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# RULES FOR THE SURVEY AND CONSTRUCTION OF SHIPS OF FIBREGLASS REINFORCED PLASTICS

## Chapter 1 GENERAL

### 1.1 General

#### 1.1.1 Application*

**1** The survey and construction of ships fibreglass reinforced plastics (hereinafter referred to as "*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.

**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 fibreglass reinforcements and unsaturated polyester resins. 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 in **1.1.1-4**, the hull construction, equipment, arrangement and scantlings are to be in accordance with the discretion of the Society.

**6** Notwithstanding preceding **-1** through **-5** *FRP* ships flying Japanese are to comply with the requirements in other Rules of NIPPON KAIJI KYOKAI (hereinafter referred to as "the Society").

#### 1.1.2 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.

#### 1.1.3 Class Notation

For *FRP* ships complying with additional requirements and/or those exempted from any requirements in accordance with the provisions of this Rules, an appropriate notation is affixed to the Classification Characters in accordance with the provisions of **Chapter 2 of the Regulation for the Classification and Registry of Ships**. In this case, notations are to be affixed in the same manner as **1.2**, **Part 1 of the Rules for High Speed Craft**, subject that the notation of "*FRP*" is affixed relating to the structural material for main hull specified in **1.2.3**, **Part 1 of the Rules for High Speed Craft**.

### 1.2 Definitions

#### 1.2.1 Application

The definitions of terms which appear in these Rules are to be as specified in this Chapter and **Part A of the Rules for the Survey and Construction of Steel Ships**, unless specified otherwise.

#### 1.2.2 Length of Ship

Length of ship ($L$) is the distance in *metres* on the designed maximum load line defined in **1.2.7-2**, 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, in case of a *FRP* ships with cruiser stern, $L$ is as defined above or 96% of the total length on the designed maximum load line, whichever is greater.

#### 1.2.3 Breadth of Ship

The breadth of ship ($B$) is the horizontal distance in *metres* between the outside of side shell laminates measured on the upper

surface of upper deck laminates at side at the broadest part of the hull.

**1.2.4 Depth of Ship**

The depth of ship ($D$) is the vertical distance in *metres* from the lower surface of bottom laminates or from the intersection of the extension line of lower surface of bottom laminates with the centre line of ship (hereinafter referred to as "base point of $D$") to the upper surface of upper deck laminates at side measured at the middle of $L$.

**1.2.5 Midship Part of Ship**

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

**1.2.6 End Parts of Ship**

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

**1.2.7 Load Line and Designed Maximum Load Line**

**1** Load line is the water line corresponding to each freeboard assigned in accordance with the provisions of **Chapter 20**.

**2** Designed maximum load line is the water line corresponding to the full load condition.

**1.2.8 Load Draught and Designed Maximum Load Draught**

**1** Load draught is the vertical distance in *metres* from the top of keel plate to the load line.

**2** Designed maximum load draught ($d$) is the vertical distance in *metres* from the top of keel plate to the designed maximum load line measured at the middle of $L$.

**1.2.9 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* ships having a discontinuous exposed deck (e.g. a stepped freeboard deck), the freeboard deck is to be determined as follows.

(1) Where a recess in the freeboard deck extends to the sides of the ship and is in excess of 1 *m* in length, the lowest line of the exposed deck and the continuation of that line parallel to the upper part of the deck is taken as the freeboard deck.

(2) Where a recess in the freeboard deck does not extend to the sides of the ship or is not in excess of 1 *m* in length, the upper part of the deck is taken as the freeboard deck.

(3) Recesses not extending from side to side in the deck designated as the freeboard deck in accordance with the provisions of **2.1.15-3, Chapter 2, Part A of the Rules for the Survey and Construction of Steel Ships** below the exposed deck may be disregarded, provided all openings in the exposed deck are fitted with weathertight closing appliances.

**1.2.10 Strength Deck**

The strength deck at a part of ship's length is the uppermost deck at that part to which the shell laminates extend. However, in way of superstructures, except sunken superstructures, which are not considered effective to longitudinal strength, the strength deck is the deck just below the superstructure deck.

**1.2.11 Fibreglass Reinforcements**

The fibreglass reinforcements are glass chopped strand mats (hereinafter referred to as "chopped mats"), glass roving cloths (hereinafter referred to as "roving cloth") and glass roving (hereinafter referred to as "rovings") of reinforcements for *FRP* manufactured from long fibres.

**1.2.12 Resins**

The resins are liquid unsaturated polyester resins for laminating and gelcoat.

**1.2.13 Blending Proportion**

The blending proportion is a ratio in weight of the applied curing agents and accelerator to the resin or the ratio in weight of the curing agents used to the base resins of structural adhesives.

**1.2.14 Laminating**

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

**1.2.15 Bonding***

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 or structural adhesives.

**1.2.16 Moulding**

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

**1.2.17 Single Skin Construction**

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

**1.2.18 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.

**1.2.19 Hand Lay-up Method***

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

**1.2.20 Spray Lay-up Method**

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

**1.2.21 Structural Adhesives**

Structural adhesives are adhesives used to connect structural members to hull structures.

**1.2.22 Ship at Beginning Stage of Construction**

A ship at its beginning stage of construction is a ship at the stage at which the first structural reinforcement of the complete thickness of the approved hull laminate schedule is laid either in or on the mould.

## 1.3 General Rules for Hull Construction and Equipment

**1.3.1 Application of the Rules for the Survey and Construction of Steel Ships**

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

**1.3.2 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.

**1.3.3 Passenger Ships**

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.

**1.3.4 Scantlings***

**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 **(1)** to **(4)**, but excluding gelcoats:

(1) Tensile strength: 98 $N/mm^2$

(2) Modulus of tensile elasticity: $6.86\times10^3$ $N/mm^2$

(3) Bending strength: 150 $N/mm^2$

(4) Modulus of bending elasticity: $6.86\times10^3$ $N/mm^2$

**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:

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

where,

$\sigma_B$ : Bending strength of the *FRP* obtained from the material tests specified in **4.4.4** ($kg/mm^2$)

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

$$\frac{98}{\sigma_T}$$

where,

$\sigma_T$ : Tensile strength of the *FRP* obtained from the material tests specified in **4.4.4** ($kg/mm^2$)

**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 material tests specified in **4.4.4**.

**4** In calculating the section modules of structural members, the actual *FRP* laminates of 150 *mm* on either side of the web are to be included.

### 1.3.5 Hat-type Construction*

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

Thickness of web : $0.034d_0K$ $(mm)$

Thickness of face : $0.05bK$ $(mm)$

where,

$d_0$ : Depth of web $(mm)$.

$b$ : Breadth of face $(mm)$.

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

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

where,

$Z_R$ : Section modules 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.

### 1.3.6 Sandwich Construction*

**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** The ratio of the thicknesses of outer and inner layers of *FRP* is not to be less than 0.8. In case where the ratio of the thicknesses of outer and inner layers is less than 0.8, the construction will be specially considered by the Society.

**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.

### 1.3.7 Weight of Fibreglass Reinforcements and Thickness Laminates

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

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

where,

$W_G$ : Designed weight per unit area of chopped mats or roving cloths ($g/m^2$).

$G$ : 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 chopped mats or roving cloths ($\gamma_G$) specified in the preceding **-1** may by taken as 2.5 in calculation of the thickness, if nothing specially intervenes.

**4** The specific gravity of 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 chopped mats and roving cloths is to be in accordance with the discretion of the Society.

### 1.3.8 Ship Identification Number

For cargo ships not less than 300 *gross tonnage* engaged on international voyages, the ship's identification number is to be permanently marked as follows:

(1) Those specified in **14.2, Part 1, Part C of the Rules for the Survey and Construction of Steel Ships** (except **14.2.1.2(3)**).

(2) The marking is to be made by a method approved by the Society not to be easily expunged.

## 1.4 Preparation for Survey and Other Items

### 1.4.1 Procedure for Tests, Wear and Tear, etc.*

In cases where it is necessary to replace any fittings, equipment, parts, etc. used on board, replacements are to comply with the regulations to be applied during ship construction. However, in cases where new requirements are specified or where deemed necessary by the Society, the Society may require that such replacements comply with any new requirements in effect at the time the relevant replacement work is carried out. In addition, replacements are not to use any materials which contain asbestos.

# Chapter 2 CLASS SURVEYS

## 2.1 General

### 2.1.1 General

**1** The class surveys of *FRP* ships are to be, except those specified in this chapter, in accordance with the requirements in **Part B of the Rules for the Survey and Construction 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, where deemed appropriate by the Society.

**3** In the first Intermediate Survey after construction, the internal inspection of fuel oil tanks made of *FRP* is to be carried out.

## 2.2 Classification Survey during Construction

### 2.2.1 General

**1** In the classification survey during construction, "the hull and equipment, machinery, fire protection and detection, means of escape, fire extinction, electrical installation, computer-based systems, stability and load lines" are to be examined in detail in order to ascertain that they meet the requirements in the relevant Chapters.

**2** Surveyors are to confirm that materials which contain asbestos are not being used.

### 2.2.2 Plans and Documents to be Submitted

With respect to *FRP* ships intended for the classification survey during construction, the plants and documents listed in the following **(1)** to **(3)** 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,

(b) General arrangement,

(c) Midship section (showing athwartships sections at the holds and machinery space, and in way of the wing tanks, if provided, and also indicating the characters of intended classification and the load draught),

(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 draught, sizes of brackets and athwartships sections of the ship at 0.1*L* and 0.2*L* from the ends of the ship),

(g) Deck plans (indicating arrangement and construction of hatchways, hatch beams, etc.),

(h) Single bottoms and double bottoms,

(i) Watertight and oiltight bulkheads (indicating the highest position of tank and position of tops of overflow pipes),

(j) Superstructures end bulkheads (indicating the construction of doors),

(k) Seatings of boilers, main engines, thrust blocks, plummer blocks, generators and other important auxiliary machinery (indicating output, height and weight of main engines and arrangement of holding-down bolts),

(l) Steering gear (indicating detailes of structural arrangement and materials),

(m) Laminating procedure and details of joints.

(n) Plans showing arrangement of ship's identification number specified in **1.3.8**

(2) Machinery

Plans and documents in relation to the machinery specified in **2.1.3-1(2), Chapter 2, Part B of the Rules for the Survey and Construction of Steel Ships**.

(3) Other plans and documents deemed necessary by the Society.

### 2.2.3 Plans and Documents to be Submitted 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 **2.2.2**:

(1) Specifications,

(2) Certificates of *FRP* material tests specified in **Chapter 4**,

(3) Moulding procedure,

(4) Calculation sheets and information with respect to structural strength,

(5) Where load lines are to be marked in accordance with the requirements in **Chapter 20**, the plans and documents specified in item 1, 2, 3, 5, 20, 47 and 59, **Table B2.1**, **Chapter 2, Part B of the Rules for the Survey and Construction of Steel Ships**.

(6) Asbestos-free declarations and supporting documents

**2** In cases where main structural members are connected by structural adhesives, the plans or documents to be submitted for reference, in addition to those required in the preceding **-1**, are as follows:

(1) Procedures for repairing defects in joints moulded by structural adhesives; and

(2) Procedures for repairing joints connected by structural adhesives.

**3** Plans and documents other than specified in the preceding **-1** and **-2** may be required to be submitted, where deemed necessary by the Society.

### 2.2.4 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. To implement surveys of items specified otherwise by the Society, in lieu of traditional ordinary surveys where the Surveyor is in attendance, the Society may approve other survey methods which it considers to be appropriate in the following cases.

(1) When the tests of *FRP* materials specified in **Chapter 4** are carried out.

(2) When designated by the Society during moulding work.

(3) When the strength tests of *FRP* specified in **Chapter 4** 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 **2.1.7, Chapter 2, Part B of the Rules for the Survey and Construction of Steel Ships**. To implement surveys of items specified otherwise by the Society, in lieu of traditional ordinary surveys where the Surveyor is in attendance, the Society may approve other survey methods which it considers to be appropriate.

**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.

## 2.3 Classification Survey Not Built under Survey

### 2.3.1 General

**1** In the classification survey of *FRP* ships not built under the Society's survey, the actual scantlings of main parts of the ship are to be measured in addition to such examinations of the hull and equipment, machinery, fire protection and detection, means of escape, fire extinction, electrical installations, computer-based systems, stability and load lines as required for the special survey corresponding to the ship's age.

**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.

## 2.4 Others

### 2.4.1 Class Survey by Means of Remote Survey

Although the survey method for class maintenance survey is generally attendance on site by a Surveyor, the Society may

approve survey methods different from the traditional ordinary survey with attendance by a Surveyor, provided that survey is carried out in accordance with the requirements specified in **Annex 1.5.3 "CLASS MAINTAINANCE SURVEY BY MEANS OF REMOTE SURVEY", Part B of the Rules for the Survey and Construction of Steel Ships**. However, in the case of matters stipulated in international conventions or instructions from Administrations, this may only be done with Administration acceptance.

# Chapter 3 WORKSHOPS

## 3.1 General

### 3.1.1 Application

Workshops intended to manufacture *FRP* ships and their facilities are to be in accordance with the requirements in this chapter.

### 3.1.2 Workshops

The workshops with manufacture *FRP* ships intended to be registered to the Society, are to submit detailed data on the facilities of the moulding shops and the storage facilities for raw materials, and are to be inspected by the Surveyor.

## 3.2 Laminating Shops

### 3.2.1 Construction and Arrangement of Laminating Shops

**1** The laminating shops are to be so arranged as to be properly subdivided or partitioned in order that the shops are separated from each other during laminating operation.

**2** The laminating shops are to be of such construction as to be free from penetration of draught, dust, moisture, etc.

**3** The facilities and their arrangement of the laminating shops are to be made reasonable in consideration of handling raw materials, laminating process, etc.

### 3.2.2 Ventilation Facilities

In providing the laminating shops with ventilation facilities, thorough considerations are to be given so that they should not give any bat influence upon the curing of laminates.

### 3.2.3 Temperature Conditioners

The laminating shops are to be provided with temperature conditioners to keep the room temperature suitable for use of resins during laminating operation.

### 3.2.4 Relative Humidity

**1** In the laminating shops, the relative humidity during laminating operation is to be kept suitable.

**2** If necessary, suitable dehumidifying appliances to be provided.

### 3.2.5 Shielding

The skylights and windows of the laminating shops are to be provided with suitable means of shielding so that the laminates are not exposed direct to the sun.

### 3.2.6 Dust Collectors

The laminating shops are to be provided with suitable dust collectors in order to get rid of dusts yielded during laminating operation.

## 3.3 Storage Facilities for Raw Materials

### 3.3.1 Equipment and Arrangement of Storage Facilities

The equipment and arrangement of the storage facilities for raw materials are to be reasonable in connection with the storage and handling of the materials.

### 3.3.2 Stores for Resins, etc.

The resins, curing agents, accelerators and structural adhesives are to be stored in cool and dark spaces.

### 3.3.3 Stores for Fibreglass Reinforcements

The fibreglass reinforcements are to be stored in dust-free and dry spaces.

# Chapter 4 MATERIALS FOR HULL

## 4.1 General

### 4.1.1 Application

The requirements in this chapter are framed for *FRP* and their raw materials, etc. The metallic materials are to be in accordance with the requirements in **Part K of the Rules for the Survey and Construction of Steel Ships**.

### 4.1.2 Raw Materials for Primary Structures*

The fibreglass reinforcements, resins for laminates, core materials for sandwich construction and structural adhesives to be used for *FRP* ships are to be tested and inspected in the presence of the Surveyor and to be accepted, except those approved by the Society in accordance with the requirements in **4.2**.

## 4.2 Approval

### 4.2.1 Approval of Raw Materials

At the request of raw material manufacturers, the Society will examine the materials used, manufacturing methods, inspection standards in the workshop, quality control system, etc., for the raw materials listed in the following **(1)** to **(4)** and execute tests and inspections specified in this Chapter on the test samples designated by the Society. Where the test samples have passed these tests and inspections, they are dealt with as the approved materials:

(1) Fibreglass reinforcements,

(2) Resins for laminates,

(3) Core materials for sandwich construction, and

(4) Structural adhesives.

### 4.2.2 Continuation of Approval

The raw material manufacturer intending to obtain continuation of the approval, is subjected to periodical surveys, as a rule, at intervals not exceeding one year, in accordance with the requirements in the following **(1)** and **(2)**:

(1) Examinations of the materials used, manufacturing methods, inspection standards in the workshop, quality control system, etc.

(2) Tests and inspections designated by the Society.

### 4.2.3 Withdrawal of Approval

In case where the approved materials correspond to either one of those specified in the following **(1)** to **(3)**, the approval of material by the Society is to be withdrawn:

(1) When the materials used, manufacturing methods, inspection standards in the workshop, quality control system, etc., are worse than those at the time of approval and deemed inadequate,

(2) When the approved materials have not passed the specified periodical inspections,

(3) When the specified periodical inspections are not carried out.

## 4.3 Raw Materials, etc.

### 4.3.1 Test and Inspections of Fibreglass Reinforcements

**1** The tests and inspections specified in **4.1.2** for fibreglass reinforcements to be used for the full structures of *FRP* ships are to be in accordance with the requirements in the following **-2** to **-4**. In this case, the procedures of tests and inspections are to be in accordance with the discretion of the Society.

**2** Chopped mats are to be tested and inspected on the items listed in the following **(1)** to **(5)**:

(1) Appearance,

(2) Weight per unit area and its maximum deviation,

(3) Ratio in weight of residual binders (including sheafing agents),

(4) Bending strength and modulus of bending elasticity obtained from laminated test specimens (in the standard condition).

(5) Tensile strength and modulus of tensile elasticity obtained from laminated test specimens (in the standard condition).

**3** Roving cloths are to be tested and inspected on the items listed in the following **(1)** to **(6)**:

(1) Appearance,

(2) Weight per unit area and its maximum deviation,

(3) Ratio in weight of residual sheafing agents,

(4) Tensile strength of fibreglasses,

(5) Bending strength and modulus of bending elasticity obtained from laminated test specimens (in the standard condition),

(6) Tensile strength and modulus of tensile elasticity obtained from laminated test specimens (in the standard condition).

**4** Roving for spray lay-up are to be tested and inspected on the items listed in the following **(1)** to **(5)**:

(1) Appearance,

(2) Weight per unit area and its maximum deviation,

(3) Ratio in weight of residual sheafing agents,

(4) Bending strength and modulus of bending elasticity obtained from laminated test specimens (in the standard condition),

(5) Tensile strength and modulus of tensile elasticity obtained from laminated test specimens (in the standard condition).

**4.3.2 Tests and Inspections of Resins for Laminating**

The tests and inspections specified in 4.1.2 for resins for laminating to be used for hull structures of *FRP* ships are to be carried out on the items listed in the following **(1)** to **(9)**. In this case, the procedures of tests and inspections are to be in accordance with the discretion of the Society.

(1) Viscosity and thixotropy,

(2) Gel time, the minimum cure time and the peak exotherm temperature,

(3) Acid value,

(4) Water absorption rate of cats test specimens,

(5) Tensile elongation and tensile strength of cast test specimens,

(6) Load deflection temperature of cast test specimens,

(7) Barcol hardness obtained from laminated test specimens,

(8) Bending strength and modulus of bending elasticity obtained from laminated test specimens (in the standard condition),

(9) Tensile strength and modulus of bending elasticity obtained from laminated test specimens (in the standard condition),

**4.3.3 Fillers**

With regard to the fillers newly mixed with the *FRP* by the users in order to improve the properties such as abrasion resistance, fire resistance, etc. the data concerning the purpose for application, kind of filler, amount used, etc. are to be submitted to the Society.

**4.3.4 Sclerotics and Accelerators**

The type and amount used of the sclerotics and accelerators are to be carefully selected so that they are suitable for resins for laminating and gelcoats and set in proper time without generating excessive local heat.

**4.3.5 Tests and Inspections of Core Materials for Sandwich Construction**

**1** The tests and inspections specified in 4.1.2 of core materials for sandwich construction used for the hull structures of *FRP* ships are to be in accordance with the following -2 and -4. In this case, the procedures of tests and inspections are to be at the discretion of the Society.

**2** Hard plastic foams are to be tested and inspected on the items listed in the following **(1)** to **(7)** :

(1) Specific gravity,

(2) Compressive strength and modules of compressive elasticity,

(3) Softening rate,

(4) Water absorption,

(5) Tensile strength and modulus of tensile elasticity (only in case where the cores are reckoned in tensile strength),

(6) Bending strength and modulus of bending elasticity (only in case where the cores are reckoned in bending strength),

(7) Shearing strength obtained from specimens of sandwich construction.

**3** Cores of balsa are to be tested and inspected on the items listed in the following **(1)** to **(3)** :

(1) Specific gravity and moisture content,

(2) Compressive strength and modulus of compressive elasticity in the direction of fibre,

(3) Shearing strength obtained from specimens of sandwich construction.

**4** Timbers and plywoods are to be tested and inspected on the items in the following **(1)** to **(4)** :

(1) Compressive strength and modules of compressive elasticity,

(2) Tensile strength and modulus of tensile elasticity (only in case where timbers of plywoods are reckoned in tensile strength).

(3) Bending strength and modules of bending elasticity (only in case where timbers or plywoods are reckoned in bending strength),

(4) Shearing strength obtained from specimens of sandwich construction.

#### 4.3.6 Timbers and Plywoods for Primary Structures*

**1** Timbers and plywoods for primary structures are to be reasonably free from knots, shakes, decays and other defects, and to have the properties suitable for the purpose of application.

**2** Timbers and plywoods for primary structures are to be well seasoned.

**3** Plywoods for primary structures are to be plywoods for structures which are deemed appropriate by the Society.

#### 4.3.7 Cores for Moulding*

**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 with.

#### 4.3.8 Tests and Inspections of Structural Adhesives

The tests and inspections specified in 4.1.2 for structural adhesives used for the hull structures of *FRP* ships are to be conducted for the following **(1)** to **(7)** items. However, the test and inspection methods are to be as deemed appropriate by the Society.

(1) Density,

(2) Viscosity,

(3) Glass transition temperature or durometer hardness,

(4) Cure shrinkage,

(5) Tensile shear strength,

(6) Tensile shear fatigue strength, and

(7) Peel strength.

### 4.4 *FRP*

#### 4.4.1 General

The material 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 Chapter.

#### 4.4.2 Tests and Inspections of *FRP*

*FRP* is to be tested in accordance with the requirements in 4.4.4 and 4.4.5 in the presence of the Surveyor.

#### 4.4.3 Omission of *FRP* Material Tests and *FRP* Strength Tests

**1** For a sister ship of others which were or are being built at the same workshop, the *FRP* material tests and *FRP* strength test may be omitted, notwithstanding the requirements in 4.4.2, 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 4.4.4.

#### 4.4.4 *FRP* Material Tests*

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

**2** The test specimens for *FRP* material tests are to be cut form *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 **(1)** and **(2)**. 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) Barcol hardness,
  (c) Glass content (ratio in weight),
  (d) Bending strength,
  (e) Modulus of bending elasticity,
  (f) Tensile strength,
  (g) 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.

**3** The *FRP* material tests are to be carried out, at least on the structural members listed in the following **(1)** to **(4)**. 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 1.3.4-2.

(1) Bottom shell laminates,
(2) Side shell laminates,
(3) Upper deck laminates,
(4) Bulkhead (only of sandwich construction).

**4** The results of *FRP* material tests containing the items listed in the following **(1)** to **(10)** are to be submitted to the Society.

(1) Names of fibreglass reinforcements, resins for laminating and cores for sandwich construction,
(2) Names and amount of application of fillers,
(3) Names and amount of application of sclerotics 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.

**5** The number of test specimens subjected to the *FRP* material tests 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.

**6** The result of *FRP* material tests is not to be less than the strength specified in 1.3.4 for *FRP* laminates and not to be less than the value obtained from the tests specified in 4.2.1 or 4.3.5 for sandwich laminates.

### 4.4.5 *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 undergo tests and inspections on the items specified in 4.4.4-2 and -3. And further, the testing procedure and location of selection of test specimens are to be at the discretion of the Society.

**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 4.4.4-4 and the location of selection of test specimens.

**4** The number of test specimens for *FRP* strength tests and the determination of test results are to be in accordance with the provisions in 4.4.4-5.

**5** Where the results of *FRP* strength tests are less than those of *FRP* material tests in 4.4.4, the structural members are to be

properly strengthened.

# Chapter 5 MOULDING

## 5.1 General

### 5.1.1 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.

### 5.1.2 Supervision over Moulding

Moulding of *FRP* is to be carried out under the supervision of a well-experienced techinical expert.

### 5.1.3 Curing of Mouldings

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.

### 5.1.4 Supporting of Moulding

After released from the mould, the mouldings are to be supported by proper means.

### 5.1.5 Blending Proportion

**1** The blending proportion between curing agents and accelerators is to be determined suitable for obtaining *FRP* of good quality, in consideration of the environmental conditions of laminating shops, such as temperature, relative humidity, etc. and also the pot life and mat life resins.

**2** The blending proportion of the base resin and curing agents of structural adhesives is to be the value specified by the structural adhesive manufacturer.

### 5.1.6 Operation Manual

Before moulding, examinations are to be made in detail with respect to the items listed in the following **(1)** to **(5)** and moulding is to be proceeded on the basis of such examinations.

(1) Environmental conditions, controlling system thereof, pot life and curing time of resins.

(2) Operation procedure, scheduled operation process and working hours,

(3) Kinds, cutting methods, overlap of joints, edge preparation and number of plies of fibreglass reinforcements,

(4) Kinds, amount, blending quantity at one time and blending procedures of resins used,

(5) Kinds, amount used, application methods and adhesive layer thicknesses of structural adhesives.

### 5.1.7 Environmental Conditions of Laminating Shops

**1** The temperature while laminating is to be kept suitable for the resins used. The temperature is, however, not to be lower than 15℃.

**2** The humidity while laminating is preferable to be not lower than 60%, but not higher than 80%.

**3** Dusts, rubbishes and detrimental fumes in the laminating shops are to be cleared off as far as practicable.

### 5.1.8 Environmental Conditions of Work Spaces Using Structural Adhesives

**1** The temperature and humidity of work spaces using structural adhesives are to be suitable for the use of the structural adhesives.

**2** Trash, dust and harmful gases, etc. within the work space are to be eliminated as much as possible.

**3** Careful consideration is to be given so that structural members are not subjected to direct sunlight.

### 5.1.9 Gelcoats

**1** Gelcoat resins are to be evenly coated or sprayed.

**2** The standard thickness of gelcoat film is approximately 0.5 *mm*.

### 5.1.10 Moulding of Structural Members

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.

### 5.1.11 Sanding

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

#### 5.1.12 Cut Edges of Laminates

The cut edges of laminates, holes for bolts, etc. are to be thoroughly covered with resin so that the fibreglass reinforcements are not exposed.

#### 5.1.13 Mould Releasing

**1** Mould releasing operation is to be carefully carried out lest permanent deformations and damages harmful to the hull laminates should be caused.

**2** After releasing, the hull laminates are to be supported by an area as wide as practicable so that they are subjected to a uniform load.

### 5.2 Hand Lay-up Method

#### 5.2.1 Seams of Fibreglass Reinforcements

Fibreglass reinforcements are to be arranged so as to have seams of reinforcements as few as practicable. The overlap at seams is not to be less than 50 *mm*. The centre lines of overlaps of two adjacent plies are not be less than 100 *mm* apart from each other so far as no obstruction exist for the work.

#### 5.2.2 Degassing

In laminating, after having the fibreglass reinforcements thoroughly impregnated with resin, air bubbles in the resin are to be removed by degassing rollers or rubber pallets. However, excessive squeezing of resins is not desirable and care is to be taken to keep the glass content proper.

#### 5.2.3 Glass Content

**1** 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.

**2** The aggregated weight of roving cloths is to be 25% to 60% of the total weight of glass. Where, however, special fibreglass reinforcements are used, the weight is to be in accordance with the discretion of the Society.

#### 5.2.4 Laminating

Where the successive laminating is interrupted in such a case of laminating 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.

#### 5.2.5 Laminating for Final Ply

As for laminating for the final ply, effective measures to cure the outer surface are to be provided.

### 5.3 Spray Lay-up Method

#### 5.3.1 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.

#### 5.3.2 Moulding of Primary Structural Members

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 approved by the Society.

### 5.4 Moulding of Sandwich Construction

#### 5.4.1 Cores

**1** 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.

**2** 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*.

### 5.4.2 Surface Treatment of Cores

In moulding of sandwich construction, the surface of cores is to be properly treated in order to obtain sufficient bonded connection between the *FRP* layer and the core.

## 5.5 Bonding and Fastening

### 5.5.1 Bonding*

**1** In cases where bonding using fiberglass reinforcements with resins is carried out, the following **(1)** to **(5)** requirements are to be complied with:

(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) Bonding is to be executed paying careful attention not to cause spring back of fibreglass reinforcements.

(3) Bonding is to be carefully executed so as not to cause any deformation due to excessive exothermic effect.

(4) Bonding is to be carefully carried out so as not to cause strength discontinuity at the joint.

(5) *T*-joints and *L*-joints are to be laminated at the site.

**2** In cases where bonding is carried out using structural adhesives, the following **(1)** to **(7)** requirements are to be complied with:

(1) Blending of base resins and curing agents is to be carefully carried out so as not to cause any air bubbles in the adhesive layer.

(2) Before bonding is carried out, effective preparations such as sanding the surface to be bonded and thoroughly removing any oils and sanding dust are to be performed as needed.

(3) Bonding is to be carefully carried out so as not to cause any condensation on the adhesive surface.

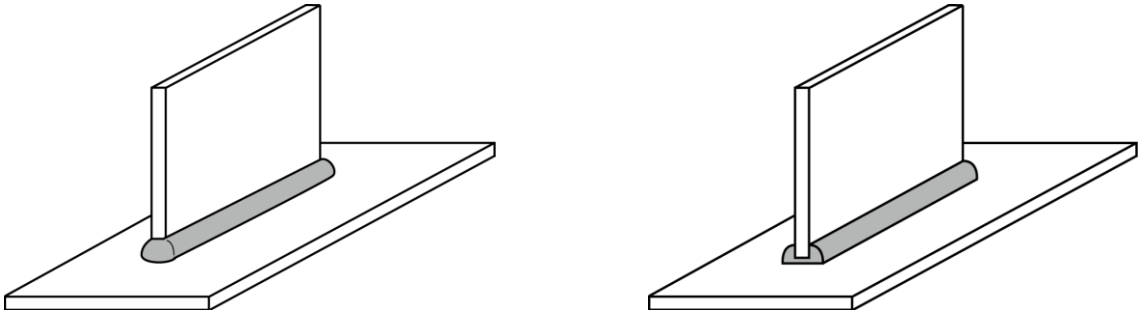
(4) Bonding is to be carefully carried out so as not to cause any spring back of structural members.

(5) Bonding is to be carefully carried out so as not to affect adhesive properties due to excessive exothermic effects.

(6) Bonding is to be carefully carried out so as not to cause any discontinuities in adhesive strength, except for cases where specified in **5.6.1-2(2)**. In addition, joint edges are to be appropriately treated as shown in **Fig. 5.1**.

(7) Until structural adhesives sufficiently cured, adhesive joints are to be appropriately fixed to prevent any deformation.

Fig. 5.1 End Treatment of Joints



(a) Example of Appropriately Treated End

(b) Example of Inappropriately Treated End

### 5.5.2 Fastening

**1** Where laminates are connected each other or where metallic fittings are fastened to laminates, mechanical fastening may be applied. In this case, the fasteners such as bolts, rivets, screws, etc. are to be sea-water-corrosion-resistant metal or to be properly protected against corrosion.

**2** 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.

#### 5.5.3 Bolts

**1** 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.

**2** Where bolts are used, washers are to be used on the surface of laminate.

#### 5.5.4 Connection of Sandwich Laminates

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.

#### 5.5.5 Watertight Construction

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.

### 5.6 Bonded Connections

#### 5.6.1 *T*-joints

**1** In cases where fiberglass reinforcements with resins are used, *T*-joints are to be in accordance with the following requirements:

(1) The overlap width of *T*-joints of structural members are generally to be in accordance with **Fig. 5.2**.

(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. 5.2**.

(3) The form of laminating of *T*-joints is to be as shown in **Fig. 5.3(a)** and **Fig. 5.3(b)**.

(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. 5.4(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. 5.4(b)** or the corners are to be sufficiently laminated by filling with soft resin puttys or other similar materials as shown in **Fig. 5.4(c)**.

**2** In cases where structural adhesives are used, *T*-joints are to be in accordance with the following requirements:

(1) Standard shapes and dimensions of *T*-joint structures are shown in **Fig. 5.5**. In the case of other joint shapes and dimensions, adhesive properties are to be considered and sufficient adhesion areas to account for loads and vibrations are to be provided.

(2) Where members which are subjected to considerably heavy loads or vibrations such as engine girders, bulkheads, etc. are connected, careful consideration is to be given to arranging such structural members on top of laminates whose thickness is increased as shown in **Fig. 5.4(a)**.

Fig. 5.2 Dimensions of Overlap of *T*-joints

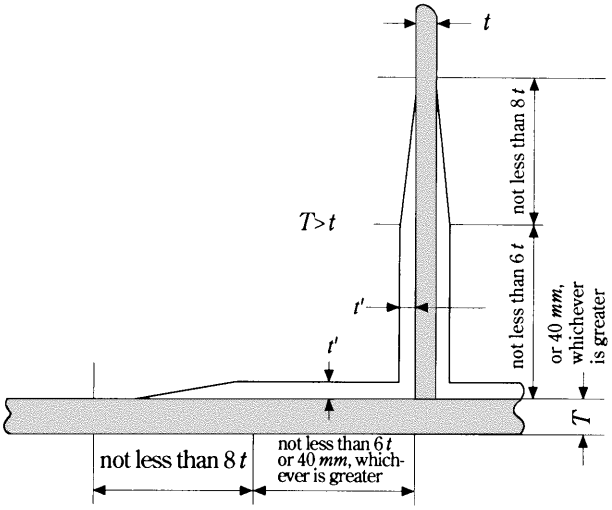
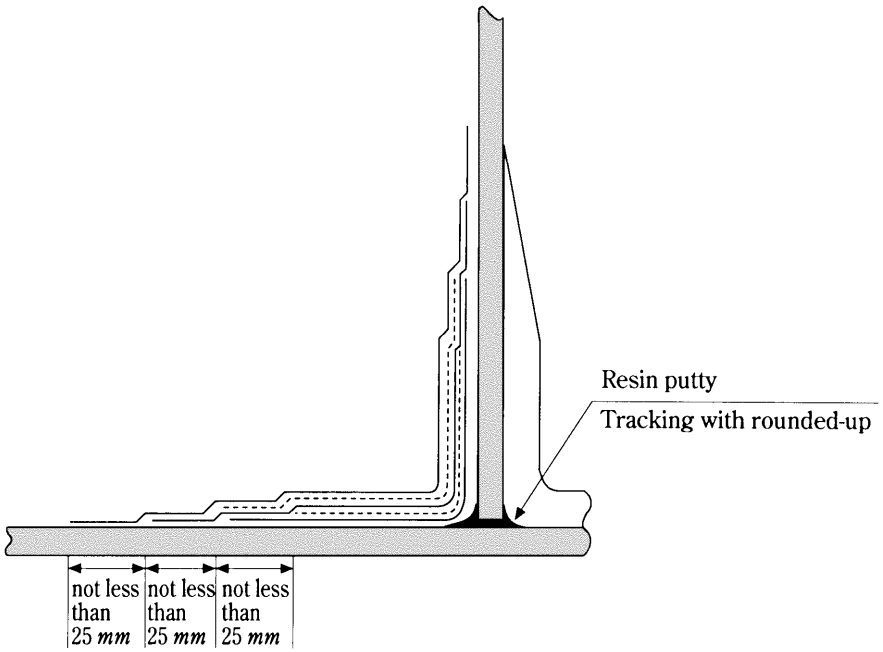



Fig. 5.3(a) In Case Chopped Mats and Roving Cloths are jointly Used




(a) Solid lines indicate chopped mat layers and dotted lines indicate roving cloth layers.
(b) Roving cloth layers are not to overlap each other.
(c) The first and final layers are to be a chopped mat layer.

Fig. 5.3(b) In Case Chopped Mats are Used

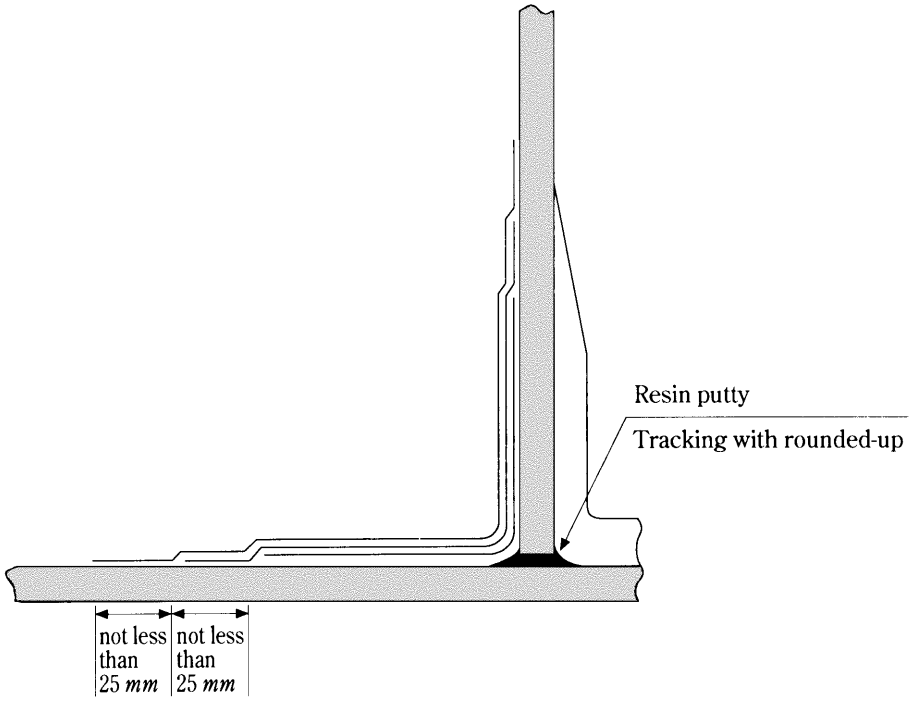



Fig. 5.4(a) In Case Consideration is to be Paid to Load or Vibration

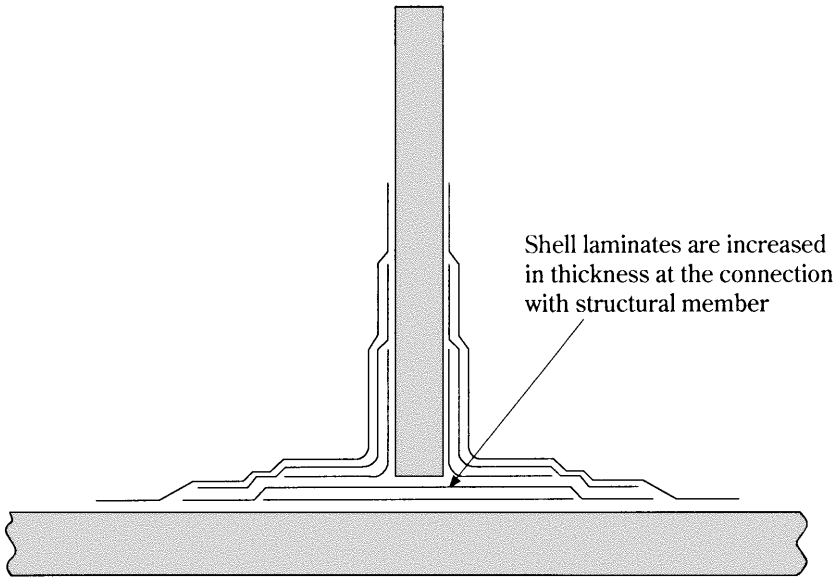


Fig. 5.4(b) Standard Form of *T*-joints

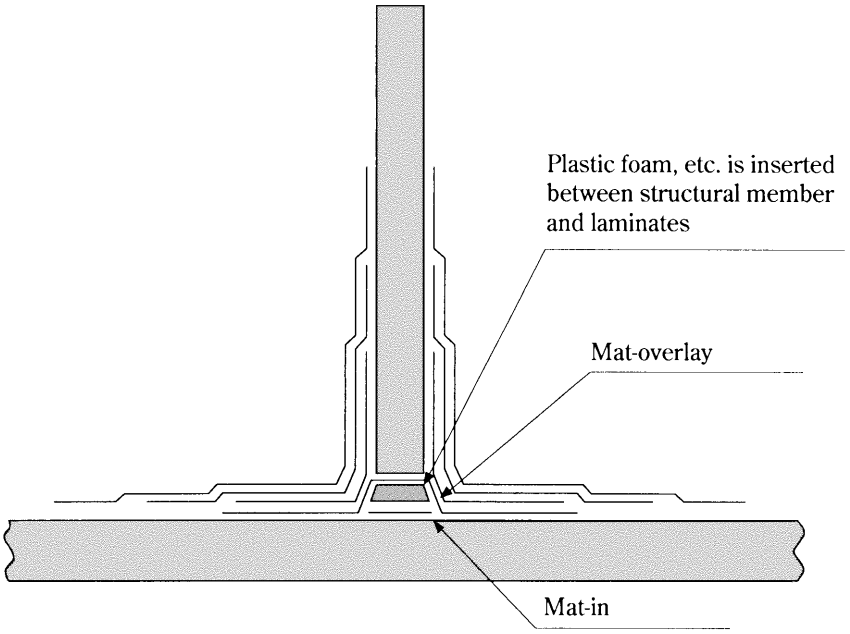



Fig. 5.4(c) Standard Form of *T*-joints

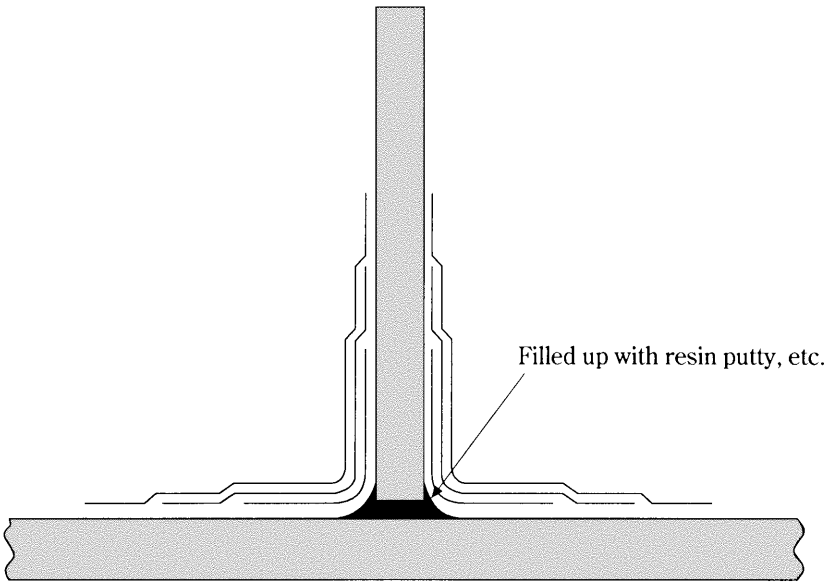
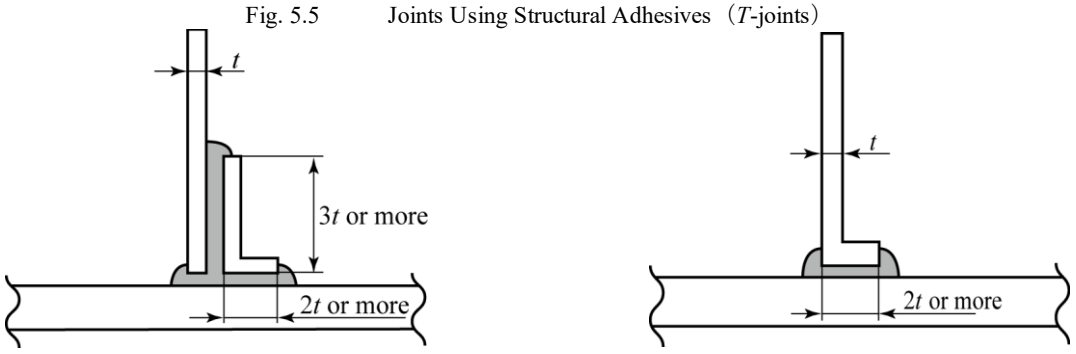
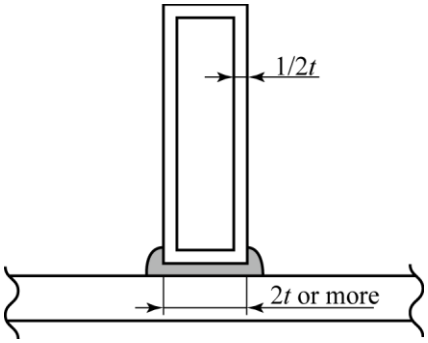


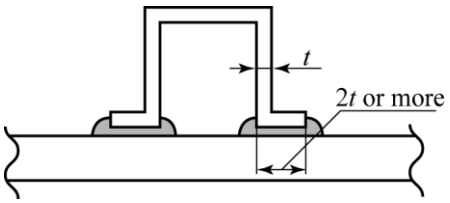
Fig. 5.5 Joints Using Structural Adhesives（*T*-joints）



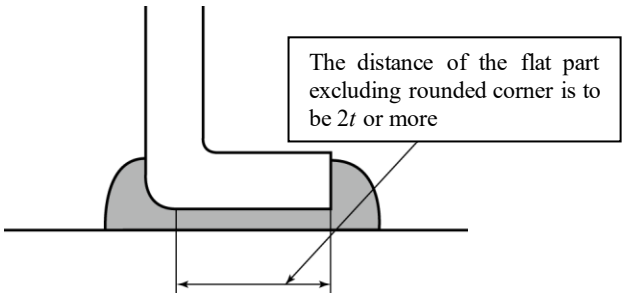

(a) Single Skin Bonding




(b) Plywood Sandwich Bonding




(c) Hat Shaped Structure Bonding




(d) Enlarged View of Rounded Corner

**5.6.2 *L*-joints***

*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, careful consideration is to be paid to the construction of the joints.

**5.6.3 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, scarph joints may be used.

**2** In the butt joints of deck laminates, joints other than scarph joints of *V*-type or *X*-type are not to be used.

# Chapter 6 LONGITUDINAL STRENGTH

## 6.1 Longitudinal Strength

### 6.1.1 Section Modulus of Athwartship Section

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

$CL^2B_W(C_b + 0.7)$ $(cm^3)$

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 $LB_W d$.

### 6.1.2 Moment of Inertia of Athwartship Section

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

$4.2ZL$ $(cm^4)$

where,

$Z$:Section modulus of the athwartship section specified in **6.1.1** $(cm^3)$.

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.

### 6.1.3 Calculation of Section Modulus of Athwartship Section*

The calculation of section modulus of the athwartship section is to be in a accordance with the requirement in the following **(1)** to **(4)**:

(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 athwartship 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) Timbers or structural plywoods are to be included in the calculation multiplying the sectional area by the ratio of the modulus of tensile elasticity of the relevant material to that of the *FRP*.

(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 $0.5L$ amidships, sufficient data with respect to the longitudinal strength and joints are to be submitted to the Society for approval.

### 6.1.4 Continuity of Strength

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

# Chapter 7 SHELL LAMINATES

## 7.1 General

### 7.1.1 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.

## 7.2 Keels

### 7.2.1 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 times $B$.

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

Thickness : $9+0.4L$ $(mm)$

## 7.3 Shell Laminates for Midship Part

### 7.3.1 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 :

$15S\sqrt{d+0.026L}$ $(mm)$

where,

$S$: Spacing of frames $(m)$.

### 7.3.2 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:

$15.8S\sqrt{d+0.026L}$ $(mm)$

where,

$S$: Spacing of frames $(m)$.

### 7.3.3 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:

$C_1S(d+0.026L)$ $(mm)$

$C_2t_f$ $(mm)$

where,

$t_f$ : Thickness in case of single skin construction specified in **7.3.1** or **7.3.2** $(mm)$.

$S$ : Spacing of frames $(m)$.

$C_1$ : Coefficient obtained from the following formula:

$$\frac{10C_3}{\tau_a}$$

$\tau_a$ : Shearing strength of sandwich laminates obtained from the test specified **4.2.1** or **4.3.5-2(7)**, **-3(3)** or **-4(4)** $(N/mm^2)$

$C_2$ and $C_3$ : As given in **Table 7.1**. For the intermediate values of a and b, $C_2$ and $C_3$ are to be obtained by linear interpolation.

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*:

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

where,

$S$ : Spacing of frames ($m$).

$C_4$ : Coefficient obtained from the following formula:

$$C_4 = \frac{1}{t_c}\frac{E_c}{E_f}\left(\frac{10}{\sigma_c}\right)^4$$

$E_f$ : Modulus of bending elasticity of inner layer or outer layer specified in **1.3.4** ($N/mm^2$).

$E_c$ : Modulus of compressive elasticity of core obtained from the test specified in **4.2.1**, **4.3.5-2(2)**, **-3(2)** or **-4(1)** ($N/mm^2$)

$\sigma_c$ : Compressive strength of core obtained from the test specified in **4.2.1**, **4.3.5-2(2)**, **-3(2)** or **-4(1)** ($N/mm^2$)

$t_c$ : Thickness of core ($mm$).

Table 7.1 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 |
| $C_2$ ($\alpha$=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 |

## 7.4 Shell Laminates for End Parts

### 7.4.1 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.

### 7.4.2 Strengthened Bottom Forward

The strengthened bottom forward is the part of flat bottom forward from the position specified in the following **(1)** to **(2)**. The flat bottom is the bottom whose slope measured at the respective athwartship sections (*See* **Fig. 7.1**) is not more than 15 degrees.

(1) Where $V/\sqrt{L}$ is not more than 1.5:

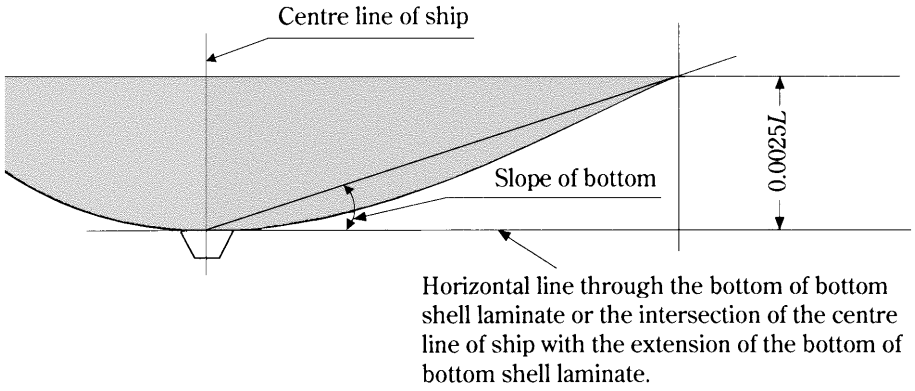
- 0.25$L$ from the fore end,

(2) Where $V/\sqrt{L}$ 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. 7.1 Slope of Bottom




### 7.4.3 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:

$CS\sqrt{L}$ $(mm)$

where,

$C$ : Coefficient given in **Table 7.2**. However, for the intermediate value of $\alpha$, $C$ is to be obtained 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 $S$.

**2** The thickness of shell laminates at strengthened bottom forward of sandwich construction is not to be less than obtained from the formula specified in **7.3.3-1**. However, in application of the formula, $C_3$ is to be taken as 1.8 *times* that given in **Table 7.1** and $t_f$ as the thickness of shell laminates specified in **7.3.3-1**.

**3** 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.

Table 7.2 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 |

## 7.5 Side Shell Laminates in way of Superstructures

### 7.5.1 Thickness of Shell Laminates

The side shell laminates in way of superstructures are to be in accordance with the requirements in the following **(1)** to **(2)**:

(1) The thickness of side shell laminates in way of superstructures for $0.25L$ 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.

(2) 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.

## 7.6 Local Strengthening of Shell Laminates

### 7.6.1 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 8 DECKS

## 8.1 General

### 8.1.1 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.

### 8.1.2 Watertightness of Decks

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

### 8.1.3 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.

## 8.2 Minimum Thickness of Deck Laminates

### 8.2.1 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:

$4.8S\sqrt{h}$ $(mm)$

where,

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

$h$: As specified in **8.2.3** $(kN/m^2)$.

**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:

$5.81S\sqrt{h}$ $(mm)$

where,

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

$h$: As specified **8.2.3** $(kN/m^2)$.

**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:

$4.2S\sqrt{h}$ $(mm)$

where,

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

$h$: As specified in **8.2.3** $(kN/m^2)$.

### 8.2.2 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:

$0.1C_1Sh$ $(mm)$

$C_2t_f$ $(mm)$

where,

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

$h$: As specified in **8.2.3** $(kN/m^2)$.

$t_f$: Thickness of deck laminates in case of single skin construction specified in **8.2.1** $(mm)$.

$C_1$ and $C_2$: As specified in **7.3.3-1**.

**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*.

$$0.17\sqrt[3]{C_4(Sh)^4}\ (mm)$$

where,

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

$h$ : As specified in **8.2.3** ($kN/m^2$).

$C_4$ : As specified in **7.3.3-2**.

**8.2.3 Deck Load h***

**1** Deck load $h$ for decks intended to carry cargoes, etc. is to be as specified in the following **(1)** to **(3)** :

(1) For decks intended to carry cargoes and stores, $h$ is to be 7 times the tween deck height at side in *metres* from the deck to the deck immediately above it ($kN/m^2$), or cargo weight per unit area of the deck ($kN/m^2$), 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 ($kN/m^2$) or the value stipulated in **-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 deckhouses, $h$ is to be 4.5 ($kN/m^2$).

**3** For weather decks, h is to be as specified in the following **(1)** and **(2)**.

(1) For weather decks afore $0.3L$ from the fore end:

$0.50L+4.5$ ($kN/m^2$)

(2) For weather decks abaft $0.3L$ from the fore end:

$0.26L+4.5$ ($kN/m^2$)

## 8.3 Local Compensation of Decks

**8.3.1 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.

**8.3.2 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.

**8.3.3 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.

**8.3.4 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 9 FRAMES

## 9.1 General

### 9.1.1 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 in creasing the scantlings of frames or by providing web frames additionally.

### 9.1.2 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.

## 9.2 Construction

### 9.2.1 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.

### 9.2.2 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.

## 9.3 Spacing of Frames

### 9.3.1 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*.

### 9.3.2 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.

## 9.4 Frames

### 9.4.1 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:

$32Shl^2$ ($cm^3$)

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 0.25*L* from the fore end, *L* is to be measured at midship. For frames between 0.25*L* and 0.15*L* from the fore end, *l* is to be measured at 0.25*L* 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 0.5*D* (*m*), *h* is to be taken as 0.5*D* (*m*).

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

$37.5Shl^2$ ($cm^3$)

where,

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

**9.4.2 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:

$49Shl^2$ $(cm^3)$

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**.

**9.4.3 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.

**9.4.4 Hat-type Construction**

With respect to the scantlings of frames of hat-type construction, the requirements in **1.3.5**, in addition to the requirements in this chapter, are to be applied.

# Chapter 10 BOTTOM CONSTRUCTION

## 10.1 General

### 10.1.1 Application

**1** The requirements is 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 **10.6**, and, in addition, the structural members of double bottoms are to be constructed with special care.

## 10.2 Centre Girders

### 10.2.1 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:

$0.4L+4.7$ ($mm$)

**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:

Thickness : $0.4L+4.7$ ($mm$)

Breadth : $4L+30$ ($mm$)

**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 then 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.

## 10.3 Side Girders

### 10.3.1 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.

### 10.3.2 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:

$0.3L+3.5$ ($mm$)

**2** 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, bayond 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:

$3.2L+24$ ($mm$)

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

### 10.3.3 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 **10.2.1-2** and **-3**, respectively.

## 10.4 Floors

### 10.4.1 Arrangement and Scantlings

**1** 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:

$62.5b$ $(mm)$

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:

$0.4L$ $(mm)$

**2** Beyond $0.5L$ 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 **10.7.2**.

**3** 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 **10.2.1-2**.

### 10.4.2 Section Modulus of Floors

**1** 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.

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

$15.4SDb^2$ $(cm^3)$

where,

$S$: Spacing of floors $(m)$.

$b$: As specified in **10.4.1-1**.

**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**.

### 10.4.3 Floor Plates Forming Part of Bulkheads

Floor plates forming part of bulkheads are to be in accordance with the requirements for watertight bulkheads in **Chapter 13** and those for deep tanks in **Chapter 14** in addition to those in this chapter.

## 10.5 Bottom Longitudinals, etc.

### 10.5.1 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.

### 10.5.2 Spacing of Bottom Longitudinals

The standard spacing of bottom longitudinals is 500 *mm*.

### 10.5.3 Section Modulus of Bottom Longitudinals

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

$55.6Shl^2$ $(cm^3)$

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 $0.5D$ $(m)$.

### 10.5.4 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 10.4.1 and 10.4.2.

## 10.6 Double Bottoms

### 10.6.1 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 10.6.2 to 10.6.6.

**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 Chapter 14.

**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.

### 10.6.2 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 10.2.1.

### 10.6.3 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 10.3.2.

### 10.6.4 Floors

**1** Floors are to be fitted at every frame.

**2** The scantlings of floors are to be in accordance with the requirements in 10.4.1.

**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 watertight bulkheads in Chapter 13, in addition to those in this chapter.

### 10.6.5 Inner Bottom Laminates

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

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

where,

$S$: Spacing of floors ($m$).

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

### 10.6.6 Bottom Longitudinals

**1** The construction, scantlings and spacing of bottom longitudinals are to be in accordance with the requirements in 10.5.1, 10.5.2, 10.5.3 and 10.8.

**2** The construction and scantling of longitudinals provided on the inner bottom laminates are to be in accordance with the discretion of the Society.

## 10.7 Construction of Strengthened Bottom Forward

### 10.7.1 Part to be Strengthened

Strengthened bottom forward is the part specified in 7.4.2.

### 10.7.2 Construction and Scantlings

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

## 10.8 Hat-type Construction

### 10.8.1 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 **10.2.1-2**, **10.3.2-1** and **10.4.1** 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 **10.2.1-3** and **10.3.2-2** respectively.

**3** The section modulus of floors and bottom longitudinals of hat-type construction are not to be less than the values specified in **10.4.2** and **10.5.3** respectively.

**4** The scantlings of structural members of hat-type construction are to be in accordance with the requirements in **1.3.5**, in addition to those in the preceding **-1** to **-3**.

# Chapter 11 BEAMS

## 11.1 Beams

### 11.1.1 Arrangement of Transverse Beams

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

### 11.1.2 Camber of Weather Deck

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

### 11.1.3 Section Modulus of Beams*

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

$CShl^2$ ($cm^3$)

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

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

$C$:Coefficient given below:

Longitudinal beams

- Midship part·····3.4
- Elsewhere·····2.9
- Transverse beams····2.9

$h$:As specified in 8.2.3 ($kN/m^2$). Where, however, the value is as specified in 8.2.3-3, $h$ is to be as specified in the following:

- Afore $0.3L$ from the fore end

  $0.32L+4.5$ ($kN/m^2$)
- Abaft $0.3L$ from the fore end

  $0.16L+4.5$ ($kN/m^2$)

### 11.1.4 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 9.4.1.

### 11.1.5 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.

### 11.1.6 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.

### 11.1.7 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.

### 11.1.8 Hat-type Construction

The scantlings of beams of hat-type construction are to be in accordance with the requirements in 1.3.5, in addition to those in this chapter.

# Chapter 12 UNDER-DECK GIRDERS AND PILLARS

## 12.1 Under-deck Girders

### 12.1.1 Arrangement

**1** At places where beams need to be supported, under-deck 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.

### 12.1.2 Construction of Girders

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

### 12.1.3 Section Modulus of Girders

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

$Cbhl^2$ ($cm^3$)

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. 12.1**)

$l$ : Distance between the supporting points of girders ($m$). (*See* **Fig. 12.1**)

$h$ : As specified in **8.2.3** ($kN/m^2$). Where, however, $h$ is to be in accordance with the requirements in **8.2.3-3**, $h$ is to be as specified in the followings

- Afore 0.3$L$ from the fore end:

  0.13$L$+4.5 ($kN/m^2$)

- Abaft 0.3$L$ from the fore end:

  0.11$L$+4.5 ($kN/m^2$)

$C$ : Coefficient given below:

- Midship part・・・・・・・・4.3
- Elsewhere・・・・・・・・・・3.4

### 12.1.4 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 under-deck 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.

### 12.1.5 Hat-type Construction

The scantlings of under-deck girders of hat-type construction are to be in accordance with the requirements in **1.3.5**, in addition to those in this chapter.

## 12.2 Pillars

### 12.2.1 Application

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

### 12.2.2 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.

### 12.2.3 Sectional Area of Pillars

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

$$\frac{0.223Sbh}{2.72-\frac{l_0}{k_0}} \ (cm^2)$$

where,

$S$ : Distance between the mid-points of the spaces from the pillar to the adjacent pillars or to the bulkhead ($m$). (*See* **Fig. 12.1**)

$b$ : 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. 12.1**)

$h$ : As specified in **12.1.3**.

$l_0$ : Distance from the lower end of pillar to the lower surface of girder or beam supported by the pillar ($m$). (*See* **Fig. 12.1**)

$k_0$ : Value obtained from the following formula:

$$\sqrt{\frac{I}{A}}$$

$I$ : Minimum moment of inertia of pillar ($cm^4$).

$A$ : Sectional area of pillars ($cm^2$).

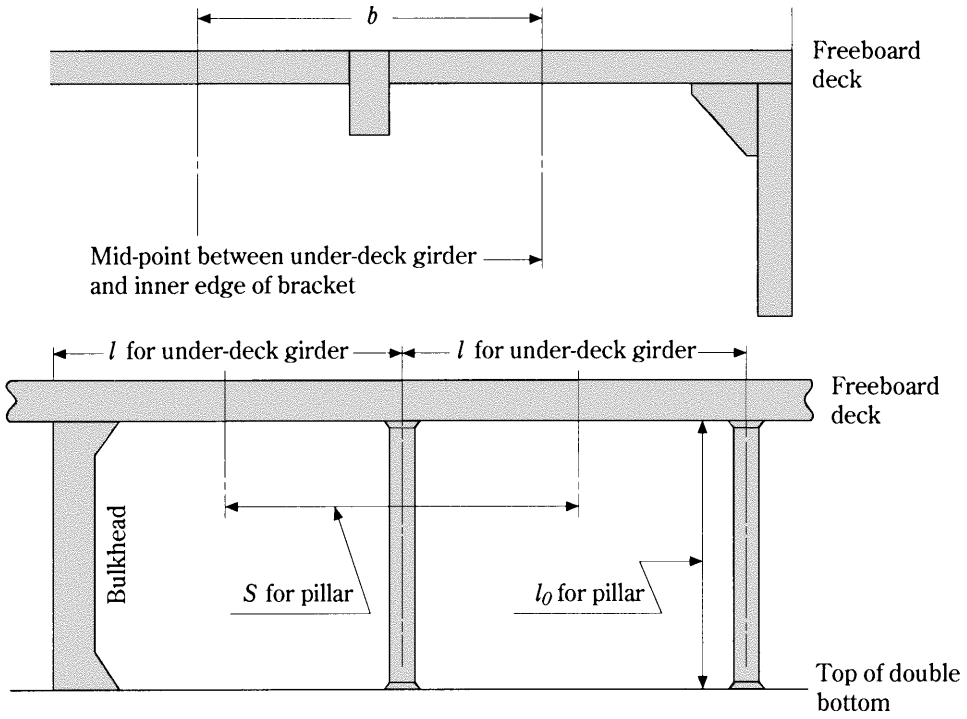
**2** The sectional area of pillars which are made of wood, is not to be less than obtained from the following formula:

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

where,

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

Fig. 12.1 Measurement of $b$, $l$, $S$ and $l_0$



# Chapter 13 WATERTIGHT BULKHEADS

## 13.1 Arrangement of Watertight Bulkheads

### 13.1.1 Collision Bulkheads

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

### 13.1.2 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.

### 13.1.3 Bulkheads of Machinery Space

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

### 13.1.4 Height of Watertight Bulkheads

The watertight bulkheads required in 13.1.1 to 13.1.3 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 $0.25L$ 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 13.1.1 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.

### 13.1.5 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.

## 13.2 Construction of Watertight Bulkheads

### 13.2.1 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:

$12S\sqrt{h}$ $(mm)$

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.

### 13.2.2 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:

$C_1Sh$ $(mm)$

$C_2t_f$ $(mm)$

where,

$t_f$ : Thickness in case of single skin construction specified in 13.2.1 $(mm)$.

$S$ : Spacing of stiffeners $(m)$.

$h$ : As specified in **13.2.1** ($m$).

$C_1$ and $C_2$: As specified in **7.3.3-1**.

**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 $mm$.

$3.6\sqrt[3]{C_4(Sh)^4}$ $(mm)$

where,

$S$ : Spacing of stiffeners ($m$).

$h$ : As specified in **13.2.1** ($m$).

$C_4$ : As specified in **7.3.3-2**.

**13.2.3 Bulkhead Laminates of Structural Plywood***

Where structural plywoods are used for bulkhead plates, the thickness of plywoods is not to be less than specified by the requirements in **13.2.1** multiplied by the coefficient given in **1.3.4-2(1)**. However, $\sigma_B$ is to be taken as bending strength ($N/mm^2$) of plywoods.

**13.2.4 Bulkheads Stiffeners**

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

$CShl^2$ $(cm^3)$

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:

- Where the both ends of stiffeners are attached by brackets‥‥‥20
- Where the ends of stiffeners are snipped‥‥‥30

**13.2.5 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:

$34Shl^2$ $(cm^3)$

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.

**13.2.6 Hat-type Construction**

The scantlings of bulkhead stiffeners and girders of hat-type construction are to be in accordance with the requirements in **1.3.5**, in addition to those in this chapter.

# Chapter 14 DEEP TANKS

## 14.1 General

### 14.1.1 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.

### 14.1.2 Earthing

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

### 14.1.3 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 flashpoint below 60℃ 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 flashpoint below 60℃ is to be in accordance with the discretion of the Society.

### 14.1.4 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 proceding **-2**, the scantlings of structural members specified in this chapter are to be properly increased.

### 14.1.5 Consideration for Watertightness of Tanks

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

### 14.1.6 Consideration for Structural Adhesives

The adhesive properties of structural adhesives used for deep tanks are not to be harmfully affected by liquids being carried in the tanks.

## 14.2 Bulkhead Laminates of Deep Tanks

### 14.2.1 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:

$13S\sqrt{h}\ (mm)$

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 ($m$).

### 14.2.2 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:

$C_1Sh\ (mm)$

$C_2t_f\ (mm)$

Where,

$t_f$ : Thickness in case of single skin construction specified in **14.2.1** ($mm$).

$S$ : Spacing of stiffeners ($m$).

$h$ : As specified in **14.2.1** ($m$).

$C_1$ and $C_2$:As specified in **7.3.3-1**.

**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 $mm$.

$$3.6\sqrt[3]{C_4(Sh)^4} \quad (mm)$$

where,

$S$ : Spacing of stiffeners ($m$).

$h$ : As specified in **14.2.1** ($m$).

$C_4$ : As specified in **7.3.3-2**.

**14.2.3 Bulkhead Laminates of Structural Plywood***

Where structural plywood are used for bulkhead plates, the thickness of plywoods is not to be less than specified by the requirements in **14.2.1** multiplied by the coefficient given in **1.3.4-2(1)**. However, $\sigma_B$ is to be taken as bending strength ($N/mm^2$) of plywoods.

**14.2.4 Bulkhead Stiffeners**

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

$$CShl^2 \quad (cm^3)$$

where,

$S$ and $l$:As specified in **13.2.4**.

$h$ : 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:

・Where the both ends of stiffeners are attached by brackets・・・・・・28

・Where the ends of stiffeners are snipped・・・・・・42

**14.2.5 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:

$$42Shl^2 \quad (cm^2)$$

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 ($m$).

**14.2.6 Hat-type Construction**

The scantlings of bulkhead stiffeners and girders of hat-type construction are to be in accordance with the requirements in **1.3.5**, in addition to those in this chapter.

**14.2.7 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.

## 14.3 Provisions for Deep Tanks

**14.3.1 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.

**14.3.2 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 matting-in connections in way of the parts required oiltight, the sparring or lining specified in **-3** may be omitted, except where specially required.

# Chapter 15 MACHINERY SPACES

## 15.1 General

### 15.1.1 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.

### 15.1.2 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.

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

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

### 15.1.4 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.

## 15.2 Construction under Main Engines

### 15.2.1 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.

**8** In cases where joints specified in -7 are moulded by structural adhesives, sufficient adhesion areas are to be provided.

# Chapter 16 SUPERSTRUCTURES AND DECKHOUSES

## 16.1 General

### 16.1.1 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.

## 16.2 Construction, etc.

### 16.2.1 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 16.1**. 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 16.1** below, multiplied by $S/500$

Table 16.1 Thickness of Plates and Scantlings of Stiffeners of Superstructure End Bulkheads and Deckhouse Boundary Wells

| *L* (*m*) | | Front wall | | Side and aft wall | |
|---|---|---|---|---|---|
| Over | Not more than | Thickness of boundary wall (*mm*) | Section modulus of stiffener ($cm^3$) | Thickness of boundary wall (*mm*) | Section modulus of stiffener ($cm^3$) |
| | 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 |

### 16.2.2 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 lease 380 *mm* above the upper surface of the deck.

# Chapter 17 HATCHWAY OPENINGS, MACHINERY OPENINGS AND OTHER DECK OPENINGS

## 17.1 General

### 17.1.1 Application

**1** The requirements in this chapter apply to *FRP* ships other than ones defined in **20.1.1-1**.

**2** *FRP* ships defined in **20.1.1-1** are to comply with the requirements in **14.6** and **14.7, Part 1, Part C of the Rules for the Survey and Construction of Steel Ships**.

## 17.2 Hatchway Openings

### 17.2.1 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 17.1**.

**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 proceeding **-1**, subject to the approval by the Society.

Table 17.1 Height of Hatch Coamings

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

### 17.2.2 Wooden Covers

Wooden covers are to be in accordance with the requirements in the following **(1)** to **(3)** :

(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 $kN/m^2$. In no case, however, is the finished thickness to be less than 48 *mm*.

$30S\ (mm)$

where,

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

(2) Materials for wooden covers are to be of good quality, straightgrained and reasonably free from knots, sapwood and shakes.

(3) The ends of wooden covers are to be protected by circling steel bands.

## 17.3 Machinery Openings

### 17.3.1 Protection of Machinery Openings

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

### 17.3.2 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)** to **(2)** :

(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 **16.2.1**.

(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 $cm^3$ 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 **16.2.2-1** and the height of sills above the upper surface of deck laminates is to be at least 380 $mm$.

### 17.3.3 Machinery Casings Provided in Enclosed Parts

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

### 17.3.4 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.

## 17.4 Companionway Openings and Other Deck Openings

### 17.4.1 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.

### 17.4.2 Companionways

**1** Companionways on the freeboard deck are to be protected by enclosed superstructures or by deckhouses or companions which have strength and weathertightness 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 **16.2.2-1**. And, the height of sills of the access openings above the surface of deck laminates is to be at least 380 $mm$.

### 17.4.3 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 18 BULWARKS, GUARDRAILS, FREEING ARRANGEMENT, SIDE OPENINGS, SCUTTLES, VENTILATORS AND GANGWAYS

## 18.1 General

### 18.1.1 General

**1** *FRP* ships defined in **20.1.1-1** are to comply with the requirements in **14.8** to **14.15, Part 1, Part C of the Rules for the Survey and Construction of Steel Ships**.

**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 19 MACHINERY

## 19.1 General

### 19.1.1 Application

Prime movers, power transmission system, shaftings, pressure vessels, auxiliaries, piping systems, electrical installations, computer-based systems, etc. are, as a rule, to be in accordance with the requirements in the relevant chapters in the **Rules for the Survey and Construction of Steel Ships**, except those specified in this chapter.

## 19.2 Installation of Propulsion Machinery, Fuel Oil Tanks and Earthing

### 19.2.1 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 bedplates 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 bedplates 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.

### 19.2.2 Fuel Oil Tanks*

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.

### 19.2.3 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.

# Chapter 20 LOAD LINES

## 20.1 General

### 20.1.1 Application

**1** Load lines of *FRP* Ships, $L_f$ of which is 24 *m* and over are to be in accordance with the requirements in **Part V of the Rules for the Survey and Construction of Steel Ships**.

**2** Notwithstanding preceding **-1** load lines of *FRP* Ships specified in following **(1)** to **(3)** are to be in accordance with the discretion of the Society.

(1) *FRP* Ships not engaged in international voyage

(2) Pleasure yachts not engaged in trade

(3) Fishing vessels

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# GUIDANCE FOR THE SURVEY AND CONSTRUCTION OF SHIPS OF FIBREGLASS REINFORCED PLASTICS

## Chapter 1 GENERAL

### 1.1 General

#### 1.1.1 Application

**1** Reductions in the scantlings of *FRP* Ships intended for Smooth Water Service are to be in accordance with the following:

(1) Reductions in the scantlings may be made at the ratios given in **Table 1.1.1-1**.

(2) Reductions in the scantlings other than those given in **Table 1.1.1-1** are to be in accordance with the discretion of the Society.

(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 1.1.1-2**.

**2** With respect to the provisions of the Rules, unless explicitly specified otherwise in the relevant requirements, distances regarding ship length, breadth, depth, and tank length, breadth, height, etc. are to be measured by using moulded dimensions. However, where the effects of plate thickness are not negligible, this requirement is not applicable. For the distance between an independent cargo tank and the hull construction, such distance is to be measured from the external face of the tank.

Table 1.1.1-1 Reductions in Scantlings

| Item | Ratio of reduction |
|---|---|
| Section modulus of athwartship hull section | 10% |
| Thickness of shell laminates(including keel) | 10% |
| Minimum thickness of deck laminates | 10% |
| Section modulus of frame | 15% |
| Section modulus of beam | 15% |
| Section modulus of deck girder | 15% |
| Thickness of single bottom or double bottom members | 10% |

Table 1.1.1-2 Sill Height of Hatchway, Access Opening, etc. (*mm*)

| Location | Still | | |
|---|---|---|---|
| | Small deck opening (area: $1.5m^2$ or below) | Companionway | Access opening in superstructure end bulkhead |
| Upon upper deck and superstructure deck within fwd $0.25L$ | 380 | 300 | 300 |
| Upon superstructure deck abaft the forward $0.25L_f$ | 230 | 100 | 100 |

## 1.2 Definitions

### 1.2.15 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)** to **(3)**.

(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)

(3) An operation of connecting the cured *FRP* laminates by applying and filling structural adhesives.

### 1.2.19 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.

## 1.3 General Rules for Hull Construction and Equipment

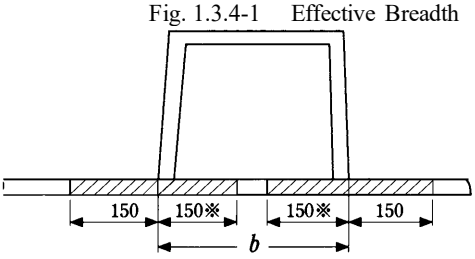
### 1.3.2 Stability

Stability is to comply with the requirements in **Part U of the Rules for the Survey and Construction of Steel Ships**.

### 1.3.4 Scantlings

The effective breadth of *FRP* laminates of Hat-type construction is to be as shown by hatched areas in **Fig.1.3.4-1**.

Fig. 1.3.4-1 Effective Breadth




Unit: *mm*

※ is to be $b/2$ at maximum

### 1.3.5 Hat-type Construction

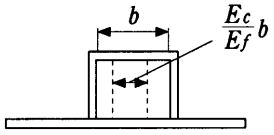
When the core for moulding of hat-type construction is reckoned in the section modulus, breadth of the core is to be calculated as $(E_C / E_f)b$ as shown in **Fig.1.3.5-1**. $E_C$ and $E_f$ are the modulus of bending elasticity of the core and *FRP* laminates respectively.

Pine and lauan··· 1.0

Plywood for structure··· 0.8

Other core material··· To be determined by the test specified in **4.3.7-2 of the Rules**.

Fig. 1.3.5-1 Inclusion of Core in Calculation




### 1.3.6 Sandwich Construction

When the core of sandwich construction is reckoned in bending strength, coefficient $C_2$ prescribed in **7.3.3-1 of the Rules** is to be determined by the following formula.

$$\frac{1}{\sqrt{1-\dfrac{1-E_C/E_f}{(1+\beta)^3}}}$$

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($N/mm^2$)

$E_C / E_f$ : The following values may be used:

Pine and lauan··· 1.0

Plywood for structure··· 0.8

Other core material··· To be determined by the test specified in **4.3.5-2 of the Rules**.

$\beta$ : as specified in **7.3.3-1 of the Rules**.

## 1.4 Preparation for Survey and Other Items

### 1.4.1 Procedure for Tests, Wear and Tear, etc.

With respect to **1.4.1 of the Rules**, surveyors are to confirm at periodical surveys that asbestos-free declarations and supporting documents are provided for any replaced or newly installed outfits, equipment, parts, etc. The wording "materials containing asbestos" means that asbestos is present in the product/material above the threshold value stipulated in Appendix 1 of *IMO* resolution *MEPC*.379(80).

# Chapter 2 CLASS SURVEYS

## 2.2 Classification Survey during Construction

### 2.2.1 Registration Surveys

With respect to **2.2.1-2 of the Rules**, surveyors are to confirm the asbestos-free declarations and supporting documents specified in **2.2.3-1(6) of the Rules**. The wording "materials containing asbestos" means that asbestos is present in the product/material above the threshold value stipulated in Appendix 1 of *IMO* resolution *MEPC*.379(80).

### 2.2.3 Plans and Documents to be Submitted for Reference

In cases where joints other than the standard joints shown in **Fig. 5.5 of the Rules** are applied, stress assessments using direct strength calculations such as finite element analysis, etc. are to be submitted for joints moulded by structural adhesives.

### 2.2.4 Inspections during Construction

**1** The wording "items specified otherwise by the Society" and the wording "survey methods which it considers to be appropriate" in **2.2.4-2(1)** and **(3) of the Rules** mean to be in accordance with the following **(1)** and **(2)** respectively:

(1) The wording "items specified otherwise by the Society" means surveys of the tests specified in **2.2.4-2(1)** and **(3) of the Rules**.

(2) The wording "the Society may approve other survey methods which it considers to be appropriate" means survey methods which it considers to be able to obtain information equivalent to that obtained through traditional ordinary surveys where the Surveyor is in attendance.

**2** The wording "items specified otherwise by the Society" in **2.2.4-3 of the Rules** means surveys of the tests specified in item 1, **Table B2.7, Part B of the Rules for the Survey and Construction of Steel Ships** and the wording "the Society may approve other survey methods which it considers to be appropriate" means to be in accordance with **-1(2)**.

# Chapter 4 MATERIALS FOR HULL

## 4.1 General

### 4.1.2 Raw Materials for Primary Structures

**1** The tests prescribed in **4.1.2** and **4.2 of the Rules** are to be carried out in accordance with the following requirements **-2** through **-6**.

**2** General rules for tests and inspection of raw materials for primary structures

(1) 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 Society in accordance with the "**Rules for Testing Machines**".

(2) 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±5℃, relative humidity=65±20%)

(3) Verification of materials

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

(4) 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.

(5) Test results

When the tests specified in this chapter are carried out, the test record describing the following **(a)** through **(i)** are to be submitted to the Society.

(a) Kind and brand name of raw materials tested

(b) The following raw materials used for the preparation of test specimens (excluding **(a)** above):

i) Kind and brand name of fibreglass reinforcements and resins for laminating

ii) Kind and blending ratio of fillers

iii) Kind and blending ratio of curing agents and accelerators

(c) Moulding method and moulding conditions

(d) Selection method of test specimens

(e) Date of moulding of test specimens and test date

(f) Test place and environmental conditions of the test place

(g) Type of testing machine

(h) Shape and dimensions of test specimens

(i) Test results

**3** Test and inspection of raw materials for primary structures

The test items at each test of raw materials for the primary structures are to be as given in **Table 4.1.2-1** to **Table 4.1.2-4**. Test procedures are to be in accordance with the requirements in **-4** to **-7**.

Table 4.1.2-1 Test Items for Fibreglass Reinforcements

| Test items | | Type of test | | | | | |
|---|---|---|---|---|---|---|---|
| | | Test per each ship specified in **4.1.2 of the Rules** | | Approval test specified in **4.2 of the Rules** | | | |
| | | | | At time of approval and every 5 *years* | | Annual test | |
| | | *M&SR* | *R* | *M&SR* | *R* | *M&SR* | *R* |
| (1) | Appearance | O | O | O | O | O | O |
| (2) | Design weight per unit or unit length and maximum deviation | O | O | O | O | O | O |
| (3) | Ratio in weight of binders (including sizing) | O | O | O | O | O | O |
| (4) | Tensile strength of glassfibre reinforcements | | O | | O | | O |
| (5) | Bending strength and modulus of bending elasticity obtained from laminates (in the standard condition) | O | O | O | O | | |
| (6) | Bending strength and modulus of bending elasticity obtained from laminates (in wet condition) | | | O | O | | |
| (7) | Tensile strength and modulus of tensile elasticity obtained from laminates (in the standard condition) | O | O | O | O | | |

Notes:

1) Mark O denotes that the test and inspection are to be carried out.

2) *M* denotes chopped mats, *R* robing cloths, and *SR* robings for spray-up.

Table 4.1.2-2 Test Items for Resins for Laminating

| Test items | | Type of test | | |
|---|---|---|---|---|
| | | Test per each ship specified in **4.1.2 of the Rules** | Approval test specified in **4.2 of the Rules** | |
| | | | At time of approval and every 5 *years* | Annual test |
| (1) | Viscosity and thixotropy | O | O | O |
| (2) | Gel time, the minimum cure time and the peak exotherm temperature | O | O | O |
| (3) | Acid value | O | O | O |
| (4) | Water absorption rate of cast test specimens | O | O | O |
| (5) | Barcol hardness of cast test specimens | | O | O |
| (6) | Rate of tensile elongation and tensile strength of cast test specimens | O | O | O |
| (7) | Load deflection temperature of cast test specimens | O | O | O |
| (8) | Barcol hardness of laminated test specimens | O | O | |
| (9) | Bending strength and modulus of bending elasticity obtained from laminated test specimens | O | O | |
| (10) | Tensile strength and modulus of tensile elasticity obtained from laminated test specimens | O | O | |
| (11) | High temperature characteristics obtained from laminated test specimens | | O | |

Notes:

Mark O denotes that the test and inspection are to be carried out.

Table 4.1.2-3 Test Items for Sandwich Construction

| Test items | | Type of test | | | | | |
|---|---|---|---|---|---|---|---|
| | | Test per each ships specified in **4.1.2 of the Rules** | | Approval test specified in **4.2 of the Rules** | | | |
| | | | | At time of approval and every 5 *years* | | Annual test | |
| | | Rigid cellular plastic | Bulsa | Rigid cellular plastic | Bulsa | Rigid cellular plastic | Bulsa |
| (1) | Specific gravity | O | O | O | O | O | O |
| (2) | Water absorption rate | O | | O | | O | |
| (3) | Moisture content | | O | | O | | O |
| (4) | Compressive strength and modulus of compressive elasticity | O | O | O | O | O | O |
| (5) | Softening temperature | O | | O | | O | |
| (6) | Tensile strength and modulus of tensile elasticity | O | | O | | | |
| (7) | Bending strength and modulus of bending elasticity | O | | O | | | |
| (8) | Shear strength obtained from laminated test specimens sandwich construction | O | O | O | O | | |

Notes:

1) Mark O denotes that the test and inspection are to be carried out.

2) Tests asterisked are required only when the core is reckoned in strength.

Table 4.1.2-4 Test Items for Structural Adhesives

| Test items | | Type of test | | |
|---|---|---|---|---|
| | | Test for each ship specified in **4.1.2 of the Rules** *1 | Approval test specified in **4.2 of the Rules** | |
| | | | At time of approval and every 5 *years* | Annual test |
| (a) | Density | | O | O |
| (b) | Viscosity | | O | O |
| (c) | Glass transition temperature *2 | | O | O |
| (d) | Durometer hardness *2 | | O | O |
| (e) | Cure shrinkage | O | O | O |
| (f) | Tensile shear strength | O | O | |
| (g) | Tensile shear fatigue strength | O | O*3 | |
| (h) | Peel strength | O | O | |

Notes:

The mark "O" denotes that tests and inspections are to be carried out.

*1 In cases where the tests specified in **4.2 of the Rules** are conducted, this test is not required

*2 Select either glass transition temperature or durometer hardness.

*3 This test need only be conducted at the time of approval.

**4** Testing procedures for fibreglass reinforcements

(1) Shape and selection of test specimens

(a) The shape and selection of test specimens used for tests of fibreglass reinforcements are to be in accordance with **Table 4.1.2-5**.

(b) The manufacturing methods of laminated sheet used for tests (excluding rovings for spray-up laminating) are to be in accordance with the following **i)** through **v)**.

i) The laminated sheet used for tests is to have a sufficient size to arrange all the required laminated test specimens by itself after trimming away a 30 *mm* breadth of its edges.

ii) The laminate constitution and glass content are to be as **Table 4.1.2-6**.

iii) The ambient temperature while laminating is to be within the temperature range stated in the specifications.

iv) The laminating operation is to be completed within 50% of the gel time of resins for the ambient temperature.

v) After completion of laminating operation, the laminated sheet is to be left for 24 *hours* at a temperature of 20±5℃, and to be subjected to curing for 16 *hours* in air bath at a temperature of 40℃. The laminated sheet may be cut up in proper sizes for the after cure.

(c) The manufacturing methods of laminated sheet used for the test of rovings for spray-up are to be in accordance with the following **i)** through **iv)**.

i) The size of test specimens is to be as specified in the preceding **(b)i)**.

However, a 250 *mm* or more breadth of edges of the laminated sheet are to be trimmed away.

ii) The thickness of the test specimen is to be not less than 3 *mm*.

iii) The glass content is to be 30±3%.

iv) The after cure is to be in accordance with the preceding **(b)v)**.

(2) Test Procedures

The procedure of the tests given in **Table 4.1.2-1** is to be in accordance with the following **(a)** through **(f)**.

(a) Design weight per unit area or unit length and the maximum deviation

i) The test samples are to be in accordance with **Table 4.1.2-5**.

ii) The weight of the test sample is to be measured to the accuracy of 0.1*g*.

iii) The deviation is to be of the value obtained from the following formula.

1) Chopped mats and roving cloths

For test sample of 1 $m^2$

$$\frac{|M_1 - W|}{W} \times 100 \ (\%)$$

For test sample of 300×300 $m^2$

$$\frac{|M_2/0.09 - W|}{W} \times 100 \ (\%)$$

where,

$M_1$ : Weight of test sample of 1 $m^2$ ($g$)

$M_2$ : Weight of test sample of 300×300 $mm^2$ ($g$)

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

2) Rovings

$$\frac{|1000M/l - W|}{W} \times 100 \ (\%)$$

where,

$l$ : Length of test sample ($m$)

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

$M$ : Weight of test sample ($g$)

(b) Ratio in weight of binder (including sheafing agents)

i) The test specimen are to be in accordance with **Table 4.1.2-5**.

ii) Each test specimen is to be heated in a heating furnace (625±25℃) for about 10 *minutes* to burn out the binder or sheafing agent, to be taken out from the furnace and to be left it to cool down to the room temperature.

iii) The test sample in **ii)** above is to be weighed to the accuracy if 0.1*g*.

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

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

where,

$W_0$ : Weight before heating ($g$)

$W_1$ : Weight after cooling ($g$)

(c) Tensile strength of glassfibres in roving cloth

i) The test specimen are to be in accordance with **Table 4.1.2-5**.

ii) Tensile speed is to be 200 *mm/min* as the standard.

iii) 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.

iv) The breaking load is to be taken as the tensile strength of glassfibres.

(d) Bending strength and modulus of bending elasticity obtained from laminates (in the standard condition)

i) The test specimen is to be in accordance with **Table 4.1.2-5**.

ii) The test is to be carried out after keeping the test specimen in the standard condition for 20 *hours* or more.

iii) The testing machine is to be in accordance with **Fig.4.1.2-5**.

iv) The loading rate during test is to be $t/2$ *mm/min* as the standard. ($t$ =thickness of the test specimen in *mm*)

v) The bending strength is to be of the value obtained from the following formula.

$$\frac{3}{2} \cdot \frac{Pl}{bt^2} \ (N/mm^2)$$

where,

$P$ : Breaking load ($N$)

$l$ : Gauge length ($mm$)

$b$ : Breadth of test specimen ($mm$)

$t$ : Thickness of test specimen ($mm$)

vi) The modulus of bending elasticity is to be of the value obtained from the following formula.

$$\frac{l^3}{4bt^3}\left(\frac{\Delta P}{\Delta y}\right) \ (N/mm^2)$$

where,

$(\Delta P/\Delta y)$ : Gradient of the straight portion of load-deflection curve ($N/mm$)

$y$ : Deflection at mid point of gauge length ($mm$)

$l$, $b$ and $t$ : As specified in **v)** above

(e) Bending strength and modulus of bending elasticity obtained from laminates

i) The test specimens are to be in accordance with **Table 4.1.2-5**.

ii) Dip the test specimen in boiling water for 2 *hours*, leave it to cool down to the room temperature, take it out of water and wipe well.

iii) Carry out tests specified in the preceding **(d)iii)** and thereafter.

(f) Tensile strength and modulus of tensile elasticity obtained from laminates (in The tests are to be carried out after keeping the test specimen in the standard condition)

i) The test specimens are to be in accordance with **Table 4.1.2-5**.

ii) The tests are to be carried out after keeping the test specimen in the standard condition for 20 *hours* or more.

iii) The tensile speed is to be 5 *mm/min* as the standard.

iv) When the test specimen failed outside the gauge length, the measured values of the test specimen are to be judged unacceptable. In such a case, a new test specimen is to be taken for additional test.

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

$$\frac{P}{A} \ (N/mm^2)$$

where;

$P$ : Breaking load ($N$)

$A$ : Sectional area of test specimen at its mid point ($mm^2$)

vi) The modulus of tensile elasticity is to be of the value obtained from the following formula.

$$\frac{l}{A}\left(\frac{\Delta P}{\Delta l}\right) \ (N/mm^2)$$

where:

$l$ : Original gauge length ($mm$)

$A$ : Sectional area at mid point of test specimen ($mm^2$)

$(\Delta P/\Delta l)$ : Gradient of the straight portion of load-deflection curve ($N/mm$)

$\Delta l$ : Elongation of the distance between gauge marks

(3) Criteria

The acceptance criteria for the test results are to be in accordance with **Table 4.1.2-7**.

Table 4.1.2-5 Fibreglass Reinforcements

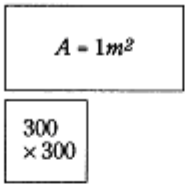
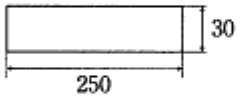
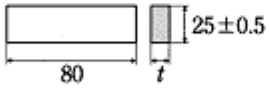
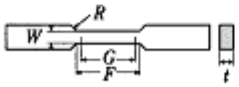
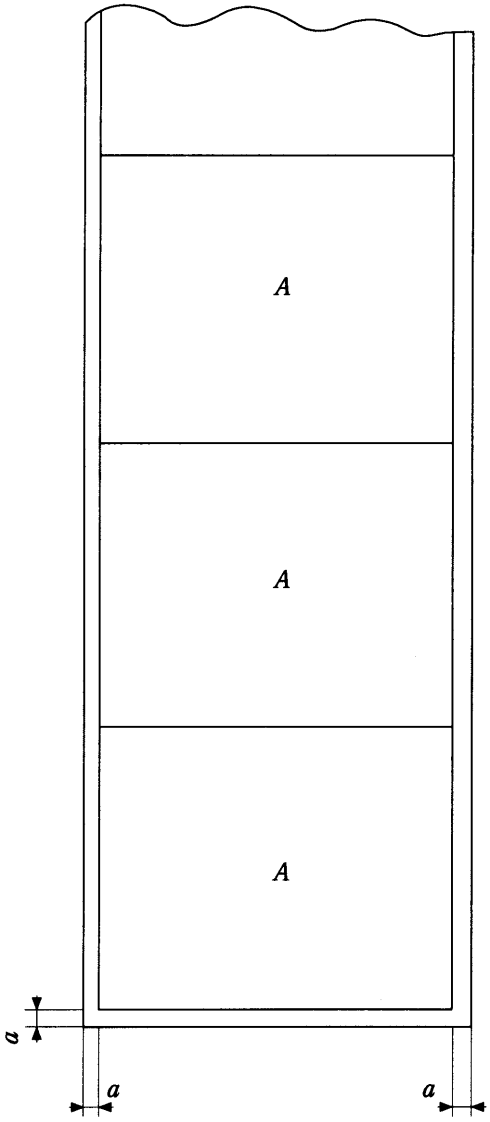
| | Test item | Shape and size of test specimen | Quantity | Sampling procedure, etc. |
|---|---|---|---|---|
| (a) | Deviation | *1) *2)   | *1) ..... 5<br>*2) ..... 10 | Discard 30*mm* form one longitudinal end and 30*mm* from both transvers ends, and take a test sample of $1m^2$ continuously in the longitudinal direction (*See* **Fig. 4.1.2-1**) |
| | | Rovings for spray-up are to have a length equivalent to approximately 15*g*. | 5 | After measuring weight of test sample *1), take a square (300 × 300) test specimen therefrom. (*See* **Fig. 4.1.2-2**) |
| (b) | Ratio in wight of binders | The same as in *2) | 5 | |
| (c) | Tensile strength of glassfibre in roving cloth |   | warp direction..... 5<br>weft direction..... 5 | Test specimens are to be taken inwarp and weft direction, respectively. (*See* **Fig. 4.1.2-3**) Finish it in the shape as shown in **Fig.4.1.2-4**. |
| (d)<br>(e) | Bending strength obtained from laminates |   $t$ = original thickness. | standard condition..... 5<br>wet condition..... 5 | In roving cloths, 5 pieces of test specimens are to be taken in warp and weft direction, respectively. Finish the cutout section smoothly. |
| (f) | Tensile strength obtained from laminates |   $t$ = original thickness<br>$F$ = 60 ± 0.5 (*mm*)<br>$G$ = 50 ± 0.5 (*mm*)<br>$W$ = 25 (*mm*) or more<br>$R$ = 60 (*mm*) or more | standard condition..... 5 | In roving cloths, 5 pieces of test specimens are to be taken from warp and weft direction respectively. Finish the cutout section smoothly. |

Table 4.1.2-6

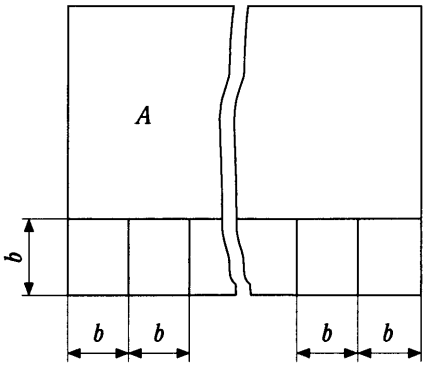
| | Laminate constitution | Glass content |
|---|---|---|
| Chopped mat | 3-ply | 30±3 (%) |
| Roving cloth | 4-ply | 50±3 (%) |

Fig 4.1.2-1 Selection of Test Specimens from Fibreglass Reinforcements



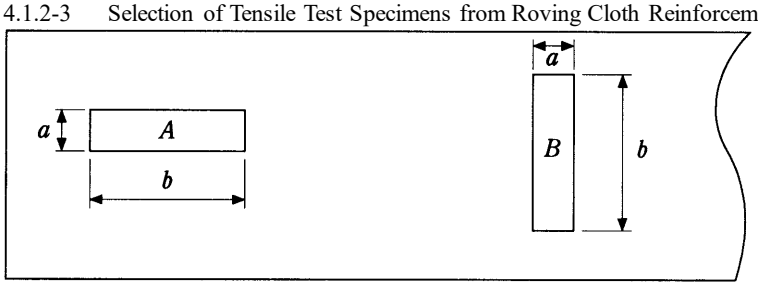

$A$=approx. 1 $m^2$
$a$ =30 $mm$

Fig 4.1.2-2 Selection of Test Specimens from Fibreglass Reinforcements



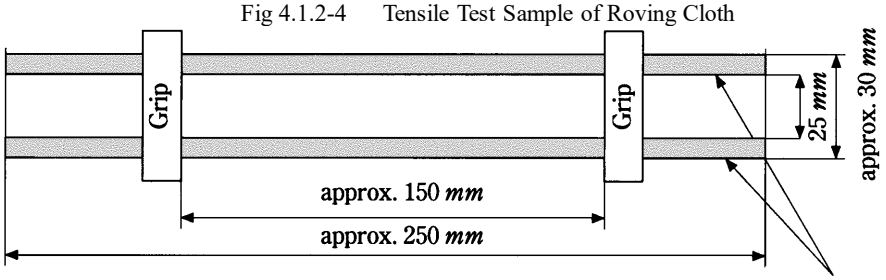

$b$ =300 $mm$

Fig 4.1.2-3 Selection of Tensile Test Specimens from Roving Cloth 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 4.1.2-4 Tensile Test Sample of Roving Cloth




This part of fibre is to be removed, and the breadth of finished specimen is to be 25 *mm*.

Fig 4.1.2-5 Testing Arrangement of Three Point Bending

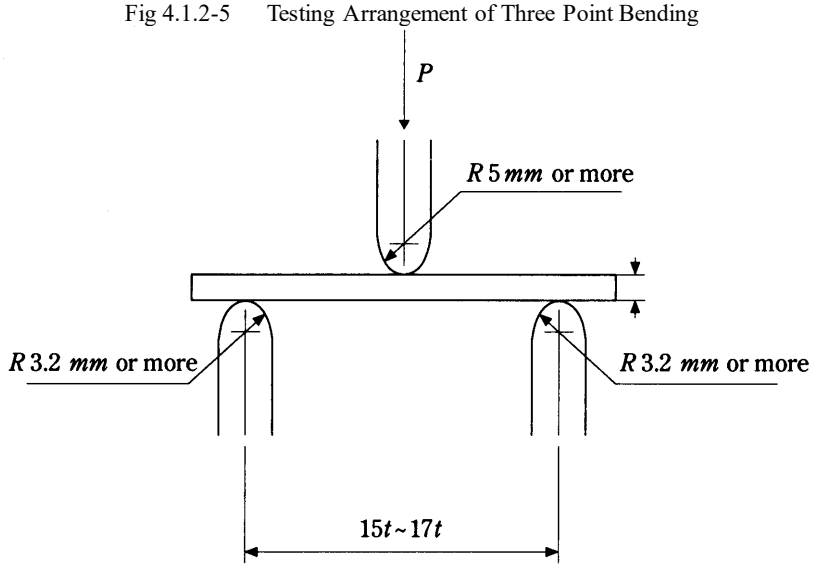


Table 4.1.2-7 Acceptance Criteria for Glassfibre Reinforcements

| Test item | | Acceptance criteria |
|---|---|---|
| Deviation | Chopped mat | $1m^2$..... Not greater than 10% for each specimen<br>$300mm \times 300mm$..... Not greater than 20% for each specimen |
| | Roving cloth | $1m^2$..... Not greater than 30% for each specimen<br>$300mm \times 300mm$ Not greater than 5% for each specimen |
| | Rovings | $15g$..... Not greater than 10% for each specimen |
| Ratio in weight of residual binders | 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% |
| | Rovings | Mean value..... Not greater than 3%<br>Test results of at least 4 test specimens are not to be greater than 3% |
| Tensile strength of glassfibres of glass roving cloth | | Mean value..... Not less than $0.35W$ ($kg$)<br>$W$: the stated weight ($g$)<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 $0.35W$ ($kg$). |
| Chopped mat Roving (standard Condition) | Bending strength | Mean value..... Not less than $150N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $150N/mm^2$ |
| | Modulus of bending elasticity | Mean value..... Not less than $6.37\times10^3N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $6.37\times10^3N/mm^2$ |
| Chopped mat Roving (wet condition) | Bending strength | Mean value..... Not less than $132N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $132N/mm^2$ |
| | Modulus of bending elasticity | Mean value..... Not less than $5.79\times10^3N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $5.79\times10^3N/mm^2$ |
| Roving cloth (standard condition) | Bending strength | Mean value..... Not less than $260N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $260N/mm^2$ |
| | Modulus of bending elasticity | Mean value..... Not less than $11.78\times10^3N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $11.78\times10^3N/mm^2$ |
| Roving cloth (wet condition) | Bending strength | Mean value..... Not less than $212N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $212N/mm^2$ |
| | Modulus of bending elasticity | Mean value..... Not less than $9.41\times10^3N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $9.41\times10^3N/mm^2$ |
| Chopped mat Roving (standard condition) | Tensile strength | Mean value..... Not less than $80N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $80N/mm^2$ |
| | Modulus of tensile elasticity | Mean value..... Not less than $6.86\times10^3N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $6.86\times10^3N/mm^2$ |
| Roving cloth (standard condition) | Tensile strength | Mean value..... Not less than $180N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $180N/mm^2$ |
| | Modulus of Tensile strength | Mean value..... Not less than $14.71\times10^3N/mm^2$<br>Test results of at least 4 test specimens are not to be less than $14.71\times10^3N/mm^2$ |

**5** Test procedures for resins for laminating

(1) Shapes and selection of test specimens

(a) The shape and selection of test specimens used for the tests of resins for laminating are to be in accordance with **Table 4.1.2-8**.

(b) The manufacturing methods of cast test specimens are to be in accordance with the following **i)** to **iii)**.

i) The curing agents and accelerators are to be as specified by the manufacturer of the resins.

ii) The size of cast sheet is to be such that all test specimens required in **Table 4.1.2-8**. for the cast test specimen can be cut out of the sheet.

iii) The cure time, temperature and after cure are to be as specified by the manufacturer of resins.

(c) The manufacturing procedures of laminates used for tests are to be in accordance with the following **i)** and **ii)**.

i) The laminating arrangements is to be of shopped mat (*EM* 450) in 3-ply and the glass content is to be 30±3% in weight.

ii) For other procedures ,the requirements in **-4(1)(b)** apply correspondingly.

(2) Test Procedures

The procedures for the tests given in **Table 4.1.2-2** are to be in accordance with the following **(a)** through **(k)**.

(a) Viscosity and thixotropy

i) The test resins are to be as given in **Table 4.1.2-8**.

ii) Brookfield viscometer is to be used.

iii) The rotor and guard (or sleeve guard) chosen according to the predicted viscosity of the liquid sample are to be mounted on the viscosmeter.

iv) The test liquid resins (25±0.5℃) 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.

v) 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.

vi) 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.

vii) The thixotropy is to be obtained by dividing the viscosity determined at the rotor run of 6 *rpm* by the viscosity at 60 *rpm*.

viii) The operations shown in **v)** and **vi)** above are to be repeated for two times or more and the respective mean, values are to be regarded as the 'viscosity' and 'thixotropy.'

ix) The effective digit is to be 2-digit and the name of the viscometer and rotor number are to be recorded.

(b) Gel time, minimum cure time and peak exotherm temperature

i) The test resins are to be given in **Table 4.1.2-8**.

ii) The testing apparatus for hardening characteristics at room temperature is to be fixed in a thermostatic water bath (25±0.5℃) (*See* **Fig.4.1.2-6**).

iii) The test resins are to be dipped in the thermostasic water bath and then the specified amount of sclerotics is to be added thereto when the temperature of the test resins reached 25±0.5℃, and the mixture is to be stirred evenly.

iv) 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*.

v) The 18 *mm* dia. 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.

vi) 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 thermister may be used in place of the above thermocouple.

vii) The time in minutes required for the test resins to reach a temperature of 30℃ 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 exotherm temperature (℃)

viii) 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 exotherm temperature'

ix) The types and amounts of the sclerotics and accelerators are to be recorded.

(c) Acid value

i) 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.

ii) Add the mixes indicator and titrate the solution with 0.1 *mol/l* (0.1*N*) ethyl alcoholic potassium hydroxide solution.

iii) When the colour of the solution turns from green into pale violet, take is as a point of termination.

iv) 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* (0.1*N*) ethyl alcoholic potassium hydroxide solution (*ml*)

$f$ : Factor of 0.1 *mol/l* (0.1*N*) 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 0.1*g* of finely ground bromothymol blue and 0.1*g* of phenol red, and adding further 0.1 *mol/l* (0.1*N*) 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*.

(d) Water absorption rate of cast test specimens

i) The test specimens are to be in accordance with **Table 4.1.2-8**.

ii) Put a filter paper on a board (thickness: approximately 10 *mm*), place the test specimen thereon, and heat the test specimen in a thermostatic air oven (50±2℃) for 24±1 *hours*.

iii) Cool the test specimen subjected to heating process in **ii)** above in a desiccator and measure the weight,

iv) Immerse the test specimen in a container with a lid filled with sufficient volume of distilled water, leave the container in a thermostatic water bath (25±1℃) for 24 *hours*, and then take the test specimen out, wipe the surface water and measure the weight. During immersion in distilled water, the test specimens are to be hold not to be brought in contact with each other.

v) The water absorption rate is to be of the value obtained from the following formula.

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

where:

$W_0$ : Weight of test specimen after heating (*g*)

$W_1$ : Weight of test specimen after immersion in water (*g*)

(e) Barcol hardness of cast test specimens

i) Use the Barcol hardness tester model 934-1.

ii) Hold the hardness tester in such a manner that the point contacts at right angles with the testing surface of the test specimen which is placed on a hard base.

iii) Apply 4.5 to 6.8 *kg* of an impact pressure and read out the maximum indication on the hardness tester.

iv) Ensure that the measuring point is 3 *mm* or more apart from the periphery of test specimen and other measuring points, and that those measuring points clear the areas from which other test specimens are taken.

v) Take measurements for 10 *points* or more.

(f) Tensile elongation and tensile strength of the cast test specimens.

i) The test specimens are to be in accordance with **Table 4.1.2-8**.

ii) The tensile speed is to be 5 *mm/min* as the standard.

iii) When the test specimen failed outside the place between gauge points, the measured value of such a test specimen is to be judged unacceptable, and a new test specimen is to be taken for additional test.

iv) The tensile elongation is to be obtained from the following formula.

$$\frac{Elongation\ of\ the\ gauge\ length\ at\ failure}{Initial\ gauge\ length} \times 100 \ (\%)$$

v) The tensile strength is to be obtained from the following formula.

$$\frac{P}{A} \ (kg/mm^2)$$

where:

$P$ : Breaking load ($kg$)

$A$ : Sectional area of test specimen at mid point ($mm^2$)

(g) Load deflection temperature of cast test specimens

i) The test specimens are to be in accordance with **Table 4.1.2-8**.

ii) The testing apparatus is to be as shown in **Fig.4.1.2-7**.

iii) The weight of balance weight is to be of the value obtained from the following formula.

$$0.123\frac{th^2}{l} - Q \ (kg)$$

where:

$t$ : Thickness of test specimen ($mm$)

$h$ : Height of test specimen ($mm$)

$l$ : Distance between supports ($mm$)

$Q$ : Weight ($kg$) obtained by adding the load read on dial gauge to the weight of loading lod including the weight pan

iv) Fix the testing apparatus with the test specimen in an oil bath, apply load and leave it from the initial temperature of 25±1℃ for 5 *minutes*.

v) Raise the temperature of the oil bath at a rate of 2.0±0.2℃/*min*.

vi) The temperature when the deflection reaches 0.26 *mm* is to be taken as the load deflection temperature.

(h) Barcol hardness of the laminate test specimens

The requirements in **(e)** above are to apply correspondingly.

(i) Bending strength and modulus of bending elasticity obtained by laminate test specimens

i) The test specimens are to be in accordance with **Table 4.1.2-8**.

ii) The testing procedures are to be in accordance with **-4(2)(d)**.

(j) Tensile strength and modulus of tensile elasticity obtained by laminate test specimens.

i) The test specimens are to be in accordance with **Table 4.1.2-8**.

ii) The testing procedures are to be in accordance with **-4(2)(f)**.

(k) High temperature characteristics obtained by laminate test specimens

i) Barcol hardness

Leave the test specimen at 60±1℃ for 24 *hours* and carry out the test specified in **(e)** above within one minute.

ii) Bending strength and modulus of bending elasticity

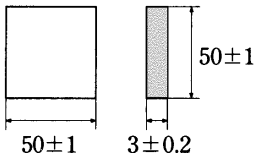
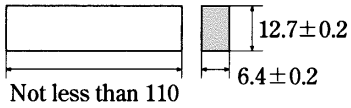
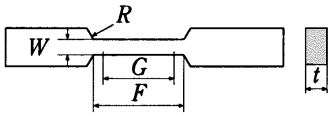
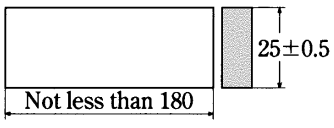
Leave the test specimen at a temperature of 60±1℃ for 24 *hours* and then carry out the test specified in **(i)** above at a temperature of 60±2℃.

(3) Criteria

The acceptance criteria for the test results are to be in accordance with **Table 4.1.2-9**.

Table 4.1.2-8 Resins for Laminating

(Unit: *mm*)

| | Test item | Shape and size of test specimen | Quantity | Selection of test specimen, etc. |
|---|---|---|---|---|
| (a) | Viscocity 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 |
| (b) | Gel time, minimum cure time and peak exotherm temperature | Resins | 50 ± 1*g* (Note 1) | |
| (c) | Acid value | Resins | 1*g* | |
| (d) | Water absorption rate |  | 5 cast test specimens | |
| (e)<br>(h) | Barcol hardness | Cast test specimens<br>Laminate test specimens | | |
| (g) | Load deflection temperature |  | 3 cast test specimens | |
| (f)<br>(j) | Tensile strength |  <br>Cast test specimens<br>*t* = 3 ± 0.2 (*mm*)<br>*F* = 60 ± 0.5 (*mm*)<br>*G* = 50 ± 0.5 (*mm*)<br>*W* = 12.5 (*mm*) or more<br>*R* = 60 (*mm*) or more<br>Laminate test specimens<br>*t* = original thickness<br>*F* = 60 ± 0.5 (*mm*)<br>*G* = 50 ± 0.5 (*mm*)<br>*W* = 25 (*mm*) or more<br>*R* = 60 (*mm*) or more | 5 cast test specimens<br>5 laminate test specimens | |
| (i) | Bending strength obtained by laminate test specimens |  | 5 | |
| (k) | High temperature characteristics obtained by laminate test specimens | The same as in (h) and (i) | | |

Note :

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.

Fig. 4.1.2-6 Testing Apparatus for Hardening Characteristics at Room Temperature

Unit: *mm*

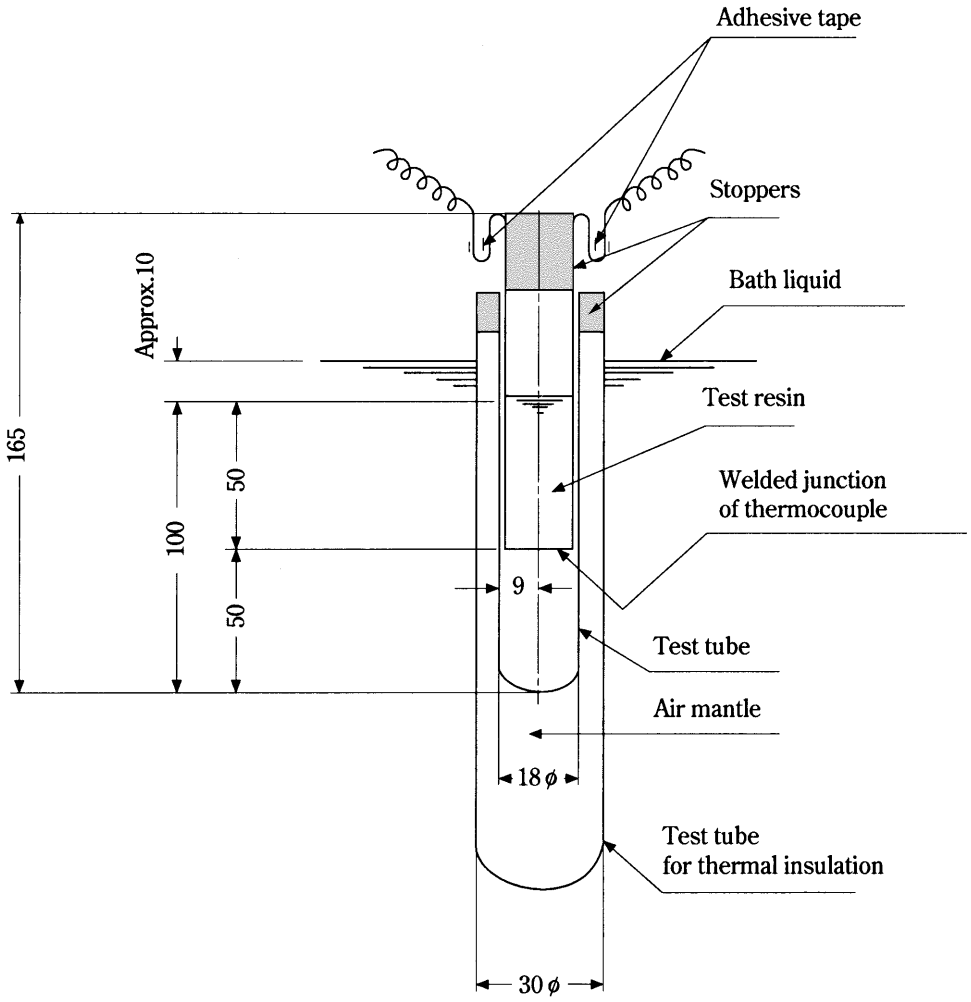
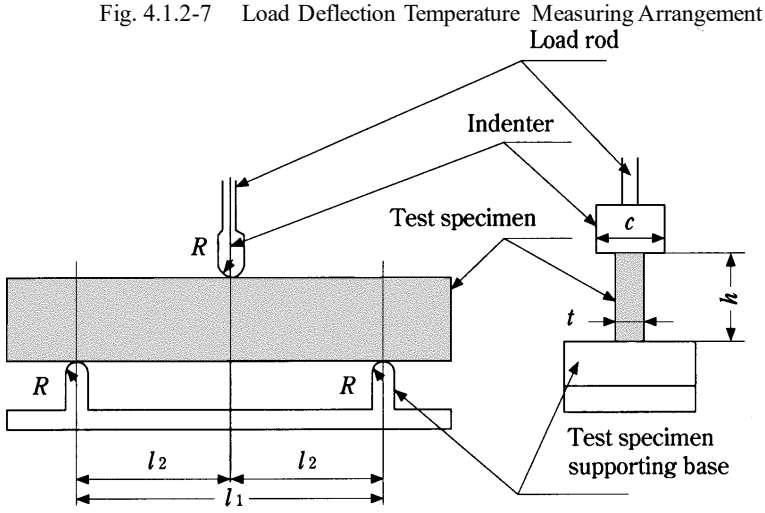


Fig. 4.1.2-7 Load Deflection Temperature Measuring Arrangement




$l_1$ = 100 ±2.0 (*mm*)
$l_2$ = 50 ±1.0 (*mm*)
$R$ = 3.0 ±0.2 (*mm*)
$t$ = thickness of test specimen (*mm*)
$h$ = height of test sepcimen (*mm*)
$c$ = to be 13 *mm* or more

Unit:*mm*

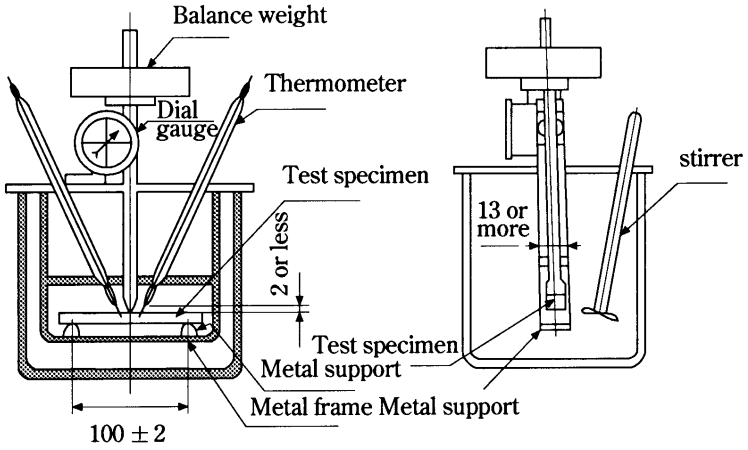


Table 4.1.2-9 Acceptance Criteria for Resins for Laminating

| | Test item | Acceptance criteria |
|---|---|---|
| (a) | Viscosity<br>Thixotropy | 1.5~8 (Poise)<br>1.2~4 |
| (b) | Gel time<br>Minimum cure time<br>Peak exotherm temperature | Reference<br>Reference<br>Not more than 190℃ |
| (c) | Acid value | Reference |
| (d) | Water absorption rate<br>Cast test specimen | <br>Mean value to be not more than 0.25% |
| (e)<br>(h) | Barcol hardness<br>Cast test specimen<br>Laminate test specimens | <br>Mean value to be not less than 35<br>Mean value to be not less than 40 |
| (f)<br>Cast test specimens | Tensile elongation | Mean value to be not less than 1.3%<br>Test results of at least 4 test specimens are to be not less than 1.3% |
| | Tensile strength | Reference |
| (g) | Load deflection temperature | Mean value to be not less than 60℃<br>Test results of at least 2 test specimens are to be not less than 60℃ |
| (i) | Bending strength<br>Modulus of bending elasticity | Mean value to be not less than $150 N/mm^2$<br>Mean value to be not less than $6.37\times10^3 N/mm^2$ |
| (j)<br>Laminate test specimens | Tensile strength<br>Modulus of tensile elasticity | Mean value to be not less than $80 N/mm^2$<br>Mean value to be not less than $6.86\times10^3 N/mm^2$ |
| (k) i)<br>(k) ii) | Barcol hardness | Mean value to be not less than 60% of the mean value of test (h) |
| | Bending strength<br>Modulus of bending elasticity | Mean value to be not less than 70% of the mean value of test (i)<br>Mean value to be not less than 50% of the mean value of test (i) |

**6** Test Procedures for Core Materials for Sandwich Constructions

(1) Shapes and selection of test specimens

(a) The shape and selection of test specimens used for the tests of core materials for sandwich construction are to be in accordance with **Table 4.1.2-10**.

(b) The manufacturing methods of sandwich constructions for the test are to be in accordance with the following **i)** through **v)**.

i) The core material is to be the largest thickness to be used as primary structural members of hull construction.

ii) On both sides of the core, the *M-R-M-R-M* laminates are to be applied where *M* denotes chop mats (specified weight: 5.88 $N/m^2$) and *R*, roving cloth (specified weight: 7.94 $N/m^2$).

iii) The glass content is to be approximately 30% at the portion of chops mats, and approximately 50% at the portion of roving cloths.

iv) The direction of wrap of roving cloth is to be aligned with the longitudinal direction of the test specimen.

v) In the case of the fibre reinforced plastics foam, test specimens of which longitudinal direction is aligned respectively with the direction of the maximum strength and the direction of the minimum strength of the core material are to be manufactured.

(2) Test procedures

(a) The test procedures for the hard plastics foam specified in **Table 4.1.2-3** are to be in accordance with the following **i)** through **vii)**.

i) Specific gravity

1) The test specimens are to be in accordance with **Table 4.1.2-10**.

2) Leave the test specimen in a thermostatic air oven (25±0.5℃) for approximately 30 *minutes*, and measure the dimensions and weight.

3) The size of the test specimen is to be measured to the order 0.1 *mm* for the thickness, length and breadth.

4) The weight of the test specimen is to be measured to the order of 0.1$g$.

5) The specific gravity is to be of the value obtained from the following formula.

$$\frac{W}{V}$$

where,

$W$ : Weight of test specimen ($g$)

$V$ : Weight of pure water corresponding to the volume of test specimen ($g$)

ii) Water absorption rate

1) The test specimens are to be in accordance with **Table 4.1.2-10**.

2) The surface skin of the test specimen, if such is the case, is to be removed, and the dimensions are to be measured to the order of 0.1 *mm*.

3) The test specimen is to be submerged in fresh water (23±3℃, to a depth of 60 *mm* below the water surface) for 10 *seconds*.

4) The test specimen is to be places on a wire gauze of 3 *mm* mesh tilted at 30 *degree* to the vertical through 30 *seconds*, and then the reference weight($W_0$) is to be measured to the order of 0.01$g$.

5) The test specimen of which reference weight has been measured is to be soaked in fresh water (23±3℃) for 24 *hours* with a pressure of 100 *kPa* being applied.

6) The weight of the test specimen ($W_1$) is to be measured by the same procedure as specified in **4)** above.

7) The water absorption rate is to be obtained from the following formula.

$$\frac{W_1 - W_0}{A} \times 100 \ (g/100cm^2)$$

where,

$W_1$ : Weight after the final water absorption ($g$)

$W_0$ : Reference weight ($g$)

$A$ : Surface area of test specimen ($cm^2$)

iii) Compressive strength and modulus of compressive elasticity

1) The test specimens are to be in accordance with **Table 4.1.2-10**.

2) The size of the test specimen is to be measured to the order of 0.1 *mm*.

3) Compression to be applied in the direction of thickness of the product.

4) The compression speed is to be 5 *mm/min* as the standard.

5) The compressive strength is to be obtained from the following formula.

$$\frac{P_C}{A} \ (N/mm^2)$$

where,

$P_c$ : Load at which 0.2% strain is caused from the elastic limit ($N$)

$A$ : Pressure bearing area of test specimen ($mm^2$)

6) The modulus of compressive elasticity is to be obtained.

$$\frac{t}{A}\left(\frac{\Delta P}{\Delta t}\right) \ (N/mm^2)$$

where,

$\Delta P/\Delta t$ : Gradient of the straight portion of load-contraction curve ($N/mm$) (*See* **Fig.4.1.2-8**)

$t$ : Thickness of test specimen

$A$ : Pressure bearing area of test specimen ($mm^2$)

iv) Softening rate

The modulus of compressive elasticity at a temperature of 60℃ is to be measured by suitable means. The method specified in **-5(2)(g)** may be applied correspondingly.

v) Tensile strength and modulus of tensile elasticity

1) The test specimens are to be in accordance with **Table 4.1.2-10**.

2) The test procedure is to be in accordance with **-4(2)(f)**.

vi) Bending strength and modulus of bending elasticity

1) The test specimens are to be in accordance with **Table 4.1.2-10**.

2) The testing apparatus is to be in accordance with **Fig 4.1.2-9**.

3) The loading speed is to be *t*/2 *mm/min* as the standard.

(*t*; thickness of test specimen (*mm*))

4) The bending strength is to be obtained from the following formula.

$$\frac{3PL_1}{bt^2} \ (N/mm^2)$$

where:

$L_1$ : Outer span (*mm*)

$b$ : Breadth of test specimen (*mm*)

$t$ : Thickness of test specimen (*mm*)

$P$ : Breaking load (*N*)

5) The modulus of bending elasticity is to be obtained from the following formula.

$$\frac{3}{4}\frac{L_1 L_2^2}{bt^3}\frac{\Delta P}{\Delta \delta} \ (N/mm^2)$$

where,

$L_1$ : Outer span (*mm*)

$L_2$ : Mid span (*mm*)

$(\Delta P/\Delta \delta)$ :Gradient of straight portion of load-deflection curve ($N/mm^2$)

$\delta$ : Deflection at mid point of gauge length at centre (*mm*)

vii) Shearing strength of sandwich constructions

1) The test specimens are to be in accordance with **Table 4.1.2-10**.

2) The testing apparatus is to be in accordance with **Fig.4.1.2-10**.

3) The loading speed is to be *t*/2 *mm/min* as the standard.

(*t*; thickness of test specimen (*mm*))

4) The shearing strength is to be obtained from the following formula.

$$\frac{P_B}{2(t_f+t_c)b} \ (N/mm^2)$$

where,

$P_B$ : Breaking load of core material (*N*)

$t_f$ : Mean thickness of inner layer and outer layer of FRP laminates (*mm*)

$t_c$ : Thickness of core material (*mm*)

$b$ : Breadth of test specimen (*mm*)

5) The outer span ($L_1$) is to be referred to the value obtained from the following formula. However, in case where either the outer or inner *FRP* laminates fails, retest is to be carried out with the smaller outer span.

$$L_1 < \frac{Z \cdot \sigma_f}{(t_f+t_c)b\tau'_a} \ (mm)$$

where :

$Z$ : Section modulus of test specimen ($mm^3$)

$t_f$ : Mean thickness of *FRP* laminates (*mm*)

$t_c$ : Thickness of core material (*mm*)

$b$ : Breadth of test specimen (*mm*)

$\sigma_f$ : Tensile strength of *FRP* laminates ($N/mm^2$)

$\tau'_a$ : Imaginary shearing strength of core material ($N/mm^2$)

(b) The test procedures for bulsa shown in **Table 4.1.2-3** are to be in accordance with the following **i)** through **iv)**.

i) Specific gravity

The test procedure is to be in accordance with **-6(2)(a)i)**. However, the size and weight are to be measured at room temperature.

ii) Moisture content

1) After having dried the test specimen in **i)** above in the thermostatic air oven to a fixed weight, the weight is to be measured to the order of $0.1g$.

2) The moisture content is to be of the value obtained from the following formula.

$$\frac{W_1 - W_2}{W_2} \times 100 \ (\%)$$

where :

$W_1$ : Weight at the standard condition $(g)$

$W_2$ : Weight after drying $(g)$

iii) Compressive strength in fibrous direction and modulus of compressive elasticity

The test procedure is to be in accordance with **-6(2)(a)iii)**. However, $P_c$ shown in **5)** is the maximum load $(kg)$, In this case, the specific gravity of the test specimen is to have been measured in accordance with **i)** above.

iv) Shearing strength of sandwich constructions

The test procedure is to be in accordance with **-6(2)(a)vii)**.

Fig. 4.1.2-8 Load-Contraction Diagram

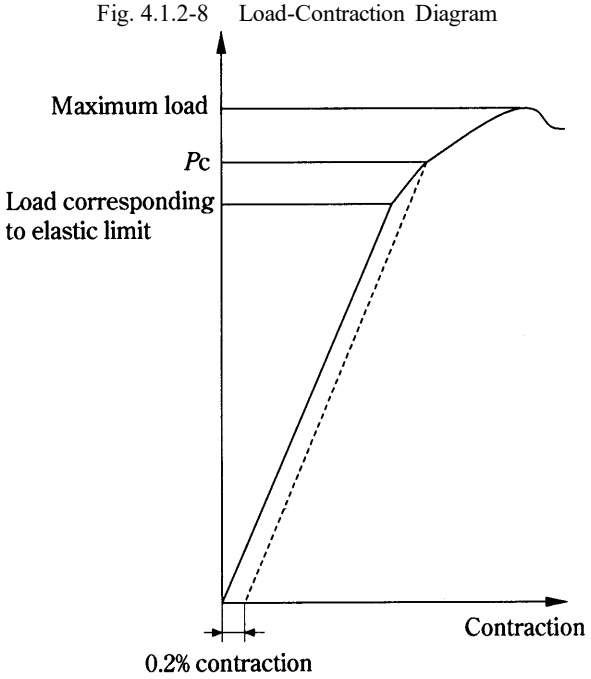



Fig. 4.1.2-9 Testing Arrangement of Four Point Bending

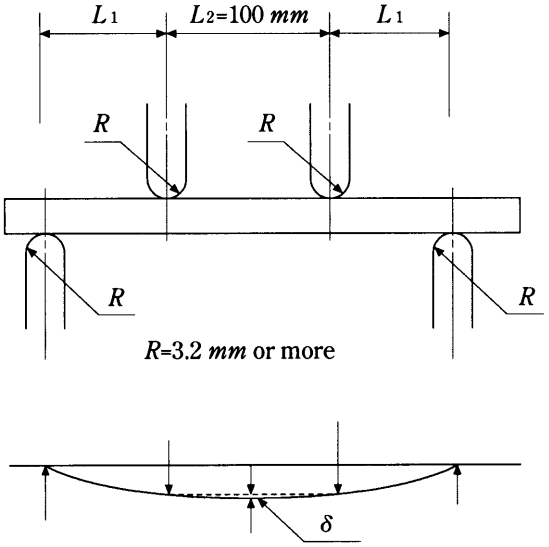


Table 4.1.2-10 Core Materials for Sandwich Construction

(Unit : *mm*)

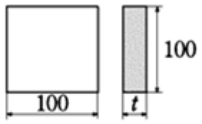
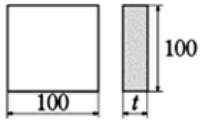
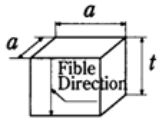
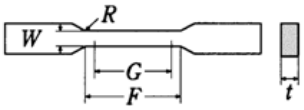
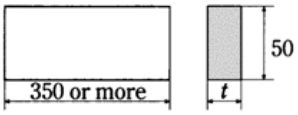
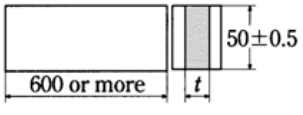
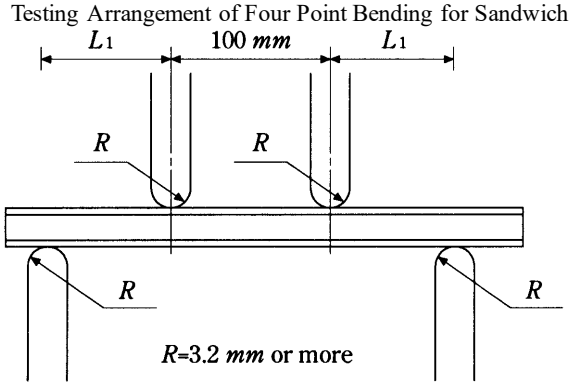
| Test item | | Shape and size of test specimen | Quantity | Selection of test specimen, etc. |
|---|---|---|---|---|
| i) | Specific gravity | Hard plastic foam<br>  <br><br>*t* : original thickness | 5 | |
| | | Bulsa<br>• Product bulsa of original thickness<br>• Compression test specimen iv) is to be used | 10<br>5 | Product bulsa boards (artificially dried bulsa boards bonded in the same direction (block) to be cut at right angle to fibrous derection) are to be taken from different lots as far as practicable. |
| ii) | Water absorption | The same as in hard plastic foam | 5 | |
| iii) | Moisture content |  <br><br>*t* : original thickness | 10 | One each test specimen is to be taken from each product bulsa of which the specific gravity was measured. |
| iv) | Compression test |  <br><br>Hard plastic foam<br>$a$ = 50 (*mm*)<br>Bulsa $a$ = 20 ~ 50 (*mm*)<br>$t$ = 50 (*mm*) | 5 | Materials for test are to be selected as differently on specific gravity as possible among those forming a block of bulsa products, and test specimens are to be taken from those respective materials. |
| vi) | Tensile test |  <br><br>$t$ = original thickness or 20 (*mm*)<br>$F$ = 60 ± 0.5 (*mm*)<br>$G$ = 50 ± 0.5 (*mm*)<br>$W$ = 25 (*mm*) or more<br>$R$ = 60 (*mm*) or more | 5 | |
| vii) | Bend test |  <br><br>$t$ = original thickness or 20 (*mm*) | 5 | |
| viii) | Shearing test |  <br><br>$t$ : to be in accordance with -5).(1)(b) i) | 5 | |

Fig. 4.1.2-10 Testing Arrangement of Four Point Bending for Sandwich Constructions




**7** Test Procedures for Structural Adhesives

(1) Shapes and selection of test specimens

(a) The shapes and selection of test specimens used for the tests of structural adhesives are to be in accordance with **Table 4.1.2-11**.

(b) The manufacturing methods of test panels of *FRP* laminates used for the tests specified in **(2)(f)** and **(g)** are to be in accordance with the following **i)** through **iv)**:

i) Chopped mat and roving cloth are to be alternately laminated and surface layers are to be of chopped mat

ii) Design weight per unit area of chopped mat and roving cloth ($g/m^2$)

Chopped mat: 450

Roving cloth: 580

iii) Glass content by weight of chopped mat and roving cloth (%)

Chopped mat: 30 ± 3

Roving cloth: 50 ± 3

iv) Test panels are to be of sufficient size from which all test specimens needed for each test condition specified in **Table 4.1.2-11** can be taken.

(c) Aluminium test panels used for the tests specified in **(2)(f)** and **(g)** are to be the *A*5052*P* specified in *JIS H*4000 and use the surface anode oxide coating specified in *JIS H*8601

(2) Test procedures

The test procedures specified in **Table 4.1.2-4** are to be in accordance with the following **(a)** through **(h)** or with standards deemed appropriate by the Society.

(a) Density

The test method is to be in accordance with the density cup method or the pycnometry method specified in *JIS K*6833-1(2008).

(b) Viscosity

The test method is to be in accordance with the measurement method specified in *JIS K*6833-1(2008) using either a single cylinder rotational viscometer, coaxial-cylinder rotational viscometer or cone and plate viscometer.

(c) Glass transition temperature

The test method is to be in accordance with the differential thermal analysis or the differential scanning calorimetry specified in *JIS K*7121(1987).

(d) Durometer hardness

The test method is to be in accordance with *JIS K*7215(1986).

(e) Cure shrinkage

The test method is to be in accordance with the measurement method of moulding shrinkage specified in *JIS K*6911(2006) or the measurement method of cure shrinkage specified in *JIS K*6024(2008).

(f) Tensile shear strength

i) The test method is to be in accordance with *JIS K*6850(1999).

ii) The test specimens are to be *FRP* laminate test plates and aluminium test plates of the dimensions specified in **Table**

**4.1.2-11**.

iii) In cases where *FRP* laminate test plates are used, surface preparation equivalent to the actual construction is to be done before structural adhesives are applied.

iv) In cases where aluminium test plates are used, appropriate surface preparation is to be done before structural adhesives are applied.

v) Adhesive layer thickness and state adjustments are as follows:

1) Standard test

Adhesive layer thickness is to be not less than 3.0*mm* and test specimens are to be maintained at a temperature of 23 ± 2°C for 24 hours.

2) High humidity and high temperature exposure test

Adhesive layer thickness is to be not less than 3.0mm and test specimens are to be maintained at a temperature of 23 ± 2°C for 24 hours and then maintained at a temperature of 50 ±2°C and a relative humidity of 90 ± 10% for 500 hours.

vi) The method for recording failures is to be in accordance with **(3)**.

(g) Tensile shear fatigue strength

i) The test method is to be in accordance with *JIS K*6864(1999).

ii) The test specimens are to be *FRP* laminate test plates and aluminium test plates of the dimensions specified in **Table 4.1.2-11**.

iii) The test specimens are to be in accordance with the preceding **(f)**.

iv) Adhesive layer thickness is to be not less than 3.0*mm* and test specimens are to be maintained at a temperature of 23 ± 2°C for not less than 24 hours.

v) The test load is to be periodically applied at a maximum stress of 3.5*MPa* and a stress ratio of 0.1 for $10^6$ cycles.

vi) The method for recording failures is to be in accordance with **(3)**.

vii) In cases where conducting tests is difficult due to device vibrations or *FRP* laminate strength decreases due to device heat, the frequency of cyclic load may be appropriately decreased.

(h) Peel strength

i) The test method is to be in accordance with *JIS K*6854-3(1999).

ii) The test specimens are to be cold rolled steel plates specified in *JIS G*3141(2011) of the dimensions specified in **Table 4.1.2-11**.

iii) Adhesive layer thickness is to be not more than 1.0*mm* and test specimens are to be maintained at a temperature of 23 ± 2°C for not less than 24 hours.

iv) The test speed is to be 100*mm/min*.

(3) Recording failures

(a) Observe the fracture surface and calculate the ratio of adherent failure for the entire adhesion area by visual inspection. In cases where the ratio of adherent failure is within the range, according to test condition, shown in the preceding **(f)v)**, calculate each area by the grid measurement method specified in the following **(c)** and determine the ratio of adherent failure.

i) The standard test specified in **(f)v)**: 35 ~ 45%

ii) The high humidity and high temperature exposure test specified in **(f)v)**: 20 ~ 30%

(b) Observe the fracture surface and calculate the total ratio of adherent failure and cohesion failure for the entire adhesion area by visual inspection. In cases where the total ratio of adherent failure and cohesion failure is within the range, according to test condition, shown in the preceding **(f)v)**, calculate each area by the grid measurement method specified in the following **(c)** and determine the total ratio of adherent failure and cohesion failure.

i) The standard test specified in **(f)v)**: 70 ~ 90%

ii) The high humidity and high temperature exposure test specified in **(f)v)**: 40 ~ 60%

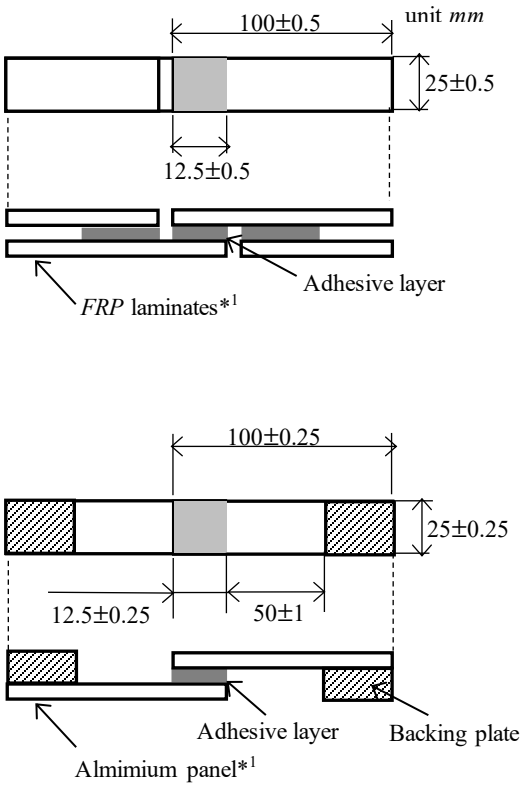
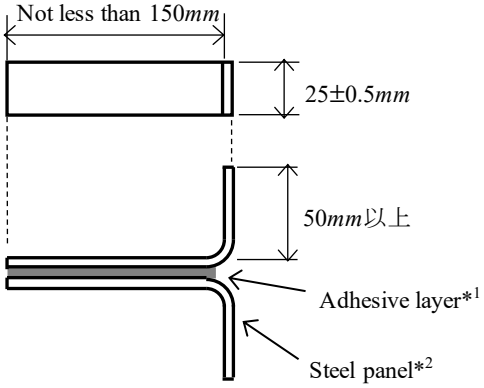
(c) Copy the fracture surface onto grided tracing paper and determine the total area of the fracture surface by counting the number of grids. In addition, determine the area of adherent failure and cohesion failure similarly and calculate the ratio of adherent failure and cohesion failure from the ratio of the area of adherent failure and cohesion failure to the area of

fracture surface. Furthermore, regarding methods other than the grid measurement method, methods with a precision equal to or greater than the grid measurement method may be used.

(4) Criteria

The acceptance criteria for test results are to be in accordance with **Table 4.1.2-12**.

Table 4.1.2-11. Structural Adhesive Test Specimens

| Test items | | Test specimen, sample shape and size | Quantity | Remarks |
|---|---|---|---|---|
| (a) | Density | · Adhesive base resin<br>· Adhesive Curing agent(s) | 3 each | |
| (b) | Viscosity | · Adhesive base resin<br>· Adhesive Curing agent(s) | 2 each | |
| (c) | Glass transition temperature | · Hardened materials | 3 | |
| (d) | Durometer hardness | · Hardened materials | 5 | |
| (e) | Cure shrinkage | · Adhesive base resin<br>· Adhesive Curing agent(s)<br>· Hardened materials | 3 each | |
| (f) | Tensile shear strength |  | 5 each | Adhesive layer thickness and state adjustment are to be in accordance with **4.1.2-7(2)(f)v)**. |
| (g) | Tensile shear fatigue strength | Test specimens specified in **(f)** | 5 each | Adhesive layer thickness and state adjustment are to be in accordance with **4.1.2-7(2)(g)iv)**. |
| (h) | Peel strength |  | 5 | Adhesive layer thickness and state adjustment are to be in accordance with **4.1.2-7(2)(h)iii)**. |

Notes:

*1: The thickness of *FRP* laminate is to be not less than 5.0*mm* and the thickness of alminium plates is to be not less than 2.0*mm*. In addition, thickness is to be sufficient so that deformation does not effect on the test results.

*2: The thickness of steel plates is to be not less than 0.5*mm*.

Table 4.1.2-12 Structural Adhesive Evaluation Criteria

| Test items | | Evaluation Criteria |
|---|---|---|
| (a) | Density*1 | Value specified by structural adhesive manufacturer |
| (b) | Viscosity*1 | Value specified by structural adhesive manufacturer |
| (c) | Glass transition temperature*1 | Value specified by structural adhesive manufacturer |
| (d) | Durometer hardness*1 | Value specified by structural adhesive manufacturer |
| (e) | Cure shrinkage*1 | Value specified by structural adhesive manufacturer |
| (f) | Tensile shear strength*2 | Standard test:<br>*FRP* laminate specimens:<br>· In cases where the ratio of adherent failure is not less than 40%, the total ratio of adherent failure and cohesion failure is to be not less than 80%.<br>· In cases where the ratio of adherent failure is less than 40%, the total ratio of adherent failure and cohesion failure is to be not less than 80% and not less than 6.9*MPa*.<br>Aluminium specimens: not less than 6.9*MPa*<br>High humidity and high temperature exposure test:<br>*FRP* laminate specimens:<br>· In cases where the ratio of adherent failure is not less than 25%, the total ratio of adherent failure and cohesion failure is to be not less than 50%.<br>· In cases where the ratio of adherent failure is less than 25%, the total ratio of adherent failure and cohesion failure is to be not less than 50% and not less than 3.5*MPa*.<br>Aluminium specimens: not less than 3.5*MPa* |
| (g) | Tensile shear fatigue strength*2 | *FRP* laminate specimens: not to be fractured for less than $10^6$ cycles or the failure is a adherent failure.<br>Aluminium specimens : Not to be fractured for less than $10^6$ cycles |
| (h) | Peel strength*3 | Not less than 98*N*/25*mm* |

Notes:

*1: Used to verify uniform quality

*2: Used to verify stress assessments and moulding procedures, etc. of joints moulded by structural adhesives.

*3: Used to verify that structural adhesives have a uniform peel strength.

## 4.3 Raw Materials, etc.

### 4.3.6 Timbers and Plywoods for Primary Structures

Plywoods used for primary members are to be of the structural plywood specified in the Japanese Agricultural Standard (*JAS*) (Notification No.1371, 1969 of the Ministry of Agriculture, Forestry and Fisheries) or equivalent in performance with the following particulars marked.

Name of resins

Ply composition

Class of waterproofness (*JAS* Standard title may be specified)

**4.3.7 Cores for Moulding**

For the test procedures when the cores are reckoned in strength, **4.4.4-4(1)(d)** and **(e)** apply correspondingly.

## 4.4 *FRP*

### 4.4.4 *FRP* Material Tests

**1** Manufacturing methods of test laminates for *FRP* laminates and sandwich constructions.

(1) One each of *FRP* test laminates 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** (*See* **Fig.4.4.4-1**) and **-3**.

**2** The selection of test specimens is to be in accordance with the following **(1)** and **(2)**.

(1) *FRP* laminates (including the *FRP* laminates of the inner layer and outer layer of sandwich construction)

(a) The tensile test specimens and bending test specimens are to be cut alternately from the test laminates clearing 60 *mm* belt from the periphery.(*See* **Fig.4.4.4-1**)

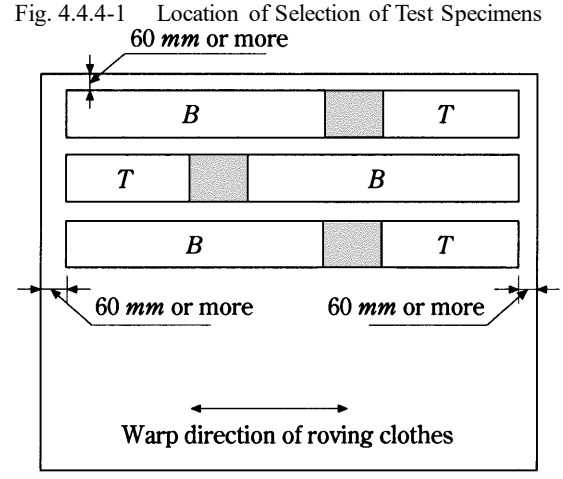
(b) The test laminates for Barcol hardness test and glass content measurement are to be of those hatched sections in the figure.

(c) The test laminates of the inner layer and outer layer of *FRP* laminates of sandwich construction are to be taken by cutting cores out of the moulded sandwich constructions and smoothing their surfaces.

(2) Sandwich constructions

For the selection of the bend test specimens, tensile test specimens and shearing test specimens, the requirements in **(1)(a)** above apply correspondingly. When the cores are reckoned in strength, joints are to be provided at two locations.

Fig. 4.4.4-1 Location of Selection of Test Specimens




*T* denotes tensile test specimen (5 *pcs.*)
*B* denotes bending test specimen (5 *pcs.*)
signifies the measuring area of Barcol hardness test or glass content measurement

**3** The shape and size of the test specimens are to be in accordance with **Table 4.4.4-1**.

**4** The test procedures are to be in accordance with the following **(1)** and **(2)**.

(1) *FRP* laminates

(a) Thickness of moulding

The thickness of five each bend test specimens and tensile test specimens is to be measured.

(b) Barcol hardness

For the test procedures, the requirements in **4.1.2-5(2)(e)** apply correspondingly.

(c) Glass content (ratio in weight)

i) After drying a crucible in an electric muffle furnace (650±20℃) till its weight reaches constant, cool the pot in a desiccator and measure weight of the crucible ($W_1$).

ii) Place the test sample (2*g* or more) specified in **-2** above into the crucible and measure weight ($W_2$).

iii) Apply heat with a Bunsen burner or an electric muffle furnace so that the test sample continues burning properly.

iv) After completion of burning ,apply heat in the electric muffle furnace at 625℃ until the carbon content completely disappears.

v) Cool the test object in a desiccator for 30 *minutes* and measure its weight ($W_3$).

vi) The glass content is to be obtained from the following formula.

$$\frac{W_3 - W_1}{W_2 - W_1} \times 100 \ (\%)$$

(d) Bending strength and modulus of bending elasticity

i) The test specimens are to be in accordance with **Table 4.4.4-1**.

ii) For the test procedures, the requirements in **4.1.2-4(2)(d)** apply correspondingly.

(e) Tensile strength and modulus of tensile elasticity

i) The test specimens are to be in accordance with **Table 4.4.4-1**.

ii) For the test procedures, the requirements in **4.1.2-4(2)(f)** apply correspondingly.

(2) Sandwich constructions

(a) Thickness of moulding

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

(b) Tensile strength

i) The test specimens are to be in accordance with **Table 4.4.4-1**.

ii) The tensile speed is to be 5 *mm/min* as the standard.

iii) 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.

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

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

where:

$P$ : Breaking load ($N$)

$A_c$ : Sectional area of core ($mm^2$)

$A_f$ : Sectional area of *FRP* laminates ($mm^2$)

$E_c$ : Modulus of tensile elasticity of core obtained by the test in **4.3.5 of the Rules** ($N/mm^2$)

$E_f$ : Modulus of tensile elasticity of *FRP* laminates obtained by **(1)(e)** above ($N/mm^2$)

(c) Shearing strength

i) The test specimens are to be in accordance with **Table 4.4.4-1**

ii) The test procedure are to be in accordance with **4.1.2-6(2)(a)vii)**.The side of *FRP* with a thicker layer is to be taken as the compression side.

**5** The test results are to be summarized in the following procedures **(1)** and **(2)**.

(1) Test results of *FRP* laminates (*See* **Table 4.4.4-2**)

(2) Test results of sandwich constructions

(a) Tensile test (*See* **Table 4.4.4-3**)

(b) Shearing test (*See* **Table 4.4.4-4**)

### 4.4.5 *FRP* Strength Tests

For the test procedure,**4.4.4** applies correspondingly.

Table 4.4.4-1 Shape and Size, etc. of Test Specimens

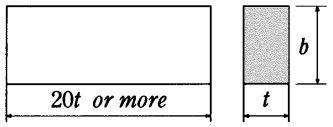
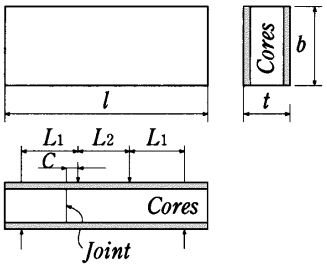
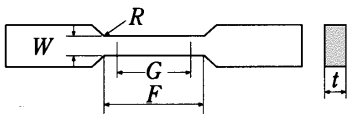
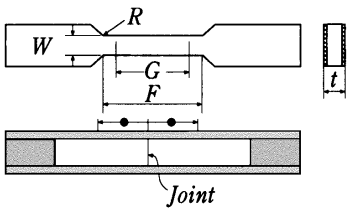
<table>
<tr><th rowspan="2">Item</th><th colspan="4">Test specimen</th><th rowspan="2">Quantity</th></tr>
<tr><th colspan="2">FRP laminates</th><th colspan="2">Sandwich construction</th></tr>
<tr><td>Thickness of moulding</td><td colspan="2">Bend test specimen and tensile test specimen are to be used</td><td colspan="2">Bend test specimen, shearing test specimen and tensile test specimen are to be used</td><td></td></tr>
<tr><td>Barcol hardness</td><td colspan="2"></td><td colspan="2"></td><td></td></tr>
<tr><td>Glass content</td><td colspan="2">2g or more per one<br>The periphery is to be finished smoothly</td><td colspan="2"></td><td>3</td></tr>
<tr><td>Bend test specimen and shearing test specimen</td><td colspan="2">Bend test specimen<br>  <br></td><td colspan="2">Shearing test specimen<br>  <br><br>t = original thickness<br>L1 = 100 ~ 200 (mm)<br>L2 = 100 (mm)<br>l = 2L1 + L2 + 60 (mm)<br>C = approx. 10 (mm)<br>(When the cores are rackoned in strength, a joint is to be provided at the position shown on the drawing.)</td><td>5</td></tr>
<tr><td></td><td>t (mm)</td><td>b (mm)</td><td>t (mm)</td><td>b (mm)</td><td></td></tr>
<tr><td></td><td>Not more than 20<br>Over 20 but not more than 35<br>Over 35 but not more than 50</td><td>30 ± 0.5<br>50 ± 0.5<br>80 ± 0.5</td><td>Not more than 20<br>Over 20 but not more than 35<br>Over 35 but not more than 50</td><td>30 ± 0.5<br>50 ± 0.5<br>80 ± 0.5</td><td></td></tr>
<tr><td>Tensile test specimen</td><td colspan="2">  <br><br>t = original thickness<br>F = 60 ± 0.5 (mm)<br>G = 50 ± 0.5 (mm)<br>W = 25 (mm) or more<br>R = 60 (mm) or more</td><td colspan="2">  <br><br>t = original thickness<br>F = 60 ± 0.5 (mm)<br>G = 50 ± 0.5 (mm)<br>W = 25 (mm) or more<br>R = 60 (mm) or more<br>• When the cores are reckoned in strength, a joint is to be provided at the centre of the parallel part.<br>• The gripped portion is to be reinforced.</td><td>5</td></tr>
</table>

Table 4.4.4-2 Test Results of *FRP* Laminates

| Location of selection | Test item | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Tensile test | | | Band test | | |
| | Barcol hardness | Glass content (%) | Thickness ($mm$) | Strength ($N/mm^2$) | Modulus of elasticity ($N/mm^2$) | Thickness ($mm$) | Strength ($N/mm^2$) | Modulus of elasticity ($N/mm^2$) |
| | | | | | | | | |
| Mean value | | | | | | | | |

Notes :

1) The mean value of thickness of *FRP* laminates is to be the mean of all the tensile test specimens and bend test specimens.
2) The test results other than the thickness are to be averaged by taking a mean of three test specimens in a smaller group of the five test specimens.

Table 4.4.4-3 Tensile Test Results of Laminates of Sandwich Construction

| Location of selection | Item | | | | | | |
|---|---|---|---|---|---|---|---|
| | Breadth of test specimen ($mm$) | Thickness of test specimen ($mm$) | Thickness of core ($mm$) | Thickness of laminates ($mm$) 1) | Breaking load ($N$) | Tensile strength ($N/mm^2$) | Remarks 3) |
| | | | | | | | |
| 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 4.4.4-4 Shearing Test Results of Laminates of Sandwich Construction

| Location of selection | Item | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Breadth of test specimen ($mm$) | Thickness of test specimen ($mm$) | Thickness of core ($mm$) | Thickness of laminates ($mm$) 1) | $\frac{P}{\varepsilon}$ ($N$) 2) | $Z_e$ ($cm^3$) 3) | $Z_c$ ($cm^3$) 4) | Breaking load ($N$) | Tensile strength ($N/mm^2$) 5) | Remarks 7) |
| | | | | | | | | | | |
| 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) $P/\varepsilon$ 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) $Z_e = \frac{L_1}{2E_f}\left(\frac{P}{\varepsilon}\right) \times 10^{-3}$ ($cm^3$)

Where :

$L_1$ : Outer span ($mm$)

$E_f$ : Modulus of elasticity of *FRP* laminates which is of the value obtained from the test specified in **4.4.4-4(1)(e)**

4) $Z_c$ is the section modulus of the test specimen of sandwich constructions obtained by following 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 **Fig.4.4.4-2**.

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

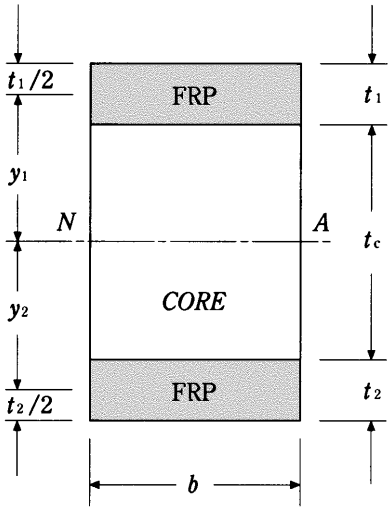
$$y_2 = \frac{(t_1 + t_2 + 2t_c)t_1}{2(t_1 + t_2)}$$

5) The shearing strength is of the value obtained from the test specified in **4.4.4-4(2)(c)**.

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.

Fig. 4.4.4-2



# Chapter 5 MOULDING

## 5.5 Bonding and Fastening

### 5.5.1 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 glassfibre reinforcements on the surface to be bonded are not to be of roving cloth but to be of chopped mat. The peripherles 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 3.0 to 3.5 *kPa*.

## 5.6 Bonded Connections

### 5.6.2 *L*-joints

Where *L*-joins are used, the overlap thickness $t'$ is to be not less than $t$ for important parts, and not less than $2/3t$ for other parts.

# Chapter 6 LONGITUDINAL STRENGTH

## 6.1 Longitudinal Strength

### 6.1.3 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 **4.3.5-2** or **4.3.7-2 of the Rules**

**2** In case where the structural plywood reckoned in longitudinal strength are provided with scarfjoints, the joint length is to be not less than 6 *times* the thickness as the standard.

# Chapter 8 DECKS

## 8.2 Minimum Thickness of Deck Laminates

### 8.2.3 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 **8.2.3-3 (1)** and **(2) of the Rules** or the value obtained from the following formula whichever is the greater.

$0.22L+10$ ($kN/m^2$)

# Chapter 11 BEAMS

## 11.1 Beams

### 11.1.3 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 **11.1.3**(a) and (b) **of the Rules** or the value obtained from the following formula whichever is the greater.

$0.15L+6.9$ ($kN/m^2$)

# Chapter 13 WATERTIGHT BULKHEADS

## 13.2 Construction of Watertight Bulkheads

### 13.2.3 Bulkhead Laminates of Structural Plywood

The bending strength of plywoods may be of the value verified by the bend test specified in *JAS* (Notification No. 1371, 1969 of the Ministry of Agriculture, Forestry and Fisheries).

# Chapter 14 DEEP TANKS

## 14.2 Bulkhead Laminates of Deep Tanks

### 14.2.3 Bulkhead Laminates of Structural Plywood

The bending strength of plywoods is to be in accordance with 13.2.3.

# Chapter 19 MACHINERY

## 19.2 Installation of Propulsion Machinery, Fuel Oil Tanks and Earthing

### 19.2.2 Fuel Oil Tanks

The terms "Proper measures for flame retardation and flame-resistance" in **19.2.2 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 Inocombustibility" class in *JIS* (Japanese Industrial Standards) *A* 1321, or those of "Incombustible","Self-extinguishing" or "Burning Resistance Class *V*-0 or *V*-1" for the burning resistance test in *JIS K* 6911.