GUIDANCE NOTES
GD21-2021

CHINA CLASSIFICATION SOCIETY

GUIDELINES FOR LOCAL STRENGTH ASSESSMENT OF CRUISE SHIPS

2021

Effective from 1 August 2021

Beijing

CONTENTS

CHAPTER 1 GENERAL

1.1 General provisions

1.1.1 The Guidelines stipulate requirements for local strength assessment of cruise ships and are applicable to cruise ships the length of which is 90 m and over.

1.1.2 The Guidelines evaluate the structural strength of plates and primary supporting members under local design loads and global loads, including the direct calculation requirements of typical structural, double bottom structure of engine rooms, fine mesh analysis of local structure, etc.

1.2 Symbols and definitions

1.2.1 Unless expressly provided otherwise, the definitions of the symbols in the Guidelines are same as those in PART TWO of CCS Rules for Classification of Sea-going Steel Ships (hereinafter referred to as “the Rules”).

1.2.2 Unless expressly provided otherwise, the following right-handed Cartesian coordinate system is used in the Guidelines:

Origin: the intersection of the longitudinal section of the ship, the aft end of the ship length L and the baseline;

X-axis: longitudinal axis, positive forward;

Y-axis: transverse axis, positive to port;

Z-axis: vertical axis, positive upwards;

AE: aft end of the ship length L.

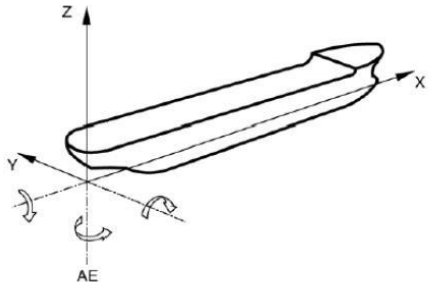

Figure 1.2.2 Definitions of the coordinate system

1.2.3 Typical structure: the typical structure of a cruise ship refers to the hull structure that constitutes typical spaces of the cruise ship such as atrium, theatre, casinos, large restaurants, swimming pools, etc.

1.2.4 The bending efficiency of the superstructure: the bending efficiency of the superstructure may be defined as the ratio of the actual stress to the assumed linear stress of the superstructure, which can be calculated as follows:

$$\eta = \frac{\sigma_s}{\sigma_s'}$$

where: σ_S——actual stress of the superstructure, in MPa;

σ_s'——assumed linear stress of the superstructure, in MPa, $\sigma_s' = (1 + \frac{h}{H}\frac{\sigma_d+\sigma_b}{\sigma_d})\sigma_d$;

H——distance from the strength deck to the baseline, in m;

h ——distance from the superstructure deck to the strength deck, in m;

σd——stress of the strength deck, in MPa;

σb——stress of the bottom, in MPa.

CHAPTER 2 DIRECT CALCULATION OF TYPICAL STRUCTURAL STRENGTH

2.1 General requirements

2.1.1 This Chapter applies to the strength assessment of the typical structure of the cruise ship.

2.1.2 Where necessary, the strength assessment of the primary members including the attached deck plating or other structures for which direct calculation is necessary may also be carried out the methods in this Chapter.

2.2 Finite Element (FE) modelling

2.2.1 The FE model of cruise ship's typical structure is to include at least the following structures:

(1) deck structure;
(2) side structure;
(3) bulkhead structure;
(4) pillar (if any).

2.2.2 The extent of the FE model of cruise ship's typical structure is as follows:

(1) Transverse extent: to be taken as the full-breadth model including the typical structure.

(2) Vertical extent: to include at least the typical structure area and one deck height extending above and below it.

(3) Longitudinal extent: generally to include the typical structure area, and 1/2 length of the typical structure area forward and aft or up to the adjacent transverse bulkhead.

2.2.3 The modeled extent of the primary members including the attached deck plating may extend to the bulkheads or strong supports according to the actual structural layout and is to include the lower pillars.

2.2.4 The FE model scantlings is based on the as-built thicknesses excluding the owner's extras.

2.2.5 The elements and meshes are to comply with the following requirements:

(1) Hull plates and webs of primary supporting members are simulated by plate elements while stiffeners and face plates of primary supporting members are simulated by beam elements.

(2) Mesh size of longitudinal stiffener spacing can be used in the model. Meshes are to be shaped square as far as practicable.

(3) Normally, the aspect ratio of plate elements is not to exceed 3. Triangular plate elements are to be minimized in modeling as far as possible; the aspect ratio of plate elements is to be close to 1 as far as possible within the high stress area or area of high stress gradient, and triangular plate elements are to be avoided.

2.3 Motions and accelerations

2.3.1 Ship's motions are to be calculated as follows:

(1) The roll period T_R of the ship is to be calculated as follows:

$$T_R = 2\frac{k_r}{\sqrt{GM}} \qquad \text{s}$$

where: k_r — roll radius of gyration, in m, to be assumed as follows if no specific values available:

$$k_r = 0.39B$$

where: B — breadth of ship, in m;

GM — initial metacentric height in the condition considered, to be assumed as follows if no specific values available:

$$GM = 0.07B$$

(2) The maximum roll angle φ_m is to be calculated as follows, but need not be greater than 0.523 rad:

$$\varphi_m = f_r k \frac{62.5 - 1.25T_R}{B + 75} \quad \text{rad}$$

where: T_R — calculated as (1);

B — breadth of ship, in m;

f_r — service coefficient, to be taken as 1;

k — coefficient, to be taken as follows:

$k = 1.2$	for ships without bilge keel;
$k = 1.0$	for ships with bilge keel;
$k = 0.8$	for ships with activated stabilizers.

(3) Pitch period T_P is to be calculated as follows:

$$T_P = 1.80\sqrt{\frac{L}{10}} \quad \text{s}$$

where: L — length of ship, in m.

(4) The maximum pitch angle ψ_m is to be calculated as follows, but need not be greater than 0.14 rad:

$$\psi_m = 0.25\frac{a_0}{C_b} \quad \text{rad}$$

where: C_b — block coefficient;

a_0 — acceleration factor, to be calculated as follows:

$$a_0 = f_\gamma\left(3\frac{C}{L} + C_V\frac{V}{\sqrt{L}}\right)$$

where: f_r — service coefficient, to be taken as 1;

$C_V = \frac{\sqrt{L}}{50}$, not to be greater than 0.2;

V — maximum service speed, in kn;

L — length of ship, in m.

C — coefficient, to be obtained from the following formulae;

$C = 10.75 - \left(\frac{300 - L}{100}\right)^{3/2}$ for $90 \le L \le 300$ m;

$C = 10.75$ for $300 < L < 350$ m;

$C = 10.75 - \left(\frac{L - 350}{150}\right)^{3/2}$ for $350 \le L \le 500$ m.

2.3.2 Ship's accelerations are to be calculated as follows:

(1) Surging acceleration a_x is to be calculated as follows:

$$a_x = 2a_0\sqrt{C_b} \quad \text{m/s}^2$$

where: C_b — block coefficient;

a_0 — see 2.3.1(4).

(2) Sway acceleration a_y is to be calculated as follows:

$$a_y = 3a_0 \qquad \text{m/s}^2$$

where: a_0 — see 2.3.1(4).

(3) Heave acceleration a_z is to be calculated as follows:

$$a_z = 7\frac{a_0}{\sqrt{C_b}} \qquad \text{m/s}^2$$

where: C_b — block coefficient;

a_0 — see 2.3.1(4) of this Chapter.

(4) Roll acceleration a_r is to be calculated as follows:

$$a_r = \varphi_m\left(\frac{6.28}{T_R}\right)^2 \qquad \text{rad/s}^2$$

where: T_R — roll period, in sec., to be calculated according to 2.3.1(1) of this Chapter;

φ_m — maximum roll angle, in rad, to be calculated according to 2.3.1(2) of this Chapter.

(5) Pitch acceleration a_p is to be calculated as follows:

$$a_p = \psi_m\left(\frac{6.28}{T_p}\right)^2 \qquad \text{rad/s}^2$$

where: T_P — pitch period, in sec., to be calculated according to 2.3.1(3) of this Chapter;

ψ_m — maximum pitch angle, in rad, to be calculated according to 2.3.1(4) of this Chapter.

(6) Transverse combined acceleration a_t is to be calculated as follows:

$$a_t = \sqrt{a_y^2 + \left[a_r\left(z - z_{rp}\right) + 10\sin\varphi_m\right]^2} \qquad \text{m/s}^2$$

where: a_y — sway acceleration, see (2) of this paragraph;

a_r — roll acceleration, see (4) of this paragraph;

φ_m — maximum roll angle, see 2.3.1(2) of this Chapter;

z — vertical distance from the point considered to baseline, in m;

z_{rp} — vertical distance from axis of gyration for roll and that for pitch to baseline, to be taken from the values obtained by the following two formulae, whichever is the lesser;

$$z_{rp1} = \frac{D}{4} + \frac{d_1}{2} \qquad \text{m}$$

$$z_{rp2} = \frac{D}{2} \qquad \text{m}$$

where:

D — moulded depth, in m;

d_1 — draught, in m.

(7) Longitudinal combined acceleration a_l is to be obtained by the following formula:

$$a_l = \sqrt{a_x^2 + \left[a_p\left(z - z_{rp}\right) + 10\sin\psi_m\right]^2} \quad \text{m/s}^2$$

where: z_{rp}, z — see (6) of this paragraph;

a_x — surge acceleration, see (1) of this paragraph;

a_p — pitch acceleration, see (5) of this paragraph;

ψ_m — maximum roll angle, in rad, calculated according to 2.3.1(4) of this Chapter.

(8) Vertical combined acceleration a_v is to be taken from the values obtained by the following two formulae, whichever is greater:

$$a_{v1} = \sqrt{a_z^2 + a_r^2 y^2} \quad \text{m/s}^2$$

$$a_{v2} = \sqrt{a_z^2 + a_p^2 (x - 0.45L)^2} \quad \text{m/s}^2$$

where: a_z — heave acceleration, see (3) of this paragraph;

a_r — roll acceleration, see (4) of this paragraph;

a_p — pitch acceleration, see (5) of this paragraph;

x — longitudinal distance from the point considered to AP, in m;

y — transverse distance from the point considered to longitudinal centerline, in m;

L — length of ship, in m.

2.4 Conditions and loads

2.4.1 The calculation of the typical structure of the cruise ship is to take into account the following calculation loads:

(1) hull girder loads (only when complete ship FE analysis is not carried out);

(2) local design loads.

2.4.2 When hull girder loads are applied, the conditions listed in Table 2.4.2 are to be considered:

Conditions Table 2.4.2

Conditions	Descriptions
1	Maximum vertical bending moment
2	Minimum vertical bending moment

(1) The hull girder loads can be achieved by applying vertical bending moments on the intersection of the neutral axis of the model end surface and the center line of the section. The vertical bending moment is calculated as follows:

1) By calculating thehull girder strength, the hull girder bending stress on each longitudinal member of the target model section was obtained under the combination of the permissible vertical hydrostatic bending moment and vertical wave bending moment. When the typical structure is located in the superstructure, the bending efficiency of the superstructure is to be taken as 80%; when the typical structure is located inside the main hull, the bending efficiency of the superstructure is to be taken as 50%.

2) The vertical bending moment of the transverse section of a typical structure is obtained by integrating the hull girder bending force on each longitudinal member (the hull girder bending force is the product of the hull girder bending stress and the area of the corresponding member) to the moment of the neutral axis of the transverse section.

(2) To calculate the strength of openings for doors and windows of typical structures, the vertical bending moment and vertical shear force are to be applied on the model simultaneously, and the additional bending moment generated by the shear force on the model is to be corrected. At the same time, the combination of vertical bending moment and vertical shear force unfavorable to the model is to be considered. The vertical bending moment is calculated according to 2.4.2 (1), and the vertical shear is calculated as follows:

1) By calculating the hull girder strength, the hull girder shear stress on the vertical members of the model's transverse section under the combination of the permissible vertical hydrostatic shear force and vertical wave shear force is obtained.

2) The vertical shear force applied to the model is obtained by integrating the hull girder shear stress on the vertical member of the model's transverse section.

2.4.3 The following conditions need to be calculated for the primary members including the attached deck plating:

(1) Only local load is to be applied in condition 1;

(2) In condition 2, local load and hull girder bending moment are to be applied, and the hull girder bending moment can be used to simulate the magnitude and distribution of the longitudinal bending stress by applying nodal forces on the front and rear ends of the model (only when the complete ship FE analysis is not performed).

2.4.4 Local design loads are as follows:

(1) The vertical uniformly distributed pressure acting on the deck is to be taken as:

$$P_V = (\mathrm{g} + 0.5a_v)(M + m) \quad \mathrm{kN/m^2}$$

where: M ——design load of the deck, in t/m^2, and not less than the value required by Table 2.4.4;

g ——acceleration of gravity, to be taken as 9.81, in m/s^2;

a_v——vertical combined acceleration, in m/s^2, see 2.3.2(8). For different areas subject to assessment, the maximum a_v in the area is to be taken;

m ——mass per unit area of deck, to be taken as not less than 0.1, in t/m^2.

Design loads of the deck Table 2.4.4

Name and location of deck	Design load, in t/m^2
Accommodation and public spaces	0.32
Weather superstructure deck	0.32
Balcony space	0.20
Luggage space	1.06
Decks for store	1.44
Decks for engine room platform	1.87
Exposed life-saving deck	0.86
Dome space	0.25

(2) To check the strength of the supporting structure of the swimming pool, the swimming pool can be regarded as a whole, the load is calculated according to the formulae below, and the load is applied at the tank center point of the swimming pool:

$$F_l = Ma_l \qquad \text{kN}$$

$$F_t = Ma_t \qquad \text{kN}$$

$$F_V = M(\mathrm{g} + 0.5a_v) \qquad \text{kN}$$

where: F_l, F_t, F_v ——longitudinal, transverse and vertical loads;

M ——mass of the swimming pool, including the weight of the swimming pool and the mass of water filled in the pool, in t;

g ——acceleration of gravity, to be taken as 9.81, in m/s^2;

a_l, a_t, a_v ——combined acceleration at the center of gravity of the swimming pool, in m/s^2, see 2.3.2(6), (7), (8).

(3) Other local vertical loads are calculated according to the formula below:

$$F_V = (\mathrm{g} + 0.5a_v)m_0 \qquad \text{kN}$$

where: m_0 ——mass, in t;

g ——acceleration of gravity, to be taken as 9.81, in m/s^2;

a_v ——vertical combined acceleration, in m/s^2, see 2.3.2(8). For different areas subject to assessment, the maximum a_v in the area is to be taken.

2.5 Boundary conditions

2.5.1 Boundary conditions of the model are as follows:

(1) The connection between both ends of the typical structure model are shown in table 2.5.1(1) and table 2.5.1(2) when hull girder loads are applied The nodes on the longitudinal members at both end sections are to be rigidly linked to independent points at neutral axis on the centreline as shown in Table 2.5.1(1). The independent points of both ends are to be fixed as shown in Table 2.5.1(2).

Rigid-link on both ends Table 2.5.1(1)

Nodes on longitudinal members at both ends of the model	Translational			Rotational		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
All longitudinal members	RL	RL	RL	-	-	-
RL means rigidly linked to the relevant degrees of freedom of the independent point						

Support condition of the independent point Table 2.5.1(2)

Location of the independent point	Translational			Rotational		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Independent points on the aft end model	Fix	-	-	-	-	-
Independent points on the fore end model	Fix	Fix	Fix	Fix	Fix	Fix

(2) When local loads are applied, all nodes on the lowest deck of the typical structure model are limited the displacement of x, y and z lines, and the boundary conditions of the longitudinal end planes are defined according to the actual connection of the boundary.

(3) Where there are transverse bulkheads extending from the upper deck to the lower deck before and after the area assessed for a typical structural model, boundary conditions in 3.4.1 may be used instead of (1) and (2) in this chapter, so as to apply the hull girder bending moments and local loads simultaneously.

2.5.2 In the primary members including the attached deck plating analysis, appropriate boundary conditions are applied at the bulkheads or strong supports according to structural connections and loads.

2.6 Yield strength assessment

2.6.1 Yield strength assessment is to be carried out for shell plating, deck plating, side and longitudinal wall of superstructure, bulkhead plating and primary supporting members of typical structures of cruise ships.

2.6.2 The yield strength criteria for typical structures of cruise ships are shown in Table 2.6.2.

Yield strength criteria for hull structure Table 2.6.2

Hull structure	Load type	Permissible stress (N/mm^2)		
		Longitudinal stress	Shear stress	Equivalent stress
Web plating of deck transverses and deck girders	Local only	-	0.35R_{eH}	0.75 R_{eH}
Face plates of deck transverses and deck girders (beam or plate element)	Local only	0.52 R_{eH}	-	-
Deck girders	Local +Global	200/K	-	220/K
Other members			110/K	220/K

Note: K is the material factor.

2.7 Buckling strength assessment

2.7.1 Buckling strength assessment is to be carried out for shell plating, inner bottom plating, deck plating, side and longitudinal walls of superstructure, bulkhead plating and webs of primary supporting members of typical structures of cruise ships.

2.7.2 In addition to the requirements of this sub-Section, buckling assessment is to be carried out according to the relevant requirements of Chapter 8, PART 9-1 of the Rules. Buckling strength is to comply with the following criteria:

$$\eta \le \eta_{all}$$

where: η ——maximum buckling utilization factor;

η_{all} ——permissible buckling utilization factor, see Table 2.7.5.

2.7.3 The capacity of a structural member is to be assessed with a standard deduction of thickness. See Table 2.7.3 for the standard deduction of thickness for each area.

Standard deduction of thicksness Table 2.7.3

Structural items	Standard deduction of thickness, in mm
Tank boundaries and shell plating	1.0
Weather decks	0.5
Other structures	0.0

2.7.4 Working stresses are corrected according to the standard deduction of thickness given in Table 2.7.3.

$$\sigma_A = \frac{\sigma t}{t - t_r} \quad N/mm^2$$

where: σ_A ——working stress after correction;

σ ——working stress obtained by calculation;
t ——plate thickness in the model;

t_r —— standard deduction of thickness, see Table2.7.3.

2.7.5 The permissible buckling utilization factors for the buckling assessment are shown in Table 2.7.5.

Permissible buckling utilization factors Table 2.7.5

Structural items	permissible buckling utilization factor
Longitudinal structures	1.0
Transverse structures	0.9

2.7.6 Buckling assessment methods for stiffened/unstiffened plate panels of hull structures of cruise ship are shown in Table 2.7.6.

Assessment methods for hull structures Table 2.7.6

No.	Structure	Assessment method
1	Shell plating Inner bottom Longitudinal bulkheads including bottom girders beneath deck	SP-A
2	Bottom girders	SP-B
3	Superstructure side bulkheads and longitudinal bulkheads Superstructure decks	SP-A
4	Deck girders, horizontal girder webs of longitudinal bulkheads	UP-B
5	Irregular plate panels around opening	UP-B
6	Plate floors beneath transverse bulkheads	SP-A
7	Plate floors	SP-B
8	deck transverses, girder web of transverse bulkheads	UP-B
9	Irregular plate panels at bulkheads, plate floors, etc.	UP-B
Note: in general, the length of plate panel is to be taken as the span of longitudinals or stiffeners, and the width of plate panel is to be taken as the spacing of longitudinals or stiffeners.		

CHAPTER 3 DIRECT STRENGTH CALCULATION OF DOUBLE BOTTOM STRUCTURE OF ENGINE ROOM

3.1 General requirements

3.1.1 This Chapter is applicable to strength assessment of double bottom structure of engine room.

3.1.2 For cruise ships that have undergone direct FE calculation in accordance with CCS Guidelines for Complete Ship Model Calculation of Cruise Ships, strength assessment of double bottom structure of engine room in accordance with this Chapter is not required.

3.2 Double bottom structure modelling of engine room

3.2.1 Double bottom structure model of engine room is to include at least the following structures:

(1) double bottom structure of engine room;
(2) bulkhead structure;
(3) side structure;
(4) pillars (if any).

3.2.2 The extent of FE model is as follows:

(1) Transverse extent: to be taken as the full-breadth model of the structure including the double bottom area of engine room.

(2) Vertical extent: to include the double bottom structure of engine room and the side structure extending to the major deck above.

(3) Longitudinal extent: generally to include the structure of the engine room and 1/2 length of the forward and aft compartments.

3.2.3 The FE model scantlings is based on the as-built thicknesses excluding the owner’s extras. The elements and meshes are to comply with the following requirements:

(1) Hull plates and webs of primary supporting members are simulated by plate elements while stiffeners and face plates of primary supporting members are simulated by beam elements.

(2) Mesh size of longitudinal stiffener spacing can be used in the model. Meshes are to be shaped square as far as practicable.

(3) Normally, the aspect ratio of plate elements is not to exceed 3. Triangular plate elements are to be minimized in modeling as far as possible; the aspect ratio of plate elements is to be close to 1 as far as possible within the high stress area or area of high stress gradient and triangular plate elements are to be avoided.

3.3 Conditions and loads

3.3.1 The calculation of double bottom structure of engine room is to take into account the following loads:

(1) hull girder bending moment;
(2) local design loads.

3.3.2 When hull girder loads are applied, the conditions listed in Table 3.3.2 are to be considered:

Conditions Table 3.3.2

Conditions	Descriptions
1	Maximum vertical bending moment
2	Minimum vertical bending moment

The hull girder loads can be achieved by applying vertical bending moments on the intersection of the neutral axis of the model end surface and the center line of the section. The vertical bending moment is calculated as follows:

(1) By calculating the hull girder strength, the hull girder bending stress of the longitudinal continuous member on the target transverse section of the double bottom area of the engine room is calculated under the combination of the permissible vertical hydrostatic bending moments and vertical wave bending moment. In the calculation, the bending efficiency of the superstructure is to be taken as 50%.

(2) The vertical bending moment applied on the transverse section of the double bottom area of the engine room is obtained by integrating the total hull girder bending force on each longitudinal member (the total hull girder bending force is the product of the hull girder bending stress and the area of the corresponding member) to the moment of the neutral axis of the transverse section.

3.3.3 Local design loads are as follows:

(1) Structural self- weight of model

The structural self- weight of model is to be applied by mass and acceleration field.

(2) Outfit and equipment loads

$$PV = (\mathrm{g} + 0.5av) \text{ kN}$$

where: M — mass of equipment, in t;

g —acceleration of gravity, to be taken as 9.81, in m/s^2;

a_v — vertical combined acceleration, in m/s^2, see 2.3.2(8). For different areas to be assessed, the maximum a_v in the area is to be taken.

(3) External sea pressure

The external sea pressure consists of hydrostatic pressure and wave pressure. The combination between pressure and hull girder load is shown in Table 3.3.3(1).

External sea pressure Table 3.3.3(1)

Condition	Global load	External hydrostatic pressure	External wave pressure
1	Maximum vertical bending moment condition	Maximum operating draught and hydrostatic pressure	Wave crest pressure
2	Minimum vertical bending moment condition	Minimum operating draught and hydrostatic pressure	Wave trough pressure

① The hydrostatic pressure *Phs* is to be calculated as follows:

$$p_{hs} = \rho_w g(d_1 - z) \quad \text{kN/m}^2, \quad \text{for } z \le d1$$

$$= 0 \quad \text{kN/m}^2, \quad \text{for } z > d1$$

where: ρ_w — density of sea water, taken as 1.025 t/m^3;

d_1 — draught, in m;

z — vertical distance measured from the considered point to the baseline, in m.

② Wave pressure

Corresponding to the maximum and minimum vertical bending moment conditions, the applied wave pressure (kN/m^2) is calculated according to Table 3.3.3(2), where the positive value indicates the wave crest, pointing inside the ship and superimposed with the hydrostatic pressure in 3.3.2(1). The negative value indicates the wave trough, pointing outside the ship, opposite to the hydrostatic pressure direction of 3.3.2(1). The definition of C in the table is shown in 2.3.1(4), and the wave pressure is shown in Figure 3.3.3.

Wave pressure Table 3.3.3(2)

Height z (m) range	wave crest (kN/m^2)	wave trough (kN/m^2)
$d_1 < z \le d_1$ +0.33C	3.3C-10(z- d_1)	0
$0 \le z \le d_1$	2.25C+1.05zC/ d_1	Max(−2.25C−1.05zC/ d_1 , ρg(z− d_1))

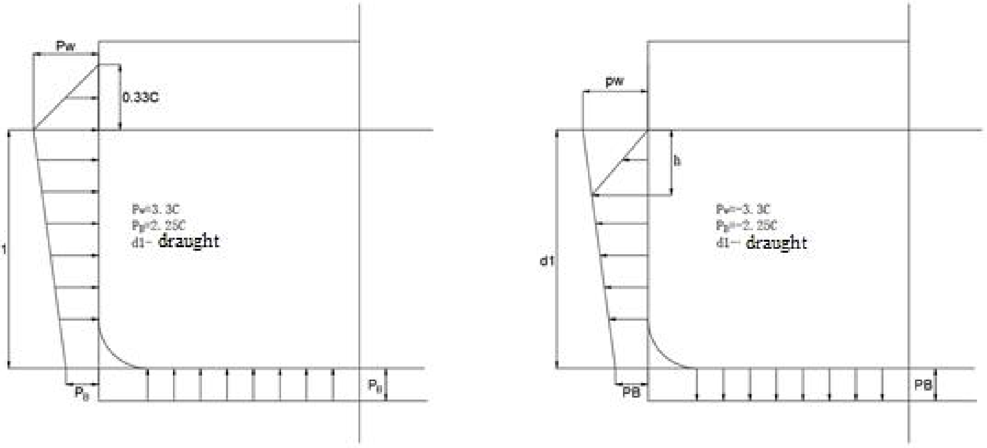

Figure 3.3.3 Wave pressure

3.4 Boundary conditions

3.4.1 Boundary conditions of the model are shown in Figure 3.4.1 and Tables 3.4.1(1) ~ (3). The independent point is the intersection point of the neutral axis with the center line of the hull girder section at both ends, and the correlation between the rigid links of the longitudinal continuous member nodes on the end planes with the independent points is shown in 3.4.1(1). The support of independent points on both end planes is shown in Table 3.4.1(2), and that of other points is shown in Table 3.4.1(3).

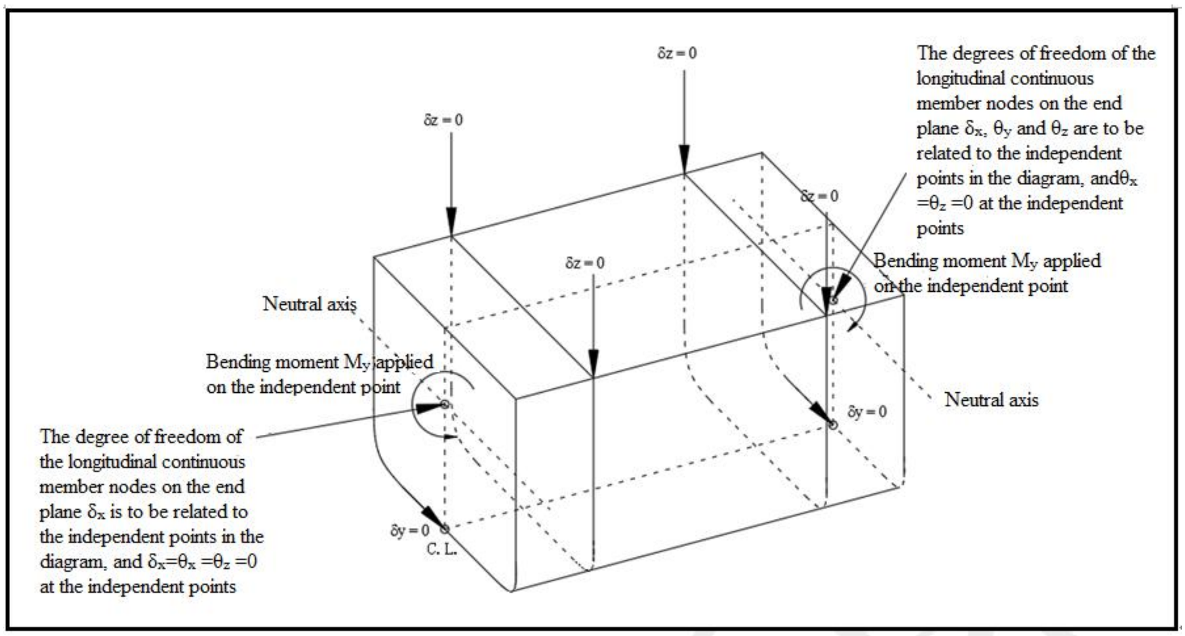

Figure 3.4.1 Boundary conditions of the model

Rigid-link of both ends Table 3.4.1(1)

Nodes on longitudinal continuous member nodes at both end planes of the model	Translational			Rotational		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
All longitudinal members on the fore end model	RL	-	-	-	RL	RL
All longitudinal members on the aft end model	RL	-	-	-	-	-
Note: RL means rigidly linked to the relevant degrees of freedom of the independent point						

Support condition of the independent point Table 3.4.1(2)

Independent points	Translational			Rotational		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Independent points on the fore end model	-	-	-	Fix	-	Fix
Independent points on the aft end model	Fix	-	-	Fix	-	Fix

Support condition of other points Table 3.4.1(3)

Independent points	Translational			Rotational		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Intersection of baselines on fore and aft end model of the model with central longitudinal section	-	Fix	-	-	-	-
Intersection of fore and aft bulkheads of engine room with uppermost deck model of the model on the side		-	Fix	-	-	-

3.5 Yield strength assessment

3.5.1 Yield strength assessment is to be carried out for shell plating, bottom plating, inner bottom plating, bulkhead plating and primary supporting members of hull structure.

3.5.2 The yield strength criteria for hull structure are shown in Table 3.5.2.

Yield strength criteria for hull structure Table 3.5.2

Hull structure	Permissible stress (N/mm^2)		
	Positive stress	Shear stress	Equivalent stress
Bottom plating, inner bottom plating	220/K	-	235/K
Bottom girders	-	110/K	-
Plate floors	145/K	90/K	175/K
Primary side transverse members	145/K	90/K	175/K
Other longitudinal members	-	110/K	220/K

Note: *K* is material factor.

3.6 Buckling strength assessment

3.6.1 Buckling strength assessment is to be carried out for shell plating, bottom plating, inner bottom plating, bulkhead plating of hull structure, and webs of primary supporting members.

3.6.2 See 2.7 for the buckling strength assessment method.

CHAPTER 4 LOCAL STRUCTURAL REFINED ANALYSIS

4.1 General requirements

4.1.1 This Chapter specifies the requirements and methods for FE refined analysis of local structures to assess the strength of local high stress structural areas.

4.1.2 Refined analysis is to include at least the following areas:

(1) the structural non-continuous area where the stress calculated in accordance with the requirements of Chapters 2 and 3 is greater than 75% permissible stress;

(2) the opening area where the stress calculated in accordance with the requirements of Chapters 2 and 3 is greater than 85% permissible stress;

(3) primary deck supporting members with the opening height exceeding 50% of the web height or with the distance from the edge of the opening to the face plate less than 20% of the web height;

(4) the connection details between misaligned pillars;

(5) the area where the structural model is insufficient to reflect the local shape at the structural connections.

4.1.3 The refined model can be inserted into the FE model of the typical structure or engine room double bottom structure, or it can be analyzed using sub-model/independent model.

4.2 Structural modelling

4.2.1 The scope of refined model is as follows:

(1) The refined model is to be such that the stresses at the areas of concern are not significantly affected by the boundary conditions.

(2) For the assessment of the opening in the web plate of the deck primary supporting member, the openings in the primary member adjacent to the assessment area are to be simulated, as shown in Figure 4.2.1(1).

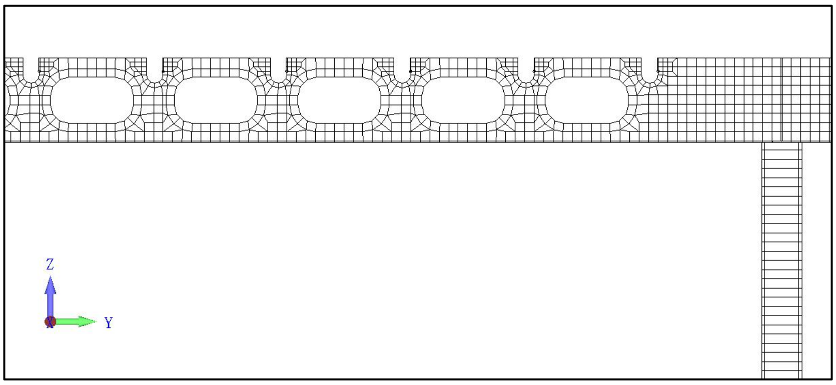

Figure 4.2.1(1) Web of deck primary supporting member and opening

(3) The connection details between misaligned pillars are to be calculated using an independent model, which is to include the target area and the upper and lower pillars. The FE model of the deck where the misaligned pillars are connected is to extend to the longitudinal girder/transverse web or bulkhead, as shown in Figure 4.2.1(2).

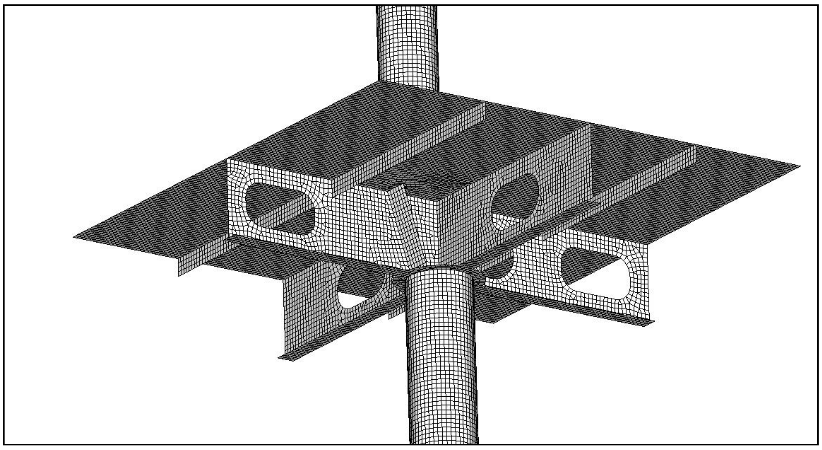
Figure 4.2.1(2) Model of the connection details between misaligned pillars

4.2.2 The fine mesh area is to be modelled using plate elements, and triangular elements and distortion elements is to be avoided. The aspect ratio of elements is to be close to 1. The fine mesh size is not to be greater than 50 mm ×50 mm and a smooth structural transition is to be maintained for the refined model.

4.2.3 The FE model scantlings is based on the as-built thicknesses excluding the owner's extras.

4.3 Boundary conditions and loads of refined sub-model

4.3.1 The following methods are to be used for the boundary conditions of refined model:

(1) Where the independent sub-model is used for the refined model, the displacement obtained from model calculation for the typical structure of the cruise ship or the double-bottom structure of the engine room is to be applied to its boundary.

(2) The lower end of the pillar below the connection details between misaligned pillars is to be fixed, the radial displacement is to be constrained on the mid-deck boundary, the vertical and rotational displacement are free. See Figure 4.3.1 and Table 4.3.1 below for details.

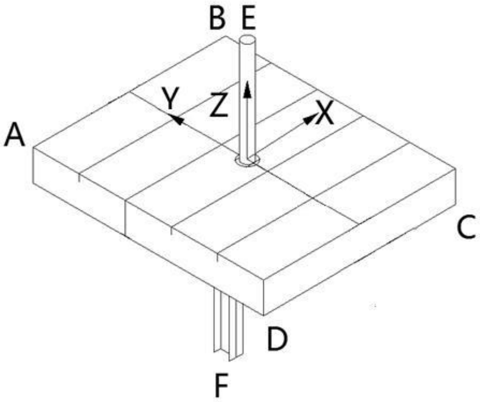

Figure 4.3.1 Boundary of the connection details between misaligned pillars

Boundary conditions of the connection details between misaligned pillars Table 4.3.1

Boundary	Translational			Rotational		
	δ_x	δ_y	δ_z	θ_x	θ_y	θ_z
Side AB, CD	-	Fix	-	-	-	-
Side AD, BC	Fix	-	-	-	-	-

E	Fix	Fix	-	Fix	Fix	Fix
F	Fix	Fix	Fix	Fix	Fix	Fix

4.3.2 Loads are to be applied as follows:

(1) The local design load is to be applied to the refined model.

(2) For the connection details between misaligned pillars, the load transferred by the upper pillar is to be applied to the upper end of the pillar on the refined model, while the uniformly distributed load is also to be applied to the deck, and simultaneously the effect of acceleration is to be taken into account in accordance with 2.3.

4.4 Permissible stress

4.4.1 The permissible stresses are based on the mesh size of 50 mm × 50 mm. Where a smaller mesh size is used, an area weighted stress calculated over an area equal to the specified mesh size may be used to check.The yield strength criteria of hull structure are shown in Table 4.4.1.

Yield strength criteria of hull structure Table 4.4.1

Hull structure	Load type	Permissible stress (N/mm^2)			
		Average normal stress①	Average shear stress①	Average von Mises stress①	Von Mises stress
Web plating of deck transverses	Local only	-	$0.35R_{eH}$	$0.75 R_{eH}$	R_{eH}
Webs of deck girders	Local only	-	$0.35R_{eH}$	$0.75 R_{eH}$	-
Face plates of deck transverses and deck girders (beam or plate element)	Local only	$0.52 R_{eH}$	-	-	-
Deck girders	Local + Global	200/K	-	220/K	$1.25 R_{eH}$
Other members			110/K	220/K	$1.35 R_{eH}$

Note ①: Average stress is the average stress of the elment in the areas shown in A, B and C in Figure 4.4.1 or within the area equivalent to the coarse mesh size. Averaging is not to be carried across structural discontinuities or abutting structure.

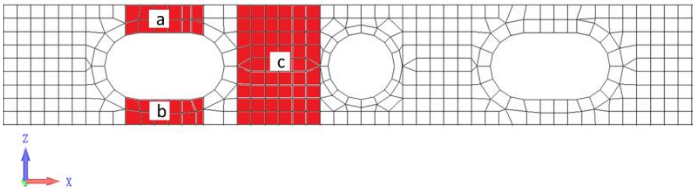

Figure 4.4.1 Average stress area of opening