Rules For Classification And Construction

Part 3 Special Ships

Volume V

RULES FOR FIBREGLASS REINFORCED PLASTIC SHIPS

Consolidated Edition 2021

Biro Klasifikasi Indonesia

www.bki.co.id

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Part 3 Special Ships

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Foreword

This Rules is a consolidated edition 2021 of Rules for Fibreglass Reinforced Plastic Ships Part. 3 – Special Ships, Volume V.

In this edition there are no new amendments added, only consolidate the 2016 edition, and Corrigenda No.1. The summary of previous edition and amendments including the implementation date are indicated in Table below:

	Edition / Rule Change Notice (RCN)	**Effective Date**	Link
1.	Edition 2016	8th January 2016	🔗
2.	Corrigenda No.1, August 2018	1st July 2018	🔗

Note : *Full previous edition and amendments including its amendment notice is available through link above.*

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Further queries or comments concerning this Rules are welcomed through communication to BKI Head Office.

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Section 1 General

A. Definitions and Abbreviations

1. Scope of application

1.1 The survey and construction of ships of fibre glass reinforced plastics (hereinafter referred to as "**FRP** Ships") to be registered in accordance with the Rules for the Classification and Surveys (Pt.1, Vol. I) are to be as stipulated in these Rules. Furthermore, the survey and construction of special **FRP** Ships are to be, notwhitstanding the requirements in these Rules, in accordance with the discretion of BKI.

1.2 The requirements in these Rules are applied to **FRP** Ships intended for unrestricted service, except oil tankers, less than 35 m in length, of normal form and proportion.

1.3 Hull construction, equipment and scantlings of **FRP** Ships intended for restricted service may be properly modified according to the conditions of service.

1.4 The requirements in these Rules are applied to **FRP** Ships moulded by hand lay-up method or spray lay-up method, using fibreglass reinforcements, unsaturated polyester resins and epoxy resins. Wooden ships covered with **FRP** or the ships of similar construction are not regarded as **FRP** Ships.

1.5 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 1.4, the hull construction, equipment, arrangement and scantlings are to be in accordance with the discretion of BKI.

2. Equivalency

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

3. Class Notation

FRP ships which are classed and entered in the Register Book will be distinguished by the class notation "**FRP**" affixed to the character of classification.

B. Definitions

1. Scope of application

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

2. Length of Ship

The length of ship **L** is the horizontal distance in meters on the load line from the fore side of stem to the after side of rudder post in case of a ship with rudder post or to the axis of the rudder stock in case of a

ship without rudder post. In case of a ship with cruiser stern, however, the length of ship is defined above or 96% of the total length on the designed maximum load line, whichever is the greater.

3. Breadth of Ship

The breadth of ship (B) is the horizontal distance in meters 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.

4. Depth of Ship

The depth of the ship (H) is the vertical distance in meters 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 "basepoint of H") to the upper surface of upper deck laminates at the side measured at the middle of L.

5. Midship Part of Ship

The midship part of ship is the part for 0,4L amidship otherwise specified.

6. End Parts of Ship

The end parts of ship is the part for 0,1L from each end of ship.

7. Load Line and Designed Maximum Load Line

7.1 The load line is the waterline corresponding to designed summer load draught or the designed sea water load draught in case of ship which is required to be marked with load lines and the waterline corresponding to the designed maximum draught in case of ship which is not required to be marked with load lines. However, in the FRP Ship which has no define designed maximum draught, the draught corresponding to 90 % of H from the base point of H is taken as the designed maximum draught.

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

8. Load Draught and Designed Maximum Load Draught

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

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

9. Freeboard Deck

9.1 The freeboard deck is normally the uppermost continuous deck. However, in case where openings without permanent closing means exits on the part of the uppermost continuous deck or where opening without permanent watertight closing means exist on the ship below that deck, the freeboard deck is the continuous deck below that deck.

9.2 In the 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 a deck below the expose deck, designated as the freeboard deck, may be disregarded, provided all openings in the weather deck are fitted with weathertight closing appliances.

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.

11. Fibreglass Reinforcements

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

12. Resins

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

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 for the base resins of structural adhesives.

14. Laminating

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

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 fibre glass reinforcements with resin or structural adhesives.

16. Moulding

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

17. Single Skin Construction

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

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.

19. Hand lay-up method

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

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.

21. Structural adhesives

Structural adhesives are adhesives used to connect structural members to hull structures or any other structures.

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.

C. General, Rules for Hull Construction and Equipment

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 Rules for Hull (Pt.1, Vol. II).

2. Stability

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

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 Regulation of the country in which the ship is registered.

4. Scantlings

4.1 The scantling required in these Rules are specified for **FRP** ships moulded with fibre glass 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	: $6,86 \times 10^3$	N/mm^2
3.	Bending strength	: 150	N/mm^2
4.	Modulus of bending elasticity	: $6,86 \times 10^3$	N/mm^2

4.2 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 4.1:

1. For the thickness, a factor f_1, obtained from the following formulae :

$$f_1 = \sqrt{\frac{150}{\sigma_B}}$$

where:

σ_B = Bending strength of the **FRP** obtained from the material tests specified in Section 4, D.4 (N/mm^2)

2. For the section modulus (including section modulus of the transverse section of hull), a factor f_2 obtained from the following formulae:

$$f2 = \sqrt{\frac{98}{\sigma_T}}$$

where:

σ_T = Tensile strength of the **FRP** obtained from the material tests specified in Section 4, D.4 (N/mm^2)

4.3 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 of sandwich construction may be as obtained from the material tests specified in Section 4, D.4.

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

5. Hat-type construction

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

Thickness of web: $0{,}034 \cdot h \cdot k$ (mm)

Thickness of face: $0{,}05 \cdot b \cdot k$ (mm)

where:

h = Depth of web (mm)

b = Breadth of face (mm)

k = 1,0

Where the section modulus of the members exceeds the specified value.

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

where:

Z_R = Section modulus specified for the member

Z_A = Actual section modulus of the member

5.2 The core for moulding may be reckoned in the strength at the discretion of BKI.

5.3 Other scantlings are to be in accordance with the requirements in the relevant Sections.

6. Sandwich construction

6.1 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 differ from these requirements is to be at the discretion of BKI.

6.2 The ratio, of the thickness of outer and inner layers of FRP is not to be less than 0,80. In case where the ratio of the thickness of outer and inner layers is less than 0,80 , the construction will be specially considered by BKI.

6.3 The cores may be reckoned in the strength at the discretion of BKI.

6.4 Other scantlings are to be in accordance with the requirements in the relevant Sections.

7. Weight of fibre glass reinforcements and thickness of laminates

7.1 The thickness of laminates per ply of chopped mats or roving cloths may be as obtained from the following formulae :

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

where:

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

G = Glass content of laminate (ratio inweight) (%)

γ_R = Specific gravity of cured resin

γ_G = Specific gravity of chopped mats or roving cloths

Guidance:

For specific weight 100 gr/m^2 the laminates thickness may be taken as follows:

t = 0,25 mm for cured resin and mat plies

= 0,16 mm for cured resin and woven roving plies.

7.2 The glass content (G) specified in the preceding 7.1 is preferable to be the value per ply for actual laminates. However, it may be taken as mean glass content of the whole laminates.

7.3 The specific gravity of chopped mats or roving cloths (γ_G) specified in preceding 7.1 may be taken as 2.5, in calculation of the thickness, if nothing specially intervenes.

7.4 The specific gravity of cured resin (γ_R) specified in preceding 7.1 may be taken as 1.2, in calculation of the thickness, unless any fillers are used in order to make the resin heavier.

7.5 Calculation of the thickness of laminates with fibre glass reinforcements other than chopped mats and roving cloths is to be in accordance with the discretion of BKI.

Section 2 Class Survey

A. General

1. General

1.1 The class surveys of **FRP** Ships are to be, except those specified in this Section, in accordance with the requirements in the Rules for the Classification and Survey (Pt.1, Vol.I).

1.2 In the survey of **FRP** Ships less than 20 m in length, the items, extent and degree of survey may be properly modified, where deemed appropriate by BKI.

1.3 In the second annual survey after construction, as a rule, the internal inspection of fuel oil tanks made of **FRP** is to be carried out.

B. Classification Survey During Construction

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, stability and load lines are to be examined in detail in order to ascertain that they meet the requirements in the relevant sections.

2. The new installation of materials which contain asbestos is to be prohibited.

2. Plans and documents to be submitted

2.1 With respect **FRP** Ships intended for the classification survey during construction, the plans and documents listed in the following 2.1.1 to 2.1.3 are, prior to the commencement of work, to be submitted for approval by BKI :

2.1.1 Hull

- List and data of raw materials,
- General arrangement,
- Midship section (showing atwartship sections at the holds and machinery space, and in way of the wing tanks, if provided, and also indicating the character of intended classification and the load draught),
- Details of fore and aft construction, and stem and stem frame,
- Propeller post and rudder (indicating materials and ship's speed)
- Construction profile (showing arrangement of watertight bulkheads, load draught, sizes of bracket and atwartship sections of the ship at 0,1**L** and 0,2**L** from the ends of the ship)
- Deck plans (indicating arrangement and construction of hatchways, hatch beams, etc.)
- Single bottoms and double bottoms

- Watertight and oiltight bulkheads (indicating the highest position of tank and positions of tops of overflow pipes)
- Superstructures end bulkheads (indicating the construction of door)
- Seatings of 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)
- Steering gear (indicating details of structural arrangement and materials)
- Laminating procedure and details of joints.

2.1.2 Machinery & electrical installation

Plans and documents in relation to the machinery and electrical installation specified in Rules for Machinery Installations (Pt.1, Vol.III) and Rules for Electrical Installations (Pt.1, Vol.IV).

2.1.3 Other plans and documents deemed necessary by BKI.

3. Plans and documents to be submitted for reference

3.1 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 B.2:

- Specifications
- Certificates of **FRP** material tests specified in Section 4,
- Moulding procedure,
- Calculation sheets and information with respect to structural strength,
- Plans and documents for determining freeboard as specified in Rules for Hull (Pt.1, Vol.II) Sec.1.

3.2 In cases where main structural members are connected by structural adhesives, the plans and documents to be submitted for reference, in addition to those required in the preceding B.3.1, are as follows:

- Procedures for repairing defects in joints moulded by structural adhesives; and
- Procedures for repairing joints connected by structural adhesives.

3.3 Plans and documents other than specified in preceding 3.1 and 3.2 may be required to be submitted, where deemed necessary by BKI.

4. Inspection during construction

4.1 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

4.2 The presence of the surveyor is required at the following stages of the work in relation to hull:

- When the tests of **FRP** materials specified in Section 4, are carried out
- When designated by BKI during moulding work
- When the strength tests of **FRP** specified in Section 4 are carried out
- When the moulding are connected (e.g. shell to deck)
- When the materials or parts manufactured away from the site are applied to the **FRP** ship concerned
- When hydrostatic tests and watertight tests are carried out
- When sea trial are carried out
- When deemed necessary by BKI.

4.3 With respect to the work in relation to the machinery and electrical equipment, the presence of the surveyor is required when important machinery and electrical equipments are installed on board, see also Rules for Machinery Installations (Pt.1, Vol.III) and Rules for Electrical Installations (Pt.1, Vol.IV).

4.4 The stages of work for which the presence of the Surveyor is required in the preceding 4.2, 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.

C. Classification Survey Not Built Under Survey

1. General

1.1 In the classification survey of an **FRP** ships not built under BKI's survey, the actual scantlings of main parts of the ship are to be measured in addition to such examinations of the construction material, workmanship and actual conditions of hull and equipment, machinery, electrical installation, fire protection and detection, means of escape, fire extinction, stability and load lines as required for the special survey corresponding to the ship's age.

1.2 As for an **FRP** ship intended for the classification survey specified in the preceding 1.1, plans and documents required for the classification survey during construction are to be submitted.

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Section 3 Workshops

A. General

1. Application

Workshops intending to manufacture FRP ships and their facilities are to be in accordance with requirements in this Section.

2. Workshop

The workshops which manufacture FRP ships intended to be registered to BKI, 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.

B. Laminating Shops

1. Construction and arrangement of laminating shops

1.1 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.

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

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

2. Ventilation facilities

In providing the laminating shops with ventilation facilides, thorough consideration are to be given so that they should not give any bad influences upon the curing of laminates.

3. Temperature conditioners

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

4. Relative humidity

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

4.2 If necessary, suitable dehumidifying appliances are to be provided.

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.

6. Dust collcctors

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

C. Storage Facilities for Raw Materials

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 materials.

2. Stores of resin, etc.

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

3. Stores for flbreglass reinforcements

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

Section 4 Material for Hull

A. General

1. Application

The requirements in this Section are framed for **FRP** and their raw materials, etc. The metallic materials are to be in accordance with the requirements in Rules for Materials (Pt. 1, Vol.V).

2. Raw materials for primary structures

The fibre glass reinforcements, resins for laminates and 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 BKI in accordance with the requirements in B.

B. Approval

1. Approval of raw materials

At the request of raw material manufacturers, BKI 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 test and inspections specified in this section on the test samples designated by BKI. Where the test samples have passed these tests and inspections, they are dealt with as the approved materials :

1. Fibre glass reinforcements,
2. Resins for laminates,
3. Core materials for constructions, and
4. Structural adhesives.

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 requirement in the following:

- Examinations of the material used manufacturing methods, inspection standards in the workshop, quality control system, etc.
- Test and inspection designated by BKI.

3. Withdrawal of approval

In case where the approval material correspond to either one of those specified in the following, the approval of material by BKI is to be withdrawn:

- When the material used, manufacturing methods, inspection standards in the workshop, quality control system, etc., are worse than those at the time of approval and deemed inadequate,
- When the approved materials have not passed the specified periodical inspection,
- When the specified periodical inspection are not carried out

C. Raw Material, etc.

1. Tests and inspection of fibre glass reinforcements

The tests and inspection specified in A.2 for fibre glass reinforcements to be used for the hull structures of **FRP** ships are to be carried out in accordance with Rules for Non Metalic Materials (Pt.1, Vol.XIV, Ch.1) Sec.2.A.3.

2. Tests and inspection of resin for laminating

The test and inspections specified in A.2 for resins for laminating to be used for hull structures of **FRP** Ships are to be carried out in accordance with Rules for Non Metalic Materials (Pt.1, Vol.XIV, Ch.1) Sec.2.A.2.

3. Filler

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 BKI.

4. Curing agents and accelerators

The type and amount used of the curing agents 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.

5. Tests and inspections of core materials for sandwich construction

5.1 The test and inspections specified in A.2 of core materials for sandwich construction used for the hull structures of **FRP** Ships are to be in accordance with Rules for Non Metalic Materials (Pt.1, Vol.XIV, Ch.1) Sec.2.A.5.

5.2 Timbers and plywood are to be tested and inspected on the items in the following:

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

6. Timbers and plywood for primary structures

6.1 The Timbers and plywood 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.

6.2 Timbers and plywood for primary structures are to be well seasoned.

6.3 Plywood for primary structures are to be plywood for structures which are deemed appropriate by BKI.

7. Cores for moulding

7.1 Cores used for moulding in frames, longitudinals, etc. are to be of oil resistance, styrene resistance and water resistance, and to have good adhesion to polyester resins.

7.2 Where the cores for moulding are reckoned in strength, test are to be carried out on tensile strength and modulus of tensi Ie elasticity or bending strength and modulus of bending elasticity. However, where sufficient data are submitted to and approved by BKI, the above mentioned tests may be dispensed with.

D. FRP

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 Section.

2. Tests and inspections of FRP

FRP is to be tested in accordance with the requirements in 4. and 5. in the presence of the Surveyor.

3. Omission of FRP material test and FRP strength tests

3.1 For a sister ship of others which were or are being built at the same workshop, the FRP material test and FRP strength tests may be omitted, notwithstanding the requirements in 2., provided that the raw materials used, manufacturing methods inspection standards in the workshop, quality control system, etc are examined and deemed appropriate by BKI. However, for ships not less than 20 m in length, the FRP strength tests are not to be omitted.

3.2 The FRP for which omission of the material tests specified in 3.1 is applicable are such FRP that have been recognized by BKI as being moulded by means of the same laminating and the same moulding procedures as those the FRP having the certificates of FRP material tests in accordance with the requirements in 4.

4. FRP material test

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

4.2 The test specimens for FRP material tests are to be cut from FRP which are of the same laminate composition (excluding ge1coats) 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 test procedures and inspections are to be in accordance with Annex 1.

1. FRP laminates (including FRP laminates of outer layer of sandwich laminates)

- Thickness of moulding
- Barcol hardness,
- Glass content (ratio in weight),
- Bending strength,

– Modulus of bending elasticity,
– Tensile strength,
– Modulus of tensile elasticity

2. Sandwich laminates

– Thickness of moulding of sandwich laminates.
– Tensile strength of sandwich laminates, only in case where the cores are reckoned in the tensile strength. In this case where the cores are joints of cores are involved are to be included.
– Shearing strength of sandwich laminates. In case where the cores are reckoned in the bending strength, the test specimens in which joints of cores are involved are to be included.

4.3 The FRP material tests are to be carried out, at least on the structural members listed in the following. 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 Section 1, C.4.2.

– Bottom shell laminates,
– Side shell laminates,
– Upper deck laminates,
– Bulkhead (only of sandwich construction).

4.4 The result of FRP material tests containing the items listed in the following are to submitted to BKI.

– Names of fibre glass reinforcements, resin for laminating and cores for sandwich construction,
– Names and amount of application of fillers,
– Names and amount of application of sclerotic and accelerators,
– Procedure and conditions of moulding,
– Direction of selection of test specimens,
– Dates of moulding and test of test specimens,
– Place of tests and environmental condition of the site of tests,
– Types of testing machines,
– Form and dimensions of test specimens,
– Test results.

4.5 The number of test specimens subjected to the FRP material test are to be 5 (five), unless specially specified, and the arithmetical mean of the smaller 3 (three) values obtained from the five specimens is to be taken as the test result.

4.6 The result of FRP material test is not to be less than the strength specified in Section 1, C.4 for FRP laminates and not to be less than the values obtained from the test specified in C.1 or C.5 for sandwich laminates.

5. FRP strength test

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

5.2 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 under go tests and inspections on the items specified in 4.2 and 4.3. And further, the testing procedure and location or selection of test specimens are to be at the discretion of BKI.

5.3 The results of FRP strength tests are to be submitted to BKI as the result of FRP strength test containing the items specified in 4.4 and the location of selection of test specimens.

5.4 The number of test specimens for FRP strength tests and the determination of test results are to be in accordance with the provisions in 4.5.

5.5 Where the results of FRP strength tests are less than those of FRP material tests in 4., the structural members are to be properly strengthened

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Section 5 Moulding

A. General

1. Application

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

2. Supervision over moulding

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

3. Curing of moulding

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 BKI.

4. Supporting of mouldings

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

5. Blending proportion

5.1 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 of resins.

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

6. Operation manual

Before moulding, examinations are to be made in detail with respect to the item listed in the following and moulding is to be proceeded on the basis of such examinations.

- Environmental conditions of laminating shops, controlling system thereof a curing time of resins.
- Operation procedure and scheduled operation process.
- Kinds, cutting methods, overlap of joints, edge preparation and number of plies of fibreglass reinforcements.
- Kinds, amount, blending quantity at one time and blending procedure of resins used.
- Kinds, amount used, application methods and adhesive layer thicknesses of structural adhesives.

7. Environmental conditions of laminating shops

7.1 The temperature while laminating is to be kept suitable for the resins used. The temperature is, however, not to be lower than 15° C.

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

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

8. Environmental conditions of works using structural adhesives

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

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

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

9. Gelcoats

9.1 Gelcoat resins are to be evenly coated or sprayed.

9.2 The standard thickness of gelcoat tilm is approximately 0,5 mm.

10. Moulding of structural members

It is recommended that the structural members are moulded in one body with the prescribed hull laminates before they advance in cure. However, structural members separately moulded may be bonded to the hull laminates.

11. Sanding

Where-the outer surface of FRP laminates is sanded, attention is to be paid so that the fibreglass on the sanded surface can be avoided.

12. Cut edges of laminates

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

13. Mould releasing

13.1 Mould releasing operation is to be carefully carried out so that permanent deformations and damages harmful to the hull laminates can be avoided.

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

B. Hand Lay-Up Method

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 to be less than 100 mm apart from each other so far as no obstruction exist for the work.

2. Degassing

In laminating, after 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 kept the glass content proper.

3. Glass content

3.1 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.

3.2 The aggregated weight of roving cloths is to be 25% to 65% of the total weight of glass. Where, however, special fibreglass reinforcements are used, the weight is to be in accordance with the discretion of BKI.

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 tirst 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. Laminating for final ply

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

C. Spray Lay-Up Method

1. Spray lay-up apparatus

1.1 The spray lay-up apparatus is to be approved by BKI.

1.2 The spray lay-up apparatus is to be those which can mould FRP so that the glass content, mechanical properties, etc., are uniform.

1.3 Moulding by means of the spray lay-up apparatus is to be carried out by skilled moulding operators.

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 BKI.

D. Moulding of Sandwich Construction

1. Cores

1.1 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, mis-alignment and other defects due to nailing. And, no penetrating clearance not less than 1 mm is to be left between the cores.

1.2 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.

2. Surface treatment of cores

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

E. Bonding and Fastening

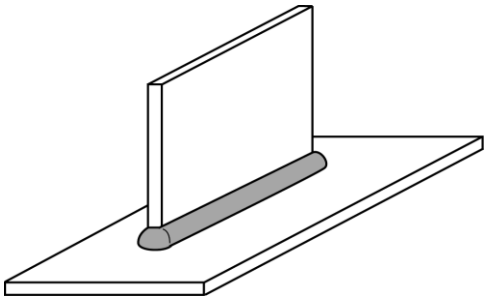
1. Bonding

1.1 In cases where bonding using fiberglass reinforcements with resins is carried out, the following requirements are to be complied with :

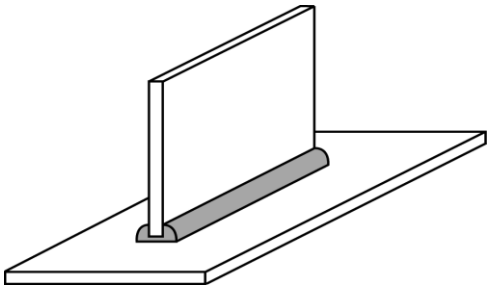
- Bonding is to be executed after making effective preparation such as sanding the surface to be bonded and thoroughly removing oils and sanding dusts.
- Bonding is to be executed paying careful attention not to cause spring back of fibreglass reinforcements.
- Bonding is to be carefully executed so as not cause to any deformation due to excessive exothermic effect.
- Bonding is to be carefully carried out so as not to cause strength discontinuity at the joint.
- T-joints and L-joints are to be laminated at the site.

1.2 In cases where bonding is carried out using structural adhesives, the following requirements are to be complied with:

- 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.
- 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.
- Bonding is to be carefully carried out so as not to cause any condensation on the adhesive surface.
- Bonding is to be carefully carried out so as not to cause any spring back of structural members.
- Bonding is to be carefully carried out so as not to affect adhesive properties due to excessive exothermic effects.
- Bonding is to be carefully carried out so as not to cause any discontinuities in adhesive strength, except for cases where specified in F.1.2.(2). In addition, joint edges are to be appropriately treated as shown in Fig. 5.1.
- Until structural adhesives sufficiently cured, adhesive joints are to be appropriately fixed to prevent any deformation.



(a) Example of Appropriately Treated End



(b) Example of Inappropriately Treated End

Fig. 5.1 End treatment of joints

2. Fastening

2.1 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 seawater corrosion-resistant metal or to be properly protected against corrosion.

2.2 As far as practicable mechanical fastening is to be carried out at a right angle to the laminates and the fastening holes are to be well coated with resins.

3. Bolts

3.1 The distance between the centre of bolts hole and the edge of laminates 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 the diameter of the hole.

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

3.3 The diameter of the bolt to be not less than the thinner component being fastened. Bolts of less than 6,5 mm are not to tie used.

4. Connection of sandwich laminates

Where bolts, screw, rivets, etc. are used, penetrating sandwich laminates with cores of hard plastic foams, timbers or plywood well seasoned are to be inserted in such parts of the cores in advance.

5. Watertight construction

Where mechanical fastening such as bolted joints, etc. is used in way of location where watertightness is required, suitable measures are to be provided to maintain watertightness.

F. Bonded Connections

1. T-joints

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

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

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

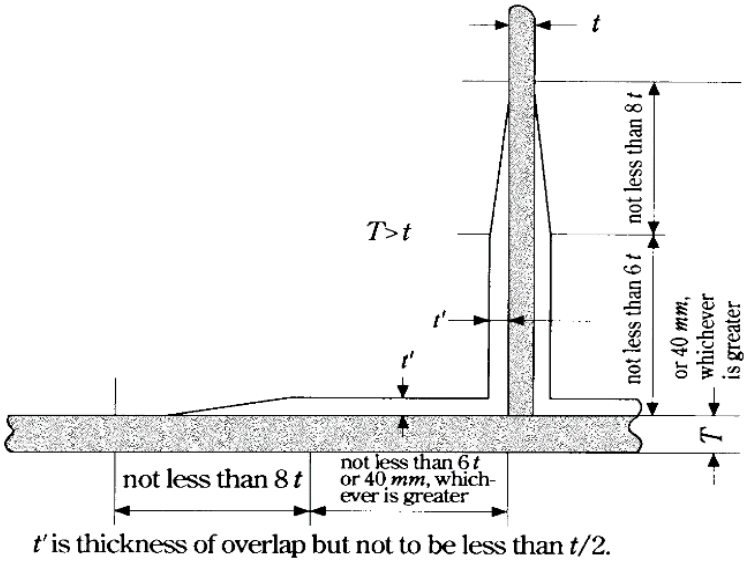
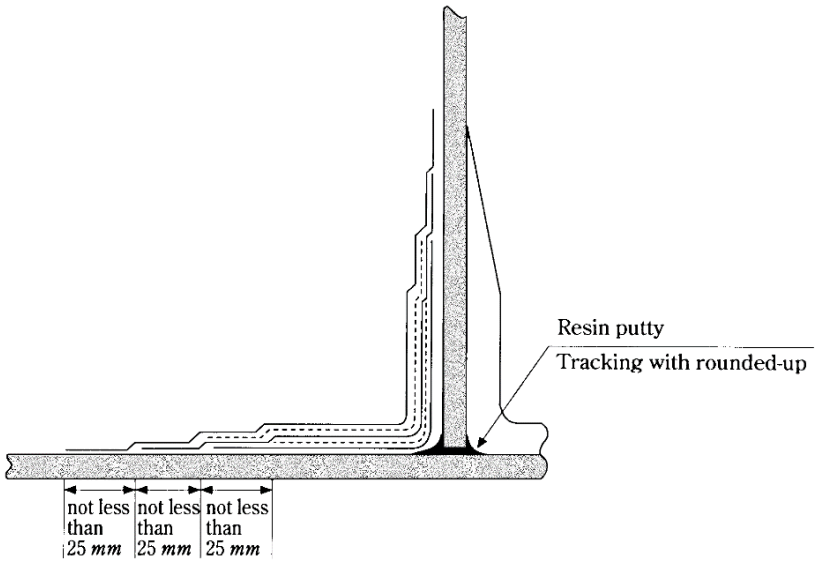


Fig. 5.2 Dimension of overlap of T-joints



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

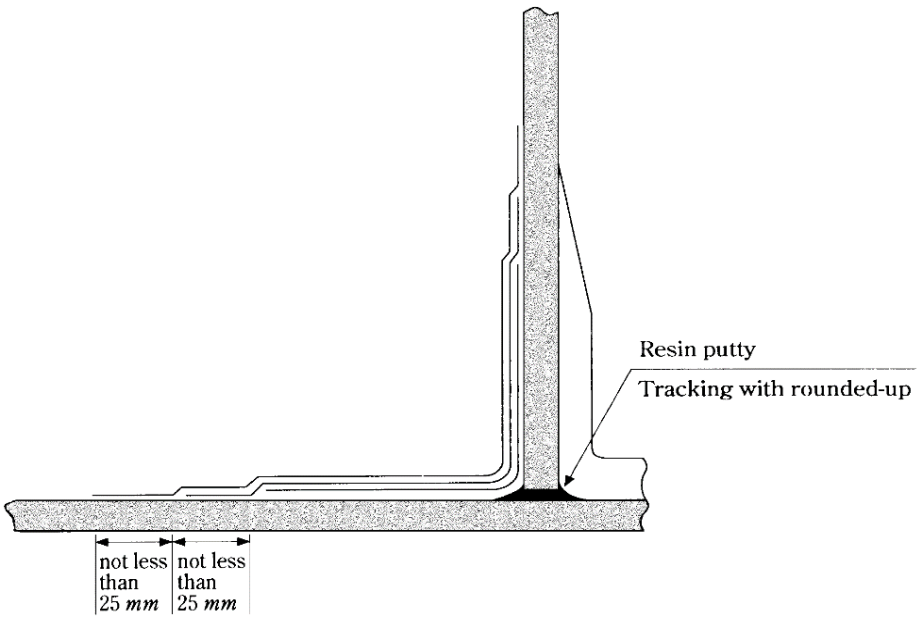


Fig. 5.3(b) In Case Chopped Mats are used

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

- 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.
- 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).

2.2 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.

3. Butt joints

3.1 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.

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

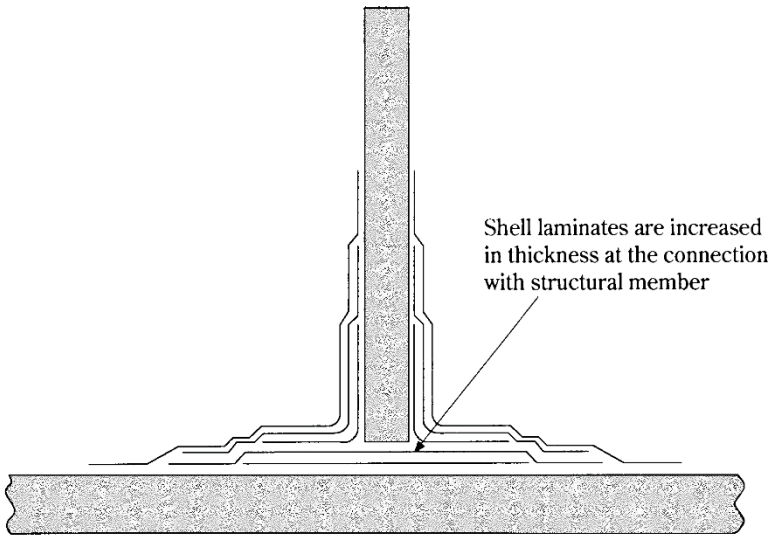


Fig. 5.4(a) In Case Consideration is to be paid to load or vibration

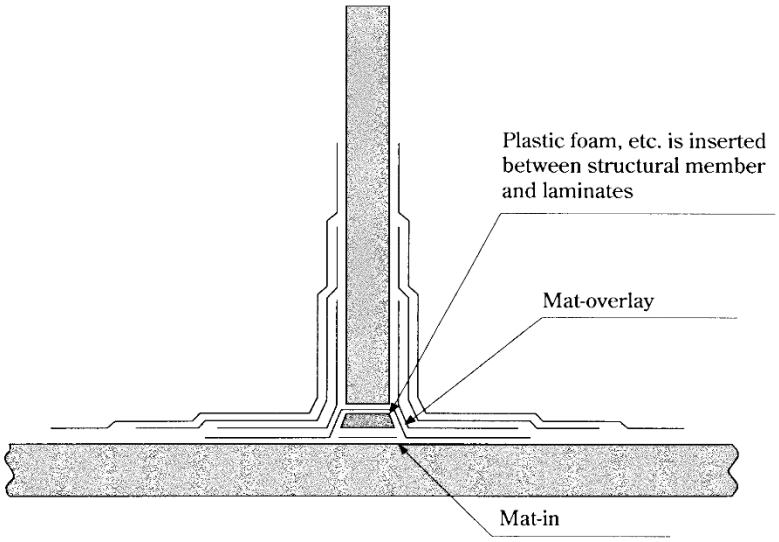


Fig. 5.4(b) Standard Form of T-Joints

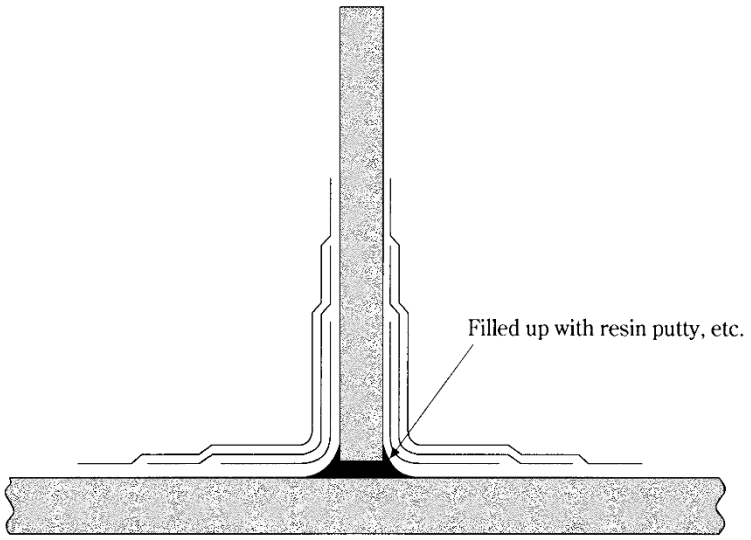
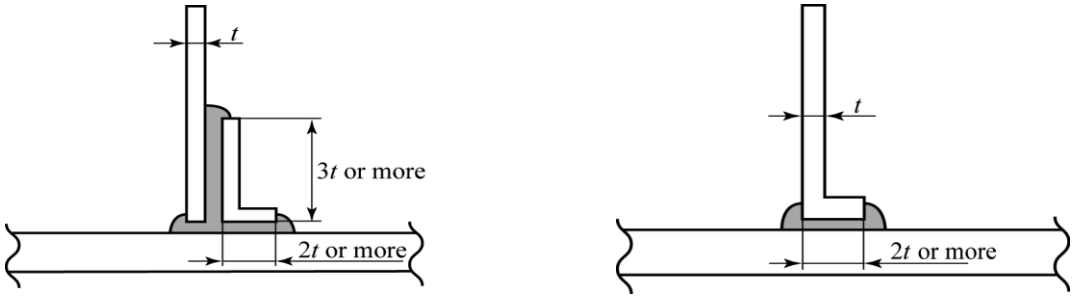
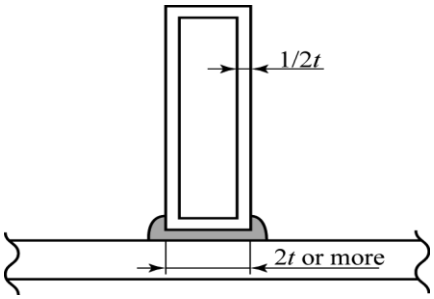


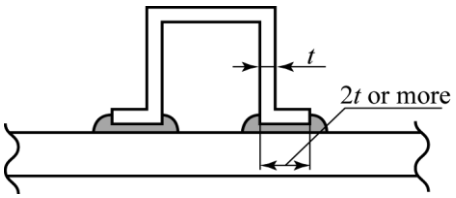
Fig. 5.4(c) Standard form of T-joints



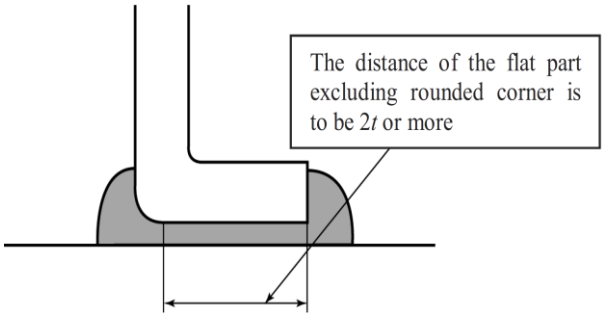
(a) Single Skin Bonding



(b) Plywood Sandwich Bonding



(c) Hat Shaped Structure Bonding



(d) Enlarged View of Rounded Corner

Fig. 5.5 Joints using structural adhesives （T-joints）

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Section 6 Longitudinal Strength

A. Longitudinal Strength

1. Midship section modulus

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

$$W = C \cdot L^2 \cdot B \cdot (C_b + 0,7) \ [cm^3]$$

where:

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

= $0,4L + 36$

B = 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 $L \cdot B \cdot T$.

2. Midship moment of inertia

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

$$I = 4,2 \cdot W \cdot L \ [cm^4]$$

where:

W = Midship section modulus of the athwarthship section specified in Section modulus specified in 1. [cm^3].

Where, however, L/H for FRP ships of single bottom is less than 12 the calculation of the moment of inertia may be dispensed with.

3. Calculation of Midship Section Modulus

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

- 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.
- 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 H, or to the bottom of keel in case where the keel is of hat-type construction.

– 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.

– 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 BKI for approval.

4. Continuity of Strength

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

Section 7 Shell Laminates

A. General

1. Application

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

B. Keels

1. Construction and Scantlings

1.1 Keels are to be as continuous from fore end to after end as practicable.

1.2 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 : $b = 530 + 14{,}6\mathbf{L}$ [mm]

Thickness : $tk = 9 + 0{,}4\mathbf{L}$ [mm]

C. Shell Laminates for Midship Part

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 :

$$t_s = 15 \cdot a \cdot \sqrt{T + 0{,}026 \cdot L} \quad [mm]$$

where:

a = Spacing of frames [m]

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 :

$$t_B = 15{,}8 \cdot a \cdot \sqrt{T + 0{,}026 \cdot L} \quad [mm]$$

where:

a = Spacing of frames [m]

3. Shell Laminates of Sandwich Construction

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

$$t_a = C_1 \cdot a \cdot (T + 0{,}026L) \quad [mm]$$

$$t_a = C_2 \cdot t_f \quad [mm]$$

where:

t_f = Thickness in case of single skin construction specified in 1. or 2. [mm].

a = Spacing of frames [m].

C_1 = Coefficient obtained from the following formula:

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

τ_a = Shearing strength of sandwich laminates obtained from the test specified in Section 4, B.1 or C.5.2, C.5.3 or C.5.4 [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,

α = The thickness of outer layer or inner layer of FRP, whichever is the divided by the greater thickness.

β = The sum of the thickness of outer layer and inner layer of FRP divided by the thickness of core.

3.2 The respective thickness of inner layer and outer layer of shell laminate of sandwich construction is not, notwithstanding the requirements in the preceding 3.1, to be less than obtained from the following formula. In no case, however, is it to be less than 2,4 mm:

where,

$$t_1 = 3{,}6 \cdot \sqrt[3]{C_4 \cdot a^4 \cdot (T + 0{,}026 \cdot L)^4} \quad [mm]$$

where:

a = Spacing of frames (m)

C_4 = Coefficient obtained from the following formula:

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

E_f = Modulus of bending elasticity of inner layer or outer layer specified in C.4 (N/mm^2).

E_c = Modulus of compressive elasticity of core obtained from the test specified in Section 4, B.1, or C.5.2, C.5.3 or C.5.4 [N/mm^2]

σ_c = Compressive strength of core obtained from the test specified in Section 4, B.1, or C.5.2, C.5.3 or C.5.4 [N/mm^2]

t_c = Thickness of core [mm].

Table 7.1 Value of C_2 and C_3

β	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
$C_2(\alpha = 1)$	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

D. Shell Laminates for End Parts

1. Thickness of Shell Laminates for End Parts

1.1 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.

1.2 Shell laminates of sandwich construction beyond the midship part are to be of the same construction as that for the midship part.

1.3 For the part where subjected to local loads such as propeller pressure, etc., the shell laminates are to be properly strengthened.

2. Strengthened Bottom Forward

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

- Where $V / \sqrt{L}$ is not more than 1,5: 0,25**L** from the fore end,
- 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).

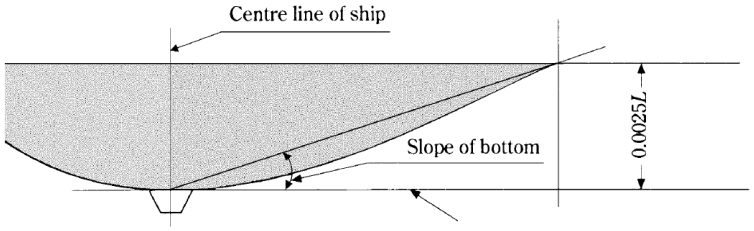

Fig. 7.1 Slope of Bottom

3. Shell Laminates at the Strengthened Bottom Forward

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

$$t_{BF} = C \cdot a \cdot \sqrt{L} \quad [mm]$$

where:

C = Coefficient given in Table 7.2. However, for the intermediate value of α, C is to be obtained by linear interpolation.

a = Spacing of frames, or spacing of girders or longitudinal shell stiffeners, whichever is smaller [m].

α = Spacing of frames, or spacing of girders or longitudinal shell stiffeners, whichever is greater [m], divided by a.

Table 7.2 Value of C

α	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

3.2 The thickness of shell laminates at strengthened bottom forward of sandwich construction is not to be less than obtained from the formula specified in C.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 C.3.1.

3.3 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 BKI to have sufficient bow draught, the thickness specified in the preceding 3.1 and 3.2 may be properly reduced.

E. Side Shell Laminates in Way of Superstructures

1. Thickness of Shell Laminates

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

– The thickness of side shell laminates in way of superstructures for 0,25**L** from the fore end and that of side shell laminates in way of sunken forecastle or sunken poop is not to be less than that of side shell laminates at the place.

– The thickness of side shell laminates in way of superstructures other than specified in the preceding 1. may be 0,8 times that of side shell laminates at the place.

F. Local Strengthening of Shell Laminates

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.

Section 8 Decks

A. General

1. Application

1.1 The requirements in this section 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 BKI.

1.2 The construction and scantlings of decks specified in this section are applied for the case where decks are of single skin construction or of sandwich construction.

2. Watertightness of Decks

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

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.

B. Minimum Thickness of Deck Laminates

1. Thickness of Deck Laminates of Single Skin Construction

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

$$t_D = 4{,}8 \cdot a \cdot \sqrt{p} \quad [mm]$$

where:

a = Spacing of longitudinal beams [m].

p = As specified in 3. [kN/m^2]

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

$$t_D = 5{,}8 \cdot a \cdot \sqrt{p} \quad [mm]$$

where:

a = Spacing of longitudinal beams [m].

p = as specified 3. [kN/m^2].

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

$$t_D = 4{,}2 \cdot a \cdot \sqrt{p} \quad [mm]$$

where:

a = Spacing of longitudinal beams or transverse beams [m]

p = As specified in 3. [kN/m^2]

2. Thickness of Deck Laminates of Sandwich Construction

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

$$t_D = 0{,}1 \cdot C_1 \cdot a \cdot p \quad [mm]$$

$$t_D = C_2 \cdot t_f \quad [mm]$$

where:

a = Spacing of longitudinal beams of transverse beams [m].

p = As specified in 3. [kN/m^2].

t_f = Thickness of deck laminates in case of single skin construction specified in 1. [mm].

C_1 and C_2 = As specified in Section 7, C.3.1.

2.2 The respective thickness of the inner laminates and outer laminates of decks of sandwich construction are not, notwithstanding the requirements in the preceding 2.1, to be less than obtained from the following formulae. In no case, however, it is to be less than 2,5 mm.

$$t_D = 0{,}17 \cdot \sqrt[3]{C_4 \cdot (a \cdot p)^4} \quad [mm]$$

where:

a = Spacing of longitudinal beams of transverse beams [m].

p = as specified in 3. [kN/m^2].

C_4 = as specified in Section 7, C.3.2

3. Deck Load p

Deck load h for decks intended to carry cargoes, etc. is to be as specified in the following:

- 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.
- 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 3.3, whichever is greater.
- For decks intended to carry cargoes whose weight is considerably light, h may be suitably modified.

3.2 For decks exclusively used for accommodation or navigation spaces and for tops of long deckhouses, p is to be 4,6 [kN/m^2].

3.3 For weather decks, h is to be as specified in the following:

For weather decks afore 0,3**L** from the fore end: $p = 0,50L + 4,6$ [kN/m^2]

For weather decks abaft 0,3**L** from the fore end: $p = 0,27L + 4,6$ [kN/m^2]

C. Local Compensation of Decks

1. Compensation for Large Openings

1.1 Deck laminates in way of corners of large openings are to be suitably increased in thickness.

1.2 Corners of openings are to be suitably rounded.

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.

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.

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.

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Section 9 Frames

A. General

1. Application

1.1 The requirements in this section are framed for the construction and scantlings of frames moulded with FRP.

1.2 For FRP ships with especially long holds or with especially large hatch openings, the transverse stiffness of the hull is to be suitable increased by increasing the scantlings of frames or by providing web frames additionally.

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.

B. Construction

1. Construction of Frames

1.1 Frames are so constructed as to avoid lateral buckling.

1.2 Where the length of ship is small, corrugated side shell laminates may be adopted in lieu of normal framing construction.

2. Cores for Frames

Timbers used for cores are to be well seasoned and free from sapwood. Care is to be taken so that dry rot in timbers wrapped in FRP can be avoided.

2.1 Plastic foams used for cores are to be non-hygroscopic.

C. Frames Spacing

1. Frames Spacing

1.1 The standard spacing of frames is 500 mm.

1.2 The spacing of frames afore 0,2L from the fore end and in the aft peak is not to exceed 500 mm.

2. Consideration for Especially Large Frames 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.

D. Frames

1. Scantlings of Transverse Frames

1.1 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:

$$W = 32 \cdot a \cdot h \cdot \ell^2 \ [cm^3]$$

where:

a = 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 **T** + 0,026**L** [m] above the base point of **H** [m]. Where, however, the distance is less than 0,5**H** [m], h is to be taken as 0,5**H** [m]

1.2 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:

$$W = 37{,}5 \cdot a \cdot h \cdot \ell^2 \ [cm^3]$$

where:

a, h and ℓ = As specified in the preceding 1.1. However, ℓ is to be measured at 0,15**L** from the fore end.

2. Side Longitudinal

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

$$W = 49 \cdot a \cdot h \cdot \ell^2 \ [cm^3]$$

where:

a = Spacing of longitudinal [m]

h = Vertical distance from the longitudinal to a point **T** + 0,026**L** [m] above the base point of **H** [m]. Where, however, the distance is less than 0,5**H** [m], h is to be taken as 0,5**H** [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].

2.2 Beyond the midship part, the section modulus of side longitudinal may be gradually reduced toward the ends of ship, and may be 0,85 times that obtained from the formula in the preceding 1.1 for the end parts. However, the section modulus of side longitudinal afore 0,15**L** from the fore end is not to be less than obtained from the formula in the preceding 1.1.

3. Web Frames supporting Side Longitudinals

Where the ship's side are longitudinally framed, 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 BKI.

4. Hat-type Construction

With respect to the scantlings of frames of hat-type construction, the requirements in Section 1, C.5 in addition to the requirements in this section, are to be applied.

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Section 10 Bottom Construction

A. General

1. Application.

1. The re requirements of this section are framed mainly for the single bottoms.

2. In which, the bottom is partially or full double bottom construction, the double bottom construction are to be in accordance with the requirement 10.6, and the member of double bottom constructions are to be constructed with special care.

B. Centre Girders

1. Centre girders are to extend from the collision bulkhead to the aft peak bulkheads as far as practicable.

2. The thickness of web of centre girders is not to be less than from the following formula. However, beyond the midship part, the thickness may be gradually reduced toward the ends and it may be 85% of the midship value for the end parts.

$$t = 0{,}4L + 5 \quad [mm]$$

3. The breadth and thickness of the face plates are not to be less than from the following formula. However, beyond the midship part, the sectional area of the face plates may be gradually reduced towards the ends and it may be 80% of the midship value for the end parts.

$$A_f = (0{,}4L + 5) \times (4L + 30) \quad [mm^2]$$

4. The webs of centre girders are to extend to the top of floors or bottom transverse girders.

5. In the engine room, the thickness of web and face plates are not to be less than 125% than the values calculated from 2. and 3., respectively.

6. The centre girder may be omitted for ships with hat-type keel with suitable height.

C. Side Girders

1. Arrangement of Side Girders

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

2. Construction and Scantlings

2.1 The thickness of web of side girders is not to be less than from the following formula. However, beyond the midship part, the thickness may be gradually reduced toward the ends and it may be 85% of the midship value for the end parts.

$$t = 0,3L + 3,5 \text{ [mm]}$$

2.2 The thickness of the face plates of side girders is not to be less than the webs thickness of side girders and the breadth is not to be less than from the following formula. However, beyond the midship part, the sectional area of the face plates may be gradually reduced towards the ends and it may be 80% of the midship value for the end parts.

$$t_f = 3,2L + 24 \text{ [mm]}$$

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

3. Side Girders in Engine Room

The thickness of the web and face plates of side girders located in the engine room are not tobe less than the thickness of the web and face plates of centre girders as specified in B.2 and B.3, respectively.

D. Floors

1. Arrangement and Scantlings

1.1 For bottom construction with transverse framing system, floors are to be fitted at every frame. The floors scantlings are determined by using following formula.

$$h = 62,5 \cdot b \text{ [mm]}$$

$$t = 0,4L \text{ [mm]}, \qquad t_{min} = 4 \text{ [mm]}$$

where:

h = Depth of the floor plates at the centre line of ship

b = Horizontal distance between the outer surfaces of the side shell laminates measured on the upper surface of the floor [m]

t = Thickness of the floor plates

1.2 Beyond 0,5L amidships, the thickness of floor plates may be gradually reduced toward the ends and it may be 90% of the values as specified in 1. at the end parts. The floors located in the strengthening bottom forwards are to determined with the requirements G.

1.3 Floors under main engines and thrust block are to be of sufficient depth and to be of specially substantial construction. The thickness is not to be less than the thickness of centre girders as specified in B.2 and B.3.

2. Section Modulus of Floors

2.1 The thickness of face plated provided on the upper edges of floors is not to be less than the thickness of web of floor at the place.

2.2 The section modulus of floors is not to be less than from the following formula.

$$W = 15,4 \cdot a \cdot H \cdot b^2 \ [cm^3]$$

where, a is floors spacing [m], b is as specified in 1.1.

2.3 The section modulus of floors under the main engine seatings is not to be less than 150% of the value as specified in 2.2.

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 Section 13 and those for deep tanks in Section 14.

E. Bottom Longitudinals, etc.

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

2. Generally, the spacing of bottom longitudinals is 500 mm.

3. Section Modulus of Bottom Longitudinal

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

$$W = 55,6 \cdot a \cdot h \cdot \ell^2 \ [cm^3]$$

where:

a = Spacing of bottom longitudinals [m]

ℓ = Spacing of bottom transverse [m]

h = Vertical distance from the bottom longitunals to a point **T** + 0,026**L** [m] above the base point of **T** [m]. h_{min} is not to be less than 0,5**H** [m].

4. Bottom Transverse 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 D.1 and D.2.

F. Double Bottom

1. General

1.1 Where bottom are partially or wholly of double bottom construction, the scantlings of structural members are to be in accordance with the requirements in 2. to 6.

1.2 Bottom laminates under the sounding pipes are to be increased in thickness or to be protected against damages due to sounding by suitable means.

1.3 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 Section 14.

1.4 Cofferdams are to be provided in the double bottom between the tanks for carrying fuel oil and fresh water, and making them oiltight.

2. Centre girders

2.1 Webs of centre girders are to extend the whole length of the bottom as far as practicable.

2.2 The thickness of webs of centre girders is to be in accordance with the requirements in B.1

3. Side girders

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

3.2 The thickness of webs of side girders is to be in accordance with the requirements in C.2.

4. Floors

4.1 Floors are to be fitted at every frame.

4.2 The scandings of floors are to be in accordance with the requirements in D.1.

4.3 Where floors are of single skin construction, stiffeners are to be provided on floors at a suitable spacing.

4.4 Floors forming lower part of bulkheads are to be in accordance with the requirements for watertight bulkheads in Section 13, in addition to those in this Section.

5. Inner bottom laminates

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

$$t = 11{,}5 \cdot a \cdot \sqrt{T} \quad [mm]$$

where:

a = Spacing of floors [m]

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

6. Bottom longitudinals

6.1 The construction, scantlings and spacing of bottom longitudinals are to be in accordance with the requirements in E.1, E.2, E.3 and H.

6.2 The construction and scandings of longitudinals provided on the inner bottom laminates are to be in accordance with discretion of BKI.

G. Construction of Bottom Strengthened Forward

1. Strengthened of bottom forward part is specified in Section 7, D.2.

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

H. Hat-Type Construction

1. Construction and scantlings

1.1 The thickness on one side of web of centre girders, side girders and floors of hat-type construction are not to be less than 70% of the values specified in B.1.2, C.2.1, and D.1 respectively.

1.2 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 B.1.3 and C.2.2 respectively.

1.3 The section modulus of floors and bottom longitudinals of hat-type construction are not to be less than the value specified in D.2 and E.3 respectively.

1.4 The scantlings of structural members of hat-type construction are to be in accordance with the requirements in Section 1, C.5, in addition to those in the preceding 1.1 to 1.3.

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Section 11 Beams

A. General

1. Arrangement of transverse beams

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

2. Camber of weather deck

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

3. Section modulus of beams

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

$$W = C \cdot a \cdot p \cdot \ell^2 \quad [cm^3]$$

where:

ℓ = Horizontal distance from the inner edge of beam brackets to the nearest line of support of deck [m]. Where ℓ is less than 0,25**B** in the upper deck beams except those at the end parts, ℓ is to be taken as 0,25**B**. Where ℓ is less than 0,2**B** in the beams at the end parts of upper deck or in the superstructure deck beams, ℓ is to be taken as 0,2**B**.

a = Spacing of beams [m]

C = Coefficient as given below;

= Longitudinal beams:

– Midship parts = 3,4

– Elsewhere = 2,9

= Transverse beams = 2,9

p = As specified in Section 8, B.3 [kN/m^2]. Where, however, the value is as specified in Section 8, B.3, p is to be as specified in the following:

Afore 0,3**L** from the fore end: $p = 0,32L + 4,6$ [kN/m^2]

Abaft 0,3**L** from the fore end: $p = 0,16L + 4,6$ [kN/m^2]

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 $\ell / 8$ specified in Section 9, D.1.

5. Beams of Decks forming tops of deep tanks

The scantling 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 stiffners regarding the decks as deep tank bulkheads, in addition to those in this section.

6. Beams of deck carrying specially heavy loads

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

7. Transverse strong beams supporting deck longitudinal

Where longitudinal framing is adopted in the deck construction, transverse strong beams supporting deck longitudinals are to be provided in a spacing of about 2,4 meters. In this case the scatlings and construction thereof are to be in accordance with the discretion of BKI.

8. Hat-type construction

The scantlings of beams of hat-type construction are to be in accordance with the requirements in Section 1, C.5, in addition to those in this section.

Section 12 Deck Girders and Pillars

A. Deck Girders

1. Arrangement

1.1 At places where beams need to be supported, deck girders or equivalent structures are to be provided in accordance with the requirements in this Section.

1.2 Deck girders are to be provided, as necessery, under masts, derrick posts, deck machinery and other heavy concentrated loads.

2. Construction of girders

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

3. Section modulus of girders

The section modulus of deck girders, W, is not to be less than obtain from the following:

$$W = C \cdot e \cdot p \cdot \ell^2 \quad [cm^3]$$

where:

ℓ = Distance between the supporting points of girders [m]

e = Distance between the mid-points of spaces from the girders to the adjacent girders or the inner edges of brackets [m]. See Fig. 12.1

C = Coefficient as given below:

= Midship parts = 4,2

= Elsewhere = 3,3

p = As specified in Section 8, B.3 [kN/m^2]. Where, however, the value is as specified in Section 8, B.3, p is to be as specified in the following:

Afore 0,3**L** from the fore end: $p = 0{,}13L + 4{,}6$ [kN/m^2]

Abaft 0,3**L** from the fore end: $p = 0{,}11L + 4{,}6$ [kN/m^2]

4. Supports and connections at ends

4.1 The ends of deck girders are to be supported by bulkhead stiffners. These stiffners are to be properly strengthend.

4.2 Where two adjacent deck girders or an deck girder and a longitudinal bulkhead are not in line in way of a transverse bulkheads, etc, each of them is to be extended beyond the transverse bulkheads, etc for at least one frame space.

5. Hat-type construction

The scantlings of deck girders of hat-type construction are to be in accordance with the requirements in Section 1, C.5 in addition to those in this section.

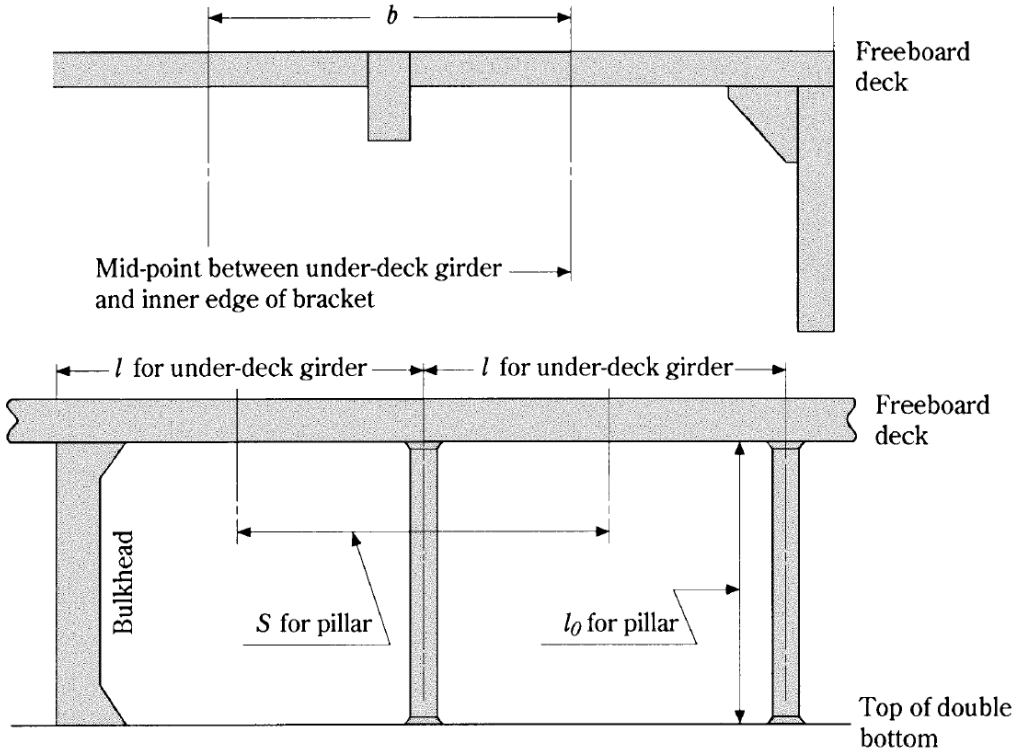

Fig. 12.1 Measurements of b, ℓ, e and ℓ_o

B. Pillars

1. Application

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

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.

3. Sectional area of pillars

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

$$f = \frac{0{,}223 \cdot p \cdot e \cdot b}{2{,}72 - \lambda}$$

where:

p = As specified in A.3

e = Distance between the mid-points of spaces from the pillars to the adjacent pillars or to the bulkhead [m]. See Fig. 12.1.

b = Distance between the mid-points of spaces from the pillars to the adjacent pillars or the inner edges of brackets [m]. See Fig. 12.1.

ℓ = Distance from the lower end of pillar to the lower surface of girder or beam supported by the pillar [m]. See Fig. 12.1.

$\lambda = \frac{\ell}{i}$

i = radius of gyration = $\sqrt{\frac{I}{A}}$ [cm]

I = minimum moment of inertia of pillars [cm^4]

A = sectional area of pillars [cm^2]

3.2 The sectional area of pillars, f_{wood}, which are made of wood, is not to be less than obtained from the following:

$$f_{wood} = \frac{1{,}32 \cdot p \cdot e \cdot b}{1{,}51 - \lambda}$$

p, e, b and λ as specified in 3.1.

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Section 13 Watertight Bulkheads

A. Arrangement of Watertight Bulkheads

1. Collision bulkheads

FRP ships are to be provided with a collision bulkhead at a position between 0,05**L** [m] and 0,13**L** [m] from the fore side of the stem on the load line.

2. Aft peak bulkheads

2.1 All FRP ships are to be provided with aft peak bulkheads at a suitable position.

2.2 Stern tubes are to be provided in a watertight compartment by means of an aft peak bulkhead or suitable arrangements.

3. Bulkheads of machinery space

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

4. Height of watertight bulkheads

The watertight bulkheads required in 1. to 3. are to extent at least to the upper deck except for those specified in the following:

1. The watertight bulkheads in way of the sunken poop or the sunken forecastle is to extend to the sunken poop deck or the sunken forecastle deck.

2. Where a forecastle having opening without closing appliances led to a space below the freeboard deck is provided or where a long forecastle not less than 0.25**L** in length is provided, the collision bulkhead is to extend up to the superstructure deck. In this case, the extend part may have steps within the limit of distance specified in 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.

5. Chain lockers

5.1 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 or pump.

5.2 Chain lockers are to be provided with screen walls at centre line.

B. Construction of Watertight Bulkheads

1. Thickness of bulkhead with laminates of single skin construction

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

$$t_f = 12 \cdot c_{Bhd} \cdot a \cdot \sqrt{h} \quad [mm]$$

where:

a = Spacing of stiffeners [m]

h = Vertical distance from the lower edge of bulkheads laminate to the top of upper deck laminate at the centre line of the ship [m]

c_{Bhd} = Coefficient for type of bulkhead

= 1,25; collision bulkhead

= 1,00; other bulkhead

2. Thickness of bulkhead with laminates of sandwich construction

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

$$t_1 = C_1 \cdot a \cdot h \quad [mm]$$

$$t_2 = C_2 \cdot t_f \quad [mm]$$

where:

t_f = Thickness in case of single skin construction as specified in 1.

a = Spacing of stiffeners [m]

h = As specified in 1.

C_1, C_2 as specified in Section 7, C.3.1.

2.2 The respective thicknesses of the inner layers and outer layers of bulkhead with laminates of sandwich construction are not, not withstanding the requirements in the preceding 2.1, to be less than obtained from the following formula. In no case, however, it is less than 2,4 mm.

$$t = 3{,}6 \sqrt[3]{C_4 (a \cdot h)^4} \quad [mm]$$

where:

a = Spacing of stiffeners [m]

h = As specified in 1.

C_4 = As specified in Section 7, C.3.1

2.3 Bulkhead with laminates of structural plywood

Where structural plywood are used for bulkhead plates, the thickness of plywood is not to be less than specified by the requirement in 1. multiplied by the coefficient given in Section 1, C.4.2.1. However, σ_B is to be taken as bending strength [N/mm^2] of plywoods.

2.4 Bulkhead stiffners

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

$$W = C \cdot a \cdot h_1 \cdot c_{Bhd} \cdot \ell^2 \quad [cm^3]$$

where:

ℓ = Total length between adjacent supports of stiffeners [m] including the length of connection at the end. Where, however, girders are provided, ℓ is the distance from the heel of the end conection to the nearest girder or the distance between girders.

h_1 = 80% of 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].

c_{Bhd} = Coefficient for type of bulkhead.

= 1,25; collision bulkhead

= 1,00; other bulkhead

a = Spacing of stiffeners [m].

C = coefficient given as:

= 20; where the both ends of stiffners are attached by brackets.

= 30; where the ends of stiffners are sniped.

2.5 Girders supporting bulkhead stiffners

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

$$W = C \cdot e \cdot h_1 \cdot c_{Bhd} \cdot \ell^2 \quad [cm^3]$$

where:

ℓ = Total length of girders including the length of end connection [m].

h_1 = 80% of 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].

c_{Bhd} = Coefficient for type of bulkhead

= 1,25; collision bulkhead

= 1,00; other bulkhead

e = Breadth of the area supported by the girders [m].

C = 3,4

2.6 Hat type construction

The scantlings of the bulkhead stiffners and girders of hat type construction are to be in accordance with the requirements in Section 1, C.5 as the addition to those in this section.

Section 14 Deep Tanks

A. General

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 oil are designated as “deep tanks”, if necessery.

2. Earthing

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

3. Application

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

3.2 The construction of deep oil tanks for carriage of oils having a flash point below 60 °C is to be in accordance with the discretion of BKI.

4. Division walls in tanks

4.1 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

4.2 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.

4.3 Where it is impracticable to be in accordance with the requirements in 4.2, the scantlings of structural members specified in this section are to be properly increased

5. Consideration for watertightness of tanks

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

B. Bulkhead Laminates of Deep Tanks

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:

$$t_f = 13 \cdot a \cdot \sqrt{h} \quad [mm]$$

where:

a = Spacing of stiffeners [m]

h = Vertical distance from the lower edge of bulkheads laminate to the top of upper deck laminate at the centre line of the ship [m].

2. Thickness of bulkhead laminates of sandwich construction

2.1 The agregated 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 formula, whichever is the greater:

$$t_1 = C_1 \cdot a \cdot h \quad [mm]$$

$$t_2 = C_2 \cdot t_f \quad [mm]$$

where:

t_f = Thickness in case of single skin construction as specified in 1.

a = Spacing of stiffeners [m]

h = As specified in 1.

C_1, C_2 as specified in Section 7, C.3.1.

2.2 The respective thicknesses of the inner layer and outer layer of bulkhead laminates of sandwich construction are not withstanding the requirements in the 1., to be less than obtained from the following formula. In no case, however, is it to be less than 2,5 mm.

$$t = 3{,}6 \sqrt[3]{C_4 (a \cdot h)^4} \quad [mm]$$

where:

a = Spacing of stiffeners [m]

h = As specified in 1.

C_4 = As specified in Section 7, C.3.2.

2.3 Bulkhead laminates of structural plywood

Where structural plywood are used for the bulkhead plates, the thicknessof plywood is not to be less than specified by the requirements in 1. multiplied by the coeficient given in Section 1, C.4.2. However, σ_B is to be taken as bending strength [N/mm^2] of plywood.

2.4 Bulkhead stiffners

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

$$W = C \cdot a \cdot h \cdot \ell^2 \quad [cm^3]$$

where:

ℓ = Total length between adjacent supports of stiffeners [m] including the length of connection at the end. Where, however, girders are provided, ℓ is the distance from the heel of the end connection to the nearest girder or the distance between girders.

h = Vertical distance measured from the mid-point of e to the mid point of the height between the top of overflow pipe and the top of tank [m]

a = Spacing of stiffeners [m]

C = Coefficient given as:

= 28; where the both ends of stiffners are attached by brackets

= 42; where the ends of stiffners are sniped

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:

$$W = 42 \cdot e \cdot h \cdot \ell^2 \quad [cm^3]$$

where:

ℓ = Total length of girders including the length of end connection [m]

h = Vertical distance measured from the mid-point of e to the mid point of the height between the top of overflow pipe and the top of tank [m]

e = Breadth of the area supported by the girders [m]

2.6 Hat-type construction

The scantlings of bulkhead stiffners and girders of hat-type construction are to be in accordance with the requirements in Section 1, C.5, in addition to those in this section.

2.7 Structural members forming top and bottom of deep tanks

The scantlings of the structural members forming the top and the bottom of deep tanks are to be in accordance with the requirements in this section. 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 at the location.

C. Provision for Deep Tanks

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.

2. Cofferdams, etc

Where there is a possibility of oil leakage from oil tanks, suitable cofferdams, gutterways, drip trays, etc. are to provided around the tanks.

2.2 Crew spaces and passenger spaces are not to be directly adjacent to the tanks for carriage of fuel oil. Such compartements are to be separated from the fuel oil tanks by cofferdams which are well ventilated and accesible. Where the top of well ventilated and accessible. Where the top of fuel oil tanks no opening and is coated by incombustible covering of 38 mm and over in thickness, the cofferdam between such compartements and the top of fuel oil tanks may be omitted.

2.3 Sparring or lining is to be provided on 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.

2.4 Where the oil tank boundaries are bounded bu matting in connections in way of the parts required oil tight, the sparring or lining specified in 2.3 may be omitted, except where specially required.

D. Application of Requirements

The requirements in Section 10, F.1.14 are also be applied to deep oil tanks.

Section 15 Machinery Spaces

A. General

1. Application

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

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.

3. Supporting structures for machinery, shafting, etc.

Machinery, shafting, etc are to be effectively supported and the adjacent structures are to be sufficientiy strengthened.

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.

B. Construction Under Main Engines

1. Construction under main engines

1.1 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.

1.2 In general, especially for high power engine, propulsion machinery is to be installed on the bottom girders through steel engine seating.

1.3 Engines are to be installed on strong girders that are effectively supported by frames and brackets in order to maintain sufficient lateral strength and rigidity. The engine beds are to be of thicknesses and widths appropriate to the holdingdown bolts, are to be set in mat or resin putty to assure uniform bearing against the girders, and are to be bolted through the webs of the girders. Figure 15.1 shows several typical, acceptable engine foundations.

1.4 Where engines having 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.

1.5 Where the temperature of the bed plates for engine seating in contact with the FRP girders may become the value to give bad influence on the creeping property of FRP in a normal operating condition, an effective insulation is to be provided between the bed plates or seating and FRP girders.

1.6 Fixing bolts for main engines are to have adequate shank length in order to lower their rigidity and effective means to avoid loosening.

1.7 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.

1.8 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.

1.9 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.

1.10 In cases where joints specified in 1.9 are moulded by structural adhesives, sufficient adhesion areas are to be provided.

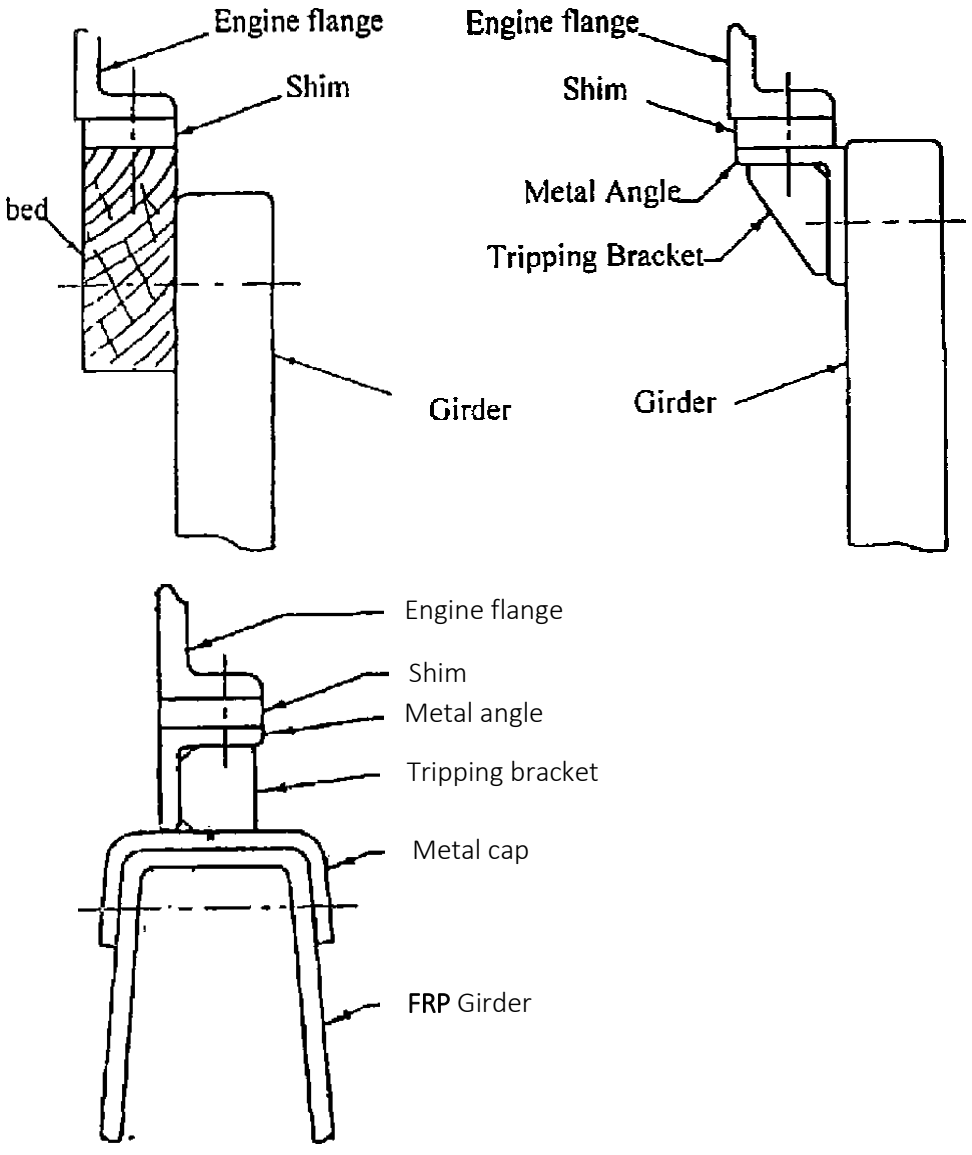

Fig. 15.1 Engine foundations

Section 16 Superstructure and Deckhouse

A. General

1. Application, etc.

1.1 The construction and scantlings of superstructures and deckhouses are to be in accordance with the requirements in the relevant sections, in addition to those in this section.

1.2 For **FRP** ships with specially large freeboard, the requirements in this section may be properly modified, subject to the approval by BKI.

B. Construction, etc.

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 a 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 a/500.

Table 16.1. The thickness of plates and scantlings of stiffener of superstructures end bulkhead and deckhouse boundary walls

L [m]		Front wall		Side and aft wall	
Over	Not more than	Thickness of boundary wall [mm]	Section modulus of stiffener [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

2. Closing Means for Access Openings and Height of Sills

2.1 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:

- The doors are to be permanently and rigidly fitted up to the walls.
- The doors are to be rigidly constructed, to be of equivalent strength to that of intact wall and to be weathertight when closed.
- 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.
- The doors are to be operated from the both sides of the wall.
- Hinged doors are, as a rule, to open outward.

2.2 The height of sills of access openings specified in the preceding 2.1 is to be at least 600 mm above the upper sutface of the deck. For shallow water service may be reduced up to at least 380.

Section 17 Hatchway Openings, Machinery Openings and Other Deck Opening

A. General

1. General

1.1 Application

The requirements in this Section are framed for **FRP** Ships for which the International Convention on Load Lines is not applied. **FRP** Ships for which the Convention is applied are also to be in accordance with the Convention.[1]

2. Hatchway Openings

2.1 Height of Hatch Coamings

The height of hatch coamings above the upper surface of deck laminates is not to be less than given in Table 17.1.

2.2. 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 2.1, subject to the approval by BKI.

Table 17.1. Height of Hatch Coamings

Position of hatchway openings	L < 20m	20m < L < 30m	30m < L < 35m
Exposed hatchway openings			
On the upper deck	380 mm	450 mm	600 mm
On the superstructure deck for 0,25**L** from the for end	380 mm	450 mm	600 mm
On the superstructure deck other than the above	300 mm	300 mm	450 mm
Un-exposed hatchway openings			
On the desk in the unclosed superstructure except for specified below	380 mm	380 mm	450 mm
On the decks in superstructures without front bulkhead	380 mm	450 mm	600 mm

3. Wooden Covers

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

– The finished thickness of wooden covers is not to be less than obtained from the following formula. Wooden covers intended to carry cargoes there on are to be increased in thickness in direct

[1] Respective National Regulation are to be observed

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 50 mm.

$$T = 30 \cdot a \ [mm]$$

where,

a = Spacing of hatch beams [m].

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

4. Machinery Openings

4.1 Protection of Machinery Openings

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

4.2 Casings of Machinery Openings in Exposed Parts

4.2.1 Exposed machinery openings on the upper decks and superstructure decks are to be in accordance with the requirements in the following:

– The thickness of casings and the section modulus of stiffeners thereupon, are to be equivalent to those of boundary walls of deckhouses specified in Section 16, B.1.
– 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.

4.2.2 The height of casings is not, except special cases, to be less than that of bulwarks.

4.2.3 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 Section 16, B.2.1 and the height of sills above the upper surface of deck laminates is to be at least 380 mm.

4.2.4 Machinery Casings provided in Enclosed Parts

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

4.2.5 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.

5. Companionway Openings and Other Deck Openings

5.1 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.

5.2 Companionways

5.2.1 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.

5.2.2 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.

5.2.3 Access openings in the deckhouses or companions specified in the preceding 5.2.1 and 5.2.2 are to be provided with doors in accordance with the requirements in Section 16, B.2.1. And, the height of sills of the access openings above the surface of deck laminates is to be at least 380 mm.

5.3 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.

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Section 18 Bulwark, Guardrail, Freeing Arrangements, Side Openings, Scuttles, Ventilators and Gangways

A. General

1. In FRP Ships for which the International Convention on Load Lines is applied, the arrangement and construction of bulwarks, guardrails, freeing arrangements, side openings, scuttles, ventilators and gangways thereof are to be in accordance with the Convention.

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 BKI in consideration with respective National regulations

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Section 19 Machinery Installation

A. General

1. Application

Prime movers, power transmission systems, shafting, pressure vessels, auxiliaries, piping systems and electrical installations are, as a rule, to be in accordance with the requirements in the relevant Section in the Part 1 Seagoing Ship, except those specified in this Section.

B. Installation of Propulsion Machinery, Fuel Oil Tanks and Earthing

1. Installation of propulsion machinery

1.1 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.

1.2 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.

1.3 Where the temperature of the bedplates for propulsion machinery 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.

1.4 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.

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.

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.

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Annex 1 FRP Material Test

A. 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 B (See Fig. A.1.1) and C.

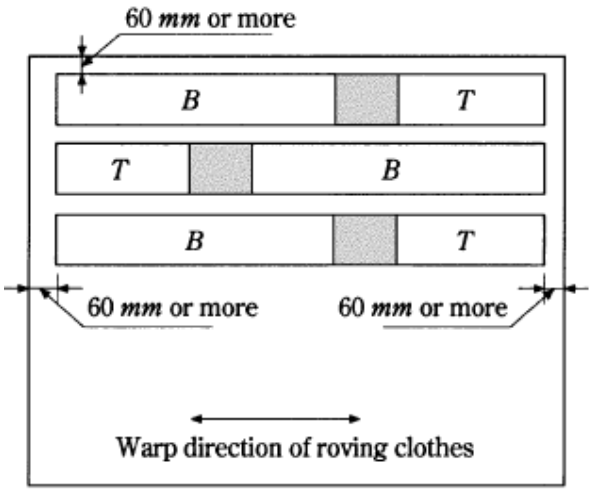
B. Selection of Test Specimens

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

1.1 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. A.1.1).

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

1.3 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.



T denotes tensile test speicimen (5 pcs)
B denotes bending test specimen (5 pcs)
Signifies the measuring area of Bacol hardness test or glass content measurent

Fig. A.1.1 Location of Selection of Test Specimens

2. Sandwich constructions

For the selection of the bend test specimens, tensile test specimens and shearing test specimens, the requirements in 1.1 above apply correspondingly. When the cores are reckoned in strength, joints are to be provided at two locations.

C. Shape and Size of Test Specimens

The shape and size of the test specimens are to be in accordance with Table A.1.1.

D. Test Procedures

1. FRP laminates

1.1 Thickness of moulding

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

1.2 Barcol hardness

The test procedures for barcol hardness are as follows:

- Use the Barcol hardness tester model 934-1.
- 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.
- Apply 4,5 to 6,8 kg of an impact pressure and read out the maximum indication on the hardness tester.
- 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.
- Take measurements for 10 points or more.

1.3 Glass content (ratio in weight)

The test procedures for glass content are as follows:

- After drying a crucible in an electric muffle furnace (650 ± 20 °C) till its weight reaches constant, cool the pot in a desiccator and measure weight of the crucible (W_1).
- Place the test sample (2g or more) specified in B. above into the crucible and measure weight (W_2).
- Apply heat with a Bunsen burner or an electric muffle furnace so that the test sample continues burning properly.
- After completion of burning apply heat in the electric muffle furnace at 625 °C until the carbon content completely disappears.
- Cool the test object in a desiccator for 30 minutes and measure its weight (W_3).
- The glass content is to be obtained from the following formula

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

1.4 Bending strength and modulus of bending elasticity

The test procedures for bending test are as follows:

- The test specimens are to be in accordance with Table A.1.1
- The test is to be carried out after keeping the test specimen in the standard condition for 20 hours or more.
- The testing machine is to be in accordance with Fig.A.1.2
- The loading rate during test is to be t/2 mm/min as the standard. (t = thickness of the test specimen in mm)
- The bending strength is to be of the value obtained from the following formula.

$$\frac{3}{2} \cdot \frac{Pl}{bt^2} \quad [N/mm^2]$$

where :

P : Breaking load [N]

l : Gauge length [mm]

b : Breadth of test specimen [mm]

t : Thickness of test specimen [mm]

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

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

where :

$\left(\frac{\Delta P}{\Delta y}\right)$: 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

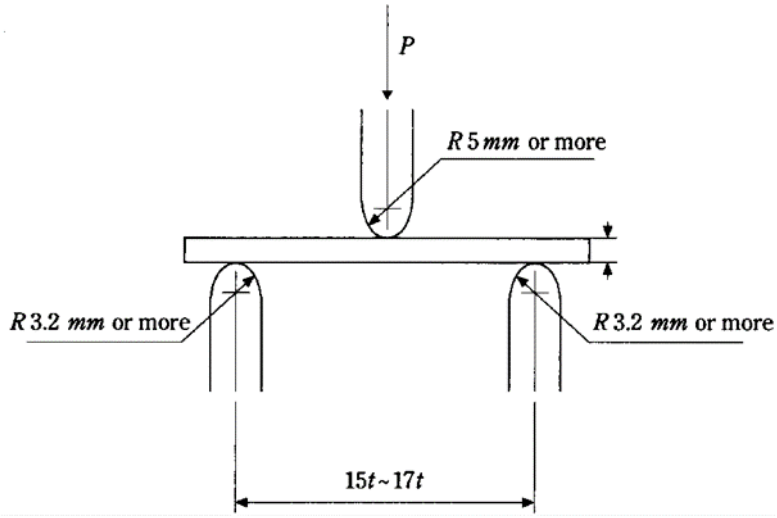


Fig. A.1.2 Location of Selection of Test Specimens

1.5 Tensile strength and modulus of tensile elasticity

The test procedures for determine tensile strength and modulus of tensile elasticity are as follows:

- The test specimens are to be in accordance with Table A.1.1.
- The tests are to be carried out after keeping the test specimen in the standard condition for 20 hours or more.
- The tensile speed is to be 5 mm/min as the standard.
- 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.
- The tensile strength is to be of the value obtained from the following formula :

$$\left(\frac{P}{A}\right) \text{ [N/mm}^2\text{]}$$

where :

P : Breaking load [N]

A : Sectional area of test specimen at its mid point [mm^2]

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

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

where :

l : Original gauge length [mm]

A : Sectional area at mid point of test specimen [mm^2]

$\left(\frac{\Delta P}{\Delta l}\right)$: Gradient of the straight portion of load-deflection curve [N/mm]

Δl : Elongation of the distance between gauge marks

2. Sandwich constructions

2.1 Thickness of moulding

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

2.2 Tensile strength

- The test specimens are to be in accordance with Table A.1.1.
- The tensile speed is to be 5 mm/min as the standard.
- 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.
- 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 Section 4, C.4 [N/mm^2]

E_f : Modulus of tensile elasticity of FRP laminates obtained by 1.5 above

2.3 Shearing strength

- The test specimens are to be in accordance with Table A.1.1. The side of FRP with a thicker layer is to be taken as the compression side.
- The testing apparatus is to be in accordance with Fig A.1.3.

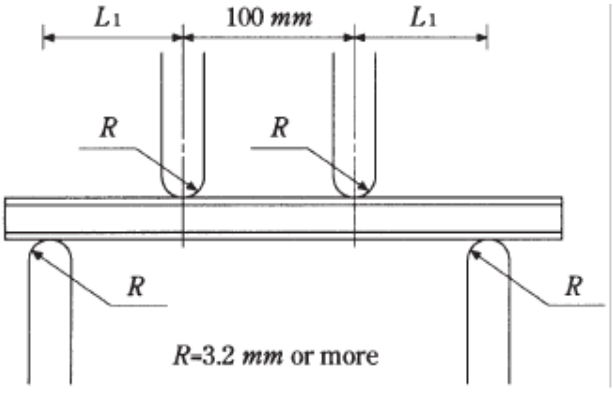


Fig A.1.3 Testing Arrangement of Four Point Bending for Sandwich Construction

- The loading speed is to be t/2 mm/min as the standard. (t: thickness of test specimen [mm])
- The shearing strength is to be obtained from the following formula.

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

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]

- 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.

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

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]

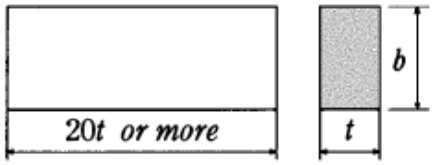
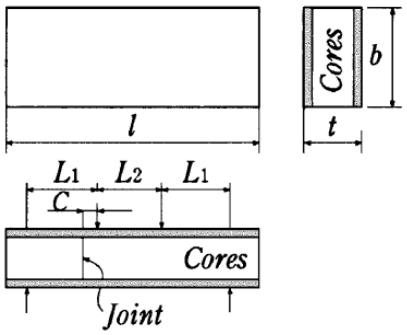
σ_f : Tensile strength of FRP laminates [N/mm^2]

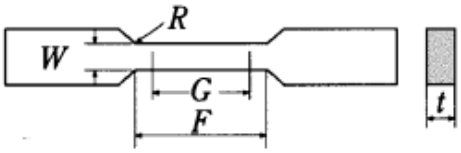
τ'_a : Imaginary shearing strength of core material [N/mm^2]

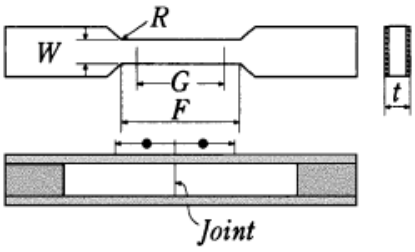
E. Test Result

The test results are to be reported according to Table A.1.2 for FRP laminates and Tables A.1.3 and A.1.4 for sandwich constructions.

Table A.1.1 Shape and Size, etc. of Test Specimens

<table>
<tr><th rowspan="2">Item</th><th colspan="4">Test Specimen</th><th rowspan="2">Quality</th></tr>
<tr><th colspan="2">FRP Laminates</th><th colspan="2">Sandwich construction</th></tr>
<tr><td>Thickness of moulting</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
The periphery is to be finished smoothly</td><td colspan="2"></td><td>3</td></tr>
<tr><td rowspan="3">Bend test specimen and shearing test specimen</td><td colspan="2">Bend test specimen
 
</td><td colspan="2">Shearing test specimen
 

t = original thickness
L_1= 100 ~ 200 [mm]
L_2= 100 [mm]
l = $2L_1 + L_2$ + 60 [mm]
C = Approx. 10 [mm]
(When the cores are reckoned in strength, a joint is to be provided at the position shown on the drawing)</td><td>5</td></tr>
<tr><td>t [mm]</td><td>b [mm]</td><td>t [mm]</td><td>b [mm]</td><td></td></tr>
<tr><td>Not more than 20
Over 20 but not more than 35
Over 35 but not more than 50</td><td>30 ± 0,5
50 ± 0,5
80 ± 0,5</td><td>Not more than 20
Over 20 but not more than 35
Over 35 but not more than 50</td><td>30 ± 0,5
50 ± 0,5
80 ± 0,5</td><td></td></tr>
<tr><td>Tensile test specimen</td><td colspan="2"> 

t = original thickness
F = 60 ± 0,5 [mm]
G = 50 ± 0,5 [mm]
W = 25 [mm] or more
R = 60 [mm] or more)</td><td colspan="2"> 

t = original thickness
F = 60 ± 0,5 [mm]
G = 50 ± 0,5 [mm]
W = 25 [mm] or more
R = 60 [mm] or more)
– When the cores are reckoned in strength, a joint is to be provided at the centre of the parallel part
– The gripped portion is to be reinforced</td><td>5</td></tr>
</table>

Table A.1.2 Test Results of FRP Laminates

Location of Selection	Test Item							
	Barcol hardness	Glass Content [%]	Tensile Test			Bend test		
			Thickness [mm]	Tensile Strength [N/mm^2]	Modulus of Elasticity [N/mm^2]	Thickness [mm]	Bending 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 A.1.3 Tensile Test Results of Laminates of Sandwich Construction

Location of Selection	Test Item						
	Breadth of test specimen [mm]	Thickness of test specimen [mm]	Thickness of core [mm]	Thickness of laminates[1)] [mm]	Breaking load [N]	Tensile strength [N/mm^2]	Remark[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 A.1.4 Shearing Test Results of Laminates of Sandwich Construction

Location of Selection	Test 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/ε 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.

Table A.1.4 Shearing Test Results of Laminates of Sandwich Construction (continued)

Notes :

3) $Z_e = \frac{L_1}{2E_f}\left(\frac{P}{\varepsilon}\right) \times 10^{-3}$ [cm³]

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 D.1.5

4) Zc is the section modulus of the test specimen of sandwich constructions obtained by following calculation.

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

Where:

t_1, t_2(t_1>t_2), t_c, b: As specified in Fig. A. 1.4

$$y_1 = \frac{\left(t_1 + t_2 + 2t_c\right) t_2}{2\left(t_1 + t_2\right)}$$

$$y_2 = \frac{\left(t_1 + t_2 + 2t_c\right) t_1}{2\left(t_1 + t_2\right)}$$

5) The shearing strength is of the value obtained from the test specified in D.2.3

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.

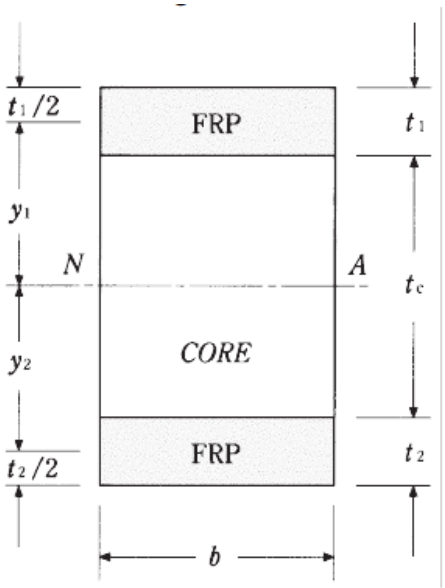


Fig. A.1.4

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