



**2014**

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**Rules and Guidance for the Classification of  
FRP Ships**

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**2014**

Rules for the Classification of  
FRP Ships

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**Rules**

**2014**

Guidance Relating to the Rules for the Classification of  
FRP Ships

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**Guidance**



**2014**

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**Rules for the Classification of  
FRP Ships**

# **APPLICATION OF "RULES FOR THE CLASSIFICATION OF FRP SHIPS"**

1. Unless expressly specified otherwise, the requirements in the Rules apply to ships for which contracts for construction are signed on or after 1 July 2014.
2. The amendments to the Rules for 2012 and their effective date are as follows;

**Effective Date 1 July 2014**

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## **CHAPTER 3 MATERIALS**

### Section 2 FRP Materials

- 202. 2. (3) has been amended.

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# CHAPTER 1 GENERAL

## Section 1 General

### 101. Application [See Guidance]

1. The survey and construction of ships of fibre reinforced plastics (hereinafter referred to as "FRP" and "FRP ships") to be registered in accordance with the Regulations for the Classification and Registry of Ships are to be as prescribed in these Rules. However, Light Craft or High-speed Light Craft defined in **Ch 1, 103. of Rules and Guidance for the Classification of High Speed and Light Crafts** were excepted.
2. The requirements in these Rules are applied to FRP Ships intended for unrestricted service, except oil tanks, less than 35 m in length, of normal form and proportion.
3. Hull construction, equipment and scantlings of FRP Ships intended for restricted service may be properly modified according to the conditions of service.
4. The requirements in these Rules are applied to FRP ships moulded by hand lay-up method or spray lay-up method, using fibre reinforcements such as fibreglass, etc. and thermosetting resins such as unsaturated polyester resins, etc. Other moulded methods and materials are to be in accordance with the discretion of the Society. However, wooden ships only covered with FRP or the ships of similar construction are not regarded as FRP ships.
5. In FRP ships of unusual form or proportion, or intended for carriage of special cargoes, or moulded by the method or with the materials other than specified as above, the hull construction, equipment, arrangement and scantlings are to be in accordance with the discretion of the Society.

### 102. Equivalency

Alternative hull construction, equipment, arrangement and scantlings will be accepted by the Society, provided that the Society is satisfied that such construction, equipment, arrangement and scantlings are equivalent to those required in these Rules.

### 103. Direct strength calculation [See Guidance]

1. Where approved by the Society, scantlings of structural members may be determined based upon direct calculation. Where calculated scantlings based on the direct calculation exceed the scantlings required in this part, the former is to be adopted.
2. Direct calculations may be required for crafts having novel design features or in support of alternative arrangements and scantlings.
3. Where the direct calculation specified in the **Par 1** is carried out, the data necessary for the calculation are to be submitted to the Society.

## Section 2 Definitions

### 201. Application

The definitions of terms which appear in these Rules are to be as specified in this Chapter, unless otherwise specified elsewhere.

### 202. Length

The length of ship ( $L$ ) is the distance in meters on the designed maximum load line, from the fore side of stem to the aft side of rudder post in case of a FRP ships with rudder post, or to the axis of rudder stock in case of a FRP ship without rudder post. However,  $L$  is as defined above or 96 %, not exceed 97 %, of the total length on the designed maximum load line.

### 203. Breadth

The breadth of ship ( $B$ ) is the horizontal distance in meters between the outside of side shell plates measured on the upper surface of upper deck plates at side at the broadest part of the hull.

### 204. Depth

The depth of ship ( $D$ ) is the vertical distance in meters at the middle of  $L$  measured from the top of keel to the top of the freeboard deck beam at side. Where watertight bulkheads extend to a deck above the freeboard deck and are to be registered as effective to that deck,  $D$  is the vertical distance to that bulkhead deck.

### 205. Midship

The midship part of ship is the part for  $0.4 L$  amidships unless otherwise specified.

### 206. Fore and End Parts

The fore and end parts of ship are the parts for  $0.1 L$  from each end of the ship.

### 207. Load Line

The load line is the waterline corresponding to the designed summer load draught or the designed sea water load draught in case of a FRP ship which is required to be marked with load lines and the waterline corresponding to the designed maximum draught in case of a FRP ship which is not required to be marked with load lines. However, the designed maximum draught is the waterline corresponding to the  $0.9 D$  from the top of keel plate for the FRP ship of which the designed maximum draught is not assigned.

### 208. Load Draught

The load draught ( $d$ ) is the vertical distance in meters from the top of keel plate to the load line measured at the middle of  $L$ .

### 209. Freeboard Deck

1. The freeboard deck is normally the uppermost continuous deck. However, in case where openings without permanent closing means exist on the exposed part of the uppermost continuous deck or where openings without permanent watertight closing means exist on the side of the ship below that deck, the freeboard deck is the continuous deck below that deck.
2. In an FRP ship having a discontinuous exposed deck, the lowest line of the exposed deck or the continuation of that line parallel to the upward deck is taken as the freeboard deck.

### 210. Strength Deck

The strength deck at a part of ship's length is the uppermost deck which reach the shell plate at any part of that deck. However, in case of having the superstructure, except sunken superstructures, which is not considered effective to longitudinal strength, the strength deck is the deck just below the superstructure deck.

### 211. Fibre Reinforcements

The fibre reinforcements are glass chopped strand mat (hereinafter referred to as "chopped mat"), roving, roving cloth, woven roving and woven cloth, single-direction roving and multi-directions roving made of fibreglass, aramid fibre or carbon fibre.

### 212. Resins

The resin is a thermosetting resin for laminating and gelcoats.

### 213. Blending Proportion

The blending proportion is a ratio in weight of the applied hardener and accelerator to the resin.



#### 214. Laminating

Laminating is an operation of laying succeeding fibre reinforcement impregnated with resin before curing or before the preceding layer advances in cure.

#### 215. Bonding [See Guidance]

Bonding is an operation of connecting the FRP already advanced in cure with other FRP members, timbers, hard plastic foams, etc. by means of impregnating fibreglass reinforcements with resin.

#### 216. Moulding

Moulding is an operation of manufacturing FRP products with definite form, strength, etc., by means of laminating or bonding.

#### 217. Single Skin Construction

The single skin construction is a construction composed of FRP single panels moulded with fibre reinforcement and resin.

#### 218. Sandwich Construction

The Sandwich construction is a construction having FRP layers adhered to the both sides of core material such as hard plastic foam, balsa, timber (including plywood), etc.

#### 219. Hand Lay-up Method [See Guidance]

The hand lay-up method is a method of manual moulding by impregnating fibre reinforcements with resin.

#### 220. Spray Lay-up Method

The spray lay-up method is a method of moulding by spraying simultaneously fibre reinforcements and resin using spray lay-up apparatus.

#### 221. FRP Material Tests

FRP Material Tests are tests and inspections of raw material to be carried out..

#### 222. FRP Specimen Tests

The FRP material tests are tests and inspections of FRP to be carried out prior to the commencement of moulding of FRP ships.

#### 223. FRP Strength Tests

The FRP strength tests are tests and inspections to be carried out after the completion of FRP ships.

### Section 3 Hull Construction and Equipment

#### 301. Application of Rules for the Classification of Steel Ships

Stern frames, rudders, steering gears, masts and equipment are to be in accordance with the requirements in the relevant Parts of **Rules for the Classification of Steel Ships**.

#### 302. Stability

The requirements in these Rules are framed for FRP ships having appropriate stability in all conceivable conditions. The Society emphasized that special attentions are to be paid to the stability by the builders in design and construction and by masters while in service.

**303. Passenger Ships [See Guidance]**

Hull construction, equipment, arrangement and scantlings of passenger ships are to be specially considered with respect to the design features in addition to the requirements in these Rules. In this case, attention is to be paid to the compliance with the international conventions and the national regulations of the country in which the ship is registered.

**304. Scantlings [See Guidance]**

1. The scantlings required in these Rules are specified for FRP ships moulded with fibreglass reinforcements composed of chopped mats and roving cloths and moulded with FRP having the strength specified in the following, but excluding gelcoats :

- (1) tensile strength : 98 N/mm<sup>2</sup>
- (2) modulus of tensile elasticity : 6.86×10<sup>3</sup> N/mm<sup>2</sup>
- (3) bending strength : 150 N/mm<sup>2</sup>
- (4) modulus of bending elasticity : 6.86×10<sup>3</sup> N/mm<sup>2</sup>

2. For single skin construction the scantlings specified in these Rules may be modified by multiplying by the factors specified in the following (1) and (2) in case where moulded with an FRP having the strength higher than specified in the preceding 1. :

- (1) For the thickness, a factor obtained from the following formula :

$$t = \sqrt{\frac{150}{\sigma_B}}$$

where,

$\sigma_B$  : Bending strength of the FRP obtained from the material tests specified in **Ch 3, 302.**  
(N/mm<sup>2</sup>)

- (2) For the section modulus (including section modulus of the transverse section of hull), a factor obtained from the following formula :

$$Z = \frac{98}{\sigma_T}$$

where,

$\sigma_T$  : Tensile strength of the FRP obtained from the material tests specified in **Ch 3, 302.**  
(N/mm<sup>2</sup>)

3. In case where the scantlings of laminates of sandwich construction are calculated, the modulus of bending elasticity of the inner or outer layer of FRP of laminates if sandwich construction may be as obtained from the FRP tests specified in **Ch 3, 302.**
4. In calculating the section modulus of structural members, the actual FRP laminates of 150 mm on either side of the web are to be included.

**305. Hat-type Construction [See Guidance]**

1. The minimum thickness of webs and faces of girders, beams, frames, floors for the hollow hat-type or hat-type with cores for moulding are not to be less than obtained from the following formula :

Thickness of web: 0.034  $d_0 K$  (mm)

Thickness of face: 0.05  $b K$  (mm)

where,

$d_0$  : Depth of web (mm).

$b$  : Breadth of face (mm).

$K$  : 1.0 However, where the section modulus of the members exceeds the specified value, the value as obtained from the following formula may be taken as  $K$ .

$$K = \sqrt{\frac{Z_R}{Z_A}}$$

where,

$Z_R$  : Section modulus specified for the member.

$Z_A$  : Actual section modulus of the member.

2. The core for moulding may be reckoned in the strength at the discretion of the Society.
3. Other scantlings are to be in accordance with the requirements in the relevant chapters.

### 306. Sandwich Construction [See Guidance]

1. The core of sandwich construction composing a panel is to be, as a rule, composed by one layer. The thickness of core is not to be larger than 25 mm. However, the composition of core different from these is to be at the discretion of the Society.
2. Thickness of inner layers for the sandwich construction is not to be less than 0.8 times of outer layers
3. The cores may be reckoned in the strength at the discretion of the Society.
4. Other scantlings are to be in accordance with the requirements in the relevant Chapters.

### 307. Weight of Fibreglass Reinforcements and Thickness Laminates [See Guidance]

1. The thickness of laminates per ply of chopped mats or roving cloths may be as obtained from the following formula :

$$t = \frac{W_G}{10\gamma_R G} + \frac{W_G}{1000\gamma_G} - \frac{W_G}{1000\gamma_R} \quad (\text{mm})$$

where,

$W_G$  : designed weight per unit area of chopped mats or roving cloths ( $\text{g}/\text{m}^2$ )

$G$  : glass content of laminate (ratio in weight) (%)

$\gamma_R$  : specific gravity of cured resin

$\gamma_G$  : specific gravity of chopped mats or roving cloths

2. The glass content ( $G$ ) specified in the preceding 1. is preferable to be the value per ply for the actual laminates. However, it may be taken as the mean glass content of the whole laminates.
3. The specific gravity of the chopped mats or the roving cloths ( $\gamma_G$ ) specified in the preceding 1 may be taken as 2.5 in calculation of the thickness, if nothing specially intervenes.
4. The specific gravity of the cured resin ( $\gamma_R$ ) specified in the preceding 1 may be taken as 1.2 in calculation of the thickness, unless any fillers are used in order to make the resin heavier.
5. Calculation of the thickness of laminates with fibreglass reinforcements other than the chopped mats and the roving cloths are to be in accordance with the discretion of the Society.  $\Downarrow$

## CHAPTER 2 CLASS SURVEYS

### Section 1 General

#### 101. General

1. The class surveys of FRP ships are to be, except those specified in this chapter, in accordance with the requirements in **Pt 1, Ch 2 of Rules for the Classification of Steel Ships**.
2. In the surveys of FRP ships less than 20 m in length, the items, extent and degree of survey may be properly modified as deemed appropriate by the Society. **[See Guidance]**
3. In the first Intermediate Survey after construction, the internal inspection of fuel oil tanks made of FRP is to be carried out.

#### 102. Classification

1. Ships built and surveyed in accordance with the Rules of the Society, or with alternatives equivalent to the Rules will be assigned to class notation prescribed in **103**. and be registered in the Register Master.
2. All ships classed with the Society are, for continuation of the classification, to be subjected to the periodical and other surveys, and are to be maintained in good condition in accordance with the requirements of the Rules.
3. The requirements, not mentioned in this chapter, are to be in accordance with , **Pt 1 of Rules for the Classification of Steel Ships**.

#### 103. Class notations

The class notations assigned to the craft classed with this Society are to be in accordance with the requirements in **Pt 1, Ch 1, Sec 2 of Rules for the Classification of Steel Ships**.

### Section 2 Classification Survey during Construction

#### 201. General

1. In the classification survey during construction, the hull and equipment, machinery, fire protection and detection, means of escape, fire extinction, electrical installation, stability and load lines are to be examined in detail in order to ascertain that they meet the requirements in the relevant Chapters. And the FRP ships are to be assigned load line as deemed necessary.
2. New installation of materials which contain asbestos is to be prohibited.

#### 202. Plans and Documents submission

1. With respect to FRP ships intended for the classification survey during construction, the plans and documents listed in the following are, prior to the commencement of work, to be submitted for the approval by the Society.
  - (1) Hull
    - (A) List and data of raw materials[Incl. Material Safety Data Sheet (hereinafter referred to as "MSDS")]
    - (B) General arrangement
    - (C) Midship section
    - (D) Details of fore and aft construction, and stem and stern frame
    - (E) Propeller post and rudder (including materials and ship's speed)
    - (F) Construction profile (showing arrangement of watertight bulkheads, load line, sizes of brackets and transverse sections of the ship at 0.1  $L$  and 0.2  $L$  from the ends of the ship)

- (G) Deck plans (including the construction of hatchways, hatch beams, etc.)
- (H) Construction of single bottoms and double bottoms
- (I) Watertight and oiltight bulkheads (indicating the tank top and position for the top of overflow pipes)
- (J) Superstructures end bulkheads (including the construction of doors)
- (K) Seatings of boilers, main engines, thrust bearings, plunger bearings, generators and other important auxiliary machinery (indicating output, height and weight of main engines and arrangement of holding-down bolts)
- (L) Steering gear (indicating materials and details of structural arrangement for each parts)
- (M) Laminating procedure and details of joints
- (2) Machinery
  - Plans and documents in relation to the machinery specified in **Pt 5, Ch 1, Sec 4 of Rules for the Classification of Steel Ships.**
- (3) Other plans and documents deemed necessary by the Society

### 203. Plans and Documents submission for Reference

1. Where intended for the classification survey during construction, the following plans or documents are to be submitted for reference, in addition to those for approval required in **202.** :
  - (1) Specifications
  - (2) Certificates of FRP material tests specified in **Ch 3, 302.**
  - (3) Moulding procedure
  - (4) Calculation sheets and information with respect to structural strength
  - (5) Other plans and documents deemed necessary by the Society

### 204. Inspections during Construction

1. In the classification survey during construction, inspections are to be carried out covering all stages of the moulding work from its commencement until its completion.
2. The presence of the Surveyor is required at the following stages of the work in relation to hull :
  - (1) When the tests of FRP specimens specified in **Ch 3, 302.** are carried out
  - (2) When designated by the Society during moulding work **[See Guidance]**
  - (3) When the strength tests of FRP specified in **Ch 3, 304.** are carried out
  - (4) When the moulding are connected (e.g. shell to deck)
  - (5) When the materials or parts manufactured away from the site are applied to the FRP ships concerned
  - (6) When hydrostatic tests and watertight tests are carried out
  - (7) When sea trials are carried out
  - (8) When deemed necessary by the Society
3. With respect to the work in relation to machinery and equipment, the presence of the Surveyor is to be in accordance with the requirements in **Pt 5, Ch 1, Sec 4 of Rules for the Classification of Steel Ships.**
4. The stages of work for which the presence of the Surveyor is required in the preceding **2** may be modified in accordance with the actual status of facilities, technical abilities and quality control system at the works, except the case of the sea trials.

## Section 3 Classification Survey after Construction

### 301. General

1. In the classification survey after construction of FRP ships, the actual scantlings of main parts of the ship are to be measured in addition to such examinations of the hull and machinery, equipment and structure, material, manufacture and condition of fixtures as required for the special survey corresponding to the ship's age. And the FRP ships are to be assigned load line as deemed necessary.
2. As for FRP ships intended for the classification survey specified in the preceding **1**, plans and documents required for the classification survey during construction are to be submitted. ↓

## CHAPTER 3 MATERIALS

### Section 1 General

#### 101. Application

1. The requirements in this chapter apply to FRP materials, FRP and metallic materials used for FRP ships' building or repairs.
2. Other materials not prescribed or not matched in this chapter may be used in specially approved cases according to designs. In this case the specified materials' details shall be submitted and approved by the Society.

#### 102. Approval and Manufacturing Control

##### 1. Approval

- (1) The workshop which FRP ship applied for survey during construction are moulded shall submit details about moulded workshop facility and FRP materials' storage facility, etc. and be subject to Manufacturing Method Approval in accordance with the Guidance relating to the Rules.  
[See Guidance]
- (2) FRP materials (fibre reinforcements, resins and core, etc.) used for FRP ship applied for survey during construction are appropriate to **Pt 2 of Rule for the Classification of Steel Ships** and are subject to Type Approval in accordance with the Guidance relating to the Rules.  
[See Guidance]
- (3) The metallic materials (rolled steel, steel pipe, cast steel, forged steel, copper alloy and aluminum alloy, etc.) used for FRP ship applied for survey during construction are in accordance with the requirements in **Pt 2 of Rules for the Classification of Steel Ships**.

##### 2. Manufacturing control

- (1) It is the manufacturer's responsibility to assure that effective process and production controls in operation are adhered to within the manufacturing specifications.
- (2) Where control imperfection inducing possible inferior quality of product occurs, the manufacturer is to identify the cause and establish a countermeasure to prevent its recurrence. Also, the complete investigation report is to be submitted to the Surveyor.
- (3) For further use, each product affected by previous (2) is to be tested to the Surveyor's satisfaction. The frequency of testing for subsequent products offered may be increased to gain confidence in the quality at the discretion of the Society.

#### 103. Materials for Constructions

1. Fibre reinforcements, resins and cores for sandwich constructions used for FRP materials are in accordance with requirements of each clause in **102. 1 (2)** and **Ch 3, Sec 2**.
2. FRP used for FRP ship constructions are in accordance with requirements of **Ch 3, Sec 3**.
3. Materials (plywoods and timbers, etc.) used for constructions except FRP constructions are in accordance with requirements of each clause in **Ch 3, Sec 2**.
4. Steel plates, angles, rivets and welding rods are to be in accordance with **Pt 2 of Rules for the Classification of Steel Ships** and steel equipment are to be protected by plating or other proper methods. Further, the surfaces of steel equipment covered by FRP are to be cleaned perfectly in order not to be included rust, oil or foreign substances.

## Section 2 FRP Materials

### 201. General

#### 1. Application

Resins, gelcoats, fibre reinforcements, cores for sandwich construction (Hard plastic foams and End-grain balsa) and timbers and plywoods for main constructions as FRP raw materials (hereinafter referred to as "FRP materials") used for hull constructions of FRP ships are to be in accordance with requirements in this section.

#### 2. FRP materials testing

- (1) The material manufacturer is to provide the purchaser with certificates of conformity for each batch of materials supplied (hereinafter referred to as "FRP materials tests"), indicating the relevant values specified in **Table 3.1** and **3.5**.
- (2) The builders are to ensure that copies of all certificates of conformity are obtained for all batches of materials received, and maintain accurate records in accordance with the previous (1).
- (3) The Surveyor may at any time select samples of materials for testing by an independent test organization, where applicable, source and should such tests result in the material failing to meet the specification, then that batch will be rejected.

### 202. Resins

1. The resin is consist of polyester resin, catalyzer, accelerant, filler, pigment and core material, etc.

#### 2. Resin

- (1) The resin is to be of approved type which are deemed appropriate by the Society.
- (2) Materials testing list and the acceptance criteria for the test results are to be in accordance with **Table 3.1**.

**Table 3.1 Materials testing list and Acceptance Criteria for the test results**

| Test item   |                             | Acceptance criteria   |
|---|-----------------------------|---|
| Viscosity <sup>(1)</sup>  |                             | 1.5 ~ 8(Poise)  |
| Thixotropy <sup>(1)</sup>   |                             | 1.2 ~ 4   |
| Gel time <sup>(1)</sup>   |                             | Reference <sup>(3)</sup>  |
| Minimum cure time <sup>(1)</sup>  |                             | Reference <sup>(3)</sup>  |
| Peak exothermic temperature <sup>(1)</sup>  |                             | Not more than 190°C   |
| Acid value <sup>(1)</sup>   |                             | Reference <sup>(3)</sup>  |
| Mould plate <sup>(2)</sup>  | Water absorption rate       | Mean value to be not more than 70 mg  |
|   | Barcol hardness             | Mean value to be not less than 35   |
|   | Tessile elongation          | Mean value to be not less than 2.0 %<br>Test results of at least 4 test specimens are not to be less than 2.0 % |
|   | Tensile strength            | 40 N/mm <sup>2</sup>  |
|   | Bending strength            | 70 N/mm <sup>2</sup>  |
|   | Load deflection temperature | Mean value to be not less than 60°C<br>Test results of at least 2 test specimens are not to be less than 60°C   |
| (Note)  |                             |   |
| (1) Test methods are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b> |                             |   |
| (2) Test methods are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b> |                             |   |
| (3) The value is to be assigned by the manufacturer.  |                             |   |

- (3) The polyester containing wax or other materials that deteriorate bonding are to be carried out interlaminar shear strength test (KS M ISO 14130) and approved by the Society.

### 3. Hardeners and Accelerators

- (1) The type and amount used of the hardeners and accelerators are to be carefully selected so that they are suitable for resins for laminating and gelcoats and capable of hardening the resin with fast and completely without heating.
- (2) In case of polyester and vinylester resins, the quantity of accelerators is not less than 1 % of resins in weight ratio.
- (3) The followings may be used as a mixture of catalyzer and accelerator. However, in case of using the mixtures other than followings, the details are to be submitted.
  - (A) Methyl-ethyl-ketone peroxide and a cobalt accelerator
  - (B) Cyclohexane peroxide and a cobalt accelerator
  - (C) Benzoyl peroxide and a tertiary amine accelerator (can not be used for gelcoats)
- (4) In general, the time required for hardening the resin is not to be exceeded one hour where the temperature of moulding shop is under working ranges.

### 4. Color pigment

- (1) Color pigment should be used after mixing with unsaturated polyester resin and styrene, and shall not be used with plasticizer.
- (2) Color pigment should not disturb hardening of resin or not give to hardening time.
- (3) The quantity of color pigment added in laminating resin is not to be exceeded that indicated by manufacturer.
- (4) It is recommended that pigments are not to be added to the gel coat or laminating resins used in the underwater portion of the hull laminate or in laminates forming the boundaries of oil fuel and water tanks.

### 5. Fillers

- (1) All fillers added by builders are to be of dispersion type and the data concerning the purpose for application, kinds of filler, amount used, etc. are to be submitted to the Society.
- (2) Quantities and types of fillers and/or additives are to allow sufficient wet out of reinforcement fibers within the resin manufacturer's specified gel time.
- (3) Calcium carbonate or other fillers similar to alkaline are not to be used in laminates required fire resistant.
- (4) In general, the quantity of fillers is not to be exceeded 20 % of resin system.
- (5) The fillers should not be used in laminates which forms fuel oil tanks and fresh water tanks.

### 6. Fire retardant additives

- (1) Where laminates are required to have fire retardant or restricting properties, details of the proposals are to be submitted for approval.
- (2) All fire retardant resin systems are to be used strictly in accordance with the resin manufacturer's recommendations.

## 203. Gelcoats

1. The gelcoat is to be approved by the Society.
2. The gelcoat may be composed of layer reinforced fiberglass or other proper material and resin for gel coat absolutely. Also the resin for gelcoats may be made of general resin for lamination with mixture of flexible resin.
3. The resin for gelcoat should have hardening time and rapid gelation.
4. The quantities of thyratrophic additive should be of minimum to prevent from loosening.
5. Materials testing list for gelcoat and the acceptance criteria for the test results are to be in accordance with **Table 3.2**.



Table 3.2 Materials testing list for gelcoat and Acceptance Criteria for the test results

| Test item   |                             | Acceptance criteria   |
|---|-----------------------------|---|
| Viscosity <sup>(1)</sup>  |                             | Not less than 20 (Poise)  |
| Thixotropy <sup>(1)</sup>   |                             | 1.2 ~ 4   |
| Gel time <sup>(1)</sup>   |                             | Reference <sup>(3)</sup>  |
| Minimum cure time <sup>(1)</sup>  |                             | Reference <sup>(3)</sup>  |
| Peak exothermic temperature <sup>(1)</sup>  |                             | Not more than 190 °C  |
| Acid value <sup>(1)</sup>   |                             | Reference <sup>(3)</sup>  |
| Mould plate <sup>(2)</sup>  | Water absorption rate       | Mean value to be not more than 60 mg  |
|   | Barcol hardness             | Mean value to be not less than 35   |
|   | Tessile elongation          | Mean value to be not less than 2.5 %<br>Test results of at least 4 test specimens are not to be less than 2.5 % |
|   | Tensile strength            | 40 N/mm <sup>2</sup>  |
|   | Bending strength            | 60 N/mm <sup>2</sup>  |
|   | Load deflection temperature | Mean value to be not less than 60 °C<br>Test results of at least 2 test specimens are not to be less than 60 °C |
| (Note)  |                             |   |
| (1) Test methods are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b> |                             |   |
| (2) Test methods are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b> |                             |   |
| (3) The value is to be assigned by the manufacturer.  |                             |   |

## 204. Fibre Reinforcements

1. All fibre reinforcements are to be approved by the Society.
2. Materials testing list and the acceptance criteria for the test results for fibre reinforcements are to be in accordance with **Table 3.3**.

Table 3.3 Materials testing list and Acceptance Criteria for Fibre Reinforcements

| Test item  |   | Acceptance criteria  |
|--|---|--|
| Tensile strength of fibre of glass roving cloth <sup>(1)</sup>   |   | Mean value : Not less than 0.35 $\bar{W}(N)$<br>$\bar{W}$ : the stated weight(N)<br>Test results of at least 4 test specimens in 5 test specimens of respective warp and weft directions are not to be less than 0.35 $\bar{W}(N)$ . |
| Deviation <sup>(1)</sup>   | Chopped mat                                       | 1 m <sup>2</sup> : Not greater than 10 % for each specimen<br>300 mm × 300 mm : Not greater than 20 % for each specimen  |
|  | Roving cloth                                      | 1 m <sup>2</sup> : Not greater than 3 % for each specimen<br>300 mm × 300 mm : Not greater than 5 % for each specimen  |
|  | Roving  | 15 g : Not greater than 10% for each specimen  |
| Ratio in weight of residual binders <sup>(1)</sup>   | Chopped mat                                       | Mean value : Not greater than 10 %<br>Test results of at least 4 test specimens are not to be greater than 10 %.   |
|  | Roving cloth                                      | Mean value : Not greater than 1 %<br>Test results of at least 4 test specimens are not to be greater than 1 %.   |
|  | Roving  | Mean value : Not greater than 3 %<br>Test results of at least 4 test specimens are not to be greater than 3 %.   |
| Laminating plate <sup>(2)(3)</sup>   | Bending strength(standard condition)              | (1) To be in accordance with the Guidance relating to the Rules.<br><b>[See Guidance]</b><br>(2) The minimum value in the wet condition is not less than 75 % of the minimum value in the standard condition.                        |
|  | Modulus of bending elasticity(standard condition) |  |
|  | Bending strength(wet condition)                   |  |
|  | Modulus of bending elasticity(wet condition)      |  |
|  | Tensile strength                                  |  |
|  | Modulus of tensile elasticity                     |  |
| (Note)   |   |  |
| (1) Test methods are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b>  |   |  |
| (2) Test methods are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b>  |   |  |
| (3) The glass/resins ratio or volume ratio(except fibre reinforcements) for manufacturing of laminating plate are to be in accordance with the Guidance relating to the Rules. <b>[See Guidance]</b> |   |  |

3. Fibre reinforcements are to be free from incompleteness, stain, foreign substance, moisture and other defects.
4. The light weight reinforcements that are capable of absorbing large quantity of resin such as 300 g chopped strand mat should be laminated in the middle of clothes weaved thickly. The medium weight reinforcements such as 900 g chopped strand mat should be used to laminate the structures or places that resins are permeated completely.
5. All reinforcements are to be stored strictly in accordance with the manufacturer's recommendations. Rolls of reinforcement are to remain in their original packaging to minimise contamination. The quality control documentation is to provide traceability of all reinforcements using the manufacturer's batch numbers.
6. Pre-impregnated reinforcements are to be suitably stored in an approved area. Detailed storage records are to be maintained as part of the quality control documentation.

### 205. Surfacing materials

1. Lightweight surfacing materials for reinforcing resin rich surfaces are to be compatible with the resin being used. Details of the materials and the fibre contents, by weight, are to be included on the Materials Data Sheet.
2. Where peel ply materials are to be used, the finish is to be such that, after removal, it does not interfere with any subsequent bonding processes.

### 206. Core Materials for Sandwich Construction

1. All core materials for sandwich construction are to be a type approved by the Society.
2. **End-grain balsa**
  - (1) Balsa wood for sandwich construction is to be end grained.
  - (2) Materials testing list and acceptance criteria for end-grain balsa are to be in accordance with **Table 3.4**.

**Table 3.4 Materials testing list and Acceptance Criteria for end-grain balsa**

| Apparent density (kg/m <sup>3</sup> ) | Strength (N/mm <sup>2</sup> ) |                        |                     |                        | Shear | Compressive modulus of elasticity (N/mm <sup>2</sup> ) |                        | Shear modulus of elasticity (N/mm <sup>2</sup> ) |
|---------------------------------------|-------------------------------|------------------------|---------------------|------------------------|-------|--|------------------------|--|
|                                       | compressive                   |                        | Tensile             |                        |       | Direction of stress                                    |                        |  |
|                                       | Direction of stress           |                        | Direction of stress |                        |       | Parallel to grain                                      | Perpendicular to grain |  |
|                                       | Parallel to grain             | Perpendicular to grain | Parallel to grain   | Perpendicular to grain |       |  |                        |  |
| 96                                    | 5.00                          | 0.35                   | 9.00                | 0.44                   | 1.10  | 2300   | 35.20                  | 105  |
| 144                                   | 10.60                         | 0.57                   | 14.60               | 0.70                   | 1.64  | 3900   | 67.80                  | 129  |
| 176                                   | 12.80                         | 0.68                   | 20.50               | 0.80                   | 2.00  | 5300   | 89.60                  | 145  |

(Note)  
(1) Test methods are to be in accordance with the Guidance relating to the Rules. **[See Guidance]**

- (3) Balsa wood is to be chemically treated against fungal and insect attack and kiln dried shortly after felling;
- (4) Balsa wood is to be an average moisture content of 12 per cent;

### 3. Hard plastic foams

- (1) Materials testing list and acceptance criteria for hard plastic foams for sandwich construction are to be in accordance with **Table 3.5**.

**Table 3.5 Materials testing list and Acceptance Criteria for Hard plastic foams**

| Material          | Apparent density (kg/m <sup>3</sup> ) | Strength (N/mm <sup>2</sup> ) |             |       | Modulus of elasticity (N/mm <sup>2</sup> ) |       |
|-------------------|---------------------------------------|-------------------------------|-------------|-------|--|-------|
|                   |                                       | Tensile                       | Compressive | Shear | Compressive                                | Shear |
| Polyurethane      | 96                                    | 0.85                          | 0.60        | 0.50  | 17.20                                      | 8.50  |
| Polyvinylchloride | 60                                    |                               |             |       |  |       |

(Note)  
(1) Test methods are to be in accordance with the Guidance relating to the Rules. **[See Guidance]**

- (2) Hard plastic foams are to be of closed-cell types and be compatible with the resin system.

- (3) Hard plastic foams are to be impervious to water, fuel and oils and have good ageing stability.
- (4) Hard plastic foams are to have good strength retention at 60 °C.

**4. Timbers and plywoods are to be tested and inspected on the items in the following :**

- (1) Compressive strength and modulus of compressive elasticity
- (2) Tensile strength and modulus of tensile elasticity (only in case where timbers or plywoods are reckoned in tensile strength)
- (3) Bending strength and modulus of bending elasticity (only in case where timbers or plywoods are reckoned in bending strength)
- (4) Shearing strength obtained from specimens of sandwich construction.

## 207. Sub Materials

### 1. Core bonding materials

- (1) Details concerning the handling, mixing and application of adhesives are to be submitted to the Society.
- (2) Details of the proposed core bonding paste to be used with the core material are to be indicated on the Materials Data Sheet and the appropriate construction plans.
- (3) The builder is to demonstrate that a uniform thickness of bonding paste is obtained by use of notched trowels or comb gauges.

### 2. Adhesives

- (1) Details concerning the handling, mixing and application of adhesives are to be submitted to the Society.
- (2) Particular attention is to be given to the surface preparation and cleanliness of the surfaces to be bonded.
- (3) Where excessive unevenness of the faying surfaces exists a suitable gap filling adhesive is to be used or local undulations removed by the application of additional reinforcements.

### 3. Sealant material

Details concerning the handling, mixing and application of adhesives are to be submitted to the Society.

### 4. Repair compounds

- (1) For acceptance purposes, the manufacturer is to submit full product details, and user instructions, listing the types of repair for which the system is to be used together with details of any installer accreditation schemes.
- (2) Dependent on the proposed uses, the Society may require testing in accordance with a specified test programme.
- (3) Materials should not be accepted for the following uses unless specific evidences of their suitability are provided:
  - (A) Any component in rubbing contact.
  - (B) Any component subject to dynamic cyclic loading.
  - (C) Any pressure part in contact with gas or vapour.
  - (D) Any pressure part in contact with liquid above 3,5 bar.
  - (E) Any component where operating temperature exceeds 90°C.

### 5. Release agents

Release agents are to have no inhibiting effect on the gelcoat resin and are to be those recommended by the resin manufacturer.

## 208. Timbers and Plywoods for Primary Structures

### 1. Wood

- (1) The woods are to be of good quality and dried properly and free from defects that might impair the strength or durability such as blueing, brittleness, rot, cracks, knots and sapwood etc.
- (2) The moisture content of the wood is to be within the limits required by the method of joining the parts (glueing, laminating, sheathing) and consideration of the dimensional stability of the structure. Timber for structural purposes where encapsulated or over-laminated should have an

average moisture content not greater than 15 %.

## 2. Plywoods

- (1) The plywoods are to be of prime quality for ships and glued by approved glues. The glues are to be of resorcinol system, phenolic system or others approved and to be used in accordance with manufacturer's guidance under the conditions which are deemed appropriate by the Society.
- (2) In general, the plywood is to be manufactured to a high standard of finish in accordance with ISO(KS) or other recognised standards and is to meet, or be equivalent to, the following general requirements:
  - (A) Have good quality face and core veneers of a durable hardwood species.
  - (B) The number of veneers due to plywoods' thickness is to be in accordance with **Table 3.6**.

**Table 3.6 Number of veneers**

| Board thickness, (mm) | Minimum number of plies(plies) |
|-----------------------|--------------------------------|
| $\leq 9$              | 3                              |
| $10 \leq t \leq 19$   | 5                              |
| $20 \leq t$           | 7                              |

- (C) The veneers are to be bonded with a WBP (water and boil proof) type adhesive.
- (D) Having a moisture content is not to exceed 15 per cent.
- (3) Plywood intended to be used for external structural members (e.g. hull, weather deck not sheathed by FRP laminate or similar, superstructures and deckhouses) should be marine-grade plywood. Where a ship is intended to be only temporarily used in the water and the hull is protected by a wood-penetrating medium(e.g. epoxy resin) other waterproof and boilproof external-grade plywood may be used.
- (4) Other members inside the hull may be made of waterproof and boilproof plywood which does not fully comply with marine-grade plywood. It should be durable.

## 209. Cores for Moulding [See Guidance]

1. Cores used for moulding in frames, longitudinals, etc., are to be of oil resistance, styren resistance and water resistance, and to have good adhesion to polyester resins.
2. Where the cores for moulding are reckoned in strength, tests are to be carried out on tensile strength and modulus of tensile elasticity or bending strength and modulus of bending elasticity. However, where sufficient data are submitted to and approved by the Society, the above-mentioned tests may be dispensed.

## 210. Receipt and Storage for FRP Materials

### 1. Receipt

The following tests are to be carried out, where applicable, on receipt of any material:

- (1) The consignment is to be divided into its respective batches and each batch is to be labelled accordingly.
- (2) Each batch is to be visually examined for conformity with the batch number, visual quality and date of expiry.
- (3) Each batch is to be separately labelled and stored separately.
- (4) Each unit, within the batch, is to be labelled with the batch number.
- (5) Records are to be maintained of the above and these are to be cross-referenced with the certificate of conformity for the material and/or the Builder's own test results.

### 2. Storage

- (1) Storage premises are to be so equipped and arranged that the material supplier's directions for storage and handling of the raw materials can be followed.
- (2) Resins are to be stored under controlled condition in accordance with manufacture's

recommendations. Where resins contain ingredients of solidifications, it is to be ensured that it is in accordance with resins manufacturer's recommendations concerning blending and conditioning before use.

- (3) Polyester, gelcoat and the like should not be stored by temperatures that will affect the qualities of the material. Raw materials which are stored at temperatures lower than 18 °C should be heated up before use to the temperature of the moulding shop. Tanks for polyester are to be equipped and arranged so that the contents can be stirred every day.
- (4) The storage temperature and the storage periods for resins and coating are to be within the limits specified by the material supplier.
- (5) Storage premises for glassfibre are to be kept clean and as free from dust as possible, so that the raw material is not contaminated. Glassfibre parcels are also to be protected against rain and moisture.
- (6) The glassfibre material is, whenever possible, to be stored for at least two days in storage premises, with air of a lower relative humidity than in the manufacturing premises, and at an air temperature at least 2 °C higher than in the manufacturing premises. If such storage of the glassfibre material before transfer to the manufacturing is not possible, the material is to be stored for at least two days in premises with air of the same condition as in the moulding premises.
- (7) Catalysts and accelerants are to be stored in accordance with manufacturer's recommendations.
- (8) Fillers and additives used for moulding procedures are to be stored in the closed container to be protected from dust and moisture.
- (9) Core materials are to be stored dry according to and protected against mechanical damages.

## Section 3 FRP

### 301. General

#### 1. Application

The tests, process tests and strength tests of FRP used for hull construction of FRP ships (including FRP laminates and sandwich laminates) are to be in accordance with the requirements in this section.

#### 2. Construction

- (1) All constructions are to be carried out using materials approved or accepted by the Society.
- (2) All materials are to be in accordance with the approved construction documentation.
- (3) All batches of materials are to be provided with unique identifications by their manufacturers. Components are to be similarly identified.
- (4) No batch of material is to be used later than its date of expiry.
- (5) The Builder is to ensure that all batches of materials are used systematically and sequentially.
- (6) The Builder is to maintain, on a continuous basis, records of the amounts of resin and reinforcement used, in order to ensure that the proportions remain within the limits set in the construction documentation.
- (7) Records are to be kept of the sequence and orientation of the reinforcements.
- (8) The Builder is to ensure that each section of the construction is traceable to the batch or batches of material used.
- (9) Any curing system used is to be demonstrated as suitable for the intended purpose and all pyrometric equipment is to be calibrated at least annually and adequate records maintained.
- (10) The post-curing temperature is to be controlled and recorded by the attachment of suitably placed thermocouples.

#### 3. Quality assurance

Where the Builder has a quality assurance system, this is to include the requirements of this Section.

#### 4. Dimensional tolerances

- (1) Dimensions and tolerances are to conform to the approved construction documentation.
- (2) The thicknesses of the laminates are, in general, to be measured at not less than ten points,

evenly distributed across the surface. In the case of large sections, at least ten evenly distributed measurements are to be taken in bands across the width at maximum spacing of two metres along the length.

- (3) The responsibility for maintaining the required tolerances and making the necessary measurements rests with the Builder. Monitoring and random checking by the Surveyor does not absolve the Builder from this responsibility.
- (4) Where ultrasonic thickness gauges are used, these are to be calibrated against an identical laminate (of measured thickness) to that on which the thickness measurement is to be carried out. If suitable pieces are not available from the construction, then a small sample of identical lay-up is to be prepared.

### 5. Visual examination

All constructional mouldings and any components are to be visually examined and are to be free from surface defects and blemishes.

## 302. FRP Specimen Tests [See Guidance]

1. The FRP specimen tests for the structural members listed in the following are tests and inspections of FRP to be carried out prior to the commencement of moulding of FRP ships. Where composition of laminates is same, repetition test may be abbreviated.
  - (1) Bottom shell laminates
  - (2) Side shell laminates
  - (3) Upper deck laminates
  - (4) Bulkhead (only of sandwich construction)
2. The FRP material tests on the other members are to be carried out only in case where scantlings are modified in accordance with the requirements in **Ch 1, 304. 2.**
3. The test specimens for FRP specimens material tests used for construction members previous **1** are to be cut from FRP which are of the same laminate composition (excluding gelcoats) and moulded by the same procedure and at the same workshop as the actual hull laminates. The test specimens are to be tested and inspected on the items listed in the following. The procedures of tests and inspections are to be in accordance with the discretion of the Society.
  - (1) FRP laminates (including FRP laminates of inner layer and outer layer of sandwich laminates)
    - (A) Thickness of moulding
    - (B) Glass content (ratio in weight)
    - (C) Bending strength
    - (D) Modulus of bending elasticity
    - (E) Tensile strength
    - (F) Modulus of tensile elasticity.
  - (2) Sandwich laminates
    - (A) Thickness of moulding of sandwich laminates
    - (B) Tensile strength of sandwich laminates, only in case where the cores are reckoned in the tensile strength. In this case, the test specimens in which joints of cores are involved are to be included.
    - (C) Shearing strength of sandwich laminates. In case where the cores are reckoned in the bending strength, the test specimens in which joints of cores are involved are to be included.
4. The test plates are size which can extract all test specimens prescribed previous **2** and the number of test specimens are to be five, unless specially specified, and the arithmetical mean of the smaller three values obtained from the five specimens is to be taken as the test result.
5. The result of FRP tests is not to be less than the strength specified in **Ch 1, 304.** for FRP laminates and not to be less than the value obtained from the tests specified in the Guidance relating to the Rules.

### 6. Certificates of FRP tests

Certificates of FRP tests containing the items listed in the following are to be submitted to the Society.

- (1) Names of fibre reinforcements, resins for laminating and cores for sandwich construction
- (2) Names and amount of application of fillers

- (3) Names and amount of application of hardeners and accelerators
- (4) Procedures and conditions of moulding
- (5) Direction of selection of test specimens
- (6) Dates of moulding and tests of test specimens
- (7) Place of tests and environmental condition of the site of tests
- (8) Types of testing machines
- (9) Form and dimensions of test specimens
- (10) Test results

### 303. FRP Process Tests

1. FRP process tests are measurements of consumption rate and hardening for FRP materials during FRP moulding.
2. During construction, tests are to be carried out on the constituents and final product in accordance with **Table 3.7**.

**Table 3.7 Process Testing during construction<sup>(1)</sup>**

| Component/operation  | Characteristic   | Rate of testing   |
|--|--|---|
| Resin/curing agent/catalyst  | Gel time<br>Rate of consumption  | Two per shift <sup>(3)</sup><br>Continuous  |
| Reinforcement  | Quality<br>Orientation<br>Rate of consumption  | Continuous<br>Continuous<br>Continuous  |
| Resin/reinforcement  | Ratio  | Continuous  |
| Construction   | Temperature during cure/post cure<br>Dimensions<br><br>Cure level (Barcol) against resin manufacturer's specification<br>Laminate thickness<br><br>Laminate fibre content <sup>(2)</sup> | Continuous<br>Continuous against approved construction documentation<br>At least one per square metre<br><br>Continuous against material usage and approved construction documentation<br>At the Surveyor's request |
| (Note)   |  |   |
| (1) The standards of acceptance for testing are those listed in the material manufacturer's specification, approved construction documentation or agreed quality control procedures as applicable. |  |   |
| (2) In particular where the thickness measured does not correlate with the specified fibre content, by weight.   |  |   |
| (3) If the batch of resin or polymer, or the curing agent, or their ratio is changed, at least two additional measurements of the gel time are to be carried out during each shift.                |  |   |

### 304. FRP Strength Tests

1. The FRP strength tests are tests and inspections to be carried out after the completion of FRP ships.
2. The test specimens which are to be cut from the laminates and sandwich laminates taken from the actual hull laminates or the laminates and sandwich laminates equivalent thereto, are to carry out tests and inspections on the items specified in **302**.
3. The results of FRP strength tests are to be submitted to the Society as the results of FRP strength tests containing the items specified in **302. 5** and the location of selection of test specimens.
4. Where the results of FRP strength tests are less than those of being reckoned in design, the structural members are to be properly strengthened.



**305. Omission of FRP Tests and FRP Strength Tests**

1. For a sister ship of others which were or are being built at the same workshop, the FRP tests and FRP strength test may be omitted, provided that the raw materials used, manufacturing methods, inspection standards in the workshop, quality control system, etc. are examined and deemed appropriate by the Society. However, for ships not less than 20 m in length, the FRP strength tests are not to be omitted.
2. The FRP for which omission of the material tests specified in **1** is applicable are such FRP that have been recognized by the Society as being moulded by means of the same laminating and the same moulding procedures as those for the FRP having the certificates of FRP material tests in accordance with the requirements in **302. 5.** ↓

## CHAPTER 4 MOULDING

### Section 1 General

#### 101. Application

The requirements in this chapter are framed for the case where FRP is moulded by the hand lay-up method or spray lay-up method. The moulding methods other than those mentioned above are to be in accordance with the discretion of the Society.

#### 102. General

1. Manufacturing premises are to be so equipped and arranged that the material supplier's directions for handling the materials, the laminating process and curing conditions can be followed.
2. The air temperature in the moulding shops is not to be less than 18 °C. The stipulated minimum temperature is to be attained at least 24 hours before commencement of laminating, and is to be maintainable regardless of the outdoor air temperature.
3. The temperature in the moulding shops is not to vary by more than  $\pm 3$  °C during 24 hours.
4. The relative humidity of the air is to be kept so constant that condensation is avoided and is not to exceed 80 %. In areas where spray moulding is taking place, the humidity is not to be less than 40 %. The stipulated air humidity is to be maintainable regardless of outdoor air temperature and humidity.
5. Air temperature and relative humidity are to be recorded regularly. In larger shops there is to be at least one thermohygrograph for each 1500 m<sup>2</sup> where lamination is carried out. The location of the instruments in the premises is to be as neutral as possible.
6. Draught through doors, windows etc. and direct sunlight is not acceptable in places where lamination and curing are in progress.
7. Manufacturing premises are to be kept clean and as free of dust as possible, so that raw materials and moulds are not contaminated.
8. The ventilation plant is to be so arranged that the curing process is not affected.
9. Sufficient scaffoldings are to be arranged so that all lamination work can be carried out without operators standing on the core or on surfaces on which lamination work is taking place.
10. During lamination of large constructions the temperature should be recorded at least at two levels vertically in the workshop and the curing system should be adjusted to compensate for possible temperature differences.
11. Fabrication of flat panels are to be carried out on a support lifted from the workshop floor level.

#### 103. Blending Proportion

1. FRP yacht manufacturers are to submit details of material types, material manufacturer and mixture ratio of materials for approval before manufacturing.
2. In mixture of all materials used in resin, the items not specified in these requirements should follow the manual of manufacturer and all materials shall be measured accurately and mixed sufficiently.

## Section 2 Laminating and Moulding

### 201. General

1. Moulding of FRP is to be carried out under the supervision of a well-experienced technical expert.
2. Mouldings which are deemed not to have been fully cured are not to be kept under the environmental condition which may prevent them from effective curing. And, post curing of moulding at high temperature, if intended, is to be approved by the Society.

### 202. Moulding

#### 1. Mould

- (1) Moulds are to be reinforced properly with proper material and of sufficient strength to maintain their shape and fairness of moulding.
- (2) Moulds are not to give harmful influence to laminates. The surface smoothness of moulding works is to comply with discussions between manufacturer and ship owners.
- (3) Where multiple section moulds are used, the sections are to be carefully aligned prior to moulding. Mismatch between mould sections is to be eliminated.
- (4) Mouldings are to be cleaned, dried and in place so that they stabilize at the workshop temperature before the releaser is applied.
- (5) Where metallic moulds are used, welding is to be minimised to avoid distortion of panels.
- (6) Prior to use all moulds are to be conditioned to the workshop temperature.

#### 2. Moulding

- (1) Before moulding, examinations are to be made in detail with respect to the items listed in the following and moulding is to be proceeded on the basis of such examinations.
  - (A) Environmental conditions of laminating shops, controlling system thereof and curing time of resins
  - (B) Operation procedure and scheduled operation process
  - (C) Kinds, cutting methods, overlap of joints, edge preparation and number of plies of fibre reinforcements
  - (D) Kinds, amount, blending quantity at one time and blending procedures of resins used.
- (2) It is recommended that the structural members are moulding in one body with the prescribed hull laminates before they advance in cure. However, structural members separately moulding may be bonded to the hull laminates.

### 203. Releaser

1. Proper releaser are to be coated evenly on the working surface of moulding. However, releaser containing silicon is not to be used.
2. The releaser is to be compatible with the mould surface, the resins applied in the laminating process and with moulding release films used previously.

### 204. Gelcoat

1. Gelcoat resins are to be evenly coated or sprayed.
2. The standard thickness of gelcoat film is approximately 0.5.

### 205. Lamination

#### 1. General

- (1) Grade 1 polyester is to be used for the hull shell laminate in single skin construction and for the outer hull skin laminate in sandwich construction.
- (2) Framing and stiffening sections are to be built up layer by layer in accordance with an approved procedure, particular attention being given to ensure a satisfactory bond and structural continuity at the ends and intersections.
- (3) Discontinuities and hard points in the structure are to be avoided, and where the strength of a

- stiffening member is impaired by any attachment of fittings, openings, drainage arrangements, etc., compensation is to be provided.
- (4) The outer reinforcement ply of the outer hull skin laminate is to be at least  $450 \text{ g/m}^2$  of chopped strand fibres containing as little water soluble bonding components as possible. Normally spray roving or powder bound mat should be used. Alternatively a  $300 \text{ g/m}^2$  mat and a light surface mat can be used. Other material systems giving an equivalent surface protection may also be accepted.
  - (5) Areas inside the hull expected to be continuously exposed to water submersion (i. e. bilge wells etc.) and the inside of tanks shall have a surface lining consisting of at least  $600 \text{ g/m}^2$  reinforcement material.
  - (6) The time interval between applications of each layer of reinforcement is to be within the limits specified by the FRP material supplier. For thicker laminates care is to be taken to ensure a time interval sufficiently large to avoid excessive heat generation.
  - (7) When laminating is interrupted, and where other than an epoxy resin system is being used, the first of any subsequent layers of reinforcement to be laid in that area is to be of chopped glass fibre or other type of material to enhance the interlaminar strength properties of the laminate.
  - (8) Curing systems are to be selected with due regard to the reactivity of the polyester and in accordance with the supplier's directions. Heat development during curing is to be kept at a safe level. The quantity of curing agents is to be kept within the limits specified by the supplier.
  - (9) The cut edges of laminates, holes for bolts, etc. are to be thoroughly covered with resin so that the fibre reinforcements are not exposed.
  - (10) The bonding and fastening are to be in accordance with the requirements of **Sec 6**.

## 2. Laminating plans

- (1) FRP ships' builders should submit details of laminating plans and they are to be approved prior to constructions
- (2) The laminate schedule is to clearly define the logical sequence of production and is to identify the specific materials to be used. The materials used for constructions and fastening are not to disturb curing of resins.
- (3) The kind, thickness, composition thickness and laminating weight of gelcoats, chopped mats and core are indicated in the laminating plans.
- (4) The extents of each reinforcement should be defined and details related in overlap, staggering thicknesses and reinforcement's cutting should be prescribed in the laminating plans .
- (5) The submitted plans are to clearly define the laminate sequence at corner joints. In general, corner laminates are to be boxed and all cuts are to be alternately staggered to avoid a fault line. At corner joints vertical and horizontal laminates are to be laid alternately and butts are to be staggered accordingly.
- (6) Changes in laminate thickness are to be made using a gradual taper. The length of such taper is, in general, not to be less than 100 mm.

## 206. Release and curing

1. After completion of the lay-up, the moulding is to be left in the mould for a period to allow the resin to cure before being removed. This period can vary with ambient temperature, the type of resin and the complexity of the moulding, but is to be not less than 12 hours or that recommended by the resin manufacturer.
2. Care is to be exercised during removal from the mould to ensure that the hull, deck and other large assemblies are adequately braced and supported to avoid damage to and maintain the form of the moulding.
3. Where female moulds are adopted, all primary stiffening and transverse bulkheads are to be installed prior to removal from the mould unless agreed otherwise.
4. Mouldings are, in general, to be stabilised in the moulding environment for at least 24 hours, or that recommended by the resin manufacturer before the application of any special cure treatment, details of which are to be submitted for approval.
5. Removal from the mould is not to be attempted until a minimum Barcol reading recommended by the resin manufacturer or a value of 20 has been attained. Subsequently, the moulding is not to be moved outside of the controlled environment until a minimum Barcol reading recommended by the resin manufacturer of 35 (or equivalent) has been recorded

### 207 Repair

1. Minor repairs are to be agreed with the attending Surveyor prior to being carried out. The Builder is to incorporate details of the agreed repair procedures in the quality control system.
2. Structural repairs are subject to individual consideration and full written details must be approved by the plan approval teams prior to introduction.

### 208. Sanding

Where the outer surface of FRP laminates is sanded, attention is to be paid lest the fibre reinforcements on the sanded surface should be heavily damaged.

## Section 3 Additional Procedure for Hand Lay-up Method

### 301. Seams of Fibre Reinforcements

Fibre reinforcements are to be arranged so as to have seams of reinforcements as few as practicable. The overlapping breadths at butts and seams of mats which are composed of reinforcement layer are not to be less than 50 mm. The centre lines of overlaps of two adjacent plies are not to be less than 100 mm apart from each other so far as no obstruction exist for the work.

### 302. Hand Lay-up

1. In laminating, after having the fibre reinforcements thoroughly impregnated with resin, air bubbles in the resin are to be removed by degassing rollers. However, excessive squeezing of resins is not desirable and care is to be taken to keep the glass content proper.
2. In case where heavy mats and fibers are used, special attention is to be taken to permeate completely
3. When the dough materials with resin and glass fiber are used to increase the thickness of lamination, they are to be same with main lamination. And the content of fiberglass is not to be less than 25 % of resin and the length of fiberglass is not to be less than 25 mm.
4. Where the successive laminating is interrupted in such a case of laminating the thick shell plating, etc., non-paraffin resins are to be used for the first of any subsequent layers of reinforcement to be laid in that area and care is to be taken not to leave over the excessive resin layer.
5. As for laminating of the final ply, effective measures to cure the outer surface are to be provided.
6. The hull lamination and other hull structural members are to be tested in glass fiber content ratio, aperture content ratio, hardening degree and mechanical strength etc.
7. The laminations are to be free from defects such as blister, delamination, excessive resin etc.

### 303. Glass Content

1. In the laminations for structures, the ratio between fiberglass and resins is to be as same as minimum resins amounts which can impregnate that reinforcement completely.
2. In laminating, the standard glass content (ratio in weight) is approximately 30 % in case of chopped mats or approximately 50 % in case of roving cloths, and laminating is to be carried out uniformly to avoid local excess or scarcity of resin.
3. The aggregated weight of roving cloths is to be 25 % to 60 % of the total weight of glass. Where, however, special fibre reinforcements are used, the weight is to be in accordance with the discretion of the Society.

## Section 4 Additional Procedure for Spray Lay-up Method

### 401. Resin Spray

The gel or laminating resin can be applied by using spray system when the attending Surveyor is satisfaction.

### 402. Spray Lay-up Apparatus

1. The spray lay-up apparatus is to be approved by the Society.
2. The spray lay-up apparatus is to be those which can mould FRP so that the glass content, mechanical properties, etc., are uniform.
3. Moulding by means of the spray lay-up apparatus is to be carried out by skilled moulding operators.

### 403. Spray moulding

1. For the spray lay-up apparatus used by filling with resin and glass fiber at the same time, it is necessary to consider specially and the Surveyor may require proper test to confirm the performance.
2. The spray moulding should be used only for the approved structures. Attention is to be paid to maintain strength continuity in the spots that reinforcement by spray lay-up and by hand lay-up are adjacent.
3. Spray lay-up of resin and/or reinforcement fibers should be limited to applications where, in general, a specified even thickness of the sprayed laminate can be achieved and consideration should be given to;
  - (1) Exothermic heat by excessive wet laminate thickness
  - (2) Sagging or drainage of the laminate
  - (3) De-aeration
4. The weight of glass reinforcement to be deposited between resin/glass consolidation depends upon the complexity of the mould. In general, this should not be more than  $1150 \text{ g/m}^2$  of fiberglass, unless it can be demonstrated that a satisfactory laminate can be achieved with a greater glass reinforcement weight.
5. The uniformity of the laminate and glass content should be checked at regular intervals. Where the back-up layer behind the gelcoat is sprayed-up, the type and length of the fibers should ensure that no wicking effect can occur. The spray equipment should be calibrated and should be checked for the desired setting for the resin/catalyst and resin/reinforcement fiber ratios at the beginning of each working day.
6. Where the chopped mat parts of the primary structural members of hull are moulded by means of the spray lay-up method, the method is to be pre-approved by the Society.

## Section 5 Additional Procedure for Sandwich Construction

### 501. Cores

1. Core material used in lamination structure of hull and exposed deck is to be of unicellular construction where it is a foam plastic.
2. The polystyrene foam is to be covered as a protection of resin containing styrene.
3. Where the cores which are composed of hard plastic foams are temporarily set by nails, care is to be taken to ensure that the cores are free from dent, misalignment and other defects due to nailing. And, no penetrating clearance not less than 1 mm is to be left between the cores.
4. Where balsas are used for cores, care is to be taken to have the balsas thoroughly impregnated with resins. The clearance between the balsas is, as a rule, not to be more than 4 mm.

### 502. Treatment of Cores

1. The surface of cores is to be properly treated in order to obtain sufficient bonded connection between the FRP layer and the core.
2. The hull structures should not be of abrupt change of thickness or strength discontinuity between sandwich lamination and adjacent single plating lamination and the core should be reduced in thickness differences by 1/2 taper or less.
3. The connection of structural cores are to be of scarf connection or similar ones. In general, scarfs are not to be steeper than a 12:1 taper. Scarf joints may be either ground or stepped and may be single or double taper. Where single taper scarf joints are proposed, a sealing laminate is to be provided, details of which are to be submitted. Where stepped joints are proposed care is to be taken to ensure that over-cutting does not occur. All joints are to be arranged so that they can be reinforced internally to maintain structural continuity of the laminate.
4. For non-structural cores made of seat material, the butt or seam of panel need not be bonded but should be crossed each other.
5. The inserts for structural material to withstand the crushing are to be fixed by using bolts and fixing steel and the inserts are to be stuck to the core and surface of sandwich.
6. Resin applied to the core material or its protective sheathing/coating should be compatible with its surface.
7. Embedded plywood should be of the waterproof and boilproof type and should have a surface that bonds easily to the resin or adhesive.

### 503. Sandwich construction using female moulds

1. Core surface cavities and other irregularities should be removed or coated with filler, resin or sandwich adhesive according to the material manufacturer's specification and depending on the following skin lay-up. When using scored core material, a sufficient amount of resin or adhesive should be used in the bond to fill the gaps.
2. When bonding core material to a wet laminate, sufficient resin should be in or on the laminate to achieve a bond between the laminate and core material without resin deficiency of the laminate.
3. The materials should be kept in contact while curing to ensure a structurally sufficient bond and to avoid air entrapment.
4. Deviations from these procedures may be made, provided that the structural requirements of ISO 12215-5 are met.

### 504. Sandwich construction using male moulds

1. Joints, scores and voids in the core material should be filled or fixed to each other before the skin laminate is applied.
2. When laying the core material, it should not be bent or deformed to such an extent that the properties of the core are adversely affected.
3. Irregularities on the core surface and the joints should be removed.
4. The core surface should be primed where required before the laminate is applied.

### 505. Laminating of Sandwich Constructions.

1. Efficient bond is to be obtained between the skin laminates and the core and between the individual core elements. Approved tools for cutting, grinding etc. of various types of core material should be specified in the production procedure. The bond is to be verified by shear or tensile testing.
2. All joints between skin laminates and core and between the individual core elements are to be completely filled with resin, glue or filler material.

3. Core materials with open cells in the surface, should normally be impregnated with resin before it is applied to a wet laminate or before lamination on the core is commenced.
4. When the core is applied manually to a wet laminate the surface should be reinforced with a chopped strand mat of 450 g/m<sup>2</sup> in plane surface and 600 g/m<sup>2</sup> in curved surface. If vacuum is applied for core bonding the reinforcement type in the laminate surface may be considered in each individual case.
5. The reinforcement next to the core is normally to be a chopped strand mat of at least 300 g/m<sup>2</sup>. A lighter mat may be accepted provided proper bond is documented by testing.
6. When a prefabricated skin laminate is glued to a sandwich core, measures are to be taken to evacuate air from the surface between skin and core.
7. The core material is to be free from dust and other contaminations before the skin laminates are applied or core elements are glued together.
8. Where the core material is to be laid onto a pre-moulded skin, it is to be laid as soon as practicable after the laminate cure has passed the exothermic stage.
9. Where the core is applied to a laminated surface, particular care is to be taken to ensure that a uniform bond is obtained. Where a core is to be applied to an uneven surface, the Surveyor may request additional building up of the surface or contouring of the core to suit.
10. Thermoforming of core materials is to be carried out in accordance with the manufacturer's recommendations. Maximum temperature limits are to be strictly observed.

## Section 6 Bonding and Fastening

### 601. Arrangements

1. Details of arrangements and building tolerances are to be laid down in the Builder's production plan.
2. Particular attention is to be given to the accurate arrangements of the following:
  - (1) girder abutting single skin bulkhead;
  - (2) girder webs with tank sides;
  - (3) frames with beams;
  - (4) deck/bottom girders with bulkhead stiffeners;
  - (5) tank baffles with floors;
  - (6) longitudinals where broken at tank ends; and
  - (7) transom stiffeners with bottom/deck girders.
3. To ensure efficient transmission of shear loads, the alignment tolerance of intercostal 'top hat' stiffener webs is, in general, to be within half of the web thickness.

### 602. Bonding [See Guidance]

1. Bonding is to be executed after making effective preparation such as sanding the surface to be bonded and thoroughly removing oils and sanding dusts.
2. If a laminate subject to secondary bonding has cured for more than 5 days the surface should be ground. If resin containing wax is used grinding is required if the curing time exceeds 24 hours.
3. If peel strips are used in the bonding surface the required surface treatment may be dispensed with.
4. Bonding is to be executed paying careful attention not to cause spring back of fibre reinforcements.
5. Bonding is to be carefully executed so as not to cause any deformation due to excessive exothermic effect.
6. Bonding is to be carefully carried out so as not to cause strength discontinuity at the joint.
7. T-joints and L-joints are to be laminated at the site.



8. The lamination may be bonded by using polyester resin or epoxy resin, and the joint part of resin connection is to be located at the position that shear force acts. The butt joint by resin connection is not to be used at the position that tensile force acts.
9. The lapping connection is to be lapped 38 mm or more for glass fiber lamination of 3600 g or less and the lapping breadth is to be increased 6.5 mm per 1200 g excess of glass fiber reinforcement.

### 603. Mat-in connection

1. The structural members are to be connected with main structures using angles made of laminations before that angles are cured completely.
2. The scantlings of mat-in angles are classified as following two types based on flange breadth per weight of reinforcements.

**Table 4.1 The Flange Breadth based on Types**

| Type | Flange breadth per 600 g reinforcement(mm) |
|------|--|
| 1    | 38   |
| 2    | 25   |

### 604. Bolts and Rivets Fastening

1. Where laminates are connected each other or where metallic fittings are fastened to laminates, mechanical fastening such as bolts and rivets may be applied. However, mechanical fastening is to be carried out at a right angle to the laminates as far as practicable and the fastening holes are to be well coated with resins.
2. For the end parts or edges of holes, the exposed ends of glass fiber reinforcement are to be covered or bonded by resin.
3. The weight of lamination is to be increased 25 % or more at the location of connections, flanges and outfitting installation.
4. The distance between the centre of bolt hole and the edge of laminate is not to be less than three times the diameter of the hole. The distance between the bolt holes is not to be less than three times diameter of the hole.
5. For lamination of chopped strand mat, the lamination panels are to be connected at the position which the distance from edge to center of bolt or rivet is to be 2.5 times of bolt diameter or more, and the distance is to be increased in accordance with the kinds of reinforcement.
6. Where bolts are used, washers are to be used on the surface of laminate.
7. The laminations may be connected with steel, alloy or copper rivets and the washers or strips are to be inserted to avoid damages on lamination when making a rivet head after inserting rivet bolts.
8. The bolts, rivets, screws, etc. are to be of the seawater corrosion resistant metal or to be the properly protected against corrosion.
9. Where bolts, screw, rivets, etc., are used, penetrating sandwich laminates with cores of hard plastic foams, timbers or plywoods well seasoned are to be inserted in such parts of the cores in advance.
10. Where mechanical fastening such as bolted joints, etc. is used in way of a location where watertightness is required, suitable measures are to be provided to maintain watertightness.

### 605. Attachment of metal equipment

1. In case of attaching equipment by bolts penetrating hull lamination, the large diameter washers are to be used to avoid damages of lamination. The washer is not to be less than  $2.25 d$  in outer diameter and  $0.1 d$  in thickness, where,  $d$  is diameter of bolt and the material of washer is to be

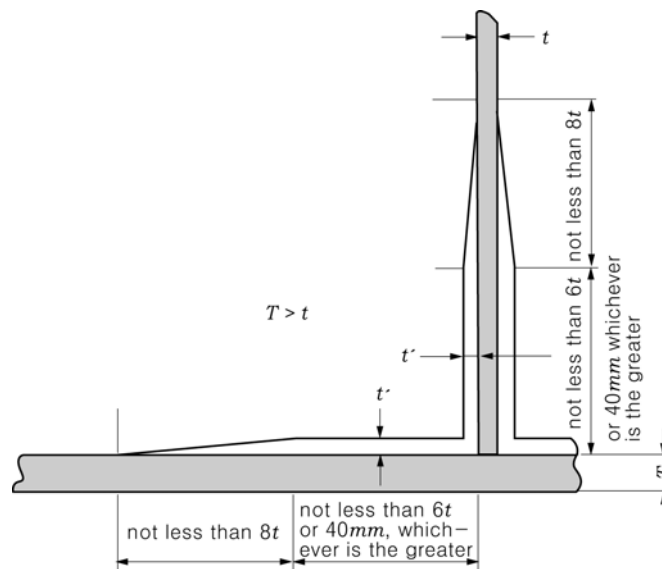
that of bolt.

2. The poromeric metal panel with rough surface treatments to be inserted in the lamination panel where heavy loads act and that metal inserted plate are to be bonded with rough surface of glass fiber by epoxy resin or polyester resin.
3. The contact surfaces of metal outfitting are to be finished by sand blasting or wire brushing and after cleansing chemically and they are to be moulded on lamination by epoxy resin or polyester resin.

## Section 7 Bonded Connections

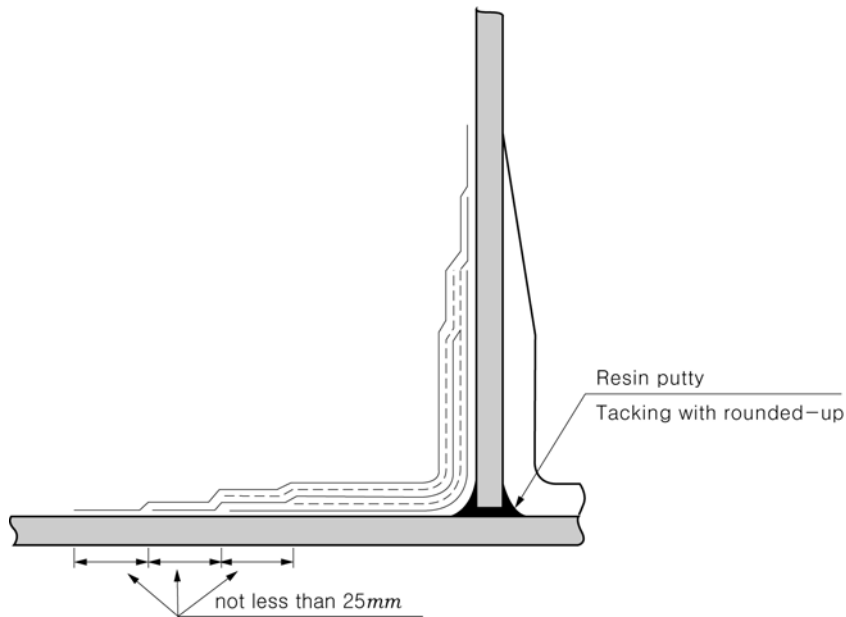
### 701. T-joints

1. The overlap width of T-joints of structural members are generally to be in accordance with **Fig 4.1**.

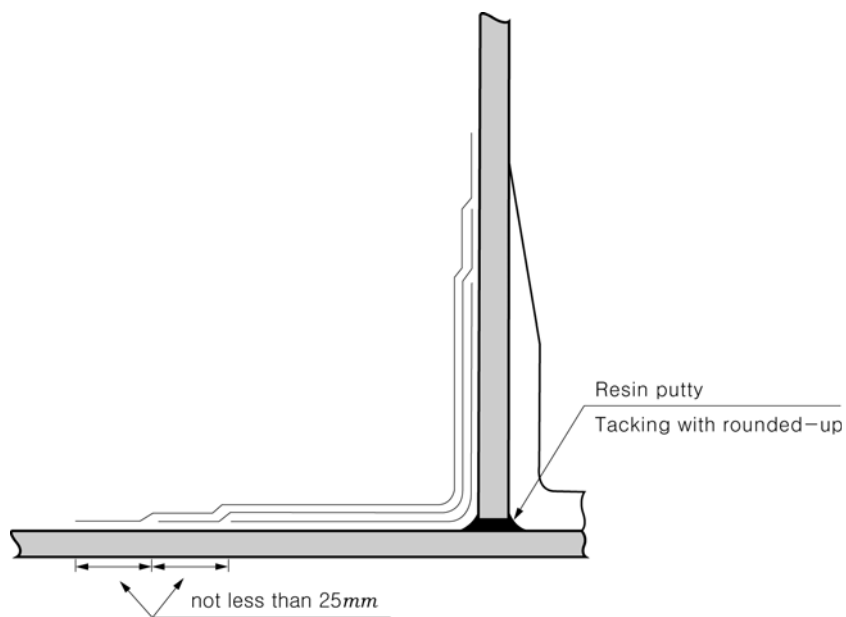


**Fig 4.1 Dimensions of Overlap of T-Joints**

2. In T-joints of members of sandwich construction, the aggregated thickness of the inner laminate and the outer laminate of FRP may be used as the thickness ( $t$ ) shown in **Fig 4.1**.
3. The form of laminating of T-joints is to be as shown in **Fig 4.2(a)** and **Fig 4.2(b)**.



**Fig 4.2(a) In Case Chopped Mats and Roving Cloths are jointly used**



**Fig 4.2(b) In Case Chopped Mats are used**

4. Where the members such as engine girders, bulkheads, etc., which are subjected to considerably heavy load or vibration are connected, careful considerations are to be given in such a manner as to arrange structural members upon the laminates which are increased in thickness as shown in **Fig 4.3(a)**.
5. Where the members other than those specified in the preceding 4, that is, the members which are not deemed subjected to specially heavy load or vibration, are connected to the structural members, plastic foams or other similar materials are to be inserted between the member and the laminate as shown in **Fig 4.3(b)** or the corners are to be sufficiently laminated by filling with soft resin puttys or other similar materials as shown in **Fig 4.3(c)**.

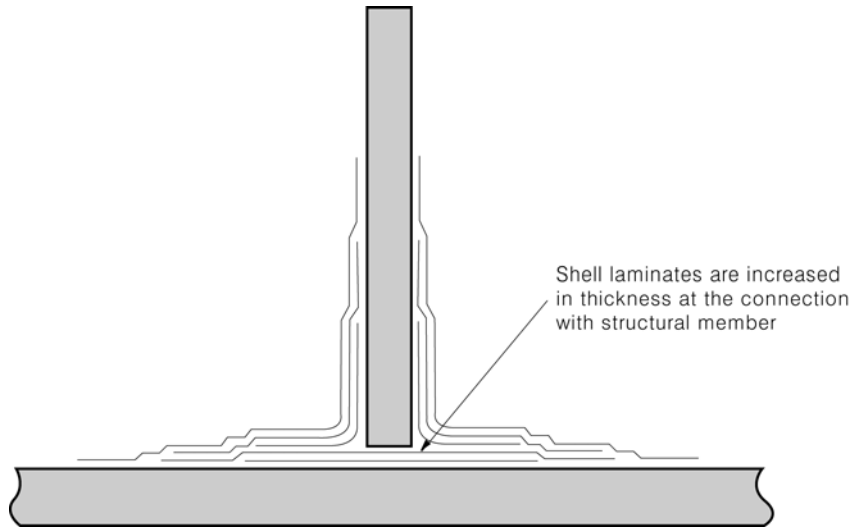


Fig 4.3(a) In Case Consideration is to be paid to Load or Vibration

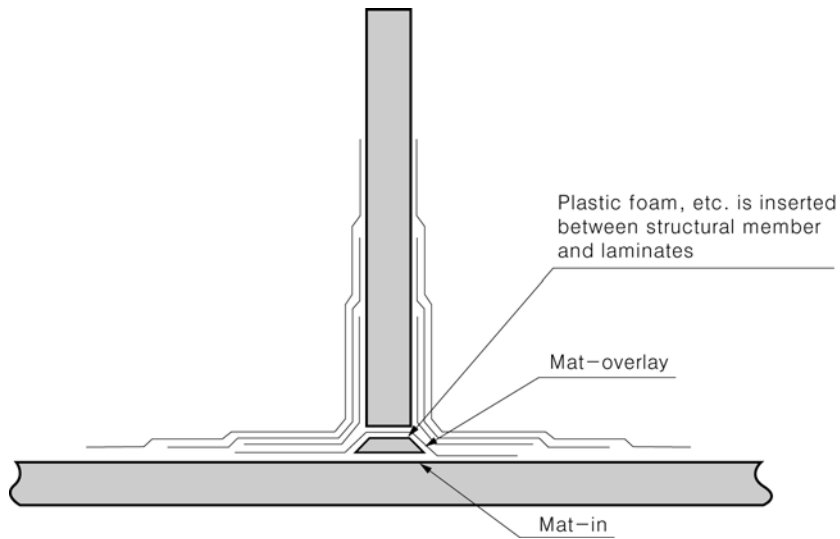


Fig 4.3(b) Standard Form of T-Joints

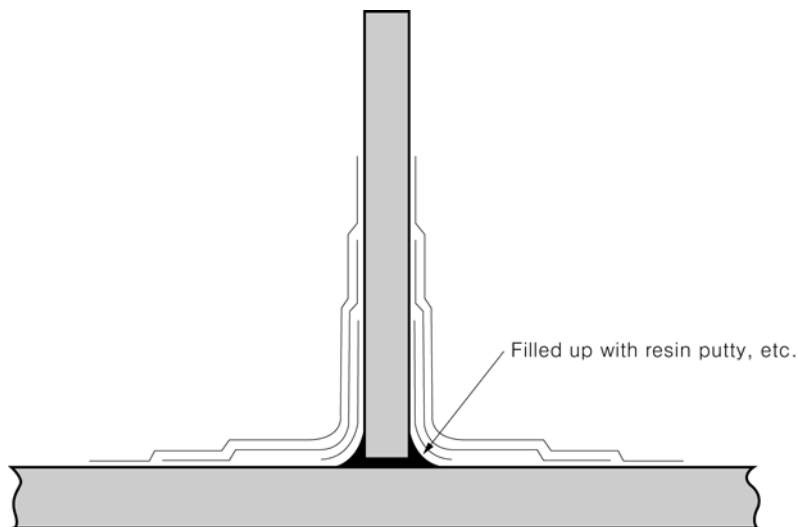


Fig 4.3(c) Standard Form of T-Joints

**702. L-Joints [See Guidance]**

L-Joints are generally not to be used for primary structural members. Where, however, L-Joints are inevitably used because adoption of T-Joints is difficult, the careful consideration is to be paid to the construction of the joints.

**703. Butt Joints**

1. In the shell laminates, butt joints are not to be provided. However, in case of repair, etc., where joints are locally provided, scarp joints may be used.
2. In the butt joints of deck laminates, joints other than scarp joints of V-type or X-type are not to be used.
  - (1) Solid lines indicate chopped mat layers and dotted lines indicate roving cloth layers.
  - (2) Roving cloth layers are not to overlap each other.
  - (3) The first and last layers are to be a chopped mat layer.

**Section 8 Coating****801. Coating**

1. The coating is not to be applied until the mould is hardened completely and repaired tiny defects.
2. The surfaces of moulds are to be polished by fine abrasive and removed dusts and if necessary, coated by proper primer. ↓

## CHAPTER 5 LONGITUDINAL STRENGTH

### Section 1 Longitudinal strength

#### 101. Section Modulus of Transverse Section

The section modulus of the hull for midship part is not to be less than obtained from the following formula:

$$Z = CL^2 B_W (C_b + 0.7) \quad (\text{cm}^3)$$

where,

$C$  : Coefficient obtained from the following formula. In no case, however, is it to be less than 44.

$$0.4L + 36$$

$B_W$ : Horizontal distance between the outside of side shell laminates at the designed maximum load line (m).

$C_b$  : Volume of displacement at the designed maximum load line divided by  $LB_W d$ .

#### 102. Moment of Inertia of Transverse Section

The moment of inertia of the transverse section for  $0.4L$  of midship part is not to be less than obtained from the following formula :

$$I = 4.2ZL \quad (\text{cm}^4)$$

where,

$Z$  : Section modulus of the transverse section specified in **101**. ( $\text{cm}^3$ )

Where, however,  $L/D$  for FRP ships of single bottom is less than 12.0, the calculation of the moment of inertia may be dispensed with.

#### 103. Calculation of Section Modulus of transverse Section [See Guidance]

The calculation of section modulus of the transverse section is to be in accordance with the requirement in the following :

1. Longitudinal members below the strength deck which are considered as continuous for  $0.5L$  amidships are to be included in the calculation. Longitudinal members above the strength deck which are considered effective to the longitudinal strength of the ship may be included in the calculation.
2. The section modulus at the strength deck is the moment of inertia about the horizontal neutral axis of the transverse section divided by the vertical distance from the neutral axis to the top of strength deck beam at side, or to the top of the longitudinal members above the strength deck in case where such members are included in the calculation in accordance with the provisions in **1**. The section modulus at the bottom is the above-mentioned moment of inertia divided by the vertical distance from the neutral axis to the base point of  $D$ , or to the bottom of keel in case where the keel is of hat-type construction.
3. The sectional area of timbers or structural plywoods multiplied the ratio of the modulus of tensile elasticity of the relevant material to that of the FRP is to be included in the calculation.
4. Where cores of sandwich laminates or cores for moulding are included in the longitudinal strength,

the sectional area multiplied by the ratio of the modulus of tensile elasticity of the relevant core to that of the FRP is to be included in the calculation. Where a joint of the core exists for  $0.5 L$  amidships, sufficient data with respect to the longitudinal strength and joints are to be submitted to the Society for approval.

#### 104. Continuity of Strength

Longitudinal strength members are to be of such a construction as to maintain good continuity of strength. ↓

## CHAPTER 6 SHELL LAMINATES

### Section 1 General

#### 101. Application

The scantlings of shell laminates specified in this chapter are applied for the case where the shell is of single skin construction or of sandwich construction.

### Section 2 Keels

#### 201. Construction and Scantlings

1. Keels are to be as continuous from fore end to after end as practicable.
2. The breadth or girth length and thickness of keel laminates over the whole length of the ship are not to be less than obtained from the following formula. In no case, however, is the thickness to be less than that of the adjacent bottom shell laminates. And, the breadth or girth length need not exceed  $0.2 B$ .

Breadth or girth length :  $530 + 14.6 L$  (mm)

Thickness :  $9 + 0.4 L$  (mm)

### Section 3 Shell Laminates for Midship Part

#### 301. Side Shell Laminates of Single Skin Construction

The thickness of side shell laminates of single skin construction is not to be less than obtained from the following formula :

$$t_f = 15S\sqrt{d+0.026L} \quad (\text{mm})$$

where,

$S$  : Spacing of frames (m)

#### 302. Bottom Shell Laminates of Single Skin Construction

The thickness of bottom shell laminates of single skin construction is not to be less than obtained from the following formula :

$$t_f = 15.8S\sqrt{d+0.026L} \quad (\text{mm})$$

where,

$S$  : Spacing of frames (m)

#### 303. Shell Laminates of Sandwich Construction

1. The aggregated thickness of inner layer, outer layer and core of sandwich construction is not to be less than obtained from the following formulae, whichever is greater :

$$t_1 = C_1 S(d+0.026L) \quad (\text{mm})$$



$$t_1 = C_2 t_f \quad (\text{mm})$$

where,

$t_f$  : Thickness in case of single skin construction specified in **301.** or **302.** (mm).

$S$  : Spacing of frames (m).

$C_1$  : Coefficient obtained from the following formula :  $\frac{C_3}{\tau_a}$

$\tau_a$  : Shearing strength of sandwich laminates obtained from the test specified in **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.** or the result for related test among **Ch 3, 206.** of this rules.  
(N/mm<sup>2</sup>)

$C_2$  and  $C_3$  : As given in **Table 6.1.** For the intermediate values of  $\alpha$  and  $\beta$ ,  $C_2$  and  $C_3$  are to be obtained by linear interpolation.

**Table 6.1 Values of  $C_2$  and  $C_3$**

| $\beta$ |              | 0.2  | 0.3  | 0.4  | 0.5  | 0.6  | 0.7  | 0.8  | 0.9  | 1.0  |
|---------|--------------|------|------|------|------|------|------|------|------|------|
| $C_2$   | $\alpha=0.8$ | 1.62 | 1.42 | 1.31 | 1.24 | 1.20 | 1.16 | 1.14 | 1.12 | 1.10 |
|         | $\alpha=1.0$ | 1.54 | 1.36 | 1.25 | 1.19 | 1.15 | 1.12 | 1.10 | 1.08 | 1.07 |
| $C_3$   |              | 2.18 | 2.26 | 2.33 | 2.40 | 2.46 | 2.52 | 2.57 | 2.62 | 2.67 |

Where,  
 $\alpha$  : The thickness of outer layer or inner layer of FRP, whichever is the divided by the greater thickness.  
 $\beta$  : The sum of the thickness of outer layer and inner layer of FRP divided by the thickness of core.

2. The respective thickness of inner layer and outer layer of shell laminate of sandwich construction is not, notwithstanding the requirements in the preceding 1, to be less than obtained from the following formula. In no case, however, is it to be less than 2.4 mm :

$$t = 3.6 \sqrt[3]{C_4 S^4 (d + 0.026L)^4} \quad (\text{mm})$$

where,

$S$  : Spacing of frames (m).

$C_4$  : Coefficient obtained from the following formula :

$$\frac{1}{t_c} \cdot \frac{E_c}{E_f} \left( \frac{1}{\sigma_c} \right)^4$$

$E_f$  : Modulus of bending elasticity of inner layer or outer layer specified in **Ch 1, 304.**  
(N/mm<sup>2</sup>)

$E_c$  : Modulus of compressive elasticity of core obtained from the test specified in **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.** or the result for related test among **Ch 3, 206.** of this rules.

(N/mm<sup>2</sup>)

$\sigma_c$  : Compressive strength of core obtained from the test specified in **Ch 3, Sec 28** of **Guidance for Approval of Manufacturing Process and Type Approval, Etc.** or the result for related test among **Ch 3, 206.** of this rules. (N/mm<sup>2</sup>)

$t_c$  : Thickness of core (mm).

## Section 4 Shell Laminates for End Parts

### 401. Thickness of Shell Laminates for End Parts

1. The thickness of shell laminates of single skin construction may be gradually reduced beyond the midship part and it may be 0.85 times the thickness of shell laminates amidships for end parts.
2. Shell laminates of sandwich construction beyond the midship part are to be of the same construction as that for the midship part.
3. For the part where subjected to local loads such as propeller pressure, etc., the shell laminates are to be properly strengthened.

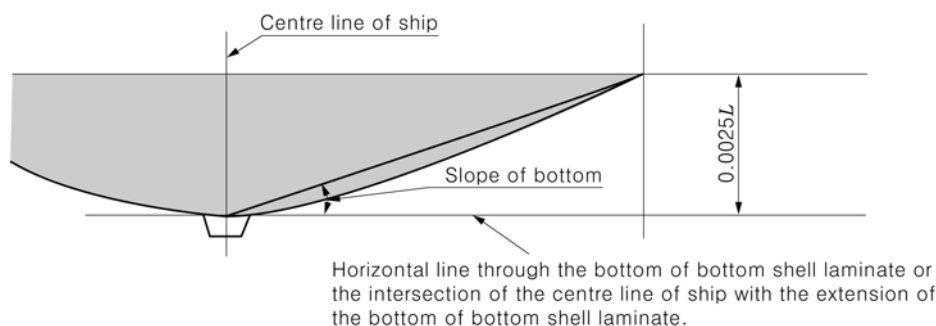
### 402. Strengthened Bottom Forward

The strengthened bottom forward is the part of flat bottom forward from the position specified in the following. The flat bottom is the bottom whose slope measured at the respective athwartship sections (See **Fig 6.1**) is not more than 15 degrees.

(1) Where  $\frac{V}{\sqrt{L}}$  is not more than 1.5 : 0.25  $L$  from the fore end

(2) Where  $\frac{V}{\sqrt{L}}$  exceeds 1.5 : 0.3  $L$  from the fore end

Where  $V$  is the designed speed in knots which the ship with clean bottom can attain at the maximum continuous output on calm sea in loading condition corresponding to the designed maximum load line (hereinafter referred to as "the full load condition in the Rules).



**Fig 6.1 Slope of Bottom**

### 403. Shell Laminates at the Strengthened Bottom Forward

1. The thickness of shell laminates at the strengthened bottom forward of single skin construction is not to be less than obtained from the following formula:

$$t = CS\sqrt{L} \quad (\text{mm})$$

where,

$C$  : Coefficient given in **Table 6.2**. However, for the intermediate value of  $\alpha$ ,  $C$  is to be ob-

tained by linear interpolation.

$S$  : Spacing of frames, or spacing of girders or longitudinal shell stiffeners, whichever is smaller(m)

$\alpha$  : Spacing of frames, or spacing of girders or longitudinal shell stiffeners, whichever is greater(m), divided by  $S$ .

**Table 6.2 Values of  $C$**

|          |      |      |      |      |      |               |
|----------|------|------|------|------|------|---------------|
| $\alpha$ | 1.0  | 1.2  | 1.4  | 1.6  | 1.8  | 2.0 and above |
| $C$      | 5.36 | 5.98 | 6.37 | 6.62 | 6.75 | 6.81          |

- The thickness of shell laminates at strengthened bottom forward of sandwich construction is not to be less than obtained from the formula specified in **303. 1**. However, in application of the formula,  $C_3$  is to be taken as 1.8 times that given in **Table 6.1** and  $t_f$  as the thickness of shell laminates specified in **303**.
- In FRP Ships whose  $L$  is less than 20 m and  $V$  is less than 14 knots or in FRP Ships which are deemed by the Society to have sufficient bow draught, the thickness specified in the preceding 1 and 2 may be properly reduced.

## Section 5 Side Shell Laminates in way of Superstructures

### 501. Thickness of Shell Laminates

The side shell laminates in way of superstructures are to be in accordance with the requirements in the following:

- The thickness of side shell laminates in way of superstructures for  $0.25 L$  from the fore end and that of side shell laminates in way of sunken forecastle or sunken poop is not to be less than that of side shell laminates at the place.
- The thickness of side shell laminates in way of superstructures other than specified in the preceding (1) may be 0.8 times that of side shell laminates at the place.

## Section 6 Local Strengthening of Shell Laminates

### 601. Strengthening of Shell Laminates fitted with Hawse Pipes and Adjacent Shell Laminates

The side laminates and others which are in danger of contact with anchors and chain cables, etc. are to be properly strengthened. ↓

## CHAPTER 7 DECKS

### Section 1 General

#### 101. Application

1. The requirements in this chapter are framed for the construction and scantlings of decks moulded with FRP. The decks such as wooden decks which are composed of other materials than FRP are to be in accordance with the discretion of the Society.
2. The construction and scantlings of decks specified in this chapter are applied for the case where decks are of single skin construction or of sandwich construction.

#### 102. Watertightness of Decks

Decks are to be made watertight construction except where specially approved by the Society.

#### 103. Continuity of Decks

Where upper decks change in level, the change is to be accomplished by gradually sloping the decks, or each of structural members which form decks is to be extended and to be effectively connected together by suitable means.

### Section 2 Minimum Thickness of Deck Laminates

#### 201. Thickness of Deck Laminates of Single Skin Construction

1. The thickness of upper deck laminates for midship part in case where longitudinally framed, is not to be less than obtained from the following formula:

$$t = 4.8S\sqrt{h} \quad (\text{mm})$$

where,

$S$  : Spacing of longitudinal beams (m)

$h$  : As specified in **203**. ( $\text{kN/m}^2$ )

2. The thickness of upper deck laminates for midship part in case where transversely framed, is not to be less than obtained from the following formula:

$$t = 5.81S\sqrt{h} \quad (\text{mm})$$

where,

$S$  : Spacing of longitudinal beams (m)

$h$  : As specified **203**. ( $\text{kN/m}^2$ )

3. The thickness of upper deck laminates except for midship part and that of other deck laminates are not to be less than obtained from the following formula:

$$t = 4.2S\sqrt{h} \quad (\text{mm})$$

where,

$S$  : Spacing of longitudinal beams or transverse beams (m)

$h$  : As specified in **203**. (kN/m<sup>2</sup>)

## 202. Thickness of Deck Laminates of Sandwich Construction

1. The aggregated thickness of inner laminates, outer laminates and cores of sandwich construction is not to be less than obtained from the following formulae, whichever is greater:

$$t_1 = 0.1 C_1 S h \quad (\text{mm})$$

$$t_2 = C_2 t_f \quad (\text{mm})$$

where,

$t_f$  : Thickness of deck laminates in case of single skin construction specified in **201**. (mm)

$S$  : Spacing of longitudinal beams of transverse beams (m)

$h$  : As specified in **203**. (kN/m<sup>2</sup>)

$C_1$  and  $C_2$  : As specified in **Ch 6, 303**.

2. The respective thickness of the inner laminates and outer laminates of decks of sandwich construction are not, notwithstanding the requirements in the preceding 1, to be less than obtained from the following formulae. In no case, however, is it to be less than 2.4 mm.

$$t = 0.17 \sqrt[3]{C_4 (S h)^4} \quad (\text{mm})$$

where,

$S$  : Spacing of longitudinal beams of transverse beams (m)

$h$  : As specified in **203**. (kN/m<sup>2</sup>)

$C_4$  : As specified in **Ch 6, 303**.

## 203. Deck Load $h$ [See Guidance]

1. Deck load  $h$  for decks intended to carry cargoes, etc. is to be as specified in the following:
  - (1) For decks intended to carry cargoes and stores,  $h$  is to be 0.7 times the tween deck height at side in metres from the deck to the deck immediately above it (kN/m<sup>2</sup>) or cargo weight per unit area of the deck (kN/m<sup>2</sup>), whichever is greater.
  - (2) Where cargoes are intended to be carried on the weather deck,  $h$  is to be cargo weight per unit area of the deck (kN/m<sup>2</sup>) or the value stipulated in the following **3**, whichever is greater.
  - (3) For decks intended to carry cargoes whose weight is considerably light,  $h$  may be suitably modified.
2. For decks exclusively used for accommodation or navigation spaces and for tops of long deck-houses,  $h$  is to be 4.5 (kN/m<sup>2</sup>).
3. For weather decks,  $h$  is to be as specified in the following (1) and (2).
  - (1) For weather decks afore 0.3  $L$  from the fore end :  $0.50 L + 4.5$  (kN/m<sup>2</sup>)
  - (2) For weather decks abaft 0.3  $L$  from the fore end :  $0.26 L + 4.5$  (kN/m<sup>2</sup>)

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### Section 3 Local Compensation of Decks

#### 301. Compensation for Large Openings

1. Deck laminates in way of corners of large openings are to be suitably increased in thickness.
2. Corners of openings are to be suitably rounded.

#### 302. Location of Openings

The distance between the ship side or hatch side and the opening is not to be less than 1.5 times the diameter of the opening. Where, however, the distance is necessary made less than this value, suitable compensation is to be provided.

#### 303. Decks in Danger of Abrasion

Deck laminates which are in danger of abrasion due to heavy loads, etc. are to be suitably protected from abrasion by means of increasing thickness or coverings.

#### 304. Decks carrying Heavy Loads

Parts of deck laminates where heavy loads such as deck machinery and others are carried are to be increased in thickness or to be suitably strengthened. ↓

## CHAPTER 8 FRAMES

### Section 1 General

#### 101 Application

1. The requirements in this chapter are framed for the construction and scantlings of frames moulded with FRP.
2. For FRP ships with especially long holds or with especially large hatch openings, the transverse stiffness of the hull is to be suitable increased by increasing the scantlings of frames or by providing web frames additionally.

#### 102 Frames in Way of Deep Tanks

The strength of frames in way of deep tanks is not to be less than required for stiffeners on deep tank bulkheads.

### Section 2 Construction

#### 201 Construction of Frames

1. Frames are so constructed as to avoid lateral buckling.
2. Where the length of ship is small, corrugated side shell laminates may be adopted in lieu of normal framing construction.

#### 202 Cores for Frames

1. Timbers used for cores are to be well seasoned and free from sapwood. Care is to be taken lest the timbers wrapped in FRP should cause dry rot.
2. Plastic foams used for cores are to be non-hygroscopic.

### Section 3 Spacing of Frames

#### 301 Spacing of Frames

1. The standard spacing of frames is 500 mm.
2. The spacing of frames afore 0.2  $L$  from the fore end and in the aft peak is not to exceed 500 mm.

#### 302 Consideration for Especially Large Frame Spacing

Where the spacing of frames is 750 mm or over, special considerations are to be given to the construction and scantlings of the primary hull structural members.

### Section 4 Frames

#### 401. Scantlings of Transverse Frames

1. The section modulus of transverse frames abaft 0.15  $L$  from the fore end is not to be less than obtained from the following formula:

$$Z = 32.5hl^2 \quad (\text{cm}^3)$$

where,

$S$  : Spacing of frames (m).

$l$  : Vertical distance from the top of inner bottom laminates or single bottom floor at side to the top of upper deck beams at side (m). For frames abaft  $0.25L$  from the fore end,  $l$  is to be measured at midship. For frames between  $0.25L$  and  $0.15L$  from the fore end,  $l$  is to be measured at  $0.25L$  from the fore end.

$h$  : Vertical distance from the lower end of  $l$  at the place of measurement to a point  $d + 0.026L$  (m) above the base point of  $D$  (m). Where, however, the distance is less than  $0.5D$  (m),  $h$  is to be taken as  $0.5D$  (m).

2. The section modulus of transverse frames afore  $0.15L$  from the fore end is not to be less than obtained from the following formula:

$$Z = 37.5Shl^2 \quad (\text{cm}^3)$$

where,

$S$ ,  $h$  and  $l$  : As specified in the preceding 1. However,  $l$  is to be measured at  $0.15L$  from the fore end.

#### 402. Side Longitudinals

1. The section modulus of side longitudinals below the upper deck for the midship part is not to be less than obtained from the following formula:

$$Z = 49Shl^2 \quad (\text{cm}^3)$$

where,

$S$  : Spacing of longitudinals (m).

$h$  : Vertical distance from the longitudinals to a point  $d + 0.026L$  (m) above the base point of  $D$  (m). Where, however, the distance is less than  $0.5D$  (m),  $h$  is to be taken as  $0.5D$  (m).

$l$  : Distance between the transverse bulkheads or where web frames are provided, distance between the web frames or between the transverse bulkhead and web frame including the length of end connection (m).

2. Beyond the midship part, the section modulus of side longitudinals may be gradually reduced toward the ends of ship and may be 0.85 times that obtained from the formula in the preceding 1 for the end parts. However, the section modulus of side longitudinals afore  $0.15L$  from the fore end is not to be less than obtained from the formula in the preceding 1.

#### 403 Web Frames supporting Side Longitudinals

Where the ship's side are longitudinally flamed, web frames supporting side longitudinals are to be provided in a spacing not exceeding about 2.4 m. However, the construction and scantlings thereof are to be in accordance with the discretion of the Society.



#### 404 Hat-type Construction

With respect to the scantlings of frames of hat-type construction, the requirements in **Ch 1, 305.** in addition to the requirements in this chapter, are to be applied. ⚴

## CHAPTER 9 BOTTOM CONSTRUCTION

### Section 1 General

#### 101. Application

1. The requirements in this chapter are framed mainly for the single bottoms.
2. Where bottom are partially or wholly of double bottom construction, the double bottoms are to be in accordance with the requirements on **Sec 6**, and, in addition, the structural members of double bottoms are to be constructed with special care.

### Section 2 Centre Girders

#### 201. Construction and Scantlings

1. Centre girders are to extend from the collision bulkhead to the aft peak bulkhead as far as practicable.
2. The thickness of web of centre girders is not to be less than obtained from the following formula. However, beyond the midship part, the thickness may be gradually reduced toward the ends and to may be 0.85 times the midship value for the end parts:

$$t = 0.4L + 4.7 \quad (\text{mm})$$

3. The breadth and thickness of the face plates are not to be less than obtained from the following formulae respectively. However, beyond the midship part, the sectional area of the face plates may be gradually reduced toward the ends and it may be 0.8 times the midship value of the end parts:

$$\text{Thickness} : 0.4L + 4.7 \quad (\text{mm})$$

$$\text{Breadth} : 4L + 30 \quad (\text{mm})$$

4. The webs of centre girders are to extend to the top of floors of bottom transverse girders.
5. In the engine room, the thickness of webs and face plates of centre girders are not to be less than 1.25 times the values specified in the preceding **2** and **3**, respectively.
6. For ships with hat-type keel of suitable height, the centre girder may be omitted.

### Section 3 Side Girders

#### 301. Arrangement of Side Girders

Where the breadth of ship measured at the top of floors exceeds 4 m, side girders are to be arranged at a suitable spacing.

#### 302. Construction and Scantlings

1. The thickness of webs of side girders for the midship part is not to be less than obtained from the following formula. However, beyond the midship part, the thickness may be gradually reduced toward the ends and it may be 0.85 times the midship value at the end parts:

$$t = 0.3L + 3.5 \quad (\text{mm})$$

- The thickness of face plates of side girders is not to be less than the thickness of webs and the breadth is not to be less than obtained from the following formula. However, beyond the midship part, the sectional area may be gradually reduced toward the ends and it may be 0.8 times the midship value at the end parts :

$$b = 3.2L + 24 \quad (\text{mm})$$

- The heights of side girders at their ends are to extend to the top of floors or bottom transverse girders.

### 303. Side Girders in Engine Room

The thickness of webs and face plates of side girders in the engine room are not to be less than the thickness of webs and face plates of centre girders specified in **201**, respectively.

## Section 4 Floors

### 401. Arrangement and Scantlings

- Where transverse framing is adopted in the bottom construction, floors are to be fitted at every frame and the scantlings of floors are not to be less than obtained from the following formula. In no case, however, is the thickness of floor plates to be less than 4 mm. Depth of floor plates at the centre line of ship:

$$62.5b \quad (\text{mm})$$

where,

$b$  : Horizontal distance between the outer surfaces of the side shell laminates measured on the upper surface of the floor (m).

Thickness of floor plates:  $0.4 L$  (mm)

- Beyond  $0.5 L$  amidships, the thickness of floor plates may be gradually reduced toward the ends and it may be 0.9 times the value specified in the preceding 1 at the end parts, However, the floors in the strengthened bottom forward are to be in accordance with the requirements in **702**.
- Floors under main engines and thrust blocks are to be of sufficient depth and to be of specially substantial construction. The thickness is not to be less than that of webs of centre girders obtained from the formula in **201**.

### 402. Section Modulus of Floors

- The thickness of face plate provided on the upper edges of floors is not to be less than the thickness of web of floor at the place.
- The section modulus of floors is not to be less than obtained from the following formula:

$$Z = 15.4SDb^2 \quad (\text{cm}^3)$$

where,

$S$  : Spacing of floors (m).

$b$  : As specified in **401**.

3. The section modulus of floors under the main engine seatings is not to be less than 1.5 times the value specified in the preceding 2.

#### 403. Floor Plates Forming Part of Bulkheads

Floor plates forming part of bulkheads are to be in accordance with the requirements for watertight bulkheads in **Ch 12** and those for deep tanks in **Ch 13** in addition to those in this chapter.

### Section 5 Bottom Longitudinals, etc.

#### 501. Construction

Bottom longitudinals are to be continuous through floors or to be attached to the floors so as to have sufficient fixing strength against bending and tension.

#### 502. Spacing of Bottom Longitudinals

The standard spacing of bottom longitudinals is 500 mm.

#### 503. Section Modulus of Bottom Longitudinals

The section modulus of bottom longitudinals is not to be less than obtained from the following formula:

$$Z = 55.6Shl^2 \quad (\text{cm}^3)$$

where,

$l$  : Spacing of bottom transverses (m).

$S$  : Spacing of bottom longitudinals (m).

$h$  : Vertical distance from the bottom longitudinals to a point  $d + 0.026L$  (m) above the base point of  $D$  (m). Where, however, the distance is less than  $0.5D$  (m),  $h$  is to be taken as  $0.5D$  (m).

#### 504. Bottom Transverses supporting Bottom Longitudinals

Where longitudinal framing is adopted in the bottom construction, bottom transverses supporting bottom longitudinals are to be provided at a spacing not exceeding about 2.4 m. The bottom transverses are to be fitted at every web frame, and the scantlings are not to be less than specified in **401.** and **402.**

### Section 6 Double Bottoms

#### 601. General

1. Where bottoms are partially or wholly of double bottom construction, the scantlings of structural members are to be in accordance with the requirements in **602.** to **606.**
2. Bottom laminates under the sounding pipes are to be increased in thickness or to be protected against damages due to sounding rods by suitable means.
3. The thickness of watertight girders and floors, and the scantlings of stiffeners attached to them are to be in accordance with the respective requirements for the relevant girders and floors, and in addition, in accordance with the requirements for deep tanks in **Ch 13.**
4. Oiltight cofferdams are to be provided in the double bottom between tanks for carrying oils and those for carrying fresh water such as that for living use, boiler feed water, etc. which may cause

any trouble when oil mixes therein.

### 602. Centre Girders

1. Webs of centre girders are to extend the whole length of the bottom as far as practicable.
2. The thickness of webs of centre girders is to be in accordance with the requirements in **201**.

### 603. Side Girders

1. Where the breadth of ship measured at the top of floors exceeds 4 m, side girders are to be arranged at a suitable spacing.
2. The thickness of webs of side girders is to be in accordance with the requirements in **302**.

### 604. Floors

1. Floors are to be fitted at every frame.
2. The scantlings of floors are to be in accordance with the requirements in **401**.
3. Where floors are of single skin construction, stiffeners are to be provided on floors at a suitable spacing.
4. Floors forming lower part of bulkheads are to be in accordance with the requirements for water-tight bulkheads in **Ch 12**, in addition to those in this chapter.

### 605. Inner Bottom Laminates

1. The thickness of inner bottom laminates is not to be less than obtained from the following formula:

$$t = 11.5S\sqrt{d} \quad (\text{mm})$$

where,

$S$  : Spacing of floors (m).

2. Inner bottom laminates are to be rigidly connected with side shell laminates, bulkhead laminates, etc.

### 606 Bottom Longitudinals

1. The construction, scantlings and spacing of bottom longitudinals are to be in accordance with the requirements in **501.**, **502.**, **503.** and **Sec 8**.
2. The construction and scantling of longitudinals provided on the inner bottom laminates are to be in accordance with the discretion of the Society.

## Section 7 Construction of Strengthened Bottom Forward

### 701. Part to be strengthened

Strengthened bottom forward is the part specified in **Ch 6, 402**.

### 702. Construction and Scantlings

The scantlings of floors, bottom longitudinals, side girders and centre girders in the strengthened bottom forward are to be properly increased.

## Section 8 Hat-type Construction

### 801. Construction and Scantlings

1. The thickness on one side of webs of centre girders, side girders and floors of hat-type construction are not to be less than 0.7 times the value specified in **201. 2**, **302. 1** and **401.** respectively.
2. The sectional areas of top plate laminates of centre girders and side girders of hat-type construction are not to be less than the products of the breadth and the thickness of face plate laminates specified in **201. 3** and **302. 2** respectively.
3. The section modulus of floors and bottom longitudinals of hat-type construction are not to be less than the values specified in **402.** and **503.** respectively.
4. The scantlings of structural members of hat-type construction are to be in accordance with the requirements in **Ch 1, 305.** in addition to those in the preceding **1** to **3.** ↓

## CHAPTER 10 BEAMS

### Section 1 Beams

#### 101. Arrangement of Transverse Beams

Transverse beams are, as a rule, to be provided at every frames.

#### 102. Camber of Weather Deck

It is recommended that the camber of weather deck is to be  $B/50$ .

#### 103. Section Modulus of Beams [See Guidance]

The section modulus of beams is not to be less than obtained from the following formula:

$$Z = CS l^2 \quad (\text{cm}^3)$$

where,

$l$  : Horizontal distance from the inner edge of Beam brackets to the nearest line of support of deck or between the adjacent lines of support of deck (m).

Where  $l$  is less than  $0.25 B$  in the upper deck beams except those at the end parts,  $l$  is to be taken as  $0.25 B$ . Where  $l$  is less than  $0.2 B$  in the beams at the end parts of upper deck or in the superstructure deck beams,  $l$  is to be taken as  $0.2 B$ .

$S$  : Spacing of beams (m).

$C$  : Coefficient given below:

Longitudinal beams

(1) Midship part : 3.4

(2) Elsewhere : 2.9

Transverse beams: 2.9

$h$  : As specified in **Ch 7, 203**. ( $\text{kN/m}^2$ ). Where, however, the value is as specified in **Ch 7, 203. 3**,  $h$  is to be as specified in the following:

(1) Afore  $0.3 L$  from the fore end :  $0.32 L + 4.5$  ( $\text{kN/m}^2$ )

(2) Aft  $0.3 L$  from the fore end :  $0.16 L + 4.5$  ( $\text{kN/m}^2$ )

#### 104. End Connections

Beams and frames are to be connected each other by means of brackets. The length of arms of the brackets is not to be less than  $1/8$  of  $l$  specified in **Ch 8, 401**.

#### 105. Beams of Decks Forming Tops of Deep Tanks

The scantlings of beams provided on the decks forming the tops of deep tanks are to be in accordance with the requirements for deep tanks as bulkhead stiffeners regarding the decks as deep tank bulkheads, in addition to those in this chapter.

#### 106. Beams of Decks Carrying Specially Heavy Loads

Beams of decks which carry heavy loads such as deck machinery and others are to be properly strengthened.

**107. Transverse Strong Beams supporting Deck Longitudinals**

Where longitudinals framing is adopted in the deck construction, transverse strong beams supporting deck longitudinals are to be provided in a spacing of about 2.4 m. In this case the scantlings and construction thereof are to be in accordance with the discretion of the Society.

**108. Hat-type Construction**

The scantlings of beams of hat-type construction are to be in accordance with the requirements in **Ch 1, 305.** in addition to those in this chapter. √



# CHAPTER 11 UNDER-DECK GIRDERS AND PILLARS

## Section 1 Under-deck Girders

### 101. Arrangement

1. At places where beams need to be supported, underdeck girders or equivalent structures are to be provided in accordance with the requirements in this chapter.
2. Under-deck girders, etc. are to be provided, as necessary, under masts, derrick posts, deck machinery and other heavy concentrated loads.

### 102. Construction of Girders

Under-deck girders are to be uniform in depth throughout the part between bulkheads and to have sufficient bending rigidity.

### 103. Section Modulus of Girders

The section modulus of under-deck girders is not to be less than obtained from the following formula:

$$Z = Cbh^2 \quad (\text{cm}^3)$$

where,

$b$  : Distance between the mid-points of spaces from the girder to the adjacent girders or the inner edges of brackets (m). (See **Fig 11.1**)

$l$  : Distance between the supporting points of girders (m). (See **Fig 11.1**)

$h$  : As specified in **Ch 7, 203.**(kN/m<sup>2</sup>). Where, however,  $h$  is to be in accordance with the requirements in **Ch 7, 203. 3**,  $h$  is to be as specified in the followings

(1) Afore 0.3  $L$  from the fore end : 0.13  $L$  + 4.5 (kN/m<sup>2</sup>)

(2) Aft 0.3  $L$  from the fore end : 0.11  $L$  + 4.5 (kN/m<sup>2</sup>)

$C$  : Coefficient given below:

(1) Midship part 0.4  $L$  : 4.3

(2) Elsewhere : 3.4

### 104. Supports and Connections at Ends

1. The ends of under-deck girders are to be supported by bulkhead stiffeners. These stiffeners are to be properly strengthened.
2. Where two adjacent under-deck girders or an underdeck girder and a longitudinal bulkhead are not in line in way of a transverse bulkhead, etc., each of them is to be extended beyond the transverse bulkhead, etc. for at least one frame space.

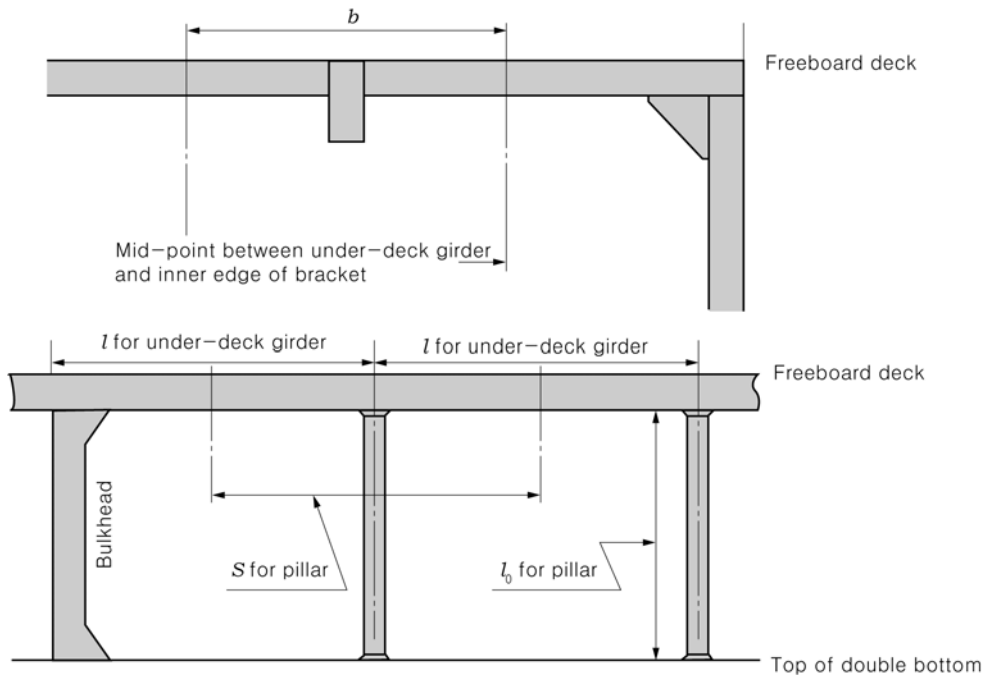


Fig 11.1 Measurement of  $b$ ,  $l$ ,  $S$ , and  $l_0$

### 105. Hat-type Construction

The scantlings of under-deck girders of hat-type construction are to be in accordance with the requirements in **Ch 1, 305**, in addition to those in this chapter.

## Section 2 Pillars

### 201. Application

Pillars supporting beams are to be in accordance with the requirements in this Chapter.

### 202. Pillars under Concentrated Loads, etc.

Special supports, by providing pillars or by other suitable means, are to be arranged at the ends and corners of deckhouses, in machinery spaces, at the ends of partial superstructures and under heavy concentrated loads.

### 203. Sectional Area of Pillars

- The sectional area of pillars which are made of steel, is not to be less than obtained from the following formula:

$$A = \frac{0.223 S b h}{2.72 - \frac{l_0}{k_0}} \quad (\text{cm}^2)$$

where,

$S$  : Distance between the mid-points of the spaces from the pillar to the adjacent pillars or to the bulkhead (m). (See **Fig 11.1**)

$b$  : Distance between the mid-points of the spaces from the pillar to the adjacent pillars or to the inner edges of brackets (m). (See **Fig 11.1**)

$h$  : As specified in **103**.

$l_0$  : Distance from the lower end of pillar to the lower surface of girder or beam supported by the pillar (m). (See **Fig 11.1**)

$k_0$  : Value obtained from the following formula:  $\sqrt{\frac{I}{A}}$

$I$  : Minimum moment of inertia of pillar (cm<sup>4</sup>).

$A$  : Sectional area of pillars (cm<sup>2</sup>).

- 2.** The sectional area of pillars which are made of wood, is not to be less than obtained from the following formula:

$$A = \frac{1.32Sbh}{1.51 - \frac{l_0}{k_0}} \quad (\text{cm}^2)$$

where,

$S$ ,  $b$ ,  $h$ ,  $l_0$  and  $k_0$  : As specified in the preceding **1**. ↓

## CHAPTER 12 WATERTIGHT BULKHEADS

### Section 1 Arrangement of Watertight Bulkheads

#### 101. Collision Bulkheads

FRP ships are to be provided with a collision bulkhead at a position between  $0.05 L(m)$  and  $0.13 L(m)$  from the fore side of the stem on the load line.

#### 102. Aft Peak Bulkheads

1. All FRP ships are to be provided with aft peak bulkheads at a suitable position.
2. Stern tubes are to be provided in a watertight compartment by means of an aft peak bulkhead or any other suitable arrangements.

#### 103. Bulkheads of Machinery Space

A watertight bulkhead is to be provided at each end of the machinery space.

#### 104 Height of Watertight Bulkheads

The watertight bulkheads required in **101.** to **103.** are to extend at least to the upper deck except for those specified in the following (1) to (3) :

- (1) The watertight bulkheads in way of the sunken poop or the sunken forecastle is to extend to the sunken poop deck or the sunken forecastle deck.
- (2) Where a forecastle having opening without closing appliances led to a space below the freeboard deck is provided or where a long forecastle not less than  $0.25 L$  in length is provided, the collision bulkhead is to extend up to the superstructure deck. In this case, the extend part may have steps within the limit of distance specified in **101.** and may be made weathertight.
- (3) Where a deck below the upper deck but above the load line is extended to the stern from the aft peak bulkheads and made watertight, the aft peak bulkhead may terminate at the afore-mentioned deck. In this case, however, the transverse strength and transverse stiffness of the hull are to be maintained by providing web frames of partial bulkheads extending up to the upper deck, directly above or in the vicinity of the aft peak bulkhead.

#### 105. Chain Lockers

1. Where chain lockers are provided abaft the collision bulkhead or in the fore peak tank, they are to be made watertight and provided with means of drainage by pump.
2. Chain lockers are to be provided with screen walls at centre line.

### Section 2 Construction of Watertight Bulkheads

#### 201. Thickness of Bulkhead Laminates of Single Skin Construction

The thickness of bulkhead laminates of single skin construction is not to be less than obtained from the following formula:

$$t = 12S\sqrt{h} \quad (\text{mm})$$

where,

$S$  : Spacing of stiffeners (m).

$h$  : Vertical distance from the lower edge of bulkhead laminate to the top of upper deck laminate at the centre line of the ship (m). However, for the collision bulkhead, the value specified

above is to be multiplied by 1.25.

## 202. Thickness of Bulkhead Laminates of Sandwich Construction

1. The aggregated thickness of the inner layers, outer layers and cores of bulkhead laminates of sandwich construction is not to be less than obtained from the following formulae, whichever is greater:

$$t_1 = C_1 S h \quad (\text{mm})$$

$$t_2 = C_2 t_f \quad (\text{mm})$$

where,

$t_f$  : Thickness in case of single skin construction specified in **201**. (mm).

$S$  : Spacing of stiffeners (m).

$h$  : As specified in **201**. (m).

$C_1$  and  $C_2$  : As specified in **Ch 6, 303. 1**.

2. The respective thicknesses of the inner layers and outer layers of bulkhead laminates of sandwich construction are not, notwithstanding the requirements in the preceding **1**, to be less than obtained from the following formula. In no case, however, is it less than 2.4 mm.

$$t = 3.6 \sqrt[3]{C_4 (S h)^4} \quad (\text{mm})$$

where,

$S$  : Spacing of stiffeners (m).

$h$  : As specified in **201**. (m).

$C_4$  : As specified in **Ch 6, 303. 2**.

## 203. Bulkhead Laminates of Structural Plywood [See Guidance]

Where structural plywoods are used for bulkhead plates, the thickness of plywoods is not to be less than specified by the requirements in **201**, multiplied by the coefficient given in **Ch 1, 304. 2 (1)**. However,  $\sigma_B$  is to be taken as bending strength ( $\text{kg/mm}^2$ ) of plywoods.

## 204. Bulkheads Stiffeners

The section modulus of bulkhead stiffeners is not to be less than obtained from the following formula:

$$Z = C S h l^2 \quad (\text{cm}^3)$$

where,

$l$  : Total length between adjacent supports of stiffener (m) including the length of connection at the end. Where, however, girders are provided,  $l$  is the distance from the heel of end connection to the nearest girder or the distance between girders.

$h$  : 0.8 times the vertical distance from the mid-point of  $l$  to the top of upper deck laminate at the centre line of ship plus 1.2 (m). However, for the collision bulkhead, the above mentioned value is to be multiplied by 1.25.

$S$  : Spacing of stiffeners (m).

$C$  : Coefficient given below:

- (1) Where the both ends of stiffeners are attached by brackets : 20

(2) Where the ends of stiffeners are snipped : 30

### 205. Girders supporting Bulkhead Stiffeners

Webs of girders supporting bulkhead stiffeners are to be connected to the bulkhead laminates and the section modulus of girders is not to be less than obtained from the following formula:

$$Z = 34Shl^2 \quad (\text{cm}^3)$$

where,

$l$  : Total length of girders including the length of end connection (m).

$S$  : Breadth of the area supported by the girders (m).

$h$  : 0.8 times the vertical distance from the mid-point of  $S$  to the top of upper deck laminate at the centre line of ship plus 1.2 (m). However, for the collision bulkhead, the above mentioned value is to be multiplied by 1.25.

### 206. Hat-type Construction

The scantlings of bulkhead stiffeners and girders of hat-type construction are to be in accordance with the requirements in **Ch 1, 305.** in addition to those in this chapter. ↓

## CHAPTER 13 DEEP TANKS

### Section 1 General

#### 101. Definition

The deep tank is a tank used for carriage of water, fuel oil and other liquids, forming a part of the hull in holds or tween decks. The deep tanks used for carriage of oils are designed as "deep oil tanks", if necessary.

#### 102. Earthing

Metallic parts, pipes, etc. in tanks are to be properly earthed.

#### 103. Application

1. The construction of all watertight division walls, aft peak tanks and all deep tanks in holds and between decks excluding deep oil tanks for carriage of oils having a flash point below 60°C is to be in accordance with the requirements in this chapter. The part concurrently serving as a watertight bulkhead is to be in accordance with the requirements for watertight bulkheads.
2. The construction of deep oil tanks for carriage of oils having a flash point below 60°C is to be in accordance with the discretion of the Society.

#### 104. Division Walls in Tanks

1. Deep tanks are to be of proper size and to be provided with longitudinal division walls to meet the necessity for stability under service conditions as well as during filling or discharging.
2. Fresh water tanks, fuel oil tanks and other deep which are not intended to be kept entirely filled in service conditions are to be provided with additional division walls or deep wash plates as necessary as to minimize the dynamical forces acting on the structural members.
3. Where it is impracticable to be in accordance with the requirements in the preceding 2, the scantlings of structural members specified in this chapter are to be properly increased.

#### 105. Consideration for Watertightness of Tanks

Frames and beams are not to pass through the top laminates and bulkheads laminates of deep tanks.

### Section 2 Bulkhead Laminates of Deep Tanks

#### 201. Thickness of Bulkhead Laminates of Single Skin Construction

The thickness of bulkhead laminates of single skin construction is not to be less than obtained from the following formula:

$$t = 13S\sqrt{h} \quad (\text{mm})$$

where,

$S$  : Spacing of stiffeners (m).

$h$  : Vertical distance measured from the lower edge of bulkhead laminate to the mid-point of the height between the top of overflow pipe and the top of tank (m).

## 202. Thickness of Bulkhead Laminates of Sandwich Construction

1. The aggregated thickness of the inner layer, outer layer and core of the bulkhead laminates of sandwich construction is not to be less than obtained from the following formulae, whichever is greater:

$$t_1 = C_1 S h \quad (\text{mm})$$

$$t_2 = C_2 t_f \quad (\text{mm})$$

Where,

$t_f$  : Thickness in case of single skin construction specified in **201**. (mm).

$S$  : Spacing of stiffeners (m).

$h$  : As specified in **201**. (m).

$C_1$  and  $C_2$  : As specified in **Ch 6, 303. 1**.

2. The respective thicknesses of the inner layer and outer layer of bulkhead laminates of sandwich construction are not, notwithstanding the requirements in the preceding **1**, to be less than obtained from the following formula. In no case, however, is it to be less than 2.4 mm.

$$t = 3.6 \sqrt[3]{C_4 (S h)^4} \quad (\text{mm})$$

where,

$S$  : Spacing of stiffeners (m).

$h$  : As specified in **201** (m).

$C_4$  : As specified in **Ch 6, 303. 2**.

## 203. Bulkhead Laminates of Structural Plywood [See Guidance]

Where structural plywood are used for bulkhead plates, the thickness of plywoods is not to be less than specified by the requirements in **201**. multiplied by the coefficient given in **Ch 1, 304. 2 (1)**. However, is to be taken as bending strength ( $\text{kg}/\text{mm}^2$ ) of plywoods.

## 204. Bulkhead Stiffeners

The section modulus of bulkhead stiffeners is not to be less than obtained from the following formula:

$$Z = C S h l^2 \quad (\text{cm}^3)$$

where,

$S$  and  $l$  : As specified in **Ch 12, 204**.

$h$  : Vertical distance measured from the mid-point of  $l$  to the mid-point of the height between the top of overflow pipe and the top of tank (m).

$C$  : Coefficient given below:

(1) Where the both ends of stiffeners are attached by brackets --- 28

(2) Where the ends of stiffeners are snapped ----- 42

## 205 Girders supporting Bulkhead Stiffeners

The section modulus of girders supporting frames and bulkhead stiffeners is not to be less than obtained from the following formula:



$$Z = 42Shl^2 \quad (\text{cm}^3)$$

where,

$l$  : Total length of girders including the length of end connection (m).

$S$  : Breadth of the area supported by the girders (m).

$h$  : Vertical distance measured from the mid-point of  $S$  to the mid-point of the height between the top of overflow pipe and the top of tank (m).

### 206. Hat-type Construction

The scantlings of bulkhead stiffeners and girders of hat-type construction are to be in accordance with the requirements in **Ch 1, 305.** in addition to those in this chapter.

### 207 Structural Members forming Top and Bottom of Deep Tanks

The scantling of the structural members forming the top and the bottom of deep tanks are to be in accordance with the requirements in this chapter regarding the members as the bulkheads of deep tanks at the location. In no case, however, are they to be less than required for the deck laminates, etc. at the location.

## Section 3 Provisions for Deep Tanks

### 301. Limber and Air Holes

In deep tanks, suitable limber and air holes are to be cut in the members to ensure that water or air does not remain stagnated in any part of the tanks.

### 302. Cofferdams, etc.

1. Oiltight cofferdams are to be provided between tanks for carrying oils and those for carrying fresh water such as that for living use, boiler feed water, etc., which may cause any trouble when oil mixes therein.
2. Crew spaces and passenger spaces are not to be directly adjacent to the tanks for carriage of fuel oil. Such compartments are to be separated from fuel oil tanks by cofferdams which are well ventilated and accessible. Where the top of fuel oil tanks has no opening and is coated by incombustible coverings of 38 mm and over in thickness, the cofferdam between such compartments and the top of fuel oil tanks may be omitted.
3. Sparring or lining is to be provided in the hold side of bulkhead dividing deep oil tanks from cargo holds, leaving suitable clearance between the bulkhead and the sparring or lining. Gutterways are to be provided along the bulkhead.
4. Where the oiltank boundaries are bonded by mattingin connections in way of the parts required oiltight, the sparring or lining specified in the preceding **3** may be omitted, except where specially required.

### 303. Compliance of Regulations

Oil-deep tanks are to be in accordance with the requirements in **Ch 9, 601. 4.** ↓

## CHAPTER 14 MACHINERY SPACES

### Section 1 General

#### 101. Application

The construction of machinery spaces is to be in accordance with the requirements in the relevant chapter, in addition to those in this chapter.

#### 102. Strengthening

Machinery spaces are to be provided with web frames, strong beams, widely spaced pillars, etc. or to be strengthened by any other suitable means.

#### 103. Supporting Structures for Machinery, Shaftings, etc.

Machinery, shaftings, etc. are to be effectively supported and the adjacent structures are to be sufficiently strengthened.

#### 104. Means of Escape

In main engine room, at least one set of means of escape which is formed of a door fitted up to the machinery casing and steel ladders leading to the door is to be provided.

### Section 2 Construction under Main Engines

#### 201. Construction under Main Engines

1. Girders upon which main engines are installed are to be of sufficient length as to the engine foundations, and the form is not to have any abrupt changes or discontinuities.
2. Girders are to be effectively supported by frames and brackets in order to maintain sufficient lateral strength and rigidity.
3. Where engines which have large unbalanced inertia force or large unbalanced moment of inertia are installed, the strength and rigidity of the girders supporting those engines are to be made especially sufficient.
4. Fixing bolts for main engines are to be have adequate shank length in order to lower their rigidity and effective means to avoid loosening.
5. Where engines which are subjected to large exciting force due to piston side thrust are installed, the connections of girders with frames and brackets are to be made rigid, and resonance is to be avoided against the vibration in the horizontal direction.
6. Webs of girders may be constructed with timbers interposed between FRP in order to increase the rigidity against compression or bending. In this case, the connections of FRP with timbers and of timbers with bottom shell laminates are to be effectively bonded.
7. The bonded connections of girders with bottom shell laminates, frames and brackets, as well as their mutual connections are to be T-type joints using ample roving cloths and the width of joints is to be sufficient. In this case, the direction of roving cloth fibres is not, as a rule, to be oblique to the connecting line. ↓

# CHAPTER 15 SUPERSTRUCTURES AND DECKHOUSES

## Section 1 General

### 101. Application, etc.

1. The construction and scantlings of superstructures and deckhouses are to be in accordance with the requirements in the relevant chapters, in addition to those in this chapter.
2. For FRP ships with specially large freeboard, the requirements in this chapter may be properly modified, subject to the approval by the Society.

## Section 2 Construction, etc.

### 201. Scantlings of End Bulkheads and Boundary Walls

The thickness of plates and the scantlings of stiffeners of superstructure end bulkheads and deckhouse boundary walls are not to be less than given in **Table 15.1**. Where the spacing of stiffeners  $S$  is different from 500 mm, the thickness of plates and the section modulus of stiffeners are not to be less than obtained from the **Table 15.1** below, multiplied by  $S/500$ .

**Table 15.1 Thickness of Plates and Scantlings of Stiffeners of Superstructure End Bulkheads and Deckhouse Boundary Walls**

| $L$ (m) |               | Front wall                      |  | Side and aft wall               |  |
|---------|---------------|---------------------------------|--|---------------------------------|--|
| Over    | Not more than | Thickness of boundary wall (mm) | Section modulus of stiffener ( $\text{cm}^3$ ) | Thickness of boundary wall (mm) | Section modulus of stiffener ( $\text{cm}^3$ ) |
|         | 15            | 5.0                             | 35   | 4.0                             | 20   |
| 15      | 20            | 5.5                             | 40   | 4.0                             | 20   |
| 20      | 24            | 5.5                             | 47   | 4.0                             | 24   |
| 24      | 27            | 6.5                             | 56   | 5.0                             | 28   |
| 27      | 30            | 6.5                             | 67   | 5.0                             | 33   |
| 30      | 33            | 6.5                             | 82   | 5.0                             | 37   |
| 33      | 35            | 7.0                             | 97   | 5.5                             | 42   |

### 202. Closing Means for Access Openings and Height of Sills

1. The doors to be provided on the access openings in the end bulkheads of enclosed superstructures and those in the deckhouses protecting companionways giving access to the spaces under the freeboard deck or the spaces in the enclosed superstructures are to be in accordance with the requirements in the following (1) to (5):
  - (1) The doors are to be permanently and rigidly fitted up to the walls.
  - (2) The doors are to be rigidly constructed, to be of equivalent strength to that of intact wall and to be weathertight when closed.
  - (3) The means for securing weathertightness are to consist of gaskets and clamping devices or other equivalent devices and to be permanently fitted up to the wall or the door itself.
  - (4) The doors are to be operated from the both sides of the wall.
  - (5) Hinged doors are, as a rule, to open outward.
2. The height of sills of access openings specified in the preceding 1 is to be at least 380 mm above the upper surface of the deck. ⚓

# CHAPTER 16 HATCHWAY OPENINGS, MACHINERY OPENINGS AND OTHER DECK OPENINGS

## Section 1 General

### 101 Application

The requirements in this chapter apply to FRP ships other than ones to which the International Convention for Load Line apply.

## Section 2 Hatchway Openings

### 201 Height of Hatch Coamings

1. The height of hatch coamings above the upper surface of deck laminates is not to be less than given in **Table 16.1**.

**Table 16.1 Height of Hatch Coamings**

| Position of hatchway openings |   | $L \leq 20\text{ m}$ | $20\text{ m} < L \leq 30\text{ m}$ | $30\text{ m} < L \leq 35\text{ m}$ |
|-------------------------------|---|----------------------|------------------------------------|------------------------------------|
| Exposed hatchway openings     | On the upper deck   | 380 mm               | 450 mm                             | 600 mm                             |
|                               | On the superstructure decks for $0.25L$ from the fore end                 | 380                  | 450                                | 600                                |
|                               | On the superstructure decks other than the above                          | 300                  | 300                                | 450                                |
| Un-exposed hatchway openings  | On the decks in the unenclosed superstructures except for specified below | 380                  | 380                                | 450                                |
|                               | On the decks in superstructures without front bulkheads                   | 380                  | 450                                | 600                                |

2. With respect to hatchway opening which are maintained weathertight by means of gaskets and clamping devices and closed with substantial weathertight covers, the height of hatch coamings may be reduced from required in the preceding 1, subject to the approval by the Society.

### 202. Wooden Covers

Wooden covers are to be in accordance with the requirements in the following:

1. The finished thickness of wooden covers is not to be less than obtained from the following formula. Wooden covers intended to carry cargoes thereon are to be increased in thickness in direct proportion either where the tween deck height exceeds 2.6 m or where the weight per unit area of cargoes to be carried on the hatchway exceeds  $18\text{ t/m}^2$ . In no case, however, is the finished thickness to be less than 48 mm.

$$t = 30S \text{ (mm)}$$

where,

$S$  : Spacing of hatch beams (m).

2. Materials for wooden covers are to be of good quality, straight grained and reasonably free from knots, sapwood and shakes.
3. The ends of wooden covers are to be protected by circling steel bands.

### Section 3 Machinery Openings

#### 301. Protection of Machinery Openings

Machinery openings are to be as small as possible, and to be enclosed by casings.

#### 302. Casings of Machinery Openings in Exposed Parts

1. Exposed machinery openings on the upper decks and superstructure decks are to be in accordance with the requirements in the following:
  - (1) The thickness of casings and the section modulus of stiffeners thereupon, are to be equivalent to those of boundary walls of deckhouses specified in **Ch 15, 201**.
  - (2) The thickness of top laminates of casings and the section modulus of stiffeners thereupon, are not to be less than 4.0 mm and 24 cm<sup>3</sup> respectively.
2. The height of casings is not, except special cases, to be less than that of bulwarks.
3. Where access openings are provided on the exposed machinery casings, these openings are to be located in protected spaces as far as practicable, the doors thereof are to be in accordance with the requirements in **Ch 15, 202. 1** and the height of sills above the upper surface of deck laminates is to be at least 380 mm.

#### 303 Machinery Casings provided in Enclosed Parts

Where access openings are provided of the machinery casings, the doors thereof are to be substantial.

#### 304 Position of Fittings

Skylights provided on the top laminates of machinery casings are to be of substantial construction and coamings of funnels and ventilators are to be provided as high as possible above the weather deck laminates.

### Section 4 Companionway Openings and Other Deck Openings

#### 401. Manholes and Flush Deck Openings

Manholes and flush deck openings which are provided in exposed parts of freeboard deck and superstructure decks or in the superstructures other than those enclosed, are to be closed with substantial covers capable of keeping watertightness.

#### 402. Companionways

1. Companionways on the freeboard deck are to be protected by enclosed superstructures or by deckhouses or companions which have strength and weather-tightness equivalent to those of enclosed superstructures.
2. Companionways on exposed superstructure decks and those on the top of deckhouses on the freeboard deck which give access to spaces below the freeboard deck or space within enclosed superstructures, are to be protected by effective deckhouses or companions.
3. Access openings in the deckhouses or companions specified in the preceding **1** and **2** are to be

provided with doors in accordance with the requirements in **Ch 15, 202. 1**. And, the height of sills of the access openings above the surface of deck laminates is to be at least 380 mm.

**403. Openings to Cargo Space**

All of access and other openings to cargo spaces are to be provided with closing means capable of being operated from outside the spaces in case of fire. ↓

# CHAPTER 17 BULWARKS, GUARDRAILS, FREEING ARRANGEMENT, SIDE OPENINGS, SCUTTLES, VENTILATORS AND GANGWAYS

## Section 1 General

### 101. General

1. FRP ships to which the International Convention for Load Line apply are to comply with the requirements of Convention for bulwarks, guardrails, freeing arrangement, side openings, scuttles, ventilators and gangways.
2. In FRP ships other than specified in the preceding **1**, the arrangement and construction of those are to be in accordance with the discretion of the Society. ↓

## CHAPTER 18 MACHINERY

### Section 1 General

#### 101. Application

Prime movers, power transmission system, shaftings, pressure vessels, auxiliaries, piping systems and electrical installations are, as a rule, to be in accordance with the requirements in **Pt 5 of Rules for the Classification of Steel Ships**, except those specified in this chapter.

### Section 2 Installation of Propulsion Machinery, Fuel Oil Tank and Earthing

#### 201. Installation of Propulsion Machinery

1. Propulsion machinery, except for those of small output, are to be installed on the bottom girders through the steel engine seatings of sufficient strength and rigidity.
2. Where machinery having large unbalanced inertia force or large unbalanced moment of inertia or subjected to large exciting force due to piston side thrust are installed, it is recommended that the steel engine seatings are of sufficient length for the engines and the engine seatings on both sides are connected each other or the engine seatings are of solid construction.
3. Where the temperature of the bed-plates for propulsion machinery or engine seatings in contact with the FRP girders may become the value to give bad influence on the creeping property of FRP in a normal operating condition, an effective insulation is to be provided between the bed-plates or seatings and FRP girders.
4. Considerations are to be given to installation of propulsion machinery or propulsion machinery seatings onto the FRP girders so that an excessive creep deformation does not occur due to the weights and clamping forces of bolts.

#### 202. Fuel Oil Tanks [See Guidance]

The surfaces of fuel oil tanks made of FRP facing the spaces such as main engine rooms, etc. where there may be usually heat of fire and to be provided with proper measures for flame retardation and flame-resistance. In case of engines using petrols, the fuel oil tanks are to be metallic.

#### 203. Earthing

1. Coverings of metallic structures, machinery and equipment in danger of electrification due to static electricity or electromagnetic induction, are to be effectively earthed, except where is no risk of persons to touch them directly.
2. Metallic fuel oil tanks and pipes are to be effectively earthed. Where FRP fuel oil tanks are used, the metallic parts of valves, manhole covers, etc. fitted up in the tanks and the fuel oil pipes are to be electrically connected effectively, and they are to be earthed. ↓





**2014**

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**Guidance Relating to  
the Rules for the Classification of  
FRP Ships**

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#### APPLICATION OF THE GUIDANCE

This "Guidance relating to rules for the survey and construction of FRP ships" (hereafter called as the Guidance) is prepared with the intent of giving guidelines as to the treatment of the various provisions for items required the unified interpretations and items not specified in details in the Rules, and the requirements specified in the Guidance are to be applied, in principle, in addition to the various provisions in the Rules. As to any technical modifications which can be regarded as equivalent to any requirements in the Guidance, their flexible application will be properly considered.

**APPLICATION OF  
"GUIDANCE RELATING TO RULES FOR THE CLASSIFICATION OF  
FRP SHIPS"**

1. Unless expressly specified otherwise, the requirements in the Guidance apply to ships for which contracts for construction are signed on or after 1 July 2014.
2. The amendments to the Guidance for 2012 and their effective date are as follows;

**Effective Date 1 July 2014**

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**No Revision (re-printed)**

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# CHAPTER 1 GENERAL

## Section 1 General

### 101. Application

1. Reductions in the scantlings of FRP Ships intended for Smooth Water Service are to be in accordance with the **Table 1.1**.
2. Reductions in the scantlings other than those given in **Table 1.1** are to be in accordance with the discretion of the Society.

**Table 1.1 Reductions in Scantlings**

| Item  | Ratio of reduction |
|---|--------------------|
| <ul style="list-style-type: none"> <li>• Section modulus of athwartship hull section</li> <li>• Thickness of shell laminates(including keel)</li> <li>• Minimum thickness of deck laminates</li> <li>• Thickness of single bottom or double bottom members</li> </ul> | 10 %               |
| <ul style="list-style-type: none"> <li>• Section modulus of frame</li> <li>• Section modulus of beam</li> <li>• Section modulus of deck girder</li> </ul>   | 15 %               |

3. Notwithstanding the requirements in **1** and **2**, the scantlings of beams of deck intended to carry cargo, inner bottom plating and inner bottom longitudinals intended to carry heavy cargo, structural members of deep tanks, etc. are not to be reduced exceeding the values specified in the requirements of the relevant chapter.
4. Sill height of hatchway, access opening, etc. may be reduced to the values given in **Table 1.2**.

**Table 1.2 Sill Height of Hatchway, Access Opening, etc.(mm)**

| Location   | Sill Height   |              |   |
|--|---|--------------|---|
|  | Small deck opening<br>(area: 1.5 m <sup>2</sup> or below) | Companionway | Access opening in<br>superstructure end<br>bulkhead |
| Upon upper deck and<br>superstructure deck within<br>fwd 0.25 <i>L</i> | 380   | 300          | 300   |
| Upon superstructure deck<br>abaft the forward 0.25 <i>L</i>            | 230   | 100          | 100   |

### 103. Direct strength calculations

1. Where scantlings of structural members are determined based on the direct strength calculation, **ANNEX 3-1 「Guidance for the Direct Strength Assessment」** of **Rules and Guidance for the Classification of High Speed and Light Crafts** should be followed. If the application of the Guidance is considered inappropriate, analysis method, loads and allowable stress as deemed appropriate by the Society may be applied.
2. Based on the results according to the direct strength calculation, the buckling strength of the structural members are to be examined by using the method and allowable stress given in **ANNEX 3-2 「Guidance for the Buckling Strength Calculation」** of **Rules and Guidance for the**

## Classification of High Speed and Light Crafts.

### Section 2 Definitions

#### 215. Bonding

Bonding is an operation of connecting the FRP already advanced in cure with other FRP members, timbers, hard plastic foams, etc. through scientific bonding procedure including the following (1) and (2).

- (1) Secondary bonding(an operation of laminating on the cured FRP laminate after sanding)
- (2) Matting-in connection(an operation of inserting chopped mat impregnated with plastic resins between two cured FRP laminates)

#### 219. Hand Lay-Up Method

The hand lay-up method is to include the method that resins spray is used in impregnating fibreglass reinforcements with resins.

### Section 3 Hull Construction and Equipment

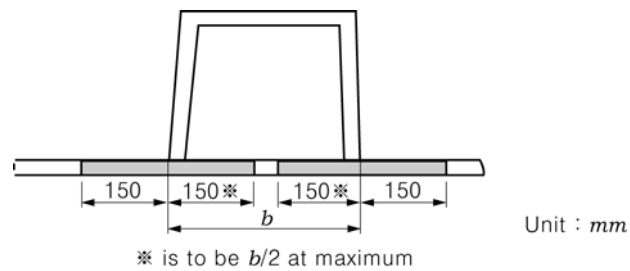
#### 303. Passenger Ships

Passenger ships are to be accordance with following for the safety.

- (1) For the inside of hull corresponding to the fire divisions(machinery spaces of category A, enclosed vehicle spaces and dangerous/inflammable liquid spaces) the "A-60" class insulation approved of thickness/construction method or the equivalent is to be applied to bulkhead or deck of them. However, for the shell plating(top) insulation is to be extended to 300 mm under light water line and for others of shell plating(bottom) may be laminated with non-combustible resins (those of the burning resistance test in KS M3305) at least 3 times(thickness is to be not less than 3 mm).
- (2) Inside of accommodation spaces, service spaces and control stations, which is not insulated with non-combustible ceilings or linings, is to be laminated with non-combustible resins at least 1 times.
- (3) The Ceilings and linings used in accommodation spaces, service spaces and control stations are to be of non-combustible materials, and furniture and furnishings(including curtains, carpet, etc.) are to be of restricted fire risk.(See the Ships Safety Law of Korea, Standard of Fire Protection, Article 23, ① and Appendix 1, Notes (6))
- (4) In addition to the Ships Safety Law of Korea, Standard of Fire-Extinguishing Appliances Article 53(however, ② is to be applied to the ships having the main engine or auxiliary engines which has sum of the output not less than 375 kW), fire detection system is to be provided in not manned machinery spaces of ship which has main engine controlled by the remote control system. Portable fire extinguisher of such machinery spaces is to be provided at the readily accessible place.

#### 304. Scantlings

The effective breadth of FRP laminates of Hat-type construction is to be as shown by hatched areas in **Fig 1.1**.



**Fig 1.1 Effective Breath**

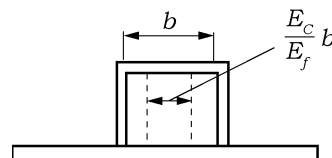
### 305. Hat-type Construction

When the core for moulding of hat-type construction is reckoned in the section modulus, breadth of the core is to be calculated as  $(E_c/E_f) \cdot b$  as shown in **Fig 1.2**.  $E_c$  and  $E_f$  are the modulus of bending elasticity of the core and FRP laminates respectively.

Pine and lauan ----- 1.0

Plywood for structure -- 0.8

Other core material ----- To be determined by the test specified in **Ch 3, 209. 2** of the Rules.



**Fig 1.2 Inclusion of Core in Calculation**

### 306. Sandwich Construction

When the core of sandwich construction is reckoned in bending strength, coefficient  $C_2$  prescribed in **Ch 6, 303. 1** of the Rules is to be determined by the following formula.

$$C_2 = \frac{1}{\sqrt{1 - \frac{1 - \frac{E_c}{E_f}}{(1 + \beta)^3}}}$$

where

$E_c$  : Modulus of bending elasticity of the core of sandwich construction ( $N/mm^2$ ).

$E_f$  : Modulus of bending elasticity of the outer laminates or inner laminates of FRP of sandwich construction ( $N/mm^2$ ).

$\frac{E_c}{E_f}$  : as specified in **305.** of the Guidance.

$\beta$  : as specified in **Ch 6, 303. 1** of the Rules

### 307. Weight of Fibreglass Reinforcements and thickness of Laminates

To calculate the thickness of laminates for chopped mats or roving cloths, the following is to be described at the drawings submitted.

- (1) Designed weight per unit area of chopped mats or roving cloths ( $g/m^2$ )
- (2) Glass content of laminates (ratio in weight) (%)
- (3) Specific gravity of cured resin.
- (4) Specific gravity of chopped mats or roving cloths.  $\downarrow$



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## CHAPTER 2 CLASS SURVEYS

### Section 1 General

#### 101. Application

The head pressure in the hydrostatic test of deep tanks of FRP Ships of less than 20 m in length may be of the height up to positions of tops of overflow pipes.

### Section 2 Classification Survey during Construction

#### 204. Inspections during Construction

1. In application to **204. 2. (2)** of the Rules, "when designated by the Society during moulding work" means the following.
  - (1) Commencement of moulding work
  - (2) One time during moulding work
  - (3) Before the mould releasing
  - (4) Bonding(shell laminates and decks, or superstructures and deckhouses) ↓

## CHAPTER 3 MATERIALS

### Section 1 General

#### 102. Approval and Manufacturing Control

##### 1. Approval

- (1) FRP ships applied for survey during construction are to be moulded at the workshop approved by Society in accordance with **Ch 2, Sec 13 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.**
- (2) FRP materials (fibre reinforcement, resins and core, etc.) used for FRP ships applied for survey during construction are to be appropriate to **Pt 2, Annex 2-8 of Rules for the Classification of Steel Ships** and are to be in accordance with **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, etc.**

### Section 2 FRP Materials

#### 202. Resins

1. Test Methods prescribed in **Table 3.1**, Note (1) of the Rules are to be in accordance with **Annex 1, 2.**
2. Test Methods prescribed in **Table 3.1**, Note (2) of the Rules are to be in accordance with **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.**

#### 203. Gelcoats

1. Test Methods prescribed in **Table 3.2**, Note (1) of the Rules are accordance with **Annex 1, 2.**
2. Test Methods prescribed in **Table 3.2**, Note (2) of the Rules are accordance with **Ch 3, Sec 28. of Guidance for Approval of Manufacturing Process and Type Approval, etc.**

#### 204. Fibre Reinforcements

1. The regulation in **Table 3.3**, Acceptance criteria (1) of the Rules are to be in accordance with **Pt 2, Annex 2-8 of Rules for the Classification of Steel Ships.**
2. Test methods prescribed in **Table 3.3**, Note (1) of the Rules are to be in accordance with **Annex 1, 3.**
3. Test Methods prescribed in **Table 3.3**, Note (2) and (3) of the Rules are accordance with **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.**

#### 206. Core for Sandwich Constructions

Test Methods prescribed in **Table 3.4**, and **3.5**, Note (1) of the Rules are to be in accordance with **Ch 3, Sec 28. of Guidance for Approval of Manufacturing Process and Type Approval, Etc.**

#### 209. Cores for Moulding

Where the cores for moulding are reckoned in strength, tests are to be carried out on tensile strength and modulus of tensile elasticity or bending strength and modulus of bending elasticity in accordance with **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, Etc.**

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## Section 3 FRP

### 302. FRP Specimen Test

1. Test Methods for FRP laminating are to be in accordance with **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, etc.**
2. Test methods for sandwich constructions plates are to be in accordance with **Annex 2**. However, those for FRP yachts are to be in accordance with **Ch 3, Sec 4 of Guidance for Recreational Crafts.** ↓

## CHAPTER 4 MOULDING

### Section 6 Bonding and Fastening

#### 602. Bonding

1. In case that the surface to be bonded is either of gel coat layer or air cure type resins(paraffin containing type), sanding of the surface is to be carried out by removing at least 0.4 mm or more of the layer.
2. The first layer of fibreglass reinforcements on the surface to be bonded are not to be of roving cloth but to be of chopped mat. The peripherals of bonded area of partial laminating such as the laminating for increased thickness or the secondary bond are to be so finished as to form smooth tapered ends as shown in **Fig 5.1** and **Fig 5.2** of the Rules.
3. In case of matting-in connections, the number of matting-in layers is to be determined corresponding to the clearance between FRP laminates, and chopped mat impregnated with slightly larger amount of resins(glass content : 25 % or thereabout) is to be inserted in between and to be clamped by a pressure ranging from 300 to 350 kg/cm<sup>2</sup>.

### Section 7 Bonded Connections

#### 702. L-Joints

Where L-joints are used, the overlap thickness  $t'$  is to be not less than  $t$  for important parts, and not less than  $\frac{2}{3}t$  for other parts. ↓

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## CHAPTER 5 LONGITUDINAL STRENGTH

### Section 1 Longitudinal Strength

#### 103. Calculation of Section Modulus of Athwartship Section

1. The ratios of timbers, structural plywoods and cores of sandwich construction to be reckoned in longitudinal strength are to be as follows.
  - (1) Pine and lauan ----- 1.0
  - (2) Structural plywood ----- 0.8
  - (3) Other core materials ----- The value obtained by the tests specified in **Ch 3, 206.** and **209.** of the Rules
2. In case where the structural plywood reckoned in longitudinal strength are provided with scarf joints, the joint length is to be not less than 6 times the thickness as the standard. ↓

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## CHAPTER 7 DECKS

### Section 2 Minimum Thickness of Deck Laminates

#### 203. Deck Load $h$

In case where fish catches are carried on deck as in fishing vessels, the deck load  $h$  is to be the value specified in **Ch 7, 203. 3** of the Rules or the value obtained from the following formula, whichever is the greater.

$$h = 0.22L + 10 \quad (\text{kN/m}^2) \quad \downarrow$$

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## CHAPTER 10 BEAMS

### Section 1 Beams

#### 103. Section Modulus of Beams

In case where fish catches are carried on deck as in fishing vessels, the deck load  $h$  is to be of the value specified in **Ch 10, 103.** of the Rules or the value obtained from the following formula, whichever is the greater.

$$h = 0.15L + 6.9 \quad (\text{kN/m}^2) \quad \downarrow$$

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## CHAPTER 12 WATERTIGHT BULKHEADS

### Section 2 Construction of Watertight Bulkheads

#### 203. Bulkhead Laminates of Structural Plywood

The bending strength of plywoods may be of the value verified by the **Annex 3**. ↓



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## CHAPTER 13 DEEP TANKS

### Section 2 Bulkhead Laminates of Deep Tanks

#### 203. Bulkhead Laminates of Structural Plywood

The bending strength of plywoods is to be in accordance with **Ch 12, 203.** of the Guidance. ↴

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## CHAPTER 18 MACHINERY

### Section 2 Installation of Propulsion Machinery, Fuel Oil Tanks and Earthing

#### 202. Fuel Oil Tanks

The terms "Proper measures for flame retardation and flame-resistance" in **Ch 18, 202** of the Rules mean the application of covering with non-combustible material or application of not less than 3 layers of laminates impregnated with fire-retardant resins. The fire-retardant resins referred to in the above are to be construed as those of "Grade 1 through 3 Incombustibility" class in KS F 2271, or those of "Incombustible", "Self-extinguishing" or "Burning Resistance Class V-0 or V-1" for the burning resistance test in KS M 3015. ↓

# ANNEX 1 Test and Inspection of FRP Materials for Primary Structures

## 1. General for Test and Inspection

### 1.1 General

Tests and inspections not mentioned this Guidance is to be in accordance with **Ch 3, Sec 28 of Guidance for Approval of Manufacturing Process and Type Approval, etc.**

### 1.2 Material testing machines

The testing machines used for the mechanical testing of materials to carry out according to this Guidance are to be those which are inspected and have the inspection certificates issued by the recognized organization.

### 1.3 Environmental conditions of test place

Except for cases specifically designated otherwise, the environmental conditions of test place are to be the standard conditions (temperature =  $20 \pm 5$  °C, relative humidity =  $65 \pm 20$  %).

### 1.4 Verification of materials

The manufacturer is to take necessary steps to ensure the relationship between product and test sample or test specimen.

### 1.5 Retests

When a part of the test results fails to comply with the requirements while the rest items of test are proved satisfactory, retest may be carried out on the failed test items by taking test specimens two times the required number of test specimens. In this case, the test is considered to have passed when all results of retests satisfy the requirements. However, in case where tests are carried out on laminates and the laminates are renewed, all the tests required for laminates are to be carried out.

### 1.6 Test results

When the tests specified in this Guidance are carried out, the test record describing the following (1) through (9) are to be submitted to the Society.

- (1) Kind and brand name of raw materials tested
- (2) The following raw materials used for the preparation of test specimens (excluding (1) above):
  - (A) Kind and brand name of fibreglass reinforcements and resins for laminating
  - (B) Kind and blending ratio of fillers
  - (C) Kind and blending ratio of curing agents and accelerators
- (3) Moulding method and moulding conditions
- (4) Selection method of test specimens
- (5) Date of moulding of test specimens and test date
- (6) Test place and environmental conditions of the test place
- (7) Type of testing machine
- (8) Shape and dimensions of test specimens
- (9) Test results

## 2. Resins and Gelcoats for Laminating

### 2.1 Shapes and Selection of Test Specimens

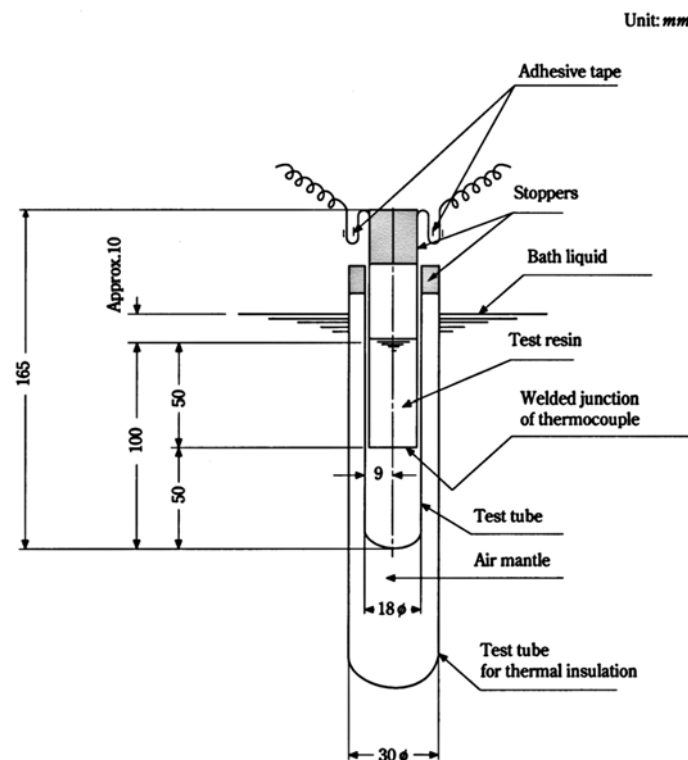
The shape and selection of test specimens used for the tests of resins and gelcoats for laminating are to be in accordance with **Table 1.1**.

**Table 1.1 Resins and Gelcoats for Laminating (unit : mm)**

| Test item   | Shape and size of test specimen | Quantity    | Selection of test specimen, etc.   |
|---|---------------------------------|-------------|--|
| Viscosity and thixotropy  | Resins                          | As required | When resins are sampled, the contents of vessel are to be stirred well to make them homogeneous, and take test resins into a suitable dry and clean vessel of two times the necessary volume for test and a light-proof plug is. |
| Gel time, minimum cure time and peak exothermic temperature   | Resins                          | 50±1 g      |  |
| Acid value  | Resins                          | 1 g         |  |
| Note<br>1. In the case of no-accelerated resins, the specified amount of accelerators is to be added and stirred according to the weight of the resins. |                                 |             |  |

### 2.2 Test Procedures

- (1) Viscosity and thixotropy
  - (A) The test resins are to be as given in **Table 1.1**.
  - (B) Brookfield viscometer is to be used.
  - (C) The rotor and guard (or sleeve guard) chosen according to the predicted viscosity of the liquid sample are to be mounted on the viscometer.
  - (D) The test liquid resins(25±0.5°C) after being stirred well are to be filled into the breaker to a depth so that the reference mark on the rotor may be equal to the liquid level.
  - (E) After leaving still for approximately 5 minutes and then turning the rotor at a rotational speed of 60 rpm for 3 minutes, the reading of the scale is to be taken. The viscosity is to be obtained by multiplying the reading by a coefficient determined according to the type of rotor used and rotational speed.
  - (F) After keeping still for another 5 minutes and then turning the rotor at a rotational speed of 6 rpm for 3 minutes, the reading is to be taken for obtaining the viscosity.
  - (G) The thixotropy is to be obtained by dividing the viscosity determined at the rotor run of 6 rpm by the viscosity at 60 rpm.
  - (H) The operations shown in (E) and (F) above are to be repeated for two times or more and the respective mean, values are to be regarded as the 'viscosity' and 'thixotropy.'
  - (I) The effective digit is to be 2-digit and the name of the viscometer and rotor number are to be recorded.
- (2) Gel time, minimum cure time and peak exothermic temperature
  - (A) The test resins are to be given in **Table 1.1**.
  - (B) The testing apparatus for hardening characteristics at room temperature is to be fixed in a thermostatic water bath(25±0.5°C)(See **Fig 1.1**).



**Fig 1.1 Testing Apparatus for Hardening Characteristics at Room Temperature**

- (C) The test resins are to be dipped in the thermostatic water bath and then the specified amount of sclerotics is to be added thereto when the temperature of the test resins reached  $25 \pm 0.5^\circ\text{C}$ , and the mixture is to be stirred evenly.
- (D) The test resins added with sclerotics are to be filled into a test tube of 18 mm in diameter to a depth of 100 mm.
- (E) The 18 mm diameter test tube is to be fixed in a test tube of 30 mm in diameter so that the top surface of the test resins assumes approximately 10 mm below the liquid surface of the thermostatic water bath.
- (F) The welded junction of thermocouple is to be placed at half the depth of the test resins and to be fixed at the centre of the test tube. However, a thermocouple ensleeved in a protection tube or a thermistor may be used in place of the above thermocouple.
- (G) The time in minutes required for the test resins to reach a temperature of  $30^\circ\text{C}$  from the time when the sclerotic are mixed is to be taken as the gel time, and the time in minutes required to reach the highest temperature after adding the sclerotics is to be taken as the minimum cure time, and the temperature indicated as the maximum temperature of the test resin is to be taken as the peak exothermic temperature( $^\circ\text{C}$ ).
- (H) Measurements are to be taken for two or more times, and the respective mean values are to be regarded as the 'gel time', 'minimum cure time' and 'peak exothermic temperature'.
- (I) The types and amounts of the sclerotics and accelerators are to be recorded.
- (3) Acid value
- (A) Take 1 g of the test resins, add it to about 10 ml of mixed solvent (mixture of 7 parts by mass of toluene (reagent) and 3 parts by mass of methyl alcohol (reagent)) and methyl alcohol (reagent), and stir the mixture well.
- (B) Add the mixes indicator and titrate the solution with 0.1 mol/l(0.1N) ethyl alcoholic potassium hydroxide solution.
- (C) When the colour of the solution turns from green into pale violet, take is as a point of termination.
- (D) The acid value is to be of the value obtained from the following formula.

$$\frac{5.61vf}{S}$$

where,

$v$  : Consumption of 0.1 mol/l(0.1N) ethyl alcoholic potassium hydroxide solution(ml)

$f$  : Factor of 0.1 mol/l(0.1N) ethyl alcoholic potassium hydroxide

$S$  : Mass of test resins (g)

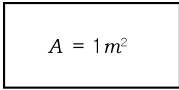

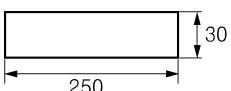
Note : The mixed indicator is the reagent obtained by adding 20 ml of distilled water to 0.1g of finely ground bromothymol blue and 0.1g of phenol red, and adding further 0.1 mol/l(0.1N) ethyl alcoholic potassium hydroxide solution thereto to the discolouring range while stirring it well, and by diluting it further with distilled water to a volume of 200 ml.

### 3. Fibre Reinforcements

#### 3.1 Shape and Selection of Test Specimens

The shape and selection of test specimens used for tests of fibreglass reinforcements are to be in accordance with **Table 1.2**.

**Table 1.2 Fibre Reinforcements (unit : mm)**

| Test items                                     | Shape and size of test specimen   | Quantity                                 | Sampling procedure, etc.   |
|--|---|--|--|
| Deviation                                      | *1)  *2)  | *1) 5<br>*2) 10                          | Discard 30 mm from one longitudinal end and 30 mm from both transverse ends, and take a test sample of 1m <sup>2</sup> continuously in the longitudinal direction(See <b>Fig 1.2</b> ).<br>After measuring weight of test sample *1), take a square(300×300) test specimen therefrom(See <b>Fig 1.3</b> ). |
|  | Rovings for spray-up are to have a length equivalent to approximately 15g.  | 5  |  |
| Ratio in weight of binders                     | The same as in *2)  | 5  |  |
| Tensile strength of fibreglass in roving cloth |    | warp direction : 5<br>weft direction : 5 | Test specimens are to be taken in warp and weft direction, respectively(See <b>Fig 1.4</b> ).<br>Finish it the shape as shown in <b>Fig 1.5</b> .  |

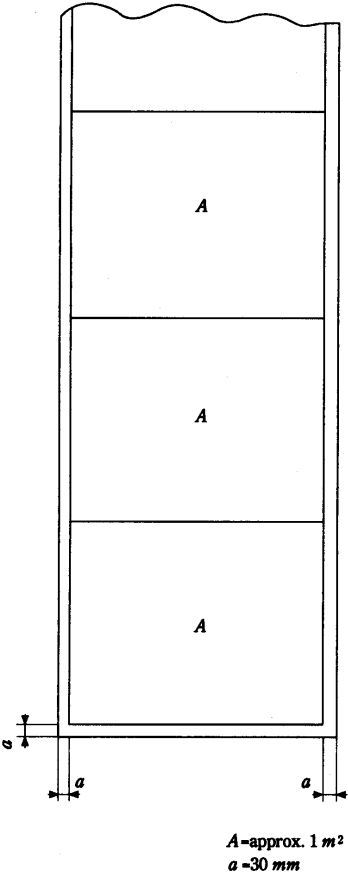


Fig 1.2 Selection of Test Specimens from Fibreglass Reinforcements

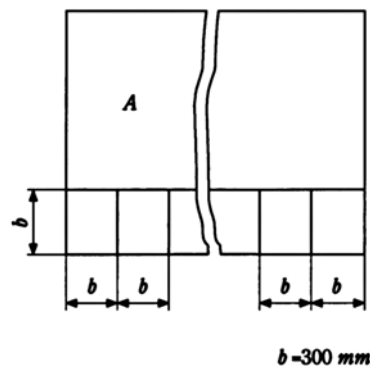
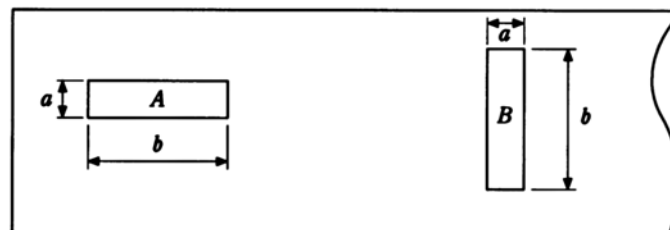


Fig 1.3 Selection of Test Specimens from Fibreglass Reinforcements



*A* : the test specimen in the direction of warp  
*B* : the test specimen in the direction of weft  
*a* = approx. 30 mm  
*b* = approx. 250 mm

Fig 1.4 Selection of Tensile Test Specimens from Roving Cloth Reinforcements

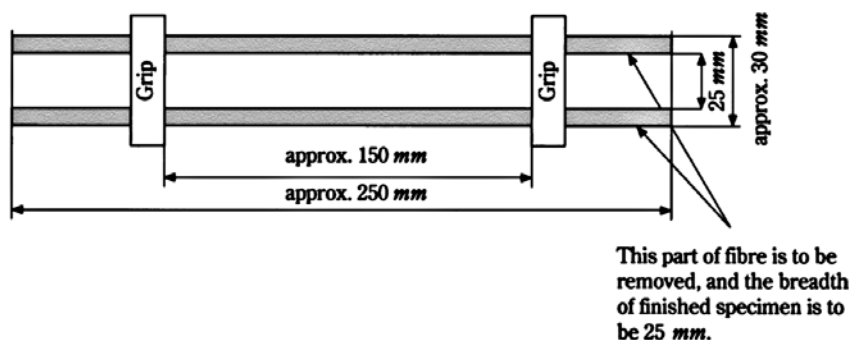


Fig 1.5 Tensile Test Sample of Roving Cloth

### 3.2 Test Procedures

The procedure of the tests given in **Table 1.2** is to be in accordance with the following (1) through (6).

- (1) Design weight per unit area or unit length and the maximum deviation
  - (A) The test samples are to be in accordance with **Table 1.2**.
  - (B) The weight of the test sample is to be measured to the accuracy of 0.1 g.
  - (C) The deviation is to be of the value obtained from the following formula.
    - (a) Chopped mats and roving cloths



$$\text{For test sample of } 1\text{ m}^2 : \frac{|M_1 - W|}{W} \times 100 \quad (\%)$$

$$\text{For test sample of } 300 \times 300 \text{ mm}^2 : \frac{|M_2/0.09 - W|}{W} \times 100 \quad (\%)$$

where,

$M_1$  : Weight of test sample of  $1 \text{ m}^2$ (g)

$M_2$  : Weight of test sample of  $300 \times 300 \text{ mm}^2$ (g)

$W$  : Weight of test sample per  $1 \text{ m}^2$  intended to be stated in the specification (hereinafter referred to as "normal weight")(g)

(b) Rovings

$$\frac{|1,000M/l - W|}{W} \times 100 \quad (\%)$$

where,

$l$  : Length of test sample(m)

$W$  : Weight per 1,000m to be stated in specification(g)(hereinafter referred to as the "normal weight")

$M$  : Weight of test sample(g)

(2) Ratio in weight of binder(including sizing agent)

(A) The test specimen are to be in accordance with **Table 1.2.**

(B) Each test specimen is to be heated in a heating furnace ( $625 \pm 25^\circ\text{C}$ ) for about 10 minutes to burn out the binder or sizing agent, to be taken out from the furnace and to be left it to cool down to the room temperature.

(C) The test sample in (B) above is to be weighed to the accuracy of 0.1 g.

(D) The ratio in weight of binders (including sizing agent) is to be of the value obtained from the following formula.

$$\frac{W_0 - W_1}{W_0} \times 100 \quad (\%)$$

where,

$W_0$  : Weight before heating(g)

$W_1$  : Weight after cooling(g)

(3) Tensile strength of fibreglass in roving cloth

(A) The test specimen are to be in accordance with **Table 1.2.**

(B) Tensile speed is to be 200 mm/min. as the standard.

(C) When the test specimen failed or slipped at the grip of the testing machine, the measured value of this test sample is to be judged unacceptable. In such a case, a new test specimen is to be taken for additional test.

(D) The breaking load is to be taken as the tensile strength of fibreglass. ↓

## ANNEX 2 Test and Inspection of Sandwich Constructions Materials

### 1. Manufacturing methods of test laminates for sandwich constructions

- (1) One each of test laminates of sandwich construction which are of the same laminate composition and the same moulding procedures as those for bottom laminates, side shell laminates and upper deck laminates is to be manufactured. However, when either of the bottom laminates, side shell laminates or upper deck laminates has the same laminate composition with the other, one test laminate may be manufactured for those of the same laminate composition.
- (2) The size of the test laminates is to be sufficient to cut all the test specimens specified in the following 2. and 3.

### 2. The selection of test specimens

- (1) The tensile test specimens and bending test specimens are to be cut alternately from the test laminates clearing 60mm belt from the periphery. (See Fig 2.1)

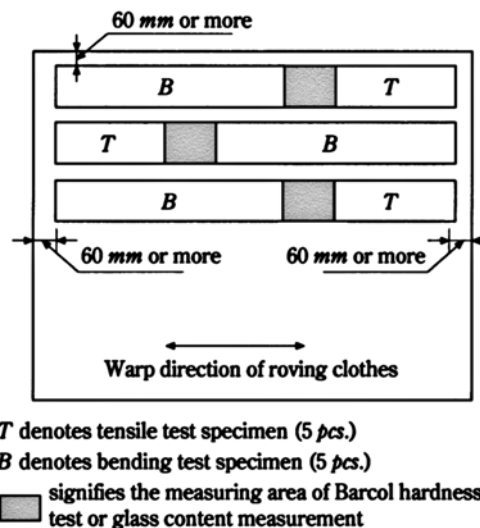


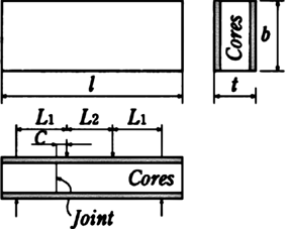
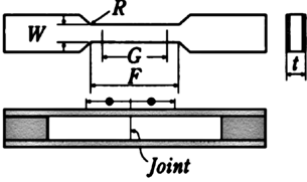
Fig 2.1 Location of Selection of Test Specimens

- (2) When the cores are reckoned in strength, joints are to be provided at two locations.

3. Shape and size of the test specimens

The shape and size of the test specimens are to be in accordance with Table 2.1.

Table 2.1 Shape and Size, etc. of Test Specimens

| Item  | Sandwich construction  | Quantity |          |             |              |                  |              |                  |              |   |
|---|--|----------|----------|-------------|--------------|------------------|--------------|------------------|--------------|---|
| Thickness of moulding                         | Bend test specimen, shearing test specimen and tensile test specimen are to be used.   | -        |          |             |              |                  |              |                  |              |   |
| Barcol hardness                               | -  | -        |          |             |              |                  |              |                  |              |   |
| Glass content                                 | -  | 3        |          |             |              |                  |              |                  |              |   |
| Bend test specimen and shearing test specimen | <p>Shearing test specimen</p>  <p> <math>t</math> = original thickness<br/> <math>L_1</math> = 100 ~ 200<br/> <math>L_2</math> = 100<br/> <math>l</math> = <math>2L_1 + L_2 + 60</math><br/> <math>C</math> = approx. 10(mm)<br/>                     (When the cores are reckoned in strength, a joint is to be provided at the position shown on the drawing.)                 </p> <table border="1" data-bbox="647 1128 1023 1317"> <thead> <tr> <th><math>t</math>(mm)</th> <th><math>b</math>(mm)</th> </tr> </thead> <tbody> <tr> <td><math>t \leq 20</math></td> <td><math>30 \pm 0.5</math></td> </tr> <tr> <td><math>20 &lt; t \leq 35</math></td> <td><math>50 \pm 0.5</math></td> </tr> <tr> <td><math>35 &lt; t \leq 50</math></td> <td><math>80 \pm 0.5</math></td> </tr> </tbody> </table> | $t$ (mm) | $b$ (mm) | $t \leq 20$ | $30 \pm 0.5$ | $20 < t \leq 35$ | $50 \pm 0.5$ | $35 < t \leq 50$ | $80 \pm 0.5$ | 5 |
| $t$ (mm)                                      | $b$ (mm)   |          |          |             |              |                  |              |                  |              |   |
| $t \leq 20$                                   | $30 \pm 0.5$   |          |          |             |              |                  |              |                  |              |   |
| $20 < t \leq 35$                              | $50 \pm 0.5$   |          |          |             |              |                  |              |                  |              |   |
| $35 < t \leq 50$                              | $80 \pm 0.5$   |          |          |             |              |                  |              |                  |              |   |
| Tensile test specimen                         |  <p> <math>t</math> = original thickness<br/> <math>F</math> = <math>60 \pm 0.5</math><br/> <math>G</math> = <math>50 \pm 0.5</math><br/> <math>W</math> = 25 or more<br/> <math>R</math> = 60 or more                 </p> <ul style="list-style-type: none"> <li>When the cores are reckoned in strength, a joint is to be provided at the centre of the parallel part.</li> <li>The gripped portion is to be reinforced.</li> </ul>  | 5        |          |             |              |                  |              |                  |              |   |

#### 4. Test Procedures

(1) Thickness of moulding

The thickness of the shearing test specimens and tensile test specimens is to be measured.

(2) Tensile strength

(A) The test specimens are to be in accordance with **Table 2.1**.

(B) The tensile speed is to be 5 mm/min. as the standard.

(C) When the test specimen fails at position outside the gauge length, the measured values of the test specimen are not to be accepted and a new test specimen is to be tested additionally.

(D) The tensile strength is to be of the value obtained from the following formula.

$$\frac{P}{A_f + A_c \frac{E_c}{E_f}} \quad (\text{N/mm}^2)$$

where:

$P$  : Breaking load(kg)

$A_c$  : Sectional area of core(mm<sup>2</sup>)

$A_f$  : Sectional area of FRP laminates(mm<sup>2</sup>)

$E_c$  : Modulus of tensile elasticity of core obtained by the test in **Ch 3, 206**. of the Rules(N/mm<sup>2</sup>)

$E_f$  : Modulus of tensile elasticity of FRP laminates obtained by **Ch 3, Sec 28** of **Guidance for Approval of Manufacturing Process and Type Approval, etc.**

(3) Shearing strength

The test procedure are to be in accordance with **Ch 3, Sec 28** of **Guidance for Approval of Manufacturing Process and Type Approval, etc.** The side of FRP with a thicker layer is to be taken as the compression side.

#### 5. Test Results

(1) Test results of sandwich constructions is to be recorded on the **Table 2.2** and **Table 2.3**. ↓

**Table 2.2 Tensile Test Results of Laminates of Sandwich Constructions**

| Location of selection   | Item                          |                                 |                        |  |                  |                                       |                       |
|---|-------------------------------|---------------------------------|------------------------|--|------------------|---------------------------------------|-----------------------|
|   | Breadth of test specimen (mm) | Thickness of test specimen (mm) | Thickness of core (mm) | Thickness of laminates <sup>(1)</sup> (mm) | Braking load (N) | Tensile strength (N/mm <sup>2</sup> ) | Remark <sup>(3)</sup> |
| Mean value  |                               |                                 |                        |  |                  | (2)                                   |                       |
| Notes   |                               |                                 |                        |  |                  |                                       |                       |
| (1) The thickness of laminates is to be obtained by deducting the thickness of the core from the total thickness of the sandwich constructions. |                               |                                 |                        |  |                  |                                       |                       |
| (2) The mean value of tensile strength is to be obtained by taking the mean of the smaller three.   |                               |                                 |                        |  |                  |                                       |                       |
| (3) In "Remarks" column, the position of failure and existence of joint(s) are to be entered.   |                               |                                 |                        |  |                  |                                       |                       |

Table 2.3 Shearing Test Results of Laminates of Sandwich Constructions

| Location of selection | Item                          |                                 |                        |  |   |   |   |                   |   |                       |
|-----------------------|-------------------------------|---------------------------------|------------------------|--|---|---|---|-------------------|---|-----------------------|
|                       | Breadth of test specimen (mm) | Thickness of test specimen (mm) | Thickness of core (mm) | Thickness of laminates <sup>(1)</sup> (mm) | $\frac{P}{\epsilon}$ <sup>(2)</sup> (N) | $Z_c$ <sup>(3)</sup> (cm <sup>3</sup> ) | $Z_c$ <sup>(4)</sup> (cm <sup>3</sup> ) | Breaking load (N) | Shearing strength <sup>(5)</sup> (N/mm <sup>2</sup> ) | Remark <sup>(7)</sup> |
| Mean value            |                               |                                 |                        |  |   |   |   |                   | (6)   |                       |

$L_1$  : \_\_\_\_\_ (mm)

Notes

(1) The thickness of laminates is to be obtained by deducting the thickness of the sandwich constructions.

(2)  $\frac{P}{\epsilon}$  is the gradient of straight portion of load-strain curve and the value of strain of either the outer layer or inner layer whichever is the greater is to be taken.

$$(3) Z_c = \frac{L_1}{2E_f} \left( \frac{P}{\epsilon} \right) \times 10^{-3} \text{ (cm}^3\text{)}$$

$L_1$  : Outer span(mm)

$E_f$  : Modulus of elasticity of FRP laminates which is of the value obtained from the test specified in 4.

(1) (E) above.(kg/mm<sup>2</sup>)

(4)  $Z_c$  is the section modulus of the test specimen of sandwich constructions obtained by calculation.

$$Z_c = \frac{\left\{ \frac{1}{12}(t_1^3 + t_2^3) + t_1 y_1^2 + t_2 y_2^2 \right\} b}{\frac{1}{2} t_2 + y_2}$$

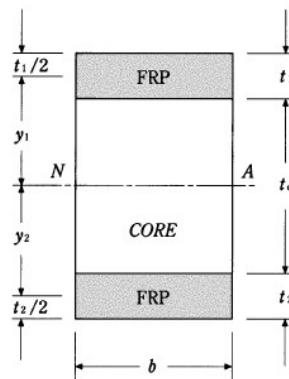
Where :  $t_1, t_2 (t_1 > t_2), t_c, b$ : As specified in the following Figure

$$y_1 = \frac{(t_1 + t_2 + 2t_c)t_2}{2(t_1 + t_2)}, \quad y_2 = \frac{(t_1 + t_2 + 2t_c)t_1}{2(t_1 + t_2)}$$

(5) The shearing strength is of the value obtained from the test specified in 4. (3) above.

(6) The mean value of shearing force is to be obtained from the mean of three in a smaller group.

(7) In “Remarks” column, the position of failure and existence of joint(s) are to be entered.

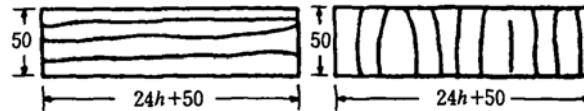


## ANNEX 3 Bending Strength Test of Bulkhead Laminates of Structural Plywood

### 1. Bending Strength Test of Bulkhead Laminates of Structural Plywood

#### (1) Specimen

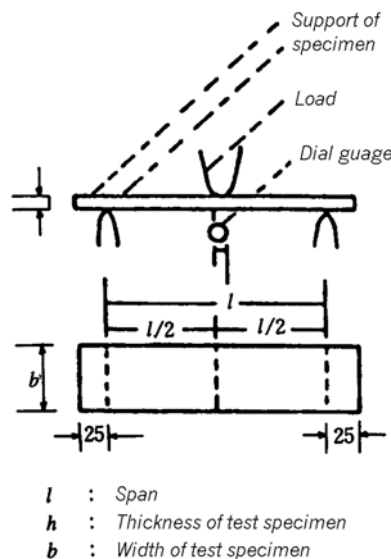
As shown in **Fig 3.1**, 2 pieces of rectangular test specimens of which dimension is 50 mm at the right angle to fibrous direction of the plywood's surface and  $20t+50$  mm at the parallel to fibrous direction, and 50 mm at the parallel to fibrous direction and  $20t+500$  mm at the right angle to fibrous direction, are to be taken from each test sample, respectively.



**Fig 3.1 Bending Strength Specimens of Structural Plywood**

#### (2) Test Procedures

Test is to be carried out under the parallel condition between the span direction and fibrous direction of the plywood's surface as shown in **Fig 3.2**. Upper and lower load of linear region are to be measured and then calculate the modulus of bending elasticity and bending strength by the following formula.



**Fig 3.2 Bending Strength Specimens of Structural Plywood**

$$\text{Modulus of bending elasticity} = \frac{pl^3}{4bh^3y} \quad (\text{N/cm}^2)$$

$$\text{Bending strength} = \frac{3P_b l}{2bh^2} \quad (\text{N/cm}^2)$$

$P_b$  : Maximum load(N)

$l$  : Length of span(cm)

$b$  : Width of specimen(cm)

$h$  : Thickness of specimen(cm)

$p$  : Difference between upper load and lower load of linear region(N)

$y$  : Deflection at the center of span corresponding to  $p$ . ↓

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# **RULES AND GUIDANCE FOR THE CLASSIFICATION OF FRP SHIPS**

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