Marine Composites

Webb Institute

Senior Elective

Framing, Stiffener and Foundation Design

Eric Greene, Naval Architect
EGAssoc@aol.com
410.703.3025 (cell)
http://ericgreeneassociates.com/webbinstitute.html

High-Efficiency Recreational Power Boat

Structure Showing Framing with Carbon Skins over PVC Core

Water-Jet Cut and Folded Settees

Presented by Eric Jolley, Bieker Boats, Seattle, 2008, WA, USA at the First Chesapeake Power Boat Symposium, Annapolis, MD, USA

Bulkhead Installation

Bulkheads installed in epoxy composite 54' sloop from Alden Yachts of Portsmouth, RI

This carbon fiber/Nomex bulkhead has the attachment flange molded with the bulkhead and bonded to the hull with a flexible epoxy adhesive

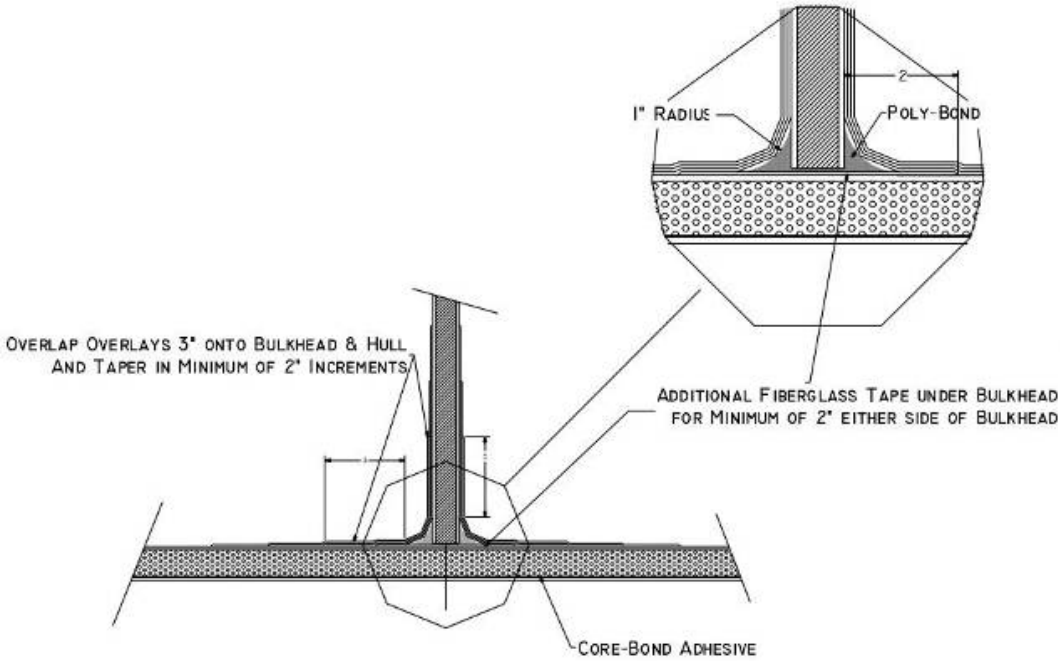
Bonded Pultruded Structural Members

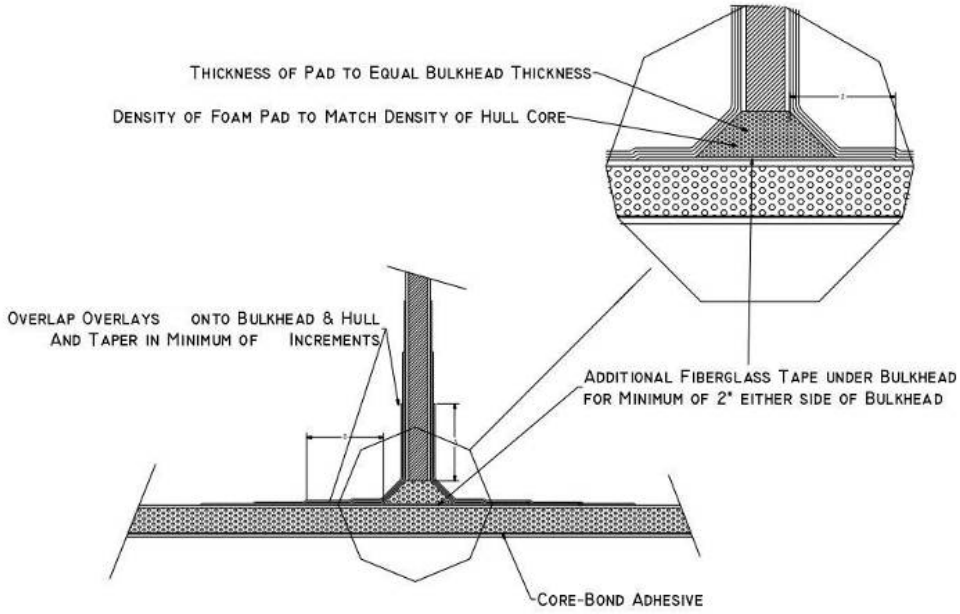
Atlas Hovercraft of Florida planned to build commercial hovercrafts in the US using bonded pultruded structural profiles to develop the large, flat surfaces.

Frigate to Yacht Conversion

Pultruded stiffeners used by Compmillennia, LLC, Washington, NC

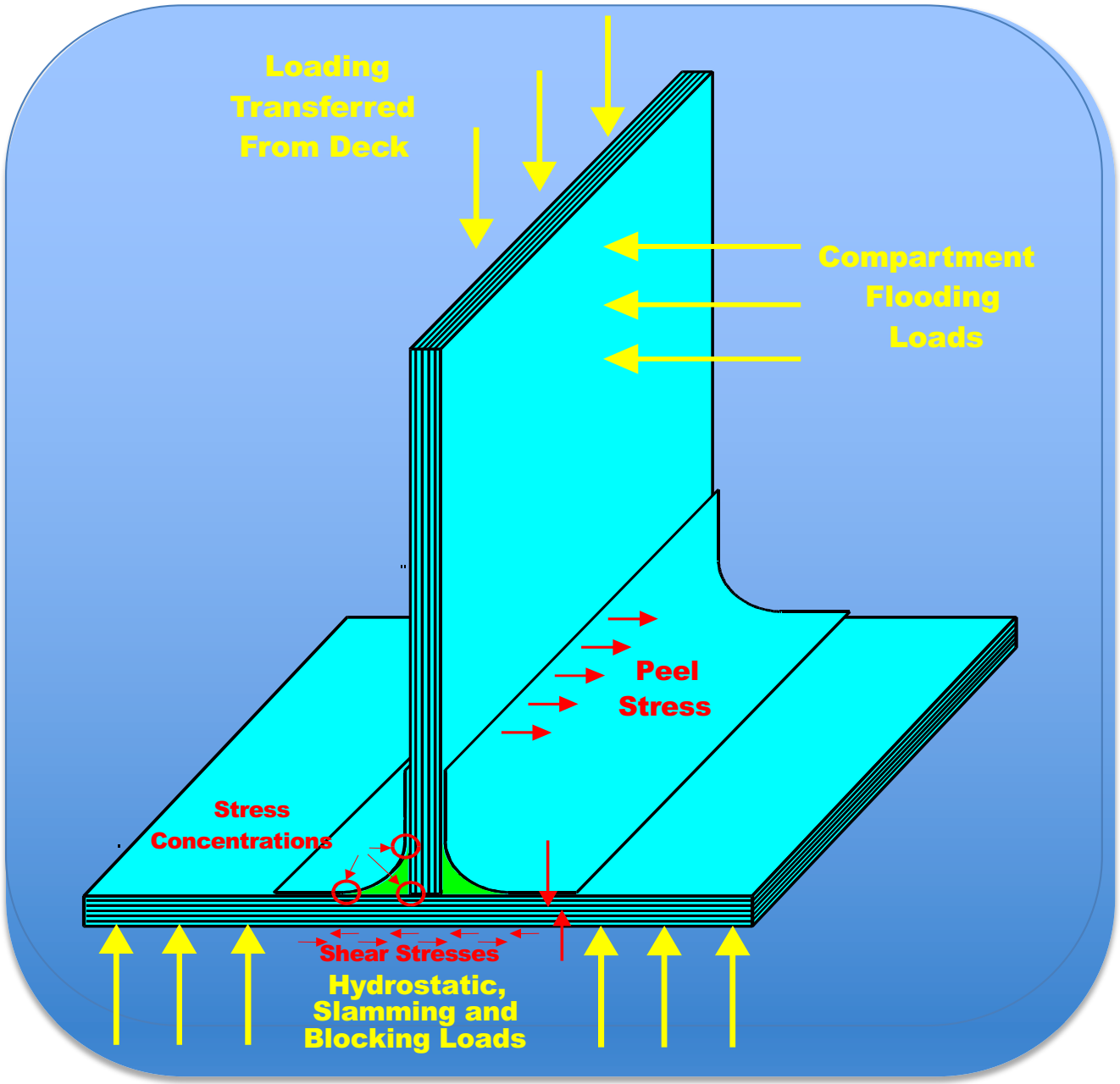
Bulkhead Detail with Putty Fillets





Illustrations courtesy of ATC Chemical Corporation (now Gurit). Drawing is for guidance only – actual laminates should be engineered to specific requirements in accordance with classification society rules.

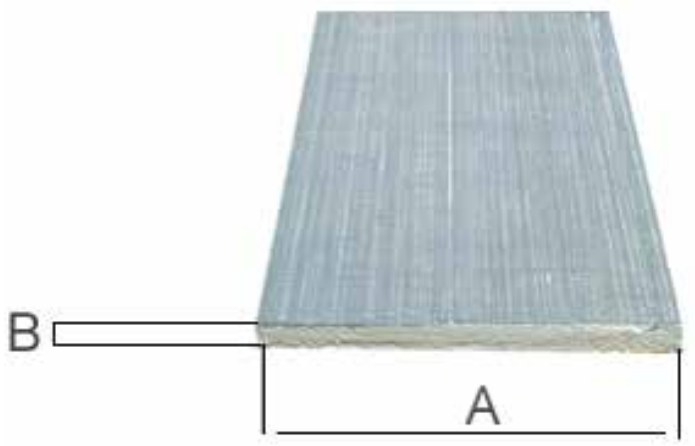
Bulkhead Attachment Stresses



Preform Bulkheads

PRISMA preformed stringers are shown here during construction of a 42-ft Cigarette hull

Stock preform bulkhead



Bulkheads Specs:0-90 or +- 45 24 oz Fiberglass w/Non-woven Polyester Backing; 2 PCF Flotation Grade Plyurethane Foam

Suggested Applications: Easily Patterned and Cut for Bulkheads, Wings, Insulated Fish Boxes and Compartments

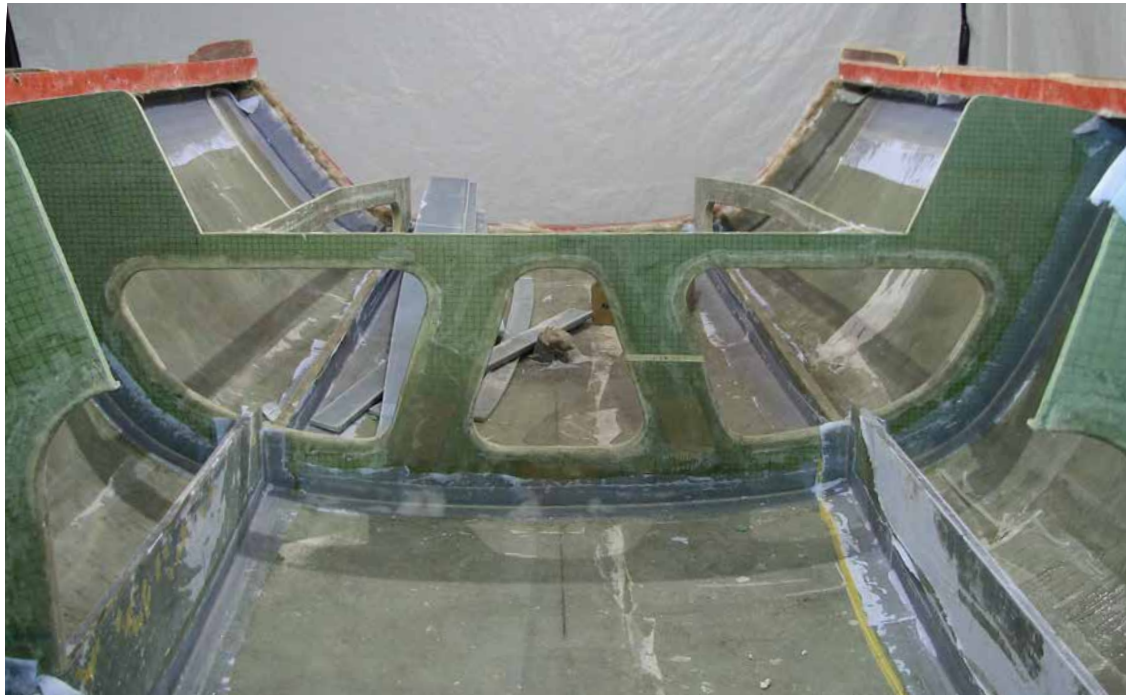
Part ID	Base Width (A)	Height (B)
BLK-4824	24 1/8"	2"

Honeycomb-Cored Carbon Fiber Bulkheads

Bulkhead Installation

Bulkheads installed in epoxy composite 54' sloop from Alden Yachts

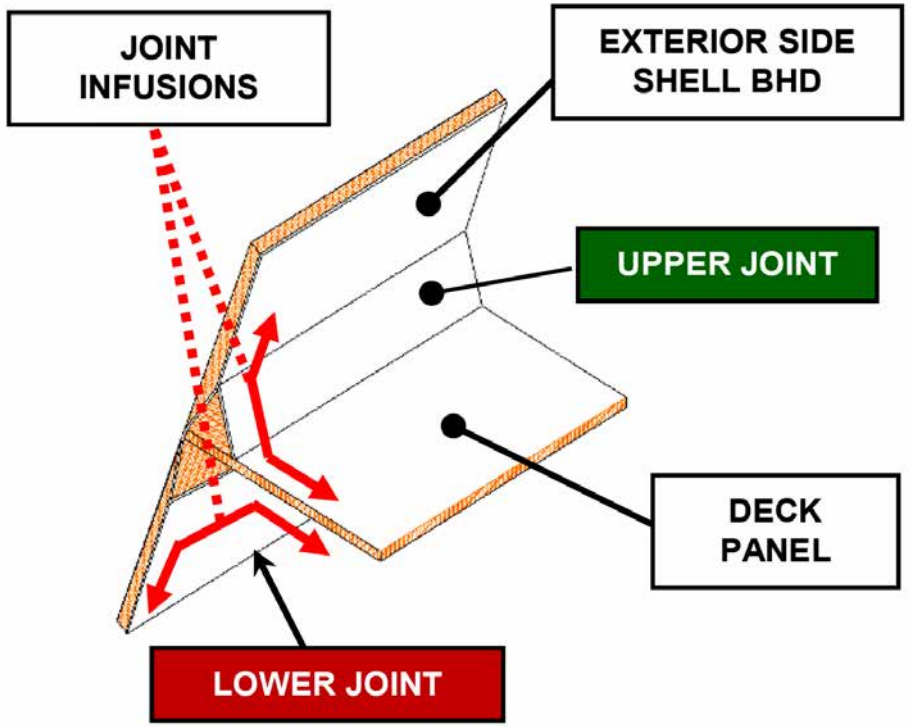
Cockpit support bulkheads on lightweight racing sailboat

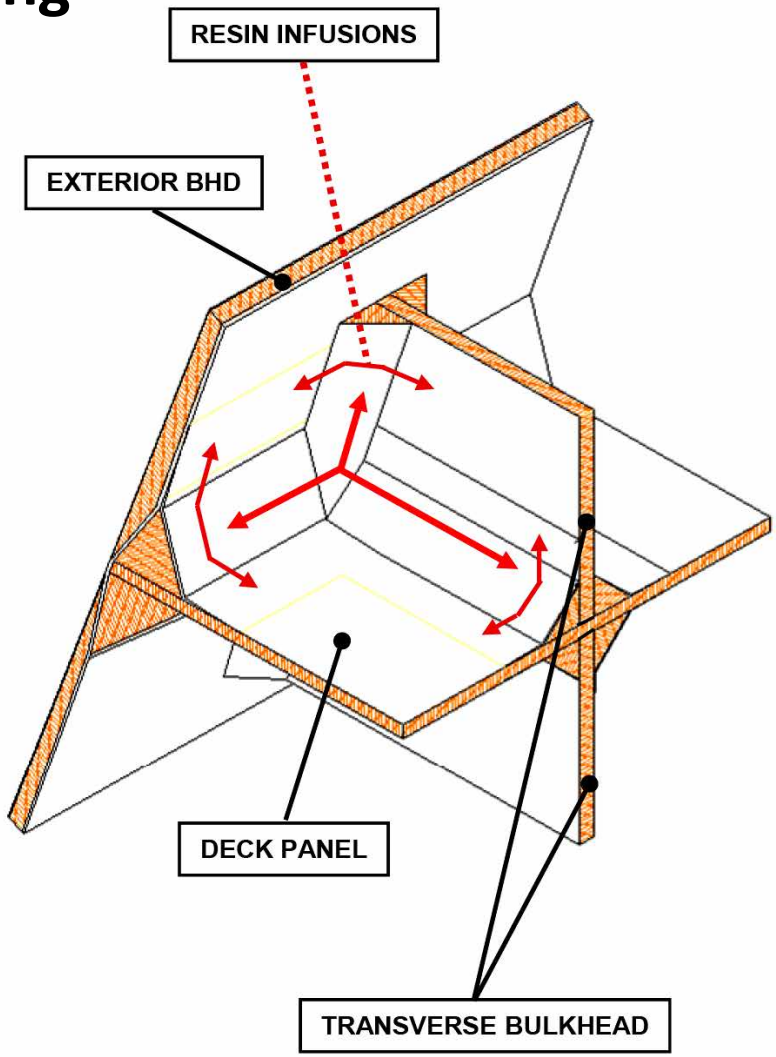


www.boatdesign.net

DDG 1000 Deckhouse Secondary Bonding

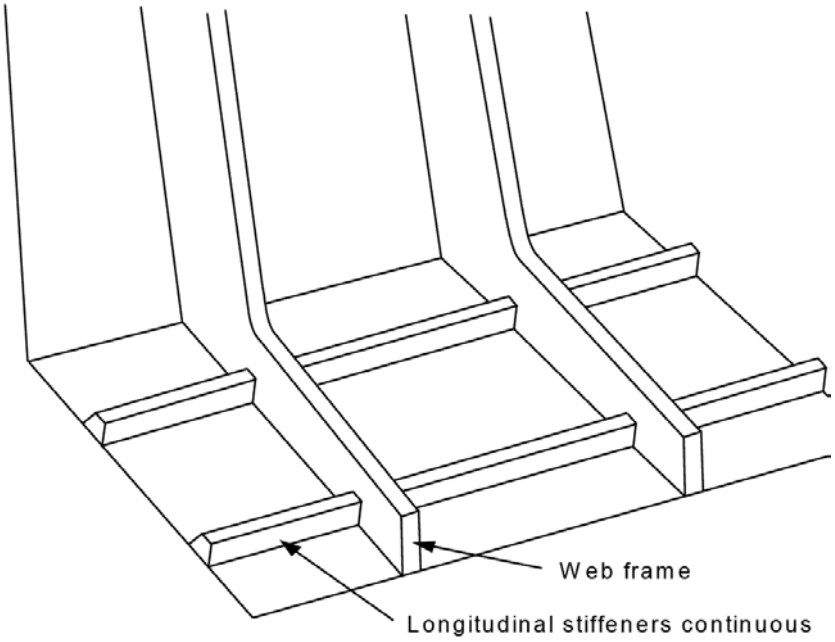
Complex 2D Joint (below) and 3D Joint (right)

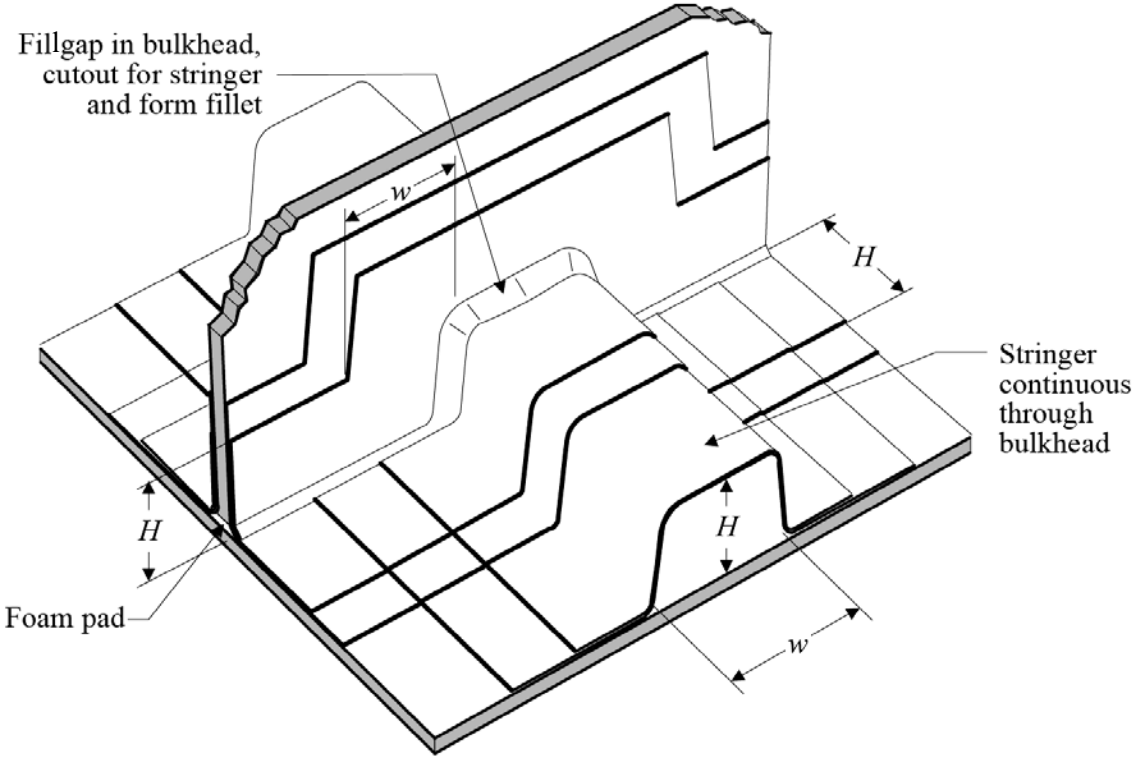




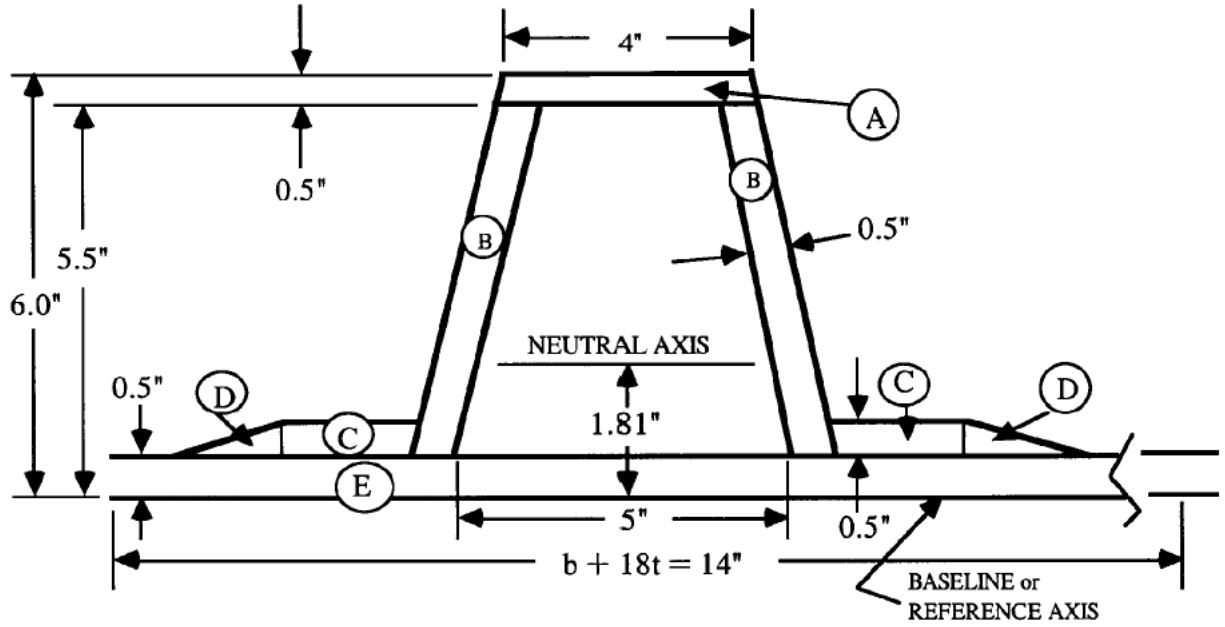
The DDG 1000 composite deckhouse contains over 8,500 linear feet of 2D composite joints and 460 3D joints

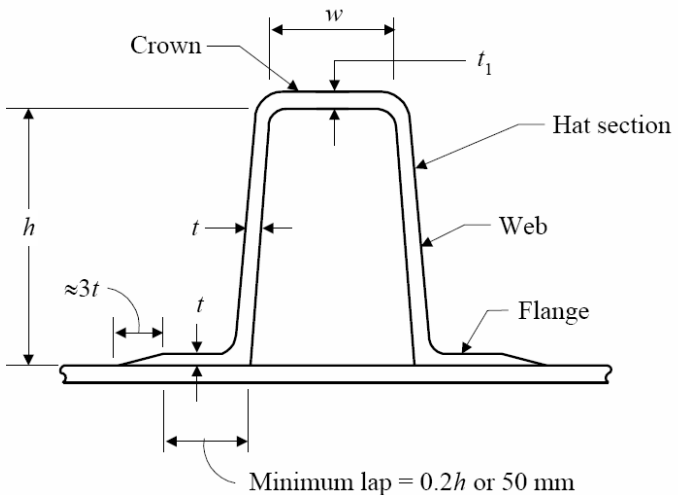
Frame and Longitudinal Intersections

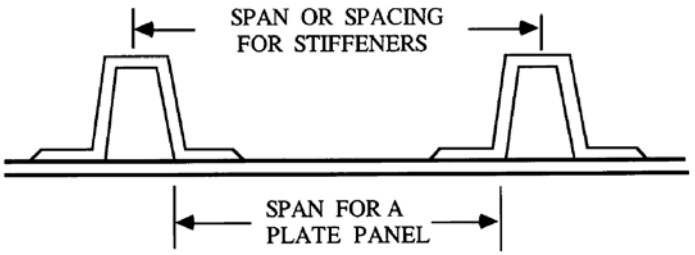




Hat Stiffeners







$$d_{NA} = \frac{\sum Ad}{\sum A} = \frac{30.55}{16.85} = 1.81 \text{ inches}$$

$$I_{NA} = \sum i_o + \sum Ad^2 - [\, Ad^2 \,] = 10.86 + 115.92 - [16.85 \text{ x } (1.81)^2] = 71.58$$

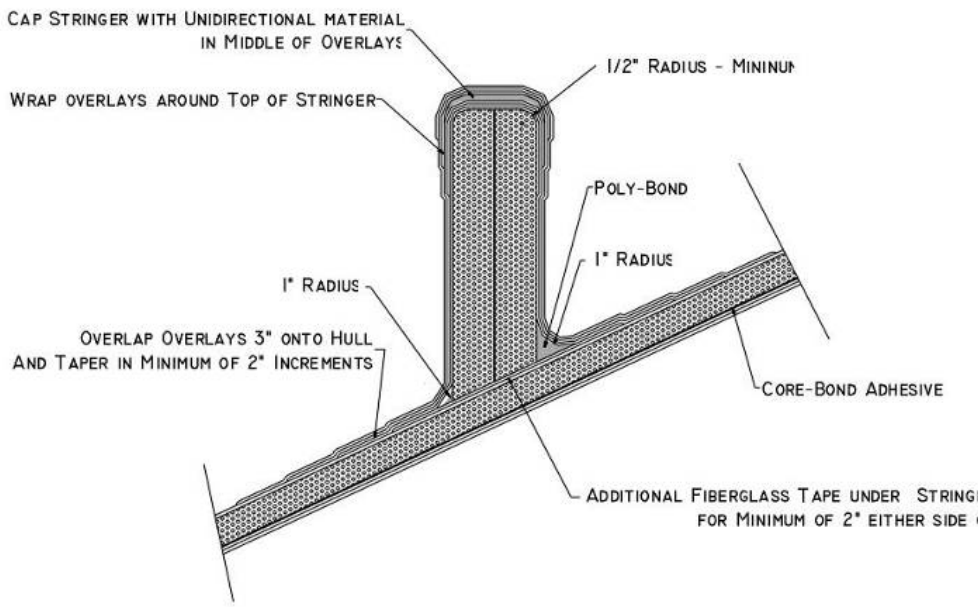
$$SM_{top} = \frac{I}{d_{NA\ top}} = \frac{71.58}{4.19} = 17.08 \text{ in}^3$$

$$SM_{bottom} = \frac{I}{d_{NA\ bottom}} = \frac{71.58}{1.81} = 39.55 \text{ in}^3$$

Example of a single skin FRP stiffener to illustrate the design process taken from USCG NVIC No. 8-87

Stiffener Construction Details

Tabbing Detail



Stiffener to Bulkhead Connection

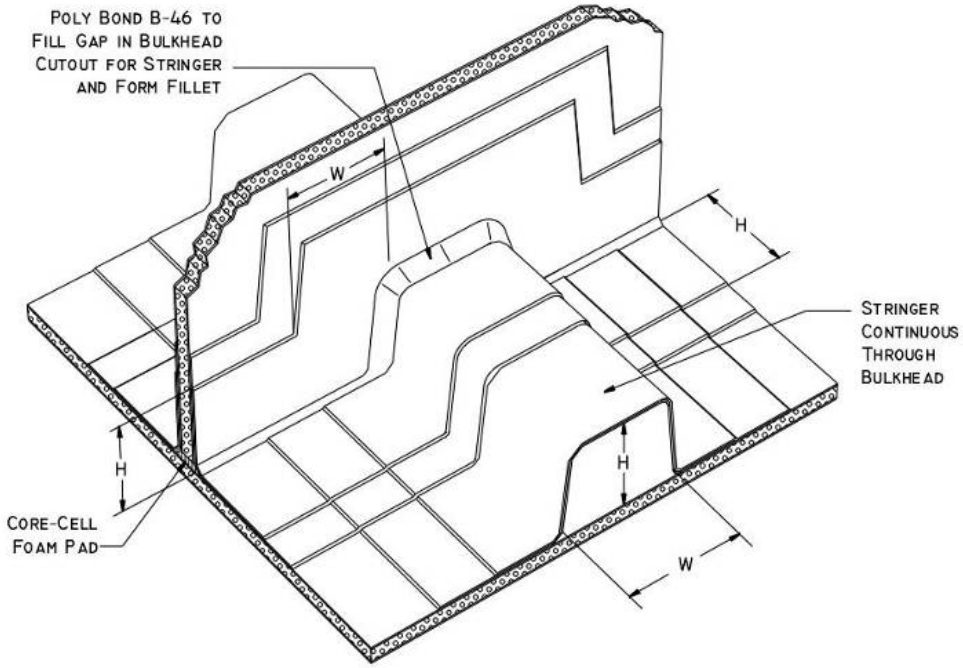


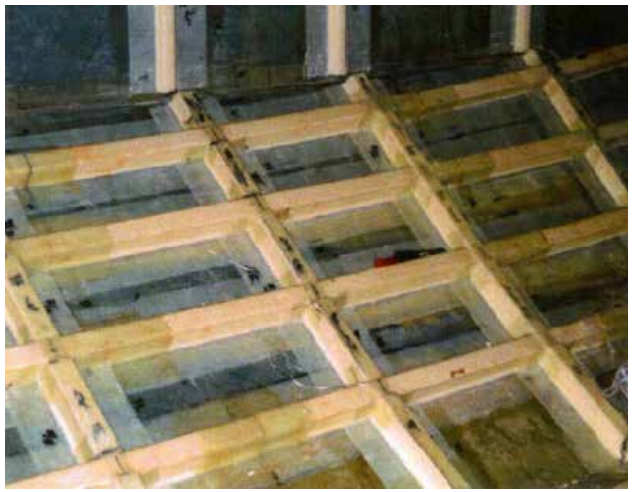
Illustration courtesy of ATC Chemical Corporation (now Gurit). Drawing is for guidance only – actual laminates should be engineered to specific requirements in accordance with classification society rules.

Examples of Stiffener Systems

Whatever type of stringer system is used, installation alignment is critical as this impacts the installation of interior subassemblies. Some types of systems used include:

- Custom, built-up systems glassed in place with secondary bonds
- Grid systems built on a separate mold bonded to the hull with either bedding compound or adhesive
- Preform stringer systems installed using either primary or secondary bonds

Sailboat Grid Stringer System (Benateau USA)

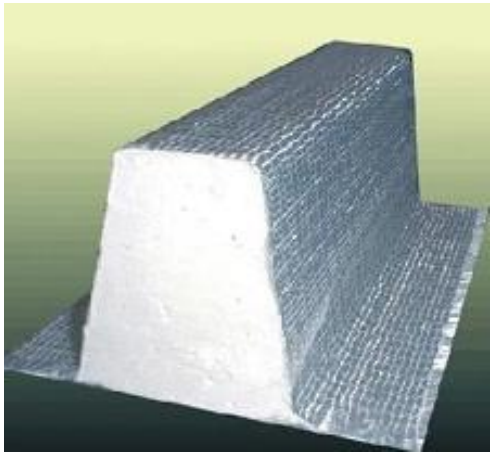


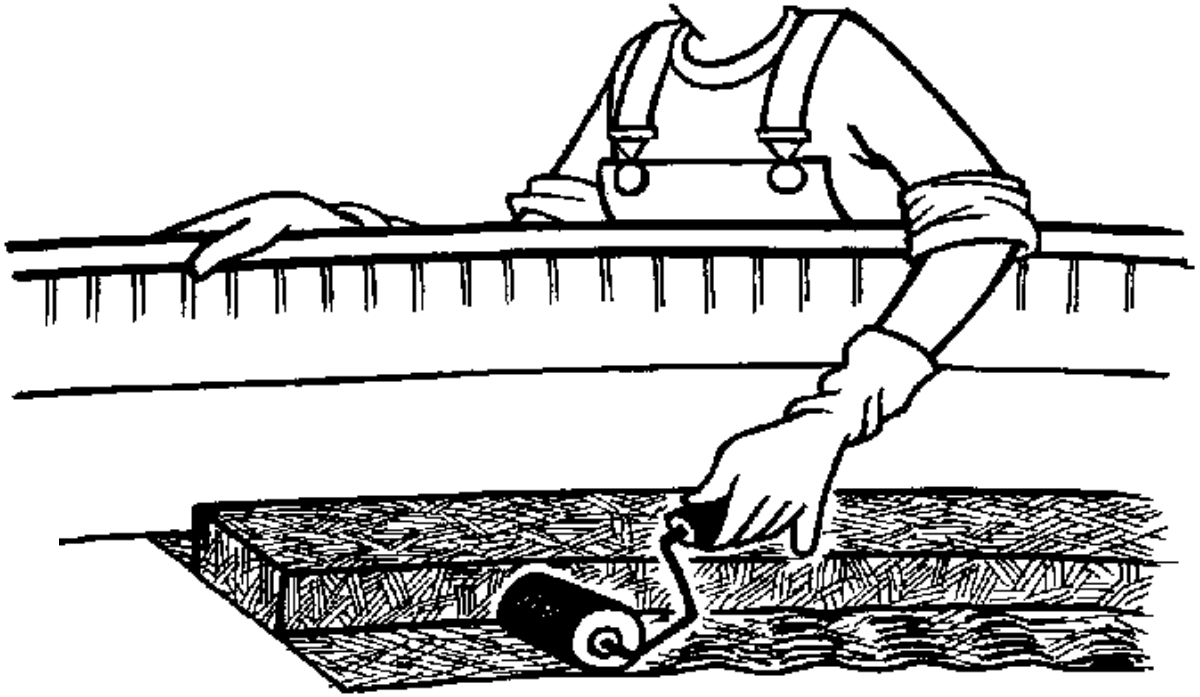
Preform Stringer Installation

Failed Grid Stringer Installation

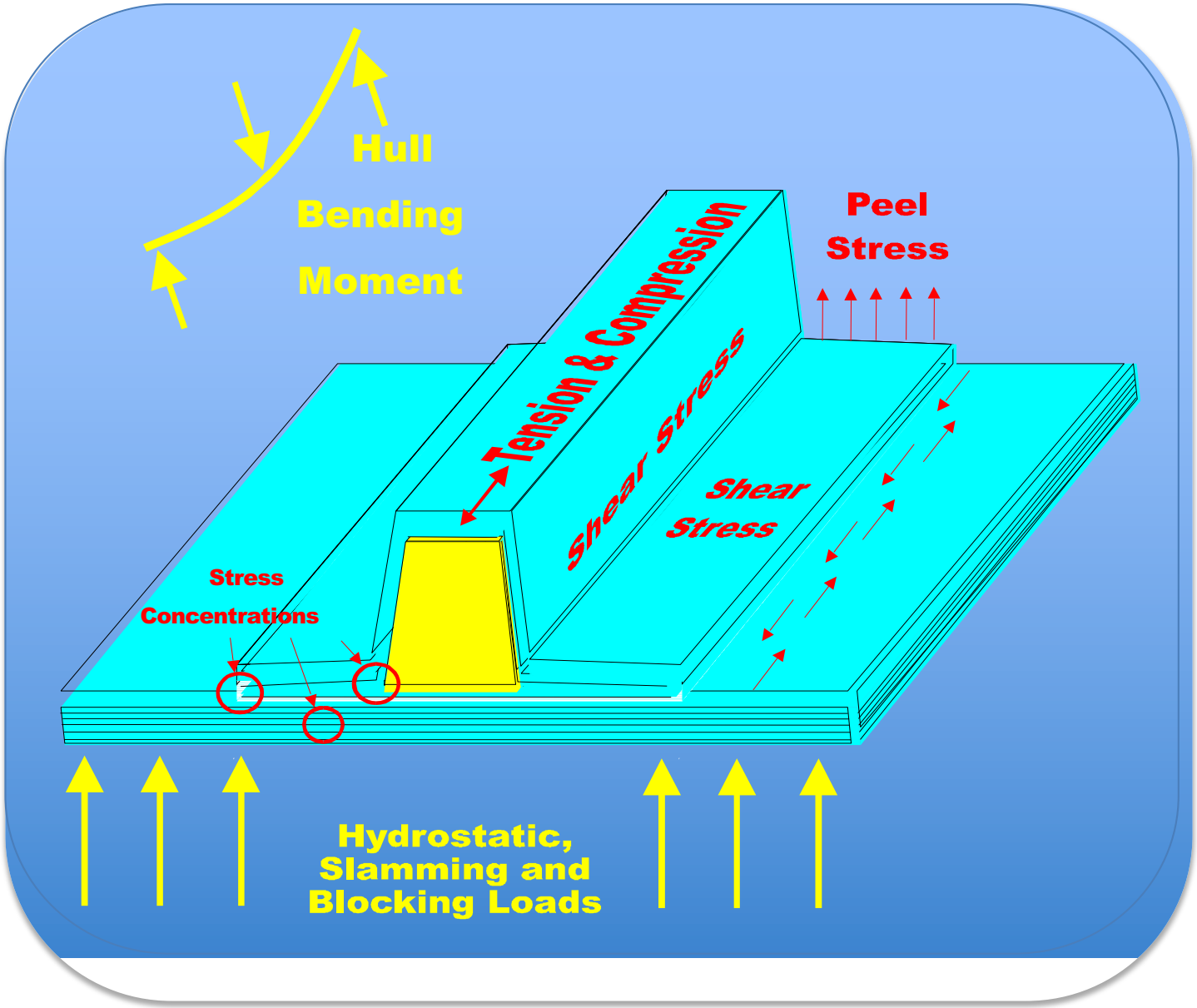
Preform Stiffeners

A preform is an assembly of dry reinforcement held together some way in a form that closely resembles the final geometry. In this case of preforms used for boat stiffeners, the fiber is held in place by an expanded foam core.





Stiffener Stresses



Grid Systems

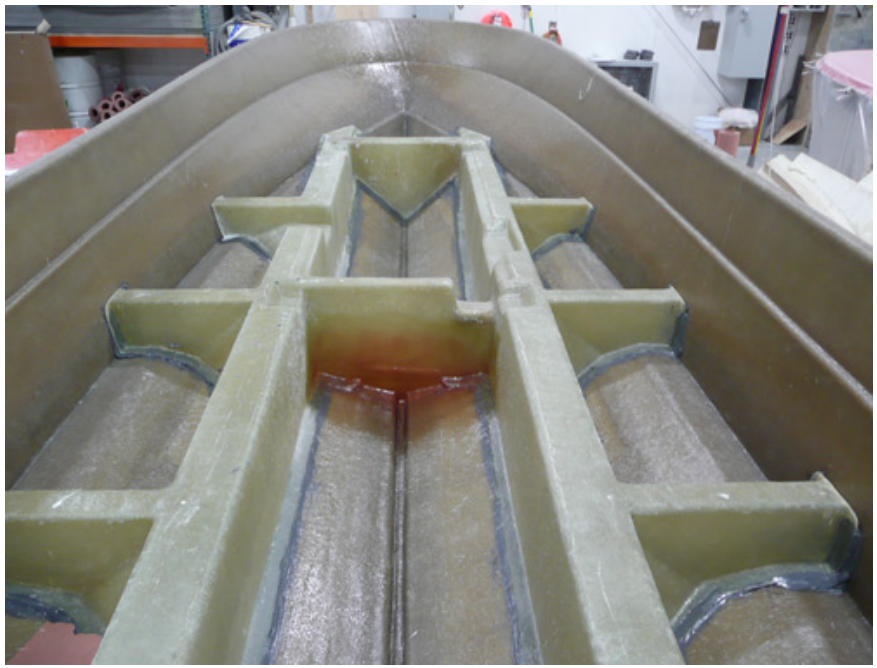
Reinforcement is Added to Structural Grid

World Cat Power Catamaran Structural Grid System

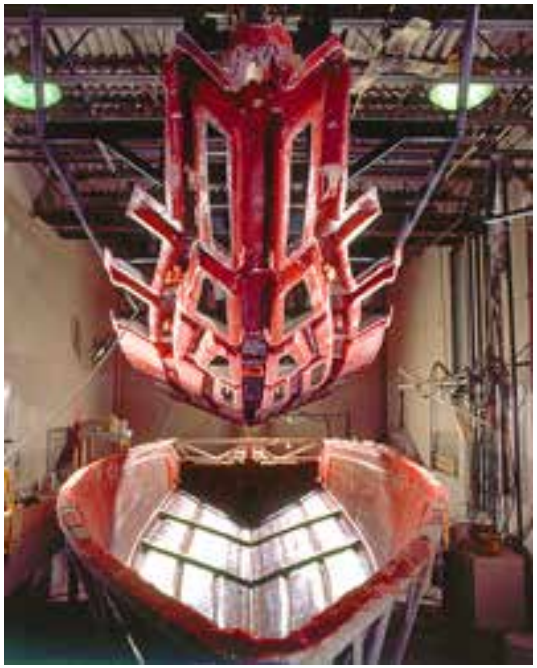
http://www.worldcat.com

Bonded Structural Grids

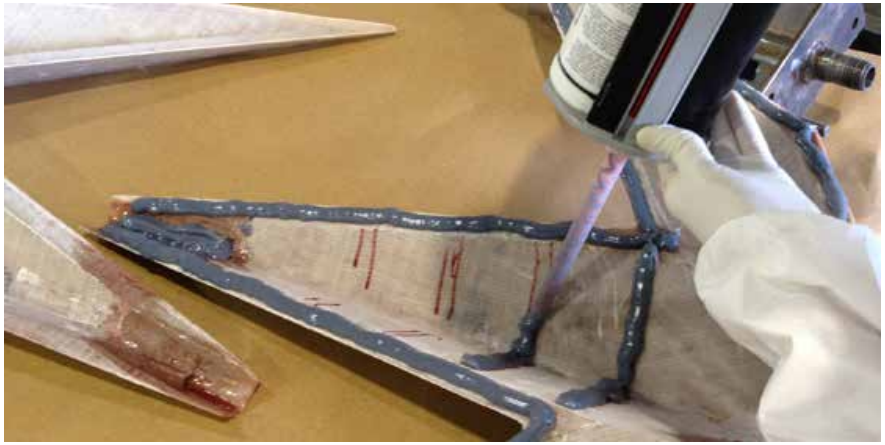
Solid fiberglass grid system is bonded to the hull with methacrylate adhesive



Maritime Marine, LLC, Augusta, Maine



ITW Plexus



ACRALOCK by Engineered Bonding Solutions, LLC

Southport Boats Augusta, ME

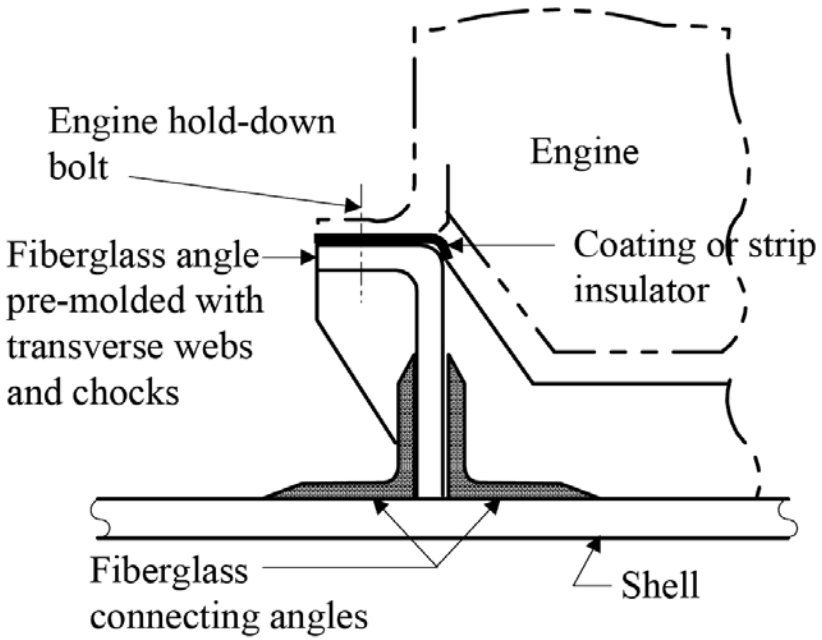
Deep Stringers

These solid foam stringers are fully encapsulated with fiberglass laminates and reinforced with a carbon composite layer. [R&R Boatworks, Stuart, FL]

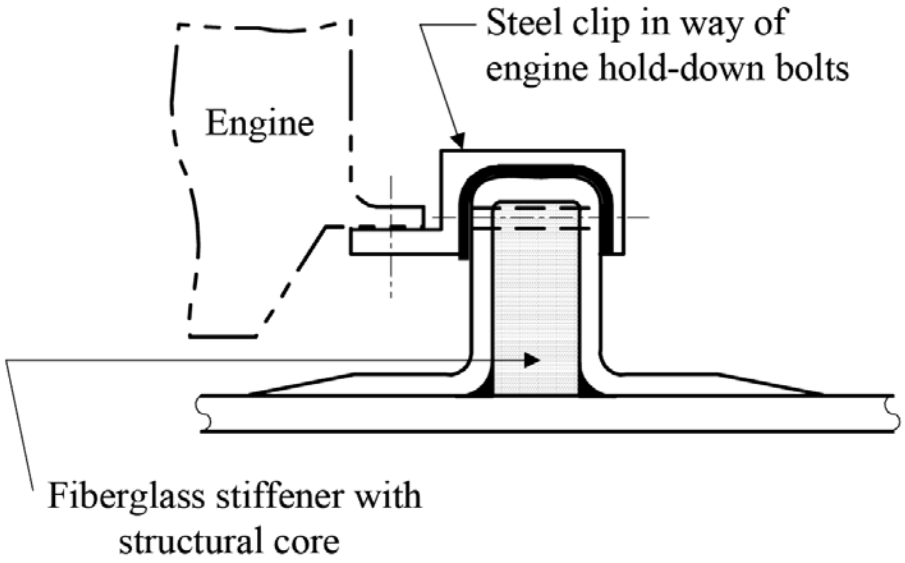
This stringer system is attached to the hull with methacrylate adhesive [Southport Boats, Augusta, ME]

Typical Engine Girder Arrangements

Girder Built from Solid Laminate



Cored Engine Girder



ABS GUIDE for High Speed Naval Craft, 2007 Part 3 , Chp 2, Sect 6, Structural Details

Examples of Engine Girders

Failed Engine Girder

Engine girder cracking apparently from improper hauling sling arrangement

Engine Girders Tie in to Transom

Aft end of engine girders of Sabre 38 Express

Aluminum Saddle over Engine Girder

Aluminum saddle is fitted to composite girder

Examples of Transom Structures

Most Dive Boats Have Large Transom Openings

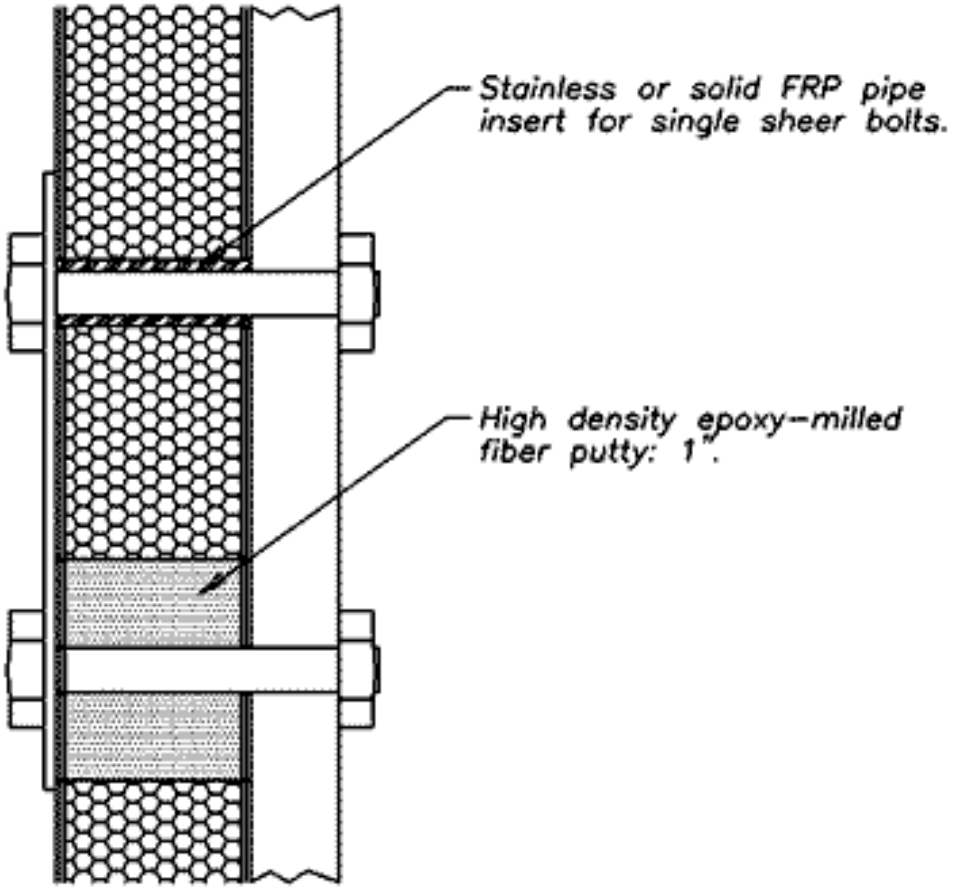
A water-saturated transom undergoing repair at Penguin Composites in Australia

Hinged Transom featured on 10 m Yacht from C.H. Marine Yachts, Shelter Island, NY

A repaired stress crack as shown in inset photo

Transom Engine Mounts

Typical through-bolt detail

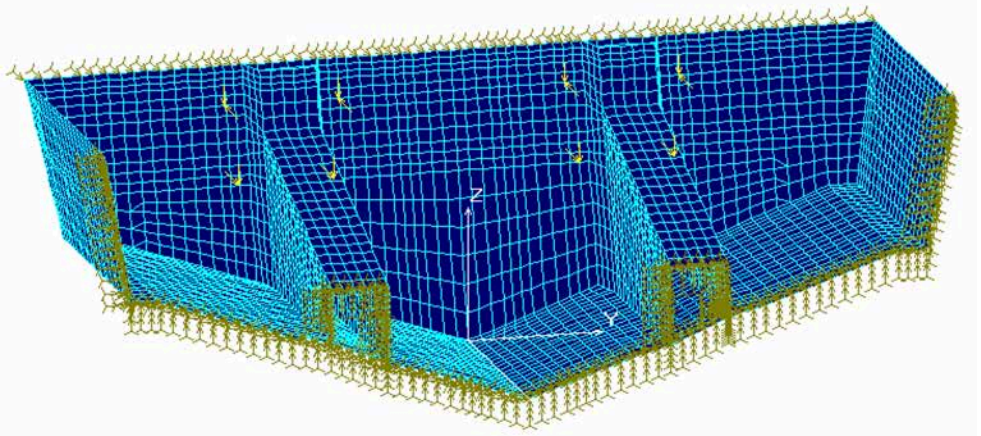


Contemporary outboard bracket with internal bracket support

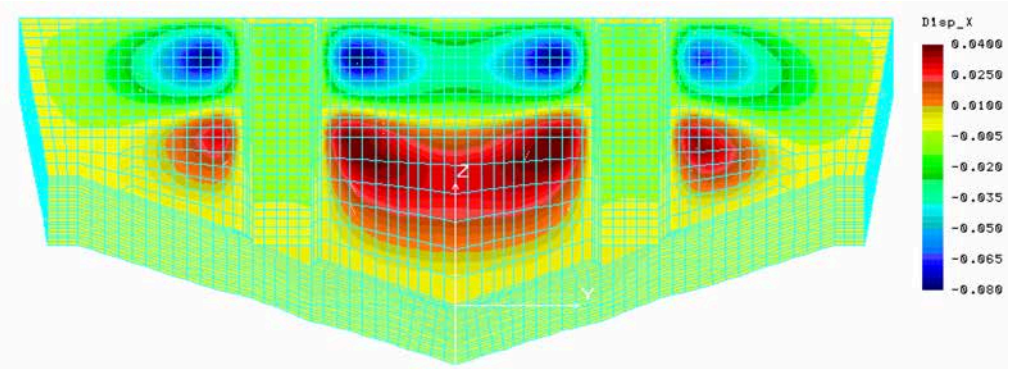
www.BoatDesign.net

Framed Single Skin Transoms

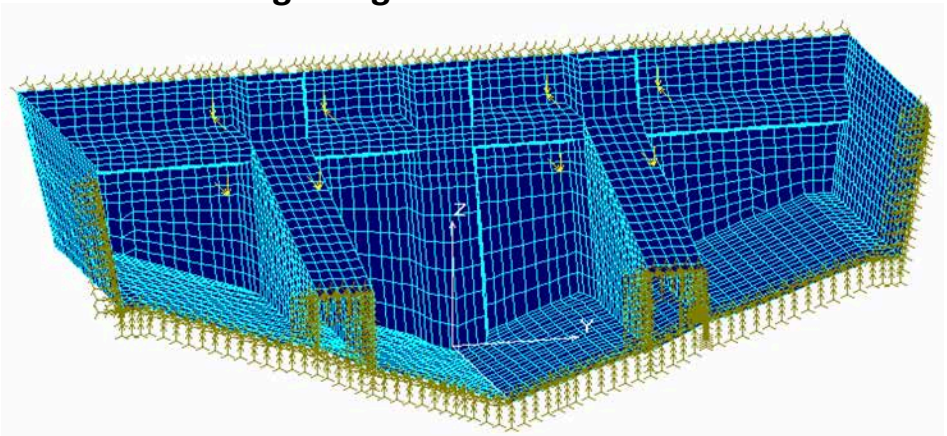
Boundary Conditions and Applied Forces for Single Engine Plywood Transom



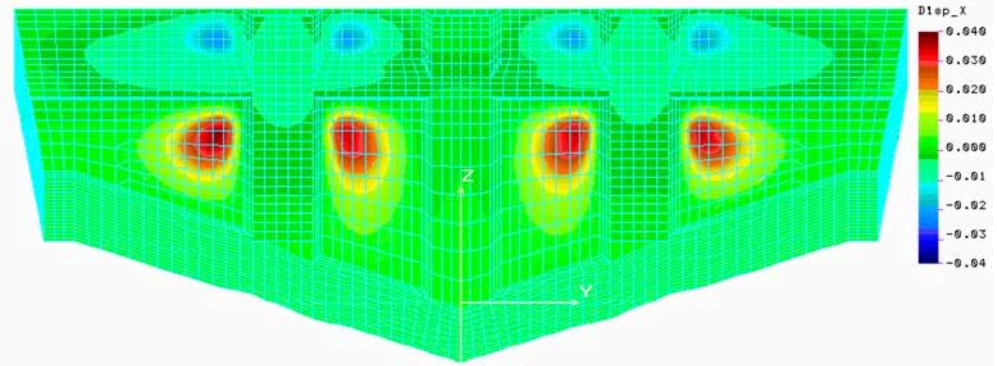
Deflection of GRP Plywood Transom with Twin Engine Loading



Boundary Conditions and Applied Forces for Single Engine Framed Transom



Deflection of GRP Framed Transom with Twin Engine Loading

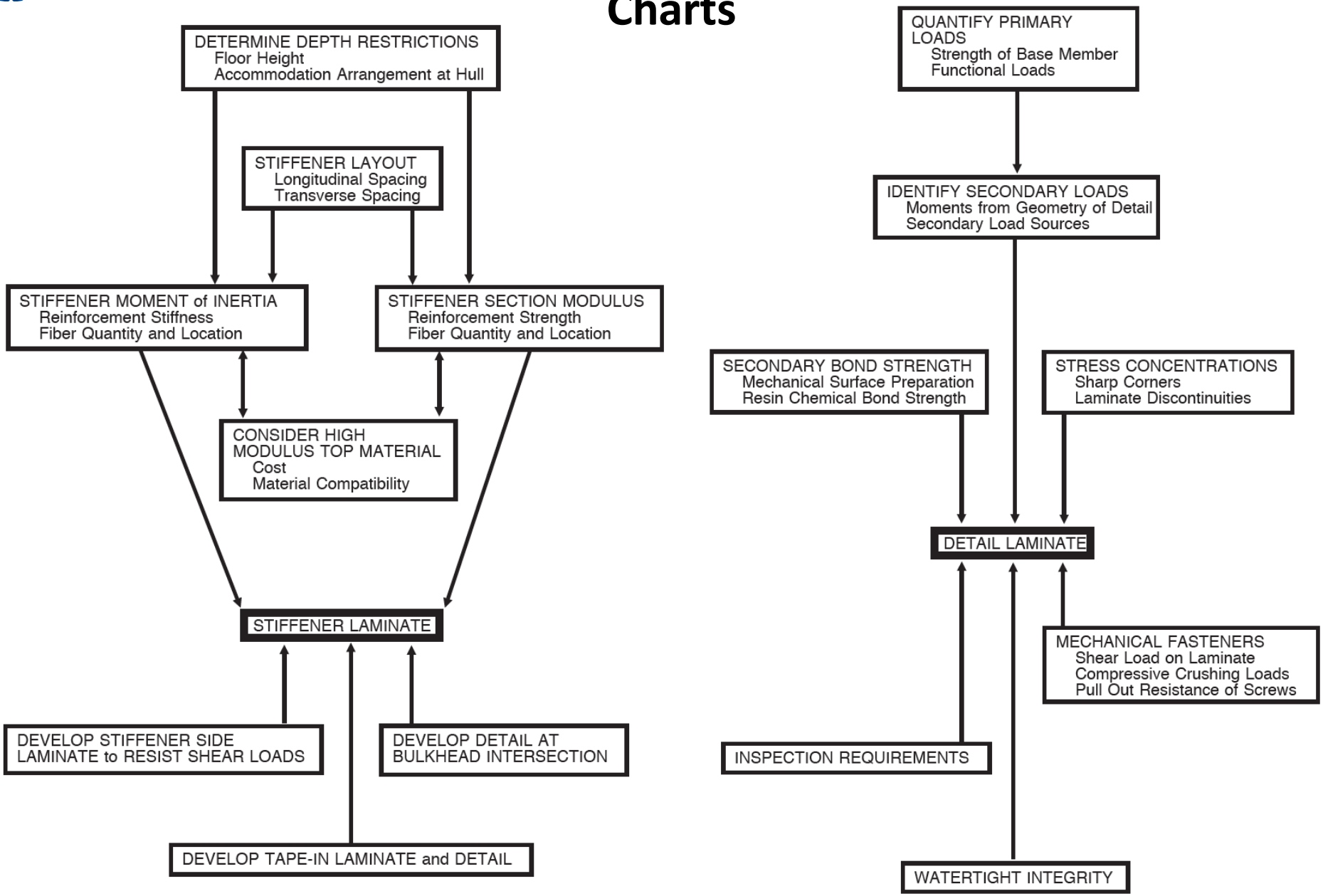


The framed single skin transom is stiffer and stronger than the GRP plywood transom.

Ronnal P. Reichard, "Framed Single Skin Laminate Transoms," COMPOSITES 2006, St. Louis, MO

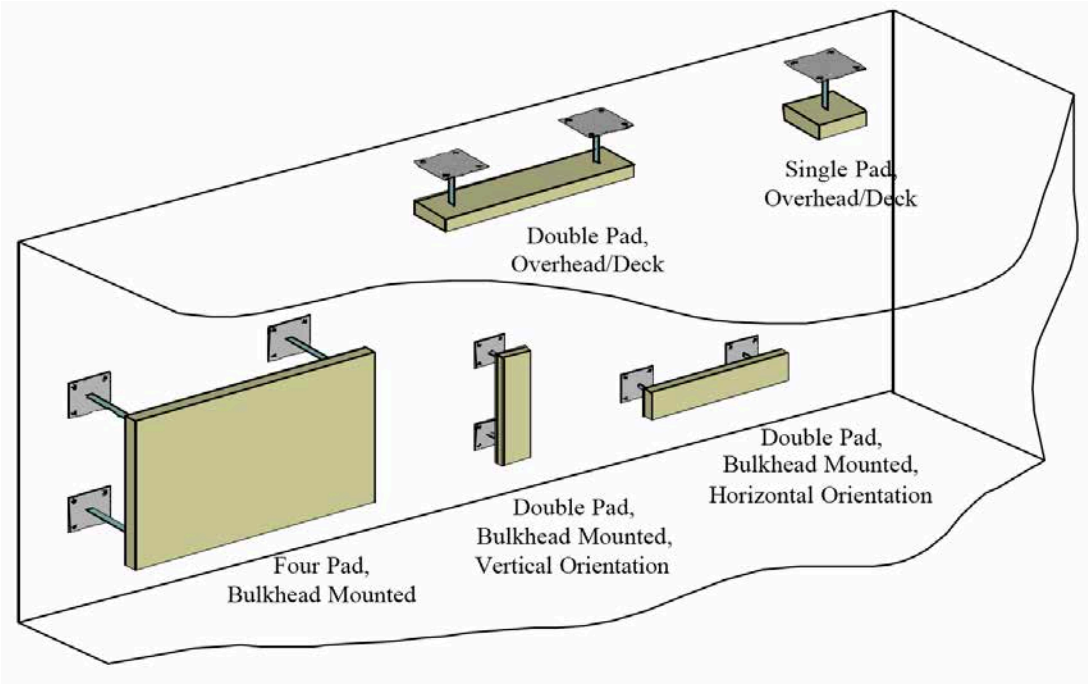
Transom Failures

Stiffener & Detail Design Flow Charts

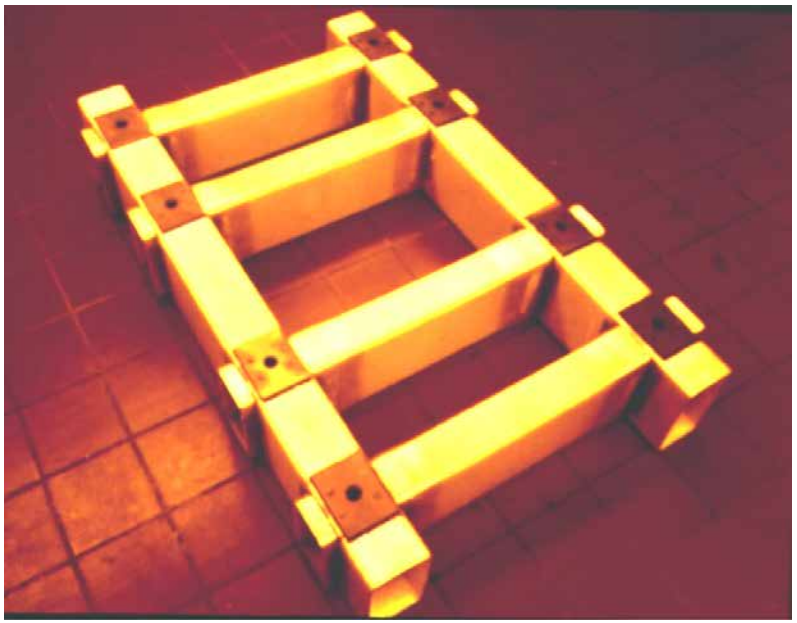


Machinery Foundations

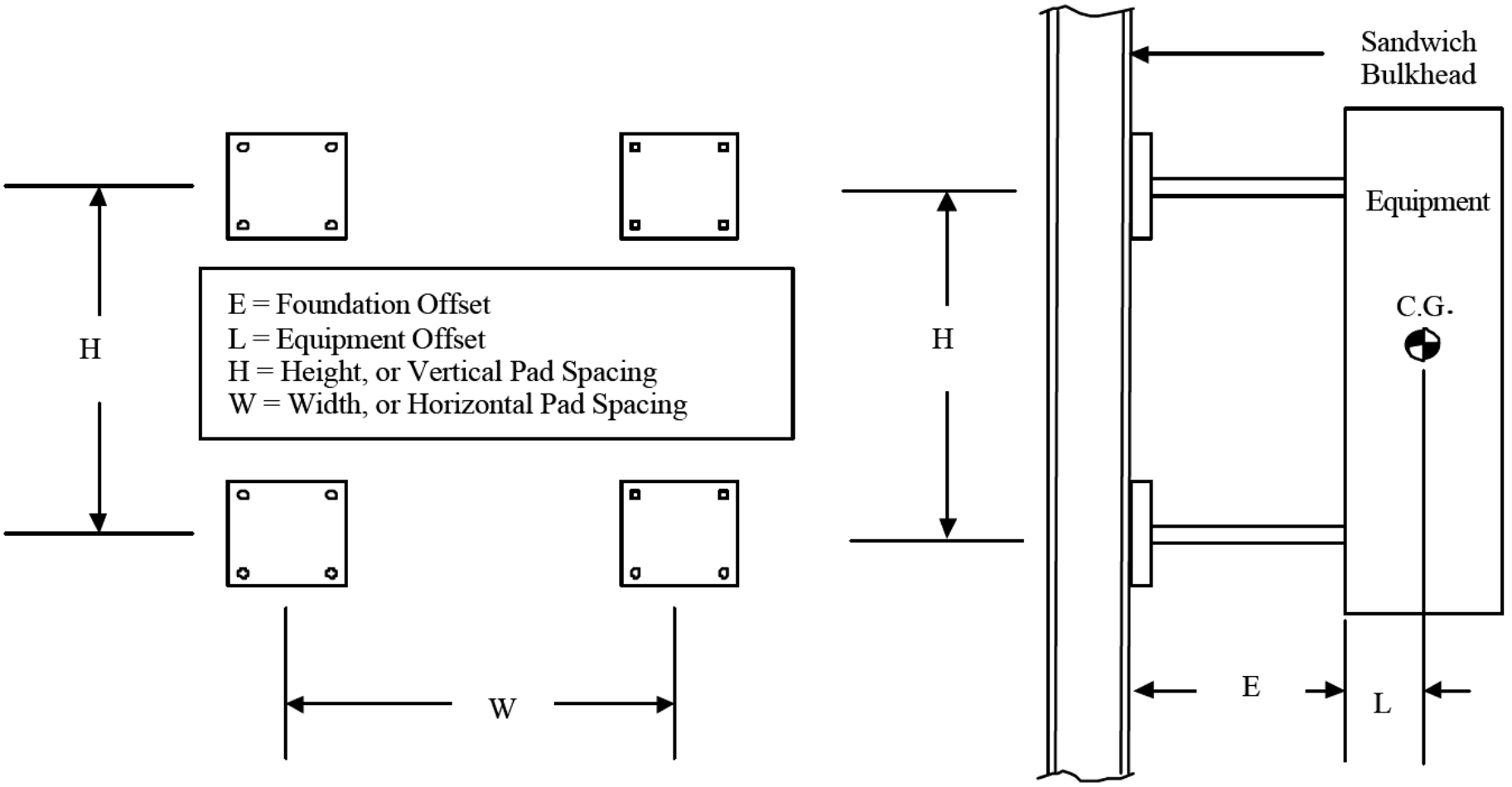
Typical Foundation Systems



Filament Wound Machinery Foundation by Brunswick Defense



Foundation Design Parameters



Framing Systems Summary

- Longitudinal and transverse framing systems reduce the span of panel sizes and allow the hull and deck to respond as a global structure
- Frames and stringers can be built outside of the hull and bonded in place or built up directly in the hull
- Unidirectional reinforcement is most effective on the top of stringers while ±45° material is most effective for sidewalls and tabbing
- Avoid direct contact of “hard” framing edges and hull
- Careful fit-up and tabbing or bonding of structural grid systems is critical
- Deep engine girders may require bracing for transverse stability
- Equipment foundations with cantilevered geometries can produce high bending moment stresses in the areas where the foundation meets the hull