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GUIDELINES FOR THE APPLICATION STEEL SANDWICH PANEL CONSTRUCTION TO SHIP STRUCTURE

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BeiJing

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CHAPTER 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 Application

1.1.1.1 The Guidelines set down the criteria for the assessment of ship structures constructed using steel sandwich panels and the other relevant requirements specified in CCS Rules for Classification of Sea-Going Steel Ships (hereinafter referred to as the Rules) also apply.

1.1.1.2 The Guidelines are applicable to mono hull ships of normal form, proportions and speed constructed in whole or partly using sandwich construction.

1.1.1.3 The Guidelines include requirements for new construction and overlay construction applicable to existing ships. Overlay construction is only to be applied when the gauged thickness after diminution is equal to or greater than 50% of the specified original plate thickness.

1.1.2 Special requirements

1.1.2.1 Application of sandwich construction on any of the following members or areas is to be specially considered:

(1) some strength members, e.g. deck transverses, deck girders, stringer plates, sheer strakes, double plate floors and girders;

(2) areas of irregular profile, e.g. fore peak and aft peak structures etc;

(3) structures or areas directly or possibly in contact with oil and organic solvent, e.g. bulkheads and inner bottoms on oil tankers, decks on oil tankers, upper decks of LNG carriers.

1.1.2.2 Where the proposed construction of any part of the hull is of novel design, special tests and examinations before and during service are to be required.

1.1.3 Definitions and terms

1.1.3.1 The definitions and terms referred to in the Guidelines, unless expressly stated otherwise, have the meanings defined in the following definitions of this Section.

(1) *Primary members* are those members supporting the steel sandwich panel and will be typically:

① deck structure – deck transverses and girders;

② side structure – side transverses and side stringers;

③ bulkheads – vertical webs and bulkhead stringers;

④ single and double bottom structure – floors and girders.

(2) The *fore end region* is considered to include all structure forward of amidships 0.4L.

(3) The *aft end region* is considered to include all structure aft of amidships 0.4L.

(4) *Overlay or Overlay construction* is defined as when the existing steel structure is overlaid with core material and a new steel top plate according to the requirements of Chapter 3 and Chapter 4.

(5) *Design organisation* is the organisation that provides the design and construction plans.

(6) A *Steel Sandwich Panel* consists of three layers. Two external layers of steel and an internal macromolecular core layer, see Fig. 1.1.3.1.

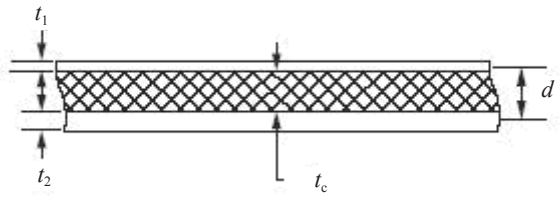


Figure 1.1.3.1 Steel sandwich panel scantling definition

(7) The term *bottom plate* applies to the steel plating to which primary members are attached.

(8) The term *top plate* applies to the steel plating at the other side of the bottom plate.

(9) The term *core* applies to the layer of macromolecular materials or macromolecular reinforcements between the steel plates. The core is injected in between the top and bottom steel plates and bonds mechanically directly to the steel surfaces.

(10) *Pot life (sec.)* is defined as the time from commencement of stirring of two base components until the moment when the mixture will not flow anymore.

(11) *Cavity* is defined as the space enclosed by the top and bottom steel plates and perimeter bars.

(12) *Panel* is defined as the sandwich panel enclosed by the primary members.

(13) The term *spacer* applies to the square or round block made of macromolecular material or steel secured to the bottom plate. A spacer is intended to maintain the required distance between the top and bottom plates.

(14) *Perimeter bar* is defined as the steel plating welded to the bottom plate to define the perimeter edges of the injection cavities.

1.1.3.2 The following symbols are applicable to the Guidelines unless otherwise stated:

a = length of the panel at longest edge, in mm

b = breadth of the panel at shortest edge, in mm

d = distance between the centrelines of the top and bottom plates. $d = 0.5(t_1 + t_2) + t_c$, in mm

D = flexural rigidity of the sandwich. $D = E_f\, t_1\, t_2\, d_2 / (t_1 + t_2)$, in N mm

E_f = modulus of elasticity of the top and bottom plates, in N/mm^2

G_c = minimum design shear modulus of core material, in N/mm^2

t_1 = thickness of the top plate, in mm

t_2 = thickness of the bottom plate, in mm

t_{a1} = thickness allowance for the top plate, in mm

t_{a2} = thickness allowance for the bottom plate, in mm

t_c = thickness of the core, in mm

v = Poisson's ratio. v= 0.3

1.1.4 Characters of classification and class notations

1.1.4.1 Reference is made to PART ONE, CHAPTER 2, Section 3 of the Rules for characters of classification and class notations of sea-going ships.

1.1.4.2 CCS will assign the notation Sandwich Construction (pt) to sea-going ships complying with the provisions of the Guidelines and the relevant requirements specified in the Rules, e.g. ★CSA , Bulk Carrier, Sandwich Construction(pt). The class notation may be assigned at the request of the Owner where overlay construction is used in ship repair.

1.1.4.3 The notation Sandwich Construction (pt) serves to identify that the ship has been built partly using sandwich construction. The exact location and extent are to be included on all construction plans.

Section 2 STRUCTURAL CONFIGURATION

1.2.1 General requirements

1.2.1.1 This Section describes a basic structural configuration for new construction and overlay construction.

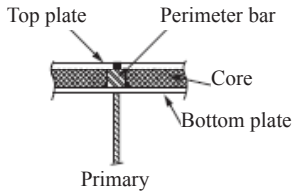
1.2.1.2 Primary members support the sandwich panels.

1.2.1.3 The requirements of this Section do not preclude the fitting of additional girders, transverses or floors in order to maintain adequate aspect ratio of the panel.

1.2.1.4 Temperature control pressure relief plugs are in general fitted to the steel sandwich panels. The size, number and location are to be such that they do not compromise the structural capability of the sandwich construction.

1.2.2 New construction

1.2.2.1 The basic structural configuration for new construction is shown in Fig. 1.2.2.1.



Typical primary member, perimeter bar arrangement

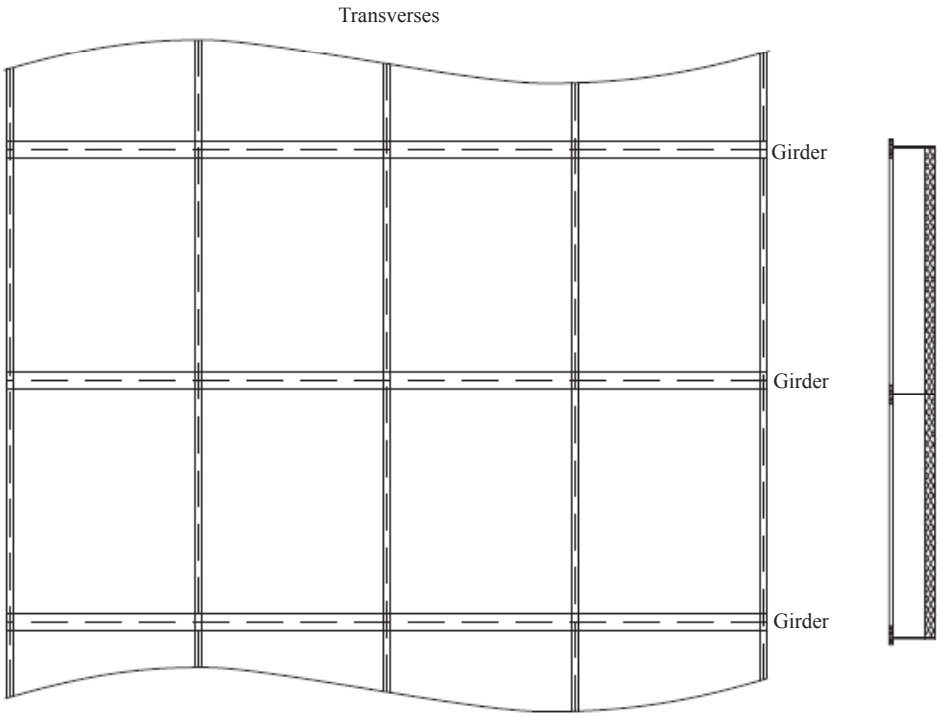


Figure 1.2.2.1 Diagrammatic arrangement of a typical sandwich new construction (for illustration only and not to scale)

1.2.2.2 The main components of a structural configuration employing sandwich construction are:

(1) top plate;

(2) bottom plate;

(3) core;

(4) primary member, supporting the panel;

(5) perimeter bar, welded to the bottom plate to define the perimeter edges of the injection cavities;

(6) temperature control pressure relief plugs fitted to the steel plating.

1.2.3 Overlay construction

1.2.3.1 The basic structural configuration for overlay construction is shown in Fig. 1.2.3.1.

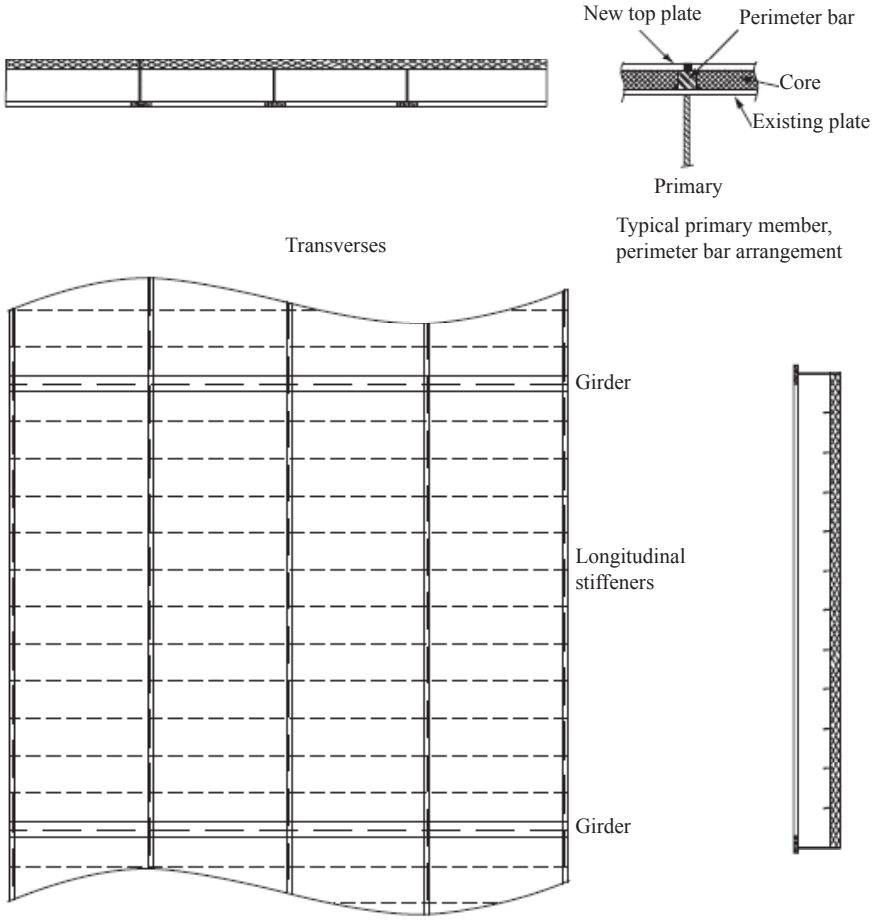


Figure 1.2.3.1 Diagrammatic arrangement of a typical sandwich overlay construction (for illustration only and not to scale)

1.2.3.2 The main components of a structural configuration employing overlay construction are:

(1) new steel top plate (becomes the new wearing surface);

(2) core;

(3) existing steel plate including any primary and secondary stiffeners attached to it;

(4) perimeter bars (flat bars). Attached to the existing plating. Size and number of perimeter bars dependent on the cavity size and not necessarily located above every supporting structure;

(5) temperature control pressure relief plugs fitted to the steel plating.

1.2.4 Electrical continuity

1.2.4.1 For protection against the possibility of electric shock in the event of an electrical earth fault, electrical continuity of the ship's metallic structure is to be ensured. Metallic parts of structural panels and members are to be effectively earthed to the ship's hull, if necessary by means of dedicated robust earthing conductor(s) having a crosssectional area of not less than 16 mm^2.

Section 3 PLANS AND INFORMATION TO BE SUBMITTED

1.3.1 General requirements

1.3.1.1 Plans are to be of sufficient detail for plan appraisal purposes. The submitted plans are to show all plating thickness, stiffener sizes and spacings, bracket arrangements and connections. Where appropriate, the plans are to clearly show the allowance for corrosion margin or owner's extra. Welding, constructional arrangements and tolerances are also to be submitted and this may be in the form of a booklet.

1.3.1.2 In addition to plans as normally required by PART TWO of the Rules applicable to the ship type, the plans and information stated in 1.3.1.3 and 1.3.1.4 are to be submitted as applicable.

1.3.1.3 Plans covering the following items are to be submitted:

(1) drawings with the sandwich panel specifications (thickness of top, bottom plating and core thickness);

(2) when sandwich construction has been utilised partly, the exact extent and location are to be indicated on all relevant plans;

(3) cavity layouts and details;

(4) details of integration with conventional steel construction, if applicable;

(5) details of integration with primary members, bulkheads, etc;

(6) construction procedure documentation;

(7) the arrangement of equipment, supports, foundations, etc. in conjunction with their weight and working load information;

(8) calculations of sandwich panel construction and primary supporing members.

1.3.1.4 For overlay construction the following information, in addition to the information required in 1.3.1.3 as applicable, is to be submitted:

(1) thickness gaugings of the existing structure to be overlaid;

(2) overlay scantlings – core and new steel plate thicknesses;

(3) cavity layouts and details;

(4) details of integration with the existing structure;

(5) plans of any proposed modifications and changes to the previously approved plans (of the existing structure).

1.3.1.5 The construction procedure documentation is to contain the following information:

(1) requirements for the preparation of new/existing steel plate (including requirements for surface roughness and cleanliness);

(2) description of the arrangement of spacers and perimeter bars;

(3) description of arrangement of the panel temporary restraint system;

(4) description of how the material components are checked prior to injection and core material preparation;

(5) machinery type, model, characteristic parameters, set-up and calibration procedure;

(6) description of the cavity preparation, cavity tightness and humidity detection method;

(7) injection, curing and post-treatment process;

(8) a description of how the effects of weld heat input will be avoided;

(9) requirements and basis for inspection;

(10) max void size;

(11) a description of the repair process;

(12) the size, number and location of temperature control pressure relief plugs where fitted.

1.3.2 Direct calculation

1.3.2.1 Direct calculation is to be carried out in the following cases:

(1) where it is specifically required by the Guidelines;

(2) where ships have novel design features;

(3) where arrangements and scantlings are not specified in the Guidelines.

1.3.2.2 Direct calculations are carried out in accordance with procedures specified in CCS guidelines and the information required therein is to be submitted.

1.3.2.3 In general, when direct calculations have been carried out the following information is to be submitted as applicable:

(1) a description of the structural modeling;

(2) a summary of analysis parameters including properties and boundary conditions;

(3) details of the loading conditions and the means of applying loads;

(4) a comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

1.3.2.4 Submission of large volumes of input and output data associated with finite element computation program will not be required.

1.3.3 Information of core material approval is to be submitted (see Chapter 2 for details).

CHAPTER 2 MATERIALS

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 For construction or repair of the ships which have been or are intended to be classed with CCS (or certified by CCS), the base components used for manufacturing sandwich panels are to be manufactured, tested and inspected in accordance with the Guidelines.

2.1.1.2 The steel material grade used for perimeter bars, panels, etc. which form sandwich panel construction are to comply with the relevant requirements of PART ONE of CCS Rules for Materials and Welding.

2.1.1.3 The core material and their base components for manufacturing are to be applied, tested and accepted according to this Chapter.

2.1.1.4 The following information is to be submitted to CCS by the sandwich panel manufacturer prior to commencement of construction:

(1) Material specification and tolerance.

(2) Listing of materials and material suppliers.

(3) Method and premises for manufacturing core material.

(4) Evidence of sandwich panel manufacturer's or sub-contractor's ability to produce the core material in accordance with the design specification.

2.1.1.5 It is the responsibility of the sandwich panel manufacturer to ensure that materials and components are available to the appropriate specification prior to commencement of construction.

Section 2 BASE COMPONENTS

2.2.1 General requirements

2.2.1.1 This Section specifies the requirements for base components used for manufacturing core material.

2.2.1.2 The base component manufacturer is to have good condition of production and quality assurance system so as to maintain a constantly high quality of products.

2.2.1.3 The base component manufacturer is to submit Technical Data Sheet (TDS), instructions of base components, and specifications of core materials to the sandwich panel manufacturer, and in addition, to provide a product certificate for each batch of components supplied indicating the inspection items specified in 2.2.2.

2.2.2 Testing requirements for base components

2.2.2.1 For polyol used for manufacturing core material, the viscosity, water content and hydroxyl value is to be measured in accordance with Table 2.2.2.1, the measured values are to be indicated in the product certificate.

Inspection item and standard of polyol Table 2.2.2.1

Item	Standard
Hydroxyl	DIN 53240
Viscosity（25℃）	DIN 53018
Water content	ISO 14897

2.2.2.2 For isocyanate used for manufacturing core material, the viscosity and isocyanate value is to be measured in accordance with Table 2.2.2.2, the measured values are to be indicated in the product certificate.

Inspection item and standard of isocyanate Table 2.2.2.2

Item	Standard
Viscosity（25℃）	DIN 53018
Isocyanate value	DIN EN ISO 14896

Section 3 CORE MATERIAL

2.3.1 General requirements

2.3.1.1 This Section specifies the requirements for core material used for sandwich panel.

2.3.1.2 The sandwich panel manufacturer is to provide evidence of his ability and equipment to produce and test sandwich panel.

2.3.1.3 The sandwich panel manufacturer is to maintain the inspection document issued by the base components manufacturer and the actual test results of the sandwich panel manufacturer for each batch of materials received. Where deemed necessary by the Surveyor, CCS may at any time select a sample of a material for testing by an independent institution and such tests are to meet the specification.

2.3.1.4 This Section is based on the base components used for the current core material procedure. The recommendations and instructions of the components manufacturer are to be complied with if a different component is to be used for a different procedure in the future.

2.3.2 Testing items

2.3.2.1 For every incoming batch of base components, testing items as required by 2.2.2 are to be conducted.

2.3.2.2 The sandwich panel manufacturer is to make core material specimens from sampling of the base components with satisfactory re-test results, for the following properties measurement:

(1) density;

(2) hardness;

(3) shear modulus;

(4) tensile strength;

(5) elongation;

(6) bond shear strength;

(7) pot life.

2.3.3 Test method

2.3.3.1 Pot life is to be tested in accordance with the following requirements:

(1) Condition both the polyol and iso-cyanate to 25℃, weigh 100 g polyol into a cardboard cup, add the appropriate amount of iso-cyanate as the mixing ratio recommended by the base components manufacturer. Mix for 10 seconds with a laboratory toothed disc stirrer, Φ 60 mm at 1500 rpm.

(2) Transfer the mixture to a 0.5 *l* glass beaker, and measure the time from starting mixing to the mixture reaching the viscosity as specified by the base component manufacturer by means of a viscosimeter.

2.3.3.2 The properties of cured core materials are to be measured in accordance with the following requirements:

(1) A core panel is to be prepared from injection of mixed base components into a mould not smaller than 50 cm×50 cm×5 cm at room temperature (23 ±5℃) and cured for at least 24 h.

(2) Test specimens are to be taken from the center of the core panel and used in the tensile strength, elongation, shear modulus, hardness and density tests.

2.3.3.3 Bond shear strength is to be tested in accordance with the following requirements:

(1) Prior to test, the surface of steel plate is to be treated by grit or shot blasting to Sa 2.5. The surface roughness achieved by grit blasting is greater than shot blasting. If using grit blasting to treat the steel plate, steel grit with Rockwell Hardness > 62 or corundum is to be used and applied at a pressure of 0.6 to 0.7 MPa with the roughness ≥ 60 μm.

(2) Mix two base components by hand at room temperature, pour it into the mould formed by two steel plates, cured for at least 24 h, and conduct the test.

2.3.4 Criteria and standards for inspection

2.3.4.1 The inspection standards for base components are given in Tables 2.2.2.1 and 2.2.2.2. The recommendations for criteria of the components manufacturer are to be complied with.

2.3.4.2 Three specimens are to be taken in the core material test. The acceptance criteria for testing of and the standards applied for core material are listed in Table 2.3.4.2. In addition, if the deviation of one result exceeds the mean by more than two standard deviations, that result is to be discarded and one further specimen tested. If a total of three specimens fail, then the batch will be rejected.

Criteria and standards for inspection **Table 2.3.4.2**

Test	Standard	Criteria
Pot life	Method approved by CCS	360 - 450s
Density	ISO 845	≥1000 kg/m^3 (RT)
Hardness	GB/T 2411 or DIN 53505	Shore D ≥ 65 (RT)
Shear modulus	Torsion pendulum test（1Hz） -20～+80℃ DIN EN ISO 6721-2 or ASTM test E 1356	G ≥ 312 - 2.4 T(℃)
Tensile strength	GB/T 1040 or ISO527 or ASTM D412	≥20 MPa (RT) ≥5 MPa + 80℃
Elongation	GB/T 1040 or ISO 527 or ASTM D412	Min. 10% -20℃ Min. 20% RT
Bond shear strength	ASTM D429	≥2.7 MPa (shot blasted) ≥4 MPa (grit blasted)
RT = Room temperature（23 ±5℃）		

2.3.5 Material storage

2.3.5.1 For incoming base materials the following are to be carried out:

(1) Emergency procedure for dealing with combustion or explosion is to be known.

(2) The consignment is to be divided into its respective batches and each batch is to be labeled accordingly.

(3) Each batch is to be examined for conformity with the batch number, visual quality and expiry date.

(4) Storage condition is to comply with the TDS from the manufacturer. And the materials are to be used following the expiry date sequence.

(5) Where the effective storage period is exceeded, the base components can be used only upon receipt of a new certificate of confirmation from the manufacturer and with prior agreement of CCS.

2.3.5.2 Ready-for-use components are to be maintained in stirred tanks at the temperatures recommended by the manufacturer. If these are above ambient ones then suitable calibrated temperature measuring devices are to be maintained.

Section 4 TYPE TEST FOR CORE MATERIAL

2.4.1 General requirements

2.4.1.1 The core material is to be produced by an approved manufacturer.

2.4.1.2 Type test of core material is to comply with the requirements in 3.2.4 of PART 0 of CCS Rules for Materials and Welding.

2.4.1.3 The items related to product performance are in general to be tested in accordance with a standard recognized by CCS in the presence of the Surveyor.

2.4.1.4 Type test sample is to be selected by the Surveyor and taken in his presence. The sample is to be representative and specially labeled. Where preparation of samples is necessary, they are to be prepared, identified and their marks transferred in the presence of the Surveyor. Prior to the test, the Surveyor is to check the compliance of the test and verify the identification of the samples.

2.4.1.5 Where the required tests are conducted in an independent laboratory approved or recognized by CCS, consideration may be given to accepting the results of such tests and if necessary, CCS may require a retest. Some or all of type test items may be tested under test conditions provided by the manufacturer. However, the appropriate test ability under such test conditions is to be confirmed by CCS.

2.4.2 Type test

2.4.2.1 CCS and the applicant are to agree a type test program prior to the type test. At least the following information is to be included in the type test program:

(1) type and specification of the product;

(2) test items and the standards or rules to be used;

(3) sampling location, diagram and description;

(4) test location and qualification of laboratory (if there is a subcontractor, the qualification of the subcontractor and the subcontract are to be submitted);

(5) name of test institution.

2.4.2.2 At least the following test items are to be included in the type approval test:

(1) Physical test for core material

① density;

② hardness;

③ tensile strength and elongation;

④ compression strength;

⑤ shear modulus;

⑥ bond shear strength;

⑦ Tensile impact test (-80℃～+80℃).

(2) Resistance of core material to salt water and chemicals

① physical property test after immersion in the salt water and chemicals, bond shear strength test of core material and steel plating;

② expansion coefficient after immersion in the salt water and chemicals.

Note: Item (1) test is to be carried out in the presence of the Surveyor, and for item (2) tests the manufacturer may only submit a test report to CCS.

2.4.2.3 After completion of the type test, the test organization is to prepare a test report, covering at least the following:

(1) type, specification and identification of the product;

(2) technical requirements for the test;

(3) specifications of test equipment and measuring instruments (including identification number and date of last calibration);

(4) environmental conditions of each test item;

(5) date and place of test;

(6) test results.

2.4.2.4 The test report is to be signed by person(s) in charge from the test organization and the Surveyor. Where the Surveyor is not present at the test, he is to confirm the test report.

CHAPTER 3 CONSTRUCTION PROCEDURES

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 This Chapter applies to the manufacture, test and inspection in situ of steel sandwich panel new construction or overlay construction.

3.1.1.2 The requirements may also be referred to for pre-fabricated steel sandwich panels.

3.1.2 General requirements

3.1.2.1 The materials used are to comply with the requirements of Chapter 2.

3.1.2.2 The injection equipment is to be maintained in accordance with the manufacturers' instructions. Metered mixing equipment is to be calibrated once per shift.

3.1.2.3 Injection operators are to be trained to appropriate level of workmanship.

3.1.2.4 Manufacturing process is to comply with the requirements in the construction procedure documentation approved by CCS.

3.1.2.5 Work areas are to be protected from rain and moisture.

3.1.2.6 All record of environmental conditions, injection data and inspection results are to be kept.

3.1.2.7 Where the polyol is not used up after the container is unsealed, the container is to be sealed up immediately. Moisture content test is to be carried out and comply with the specifications of the manufaturer of base components when the polyol is used again.

3.1.3 Panel manufacturing process

3.1.3.1 The manufacture of steel sandwich panel using base components specified in the Guidelines are to be in accordance with the following steps:

(1) Surface preparation: The surfaces of top and bottom plates that form the internal cavity are treated to remove paint and rust and to provide the required surface roughness and cleanliness.

(2) Preparation of the perimeter: Flat bars of thickness equal to the nominal core material thickness are welded or adhered to the bottom plate to create perimeter to the cavities.

(3) Placement of spacers: Steel or macromolecule spacers are fixed to the bottom plate to provide correct spacing of plates and the required core thickness.

(4) Location of top plate and attachments: The top plates are positioned and welded to the perimeter bars to form airtight cavities.

(5) Attachment of temporary restraint system: Temporary restraint system is positioned on the top plate in order to prevent out-of-plane deflections caused by internal pressure of the core material during injection and curing.

(6) Preparation of the cavity injection: Injection and vent ports are created, the injection head is secured, valves and overflow funnels are fitted and checks are made for air tightness and humidity.

(7) Cavity injection: Mixing and injection of core material is carried out under controlled conditions.

(8) Removal of temporary restraint system: After cavity injection and once the core material is set, the restraint systems are removed. The injection and vent ports are sealed and if necessary, temperature control pressure relief valves (TCPRVs) are fitted.

(9) Data recording and post-injection inspection: Record of environmental conditions and injection data made, checks include tests for voids and lack of surface bonding, quality assurance documents completed.

Section 2 MANUFACTURING PROCESS

3.2.1 Surface preparation of steel panel

3.2.1.1 The surfaces of top and bottom plates are to be blasted in order that the cavity surfaces are to be clean and dry, free from surface rust, grease and grit.

3.2.1.2 A minimum surface roughness of 60 μm and cleanliness to Sa2.5 is to be achieved on the bonding surfaces before cavity injection.

3.2.1.3 In general major structural welds are to be completed before injection into the cavity. These include lashing pots and other cargo securing details, and where highly loaded structural arrangements, such as crane foundations are welded directly to the sandwich support members.

3.2.1.4 Perimeter bars are to be welded by continuous fillet welding on to the bottom plate to form the cavity walls. The dimensions and tolerance of perimeter bars, the weld sizes are to be as specified in the construction procedure documentation. Any welds in way of the perimeter bars are to be ground smooth.

3.2.1.5 The required core thickness is to be maintained by spacers made of steel or macromolecule arranged on the bottom plate. The size, spacing and material to be used for the spacers are to be specified in the construction procedure documentation. In general, the spacers are to be welded or glued to the bottom plate at intervals of approximately 750 mm in each direction.

3.2.1.6 The top plates are to be welded to the perimeter bars as indicated in the plans, to create cavities between the bottom plate and top plate.

3.2.1.7 Lifting arrangements are to be designed such that the steel plates are subjected to minimal distortion and unnecessary loads in order to avoid permanent deformation or damage to the blasted surface of the plates. This principle is to be referred to in storage and transportation of the plates.

3.2.1.8 Welding of lifting lugs to the top surface of the top or bottom plate is acceptable, provided that the lugs are carefully removed and the attachment points made good and ground flush to the Surveyor's satisfaction.

3.2.1.9 In general, welding of the cavities immediately adjacent is to be completed prior to any cavity injection.

3.2.2 Preparation for cavity injection

3.2.2.1 Venting and injection holes will be located on the top plate, the injection head and valves will be fitted.

3.2.2.2 The cavity formed by the steel plates and perimeter bars is to be airtight. Airtightness is to be demonstrated to the Surveyor's satisfaction prior to cavity injection. The requirements given in 4.3.3.2 of PART ONE of the Rules are to be followed. However, it is recommended that the air pressure be raised to 0.02 MPa and kept at this level for about 1 min. Any failed welds are to be repaired and retested.

3.2.2.3 Temporary restraint system is to be positioned on the top plate as specified in the approved construction procedure documentation. Restraint beams can be held in place using clamps and high power magnets, or by dogs and wedges.

3.2.2.4 Prior to injection, the relative humidity of the air in the cavity is to be checked. Seal the cavity up and only leave one air inlet and one air outlet. Pass compressed air into the air inlet and take two measurements of air humidity when it enters and exits the cavity. Where the air exiting the cavity has moisture content more than 1 g/kg above the air entering the cavity, measures are to be taken (e.g. passing dried hot air through the cavity) to reduce the relative humidity to less than 1 g/kg.

3.2.3 Cavity injection

3.2.3.1 After the cavity is deemed satisfactory as described above, all vent holes are opened and the injection is started.

3.2.3.2 When one of the funnels is approximately one half full, the vent is to be closed.

3.2.3.3 After the injection is completed, the vents furthest from the injection head are to be partially opened and any residual air is bled from the cavity.

3.2.3.4 The minimum temperature that the top plate reaches after injection is required to be at least 50℃ for a duration of 30 min in order to achieve satisfactory bonding of the core material to the steel. It is to be measured by appropriate thermometer. Depending on the ambient condition it may be necessary to cover the top plate with thermal blankets. Additional heat can also be applied to cavity prior to injection or to top plate after injection if required.

3.2.4 Post injection

3.2.4.1 After cavity injection and once the core material is set, the temporary restraint system is removed. When the dogs are used, the dogs are to be carefully removed to avoid damage to the top plate and core, and the welds are to be ground flush.

3.2.4.2 The injection and venting holes are to be sealed by welding a steel disk into each hole or by other equivalent measures.

3.2.4.3 Where required, or as specified in the construction procedure documentation, temperature controlled pressure relief valves are to be fitted.

Section 3 TEST, INSPECTION AND REPAIR

3.3.1 Performance test of core material

3.3.1.1 After completion of the injection, the injected core material is to be Shore D Hardness tested and the Surveyor is to witness the test.

3.3.1.2 The test is to be carried out as follows: For each panel, one funnel is to be kept and the hardness of three spots measured after 24 h. Measured mean values are to comply with the requirement given in Table 2.3.4.2.

3.3.2 Void inspection

3.3.2.1 After the core material has set, each panel is to be tested to assess the cavity fill and to check for voids.

3.3.2.2 The cavity fill is to be checked by acoustic equipment or tap-testing the top plate to identify any void areas. The method is to be satisfactorily demonstrated to the Surveyor.

3.3.2.3 The construction procedure documentation is to define the maximum allowable void size.

3.3.3 Repair

3.3.3.1 Voids larger than the maximum allowable void size are to be repaired. All areas requiring repair are to be identified.

3.3.3.2 The repair procedure is to be defined in the construction procedure documentation. When modifications or repairs are required, that result in a procedure, which is different to the procedures given in the design specification, these procedures are subject to prior agreement of the Surveyor.

3.3.3.3 The repair method to be used is “Drill holes” or “Cut plate”, depending on the shape and quantity of voids. The results of repair are to be to the Surveyor’s satisfaction.

3.3.3.4 The repair procedure of “Drill holes” is as follows:

(1) The perimeter of the void is established by testing and the top plate is marked.

(2) Depending on void shape and size, three holes are drilled and tapped near the edge of the void, which will be used to vent the secondary injection.

(3) An injection port is drilled at the approximate centre of the void.

(4) Run cavity injection until it comes out of the vent ports.

(5) The injection and venting holes are welded closed.

3.3.3.5 The repair procedure of “Cut plate” is as follows:

(1) The top plate of area requiring repair is cold-cut and removed.

(2) The core with voids is to be routed or ground to minimum of 30 mm from the cut edge.

(3) Once the core material surface is dry and cleared of any debris, backing bars tack welded in place.

(4) The replacement plate is welded in place with a square butt weld.

(5) New core material is injected to the repair cavity ,the injection port and vent holes are sealed.

3.3.3.6 The effectiveness of any repair is to be verified using the techniques specified in 3.3.2.2.

Section 4 WELDING

3.4.1 General requirements

3.4.1.1 All welding is to comply with the requirements of PART THREE of CCS Rules for Materials and Welding.

3.4.1.2 Welding procedures are to be approved by CCS.

3.4.1.3 All welders are to have corresponding qualification certificates issued by CCS.

3.4.2 Weld position and joint design

3.4.2.1 Care is to be taken to ensure that structural continuity is maintained, the detail is smooth and proper alignment is achieved. Special care is to be taken in the design and positioning of perimeter bars. Unless otherwise agreed, the perimeter bar is to be positioned above stiffening.

3.4.2.2 Typical node design details are provided in the Appendix.

3.4.2.3 In cases where detailed node requirements are not given in the Appendix, specific solutions are to be based on the principles of this Section and submitted to CCS for appraisal.

3.4.2.4 Alternative structural arrangements may be acceptable provided it can be demonstrated through a Finite Element assessment that a satisfactory performance will be maintained.

3.4.3 The requirements for welding

3.4.3.1 In general, welding of adjacent panels is to be completed prior to any cavity injection. But welding to the face plates of injected steel sandwich panels (including pre-fabricated panels) can be carried out, provided that any effect of heat input on the core material does not affect the capacity of the panel. The construction procedure documentation is to include details of how the effects of heat input will be addressed.

3.4.3.2 Minor temporary attachments, cable trays, and small pipe clamps etc. can be welded directly to the top or bottom plate without the use of internal reinforcing plates.

3.4.3.3 Attention is to be given to the examination of the top or bottom plate in way of the minor welding carried out to ensure freedom from cracks and that for each weld there are no voids present larger than the maximum void size.

3.4.3.4 In areas subject to high stress, deep penetration or full penetration welding is to be required.

Section 5 ADDITIONAL PROCEDURES FOR OVERLAY CONSTRUCTION

3.5.1 General requirements

3.5.1.1 This Section applies to sandwich panels of overlay construction.

3.5.1.2 This Section contains requirements for overlay construction, in addition to the requirements of other sections, as appropriate.

3.5.1.3 Overlay construction is to be applied only when the average gauged thickness after diminution is equal to or greater than 50% of the specified original plate thickness.

3.5.2 Preparation of existing steel surface

3.5.2.1 All existing surface mounted fittings are to be removed. Any potential leak points in the overlay area are to be sealed.

3.5.2.2 After blasting, incidental cracks or holes are to be repaired to an approved repair procedure prior to commencement of construction.

3.5.2.3 Existing butts or seams are to be ground smooth at locations where they intersect a perimeter bar prior to fitting the bars.

3.5.2.4 Spacers are normally attached directly over existing stiffening members to achieve a uniformly flat surface for the new top plate. The height of spacers can be adjusted.

3.5.2.5 When the local distortion is so obvious that the interval of the top and bottom plate is greater than 50 mm, the wire netting in the area between spacers is to be required.

3.5.2.6 The overlay construction attaching the perimeter bars to the existing plates by methods other than welding will be specially considered.

CHAPTER 4 DESIGN BASIS FOR PANEL

Section 1 GENERAL PROVISIONS

4.1.1 Application

4.1.1.1 The requirements of this Chapter are applicable to steel sandwich panels used in the construction of shell envelopes and deck structure.

4.1.1.2 To determine the required scantlings for sandwich panels, the formulae given in the Guidelines are, in general, to be used.

4.1.2 Equivalent requirements

4.1.2.1 CCS also accepts direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by the requirements of the Guidelines.

4.1.3 Scantlings

4.1.3.1 The scantling derivation of a steel sandwich panel is based on an equivalent strength approach whereby the strength of the steel sandwich panel is to be equivalent to a conventionally framed steel panel construction.

4.1.3.2 Where steel sandwich panel construction is to be used as part of the continuous longitudinal material contributing to longitudinal strength, the structure is also to be in accordance with requirements of appropriate chapters of the Rules.

Section 2 PANEL SCANTLING REQUIREMENTS

4.2.1 Application

4.2.1.1 The requirements of this Section are applicable to steel sandwich panel construction.

4.2.2 General requirements

4.2.2.1 In this Section the scantling requirements for the top and bottom plates and core of steel sandwich panels are given.

4.2.2.2 The thickness of the top and bottom plates of the steel sandwich panels may, in addition, need to be increased to meet the hull girder requirements.

4.2.3 Taper requirements

4.2.3.1 The scantlings of the steel sandwich panels are to taper gradually from the midship region to the fore and aft ends, see 1.2.1.3 of PART TWO of the Rules. Where it is proposed to taper from steel sandwich panel construction to single steel construction the rule thickness is to be used as the basis for the tapering ($t_c = t_{rule}$), see 4.2.4.3 for the calculation of trule.

4.2.3.2 Changes in steel sandwich thickness are to be made using a gradual taper.

4.2.3.3 Where the construction changes from steel sandwich panel to a single steel plate construction a taper of not less than 4:1 is to be adopted and additional stiffening is to be required.

4.2.4 Thickness of sandwich panel

4.2.4.1 The thickness of the top and bottom plates and core of the steel sandwich panel is to be determined, as shown in Fig. 4.2.4.1, on the basis of the equivalent scantlings given in the Rules.

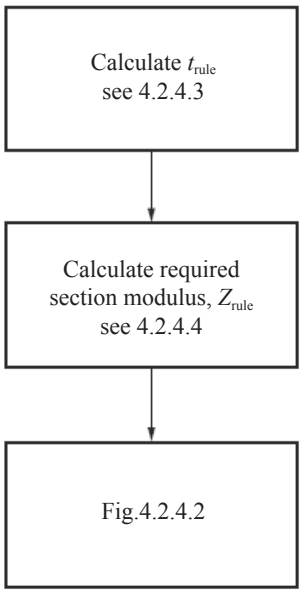


Figure 4.2.4.1 Determination of equivalent scantlings trule and Zrule

4.2.4.2 In no case are the thickness of the top and bottom plating and the core thickness, determined as shown in Fig. 4.2.4.2, to be less than the minimum values given in Section 4.

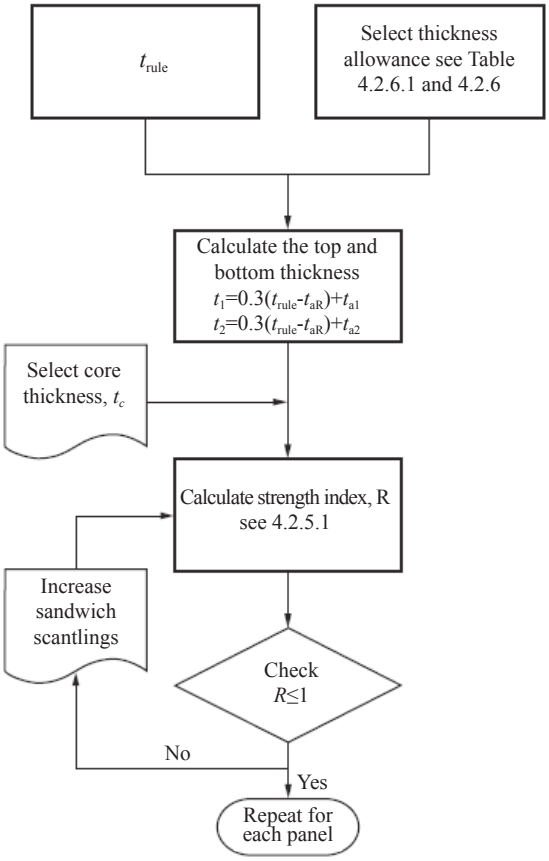


Figure 4.2.4.2 Determination of top and bottom plate thickness and core thickness

4.2.4.3 The equivalent rule thickness, t_{rule}, is to be calculated in accordance with the appropriate chapter for the relevant ship type of the Rules. For example, the equivalent rule thickness trule, for the bottom shell of a general cargo ship is to be calculated from 2.3.1 of PART TWO of the Rules and the equivalent rule thickness trule, for the inner bottom plating is to be calculated from relevant requirements for the particular ship type of the Rules.

4.2.4.4 The equivalent section modulus, Z_{rule}, of secondary member is to be calculated in accordance with the appropriate requirements for the particular ship type. For example, the equivalent section modulus for the bottom shell longitudinals of a general cargo ship is to be calculated from 2.6.7.2 and 2.6.12 of PART TWO of the Rules.

4.2.4.5 In the calculation of trule and Z_{rule} the material factor is always to be taken as $k = 1$ and the spacing is always to be taken as $s = 700$ mm.

4.2.5 Strength index

4.2.5.1 The steel sandwich panel is to be dimensioned in accordance with the strength index, R, given below. This will ensure that the steel sandwich panel is equivalent to a conventional steel construction:

$$R = 0.01A_R[0.1\frac{b^2}{d(t_1+t_2)} + 11.7(\frac{bt_c}{d^2})^{1.3}]kP_{eq,R}$$

where:

$A_R = (\frac{a}{b})^{0.65}$;

$P_{eq,R} = 0.0017\frac{Z_{rule}}{R}$, in N/mm^2;

l = length of panel in the longitudinal direction, in m;

Z_{rule} = equivalent section modulus, in cm^3, see 4.2.4.4;

t_c = selected core thickness, in mm;

a, b, d = see 1.1.3.2 of Chapter 1;

t_1, t_2 = thicknesses of the top and bottom plating, in mm, see Fig. 4.2.4.2;

k = see Section 5, PART TWO of the Rules.

4.2.5.2 The strength index for steel sandwich panel is to be such that:

$R \leq 1$

4.2.6 Thickness allowance

4.2.6.1 The local thickness allowances for individual structural members are given in Table 4.2.6.1. Structural elements not listed in the table, and ships having non-typical structural configurations will be subjected to special consideration.

4.2.6.2 The thickness allowance is to be applied to the plate thickness in direct contact with the application in Table 4.2.6.1. For example the crown of a deep tank which also forms a vehicle deck would have $t_a = 1.0$ for the top plate and $t_a = 2.5$ for the bottom plate.

4.2.6.3 For the protection of steelwork, in addition to the requirements specified in Section 3, any ship which is regularly to be discharged by grabs the thickness of the top plating is to be increased by the allowances given below.

Inner bottom and hopper plating:

- Continuous wooden ceiling: 2.0 mm;
- No continuous wooden ceiling: 3.7 mm.

Thickness allowance **Table 4.2.6.1**

Structural elements	t_{aR}	t_{a1}	t_{a2}
Bottom shell	1.0	0.0	1.0
Side shell	1.0	0.0	1.0
Inner bottom, hopper plating	2.0	1.0	1.0
Inner bottom at crown of tank	3.5	1.0	2.5
Strength deck	2.5	2.5	0.0
Internal decks	0.0	0.0	0.0
Superstructure decks	0.0	0.0	0.0
Watertight bulkheads	0.0	0.0	0.0
Deep tank bulkheads	2.5	0.0	2.5
Deep tank crowns which is also a deck	3.5	1.0	2.5
Vehicle deck clear of tanks	2.0	2.0	0.0
Symbols			
t_{aR} = rule thickness allowance, in mm; t_{a1} = thickness allowance for the top plate, in mm; t_{a2} = thickness allowance for the bottom plate, in mm (steel plating to which primary members are attached).			

Section 3 OVERLAY CONSTRUCTION REQUIREMENTS

4.3.1 Application

4.3.1.1 The requirements of this Section are applicable to overlay construction.

4.3.2 Strength index

4.3.2.1 The overlay construction is to be dimensioned in accordance with the strength index, R, given below:

$$R = 0.0125[0.1\ \frac{s^2}{d(t_1 + t_2)} + 11.7(\frac{st_c}{d^2})^{1.3}]P_{eq}$$

where:

s = spacing of the longitudinals, in mm;

$P_{eq} = 200(\frac{t_{rule}}{s})^2$, in N/mm^2;

t_{rule} = see 4.2.4.3, in mm;

t_c = selected core thickness, in mm;

t_1 = thickness of top plating, in mm, not to be less than $t_{1MIN} + t_{a1}$;

t_2 = thickness of bottom plating, in mm.

4.3.2.2 The strength index for the overlay construction is to be such that:

$R \leq 1$

4.3.2.3 In no case is the thickness of the top and bottom plating to be less than the minimum value given in Section 4.

Section 4 MINIMUM THICKNESS

4.4.1 Application

4.4.1.1 The requirements given in this Section are applicable to new construction and overlay construction.

4.4.2 Minimum top and bottom plate thickness

4.4.2.1 The thickness of the top and bottom plate, exclusive of any thickness allowance, is not to be less than as given in Table 4.4.2.1.

Minimum thicknesses **Table 4.4.2.1**

Item	Minimum thicknesses in mm	
	New construction	Overlay construction
t_{1MIN}	3.0	3.0
t_{2MIN}	3.0	50% of the as-built thickness

4.4.3 Minimum core thickness

4.4.3.1 The minimum thickness of the core is not to be less than 15 mm.

Section 5 BUCKLING

4.5.1 General requirements

4.5.1.1 This Section contains the requirements for buckling control of steel sandwich panels subject to in-plane uni-axial compressive stresses.

4.5.1.2 In general, all areas of the structure are to meet the buckling strength requirements for the design compressive stresses, see 4.5.3.

4.5.1.3 The buckling requirements are to be met using the thickness of plating less standard deduction for corrosion, dt, hence any additional thickness for corrosion margin or Owner's extra is not to be included in scantling used to assess the buckling performance.

4.5.2 Derivation of the buckling stress for steel sandwich panels

4.5.2.1 The critical compressive buckling stress, σ_E, for a steel sandwich panel subjected to uni-axial in-plane compressive loads is to be derived as follows:

$$\sigma_E = \frac{\pi^2 Df}{l^2 (t_{p1} + t_{p2})} \qquad \text{N/mm}^2$$

where:

$$f = \frac{4}{(1+\mu)^2} \quad \mu \leq 1{,}0$$

$$= \frac{1}{\mu} \quad , \mu > 1{,}0$$

$$\mu = \frac{\pi^2 D}{(1-v^2) l^2 K}$$

$$K = \frac{G_c d^2}{t_c}$$

D, v, d, t_c, G_c, see 1.1.3.2 of Chapter 1;

l = length of panel in the loaded direction, in mm;

$t_{p1} = t_1 - d_t$

$t_{p2} = t_2 - d_t$

d_t = standard deduction for corrosion, see 1.6.5 of PART TWO of the Rules.

4.5.2.2 Where the elastic critical buckling stress, as evaluated from 4.5.2.1, exceeds 50% of the specified minimum yield stress of the material, then the buckling stress is to be adjusted for the effects of plasticity using Johnson-Ostenfeld correction formula, given below:

$$\sigma_c = \sigma_E \qquad \text{when } \sigma_E \leq 0.5\sigma_0$$

$$\sigma_c = \sigma_0 \left(1 - \frac{\sigma_0}{4\sigma_E}\right) \qquad \text{when } \sigma_E > 0.5\sigma_0$$

4.5.3 Buckling requirements

4.5.3.1 This sub-Section contains requirements for the critical buckling stress for steel sandwich panels exposed to uni-axial compression.

4.5.3.2 The plate panel buckling requirements will be satisfied if the following is satisfied:

Uni-axial compressive loads: $\frac{\sigma_c}{\sigma_E} \geq 1.1$

where:

σ_d = design compressive stress.

4.5.3.3 The design compressive stresses, σ_d, are to be taken as the global hull girder bending in accordance with 2.2.5.5 of PART TWO of the Rules. In addition, where the structural member is subject to local compressive loads, then the design stresses are to be based on these loads.

CHAPTER 5 ARRANGEMENT OF PRIMARY SUPPORT MEMBER

Section 1 GENERAL PROVISIONS

5.1.1 Application

5.1.1.1 The requirements in this Chapter apply to the primary steel support members intended for use in conjunction with steel sandwich panels.

5.1.1.2 To determine the equivalent scantlings, the formulae given in the Rules are, in general, to be used.

5.1.1.3 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, bollards, etc. are not specifically indicated within the Guidelines. However the approval of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

Section 2 PRIMARY STEEL SUPPORT MEMBER ARRANGEMENT

5.2.1 General requirements

5.2.1.1 The arrangement of the primary support members is to be such as to:

(1) ensure an aspect ratio of the panel in the range from a/b = 1.2 to 1.7 can be maintained, where a is the longest side and b the shortest side; and

(2) the largest side of the panel is not to be greater than 3.6 m.

5.2.1.2 The spacing of the primary steel support member is in general to be as described in 5.2.1.1. The arrangement of primary steel support members is to be such that an adequate aspect ratio of the supported steel sandwich panel can be maintained. Additional strengthening may be required in order to achieve the aspect ratio described in 5.2.1.1.

5.2.2 Design node

5.2.2.1 Typical connection nodes between the steel sandwich panels and primary supporting members are given in the Appendix.

5.2.2.2 Primary steel support members are in general to be connected to both top and bottom plating of the steel sandwich panels.

5.2.2.3 The primary support members are to be arranged and designed with sufficient stiffness to provide support to the ship's structure. In general, primary support members are to be arranged in one plane to form continuous transverse rings. Connection between primary support members forming the ring are to be provided with brackets designed in accordance with the Rules.

5.2.2.4 Connections between primary steel support members forming a ring system are to be designed so as to minimise stress concentrations at the junctions.

5.2.2.5 Primary steel support members are to have adequate lateral stability and web stiffening and the stiffening structure is to be arranged to minimise hard spots and other sources of stress concentrations.

5.2.2.6 Where primary steel support members are subject to concentrated loads, particularly if these loads are out of line with the member web, additional strengthening is to be required.

5.2.2.7 Adequate transition brackets are to be fitted at the ends of effective continuous longitudinal primary steel members in the deck and bottom structures.

Section 3 PRIMARY STEEL SUPPORT MEMBER SCANTLING DETERMINATION

5.3.1 General requirements

5.3.1.1 The requirements for section modulus and inertia of primary support members are given in the appropriate chapters for the particular ship type of the Rules.

5.3.1.2 The requirements for stiffening and construction nodes of primary steel supporting members are given in 1.2.5 of PART TWO of the Rules. The plate thickness requirement for deck plating forming the upper flange of underdeck girders is to be applied to the combined thickness of the top and bottom plating of the steel sandwich panel.

5.3.1.3 In addition, where the primary steel support member contributes to the global strength of the ship, the thickness is to be not less than that required to satisfy the global strength requirements detailed in Section 2 of PART TWO of the Rules.

5.3.2 Geometrical properties of primary steel support member

5.3.2.1 In cases where the primary steel support member is not connected to both the bottom and top plating, see Fig. 5.3.2.1 (b), the section modulus of the primary steel support member is to be calculated by reducing the thickness of the top plating:

$$t_{1R} = \alpha_{t1}$$

where:

t_{1R} = reduced thickness of the top plating, in mm;

t_1 = minimum required thickness of the top plating, in mm, see Section 2, Chapter 4;

$$\alpha = (14\ \frac{t_c}{d^2})^{0.63}$$

t_c, d = see Section 2, Chapter 4.

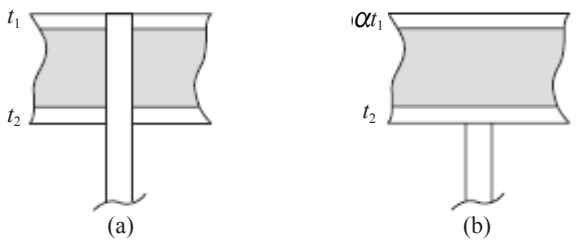


Figure 5.3.2.1 Top plate thickness reduction (for illustration only)

5.3.3 Corrosion margins

5.3.3.1 The requirements for primary steel support member calculated according to the Rules include a corrosion margin. No additional corrosion margin is required.

5.3.4 Effective breadth

5.3.4.1 The section modulus of the primary steel support members given by these requirements are to be determined in association with the effective attached plating as specified in 1.2.2.1 of PART TWO of the Rules.

5.3.5 Hull girder strength

5.3.5.1 For all ships, the hull girder strength requirements of Section 2, Chapter 2 of PART TWO of the Rules are to be complied with.

5.3.5.2 The scantling distribution of primary steel support members contributing to the hull girder strength is to be carefully selected so as to avoid structural discontinuities resulting in abrupt variations of stress.

5.3.5.3 All continuous longitudinal structurally effective material is to be included in the calculation of the hull girder strength, of the hull midship section. The lever, may be measured vertically from the neutral axis to the centre of the steel sandwich panel.

5.3.5.4 The effective geometric properties of the midship section are to be calculated directly from the dimensions of the section using only the effective material elements which contribute to the global longitudinal strength.

5.3.6 Decks

5.3.6.1 The scantlings of primary steel support members are not to be less than those given in:

(1) Section 9, Chapter 2 of PART TWO of the Rules;

(2) requirements of the appropriate chapter for the particular ship type.

5.3.7 Decks loaded by wheeled vehicles

5.3.7.1 The primary steel support members for decks loaded with wheeled vehicles are to be in accordance with Chapter 9 of PART TWO of the Rules.

5.3.8 Superstructure

5.3.8.1 This sub-Section contains scantling requirements applicable to the internal decks of superstructure. All internal decks are to be evaluated according to 5.3.8.2.

5.3.8.2 The section modulus of primary steel support members is to be in accordance with the requirements of relevant chapters of PART TWO of the Rules. See Table 5.3.8.2.

Applicable Rules **Table 5.3.8.2**

Type of Ship	Applicable Rules
All types of ships, except: Deckhouses situated on forecastles of offshore supply ships	Section 17, Chapter 2 of PART TWO of the Rules
Ferries, Roll on-Roll-of ships and Passenger Ships	Chapter 9 of PART TWO of the Rules

5.3.9 Double bottom

5.3.9.1 The scantlings of primary steel support members in the double bottom are not to be less than those given in:

(1) Section 6, Chapter 2 of PART TWO of the Rules;

(2) the appropriate chapter for the particular ship type of the Rules.

5.3.10 Shell envelope

5.3.10.1 The scantlings of primary steel support members are not to be less than those given in:

(1) Section 7, Chapter 2 of PART TWO of the Rules;

(2) the appropriate chapter for the particular ship type.

5.3.10.2 Where applicable, bottom and side shell structure below the waterline is to be evaluated against the slamming requirements in Chapter 2 of PART TWO of the Rules.

5.3.10.3 Side shell structure above the waterline is not to be less than those given in Section 7, Chapter 2 of PART TWO of the Rules depending on the requirements of appropriate chapters for the particular ship type.

Section 4 DIRECT CALCULATIONS

5.4.1 General requirements

5.4.1.1 This Section gives the basic principles and requirements to be followed when carrying out direct calculations.

5.4.1.2 The scantlings of primary steel support members are to be examined by CCS guidelines for direct calculations of applicable ship type.

5.4.1.3 The modelling and criteria specified in CCS guidelines also apply to steel sandwich panels.

5.4.2 Structural modelling of steel sandwich panel

5.4.2.1 In this sub-Section requirements are provided for the modelling of the sandwich panel.

5.4.2.2 In general, the plate element mesh is to be sufficiently fine to recover the stress at the panel boundaries. The recommended Finite Element mesh sizes for sandwich structure are:

(1) for the core material two elements between the steel face plates;

(2) for the face plates a mesh size equal to the core thickness. Care is to be taken so as the aspect ratio does not to exceed 4:1.

5.4.2.3 Top and bottom plates of the steel sandwich panel are to be represented by shell elements and the core material by solid elements. The core material may be modelled using shell elements where it has been demonstrated that the shell element method will give equivalent result as obtained by 3-D solid element method. The nodes of the shell elements are to be placed at a distance d from each other, see Fig.5.4.2.3.

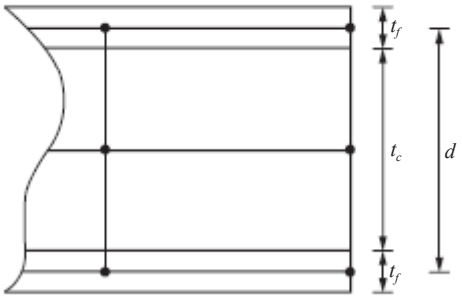


Figure 5.4.2.3 Modelling of sandwich by Finite Element with a combination of solid and shell elements

Section 5 BUCKLING

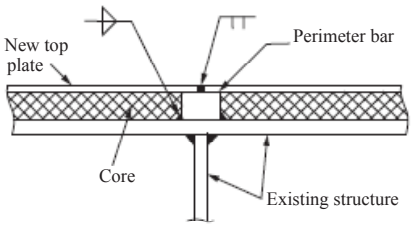
5.5.1 Buckling requirements

5.5.1.1 The elastic critical buckling stress of the web plating of the primary steel support member is to be determined from 2.2.7 in PART TWO of the Rules. Additional requirements for specific ship types are also to be complied with.

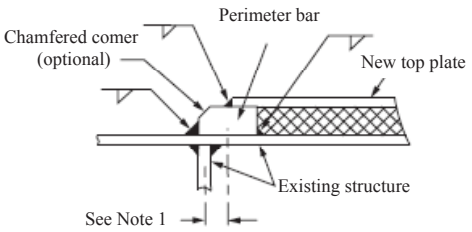
APPENDIX TYPICAL NODE DESIGN

1. Typical node design for overlay construction

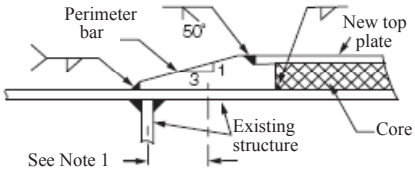
Overlay construction node design details for structural items Table 1.1



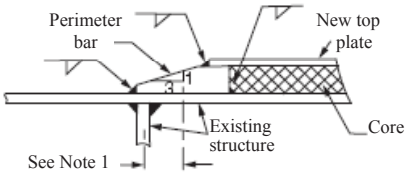
OS1: Perimeter bar - Adjacent panels



OS2: Perimeter bar - Clear of traffic (see Note 1)

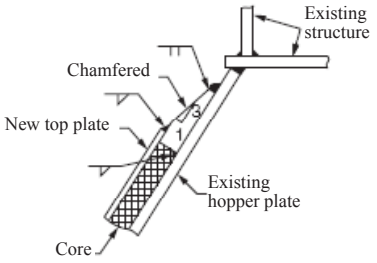


Recessed Top Plate

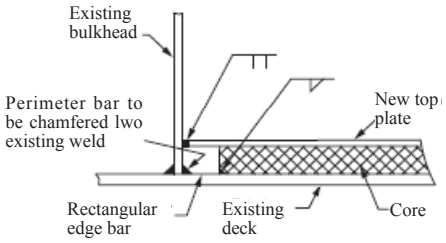


Lapped Top Plate

OS3: Perimeter bar - In way of traffic(see Note 1)

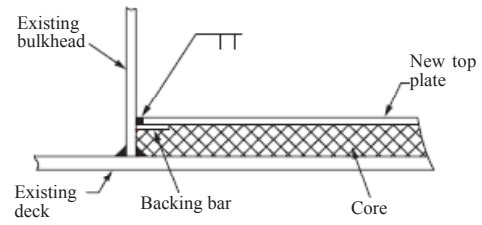


OS4: Upper edge of bulkhead stool

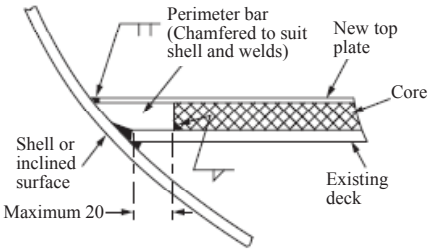


OS5: Abutting vertical surface - Perimeter bar

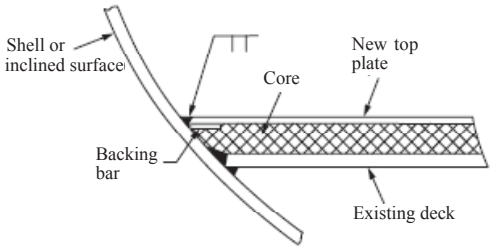
Overlay construction node design details for structural items (continued) Table 1.1



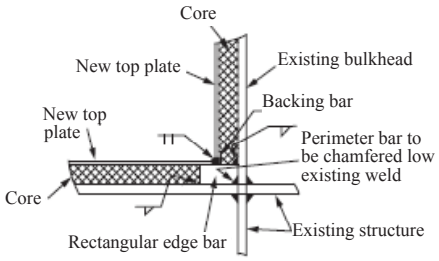
OS6:Abutting vertical surface - backing bar



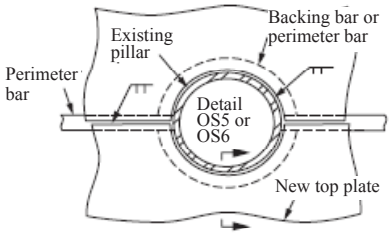
OS7:Abutting iclined surface - perimeter bar



OS8:Abutting inclined surface - backing bar

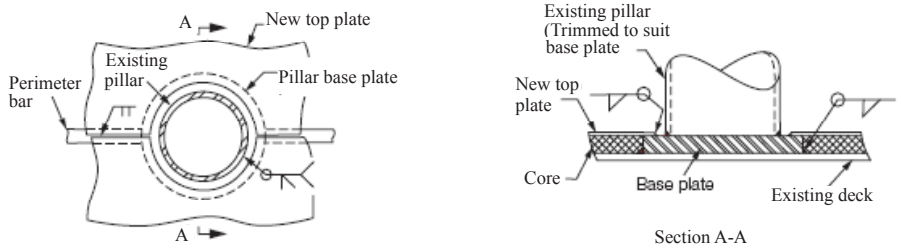


OS9:Abutting vertical sandwich surface - perimeter bar

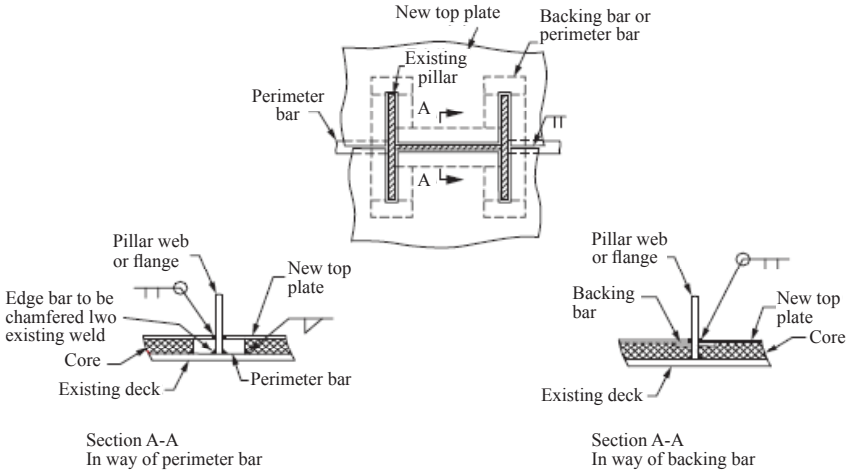


OS10:Pillars - round(without base plate)

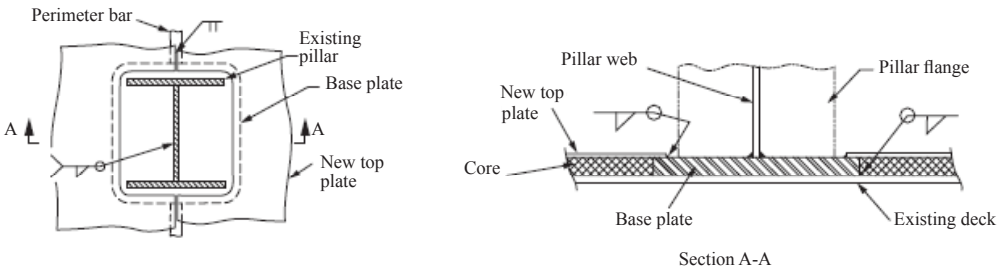
Overlay construction node design details for structural items (continued) Table 1.1



OS11:Pillars - round (with base plate)

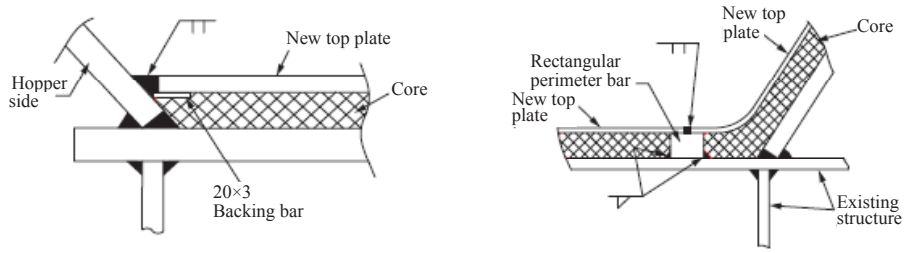


OS12:Pillars - 'H' section (with base plate)



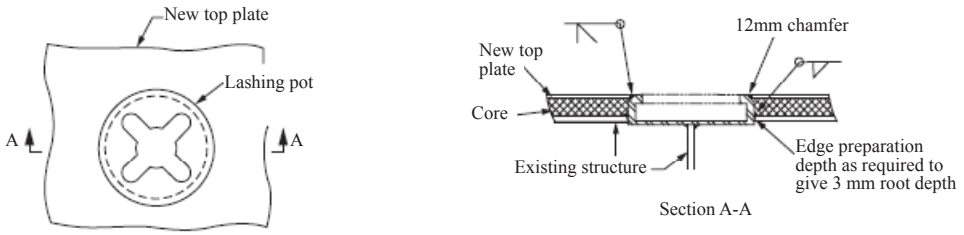
OS13:Pillars - 'H' section (with base plate)

Overlay construction node design details for structural items (continued) Table 1.1

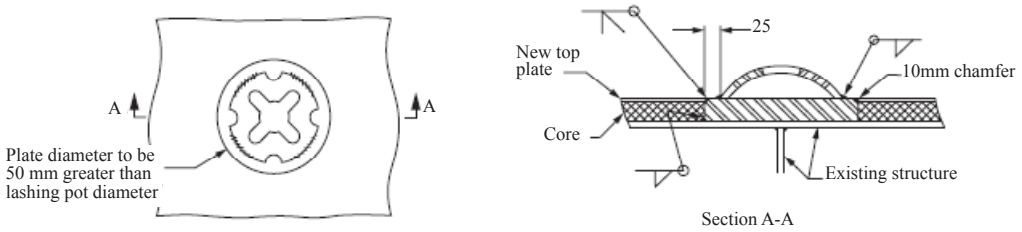


OS14: Hopper knickle details

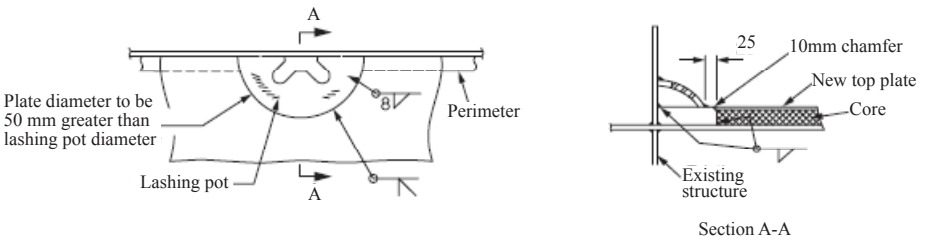
Overlay construction node design details for hull outfitting items Table 1.2



OH1: Recessed lashing pot

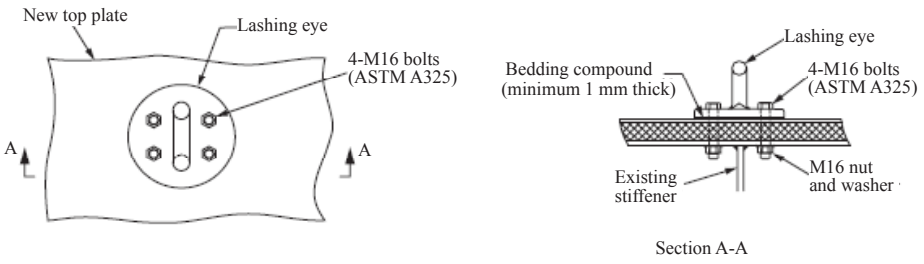


OH2: Raised dome(mid-panel)

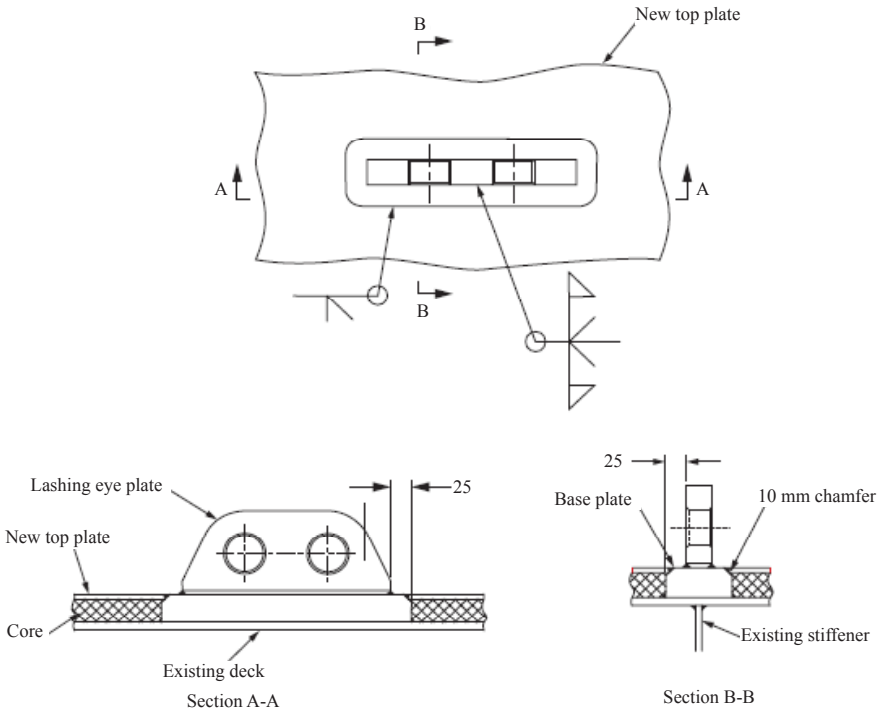


OH3: Raised half dome(panel edge)

Overlay construction node design details for hull outfitting items (continued) Table 1.2

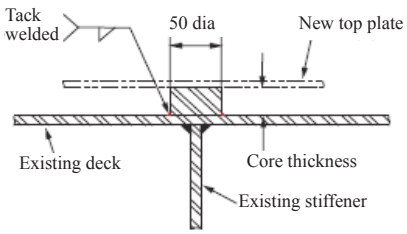


OH4: Lashing eye bolted

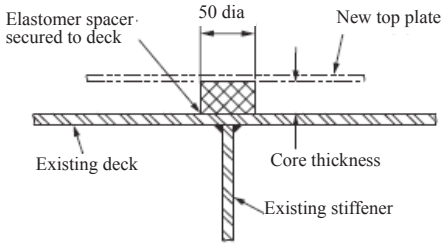


OH5: Lashing eye plates

Overlay construction node design details for fabrication Table 1.3



OF1: Metallic spacer (see Note 2)

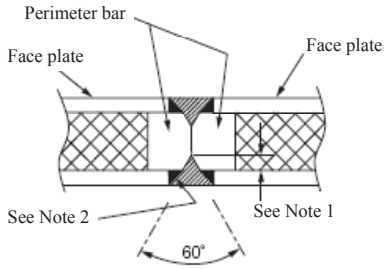


OF2: Elastomer spacer

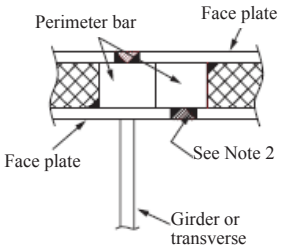
NOTES
1. Location of the perimeter bar relative to existing longituindal or transverse member can be varied according to the design of the overlay.
2. Generally tack welding is not to be carried out on higher tensile steel plates.
3. Welding to be as required in CHAPTER 3, Section 4.

2. Typical node design for new construction

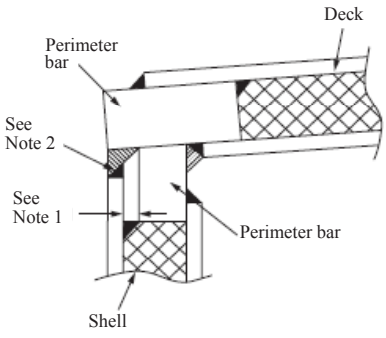
Node design details for new construction Table 2

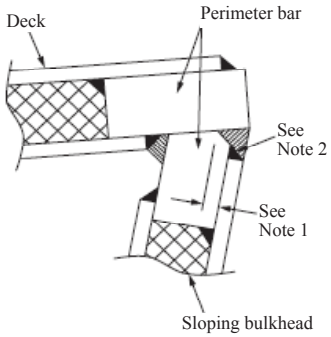


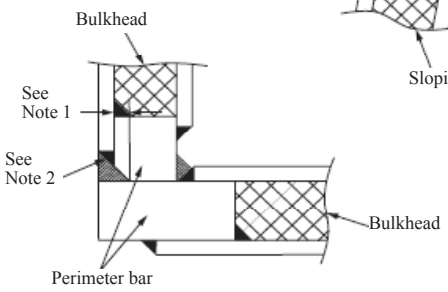
NS1: Perimeter bar - adjacent panels
(see Notes 1,2 and 3)



NS2: Perimeter bar - adjacent panels in way of primary steel support members or bulkheads
(see Notes 1 and 2)

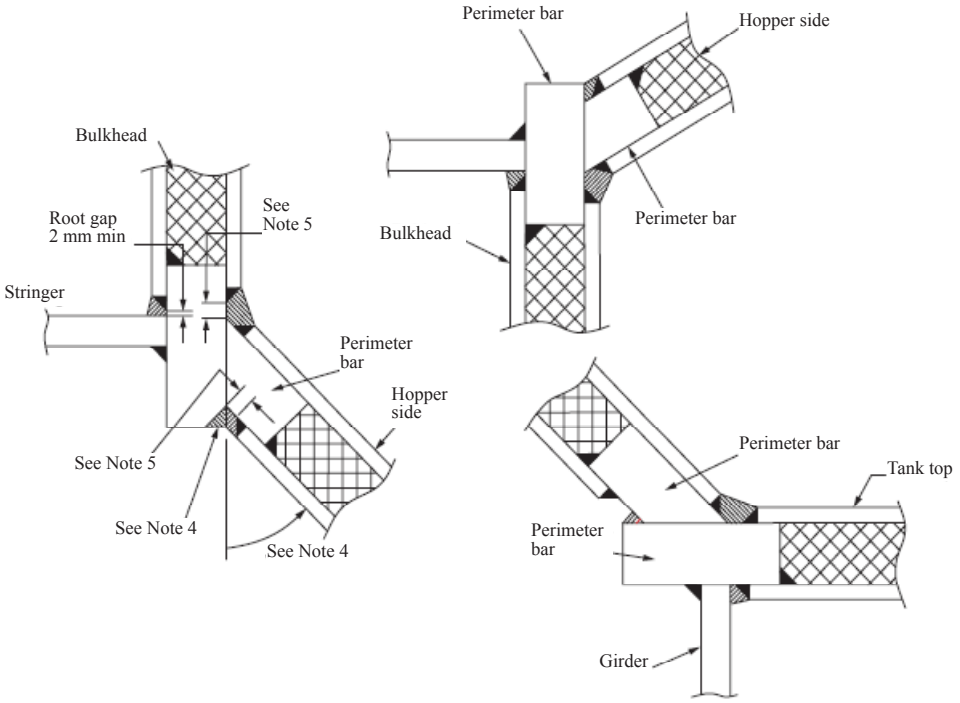




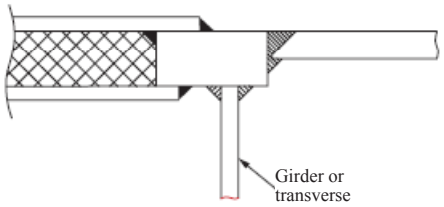


NS3: Perimeter bar - Deck shell and bulkhead connection (see Notes 1 and 2)

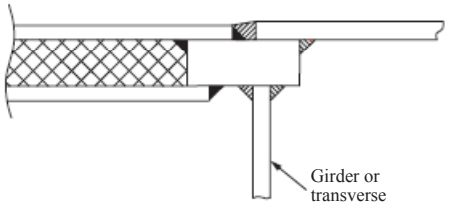
Node design details for new construction (continued) Table 2



NS4: Perimeter bar - Deck and sloping bulkhead connection (see Notes 1,2,4 and 5)



NS5: Sandwich panel abutting single panel steel structure (see Note 6)



NS6: Sandwich panel abutting single panel steel structure (see Note 6)

NOTES
1. Chamfered preparation on perimeter bar to be at least the thickness of the steel face plates.
2. Weld between face plates and perimeter bar to be made as part of panel pre-fabrication, prior to joining panels.
3. Only in way of pillar bulkheads.
4. If the angle is less than 45°, chamfer is required.
5. In general, the root gap is to be equal to the thickness of the largest adjacent faceplate thickness.
6. A taper of not less than 4:1 is to be adopted and additional stiffening may be requeird when utilised in way of hull girder. Not permitted for transverse butts in the strength deck and bottom plating.
7. Where steel sandwich panel abuts deck stringer plates of single panel steel structure, the breadth of deck stringer plates is not to be less than 6.8L+500mm (L being length of ship, in m), but not greater than 1800mm.