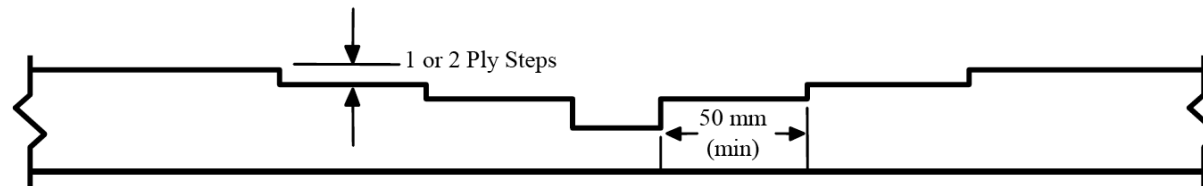
Single-Sided Scarf



12:1 Tapered Scarf

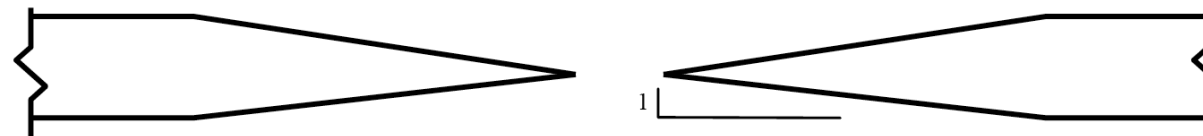


12:1 Tapered Scarf Through Thickness Damage

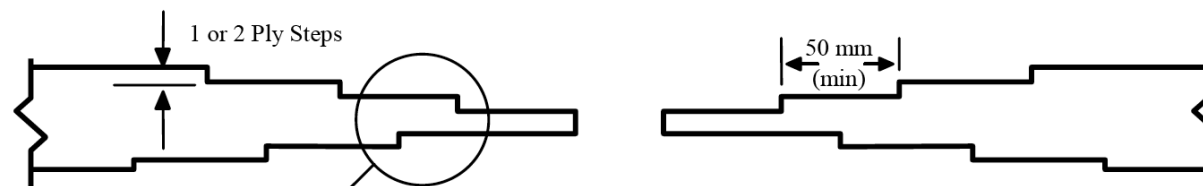


Stepped Scarf Joint

Double-Sided Scarf



12:1 Tapered Scarf

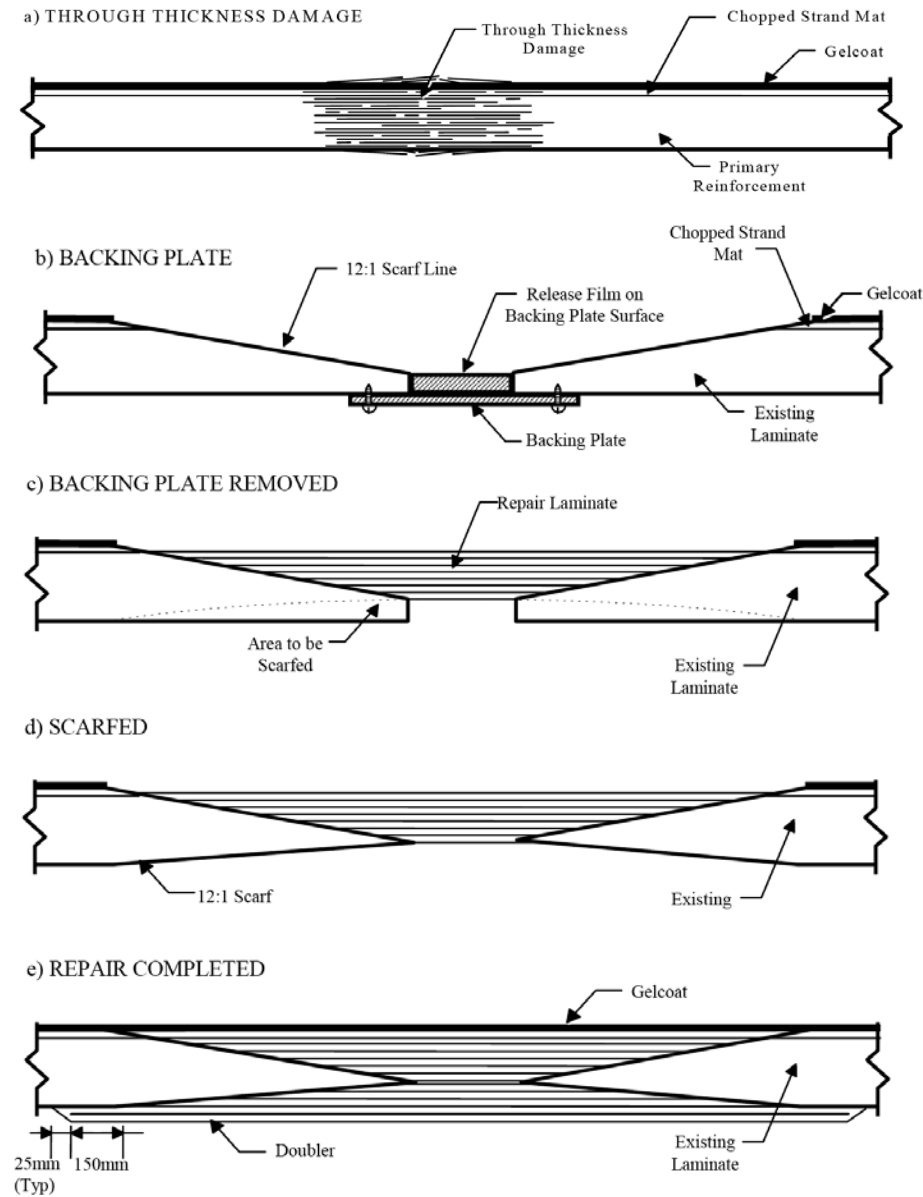


Staggered Steps

Stepped Scarf Joint



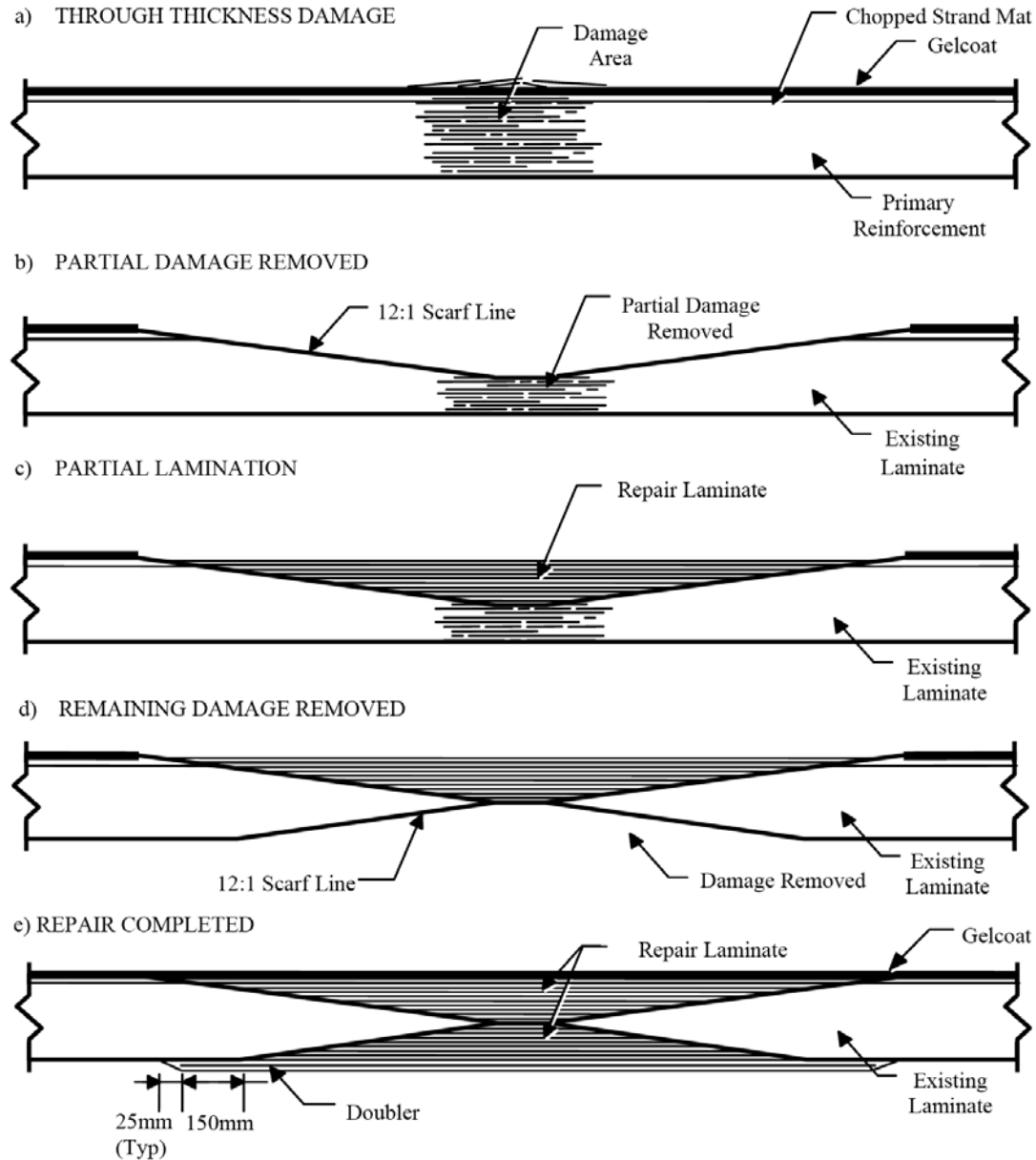
One Sided Scarf Repair - Backing Plate Installation



Note: Repair Shown With Additional Plies Onto Non-Molded Side



Repair Using Damaged Section as Backing Plate

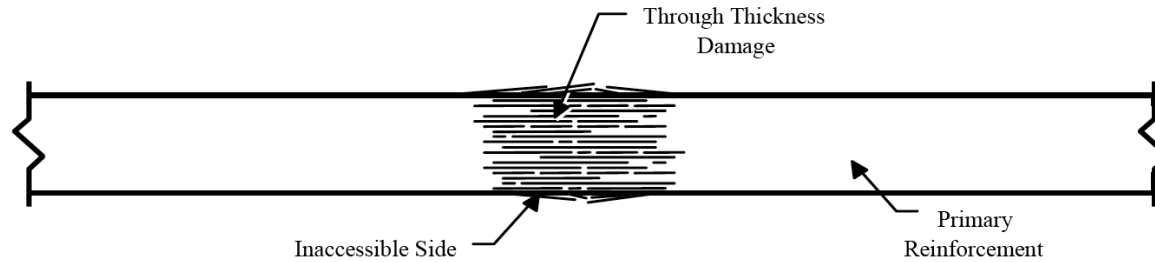


Note: Repair Shown With Additional Plies on the Non-Molded Side

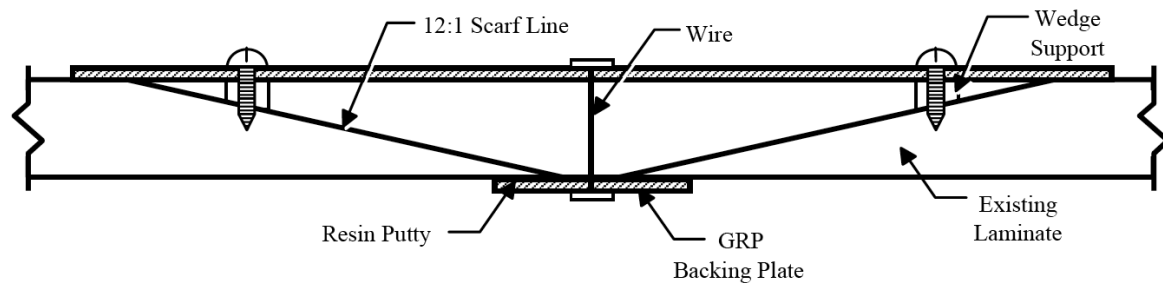


Backing Plate Installation - Access from One Sided Repair

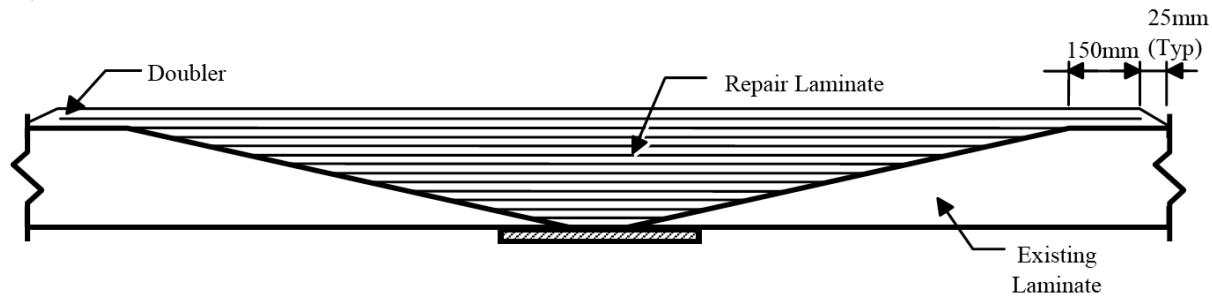
a) DAMAGED LAMINATE



b) BACKING PLATE INSTALLATION



c) COMPLETED REPAIR



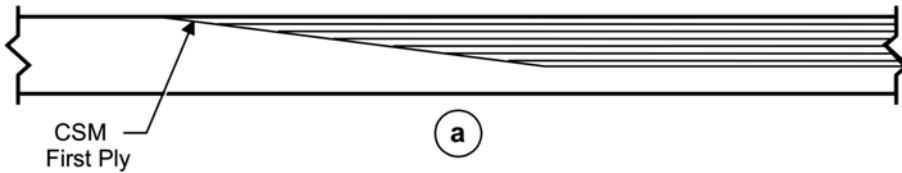
Note: Repair Shown With Additional Plies for Added Reinforcement



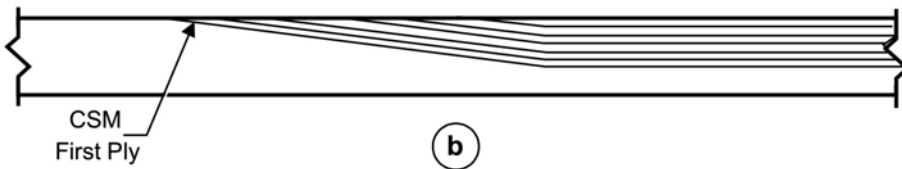
Planning Composite Repair

Ply Taper Alternatives

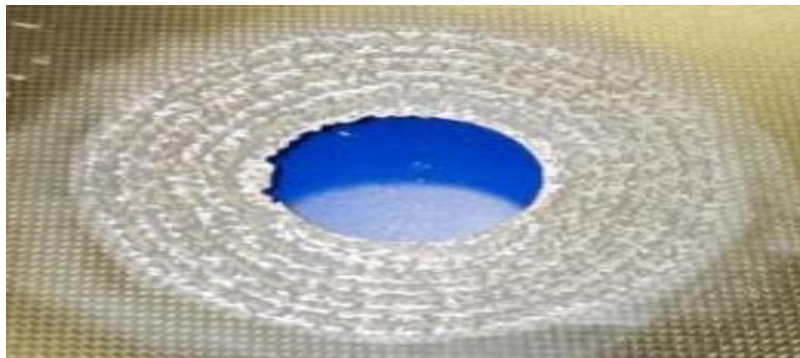
BUTTED LAY-UP



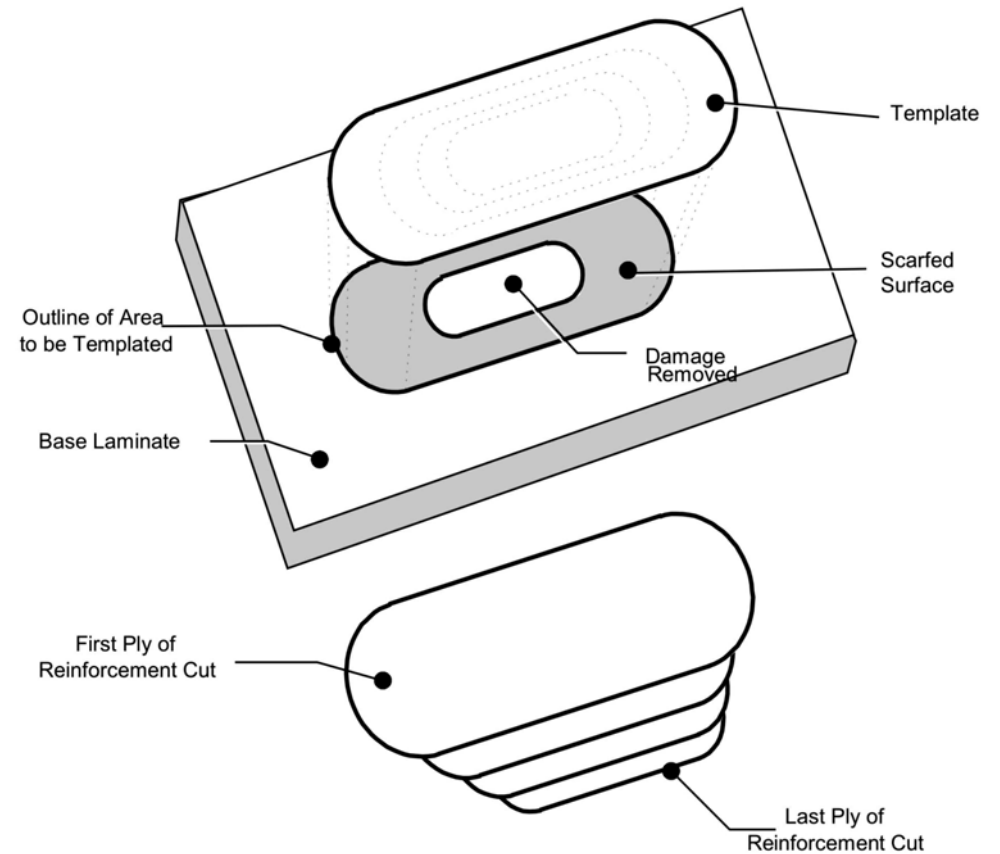
PARALLEL LAY-UP



Placing largest ply last provides best moisture resistance – placing largest ply first provides best bond



Reinforcement Preparation

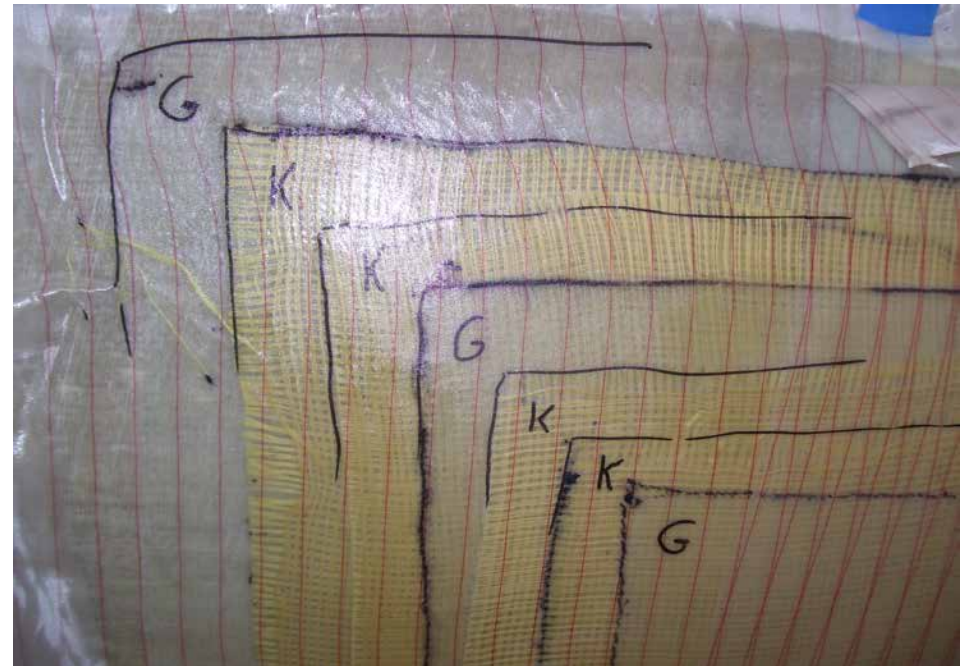
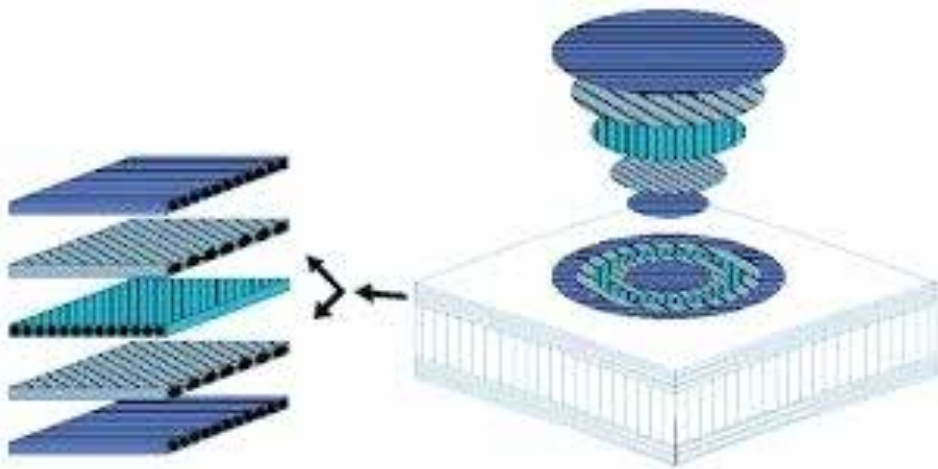


template repair plies



Layout Repair Laminate

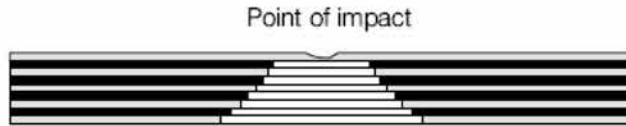
It is necessary to first determine what materials were used in the original manufacturing process, the matrix resin, fibers/fabrics and their ply orientations





Types of Sandwich Damage

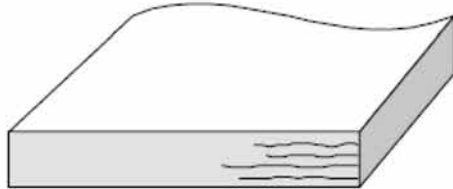
Delamination following impact on a monolithic laminate



Underlying damage can extend to a much greater extent in laminate structures.

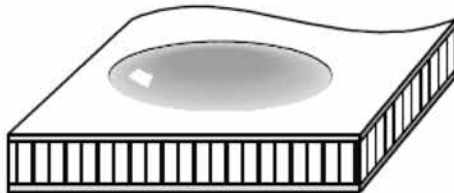
Laminate Splitting

The damage does not extend through the full length of the part. The effects on the mechanical performance depend on the length of split relative to the component thickness.



Heat Damage

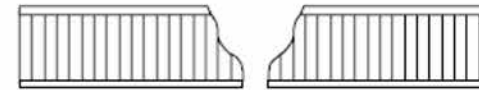
A local fracture with separation of surface plies. Its effect on the mechanical performance depends on the thickness of the part.



Dents in Sandwich Structure



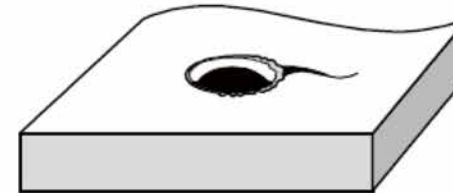
Puncture Damage in a Sandwich Structure



Both skins may be damaged.

Bolt Hole Damage

The damage could be elongation of the hole causing laminate splitting, or damage to the upper plies.

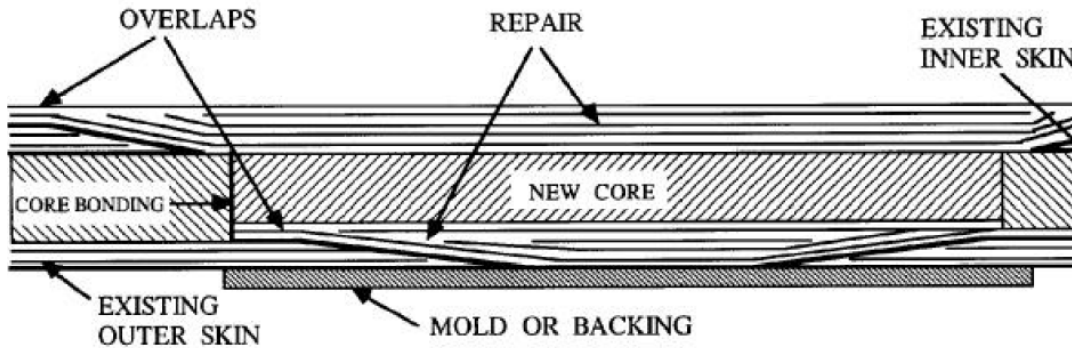


from Hexcel "Guide to Composite Repair"



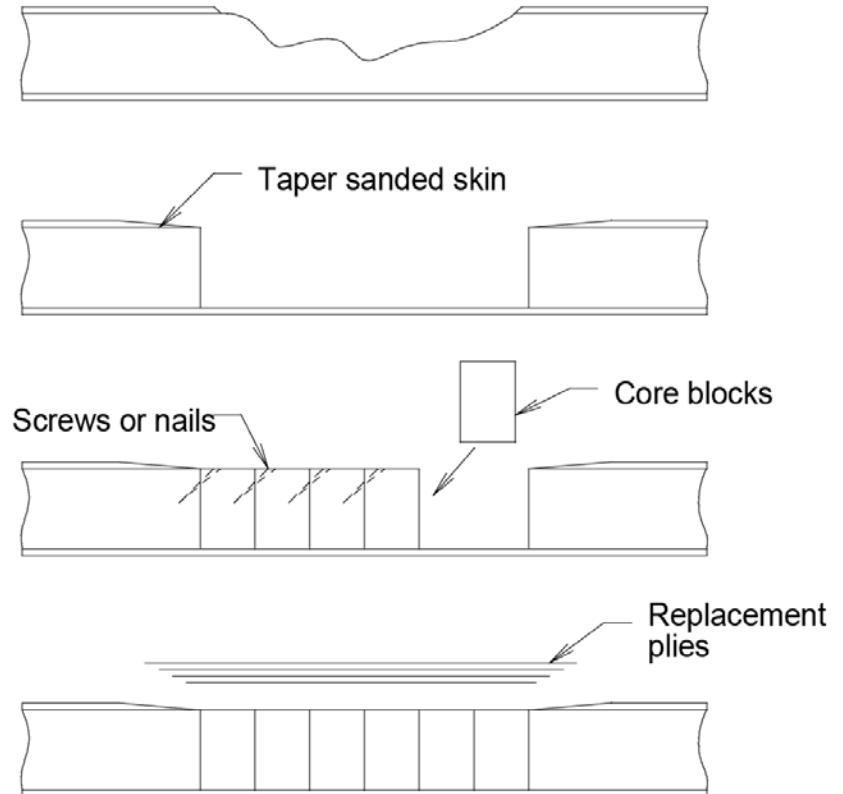
Sandwich Laminate Damage Repair

Sandwich Repair Schematic



Technique for Repairing Damage to Sandwich Construction
[USCG NVIC No. 8-87]

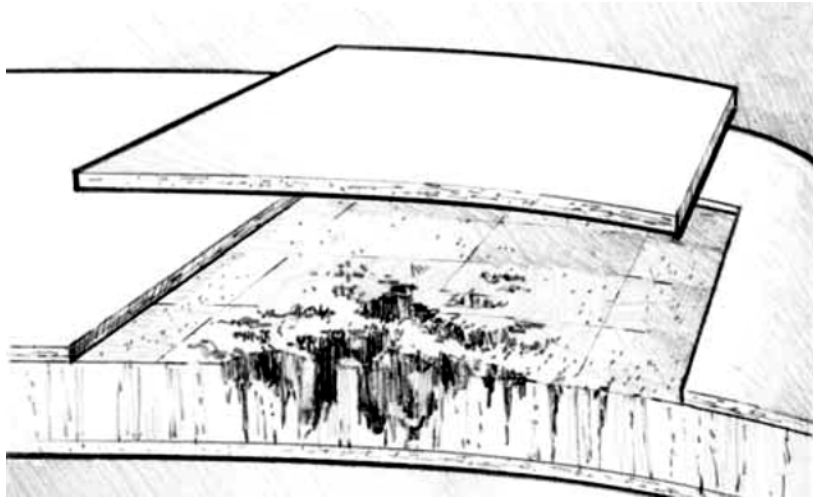
Repair technique for damage to GRP/foam sandwich panels developed for the Swedish MCMV



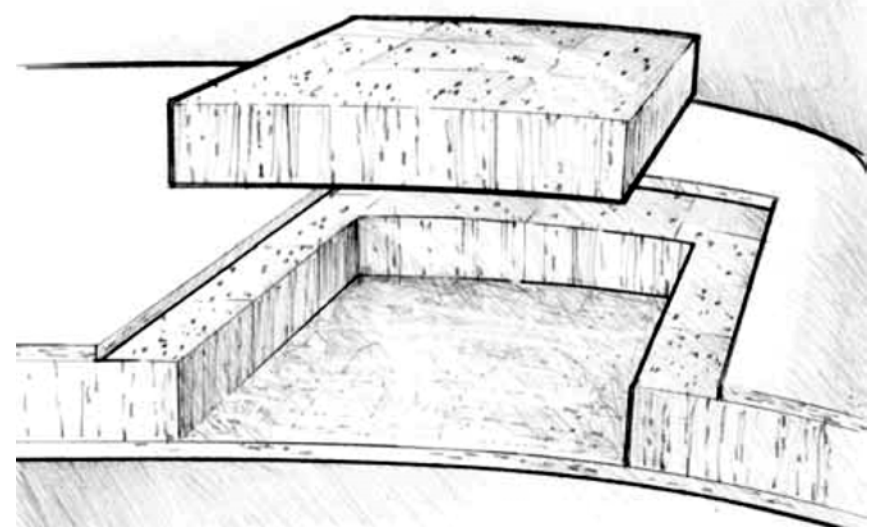


Core Repair

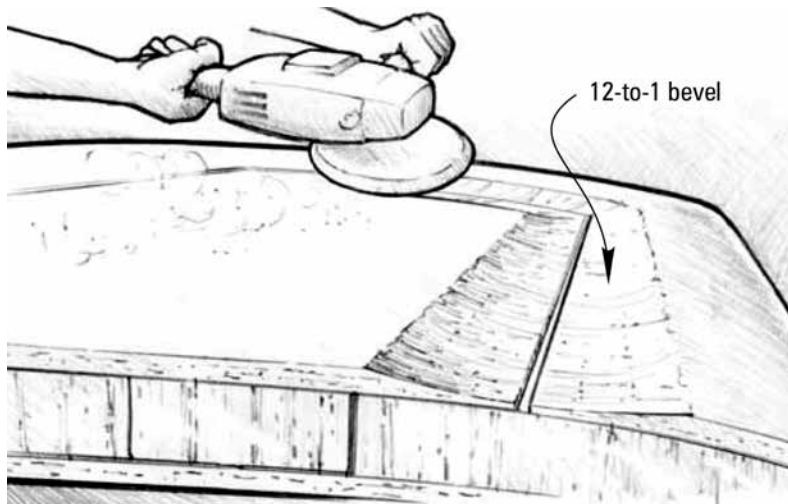
Cut through the skin only, outside of the area of delamination



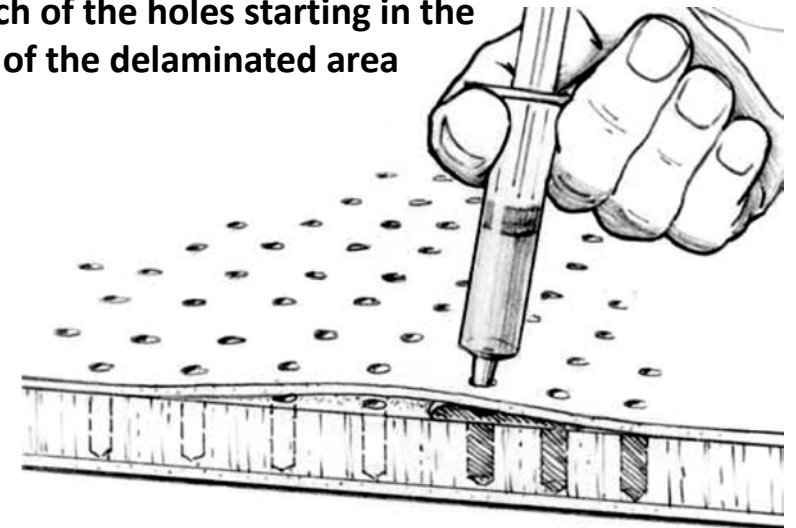
Fit a new piece of core material to match the shape, thickness and density of the damaged core material



Grind a bevel on the edges of the joint, so the joint repair patch can be faired flush with the surface



Inject the epoxy mixture under the skin through each of the holes starting in the center of the delaminated area

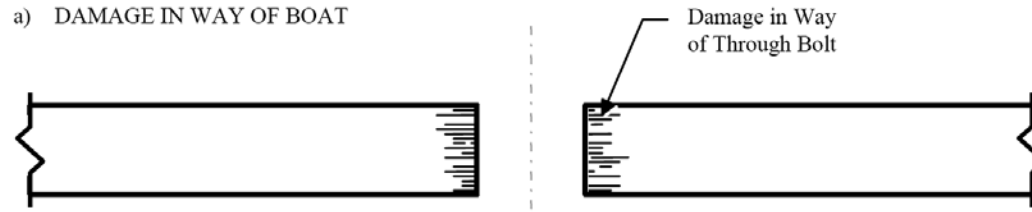


Gougeon Brothers Inc., "WEST System Fiberglass Boat Repair & Maintenance," 15th Edition, April 2011

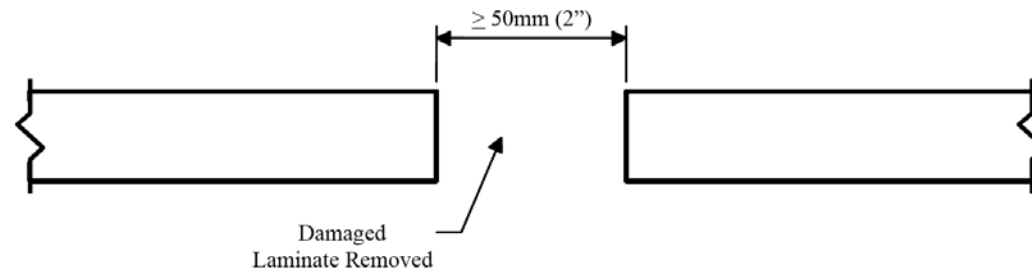


Repair in Way of Through Bolt Failure

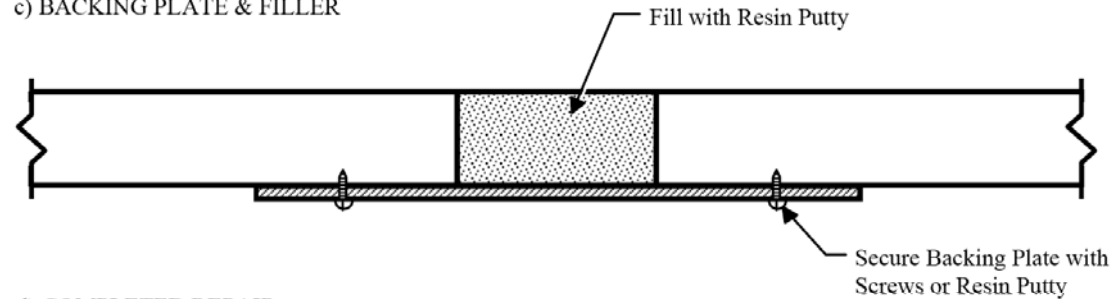
a) DAMAGE IN WAY OF BOAT



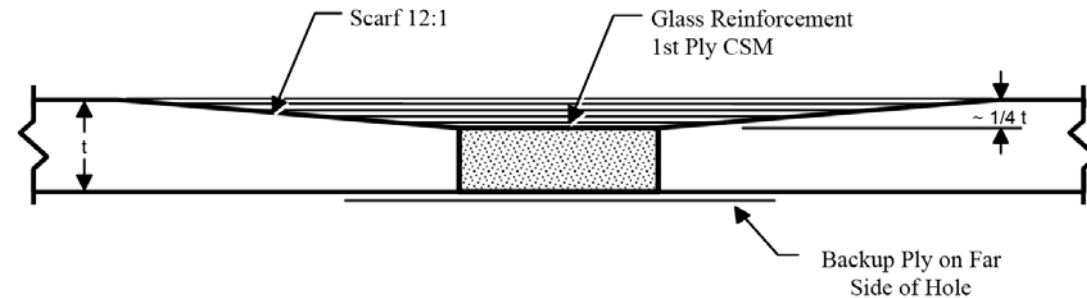
b) LAMINATE REMOVAL



c) BACKING PLATE & FILLER



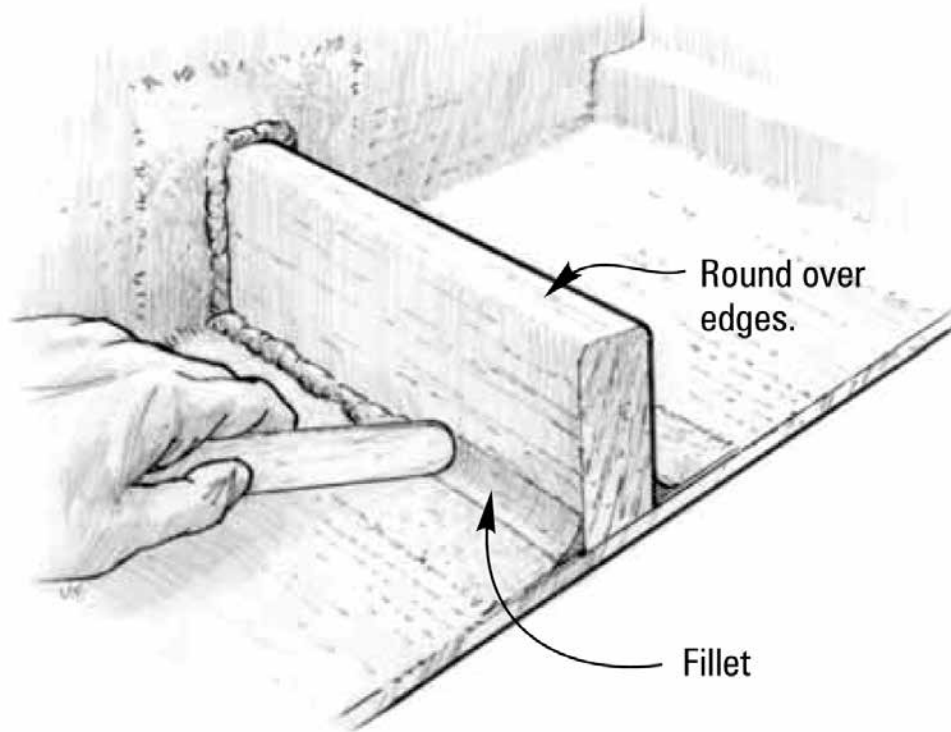
d) COMPLETED REPAIR



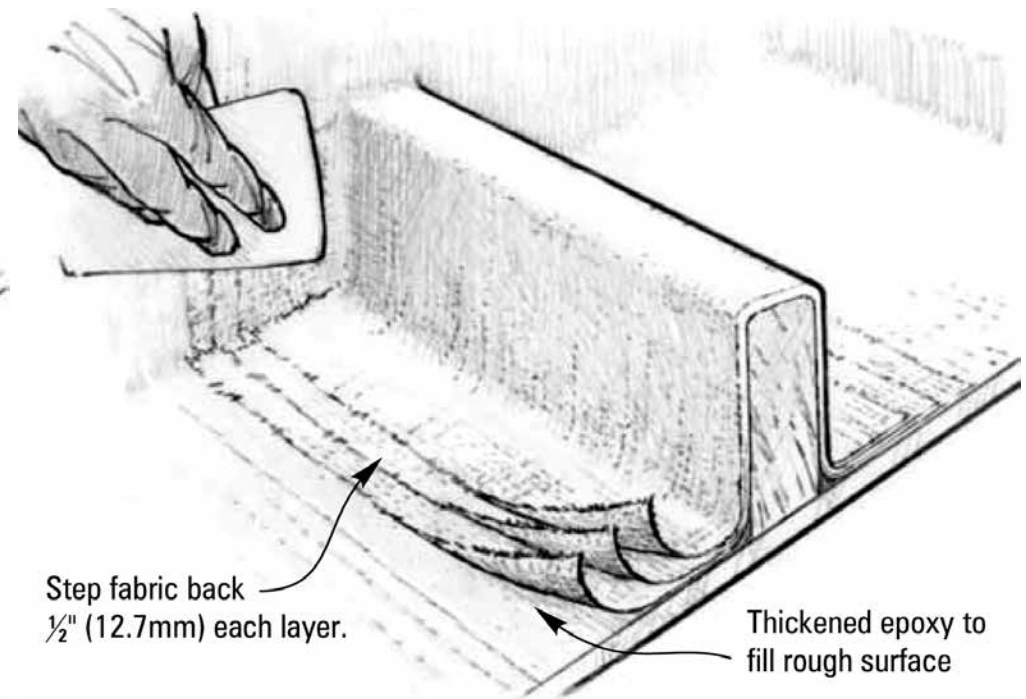


Stiffener Repair

Create Fillets



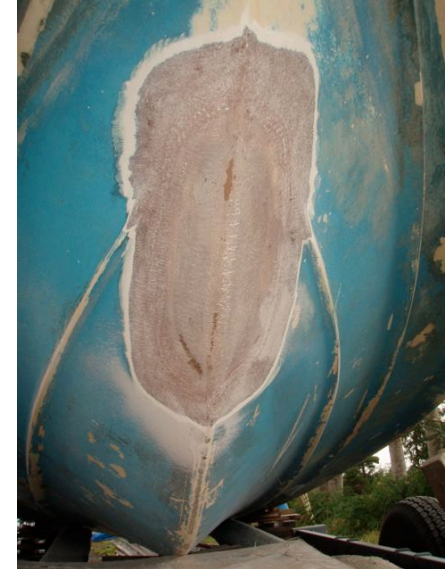
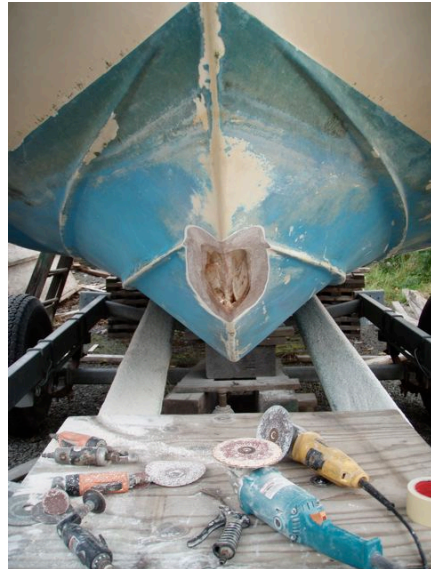
Taper Reinforcement Layers



Gougeon Brothers Inc., "WEST System Fiberglass Boat Repair & Maintenance," 15th Edition, April 2011

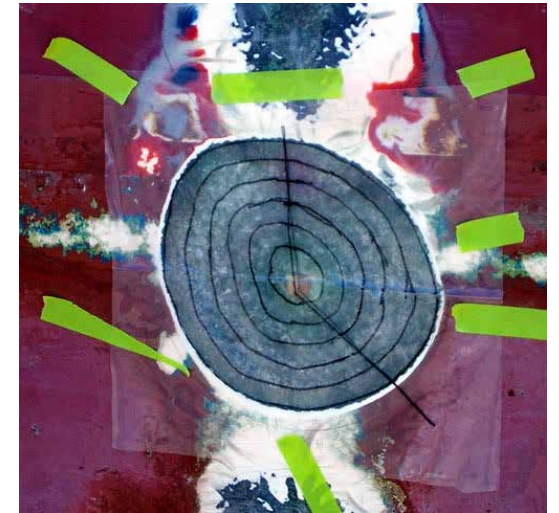
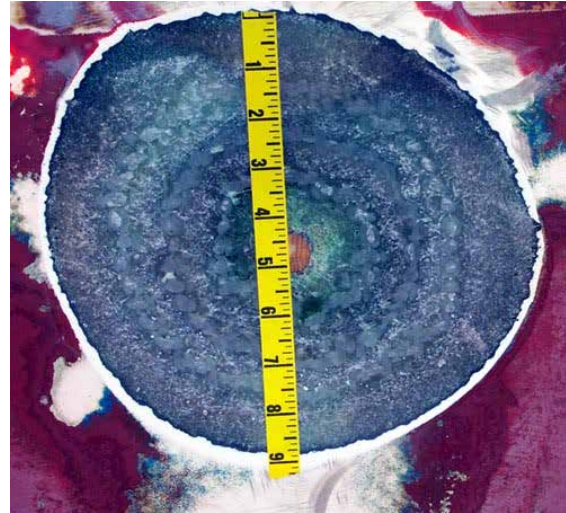


Small Boat Repair Example





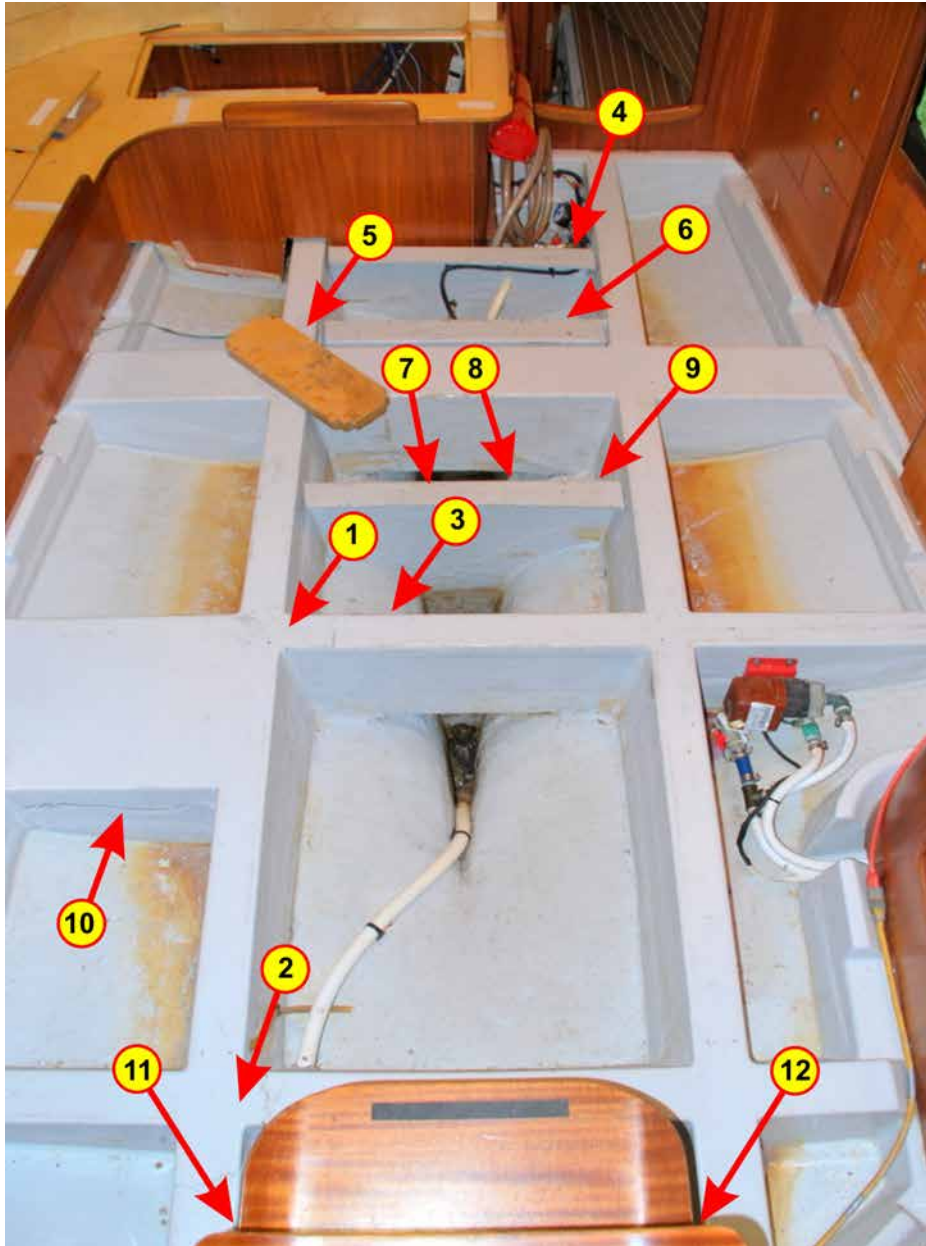
Repair Reinforcement Geometry



Tony Guild, Maritime Technical Services



Framing Repairs



2

1. Grind laminate 9" beyond detected damage
2. Repair with structural laminate up to 16 layers for full thickness



5

1. Grind laminate 4" beyond detected damage
2. Create corner radius with structural putty
3. Repair tabbing with E-BXM 1708/E-LTM 1808/E-BXM 1708 with 1" taper (smallest first)





Overhead Repair



Osprey Marine Composites



Install Transverse Frames





Repair to 120-Foot Motoryacht



Peeling started on starboard side bow area, failed fairing, delamination and failed bottom paint



Multiple layers of existing fairing



Delamination



Mark area for repair reinforcements



Waterline lamination in progress



Using vacuum bags to consolidate repairs



Damaged Core Replacement



Roby Scalvini, Marine Survey Bureau



Laminate Quality Requirements

The repair should be inspected prior to finishing and the following should not be observed:

- No open voids, pits, cracks, crazing, delaminations or embedded contaminants in the laminate;
- No evidence of resin discoloration or other evidence of extreme exotherm;
- No evidence of dry reinforcement as shown by a white laminate; and
- No wrinkles in the reinforcement and no voids greater than ½" (12 mm). (Voids greater than ½" (12 mm) should be repaired by resin injection. Two 3/16" (5 mm) diameter holes can be drilled into the void; one for injecting resin and the other to let air escape and verify that hole is filled).

The surface of the repair should be smooth and conform to the surrounding surface contour. The degree of cure of the repaired laminate should be within 10% of the resin manufacturer's specified value, as measured by a Barcol Hardness test.



Repair to Offshore Metal Structures

'Clockspring' repair to an externally corroded pipe



Carbon fiber repair of 14 inch tee joint on a seawater return header



“The cost effective use of fibre reinforced composites offshore,” University of Newcastle Upon Tyne for the UK Health and Safety Executive, 2003



Repair Summary

- In-plane properties are always degraded for repaired composite structures
- 20:1 scarf repairs are more effective than repairs made involving less area
- Special skills, materials and environmental controls required for effective repairs
- Aerospace level repair methods not envisioned for typical marine structures
- Single-skin, E-glass laminates are easier to repair than carbon fiber sandwich constructions