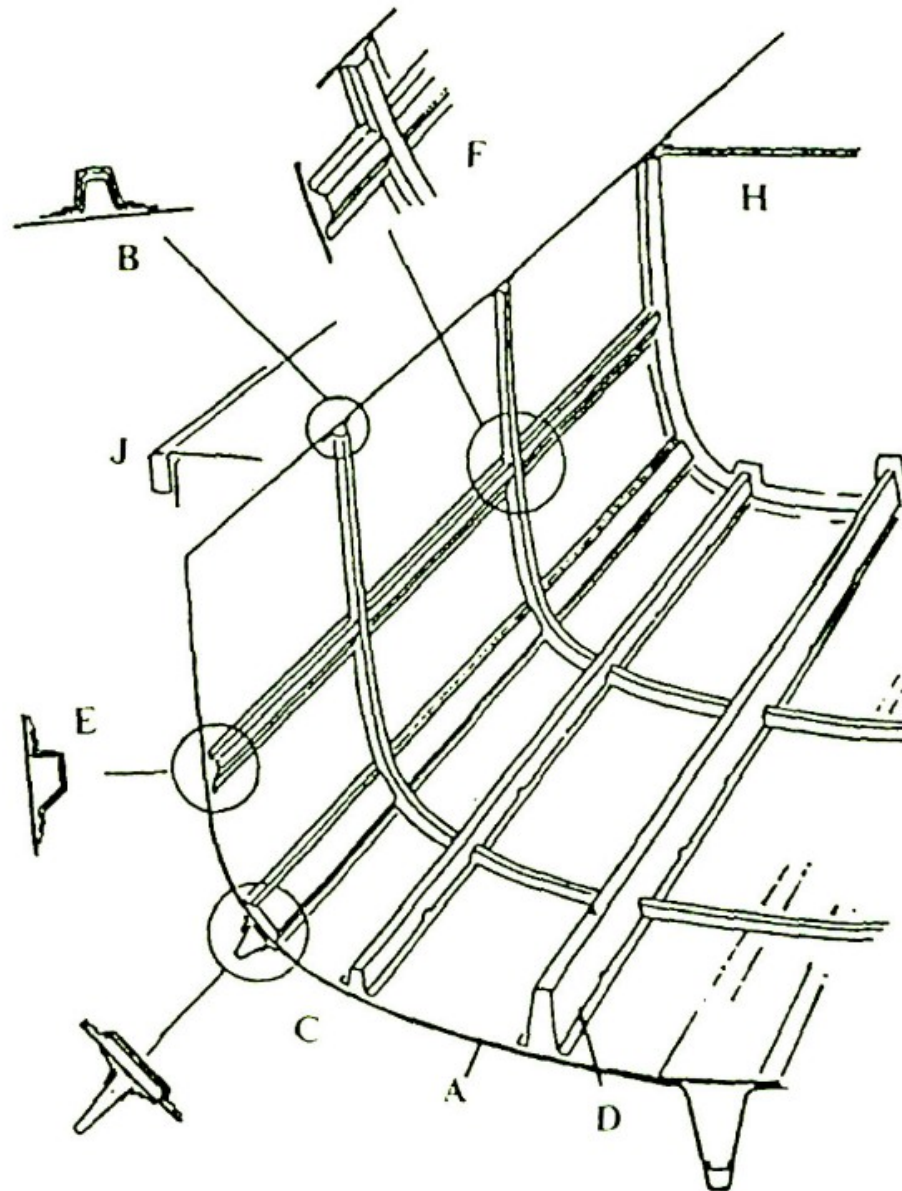


# COSTRUZIONI NAVALI II

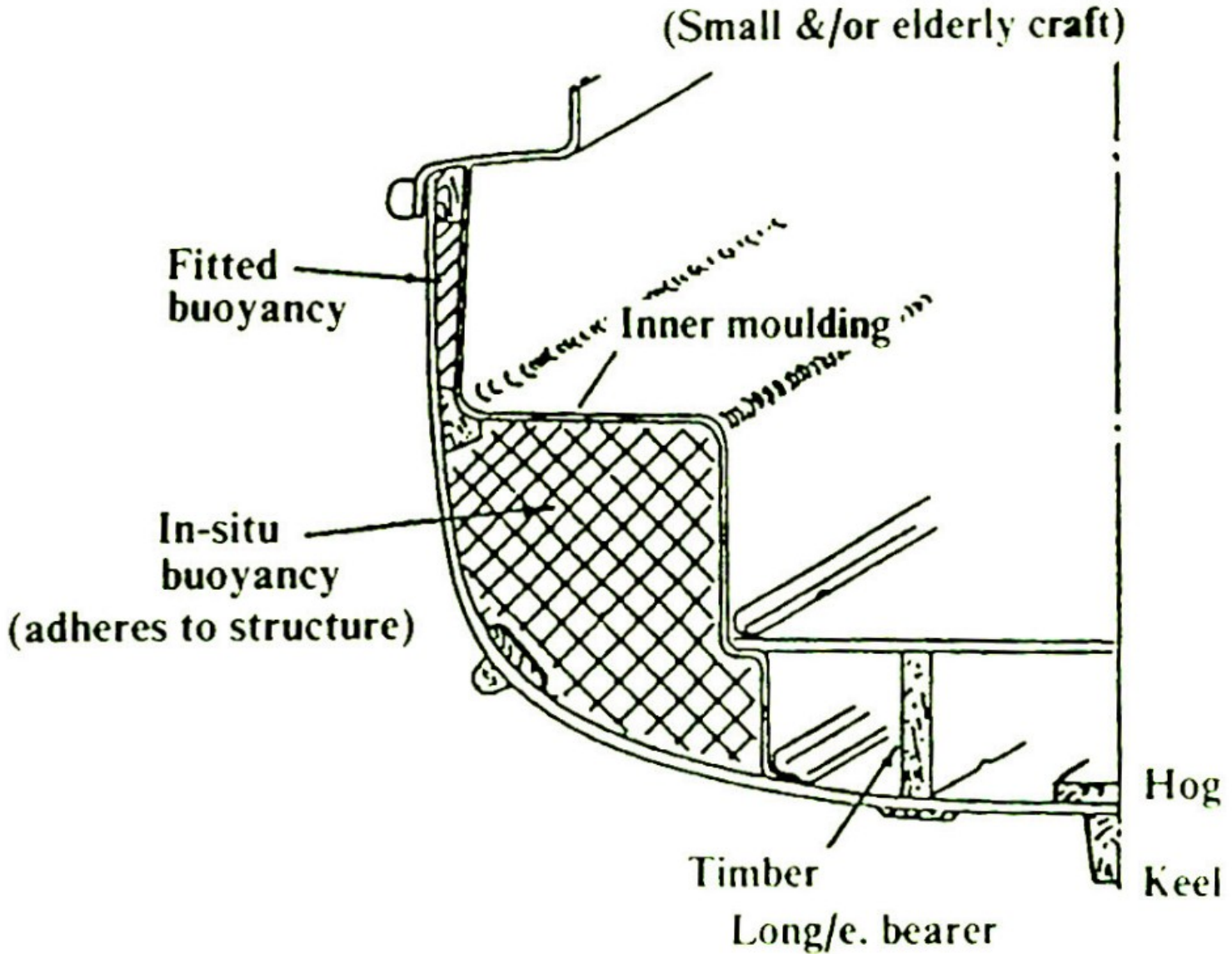
**(materiali compositi: dettagli costruttivi)**



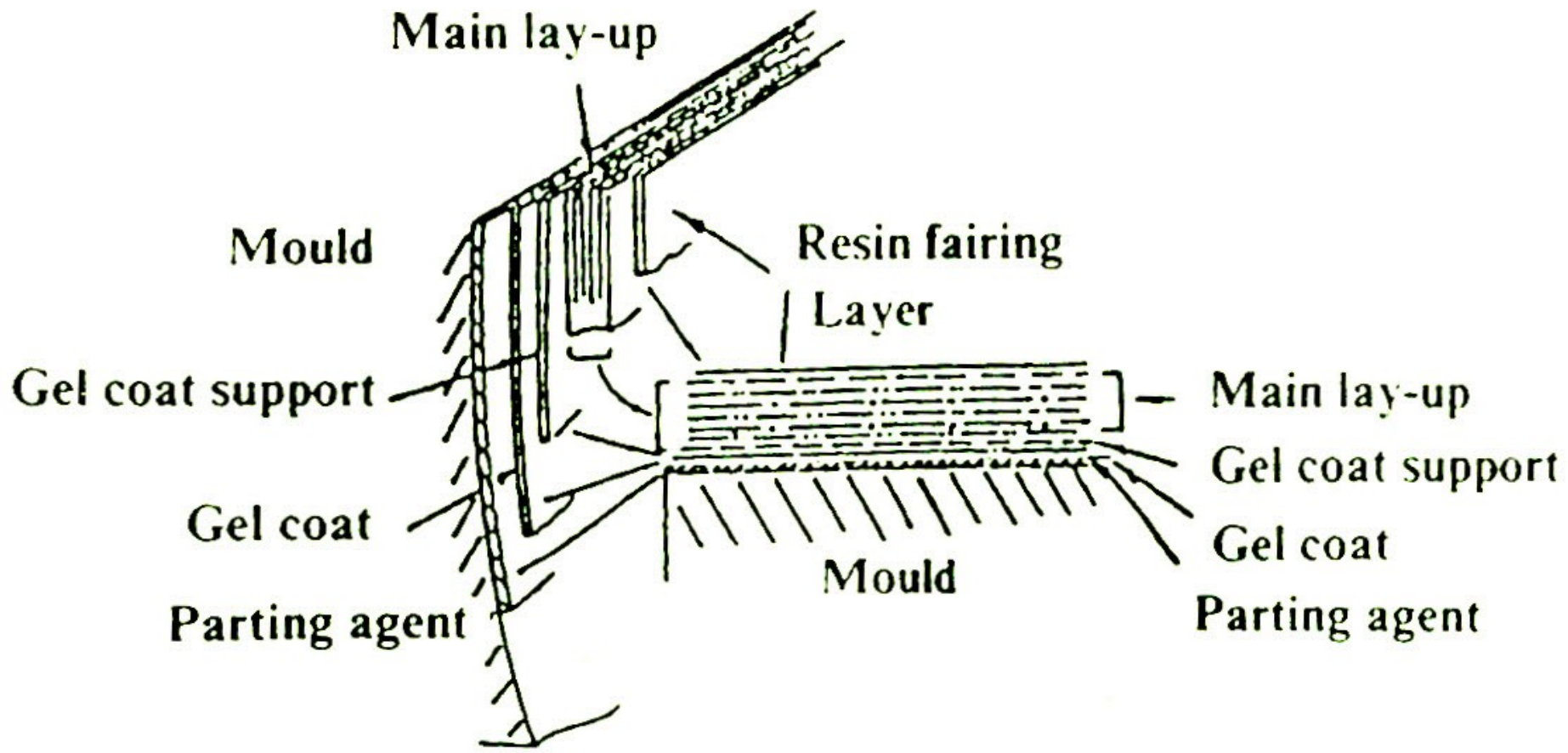
**Typical single skin hull structure**



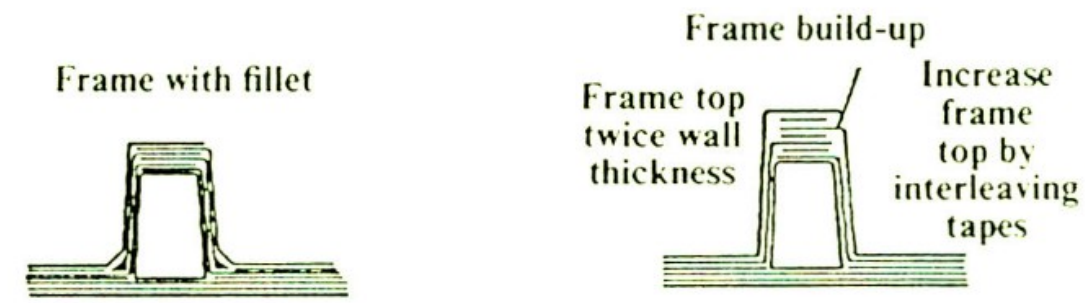
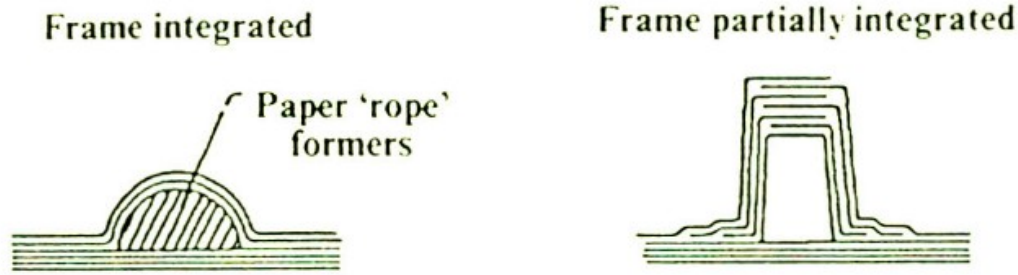
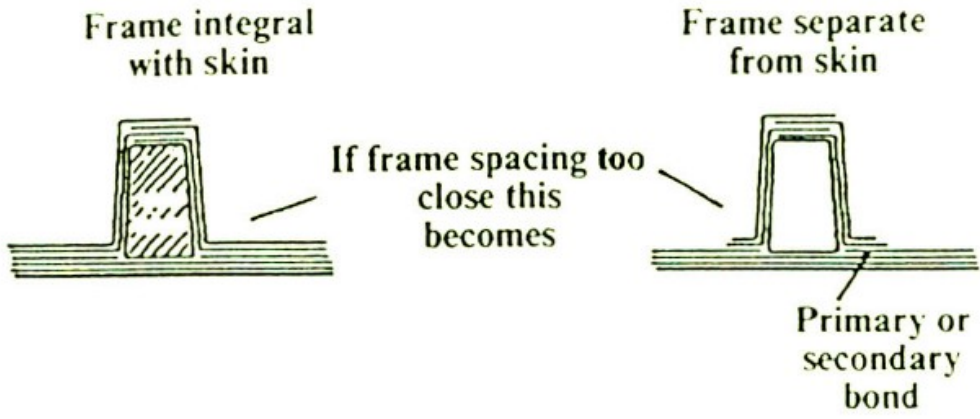
### Alternative hull construction



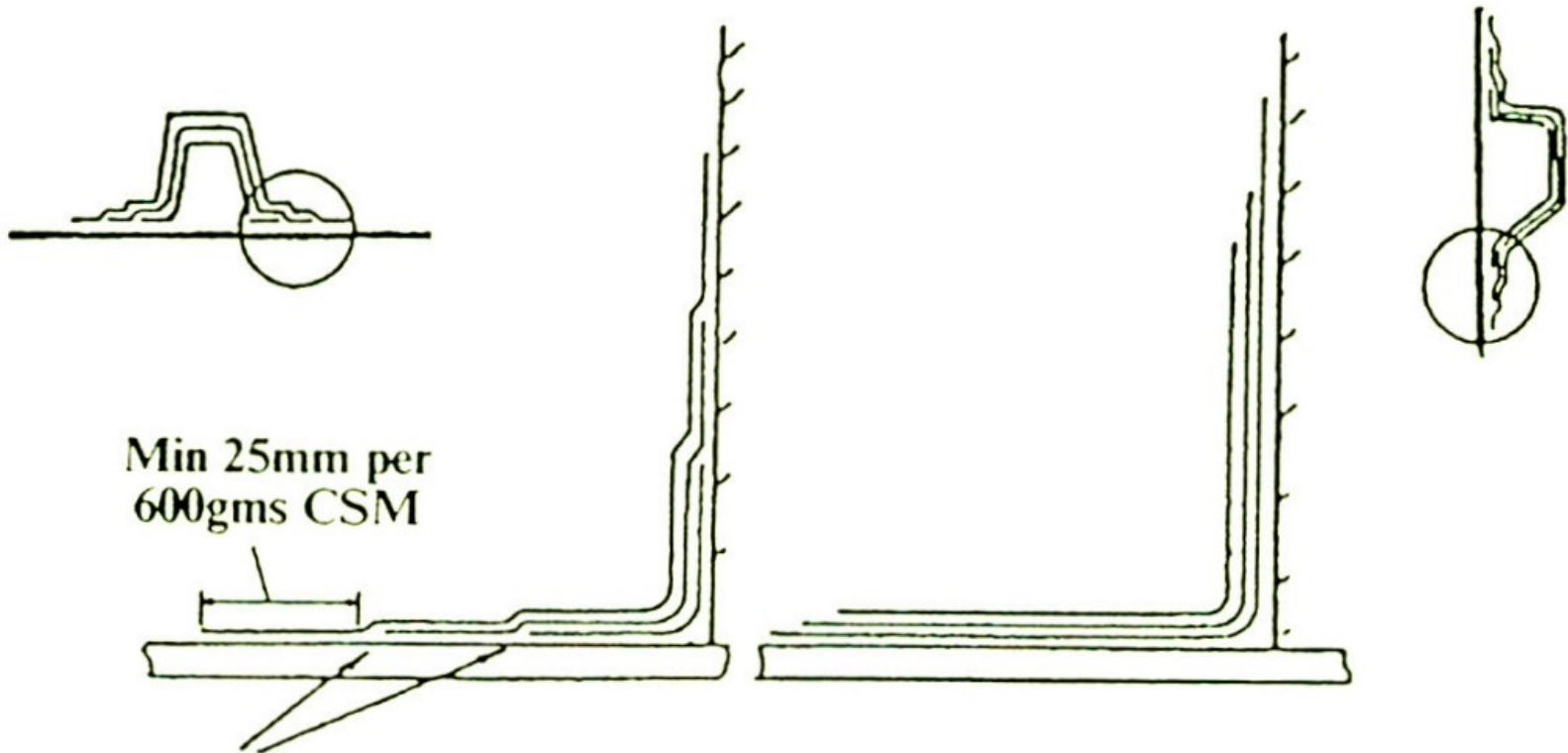
### Typical skin/shell lay-up



Types of frame/stiffener



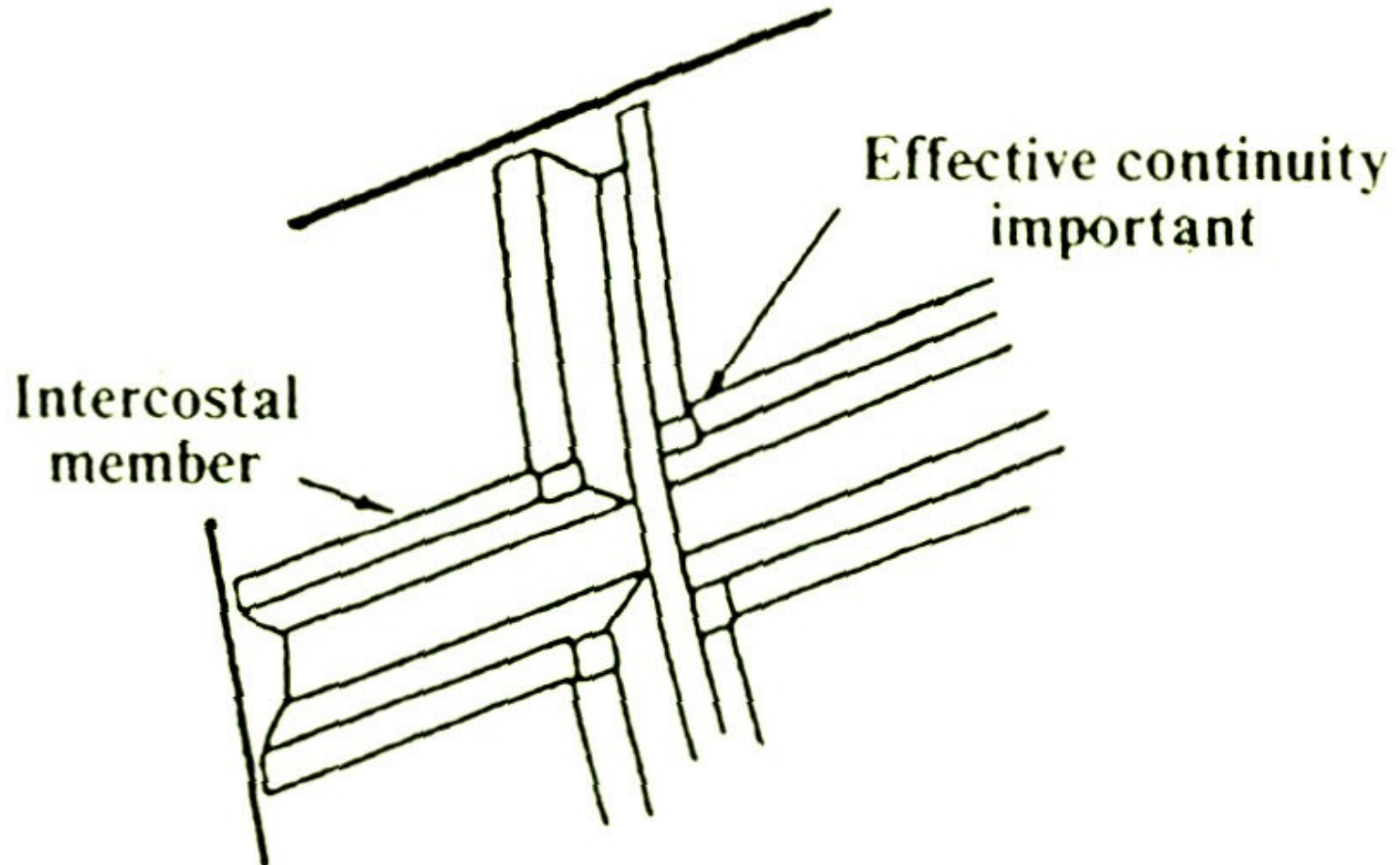
## Flange laminations



These interruptions “perform”  
a crack arrestor function  
should the flange begin to  
fail

Once this flange begins to debond  
it is able to continue unabated

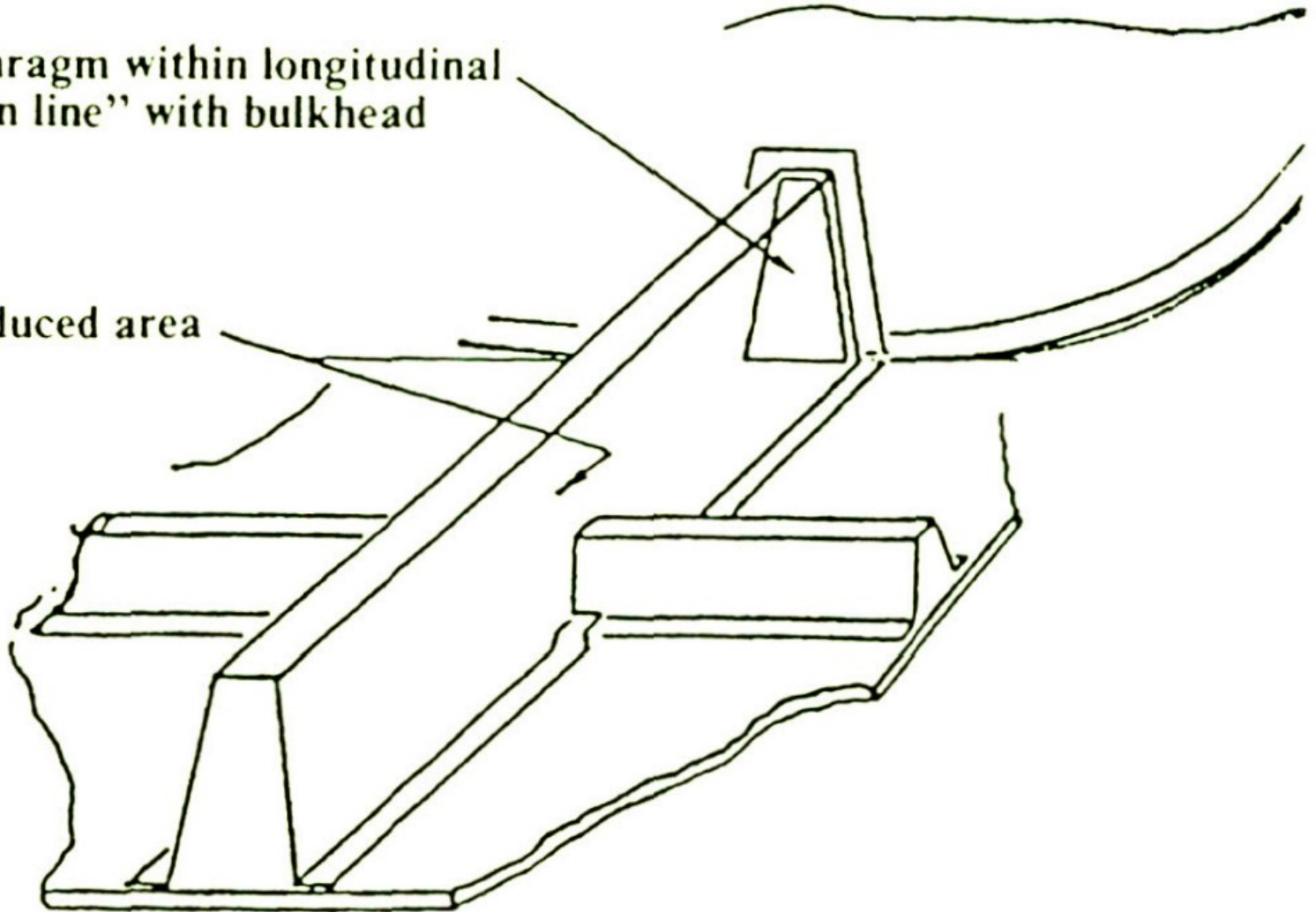
## Intersection of frame – side stringer



## Intersection of frame/main longitudinal

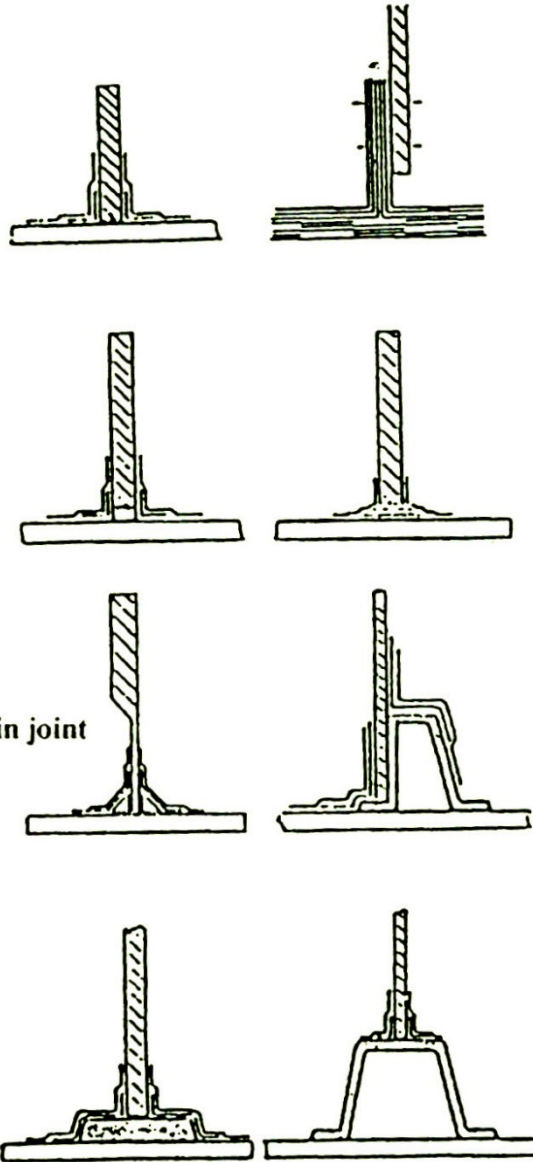
Diaphragm within longitudinal  
"in line" with bulkhead

Reduced area





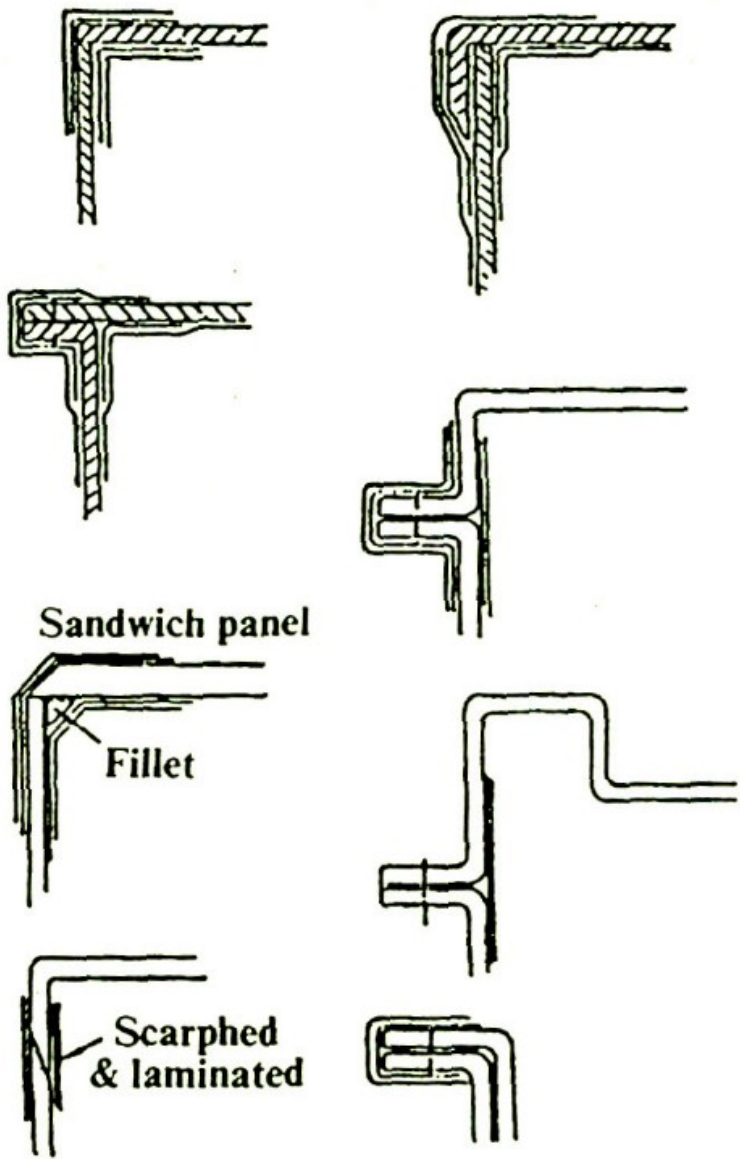
**Various bulkhead securing arrangements**



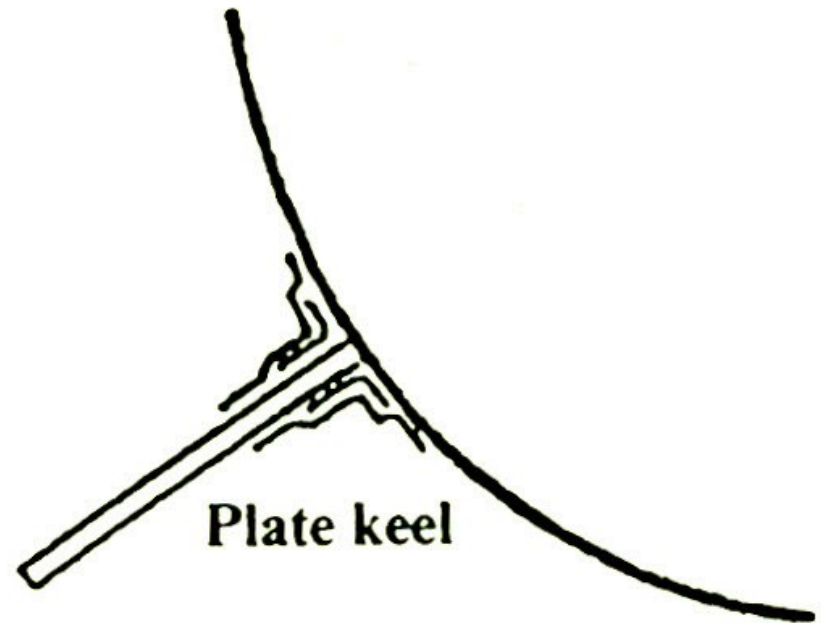
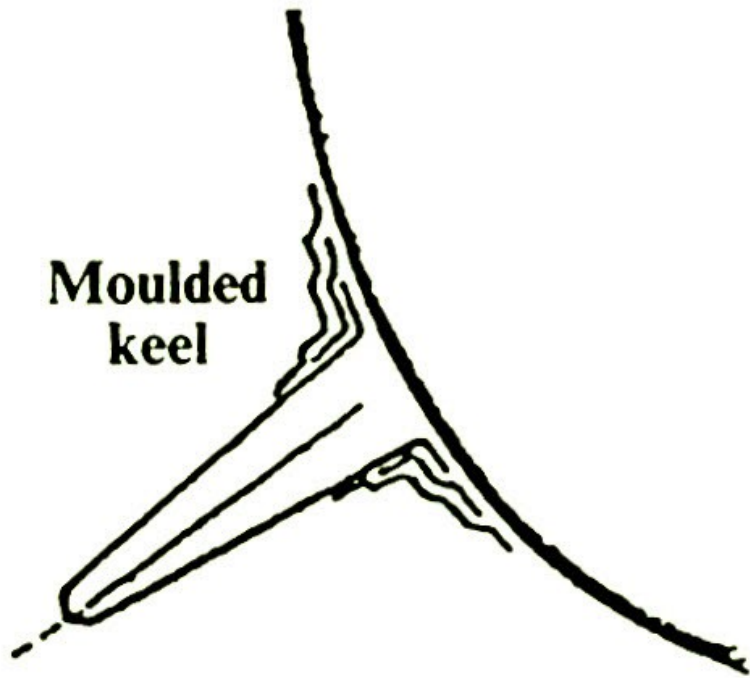
Pin joint

**Preferred — those providing support and spreading load**

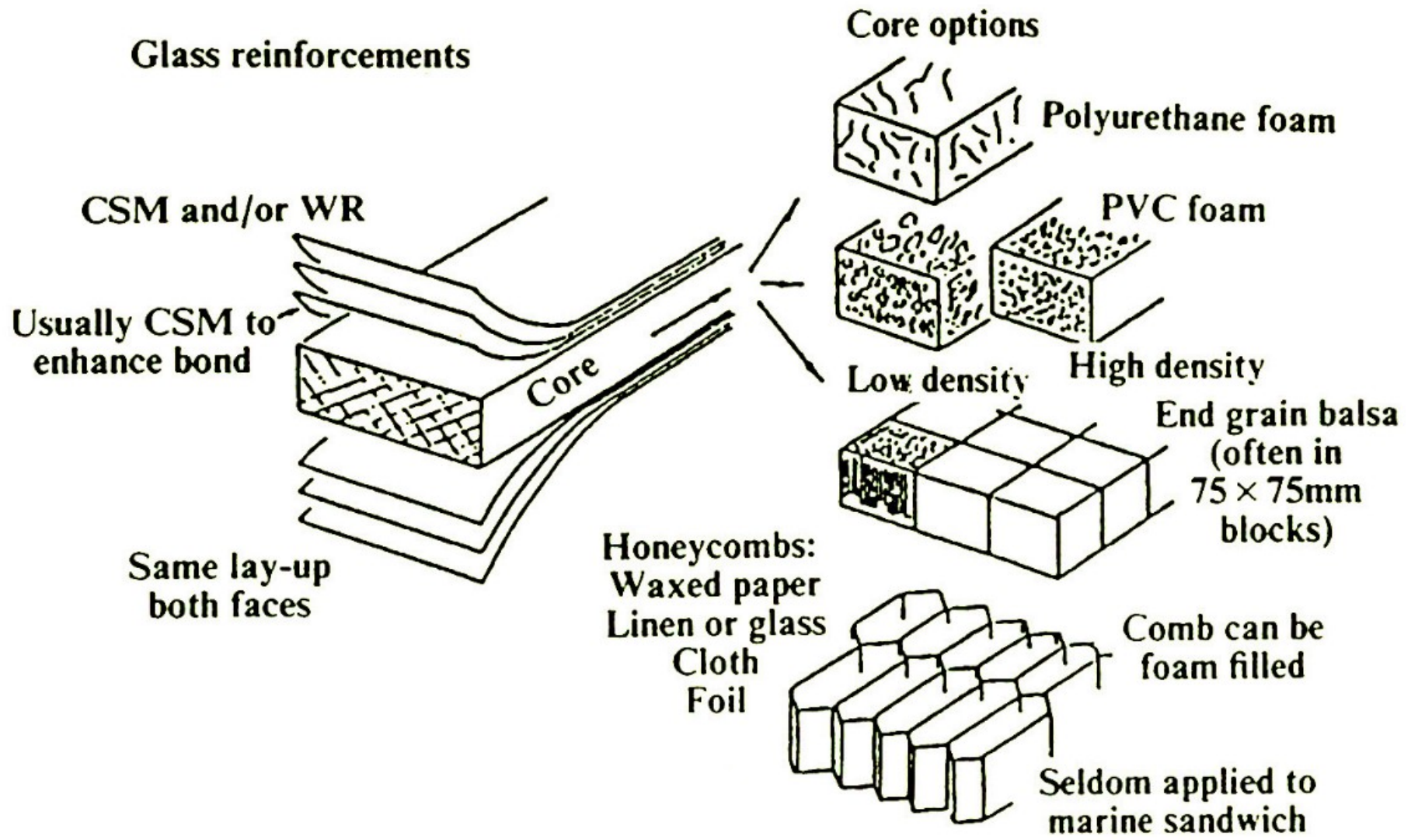
### Types of corners



## **Bilge keels**

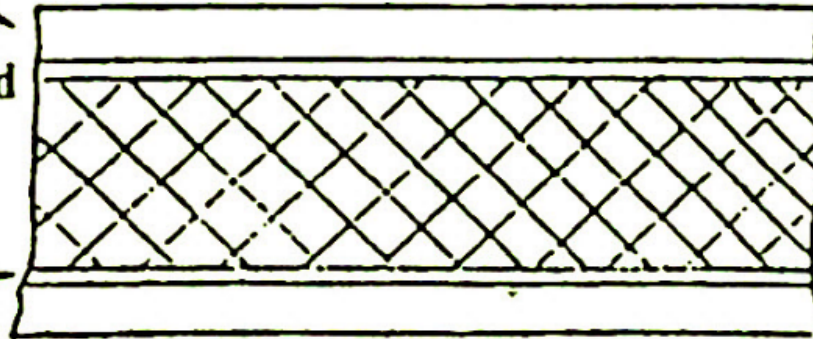


# Typical GRP sandwich



## Sandwich variables

Laminate — thickness  
— make-up  
— lay-up standard



Core — materials  
— density  
— thickness

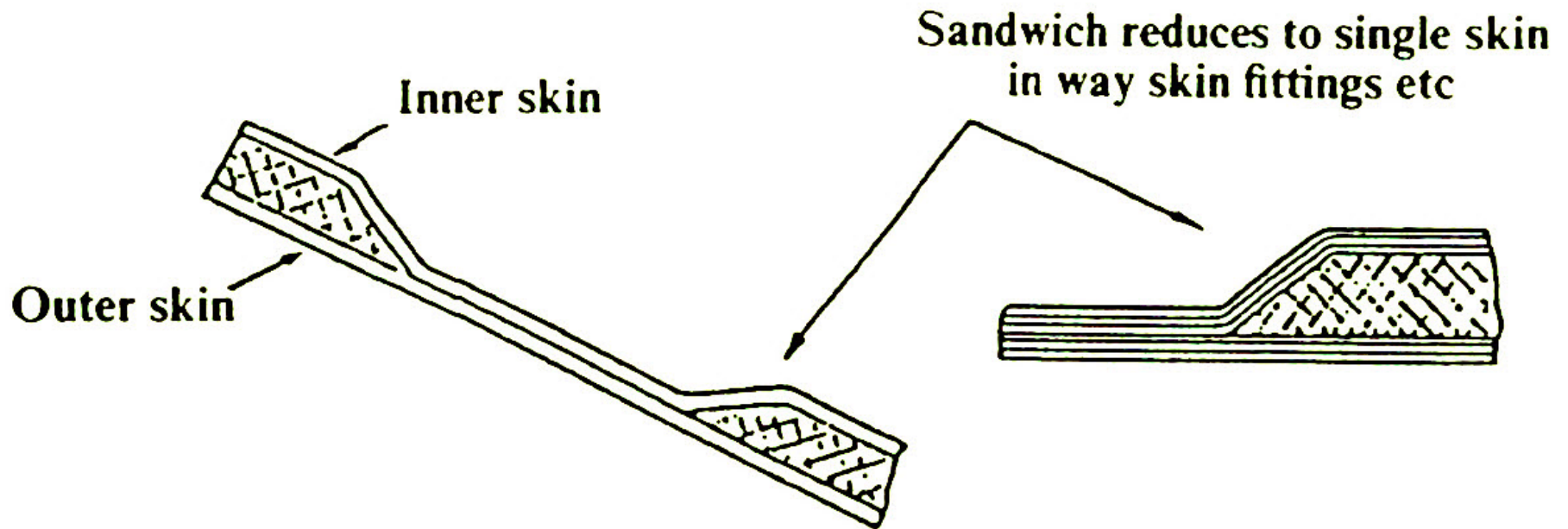
Skin/core bond — process  
— resin  
— surface treatment

Core — plastic foams (various)  
— balsa (end grain)  
— honeycombs (various)  
— densities from  $20\text{kg/m}^3$  ( $1.5\text{lb/ft}^3$ ) to  $450\text{kg/m}^3$  ( $29\text{lb/ft}^3$ )

Laminate skins — polyester/epoxide resin  
— reinforcement — mats/cloths or combinations  
— properties — UTS 65 to  $250\text{MN/m}^2$

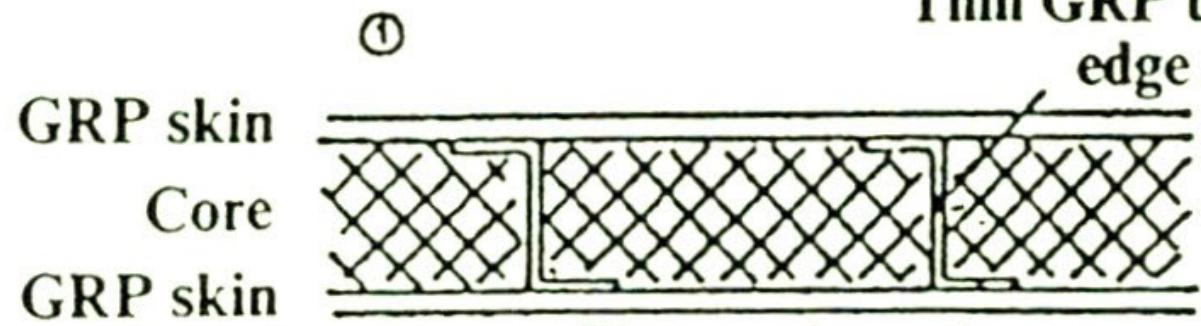
The bond — usual made with laminating resin + interface ply — mat layer

## Sandwich/single skin transition



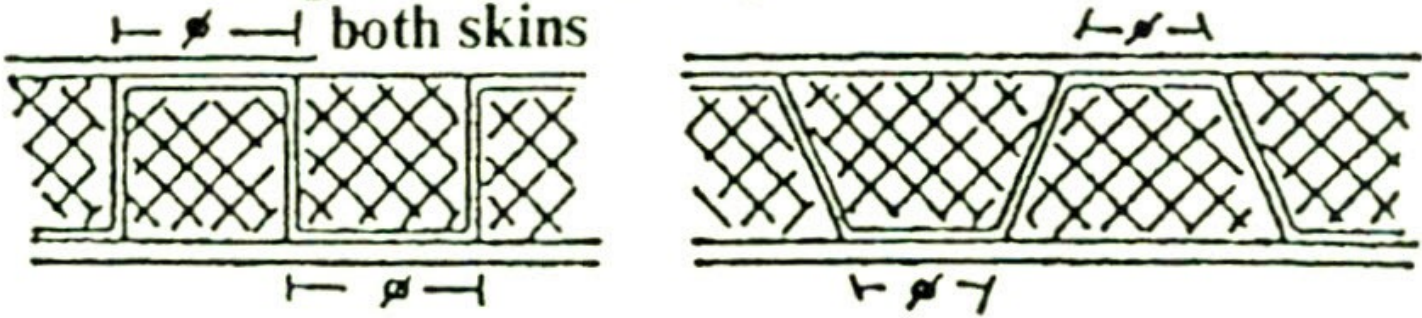
# Shear web

Thin GRP usually laminated on edge of core block



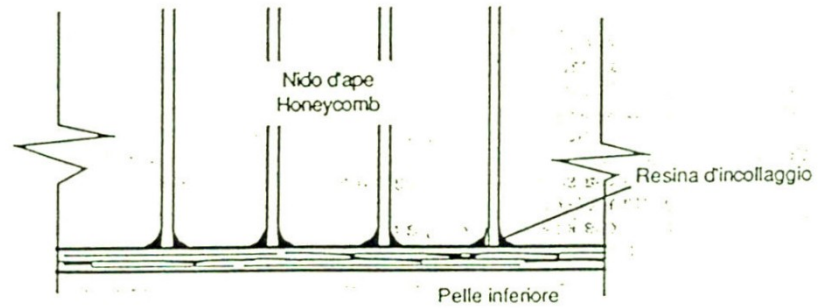
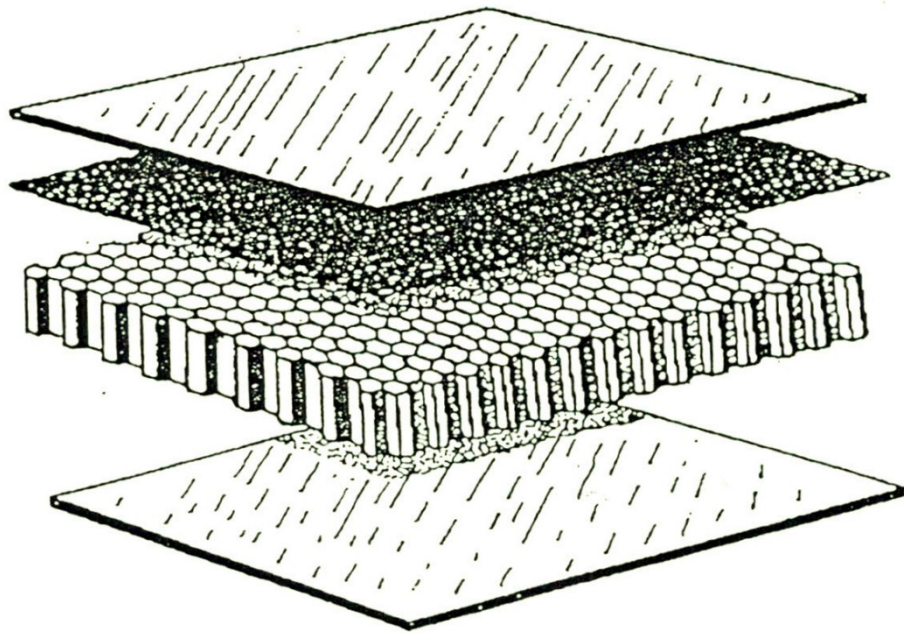
Shear webs — transverse and/or longitudinal

② Large bond areas to ③



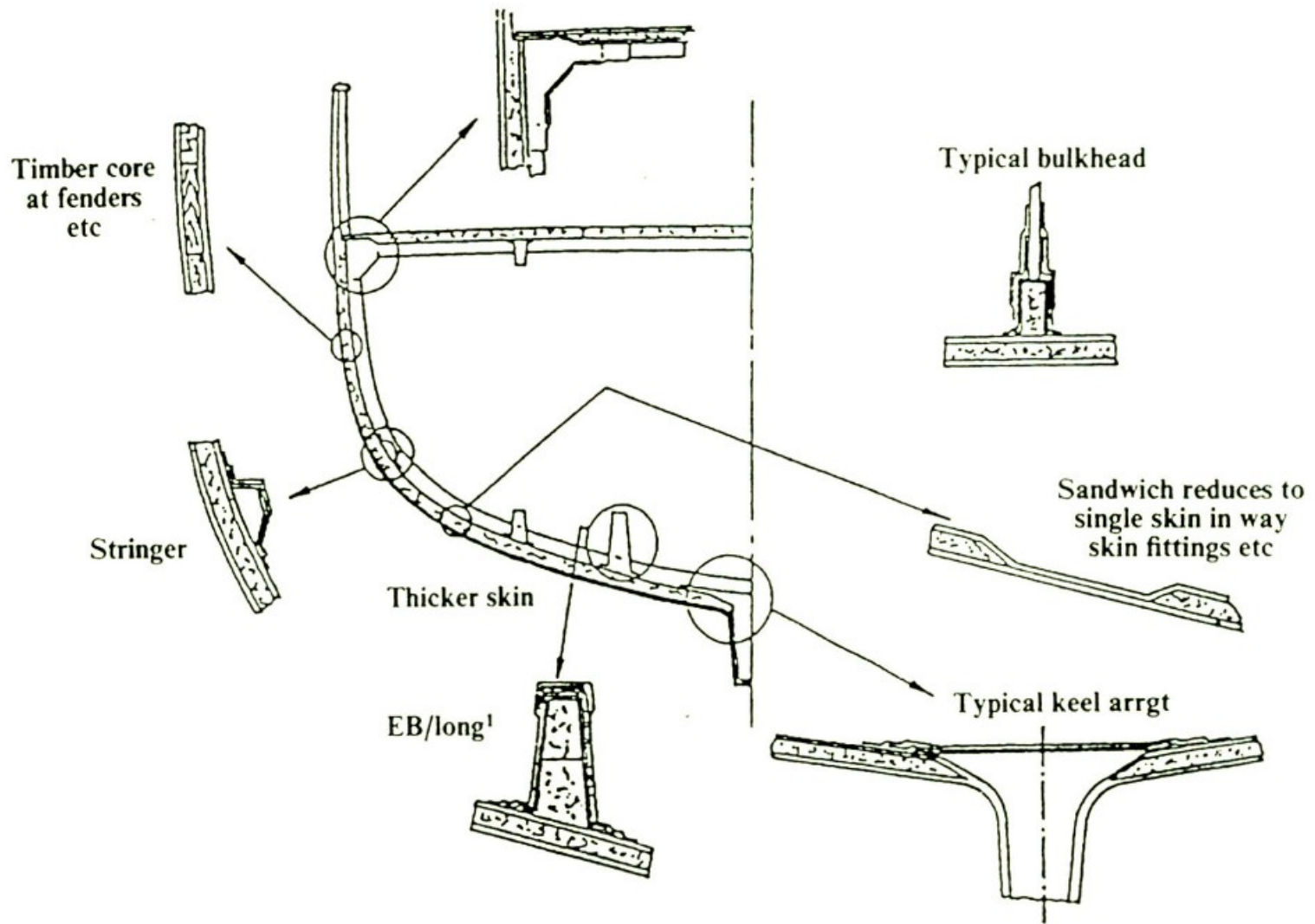
Shear web alternatives  
uni-directional  
(construction complications)

# Particolari costruttivi di strutture in GRP

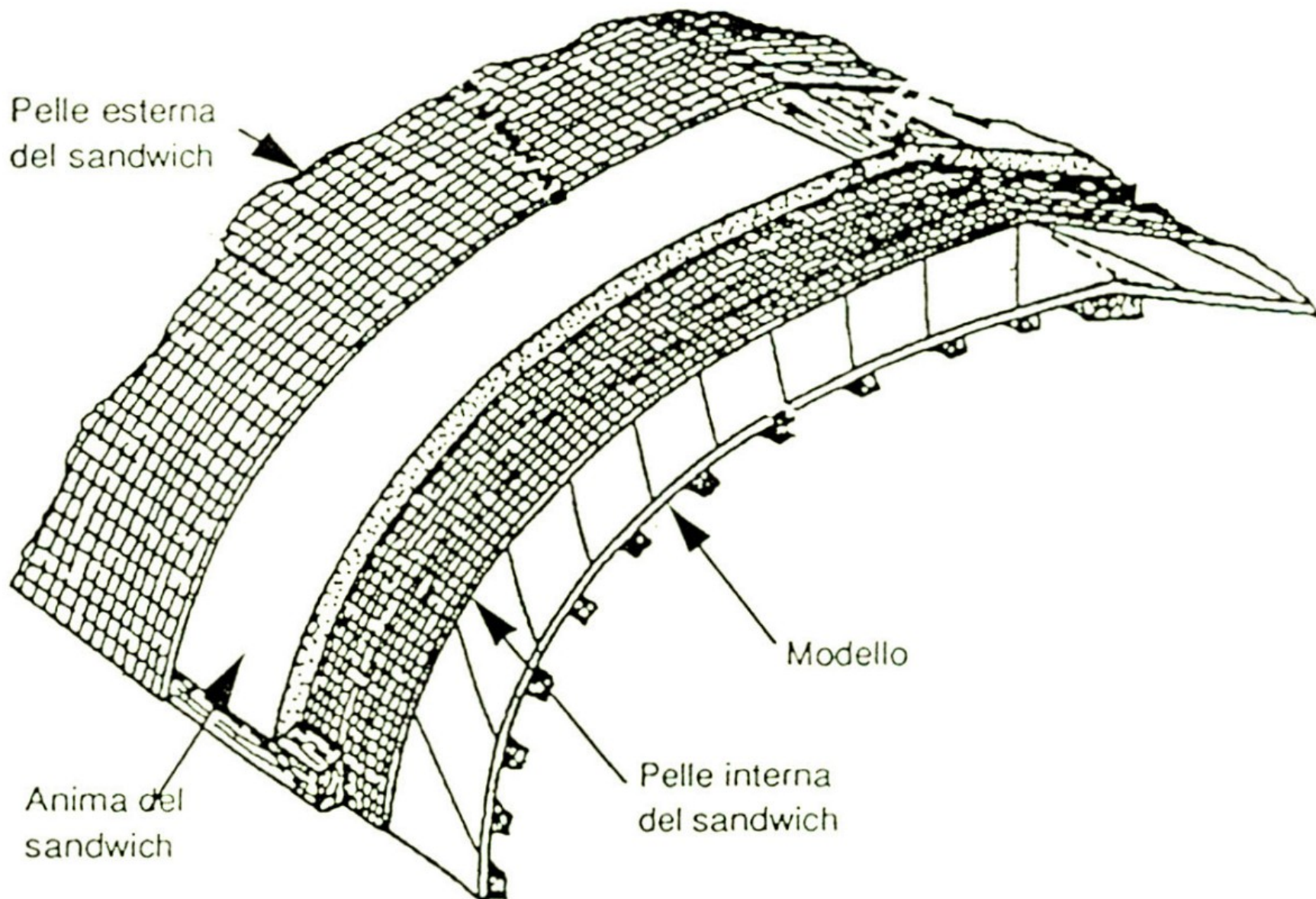




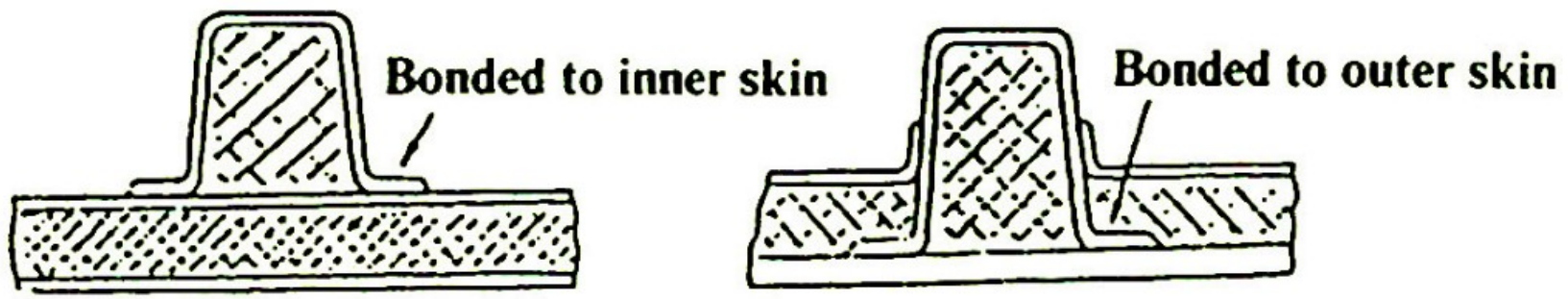
Typical sandwich hull structure



*Particolari costruttivi di strutture in GRP*



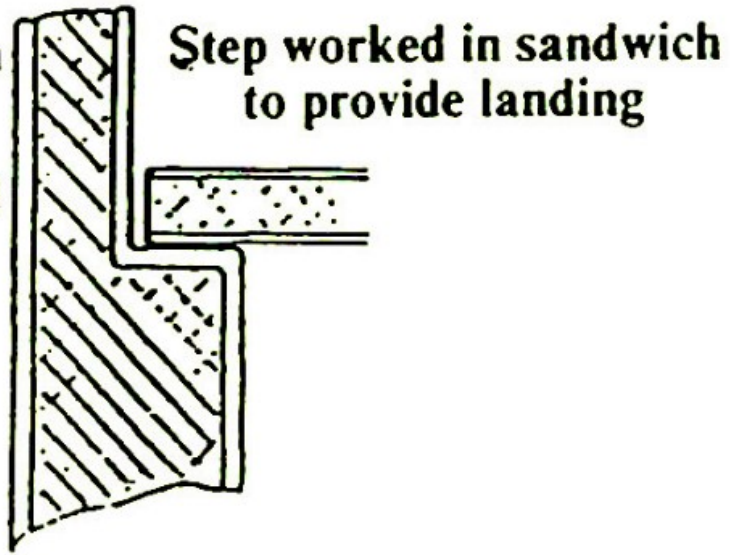
### Frames to sandwich skin alternatives



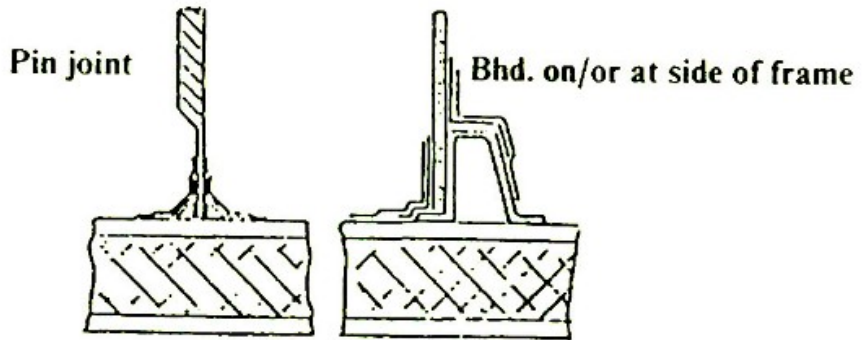
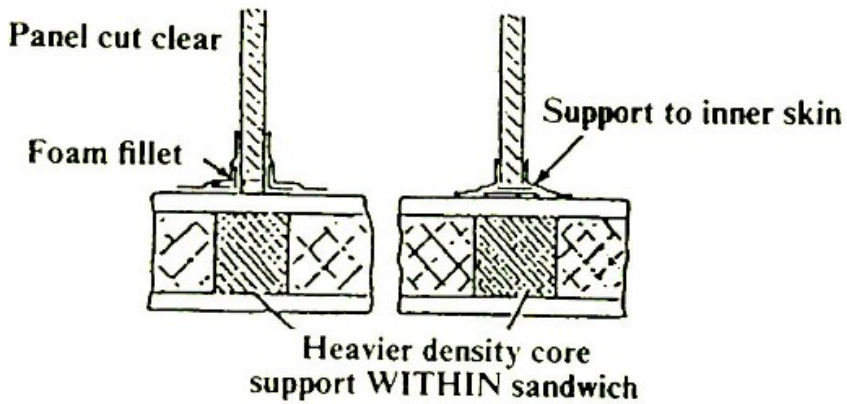
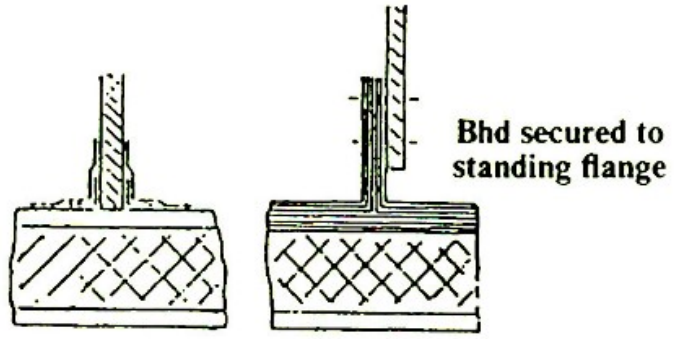
Joggled skin sandwich

not usual

But often



**Alternative bulkhead/sandwich arrangements**



# Guidance Notes for the Classification of Special Service Craft



Design Details

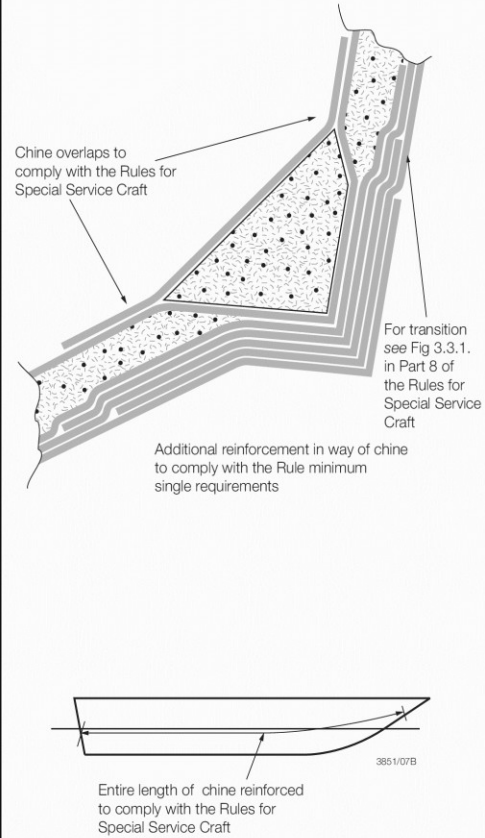
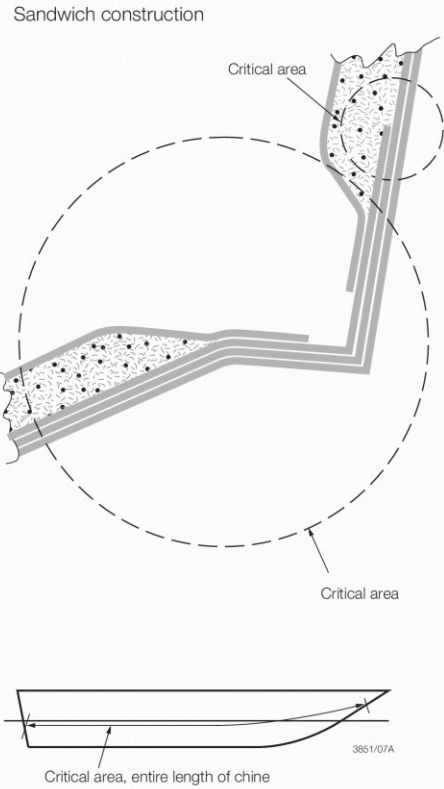
AREA: Chine in way of side shell and bottom shell connection

ITEM: Chine reinforcement



CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



NOTES

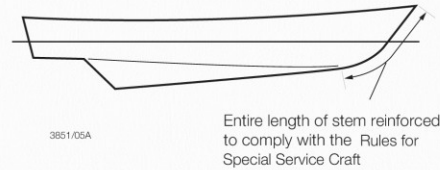
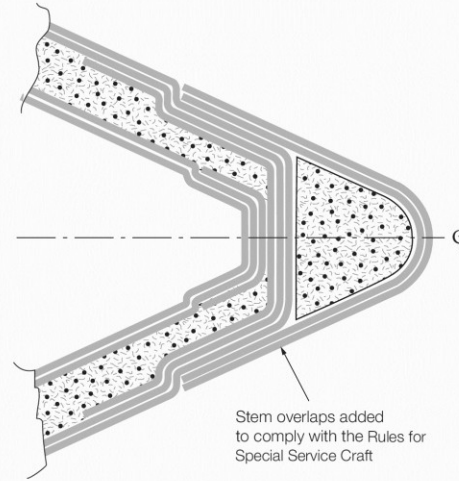
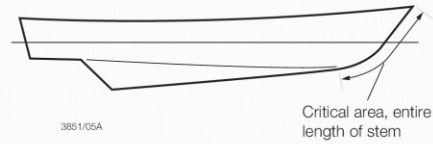
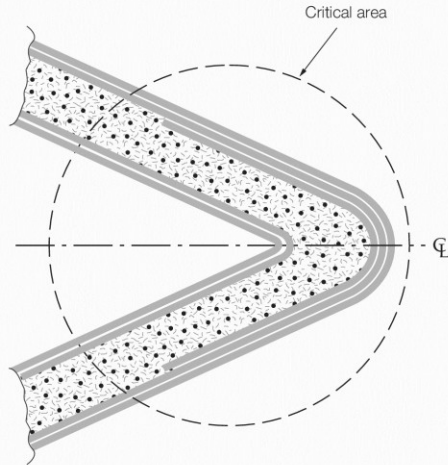
- Failure Mechanism Excess loads due to grounding, docking, slinging, hydrodynamic and other types of impact.
- Building Tolerance All FRP materials to comply with the Rules for Special Service Craft.
- Laminating Requirements To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Stem  
 ITEM: Stem reinforcement

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

Sandwich construction



NOTES

- Failure Mechanism            Excess loads due to collision and impact with floating debris.
- Building Tolerance            All FRP materials to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

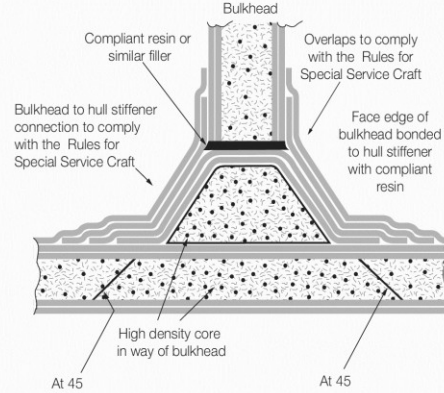
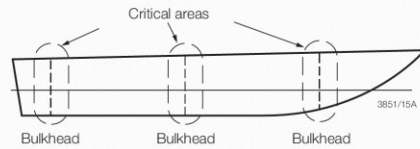
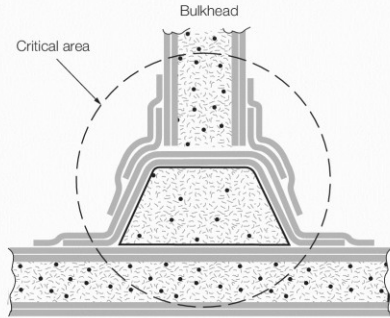
AREA: Hull bottom structure  
 ITEM: Bulkhead to hull connection



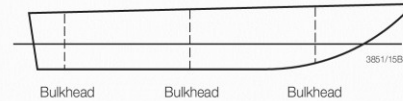
CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

Sandwich construction, high speed



All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

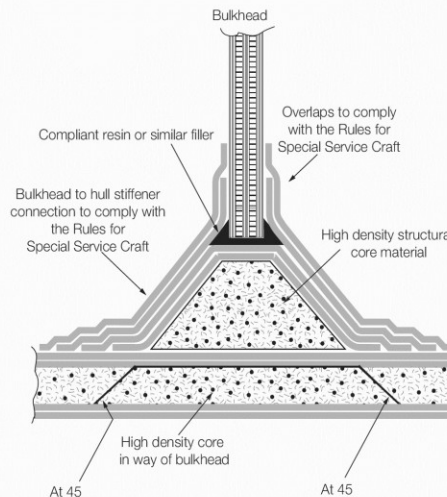
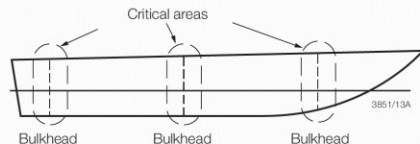
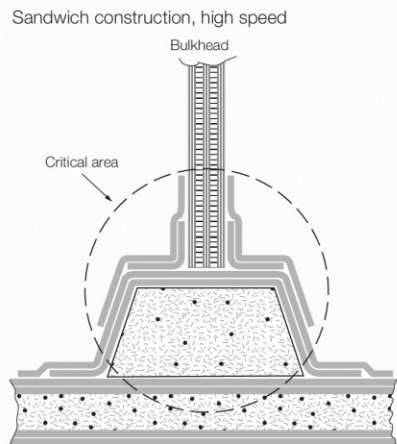
- Failure Mechanism      Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking.
- Building Tolerance      All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements      To be in accordance with Part 8 of the Rules for Special Service Craft.



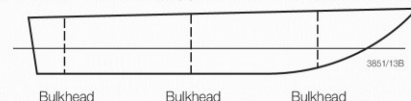
AREA: Hull bottom structure  
 ITEM: Bulkhead to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

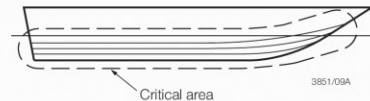
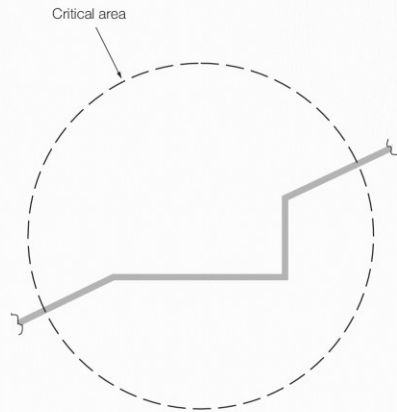
- Failure Mechanism      Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking.
- Building Tolerance      All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull structure

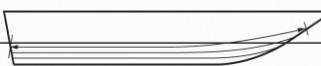
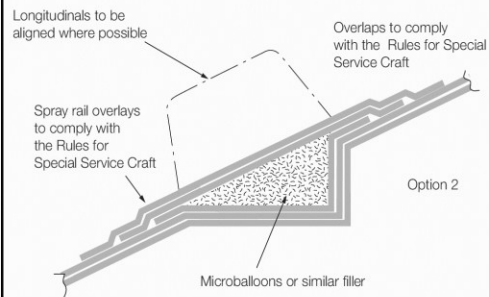
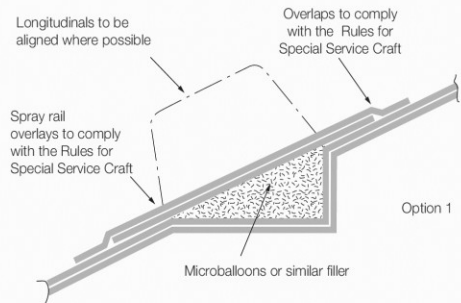
ITEM: Spray rails

CRITICAL AREAS

Single skin construction



DETAIL DESIGN IMPROVEMENT



NOTES

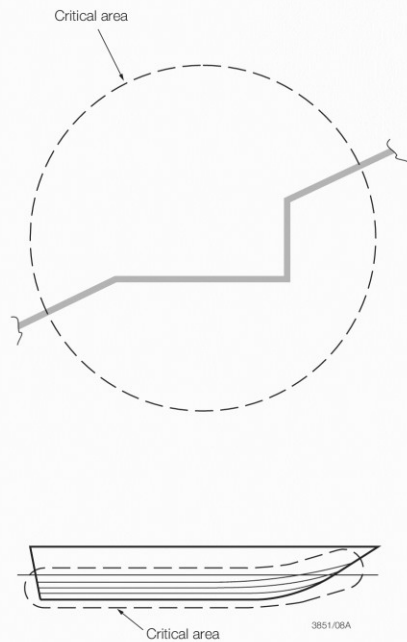
- Failure Mechanism Excess loads due to grounding and impact.
- Building Tolerance All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull structure

ITEM: Spray rails

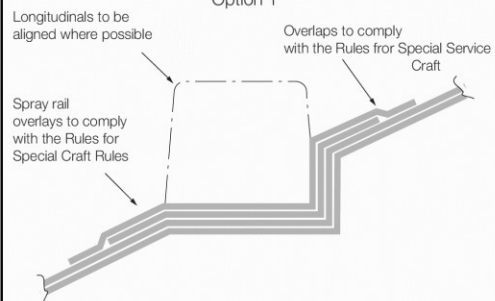
CRITICAL AREAS

Single skin construction

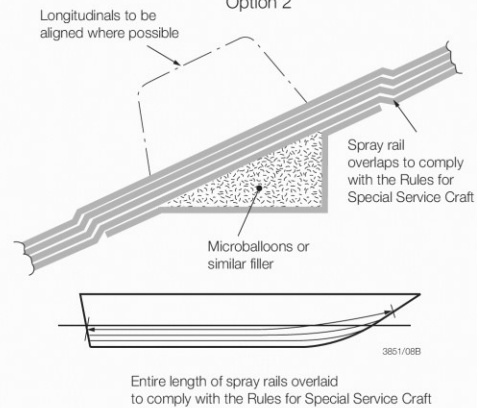


DETAIL DESIGN IMPROVEMENT

Option 1



Option 2



NOTES

Failure Mechanism Excess loads due to grounding and impact.

Building Tolerance All FRP material to comply with the Rules for Special Service Craft.

Laminating Requirements To be in accordance with the Part 8 of the Rules for Special Service Craft.

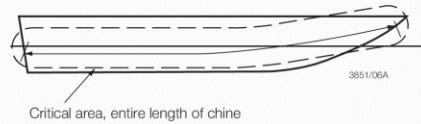
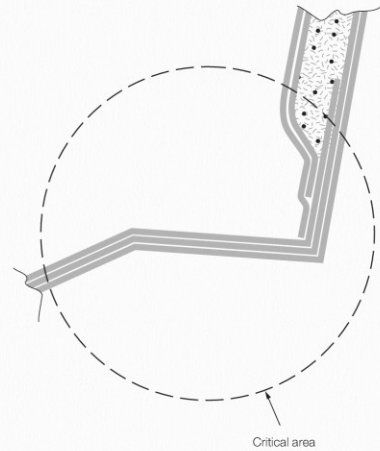
AREA: Chine in way of side shell and bottom shell connection

ITEM: Chine reinforcement



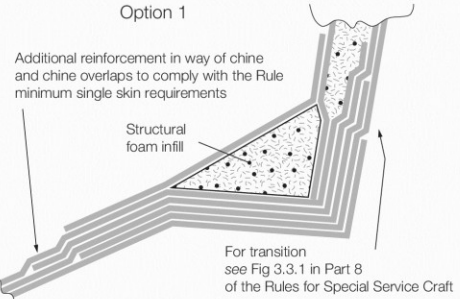
CRITICAL AREAS

Sandwich side and single skin bottom

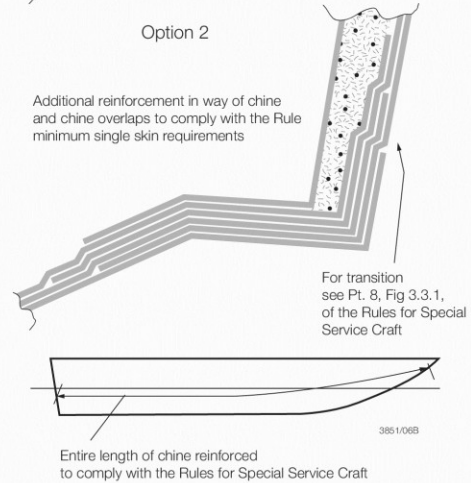


DETAIL DESIGN IMPROVEMENT

Option 1



Option 2



NOTES

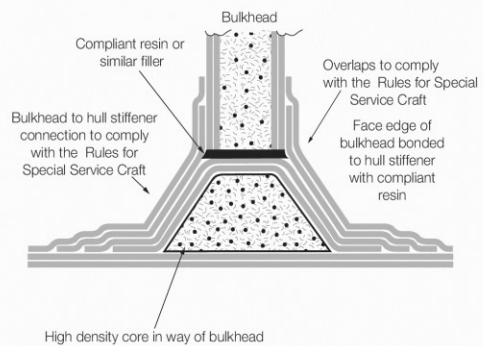
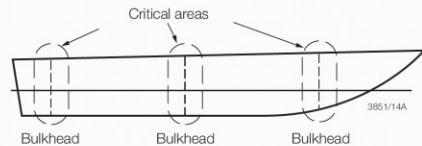
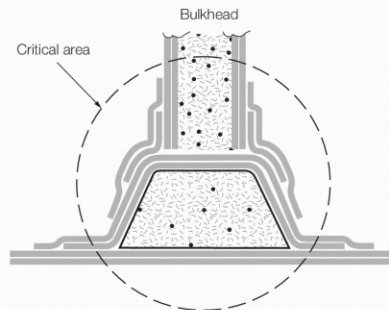
- Failure Mechanism Excess loads due to grounding, docking, slinging and hydrodynamic impact.
- Building Tolerance All FRP material to comply with the Rules for Special Service Craft
- Laminating Requirements To be in accordance with the Part 8 of the Rules for Special Service Craft.

AREA: Hull internal structure  
 ITEM: Bulkhead to hull connection

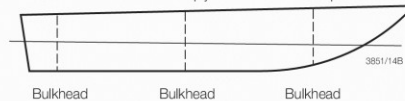
CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

Single skin construction, high speed



All bulkhead hull connections to comply with the Rules for Special Service Craft



NOTES

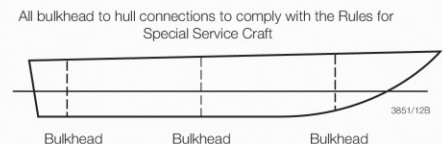
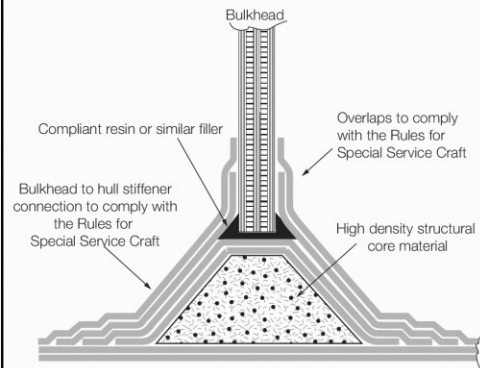
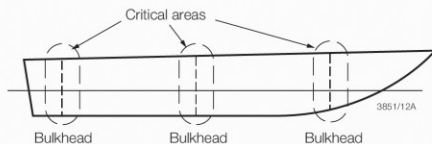
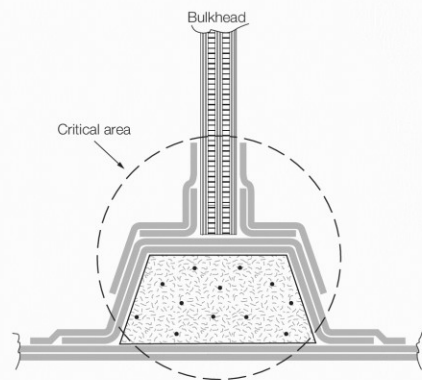
- Failure Mechanism            Excess loads due to berthing, slinging, impact and racking.
- Building Tolerance            All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with the Part 8 of the Rules for Special Service Craft.

AREA: Hull internal structure  
 ITEM: Bulkhead to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

Single skin construction, high speed



All bulkhead to hull connections to comply with the Rules for Special Service Craft

NOTES

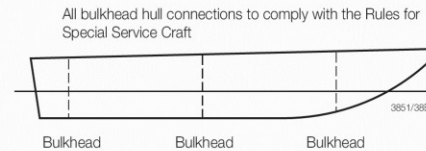
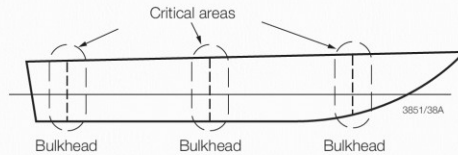
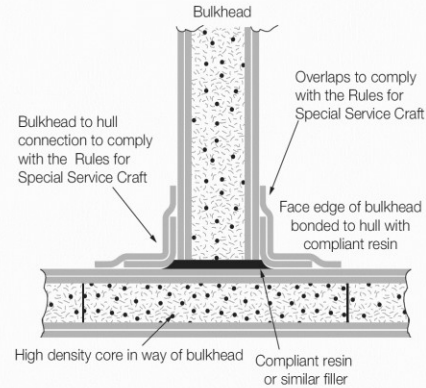
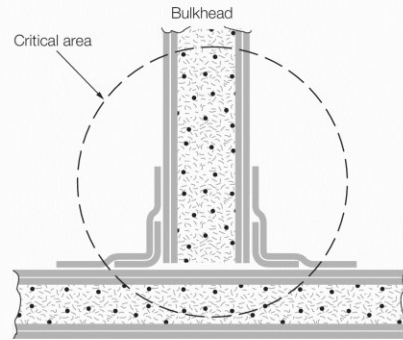
- Failure Mechanism            Excess loads due to berthing, slinging, impact and racking.
- Building Tolerance            All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull internal structure  
 ITEM: Bulkhead to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

Sandwich construction, low speed



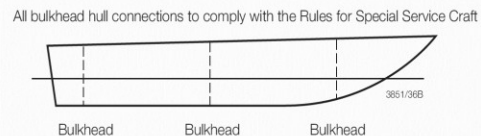
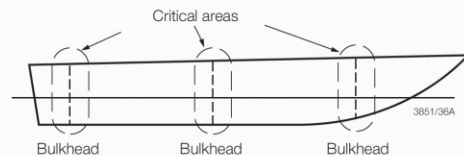
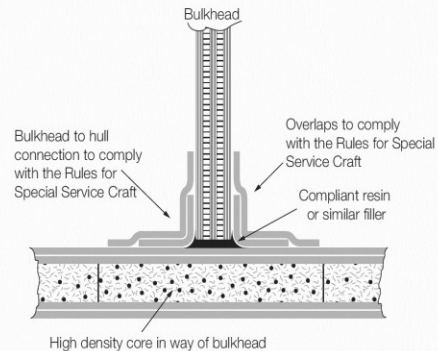
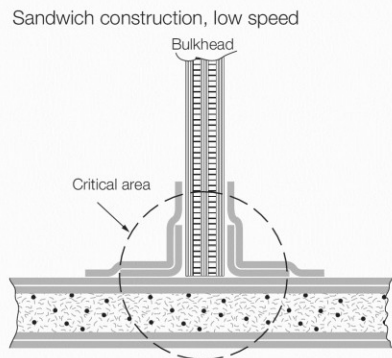
NOTES

- |                         |  |
|-------------------------|--|
| Failure Mechanism       | Crushing of the sandwich core under the bulkhead, and delamination of the sandwich bulkhead due to excess loads arising from berthing, slinging, impact and racking. |
| Building Tolerance      | All FRP material to comply with the Rules for Special Service Craft.   |
| Laminating Requirements | To be in accordance with Part 8 of the Rules for Special Service Craft.  |

AREA: Hull internal structure  
 ITEM: Bulkhead to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



NOTES

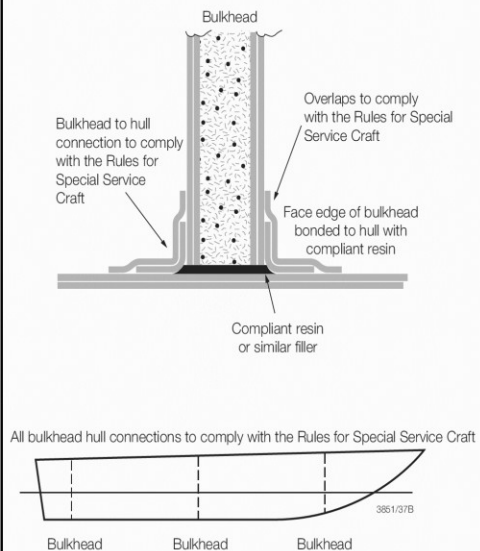
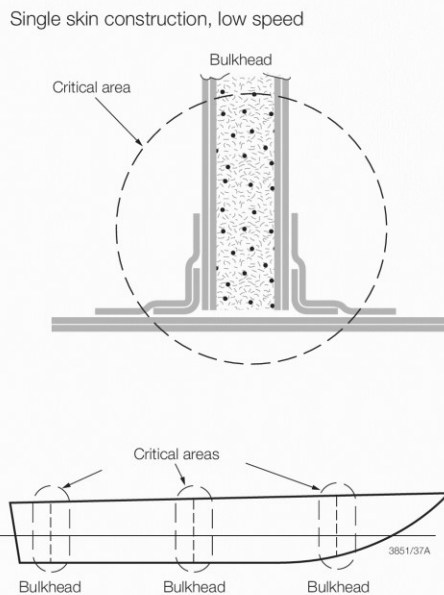
- |                         |   |
|-------------------------|---|
| Failure Mechanism       | Crushing of the sandwich core under the bulkhead due to excess loads arising from berthing, slinging, impact and racking. |
| Building Tolerance      | All FRP material to comply with the Rules for Special Service Craft.  |
| Laminating Requirements | To be in accordance with Part 8 of the Rules for Special Service Craft.   |



AREA: Hull bottom structure  
 ITEM: Bulkhead to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



NOTES

- |                         |   |
|-------------------------|---|
| Failure Mechanism       | Excess loads due to berthing, slinging, impact and racking.             |
| Building Tolerance      | All FRP material to comply with the Rules for Special Service Craft.    |
| Laminating Requirements | To be in accordance with Part 8 of the Rules for Special Service Craft. |

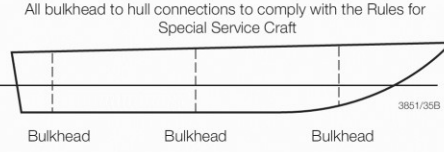
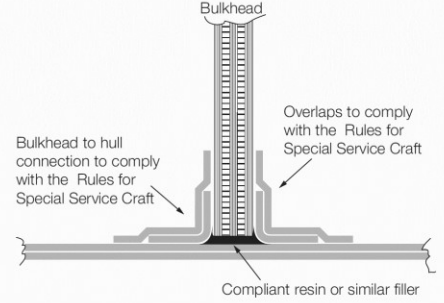
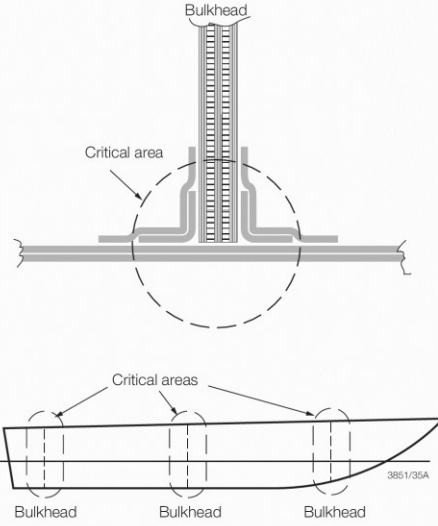
AREA: Hull bottom structure  
 ITEM: Bulkhead to hull connection



CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

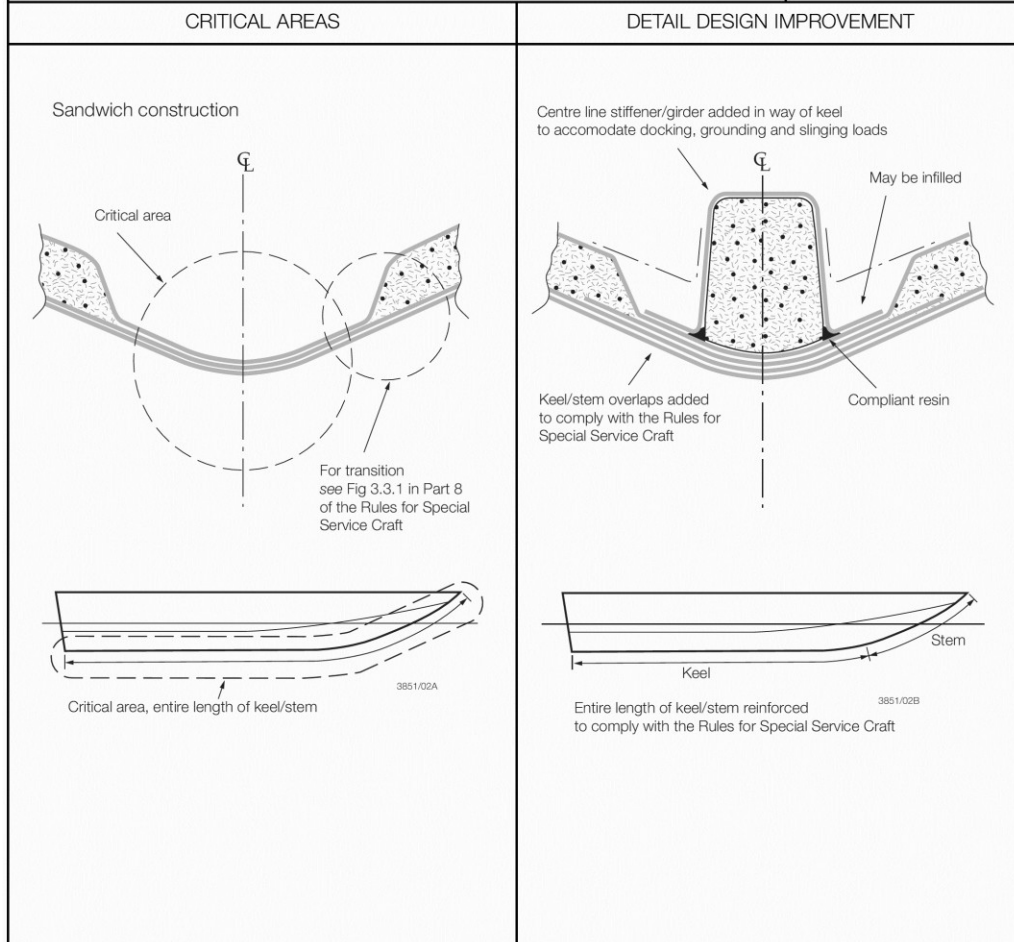
Single skin construction, low speed



NOTES

- Failure Mechanism      Excess loads due to berthing, slinging, impact and racking.
- Building Tolerance      All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull centreline structure  
 ITEM: Keel/stem reinforcement and keel stiffening



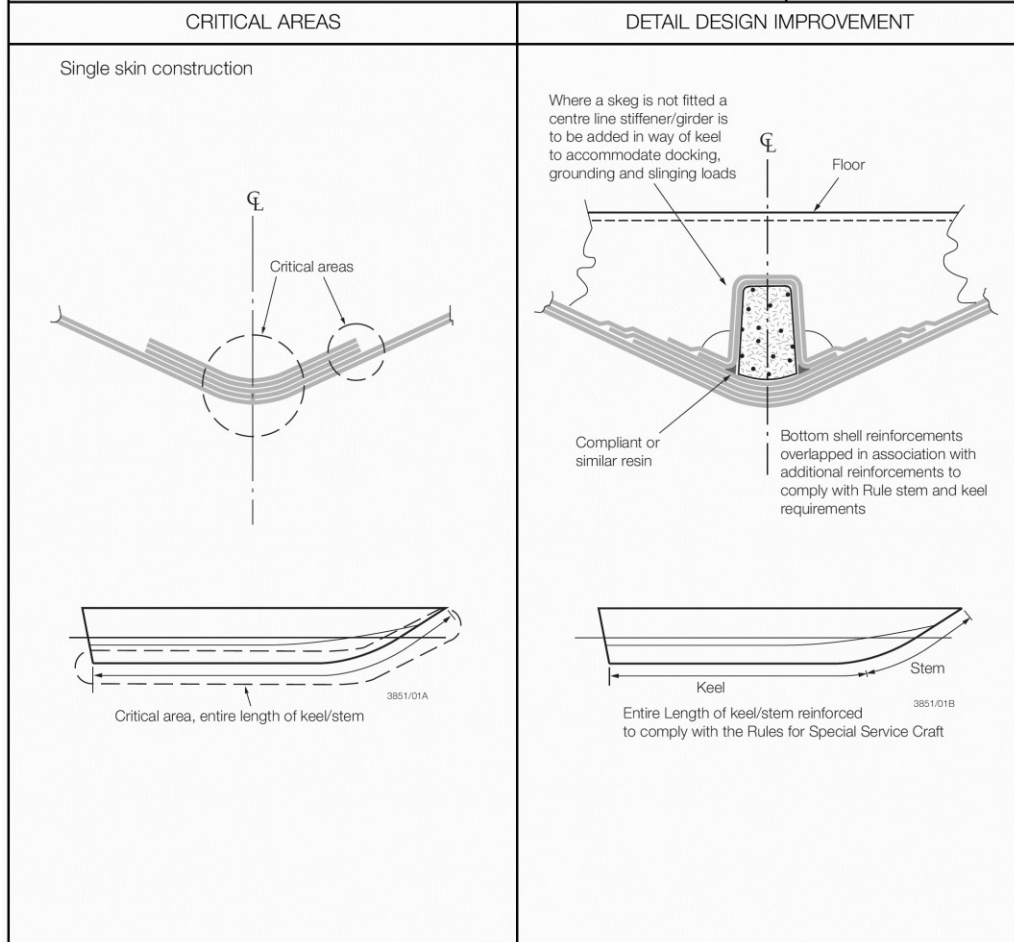
**NOTES**

Failure Mechanism            Excess loads due to grounding, docking and slinging.

Building Tolerance            All FRP materials to comply with the Rules for Special Service Craft.

Laminating Requirements    To be in accordance with the Part 8 of the Rules for Special Service Craft.

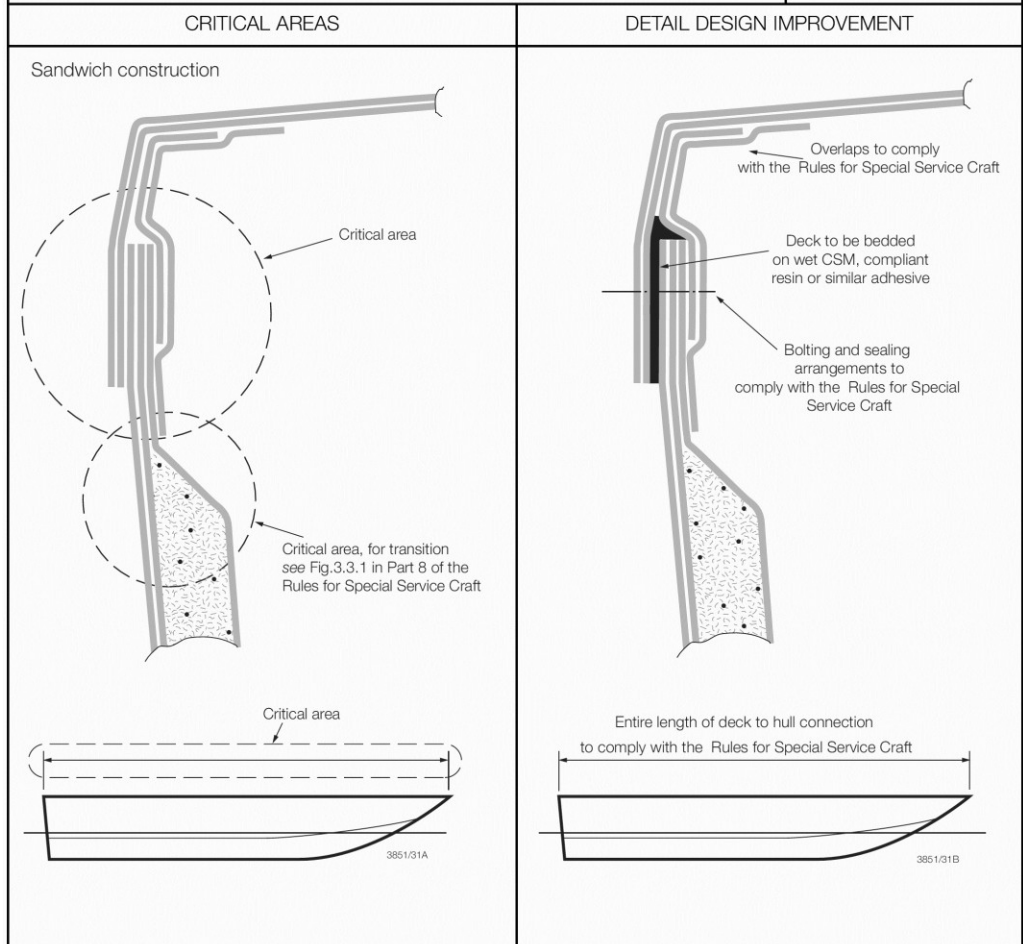
AREA: Hull centreline structure  
 ITEM: Keel/stem reinforcement and keel stiffening



NOTES

- Failure Mechanism      Excess loads due to grounding, docking and slinging.
- Building Tolerance      All FRP materials to comply with the Rules for Special Service Craft.
- Laminating Requirements      To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull structure  
 ITEM: Deck to hull connection



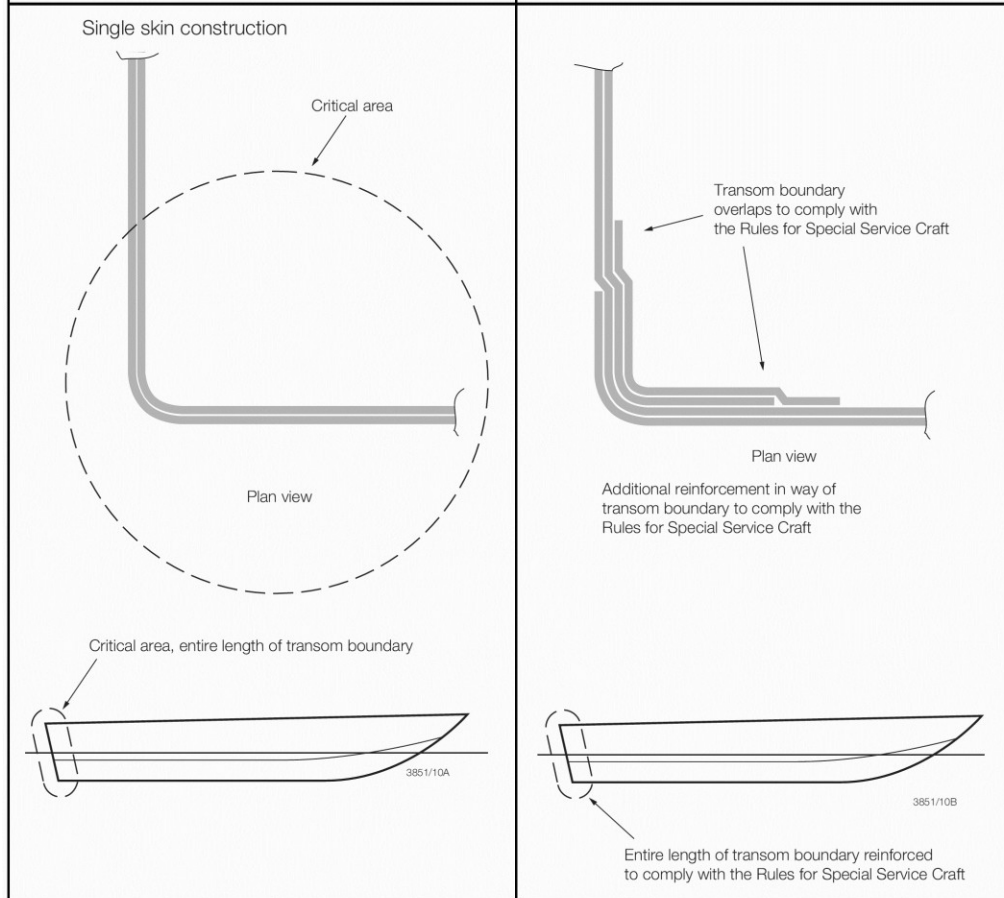
**NOTES**

Failure Mechanism	Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather.
Building Tolerance	All FRP material to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull structure  
 ITEM: Transom boundary

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



NOTES

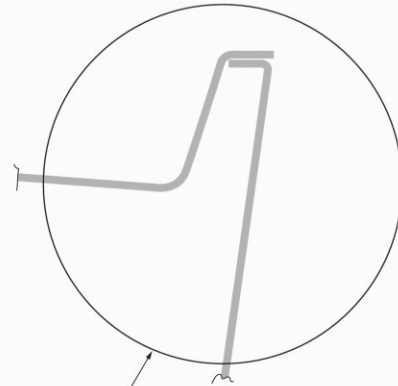
Failure Mechanism            Excess loads due to docking and impact due to berthing.  
 Building Tolerance            All FRP materials to comply with the Rules for Special Service Craft.  
 Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull structure  
 ITEM: Deck to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

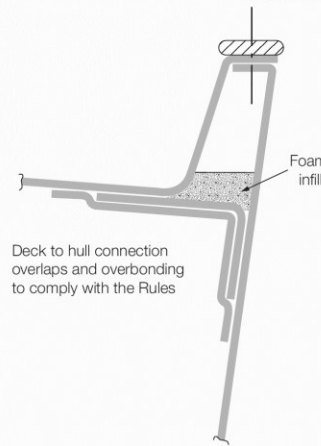
Single skin construction



Critical area

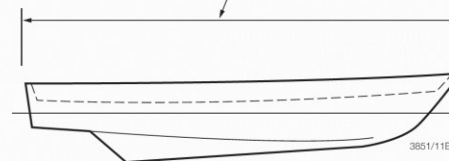


Bolts, nuts and washers to be suitably sealed



Deck to hull connection overlaps and overbonding to comply with the Rules

Deck to hull connection to comply with the Rules



NOTES

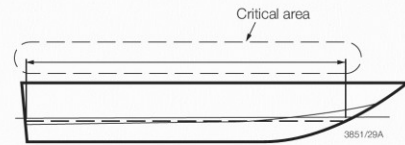
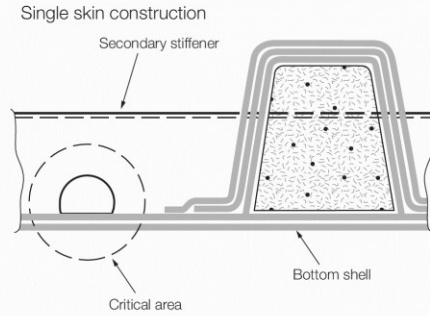
- |                         |   |
|-------------------------|---|
| Failure Mechanism       | Excess loads due to berthing, slinging, impact from green seas and other loadings arising from heavy weather. |
| Building Tolerance      | All FRP material to comply with the Rules for Special Service Craft.  |
| Laminating Requirements | To be in accordance with Part 8 of the Rules for Special Service Craft.                                       |

AREA: Hull bottom structure

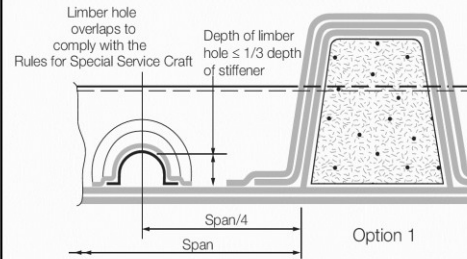
ITEM: Limber holes



CRITICAL AREAS

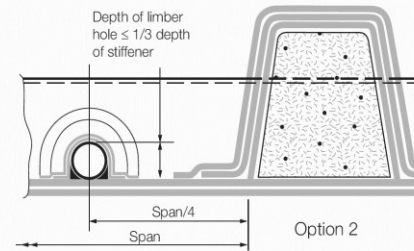


DETAIL DESIGN IMPROVEMENT



FRP preform bonded to shell and stiffener with compliant resin adhesive

NOTE: PVC preforms to be overlaminated to shell before installation of stiffener



All limber holes to comply with the Rules for Special Service Craft



NOTES

- Failure Mechanism Excess loads due to hydrodynamic impact, grounding, docking and slinging leading to stiffener web failure.
- Building Tolerance All FRP materials to be in accordance with the Rules for Special Service Craft.
- Laminating Requirements To be in accordance with Part 8 of the Rules for Special Service Craft.

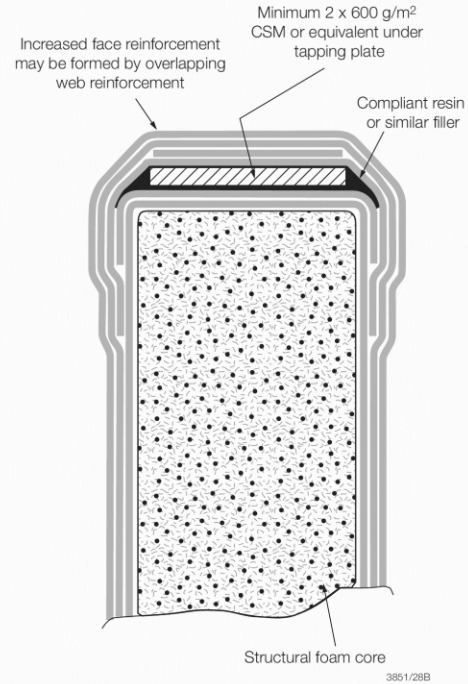
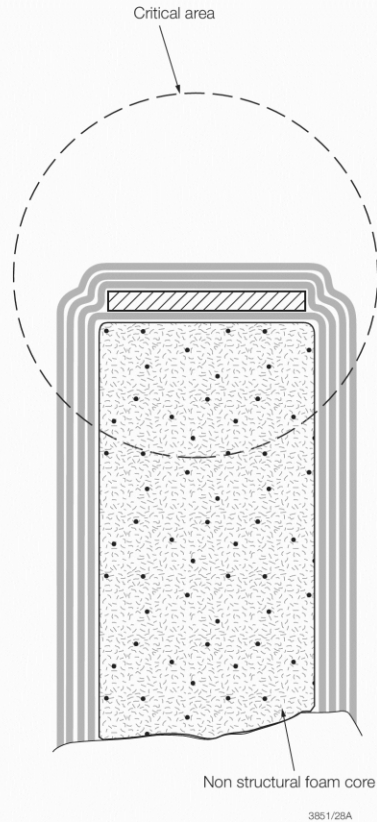


AREA: Hull bottom structure  
 ITEM: Machinery seating, tapping plates



CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



Tapping plate is to be suitably abraded, all sharp edges removed and all corners radiused prior to encapsulating

NOTES

- Failure Mechanism Engine loadings arising from thrust, torque and mass.
- Building Tolerance All FRP materials to comply with the Rules for Special Service Craft.
- Laminating Requirements To be in accordance with Part 8 of the Rules for Special Service Craft.

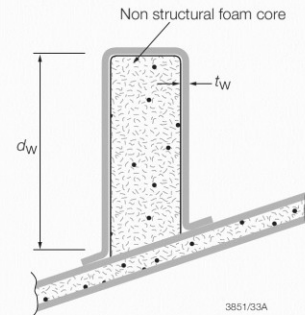
AREA: Hull internal structure

ITEM: Deep girders and floors

CRITICAL AREAS

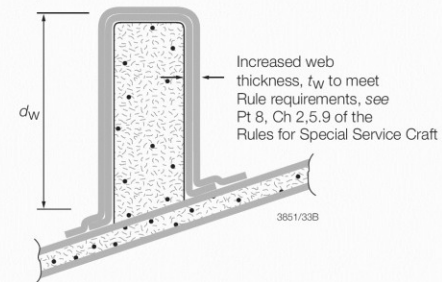
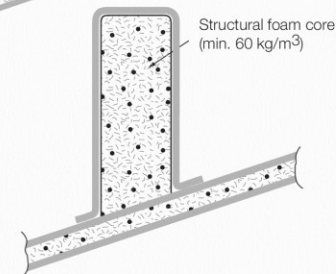
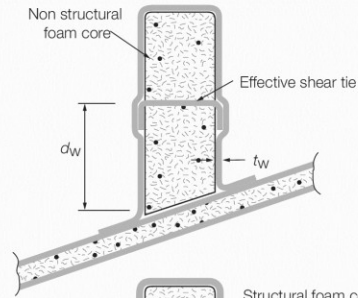
DETAIL DESIGN IMPROVEMENT

Sandwich construction/single skin construction



$t_w$  is to satisfy the Rule requirement for  $d_w$ , see Pt 8, Ch 2.5.9 of the Rules for Special Service Craft

$d_w$  = unsupported web depth  
 $t_w$  = web thickness



NOTES

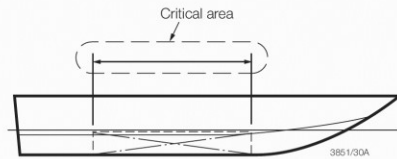
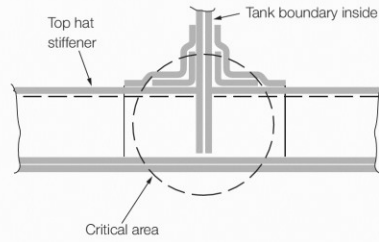
Failure Mechanism Web buckling under design load, docking and berthing loads.

Building Tolerance All FRP material to comply with the Rules for Special Service Craft.

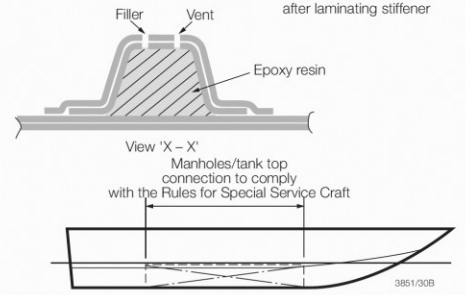
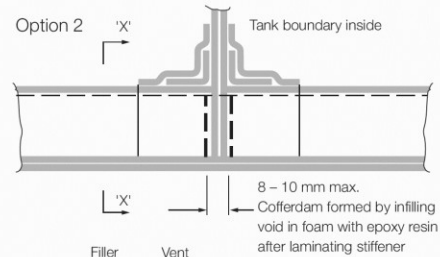
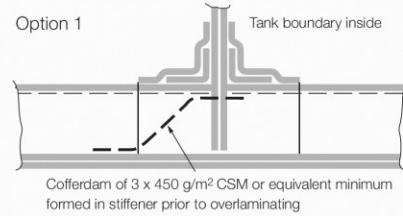
Laminating Requirements To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull internal structure  
 ITEM: 'Top-hat' stiffeners penetrating tank boundaries

CRITICAL AREAS



DETAIL DESIGN IMPROVEMENT



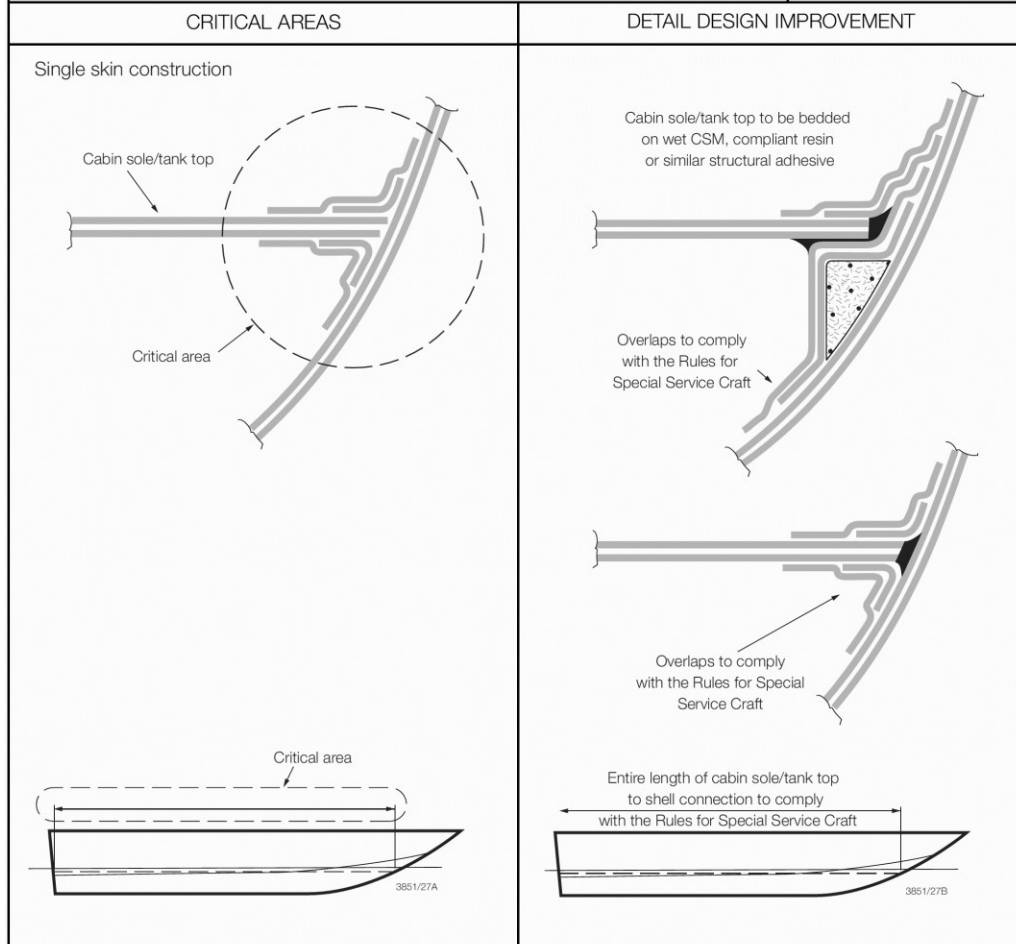
NOTES

Failure Mechanism      Ingress and permeation of fluid along stiffener.

Building Tolerance      All FRP material to comply with the Rules for Special Service Craft. Fit-up is to be very good.

Laminating Requirements      To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull internal structure  
 ITEM: Lower deck/tank top to bottom shell connection

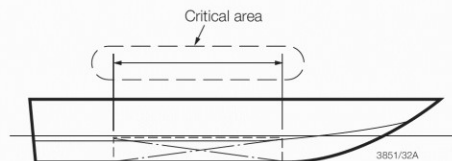
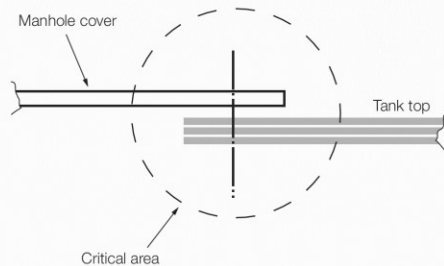


NOTES

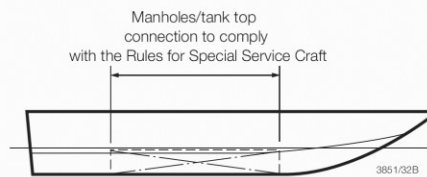
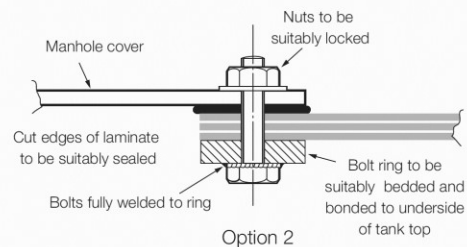
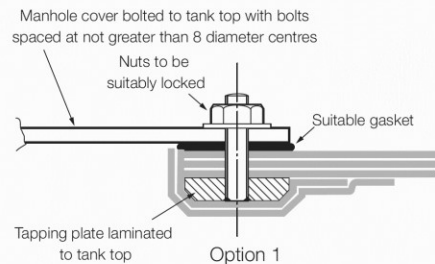
Failure Mechanism	Excess loads due to impact also hydrostatic pressure where the internal structure forms the boundary of an integral tank.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Hull internal structure  
 ITEM: Integral tanks access manholes

CRITICAL AREAS



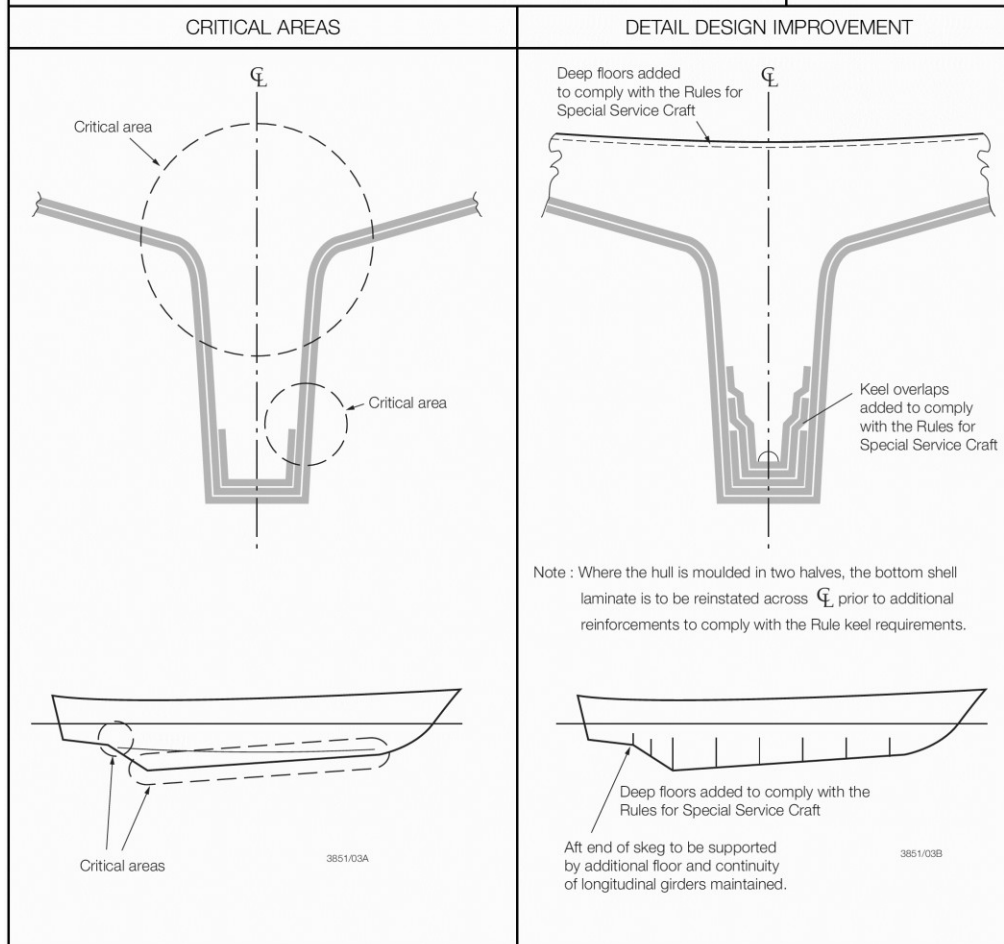
DETAIL DESIGN IMPROVEMENT



NOTES

- Failure Mechanism            Leakage under hydrostatic pressure.
- Building Tolerance            All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

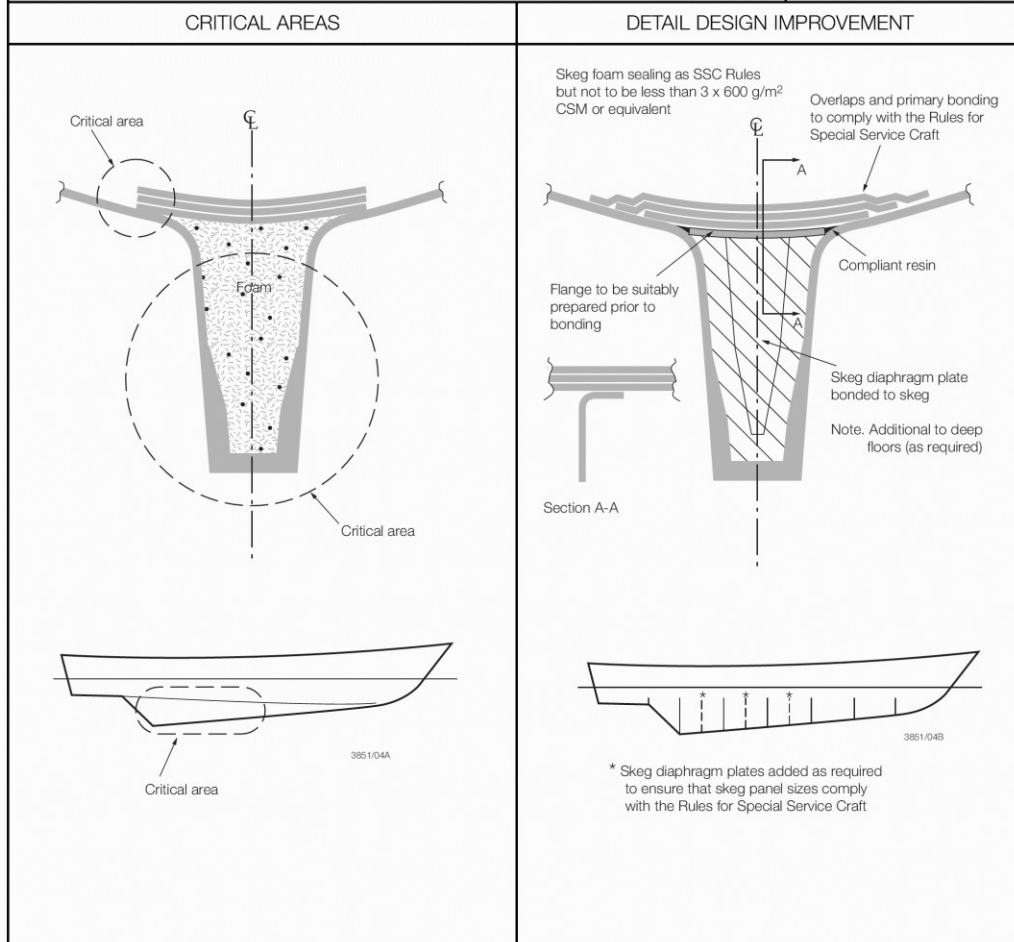
AREA: Skeg (open type)  
 ITEM: Skeg stiffening and reinforcement



**NOTES**

Failure Mechanism	Excess loads due to grounding, docking, slinging and hydrostatic pressure.
Building Tolerance	All FRP materials to comply with the Rules for Special Service Craft.
Laminating Requirements	To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Skeg (closed type)  
 ITEM: Skeg diaphragm plates and sealing laminate



**NOTES**

Failure Mechanism      Excess loads due to grounding, docking, slinging and hydrostatic pressure both externally and internally in the case of integral tanks.

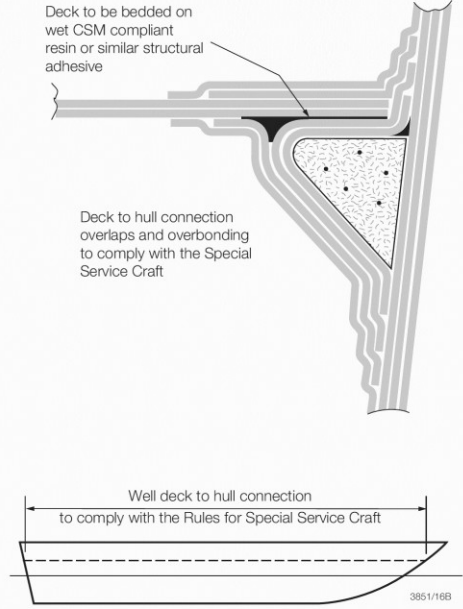
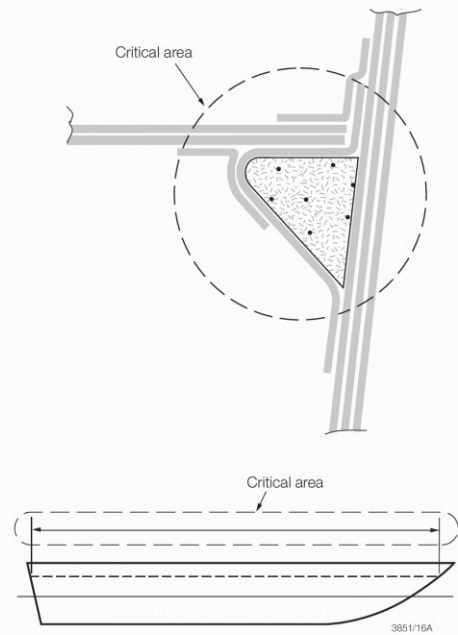
Building Tolerance      To align with bottom framing. All FRP materials to comply with the Rules for Special Service Craft.

Laminating Requirements      To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Deck structure  
 ITEM: Well deck, lower/sole deck to hull connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT

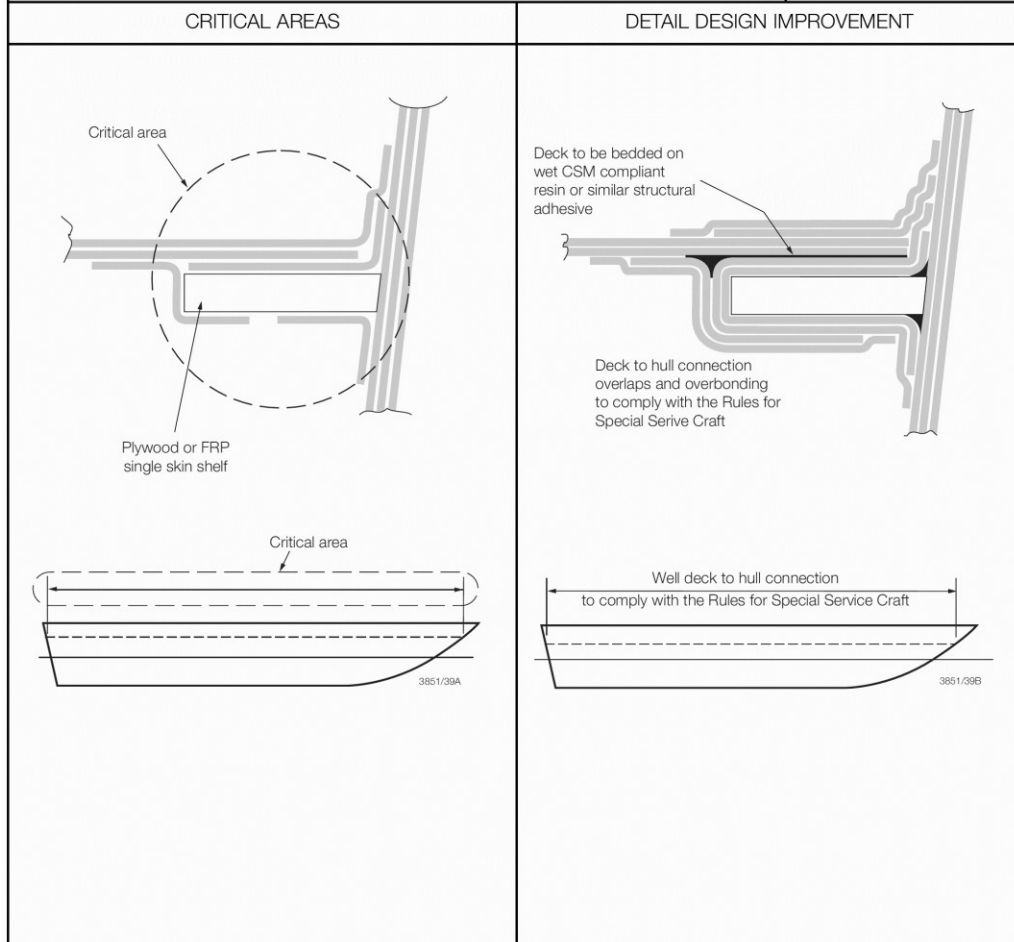


NOTES

- Failure Mechanism            Excess loads due to berthing and slinging.
- Building Tolerance            All FRP material to comply with the Rules for Special Service Craft.
- Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.



AREA: Deck structure  
 ITEM: Well deck, lower/sole deck to hull connection



**NOTES**

Failure Mechanism            Excess loads due to berthing and slinging.

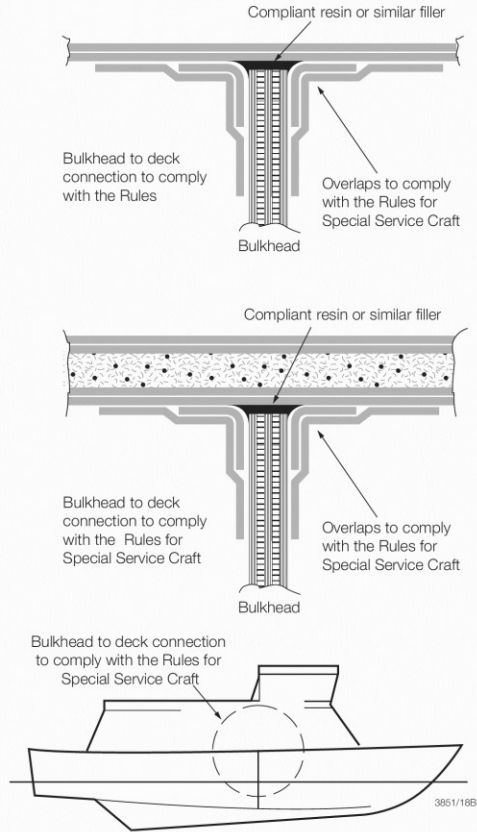
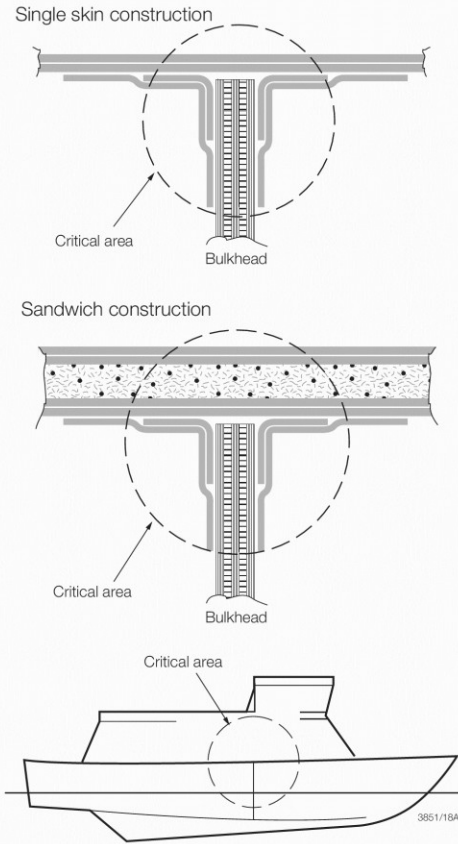
Building Tolerance            All FRP material to comply with the Rules for Special Service Craft.

Laminating Requirements    To be in accordance with Part 8 of the Rules for Special Service Craft.

AREA: Deck  
 ITEM: Bulkhead to deck connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



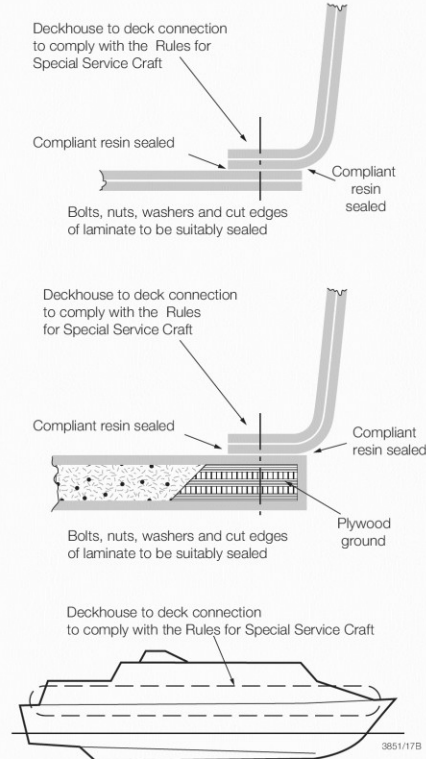
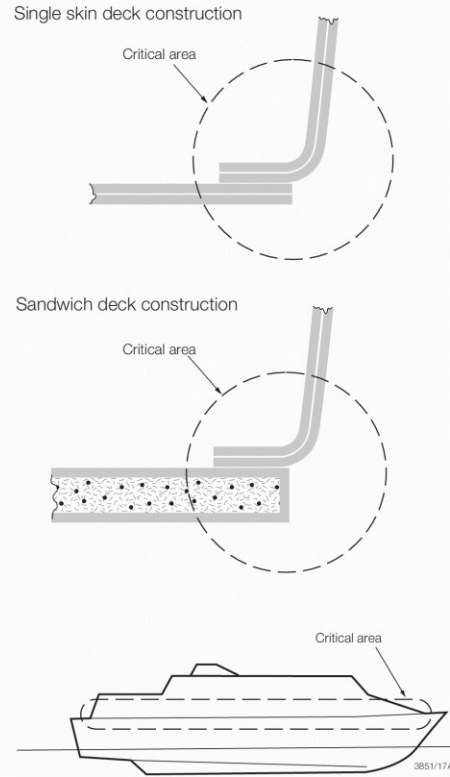
NOTES

- |                         |   |
|-------------------------|---|
| Failure Mechanism       | Excess loads due to berthing, slinging and impact.  |
| Building Tolerance      | All FRP material to comply with the Rules for Special Service Craft. Alignment and fit to be good, all gaps to be filled. |
| Laminating Requirements | To be in accordance with Part 8 of the Rules for Special Service Craft.   |

AREA: Deck  
 ITEM: Deckhouse to deck connection

CRITICAL AREAS

DETAIL DESIGN IMPROVEMENT



NOTES

Failure Mechanism Excess loads due to berthing, slinging, impact from green seas and other loads arising from heavy weather.

Building Tolerance All FRP material to comply with the Rules for Special Service Craft.

Laminating Requirements To be in accordance with Part 8 of the Rules for Special Service Craft.