## Annex 4: FRP CONSTRUCTION STANDARDS*

### 1.1 Definitions

For the purpose of these recommendations, unless expressly provided otherwise, the following definitions apply:

1.1.1 *Breadth (B)*** is the maximum breadth of the vessel, measured at maximum beam to the moulded line of the frame in a vessel with a metal shell and to the outer surface of the hull in a vessel with a shell of any other material.

1.1.2 *Competent authority* is the Government of the State whose flag the vessel is entitled to fly. The competent authority may delegate certain of its duties to entities authorized by it and that it deems suitably qualified to undertake those duties.

1.1.3 *Cubic Numeral (CuNo)*** is the result of multiplying LOA x B x D.

1.1.4 *Decked vessel* is a vessel having a fixed watertight deck covering the entire hull above the deepest operating waterline. Where open wells or cockpits are fitted in this deck the vessel is considered a decked vessel if flooding of the well or cockpit will not endanger the vessel.

1.1.5 The *depth (D)*** is the moulded depth amidships.

1.1.6 *Design categories*

The categories here indicate sea and wind conditions for which a vessel is assessed by this standard to be suitable, provided the vessel is correctly operated and at a speed appropriate to the prevailing sea state.

1. **Design category A**

   Category of vessels considered suitable to operate in seas with significant wave heights above 4 m and wind speeds in excess of Beaufort Force 8 (19 m/s), but excluding abnormal conditions, e.g. hurricanes.

2. **Design category B**

   Category of vessels considered suitable to operate in seas with significant wave heights up to 4 m and winds of Beaufort Force 8 (19 m/s), or less.

3. **Design category C**

   Category of vessels considered suitable to operate in seas with significant wave heights up to 2 m and a typical steady wind force of Beaufort Force 6 (12 m/s), or less.

4. **Design category D**

   Category of vessels considered suitable to operate in waters with significant wave heights up to and including 0.30 m with occasional waves of 0.5 m height, for example from passing vessels, and a typical steady wind force of Beaufort 4 (7 m/s), or less.

1.1.7 *Length overall (LOA)*** should be taken as the distance in a straight line parallel to the design waterline, between the foremost point of the bow to the aftermost point of the stern.

1.1.8 *Undecked* vessel is a vessel which is not a decked vessel.

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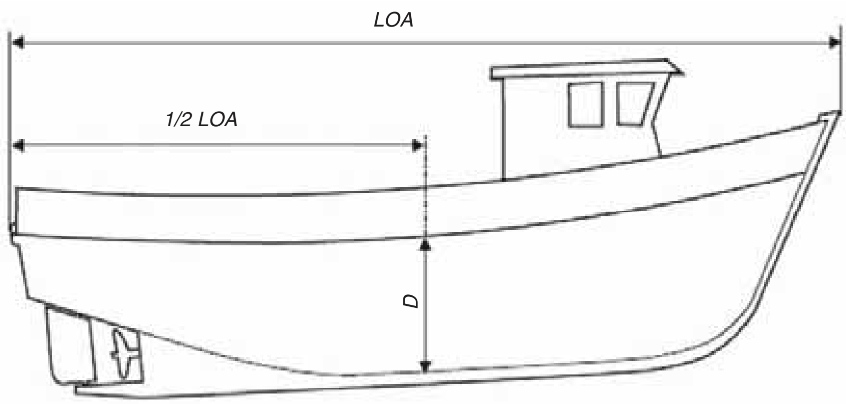
* *Drawn from the draft FAO/ILO/IMO Safety recommendations for decked fishing vessels of less than 12 metres in length and undecked fishing vessels.*

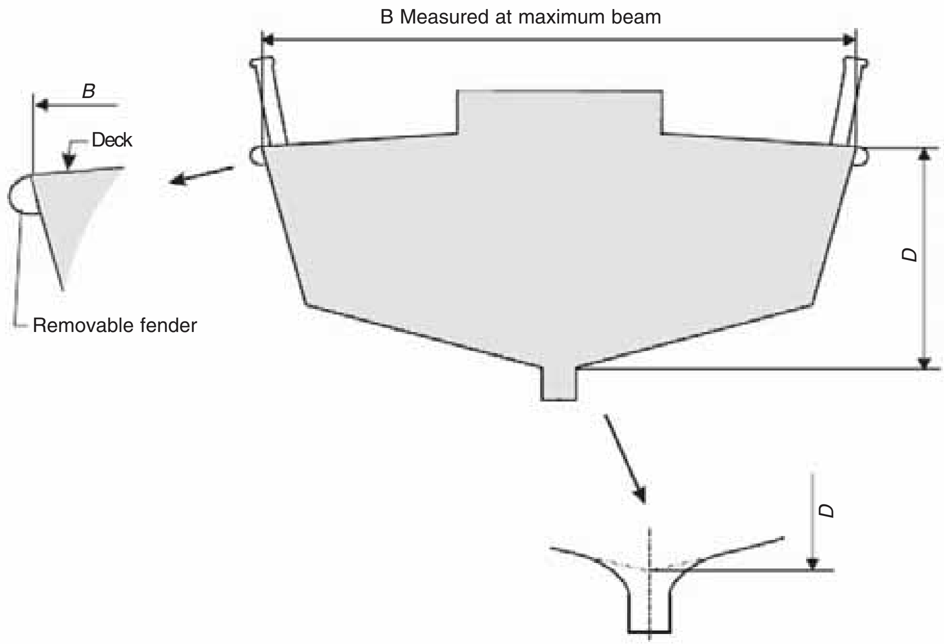
** *The dimensions are illustrated in Appendix 1.*

## Appendix 1: ILLUSTRATION OF TERMS USED IN THE DEFINITIONS

| DECKED BOATS - MEASUREMENTS |
| --- |

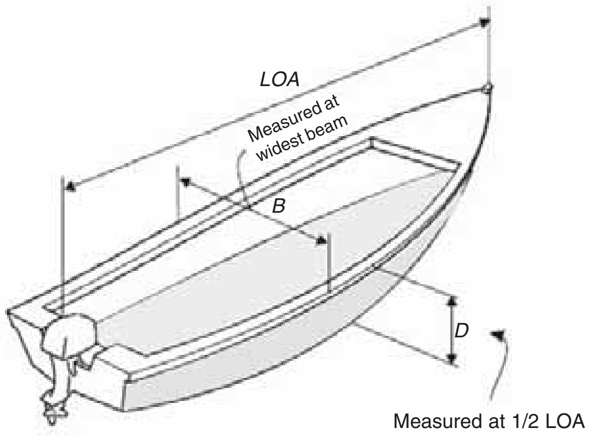
LENGTH OVER ALL (LOA)
BREADTH (B)
DEPTH (D)

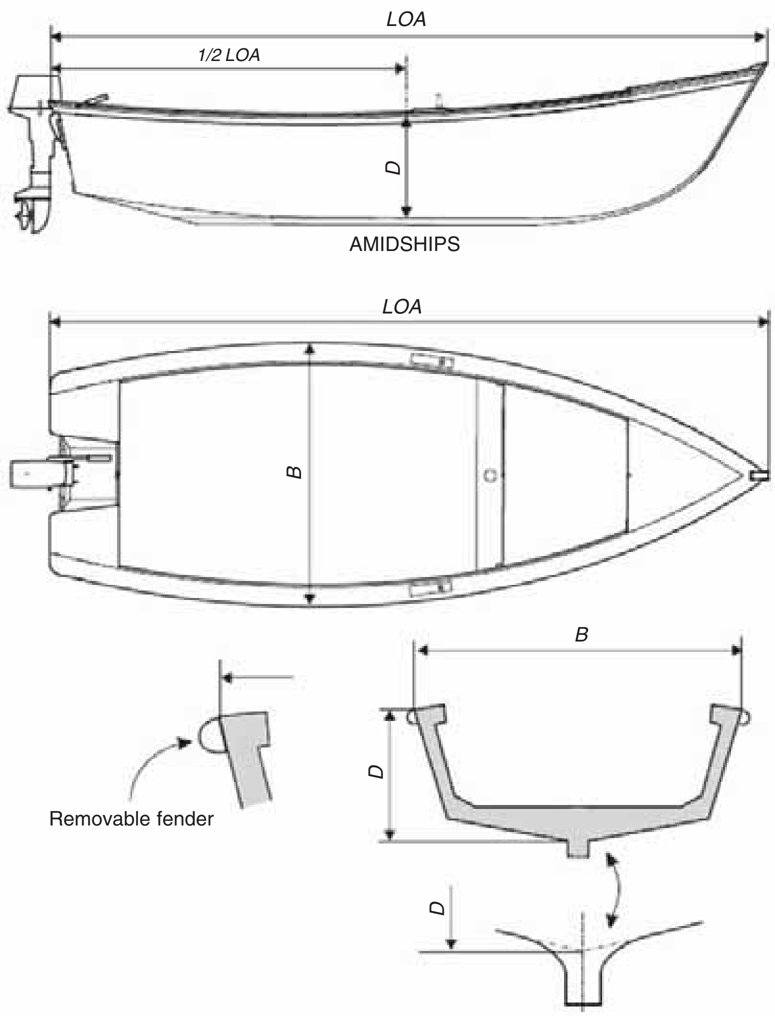


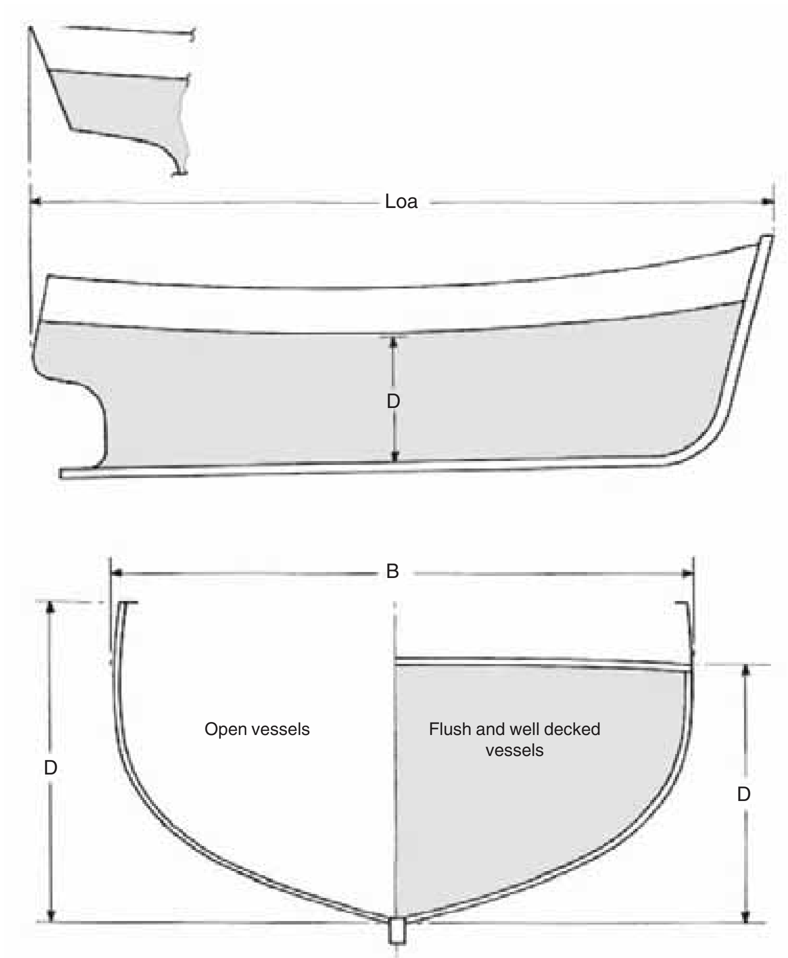
## OPEN BOATS - MEASUREMENTS

LENGTH OVER ALL (LOA)
BREADTH (B)
DEPTH (D)



LOA x B x D = Cubic numeral (CuNo)



## Appendix 2: RECOMMENDED CONSTRUCTION STANDARDS FOR GRP FISHING VESSELS

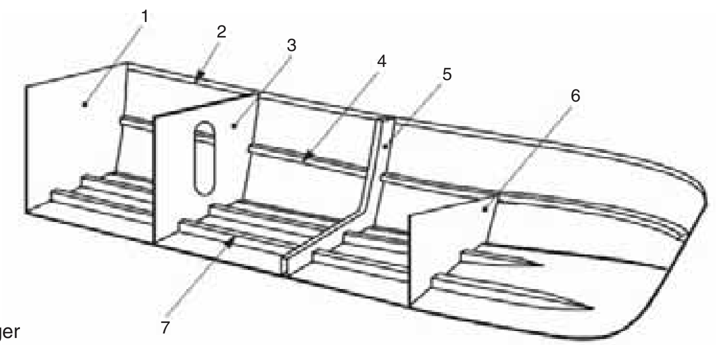
### PART I - GENERAL

**1. Scope**

1.1 These construction standards apply to decked vessels of less than 12 m in length and undecked vessels of any size.

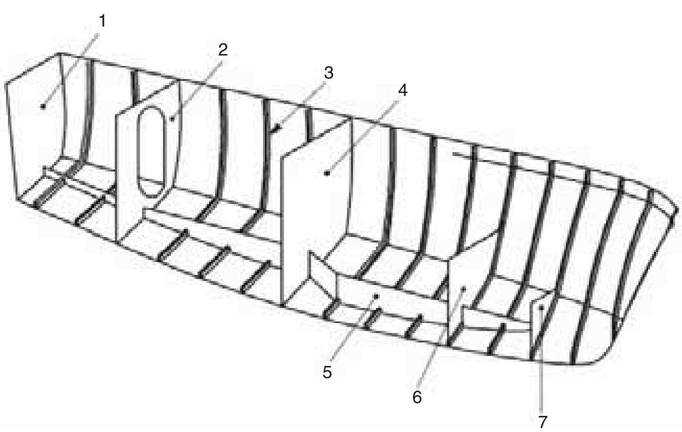
1.2 In general the standards apply to vessels of conventional form and of glass reinforced plastic construction (GRP), i.e. single hull vessels of glass rovings and mat and polyester resin construction that in general should consist of:

- moulded hull of single-skin construction;
- deck of GRP sheathed plywood, GRP or traditional timber construction;
- transverse framing;
- longitudinal structure including gunwale, stringers and engine beds;
- in small vessels internal furniture and hull form may provide adequate stiffening.



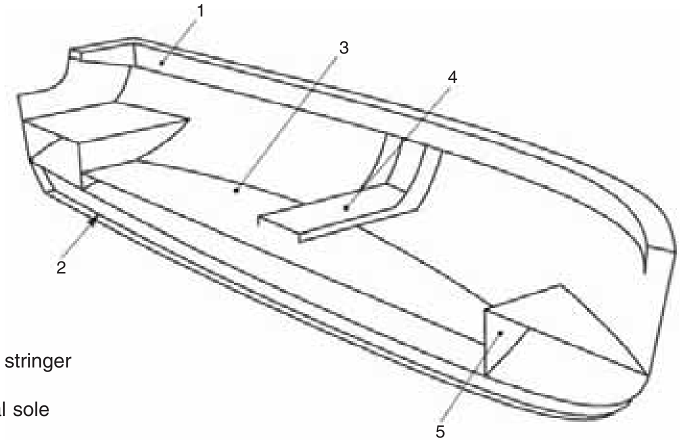

**Key**
1 transom
2 gunwale stringer
3 bulkhead
4 side longitudinal stiffener (stringer)
5 web frame
6 deep floor
7 bottom longitudinal stiffener (girder or stringer).

**Typical longitudinal framing in a GRP vessel**




**Key**
1 transom
2 bulkhead
3 frame
4 bulkhead
5 bottom girder
6 deep floor
7 deep floor

**Typical transverse framing in a GRP vessel**




**Key**
1 gunwale stringer
2 keel
3 structural sole
4 thwarts
5 deep floor

**Typical framing in a small GRP vessel**

1.3 Standards are given for vessels operating at speeds of up to 16 knots as shown in Table 1 in Part III. Vessels operating at higher speeds require special consideration by the competent authority.

1.4 A number of vessel types are not covered by the requirements of these construction standards, including the following.

- Vessels constructed of other materials such as Kevlar reinforcements and epoxy resins.
- Vessels of sandwich construction.
- Vessels judged by the competent authority to be outside the scope of this standard.

## 2 Design categories

2.1 These construction standards are based on the division of vessels into appropriate design categories. The categories indicate sea and wind conditions for which a vessel is considered to be suitable, provided that the vessel is correctly operated and at a speed appropriate to the prevailing sea state. Design categories are defined in 1.1.6 (see page 127).

## 3 Construction standards

3.1 The appropriate standards of construction for GRP vessels should be determined as set out in Parts I-III.

| Design category | Part I | Part II | Part III |
|---|---|---|---|
| A | ✓ | ✓ | |
| B | ✓ | ✓ | |
| C | ✓ | | ✓ |
| D | ✓ | | |

3.2 Vessels fitted with sails should be considered to operate in categories C and D only unless given special consideration by the competent authority.

3.3 Consideration should be given by the competent authority to increasing the scantlings given in the standards in parts of a vessel where special conditions may arise, including:

- operation of fishing gear likely to damage structure by impact or abrasion;
- landing and hauling out of vessels on beaches and river banks.

Information on appropriate factors is given in Table 5.

## 4 Construction standards for GRP vessels of all design categories

### 4.1 Materials

4.1.1 Resins should be approved for marine use and be mixed and used in accordance with the manufacturers' recommendations.

4.1.2 Glass reinforcements should be approved for marine use and may be in the form of chopped strand mat, woven rovings, fabric, powder bound mat or other approved materials.

4.1.3 Colour pigment may be used in the gelcoat sufficient to give a satisfactory colour; the amount used should be in accordance with the manufacturers' recommendations. No pigment should be used in the lay-up resin of the hull laminates.

4.1.4 Formers for stiffeners should be of rigid foam, timber, metal or other approved materials. Where timber is used it should have a moisture content of not more than 15 percent. A common type of former for top-hat stiffeners is made of one layer of mat in a mould of the required stiffener dimensions.

4.1.5 Careful attention should be paid to the manufacturers' recommendations concerning the storage and use dates of the materials to be used.

### 4.2 Workshop practice

4.2.1 All building activities should be carried out under a fixed roof and preferably in an enclosed workshop.

4.2.2 The cleanliness of the workshop is important for the health of workers and to prevent contamination of the resin and reinforcements.

4.2.3 Waste material, dust, sand and other contaminants should be removed immediately from the workshop.

4.2.4 The moulding area should be kept clear of dust and accumulation of waste material that could contaminate the mould surfaces.

4.2.5 The recommended humidity and temperature ranges under which laminating may take place are: temperature 15 to 25 degrees C, humidity 70 percent. The moulding process should cease if the following limits are reached: temperature <13 or >32 degrees C, humidity >80 percent.

4.2.6 The workshop should be as free as practical from dust and fumes to allow comfortable and safe working conditions. Styrene fumes are heavier than air and should be removed from moulds by the use of mechanical ventilation systems.

4.2.7 Completed mouldings should not be taken outside the workshop environment within seven days of the start of the moulding process. Where mouldings are moved outside after this period they should be protected from rain.

4.2.8 The addition of catalyst to polyester products should be strictly controlled within the limits set by the manufacturers. Tables giving amounts of catalyst/resin should be available in the workshop.

4.2.9 The catalyst must be properly dispersed through the resin by very thorough mixing.

4.2.10 Where a primary bond is to be achieved, little preparation of the surface is required prior to further laminating or bonding. A primary bond is generally achieved if the surface has cured for about 24 to 48 hours and is still chemically active, allowing a chemical bond.

4.2.11 Where a secondary bond is to be achieved, additional surface preparation is required in the form of abrasion and cleaning. A secondary bond is achieved when the surface has cured for over 48 hours and is no longer chemically active; in this case, the bond relies on the adhesive properties of the resin.

### 4.3 Laminate lay-up

4.3.1 The outside surface of all laminates should have a layer of gelcoat or be treated with equivalent surface protection after completion of moulding. This layer should be 0.4 to 0.6 mm thick.

4.3.2 The gelcoat should only be left exposed in accordance with the manufacturers' recommendations; generally a maximum of 24 hours.

4.3.3 Heavy reinforcements should not be applied directly to the gelcoat; the first two layers should consist of a light chopped strand mat of maximum weight 300 g/$m^2$, unless the competent authority is satisfied that manufacturing experience justifies variation from this figure.

4.3.4 Where woven rovings are incorporated, these should be alternated with layers of chopped strand mat.

4.3.5 A suitable topcoat should be applied in bilge and keel areas where water could accumulate, unless the competent authority is satisfied that manufacturing experience justifies variation.

4.3.6 Laminates should be locally increased in thickness in way of fittings and equipment. The increase should be gradually reduced to the normal thickness by stepped layers.

4.3.7 Any holes or openings cut in laminates should be sealed with resin or other suitable material.

4.3.8 The overlap of mats or woven rovings should be at least 50 mm and the shift of subsequent reinforcement overlaps at least 100 mm.

4.3.9 Laminate should be laid up in accordance with a documented sequence.

4.3.10 Laminates should be worked in such a way that they are fully consolidated, *i.e.* thoroughly wetted out, free from blisters, air gaps, delamination, resin-starved areas or excess resin.

4.3.11 The interval between layers should be carefully timed to enable proper completion of each laminate.

4.3.12 The time elapsed between the completion of hull or deck laminate and the bonding of structural members should be kept within the limits of the manufacturers' recommendations.

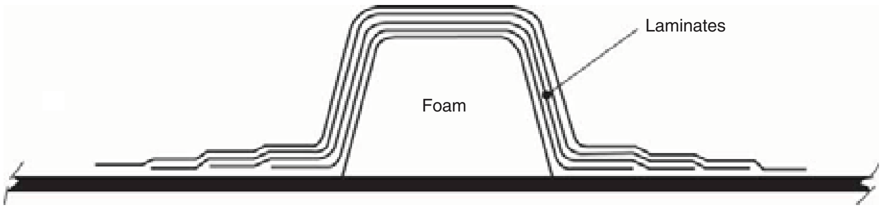
**4.4 Hull construction**

4.4.1 The hull bottom should be a solid laminate of glass reinforcements in resin, laid up to a satisfactory weight. The keel and sheer strake areas of the hull should have additional reinforcements. See Table 6.

4.4.2 Hulls should be adequately stiffened; this may be in the form of longitudinal or transverse stiffeners or a combination of both. Small vessels may make use of internal structures and features for stiffening.

4.4.3 Stiffeners may be constructed by moulding over foam or hollow formers, which should be bonded to the inside hull laminate; see sections 4.2.10 and 4.2.11 for a description of primary and secondary bonding. Frame formers may be of top-hat or rectangular section. Where frames have gunwales or stringers through bolted, the core of the frames is to be of timber.

4.4.4 Floors moulded over formers should be fitted to the top of the frames at the centreline and bonded to the frames.




**Typical framing construction**

4.4.5 Stringers, where fitted, may use foam or hollow formers and should be bonded to the hull shell; see sections 4.2.10 and 4.2.11 for a description of primary and secondary bonding. Alternatively, these may be formed in combination with other longitudinal structural members such as soles, decks and lockers.

4.4.6 In vessels below 7 m LOA where a combination of bonding of internal furniture and hull form provides adequate stiffening, the framing may be omitted subject to the approval of the competent authority.

4.4.7 In undecked boats, the required bottom stiffening may be provided wholly or partly formed by the bonded-in flooring arrangement.

4.4.8 Where through-bolting connections are required, e.g. for gunwales or beam stringers, fastenings should be hot-dip galvanized or stainless steel. The edges of the laminate and the fastening holes should be sealed with resin or other suitable material.

4.4.9 The hull surface gelcoat should be adequately protected in the way of all fishing gear hauling positions by glass-reinforced plastic (GRP) sheathing, metal, hard rubber or plastic to prevent damage.

4.4.10 Discontinuities and hard points in the structure should be avoided. Where the strength of a stiffener may be reduced by attachment of fittings, openings, etc., additional laminates should be included.

4.4.11 Transoms not subjected to loads from outboard engines or steering arrangements should have scantlings as required for the shell laminate.

4.4.12 The glass weight at the corner of the transom and hull shell should be increased to provide additional reinforcement. See Table 6.

4.4.13 Transoms that are to be used for the mounting of outboard engines should be constructed to include a marine-grade plywood panel of sufficient dimension and of adequate strength for the proposed installation.

4.4.14 The stem should be moulded to include a gradual reduction from the keel weight to that required for the sheer.

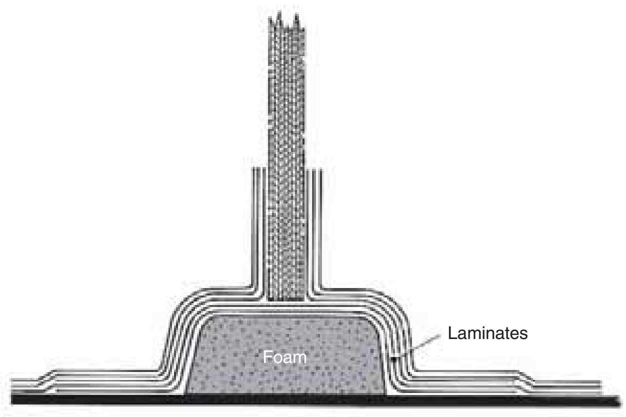
4.4.15 The centre of the hull aft of the keel to the transom should be stiffened by lay-ups as required for the keel.

4.4.16 Where fitted, rubbing strakes may be of hardwood, rubber or plastic; securing bolts should be hot-dip galvanized and sealed to prevent leakage.

4.4.17 Engine seatings should generally be continuous structures and where space permits, the seatings should extend at least twice the length of the engine, unless the competent authority is satisfied that manufacturing experience justifies variation.

4.4.18 The seatings should be bonded to the hull and stiffened transversely with floor sections and side support brackets. A continuous flat steel plate of adequate thickness and width should be fitted to the top of the seating in way of the engine and gearbox and bonded to the seating.

4.4.19 Where included, it is recommended that bulkheads are fitted to a rigid foam core seating or frame section. When not practical to fit on a frame position, the bulkhead should be bonded to the shell with double angles of a satisfactory weight.




**Typical bulkhead installation**

4.4.20 Bolt connections should be well sealed and glassed over to prevent leakage.

4.4.21 Consideration should be given to including easily replaceable sacrificial structures in locations where impact or abrasion may occur. These include areas subject to wear such as gunwales and keels and areas subject to impact or abrasion by fishing gear.

**4.5 Deck construction**

4.5.1 Decks may be of GRP sheathed plywood, GRP or traditional timber construction.

4.5.2 A beam shelf or stringer should be bonded to the hull shell to support the deck beams. A system combining through bolting and bonding is recommended.

4.5.3 Deck beams should be fitted at each frame position; with longitudinal stiffening provided by hatches and carlings as required.

4.5.4 Decks in way of gallows, warp leads, deck machinery and heavy work positions should have additional stiffening and pillars to the approval of the competent authority.

4.5.5 Main beams should be fitted in way of all deck openings, machinery and deckhouse casings and in way of masts and heavy deck machinery.

4.5.6 Where deck beams of timber are fitted, reference should be made to appropriate construction standards for wooden vessels.

4.5.7 Where decks and deck beams are of GRP construction, openings in the deck may be stiffened by forming continuously moulded flanges, the weight of which should be 25 percent greater than the laid-up deck laminate weight. Deck openings over 500 mm in length should be fitted with longitudinal stiffening.

4.5.8 Plywood decks should be bolted and bonded to the beam shelf and bonded to the hull. The complete deck area should be sheathed with a GRP laminate. Special attention should be paid to the sheathing in way of working areas that may require extra protection.

4.5.9 Where laid timber planked decking is used for decks, reference should be made to appropriate construction standards for wooden vessels.

## PART II – RECOMMENDED CONSTRUCTION STANDARDS FOR GRP VESSELS OF DESIGN CATEGORIES A AND B

### 1 Introduction

1.1 The construction standards described here should be applied to all decked vessels in design categories A and B.

### 2 Construction

2.1 In general, the requirements of Part I should be complied with in addition to the requirements below.

2.2 The strength and construction of the hull, deck and other structures should be built to withstand all foreseeable conditions of the intended service.

2.3 All vessels should meet requirements that are compatible with a recognized GRP vessel construction standard* or an equivalent standard and be built to the satisfaction of the competent authority.

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* *The standards include:*

1. *the Nordic Boat Standard;*
2. *the construction rules of the United Kingdom Sea Fish Industry Authority (Seafish); and*
3. *the construction rules of recognized organizations.*

**PART III – RECOMMENDED CONSTRUCTION STANDARDS FOR GRP VESSELS OF DESIGN CATEGORY C**

## 1 Introduction

1.1 The construction standards described here should be applied to all decked and undecked vessels in design category C.

1.2 The tables and figures given in this part are based on the ISO standards 12215-5&6 – Small Craft Hull Construction and Scantlings.

1.3 The construction standards described here should always be read in conjunction with Part I of this Appendix.

1.4 The hull construction standard is based on maximum operating speeds according to vessel length. The operating speeds are shown in Table 1.

1.5 The hull construction standard is based on the loaded displacement of the vessel including vessel, crew, fishing gear, fuel, fish and ice, stores and equipment. Where this is not known, an approximation can be made from the Cubic numeral (CuNo) of the vessel; approximate values are shown in Table 2.

## 2. Construction

### 2.1 Hull and deck

2.1.1 Hull laminate should be of a thickness suitable for the size of vessel and the spacing of framing. Table 3 shows the minimum required laminate weight (w) and equivalent thickness (t).

2.1.2 Deck laminate should be of a thickness suitable for the loaded displacement of the vessel and the spacing of frames (or panel size). Table 4 shows the minimum required laminate weight (w) and equivalent thickness (t).

2.1.3 Additional factors should be applied to the minimum laminate weight according to the intended use of the vessel; appropriate factors are shown in Table 5. The factors account for the design and use of the vessel and should be applied as considered necessary by the competent authority.

2.1.4 The following areas should be reinforced by additional laminates: keel, stem, chine and deck edge. Table 6 gives the total laminate weight required and the width of the reinforcement.

### 2.2 Stiffeners

2.2.1 Hull and deck stiffeners should be of a size suitable for the size of vessel, the spacing of stiffeners (or panel size). Tables 7 and 8 show the required section modulus.

2.2.2 The section modulus can be modified by the application of factors to the table values. Table 9 shows the factors for stiffener curvature and glass mat/roving content. If in doubt the table and figures without factors should be used.

2.2.3 The properties of various “top hat” type stiffeners are given in Tables 10 and 11.

**Table 1: Maximum operating speeds**

| | | | | | |
|---|---|---|---|---|---|
| Length Overall LOA (m) | 4 | 6 | 8 | 10 | 12 |
| Maximum Speed (knots) | 9 | 11 | 13 | 15 | 16 |

**Table 2: Cubic numeral and loaded displacement**

| Cubic numeral | Undecked Vessel | Decked Vessel |
|---|---|---|
| (CuNo) | Approximate Loaded | Approximate Loaded |
| | Displacement | Displacement |
| $m^3$ | kg | kg |
| 4 | 600 | - |
| 6 | 900 | - |
| 8 | 1200 | - |
| 10 | 1500 | - |
| 12 | 1800 | - |
| 14 | 2100 | - |
| 16 | 2400 | - |
| 18 | 2700 | - |
| 20 | 3000 | 4800 |
| 25 | 3750 | 6000 |
| 30 | 4500 | 7200 |
| 35 | - | 8400 |
| 40 | - | 9600 |
| 45 | - | 10800 |
| 50 | - | 12000 |
| 60 | - | 14400 |
| 70 | - | 16800 |
| 80 | - | 19200 |
| 90 | - | 21600 |
| 100 | - | 24000 |

*Note: The figures given are approximate and where possible it is better to obtain accurate displacement figures from calculations and measurements.*

**Table 3: Table of minimum hull laminate weight**

| Panel Width (mm) | 500 | 500 | 600 | 600 | 800 | 800 | 1000 | 1000 | 1200 | 1200 | 1400 | 1400 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Loaded Displ (kg) | t mm | w (min) $g/m^2$ | t mm | w $g/m^2$ | t mm | w $g/m^2$ | t mm | w $g/m^2$ | t mm | w $g/m^2$ | t mm | w $g/m^2$ |
| 250 | 3.9 | 1670 | 4.4 | 1880 | 5.2 | 2250 | 6.6 | 2810 | 7.9 | 3370 | 9.2 | 3930 |
| 500 | 4.3 | 1860 | 4.9 | 2090 | 5.8 | 2490 | 6.9 | 2960 | 8.3 | 3550 | 9.7 | 4140 |
| 1000 | 4.8 | 2070 | 5.4 | 2330 | 6.5 | 2780 | 7.7 | 3280 | 9.2 | 3930 | 10.7 | 4580 |
| 2000 | 5.4 | 2330 | 6.1 | 2620 | 7.3 | 3130 | 8.6 | 3690 | 10.3 | 4400 | 12.0 | 5140 |
| 4000 | 6.2 | 2640 | 6.9 | 2960 | 8.3 | 3540 | 9.8 | 4180 | 11.5 | 4930 | 13.4 | 5760 |
| 6000 | 6.6 | 2840 | 7.5 | 3190 | 8.9 | 3820 | 10.5 | 4500 | 12.3 | 5280 | 14.4 | 6160 |
| 8000 | 7.0 | 3000 | 7.9 | 3370 | 9.4 | 4030 | 11.1 | 4750 | 12.9 | 5530 | 15.1 | 6450 |
| 10000 | 7.3 | 3130 | 8.2 | 3520 | 9.8 | 4200 | 11.6 | 4960 | 13.4 | 5740 | 15.6 | 6700 |
| 12000 | 7.6 | 3240 | 8.5 | 3650 | 10.2 | 4360 | 12.0 | 5140 | 13.8 | 5920 | 16.1 | 6900 |
| 15000 | 7.9 | 3390 | 8.9 | 3810 | 10.6 | 4550 | 12.5 | 5370 | 14.3 | 6140 | 16.7 | 7160 |
| 18000 | 8.2 | 3510 | 9.2 | 3950 | 11.0 | 4720 | 13.0 | 5570 | 14.8 | 6330 | 17.2 | 7380 |
| 20000 | 8.4 | 3590 | 9.4 | 4030 | 11.3 | 4820 | 13.3 | 5680 | 15.1 | 6470 | 17.5 | 7510 |
| 22000 | 8.5 | 3660 | 9.6 | 4110 | 11.5 | 4910 | 13.5 | 5790 | 15.4 | 6590 | 17.8 | 7630 |
| 25000 | 8.8 | 3750 | 9.8 | 4220 | 11.8 | 5040 | 13.9 | 5950 | 15.8 | 6770 | 18.2 | 7790 |

*Note: The figures listed for a 500mm panel width are the minimum figures to be used and weights below this should not be used after the application of factors.*

### Table 4: Table of minimum deck laminate weight

| Panel Width (mm) | 500 | 500 | 600 | 600 | 700 | 700 |
|---|---|---|---|---|---|---|
| Length Overall (m) | t mm | w g/m$^2$ | t mm | w g/m$^2$ | t mm | w g/m$^2$ |
| 4 | 3.3 | 1420 | 3.8 | 1650 | 4.5 | 1920 |
| 5 | 3.5 | 1510 | 3.8 | 1650 | 4.5 | 1920 |
| 6 | 3.8 | 1650 | 3.8 | 1650 | 4.5 | 1920 |
| 7 | 4.0 | 1700 | 4.0 | 1700 | 4.5 | 1920 |
| 8 | 4.2 | 1790 | 4.2 | 1790 | 4.5 | 1920 |
| 9 | 4.4 | 1880 | 4.4 | 1880 | 4.5 | 1920 |
| 10 | 4.6 | 1970 | 4.6 | 1970 | 4.6 | 1970 |
| 11 | 4.8 | 2060 | 4.8 | 2060 | 4.8 | 2060 |
| 12 | 5.0 | 2150 | 5.0 | 2150 | 5.0 | 2150 |
| 13 | 5.2 | 2240 | 5.2 | 2240 | 5.2 | 2240 |
| 14 | 5.5 | 2340 | 5.5 | 2340 | 5.5 | 2340 |
| 15 | 5.7 | 2430 | 5.7 | 2430 | 5.7 | 2430 |

*Notes: 1. The figures given show w, the minimum required weight in g/m$^2$ of dry laminate to be used in construction.*

*2. The table shows weights of laminates where chopped strand mat is 90 to 100% of the total glass weight. Correction for other combinations of mat and roving are accounted for in Table 5.*

*3. The figures listed for a 500mm panel width are the minimum figures to be used and weights below this should not be used after the application of factors.*

### Table 5: Table of factors applied to minimum laminate

| Panel Curvature Factor, Fc | | | | | | |
|---|---|---|---|---|---|---|
| c/b | 0.03 and below | 0.06 | 0.09 | 0.12 | 0.15 | 0.18 and above |
| Fc | 1 | 0.9 | 0.8 | 0.7 | 0.6 | 0.5 |

| Glass Mat/Roving Factor, Fw | | | | | | | |
|---|---|---|---|---|---|---|---|
| R | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 - 1.0 |
| Glassfibre content | 0.41 | 0.39 | 0.37 | 0.35 | 0.33 | 0.32 | 0.30 |
| Mat/Roving Factor Fw | 0.89 | 0.91 | 0.93 | 0.95 | 0.97 | 0.98 | 1.0 |

Where

$$R = \frac{\text{Weight of Chopped Strand Mat (CSM) in g/m}^2}{\text{Total weight of Glassfibre in g/m}^2}$$

| Usage Factor | Type | Conditions | Factor |
|---|---|---|---|
| **Fv** Vessel landing | River landing | Calm water | 1.00 |
| | Harbour landing | Impact on quays, walls etc | 1.05 |
| | Beach landing | Small surf | 1.10 |
| | Beach landing | Large surf | 1.20 |
| **Fg** Fishing gear | Light fishing gear (nets & lines) | Damage unlikely | 1.00 |
| | Heavy fishing gear (trawl) | Impact structure | 1.10 |
| Usage Factor = Fv x Fg | | | |

*Notes: 1. The minimum required weight in g/m$^2$ of dry laminate should be multiplied by the relevant factors from the tables above. Thus the required weight of dry laminate = minimum weight x Fc x Fw x Fv x Fg.*

*2. The total factor applied (Fc x Fw x Fv x Fg) need not be greater than 1.2.*

**Table 6: Table of hull additional reinforcement weight and width**

| Loaded Displacement (kg) | Width of Additional Reinforcement (mm) |
|---|---|
| 250 | 50 |
| 500 | 60 |
| 1000 | 70 |
| 2000 | 90 |
| 4000 | 110 |
| 6000 | 120 |
| 8000 | 130 |
| 10000 | 140 |
| 12000 | 150 |
| 15000 | 160 |
| 18000 | 170 |
| 20000 | 180 |
| 22000 | 190 |
| 25000 | 200 |

| Keel | Stem | Chine & Deck Edge |
|---|---|---|
| multiply min fibre weight by | multiply min fibre weight by | multiply min fibre weight by |
| 2.2 | 2.0 | 1.7 |

***Note: The width of additional reinforcement is distributed either side of the keel/stem/chine; see illustration below.***

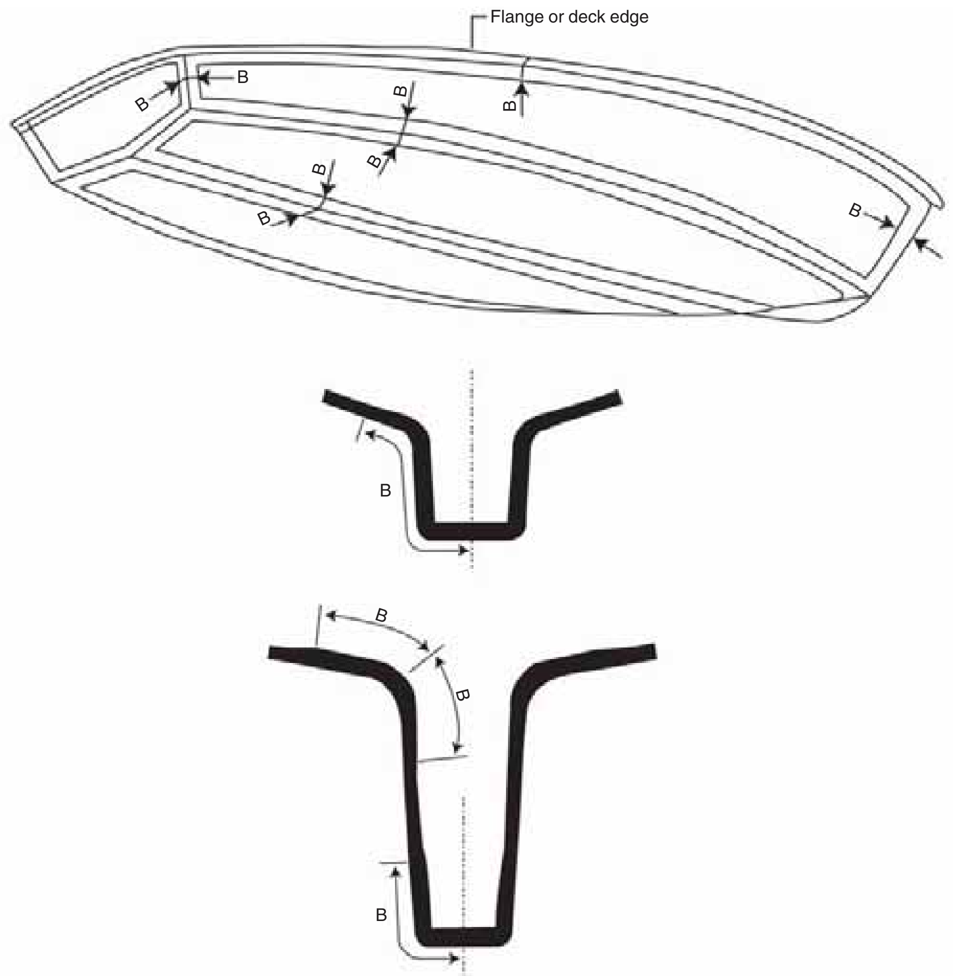


**Table 7: Hull stiffeners section modulus – SM cm³**

| Loaded displacement $m_{LDC}$ (kg) | Stiffener spacing s = 500 mm Stiffener span $\ell$ (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 |
| 500 | 2.5 | 4.6 | 7.1 | 11 | 16 | 22 | 28 |
| 1000 | 3.1 | 5.9 | 9.0 | 13 | 19 | 26 | 34 |
| 5000 | 5.4 | 10 | 16 | 21 | 30 | 41 | 54 |
| 10000 | 7.0 | 13 | 20 | 28 | 38 | 52 | 68 |
| 15000 | 8.2 | 15 | 24 | 33 | 44 | 60 | 78 |
| 20000 | 9.2 | 17 | 27 | 36 | 48 | 65 | 86 |
| 25000 | 10 | 19 | 29 | 40 | 52 | 70 | 92 |

| Loaded displacement $m_{LDC}$ (kg) | Stiffener spacing s = 600 mm Stiffener span $\ell$ (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 |
| 500 | 2.8 | 5.3 | 8.5 | 13 | 19 | 26 | 34 |
| 1000 | 3.5 | 6.6 | 10 | 16 | 23 | 32 | 41 |
| 5000 | 6.1 | 12 | 18 | 25 | 37 | 50 | 65 |
| 10000 | 8.0 | 15 | 23 | 32 | 46 | 63 | 82 |
| 15000 | 9.3 | 18 | 27 | 37 | 53 | 71 | 93 |
| 20000 | 10 | 20 | 30 | 41 | 58 | 79 | 103 |
| 25000 | 11 | 22 | 33 | 45 | 62 | 85 | 110 |

| Loaded displacement $m_{LDC}$ (kg) | Stiffener spacing s = 700 mm Stiffener span $\ell$ (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 |
| 500 | 3.1 | 5.9 | 10 | 16 | 22 | 31 | 40 |
| 1000 | 3.9 | 7.3 | 12 | 19 | 27 | 37 | 48 |
| 5000 | 6.8 | 13 | 21 | 32 | 46 | 63 | 82 |
| 10000 | 9.0 | 17 | 26 | 37 | 54 | 73 | 95 |
| 15000 | 10 | 20 | 30 | 43 | 61 | 83 | 109 |
| 20000 | 12 | 22 | 34 | 47 | 67 | 92 | 120 |
| 25000 | 13 | 24 | 37 | 50 | 72 | 99 | 129 |

| Loaded displacement $m_{LDC}$ (kg) | Stiffener spacing s = 800 mm Stiffener span $\ell$ (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 500 | 750 | 1000 | 1250 | 1500 | 1750 | 2000 |
| 500 | 3.4 | 6.4 | 11 | 18 | 26 | 35 | 46 |
| 1000 | 4.3 | 8.0 | 14 | 22 | 31 | 42 | 55 |
| 5000 | 7.5 | 14 | 22 | 34 | 49 | 66 | 87 |
| 10000 | 9.7 | 18 | 28 | 43 | 61 | 83 | 109 |
| 15000 | 11 | 21 | 33 | 49 | 70 | 95 | 124 |
| 20000 | 13 | 24 | 37 | 53 | 77 | 105 | 137 |
| 25000 | 14 | 26 | 40 | 58 | 83 | 112 | 147 |

### Table 8: Deck stiffeners section modulus – SM $cm^3$

| Stiffener spacing $s$ = 500 mm | | | | | | |
|---|---|---|---|---|---|---|
| Stiffener span $\ell$ (mm) | | | | | | |
| **1000** | **1500** | **2000** | **2500** | **3000** | **3500** | **4000** |
| 7.0 | 16 | 28 | 44 | 64 | 87 | 113 |

| Stiffener spacing $s$ = 600 mm | | | | | | |
|---|---|---|---|---|---|---|
| Stiffener span $\ell$ (mm) | | | | | | |
| **1000** | **1500** | **2000** | **2500** | **3000** | **3500** | **4000** |
| 9 | 19 | 34 | 53 | 77 | 104 | 136 |

| Stiffener spacing $s$ = 700 mm | | | | | | |
|---|---|---|---|---|---|---|
| Stiffener span $\ell$ (mm) | | | | | | |
| **1000** | **1500** | **2000** | **2500** | **3000** | **3500** | **4000** |
| 9.8 | 20 | 36 | 56 | 81 | 110 | 143 |

### Table 9: Stiffener - curvature factor $f_{cs}$

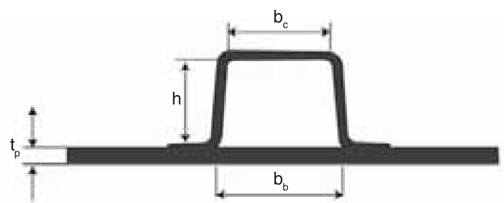
| $\frac{c}{\ell}$ | **0.03 and below** | **0.06** | **0.09** | **0.12** | **0.15** | **0.18 and above** |
|---|---|---|---|---|---|---|
| $f_{cs}$ | 1.0 | 0.90 | 0.80 | 0.70 | 0.60 | 0.50 |

### Stiffener mat - roving factor $f_{ws}$

| R | 0.3 | 0.4 | 0.5 | 0.6 | 0.7 | 0.8 | 0.9 – 1.0 |
|---|---|---|---|---|---|---|---|
| Glass fibre content | 0.32 | 0.31 | 0.30 | 0.28 | 0.27 | 0.26 | 0.25 |
| $f_{ws}$ | 0.72 | 0.75 | 0.78 | 0.87 | 0.91 | 0.96 | 1.00 |

## Table 10: Top hat stiffeners

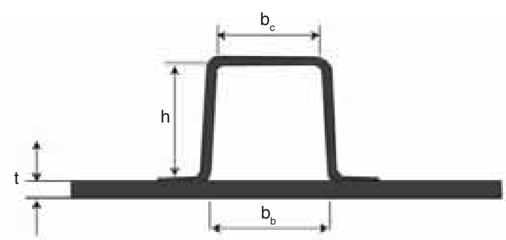
**Low top hat stiffener**




**Glass content: g = 0.30**
**(Chopped strand mat CSM)**

| Dimensions of former | | | Plating thickness | Stiffener glass weight | Section modulus |
|---|---|---|---|---|---|
| h mm | $b_b$ mm | $b_c$ mm | *t* mm | w g/m$^2$ | $SM_{MIN}$ cm$^2$ |
| 25 | 36 | 30 | 5 | 600 | 1.8 |
| | | | 10 | 600 | 2.7 |
| | | | 15 | 600 | 5.1 |
| 40 | 60 | 50 | 5 | 600 | 4.5 |
| | | | 10 | 600 | 5.4 |
| | | | 15 | 600 | 7.5 |
| 50 | 75 | 65 | 5 | 900 | 10 |
| | | | 10 | 900 | 12 |
| | | | 15 | 900 | 14 |
| 60 | 90 | 75 | 5 | 1200 | 19 |
| | | | 10 | 1200 | 21 |
| | | | 15 | 1200 | 24 |
| 75 | 100 | 85 | 5 | 1200 | 27 |
| | | | 10 | 1200 | 30 |
| | | | 15 | 1200 | 33 |
| 100 | 150 | 125 | 5 | 1800 | 73 |
| | | | 10 | 1800 | 81 |
| | | | 15 | 1800 | 87 |
| 125 | 175 | 150 | 5 | 2100 | 125 |
| | | | 10 | 2100 | 140 |
| | | | 15 | 2100 | 149 |
| 150 | 220 | 190 | 5 | 2700 | 230 |
| | | | 10 | 2700 | 260 |
| | | | 15 | 2700 | 280 |

**Square top hat stiffener**

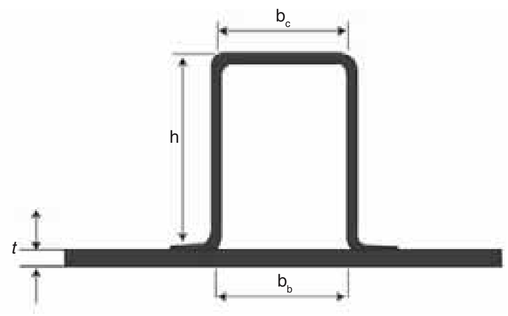



**Glass content: g = 0.30**
**(Chopped strand mat CSM)**

| Dimensions of former | | | Plating thickness | Stiffener glass weight | Section modulus |
|---|---|---|---|---|---|
| h mm | $b_b$ mm | $b_c$ mm | *t* mm | w g/m$^2$ | $SM_{MIN}$ cm$^3$ |
| 25 | 25 | 20 | 5 | 600 | 1.5 |
| | | | 10 | 600 | 2.2 |
| | | | 15 | 600 | 4.6 |
| 40 | 40 | 35 | 5 | 600 | 3.6 |
| | | | 10 | 600 | 4.4 |
| | | | 15 | 600 | 6.3 |
| 50 | 50 | 45 | 5 | 900 | 8.2 |
| | | | 10 | 900 | 9.5 |
| | | | 15 | 900 | 12 |
| 60 | 60 | 50 | 2 | 1200 | 15 |
| | | | 10 | 1200 | 17 |
| | | | 15 | 1200 | 19 |
| 75 | 75 | 65 | 5 | 1200 | 23 |
| | | | 10 | 1200 | 26 |
| | | | 15 | 1200 | 28 |
| 100 | 100 | 85 | 5 | 1800 | 56 |
| | | | 10 | 1800 | 65 |
| | | | 15 | 1800 | 69 |
| 125 | 125 | 105 | 5 | 2100 | 98 |
| | | | 10 | 2100 | 112 |
| | | | 15 | 2100 | 112 |
| 150 | 150 | 125 | 5 | 2700 | 173 |
| | | | 10 | 2700 | 198 |
| | | | 15 | 2700 | 213 |

## Table 11: Top hat stiffeners and laminate step stiffener

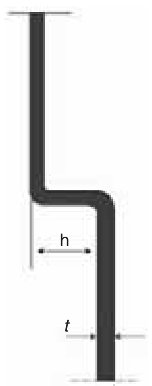
**Tall top hat stiffener**




**Glass content: g = 0.30**
**(Chopped strand mat CSM)**

| Dimensions of former h mm | Dimensions of former $b_b$ mm | Dimensions of former $b_c$ mm | Plating thickness *t* mm | Stiffener glass weight w kg/m² | Section modulus $SM_{MIN}$ cm³ |
|---|---|---|---|---|---|
| 100 | 50 | 50 | 5 | 1.800 | 41 |
| | | | 10 | 1.800 | 48 |
| | | | 15 | 1.800 | 53 |
| 125 | 50 | 50 | 5 | 2.100 | 65 |
| | | | 10 | 2.100 | 77 |
| | | | 15 | 2.100 | 84 |
| 150 | 50 | 50 | 5 | 2.700 | 104 |
| | | | 10 | 2.700 | 126 |
| | | | 15 | 2.700 | 139 |
| 150 | 75 | 75 | 5 | 2.700 | 126 |
| | | | 10 | 2.700 | 150 |
| | | | 15 | 2.700 | 163 |
| 175 | 75 | 75 | 5 | 3.000 | 161 |
| | | | 10 | 3.000 | 194 |
| | | | 15 | 3.000 | 213 |
| 200 | 75 | 75 | 5 | 3.600 | 240 |
| | | | 10 | 3.600 | 290 |
| | | | 15 | 3.600 | 322 |
| 200 | 100 | 100 | 5 | 3.600 | 277 |
| | | | 10 | 3.600 | 331 |
| | | | 15 | 3.600 | 364 |
| 250 | 100 | 100 | 5 | 4.200 | 433 |
| | | | 10 | 4.200 | 518 |
| | | | 15 | 4.200 | 576 |

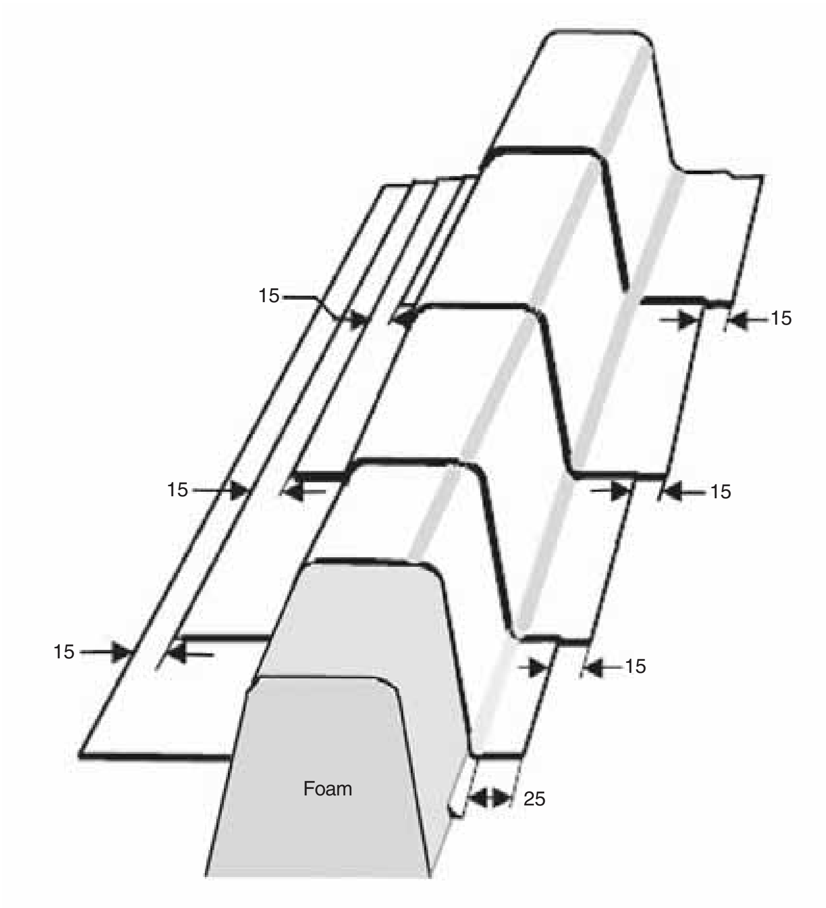
**Laminate step stiffener**



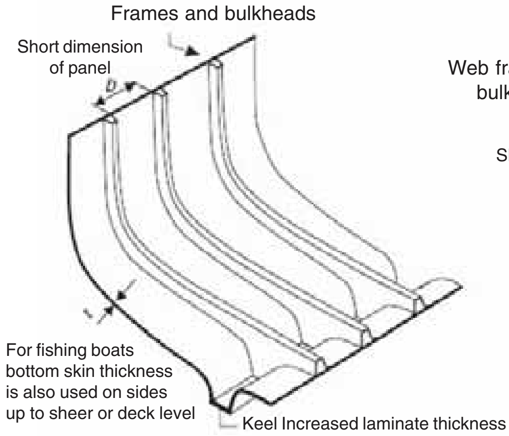

**Glass content: g = 0.30**
**(Chopped strand mat CSM)**

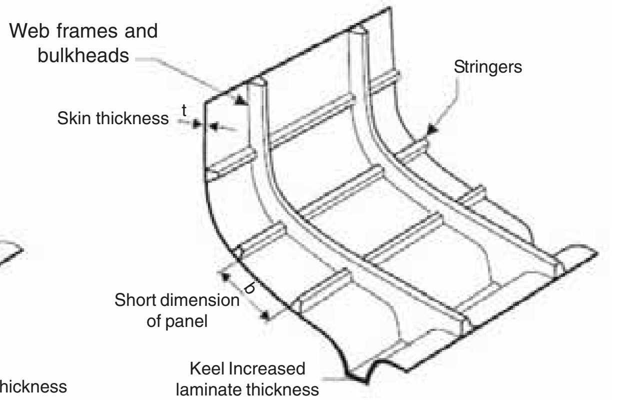
| Height of step h mm | Laminate thickness *t* mm | Laminate glass weight w kg/m² | Section modulus SM cm³ |
|---|---|---|---|
| 15 | 5 | 2.100 | 1.0 |
| | 10 | 4.300 | 2.2 |
| | 15 | 6.400 | 3.6 |
| 20 | 5 | 2.100 | 2.9 |
| | 10 | 4.300 | 3.4 |
| | 15 | 6.400 | 5.2 |
| 30 | 5 | 2.100 | 4.4 |
| | 10 | 4.300 | 8.0 |
| | 15 | 6.400 | 11 |
| 40 | 5 | 2.100 | 8.2 |
| | 10 | 4.300 | 14 |
| | 15 | 6.400 | 20 |
| 50 | 5 | 2.100 | 14 |
| | 10 | 4.300 | 23 |
| | 15 | 6.400 | 32 |
| 60 | 5 | 2.100 | 20 |
| | 10 | 4.300 | 34 |
| | 15 | 6.400 | 46 |

**Bonding stiffeners**



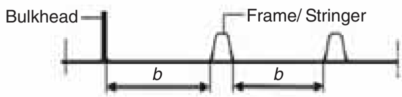
## Design details: Single skin laminate



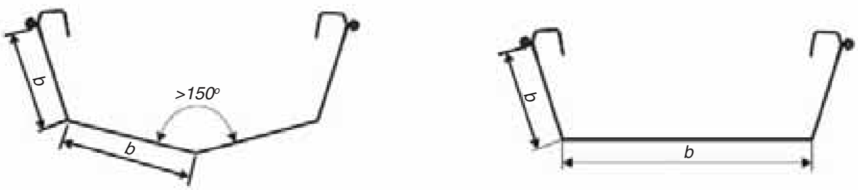




TRANSVERSE STIFFENERS

TRANSVERSE AND LONGITUDINAL STIFFENERS

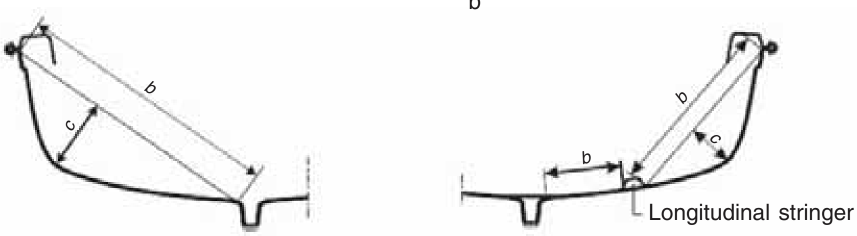



*b* = shorter dimension of plate panel

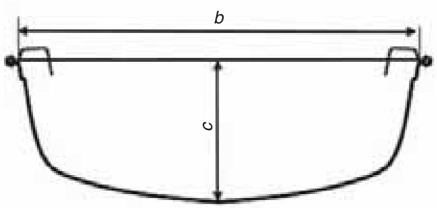



SMALL BOATS WITH HARD CHINES. TRANSVERSE FRAMES WITH GREATER SPACING THAN b

Panel curvature $= \frac{c}{b}$

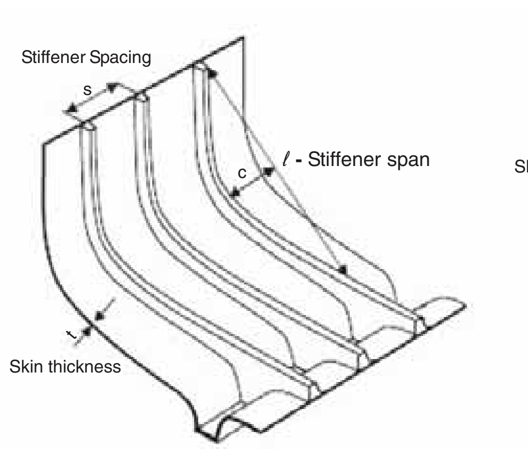



BOAT WITH CURVED BOTTOM AND KEEL + TRANSVERSE FRAMES SPACED MORE THAN b

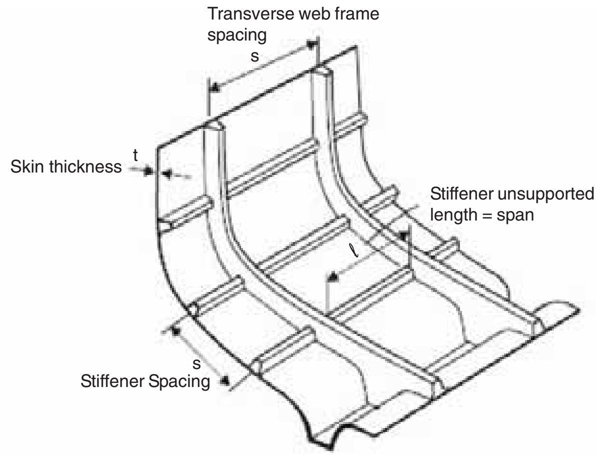



SMALL BOAT WITHOUT KEEL

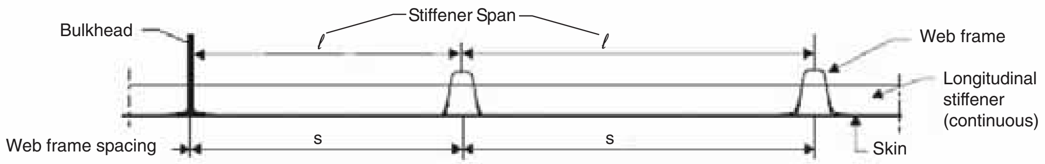
## Stiffeners



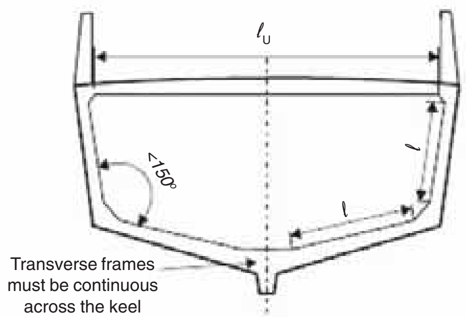

TRANSVERSE STIFFENERS: Frames and bulkheads



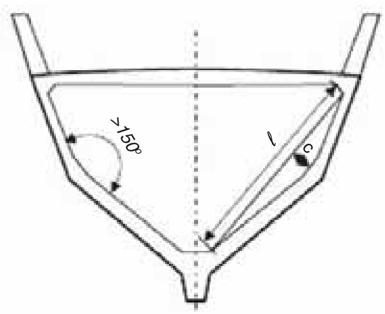

TRANSVERSE AND LONGITUDINAL STIFFENERS
PRIMARY STIFFENERS: Web frames and bulkheads
SECONDARY STIFFENERS: Longitudinal stiffeners



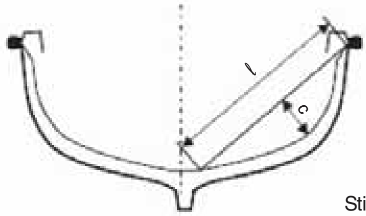

TRANSVERSE WEB FRAMES AND LONGITUDINAL STRINGERS




STIFFENER LENGTH ℓ
CHINE ANGLE LESS THAN *150°*

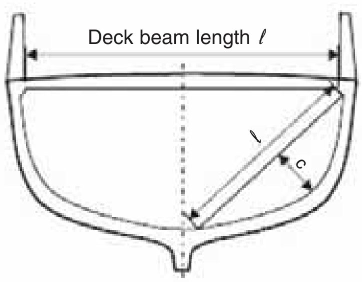



STIFFENER LENGTH ℓ
CHINE ANGLE MORE THAN *150°*




Stiffener curvature $= \frac{c}{\ell}$

SMALL OPEN BOAT
TRANSVERSE FRAME
Keel and rail are main longitudinal stiffeners




DECKED BOAT
TRANSVERSE FRAME

*Notes*

BOBP/REP/119

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