Polski Rejestr Statków

RULES

PUBLICATION NO. 17/P

**ZONE STRENGTH ANALYSIS OF HULL STRUCTURE
OF ROLL ON/ROLL OFF SHIP**

1995

Publications P (Additional Rule Requirements), issued by Polski Rejestr Statków, complete or extend the Rules and are mandatory where applicable.

GDAŃSK

Publication No. 17/P "Zone Strength Analysis of Hull Structure of Roll on/Roll off Ship – 1995" is an extension of the requirements contained in Part II "Hull" of the Rules for the Classification and Construction of Sea-going Ships – 1995.

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The present Publication replaces its 1986 edition.

PRS/TW, 12/95

CONTENTS

1 GENERAL

1.1 Introduction

1.1.1 For design of ro-ro ships, documentation of which is subject to approval of PRS, the “Rules for the Classification and Construction of Sea-going Ships” (henceforth referred to as the “Rules”) require a zone strength analysis to be carried out.

1.1.2 The zone strength analysis is to show that in all, described below, design load conditions (LC) the stresses in the chosen sections will not exceed the values prescribed by the Rules.

1.1.3 Acceptable results of zone strength analysis carried out in accordance with the procedure given in the present Publication, as well as compliance with the requirements of the relevant Chapters of the Rules will be the basis for the PRS approval of hull structural documentation.

1.1.4 Zone strength analysis is usually related, to fragments of particular hull structures (sides, bottom, decks, bulkheads) or their combinations. It is generally related to the girder systems of these structures considered as 2- or 3- dimensional bar systems. In special cases structural idealization by means of other types of finite elements may be required. The present Publication refers to bar idealization.

1.1.5 Any calculation method or computer programme taking into consideration the effects of bending, shear, axial and torsional deformations may be applied in zone strength analysis.

1.1.6 The present Publication contains guidelines for carrying out stress analysis of cross-sections of primary girders of roll on/roll off ships or other ships without transverse bulkheads in the cargo region.

1.2 Strength Analysis Procedure

1.2.1 The method, discussed below, enables to carry out the necessary calculations for 3- dimensional structural system by means of 2- dimensional models (2- dimensional frameworks and grillages).

Fig. 1.2.1 presents a scheme of the strength analysis method of roll on/roll off ships with pillars supporting the deck structures directly on the double bottom.

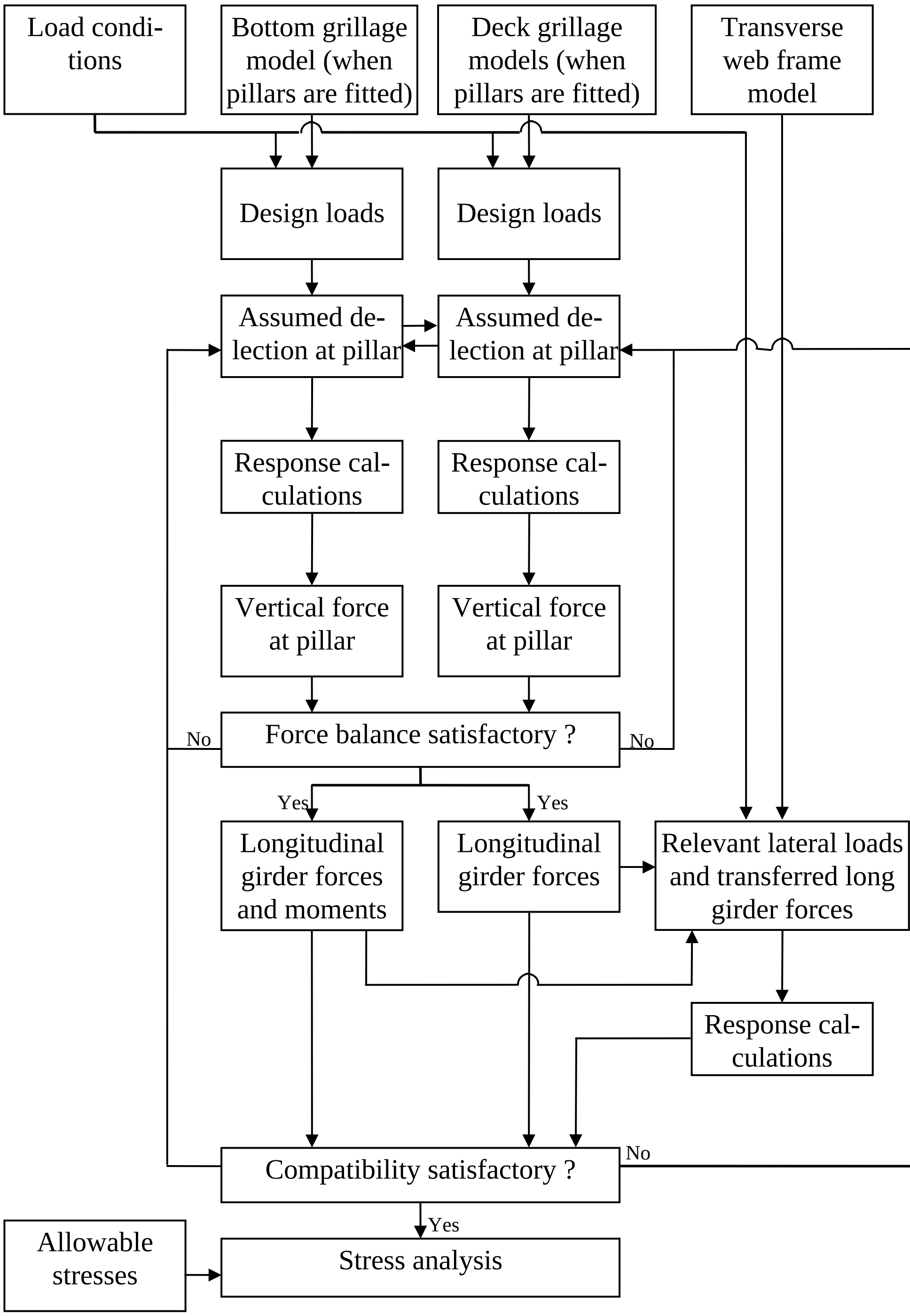


Fig. 1.2.1 Strength analysis procedure of roll on/ roll off ship

1.2.2 The design loads to be applied to particular structural members may be derived from the load conditions given in Chapter 2. Additional load conditions may be required in order to investigate the local strength of decks and double bottom.

1.2.3 The load conditions LC 1 – LC 5 are to be, in general, investigated for the complete transverse sections of the hull.

1.2.4 Where pillars are fitted along the ship's centreplane, the unsymmetric load conditions LC 6 and LC 7 are to be investigated for individual decks and bottom.

For designs with no longitudinal discontinuities, such as pillars, simple procedures involving only modelling of transverse web frames, may be applied.

1.2.5 If pillars are fitted at regular intervals over the length of the cargo region, modelling analysis of the bottom and deck (grillages) will be necessary in addition to the analysis of transverse web frames. These additional calculations involve an iteration process to obtain vertical force balance between the various grillage models, at the pillar. The iteration process is to be carried out until the compatibility between the grillage models and the framework model has been proved satisfactory.

1.3 Definitions

1.3.1 Symbols not mentioned in the following list are given in connection with appropriate formulae:

L – length of the ship, in m;
B – breadth of the ship, in m;
H – depth of the ship, in m;
T – draught, in m;
δ – block coefficient,

For details, see 1.2.1, Part II of the Rules, "Hull"

v – maximum service speed at draught T, in knots;
h_{dp} – height of double bottom, in m;
E – modulus of elasticity (Young's modulus), in MPa, $E = 2.06 \cdot 10^5$ MPa may be taken for steel;
g = 9,80665 m/s – standard acceleration of gravity;
C_W – wave coefficient;
a_V – combined vertical acceleration, in m/s^2;
a_T – combined transverse acceleration, in m/s^2;
Φ_A – roll angle (amplitude of roll) in radians;
Θ_A – pitch angle (amplitude of pitch) in radians.

For details, see Chapter 17, Part II of the Rules, "Hull"

1.3.2 Units

SI – units (the units of the International System of Units (SI)), as well as other units not covered by the system and permitted temporarily for use, are adopted in the present Publication.

The following SI – units are used in the Publication:

- Mass unit – tonne (t),
- Length unit – millimetre (mm), centimetre (cm) or metre (m),
- Angle unit – radian (rad),
- Time unit – second (s),
- Force unit – newton (N) or kilonewton (kN),
- Pressure unit – kilopascal (kPa),
- Stress unit – megapascal (MPa).

Attention is to be paid to the units used in computer programmes. They may differ from those listed above.

2 LOAD CONDITIONS

2.1 Maximum Cargo on Lower Part of Section, Upright Condition (LC1)

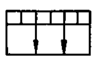
2.1.1 This condition, shown in Fig. 2.1.1, may be decisive for the double bottom and lower deck strength.

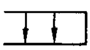
It should be noted that this condition, the higher decks are also loaded.

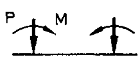
The total sum of static cargo load on the section need not exceed the buoyancy on the same section. For this purpose, the loads on the higher decks need not be taken as the maximum permissible values.

Explanations to the figures:

 – steel weights $q_0 (g + 0.5a_v)$, KPa

 – sea pressure P_2 (static and dynamic)

 – distributed cargo load $q_1 (g + 0.5a_v)$, KPa



– transferred forces and moments from adjacent structure

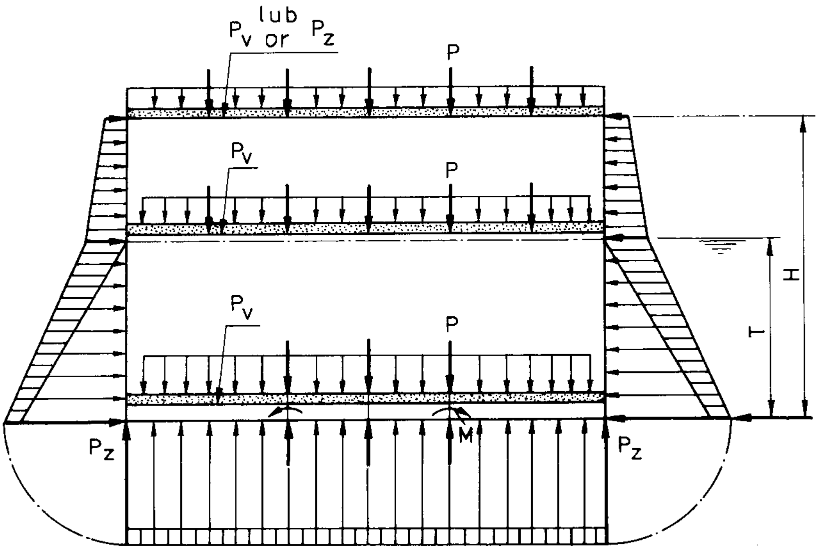


Fig. 2.1.1 Load condition LC1

2.1.2 The design pressures due to cargo loads (including the mass of structures) are to be determined from the formula:

$$P_v = (g + 0.5a_v)(q_0 + q_1), \text{ kPa} \tag{2.1.2}$$

q_1 – intensity of cargo mass distribution, in t/m^2;
q_0 – intensity of structure mass distribution, in t/m^2.

For accomodation decks, the pressure of mass distribution (q_0 + q_1) may be taken equal to 0.4 t/m^2.

2.1.3 The design sea pressures P_Z, kPa, are to be determined for full draught, including dynamic sea pressures, from the formulae given in 16.2 Part II, "Hull", of Rules the for Classification and Construction of Sea-going Ships.

For the weather deck, the greater of the values – the sea pressure or the pressure due to cargo – is to be applied. In both cases the mass of structure is to be taken into consideration.

2.2 Maximum Cargo on Lower Part of Section, Heeled Condition (LC2)

2.2.1 This condition, shown in Fig. 2.2.1, may be decisive for the double bottom and decks strength. The cargo distribution on the section is to be the same as for LC1.

Symbols – according to 2.1.1

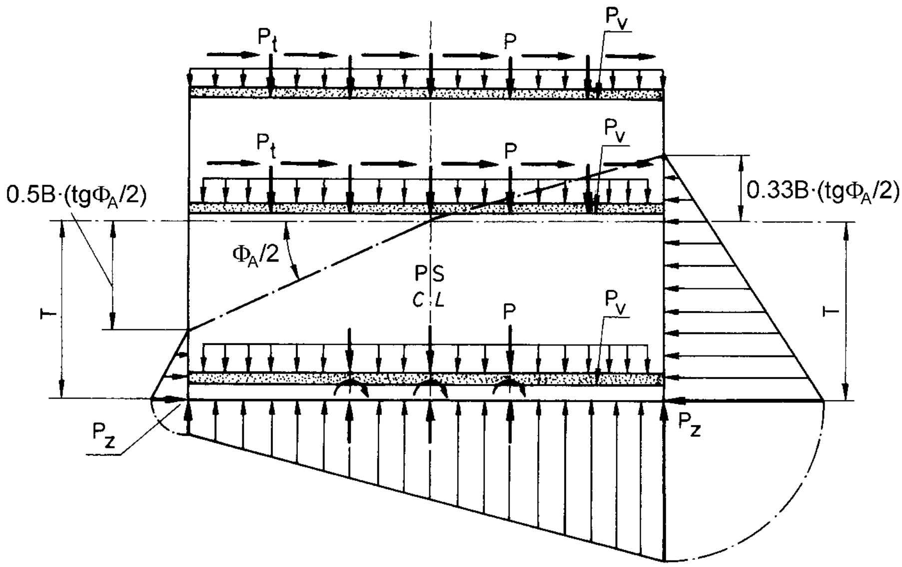


Fig. 2.2.1 Load condition LC2

2.2.2 The design pressures due to cargo (including the mass of structures) are to be assumed as acting at an oblique angle to the deck.

The pressure components in the ship's vertical direction are to be taken as:

$$P_v = g\left(q_0 + q_1\right), \text{ kPa} \qquad (2.2.2\text{-}1)$$

The pressure components in the ship's transverse direction are to be taken as:

$$P_t = 0.67 a_T\left(q_0 + q_1\right), \text{ kPa} \qquad (2.2.2\text{-}2)$$

q_0, q_1 – as defined in 2.1.2.

In the case of different cargo loads specified areas, the mean value of q_1 for the whole deck area may be applied.

Where movable decks for the carriage of vehicles are used, the pressure components (in the ship's transverse direction) due to the mass of vehicles and their cargo, determined in accordance with 2.2.2-2, are to be taken into consideration and are to be applied in accordance with real conditions of the decks supports.

2.2.3 The design sea pressures are to be determined for full draught, corrected for the effects of wave form and roll.

The pressure at the bilge for the emerged side is to be determined from the formula:

$$P_Z = 10T - 5B\cdot\left(tg\Phi_A/2\right), \text{ kPa} \qquad (2.2.3\text{-}1)$$

For the position $T - 0.5B\cdot\left(tg\Phi_A/2\right)$ m, above the baseline, $P_Z = 0$ is to be taken.

The pressure at bilge for the submerged side is to be determined from the formula:

$$P_Z = 10T + 3.3B \cdot \left(tg\Phi_A / 2\right), \text{ kPa} \tag{2.2.3-2}$$

For the position $T + 0.33B \cdot \left(tg\Phi_A / 2\right)$ m, above the baseline, P_Z = 0 is to be taken.

Between the positions specified above the value of P_Z is to be varied linearly. If, at the above – specified pressure distribution, the weather deck is partly submerged, then the sea pressure on the weather deck may be disregarded when cargo loads are applied.

2.3 Maximum Cargo on Upper Part of Section, Upright Condition (LC3)

2.3.1 This condition, shown in Fig. 2.3.1, may be decisive for the double bottom and higher decks strength. All cargo spaces, except those above the double bottom are to be considered loaded to maximum. If the total sum of static cargo load exceeds the buoyancy on the same section, the loads on lower decks may be reduced.

If this condition is unrealistic for stability reasons, adjustments of this condition are to be made and submitted for consideration.

Symbols – according to 2.1.1

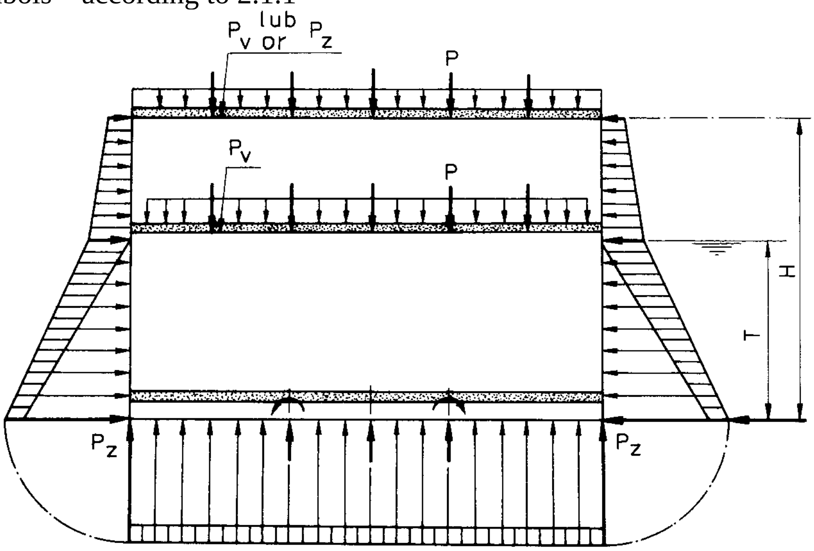


Fig. 2.3.1 Load condition LC3

2.3.2 The design pressures due to cargo and design sea pressures are to be calculated as for LC1.

2.4 Maximum Cargo on Upper Part of Section, Heeled Condition (LC4)

2.4.1 This condition, shown in Fig. 2.4.1, may be decisive for the strength of the double bottom, higher decks, as well as the strength of the ship's sides. The cargo distribution on the section is to be the same as for LC2.

Symbols – according to 2.1.1

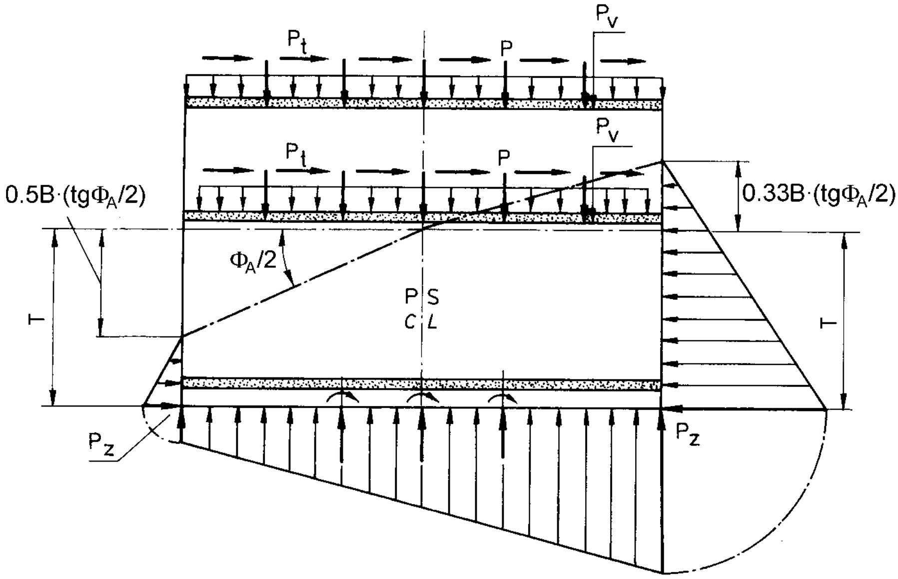


Fig. 2.4.1 Load condition LC4

2.4.2 The design pressures due to cargo and design sea pressures are to be calculated as for LC2.

2.5 Ballast Condition (LC5)

2.5.1 This condition, shown in Fig. 2.5.1, may be decisive for the strength of the double bottom in ships with pillars. The design pressures due to the mass of deck or double bottom structures are to be calculated as for LC1. For the decks, the value of q_1 is to be taken as zero. Double bottom tank for bunker is to be considered empty. Ballast in double bottom tank may be included.

Symbols – according to 2.1.1

2.5.2 Design bottom pressure P_Z, kPa, are to be determined taking into consideration dynamic components. Pressures dynamic components are to be determined from the formulae given in Part II – "Hull", of PRS' Rules, substituting to them draught T. Static pressure are to be determined for maximum ballast draught T_b.

At position h = 0.1 P_Z above the baseline, P_Z = 0 is to be taken.

Liner variability at the pressures are to be taken along ship's side.

2.6 Transversely Unsymmetric Deck Load (LC6)

2.6.1 This condition, shown in Fig. 2.6.1, is applicable only to strength analysis of deck grillage supported by pillars.

2.6.2 The loads are to be calculated as for LC1.

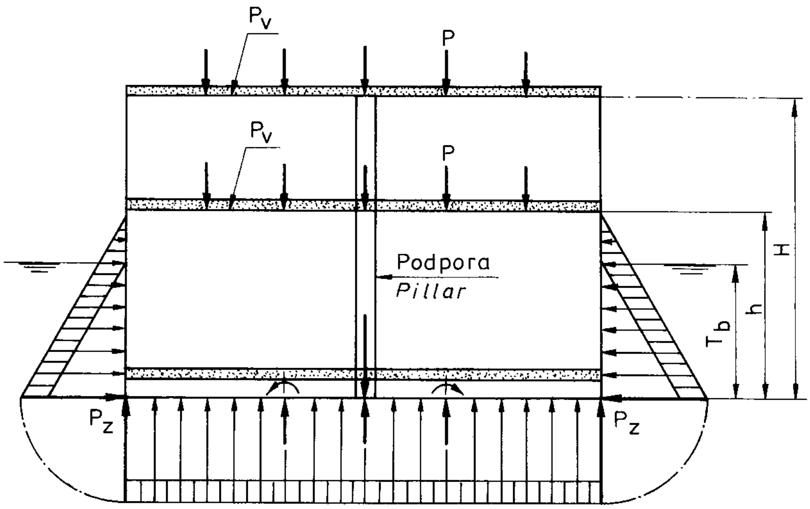


Fig. 2.5.1 Load condition LC5

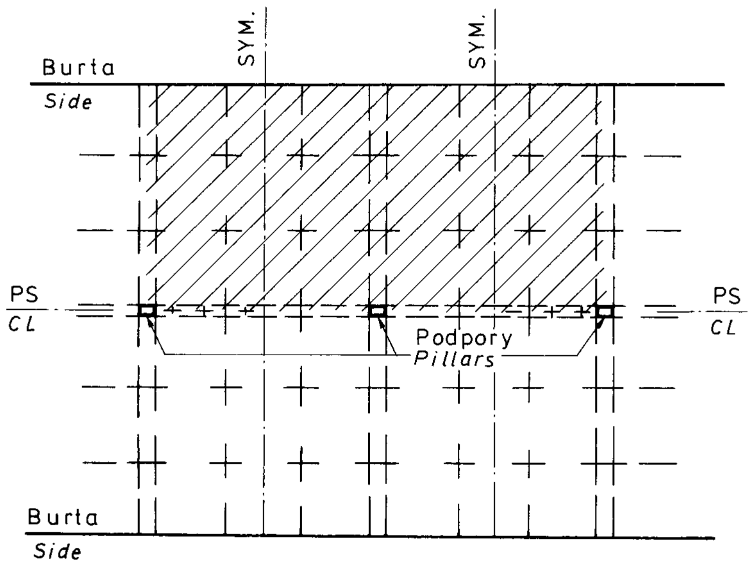


Fig. 2.6.1 Load condition LC6

2.7 Longitudinally Unsymmetric Deck Load (LC7)

2.7.1 This condition, shown in Fig. 2.7.1, is applicable only to strength analysis of deck grillage supported by pillars.

2.7.2 The loads are to be calculated as for LC1.

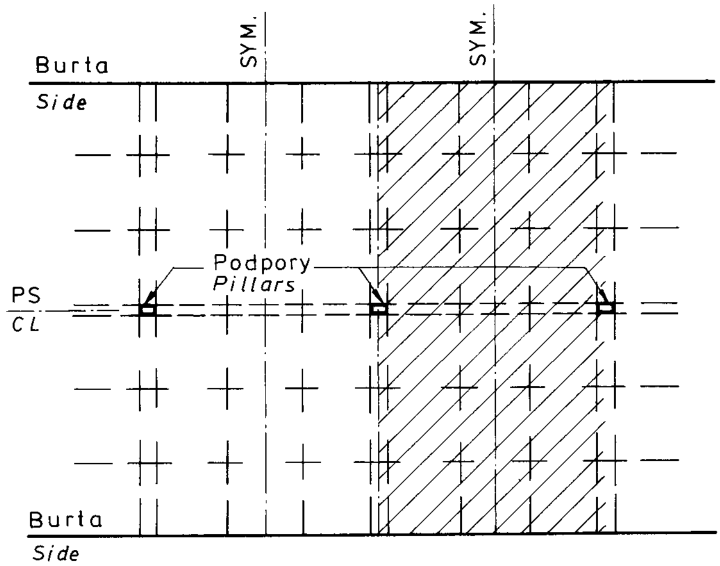


Fig. 2.7.1 Load condition LC7

2.8 Deck Loaded with Concentrated Forces (LC8)

2.8.1 This condition is applicable only to strength analysis of deck grillage (or to transverse plane framework) to allow for concentrated forces from a pile of containers or from other cargo.

2.8.2 Loads are to be calculated for the maximum permissible mass of pillar of containers and the mass of structure, including vertical accelerations calculated in accordance with 2.1.2.

3 MODELLING OF STRUCTURE

3.1 General

3.1.1 For structures where the transverse strength members are supported only at the ship's sides, one model of the transverse web frame structure will be sufficient.

3.1.2 If the deck and the double bottom are designed with pillars and longitudinal girders in addition to the transverse web frames, force distribution from adjacent structure to the transverse frame in question is to be considered. This can normally be calculated by 2- dimensional grillage models.

3.1.3 The correlation between individual 2- dimensional models is to be satisfactory.

Symbols used in the description of the models are given in Fig. 3.1.3.

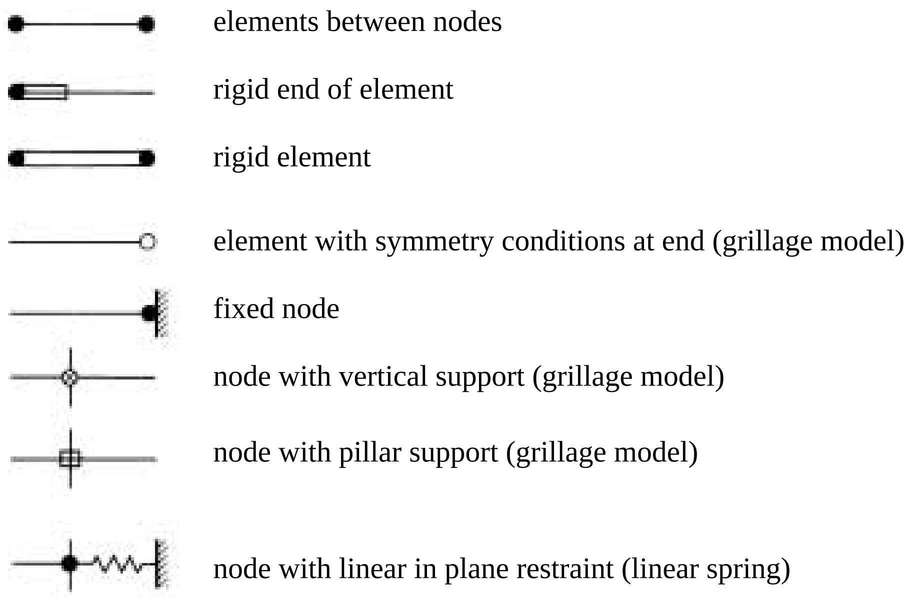


Fig. 3.1.3 Symbols

3.1.4 Structures in way of openings for ramps, lifts, etc., may be analysed on the basis of modified 2- dimensional models. Necessary modifications will be considered in each particular case.

3.2 Transverse Web Frames

3.2.1 Figs. 3.2.1-1 and 3.2.1-2 show typical models of a transverse frame at pillars and between pillars when centreline pillars are fitted. The model is to extend from side to allow for unsymmetric load conditions.

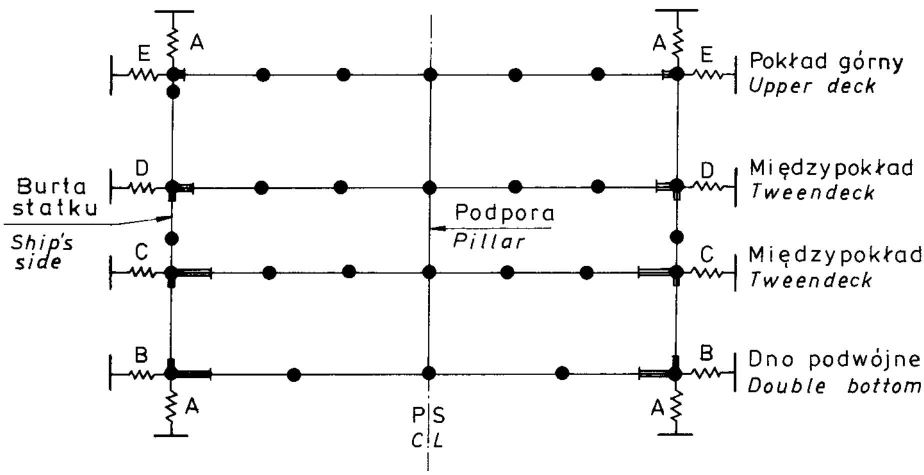


Fig. 3.2.1-1 Transverse web frame

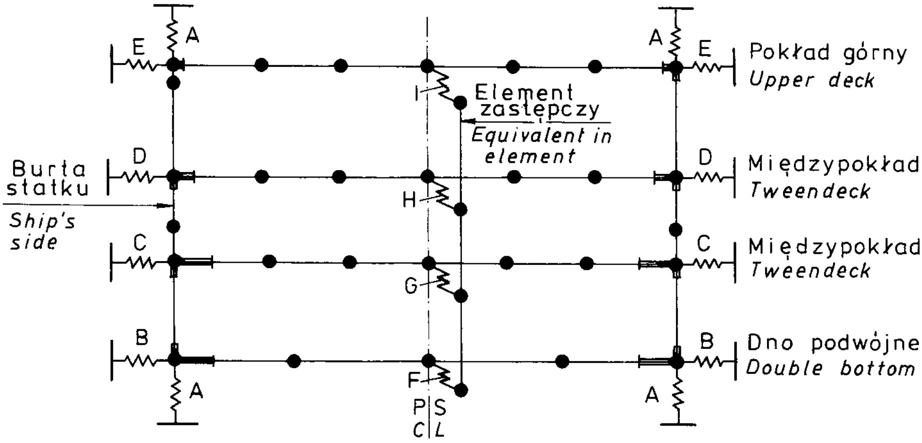


Fig. 3.2.1-2 Transverse web frame between pillars

3.2.2 Vertical and horizontal supporting springs corresponding to the stiffness of ship's sides and decks are to be applied. The stiffness coefficient for springs A, B, C, D and E may be calculated from the formula:

$$K = \frac{0.5E}{n\left(\dfrac{5k_2 l^3}{384 I} + \dfrac{2.6 k_1 l}{8 A_s}\right)}, \text{ N/mm} \qquad (3.2.2)$$

l – distance between effective transverse bulkheads; the value l, taken for calculations, need not be greater than 0.9 L;

I – actual moment of inertia of that part of hull cross-section which acts as the spring support: ship's side (spring A) and deck or bottom (springs B, C, D, E), taking into account effective face areas (parts of decks and bottom cross sections – for spring A and those of side structures and longitudinal bulkheads – for springs B, C, D, E).

A_s – actual shear arce of that part of hull cross-section which acts as the spring support: of ship's side (spring A) and of bottom or deck (springs B, C, D, E);

$$n = \frac{l}{l_m}$$

(l_m – length of load area included in the model; l_m is to be taken as the length of bottom or deck grillage model);

k_1, k_2 – correction factor taken from Table 3.2.2.

Table 3.2.2

n	1	2	3	4	5	6	7	8	9	10
k_1	2.00	1.50	1.33	1.25	1.20	1.18	1.14	1.12	1.11	1.10
k_2	1.50	1.33	1.25	1.20	1.18	1.14	1.12	1.11	1.10	1.10

3.2.3 Transverse frames between pillars are normally connected to the pillar by a longitudinal centreplane deck girder. In 2- dimensional model, this connection may be represented by springs F, G, H and I. The stiffness coefficient of these springs may be calculated from the formula:

$$K = \frac{E}{nk_1\left(\frac{l^3}{384I} + \frac{2.61}{8 \cdot A_s}\right)} \tag{3.2.3-1}$$

l – distance between pillars;

I – actual moment of inertia of longitudinal deck girder;

A_s – actual shear area of longitudinal deck girder;

n – number of transverse frames between pillars;

k_1 – factor determined in 3.2.2.

If spring stiffnesses between internal nodes are not available in the computer programme used, the spring may be replaced by a "spring element" with cross – sectional area:

$$A = \frac{Kl_s}{E} \tag{3.2.3-2}$$

l_s – length of "spring element".

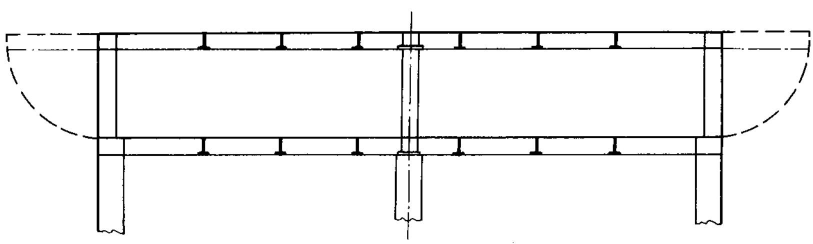
3.3 Deck and Bottom Structures

3.3.1 A typical deck design and corresponding model are shown in Fig. 3.3.1. This model may by used for analysis of load conditions LC6 and LC7. In addition, the force distribution in deck or bottom longitudinal girders may be determined for load conditions LC1 – LC5 and applied to transverse web frame model given in Fig. 3.2.1-1.

This applies when pillars are used to support deck and bottom structure.

The compatibility at the intersections between the web frame and grillage models may be difficult to obtain when the number of longitudinal girders is large. In this case it may be more convenient (or necessary), to apply a 3- dimensional model combining web frames models and grillage models.

a) Typical deck structure (transverse section)



b) Grillage model (upper deck), including ship's sides unfolded

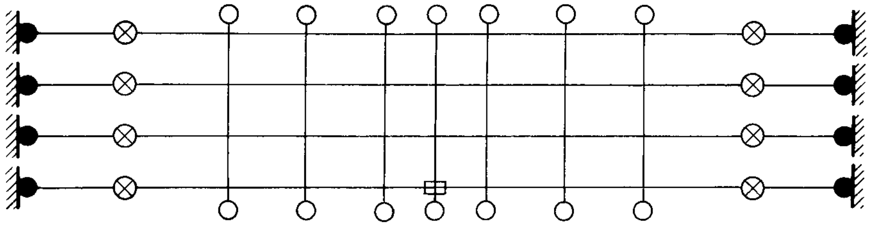


Fig. 3.3.1 Deck structure

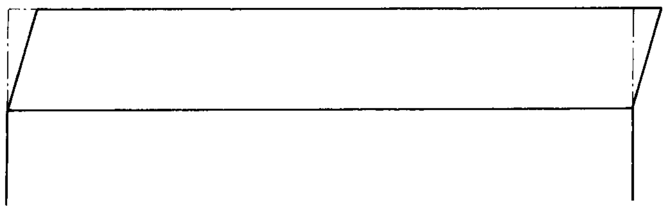


Fig. 3.3.2 Deflections of transverse web frame under angle of heel

Pre-set displacement of boundary nodes in grillage model

Fig. 3.3.3 Racking

The grillage model of deck structure for load condition LC8 (in some cases 2- dimensional model may be sufficient) is to include such part of the deck area which would adequately represent heterogeneity of loads and the symmetry of structure.

3.3.2 The node supported by pillar is to be given rotational spring stiffness in x- and y- direction, calculated from the formula:

$$K_r = \frac{E}{\frac{l}{4I} + \frac{3,9}{A_s l}}, \text{ moment unit/rad} \qquad (3.3.2)$$

l – length of pillar;
I – relevant moment of inertia of pillar (in x- or y- direction);
A_s – relevant shear area of pillar (in x- or y- direction).

It should be noted that for tween decks the value of k_s is to be taken as the sum of stiffness of pillars above and below the deck.

3.3.3 In the vertical direction the node supported by pillar in each grillage model is to be given preset displacement corresponding to the deflection (relative displacements) obtained in the successive transverse web frame calculation. For the loading conditions LC2 and LC4 the transverse boundary nodes of grillage are to be given similar pre-set displacement corresponding to the deflections due to racking between the decks (see Fig. 3.3.3).

4 STRESS ANALYSIS

4.1 General

4.1.1 Permissible girder stresses given in Part II of the Rules, “Hull”, Section 14.4, are to be complied with.

4.1.2 The stability factor (usage factor) of pillars is to comply with:

$$\eta = \frac{\sigma_a}{\sigma_c} \le \frac{0.7}{1 + \frac{l}{i}}, \tag{4.1.2}$$

where

$$\frac{0.7}{1 + \frac{l}{i}} \ge 0.3$$

σ_a – calculated compressive stress;
σ_c – critical buckling stress; it may be calculated according to 13.7, Part II of the Rules, “Hull”
l – length of pillar, in m;
i – radius of gyration, in cm.

4.1.3 The stability factor (usage factor) for plating acting as girder flange is to comply with:

$$\eta = \frac{\sigma_a}{\sigma_c} \le 0.87 \tag{4.1.3}$$

For σ_a and σ_c, see 4.1.2.

4.2 Strength of Cross Joints

4.2.1 The flange discontinuity at cross joints of highly stressed girders is to be normally compensated for by brackets. If brackets are not possible, e.g. between deck transverse and ship's side vertical girders, high shear stresses in the web area combining the girders may occur.

The design shear stress may normally be taken as the average of stresses calculated from the formula:

$$\tau = 10\frac{P_{m1} - Q_{s2}}{A_{s2}}, \text{ MPa} \tag{4.2.1-1}$$

and

$$\tau = 10\frac{P_{m2} - Q_{s1}}{A_{s1}}\text{, MPa} \tag{4.2.1-2}$$

Q_s – shear force in the girder web, in kN;
P_m – axial force in the girder face plate, in kN;
A_s – shear area of girders, in cm^2.

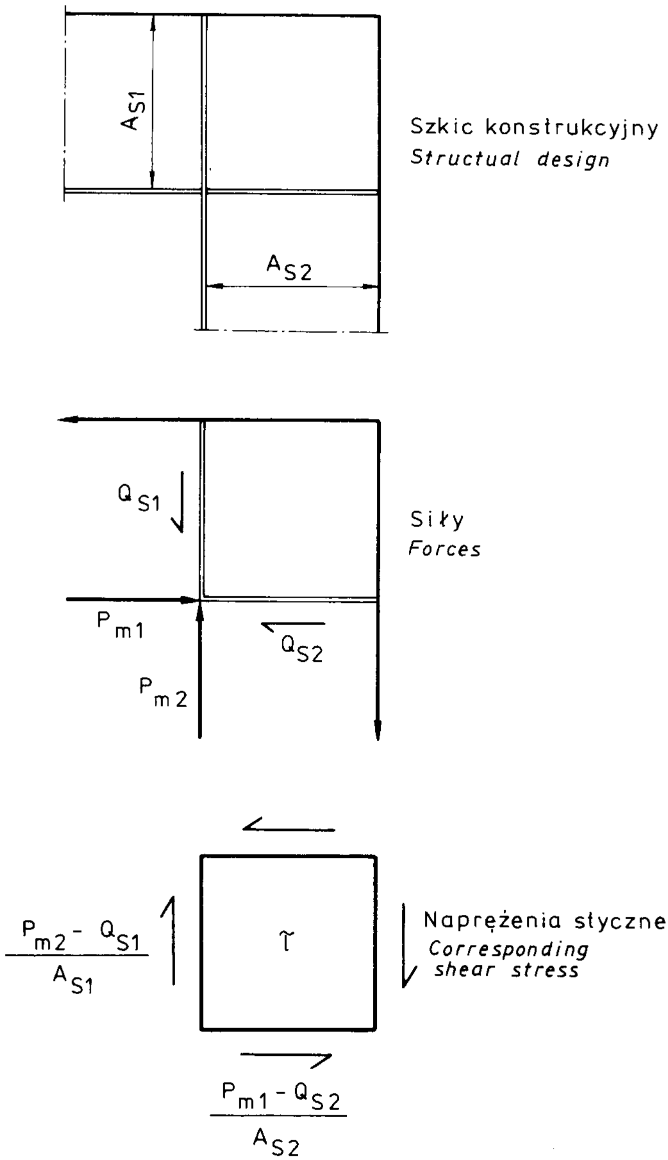


Fig. 4.2.1 Stress analysis of cross joint