RUSSIAN MARITIME REGISTER OF SHIPPING

COLLECTION

OF REGULATING DOCUMENTS

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The present Collection of Regulating Documents contains:

Draft proposal to complete the Rules for the Classification and Construction of Sea-Going Ships with regulating requirements for ships, which are periodically grounded in operation (**NAABSA** ships);

Risk assessment methodology for evaluation of loss of stability by a ship under hazardous dynamic phenomena in rolling seas.

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DRAFT PROPOSAL
TO COMPLETE THE RULES
FOR THE CLASSIFICATION AND CONSTRUCTION
OF SEA-GOING SHIPS
WITH REGULATING REQUIREMENTS FOR SHIPS, WHICH ARE PERIODICALLY GROUNDED IN OPERATION (NAABSA SHIPS)

PART I. CLASSIFICATION

2.2 CLASS NOTATION OF A SHIP

New item 2.2.29 is introduced reading as follows:

“**2.2.29 Marks of the ships, which are periodically grounded in operation.**

One of the following distinguishing marks shall be added to the character of classification of a ship, which is periodically grounded in operation and the hull structure and equipment of which complies with the requirements of the relevant sections of the Rules:

.1 NAABSA1 – partial or full ship hull baring is permitted on plane homogeneous sand-and-shingle or sand-and-mud sea beds with no motion in calm water as harbors or sheltered areas;

.2 NAABSA2 –in addition to **NAABSA1** notation specified, motion and ship bow impact contact with seabed at defined wave parameters are permitted;

.3 NAABSA3 – in addition to **NAABSA2** notation, hull baring of moored ship is permitted at specified distance from seashore line in rolling conditions with impact contact against the seabed in any point of the seabed.”

The existing items 2.2.29 и 2.2.30 are replaced by items 2.2.30 and 2.2.31 accordingly.

PART II. HULL

3.13 SHIPS, WHICH ARE PERIODICALLY GROUNDED IN OPERATION

3.13.1 General provisions and symbols

3.13.1.1 Application.

3.13.1.3.1 The requirements of this Chapter apply to **NAABSA** ships (Not Always Afloat But Safely Aground), which may lie aground in safety with partial or full hull baring in places, fit for grounding the ships.

3.13.1.3.2 The ships with the design, which complies with the requirements of this Chapter, shall receive a ship distinguishing mark in the character of classification of a ship in accordance with 2.2.29, Part I "Classification".

3.13.1.3.3 Requirements for hull structures, which are not specified in this Chapter, shall be taken in compliance with Sections 1 and 2.

3.13.1.2 The following symbols have been adopted in this Chapter:

Δ_N –design displacement of **NAABSA** ship equal to the maximum value at the beginning of baring or upon emersion from the ground, but in all cases not more than summer load line displacement, in t;

L_{BN} – design length of ship's bottom along the keel line, in m;

L_N – design length of bottom, in m, considering the bow (1) and stern (2) external structural strengthening of hull (refer to Fig. 3.13.1.2);

Δ_d – change of midship mean draft relative to level d_N corresponding to design displacement Δ_N**,** in m;

Ψ_0 – design trim angle of the ship, in deg. (positive nose-up trim);

Ψ_N – design seabed slope angle along the ship, in deg.;

Ψ_S – operating trim angle of the ship, in deg.;

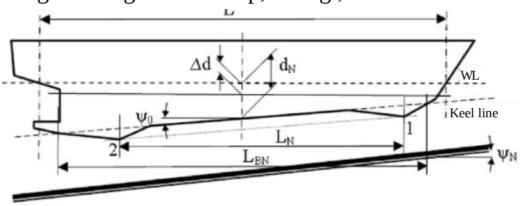


Fig. 3.13.1.2

Ψ_{ON} – ship trim angle due to grounding on the move, in deg.;

R_{ON} – initial bow response to ship grounding on the move, in kN;

$\mathbf{R_N^m}$ – static end (local) response for the ship, in kN;

$\mathbf{R_N^n}$ – static nominal (distributed) response for the ship, in kN;

M_N – ship hull bending moment considering the seabed response, in kN·m;

N_N – ship hull shear force considering the seabed response, in kN;

B_N – width of flat horizontal section of the bottom, in m;

β_K – deadrise angle, in deg.;

h_K – design height of external structural protection below the keel line, in m;

v_N – design forward speed of ship upon grounding, in knots;

h_N – design (allowable) wave height for **NAABSA** conditions, in m.

3.13.1.3 Hull shape.

3.13.1.3.1 It is recommended that the shape of bottom lines in hull cross sections shall be determined in accordance with Fig. 3.13.1.3.1. In the area of impact contact with seabed, it is recommended to reduce the width of the flat horizontal part of the bottom and to increase the deadrise angle.

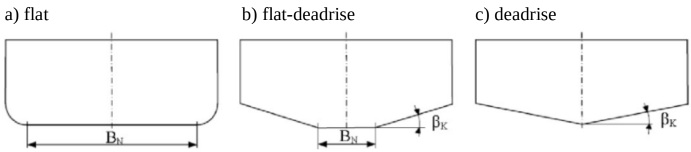
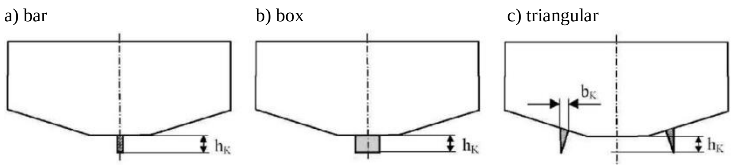


Fig. 3.13.1.3.1

3.13.1.3.2 It is recommended that in order to decrease the direct seabed impact on the hull shell plating and on the screw-rudder system of **NAABSA** ships, external structural protection (false keels, welded bars, etc.) shall be installed in the bottom area. Such structural protection can have various design (refer to Fig. 3.13.1.3.2) and, as a rule, shall go down below the keel line in this section by the value of h_K, in m, which is selected in course of design process.



b_K – false keel width in its junction with the hull

Fig. 3.13.1.3.2

3.13.1.4 Strengthened areas.

3.13.1.4.1 The bottom of **NAABSA** ships is divided into three strengthened areas over the hull length: fore area – *A,* midship area – *B* and aft area – *C*.

3.13.1.4.2 Distance L_A, in m, from the fore perpendicular to the aft boundary of the strengthened area *A* shall be determined (refer to Fig. 3.13.1.4.2) by the formula

$$L_A = 0{,}3L(1 + 0{,}175\psi_0) - 20h_k \geqslant 2L, \qquad (3.13.1.4.2\text{-}1)$$

where L_3 is the distance between point 3 and fore perpendicular, in m.

3.13.1.4.3 A distance L_c, in m, from the aft perpendicular to the forward boundary of the strengthened area *C* shall be determined (refer to Fig. 3.13.1.4.2) by the formula

$$L_A = 0{,}3L(1 + 0{,}175\psi_0) - 20h_k \geqslant 0{,}05L. \qquad (3.13.1.4.2\text{-}1)$$

If the engine room is located in the aft of the ship, such an engine room shall be attributed to the strengthened area *C*.

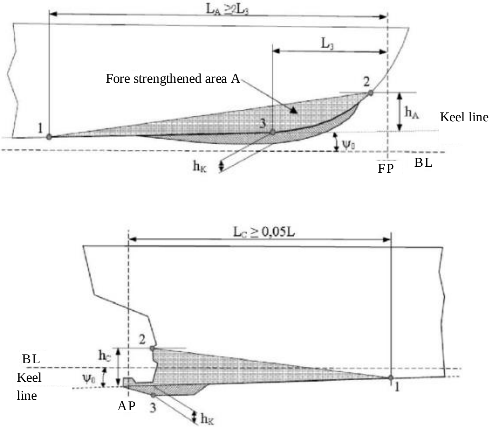


Fig. 3.13.1.4.2:
1 – point of distance from perpendicular; *2* – upper boundary;
3 – point to determine the height of external structural protection

3.13.1.4.4 The midship strengthened area *B* is located between the fore and the aft areas.

3.13.1.4.5 The upper boundary of the strengthened areas shall rise above the keel line (point *2* in Fig. 3.13.1.4.2) for at least, in m:

for the fore area $h_A = 0{,}1\psi_L - h_K$; (3.13.1.4.5-1)

for the aft area $h_C = 0{,}2L\psi_L/3 - h_K$, (3.13.1.4.5-2)

where ψ – design trim angle at rolling in the place of grounding, in rad; if no exact data is available, ψ can be determined by Formula (1.3.3.1-4) as for a ship operating in restricted area of navigation **R3**.

The rise h_B, in m, for the midship strengthened area shall be at least:

$h_B = (0{,}5B - B_K)\mathrm{tg}\theta - h_K$, but not bigger than h_A, (3.13.1.3.5-3)

where B_K – distance from CL to the nearest false keel side, in m;

h_{AN} – height to top of floors in case of curved lines and up to the lift point of bottom in case of simplified lines, in m;

θ – design heel angle at rolling in the place of grounding, in rad.

If no exact data is available θ is determined by Formula (1.3.3.1-5) as for a ship operating in restricted area of navigation **R3** at $\varphi_r = \varphi$.

Boundaries of the special hull strengthened areas are determined on the basis of the calculation results, as it is shown in Fig. 3.13.1.4.5

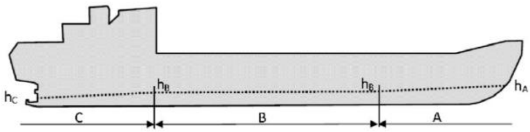


Fig. 3.13.1.4.5

3.13.2 Design requirements.

3.13.2.1 It is recommended that all the **NAABSA** ships shall have the double bottom. Ships with no double bottom or with only partially fitted double bottom require calculation of damaged stability for the following sizes of bottom damage, in m:

$l_D = L^{2/3}/3$ – in longitudinal direction;

$b_D = B/6$ – in transverse direction;

$h_D = B/20$ – in vertical direction.

For ships with the distinguishing mark **NAABSA2,** the double bottom is required to be fitted in the fore-strengthened area. For ships with the distinguishing mark **NAABSA3** the double bottom is required to be fitted extending along the entire length of the ship – from forepeak to afterpeak bulkheads.

Deviation from the above given requirements shall be a matter of a special examination by the Register.

3.13.2.2 Framing systems.

3.13.2.2.1 It is recommended that the bottoms of **NAABSA** ships shall have transverse framing system along the entire length with the flooring installed on each frame. For longitudinal framing system of bottom on ships with **NAABSA2** and **NAABSA3** marks, the flooring shall be installed at two frame spacing intervals.

3.13.2.2.2 A distance a_{BS}, in m, between bottom stringers, stringer and keel, as a rule, shall not exceed

$$a_{BS} = 1{,}4 + 2{,}5(L/100) - (L/100)^2. \qquad (3.13.2.2.2)$$

Besides this, the specified distance shall not exceed:

1,1 m – in area *A* for ships with the distinguishing mark **NAABSA2** and in areas *A* and *C* for ships with the distinguishing mark **NAABSA3**;

2,1 m – in area *B* for ships with the distinguishing mark **NAABSA3**.

3.13.2.2.3 For the upper deck of **NAABSA** ships over 50 m long, the longitudinal framing system in the midship hull area is recommended.

3.13.2.2.4 Web frames and/or double side diaphragms shall be installed at least 4 frame spacing apart.

3.13.2.2.5 Plane longitudinal and transverse bulkheads shall have vertical stiffeners as primary members. Corrugations of corrugated bulkheads shall be vertical.

3.13.2.3 External structural protection.

3.13.2.3.1 It is recommended that in order to decrease the direct seabed impact on the hull shell plating of **NAABSA** ships the bottom part of the ships shall be fitted with external structural protection – the false keels, which can have various design (refer to Fig. 3.13.1.3.2).

3.13.2.3.2 False keels shall be arranged in the plane of longitudinal bulkheads and longitudinal deep bottom framing system. It is permitted to install additional bottom stiffening in places, where the false keels shall be installed. Fastening of the false keels to the external shall plating shall comply with the applicable requirements of 2.2.5.3.

3.13.2.4 Framing beams.

3.13.2.4.1 If effective external structural protection of the hull is available in this area, the frame beams are designed in compliance with the general requirements of Sections 1 and 2. The effective external structural protection means such protection, which ensures decreasing seabed pressure to hull shell plating by at least 1,5 times.

3.13.2.4.2 In the impact load areas, if no external structural protection is available, frame beams shall be designed by limit state.

3.13.2.4.3 Webs of deep bottom framing – center girder, stringers and floorings in the areas of direct seabed impact on the plating shall be reinforced with vertical stiffeners, stability of which shall be ensured in worn-out state at the end of structure service life.

3.13.2.4.4 For the longitudinal framing system of bottom on ships with the distinguishing mark **NAABSA3,** the bilge brackets shall be placed at each frame. It is recommended to install lightened dock and bilge brackets between the frames (refer to Fig. 3.10.2.1.3-1).

3.13.2.5 Support sections of beams.

3.13.2.5.1 For designing framing beams by allowable stresses, the support sections and design spans shall be determined according to 1.6.3.1.

3.13.2.5.2 For designing framing beams by limit state, the support section shall be taken considering availability of brackets and arranged as follows:

at the end of brackets with a free edge stiffened with a face plate;

in the middle of bracket side with unstiffened free edge.

3.13.2.6 Beam connections.

3.13.2.6.1 Connections of beams shall comply with the requirements of 1.7.2.

3.13.2.6.2 For areas of impact loads on ships with the distinguishing marks **NAABSA2** and **NAABSA3,** it is not recommended to use beam connections with technological gaps.

3.13.2.7 Holes in bottom framing webs

3.13.2.7.1 Holes in bottom framing webs shall comply with the requirements specified in 2.3.5.2 and 2.4.2.7. For **NAABSA** ships, the number of holes (manholes) shall be minimum.

3.13.2.7.2 Holes in primary framing webs for bottom beams in the areas where the bottom contacts the seabed shall be compensated by installation of fixings similar to the intersections specified in Table 3.10.2.4.5. In the areas of impact loads, it is recommended to use fixings with edges welded to shell.

3.13.2.8 Special requirements.

3.13.2.8.1 It is recommended that in order to increase strength, durability and repairability of hull shell plating in areas of bottom contact with the ground external protective longitudinal welded members of semicircular or other solid cross section shall be used. Variants of hollow cross section (half pipes, L-profiles, bars, etc.) are permitted if they ensure watertight condition of the internal hollow space.

3.13.2.8.2 External welded elements in their ending places shall be gradually tapered by height and their ending places, as a rule, shall be located at the lines, where frame is welded to the shell plating.

3.13.3 Design loads.

3.13.3.1 The loads are divided into service (static) and extreme (impact) loads.

3.13.3.2 The service loads include:

.1 end (in the fore and aft areas) seabed responses, appearing in course of baring and emersion of the ship, when its keel line in displacement condition shall not be parallel to the seabed slope line;

.2 seabed pressure to the ship's bottom in partial or full baring conditions (the ship lies aground without motion);

.3 responses passed from the external structural protection (false keels) with regard to their location; the seabed loads for the false keels themselves hall be considered as the extreme ones.

3.13.3.3 The extreme loads shall include all the impact loads related to motion and rolling of the ship at the moment of contact with the seabed.

3.13.3.4 In any case, the extreme loads shall not be taken lower, than the service ones.

3.13.3.5 Calculations for baring conditions are required for cases of weight load distribution along the length of a ship shall, which are practically possible in operation, with regard to irregular distribution of buoyancy forces from the ground, as well as from water on different stages of baring.

3.13.3.6 If no calculations of ship baring and emersion are available, static end response of the ground $\mathbf{R_N^m}$ to ship hull, in kN, can be evaluated by the following formula for **NAABSA1** ships $R_{0N} = 0$ and $\psi_{0N} = 0$ shall be taken.

$$R_N^m = g\Delta_N\left[\frac{\mathrm{tg}(\psi_N - \psi_0 - \psi_{0N})}{6}\,\frac{L}{d_N}\right] + R_{0N}, \qquad (3.13.3.6)$$

In any case, for full hull baring conditions the value of static end response of the ground $\mathbf{R_N^m}$, in kN, shall be at least:

$R_N^m = 3g\Delta_N/12$ – for the ships with the distinguishing mark **NAABSA1**;
$\mathbf{R_N^m} = 4g\Delta_N/12$ – for the ships with the distinguishing mark **NAABSA2**;
$\mathbf{R_N^m} = 5g\Delta_N/12$ – for the ships with the distinguishing mark **NAABSA3**.

3.13.3.7 If the ship is bared with the keel line in parallel to the ground, the value of static response $\mathbf{R_N^m}$, in kN, is determined by the formulas:

$$R_N^m = g\Delta_N \frac{\Delta d}{d_N}\frac{\alpha}{C_b}$$ – for partial baring conditions, (3.13.3.7-1)

$$R_N^m = g\Delta_N$$ – for full baring conditions, (3.13.3.7-2)

where α – waterplane area coefficient for summer load waterline.

3.13.3.8 Design static load Q_{0s}, in kN, from the ground to check transverse strength **NAABSA** ship hull compartment is determined by Formula

$$Q_{0s} = k_\varphi R_N^n \frac{L_{0S}}{C_{BN}}, \qquad (3.13.3.8)$$

where k_φ = 1,5 with no design-based justifications;
L_{0s} – length of ship compartment/hold, in m.

For the recommended diagrams of design load application to ship compartments are specified in Fig. 3.13.3.8.

3.13.3.9 Design local pressures p_i, in kPa, on the structural members immediately perceiving the seabed are determined by the formula

$$p_i = 10d_N(1 + 4/\sqrt{A_i}), \qquad (3.13.3.9)$$

where A_i – calculated area of the member zone, in m^2.

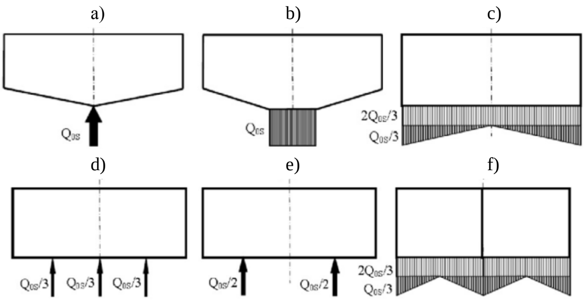


Fig. 3.13.3.8:
a – deadrise; *b* – flat-deadrise; *c* – flat; *d* – with 3 false keels;
e – with 2 false keels; *f* – flat with one longitudinal bulkhead at CL

3.13.3.10 Design nominal ship pressure to the ground shall not exceed design resistance of ground, R_0, in kPa:

$$R_0 > 10\Delta d. \qquad (3.13.3.10\text{-}1)$$

For **NAABSA** ships,which are loaded/unloaded when grounded in safe mode with use of heavy wheeled and trackedvehicles, design ground resistance shall be at least

$$R_0 = 100, \text{ kPa}. \qquad (3.13.3.10\text{-}2)$$

The required total area of contact with the seabed in case of full ship hull baring $A_N^{\min}$, in m^2, shall be at least:

$$A_N^{\min} = g\Delta_N/R_0. \qquad (3.13.3.10\text{-}3)$$

3.13.3.11 Impact loads of the seabed for ships with the distinguishing marks **NAABSA2** and **NAABSA3** shall not be less than the limits, specified in 3.13.3.6.

3.13.4 Bending moments and shear forces for hull.

3.13.4.1 Bending moments and shear forces for hull of a ship, which is periodically grounded in normal operation, shall be determined for ships with the distinguishing mark **NAABSA1** and length over 50 m and for ships with the distinguishing mark **NAABSA2** and **NAABSA3** irrespective of the ship's length.

3.13.4.2 The values of maximum bending moments and shear forces can be determined by approximation formulas given below.

3.13.4.2.1 For full hull baring when aground and hull hogging of **NAABSA** ships of all levels:

M_N = 0,315$\Delta_N L$, in kN·m; (3.13.4.2.1-1)

N_N = –1,03Δ_N, in kN. (3.13.4.2.1-2)

For partial hull baring of **NAABSA1** ships, the obtained values can be reduced by replacing A_N with the nominal response of the ground:

$R_N^n = \Delta_N(\Delta d/d_N)(\alpha/C_b)$, but not more than twice

3.13.4.2.2 In case of action of end force and hull sagging of ships with the distinguishing mark **NAABSA1**:

M_N = –0,36$\Delta_N L$, in kN·m; (3.13.4.2.2-1)

N_N = 2,4Δ_N, in kN. (3.13.4.2.2-2)

3.13.4.2.3 In case of action of end force, including bow impact of ships with the distinguishing mark **NAABSA2**:

M_N = –0,629$\Delta_N L$, in kN·m; (3.13.4.2.3-1)

N_N = 3,27Δ_N, in kN. (3.13.4.2.3-2)

3.13.4.2.4 In case of action of end force, including bow or stern impact of ships with the distinguishing mark **NAABSA3**:

M_N = –0,921$\Delta_N L$, kN·m; (3.13.4.2.4-1)

N_N = 4,09Δ_N, kN. (3.13.4.2.4-2)

3.13.4.2.5 Formulas specified in 3.13.4.2.1–3.13.4.2.4 determine maximum values of bending moments in the midship area of the hull and shear forces on the bow and stern. In case of sagging due to end forces, including impacts forces, the obtained values shall be summed up algebraically with design bending moments for the ship in still water.

3.13.5 Overall strength check conditions.

3.13.5.1 For **NAABSA** ships, it is required to perform a check of the residual (actual) ultimate hull section modulus, which shall not be less than the permissible residual ultimate section modulus of hull cross section.

3.13.5.2 The permissible residual ultimate section modulus of hull cross section $[W_{LM(bot)}]_i$, in cm^3, for deck/bottom is determined by the formula:

$$[W_{LM(bot)}]_i = 1{,}1\,\frac{|0{,}92M_{Ni} + M_{SW}|}{R_{eH}}10^3, \qquad (3.13.5.2)$$

where M_{Ni}, – design bending moment, in kN·m, according to 3.13.4;
i – level index of **NAABSA** category;
R_{eH} – upper yield stress of deck (bottom) material, in MPa.

3.13.5.3 The residual (actual) ultimate section modulus of hull cross section of a ship in operation shall be determined on the basis of field measurement data for residual thickness and residual deformations of hull members.

At ship design and modernization, stage the ultimate section modulus of hull cross section by the end of service life can be approximately determined with regard to the following assumptions:

.1 wear of all hull members is 30%;

.2 deformations of bottom structures breadthwise in design section are 50%;

.3 the ship hull is in sagged condition from the end response of the ground;

.4 compressed flexible braces of the deck and upper part of sides are not allowed;

.5 tension braces of the bottom with deformations are not allowed.

3.13.5.4 The residual ultimate section modulus of hull cross sections of a ship according to 3.13.5.3 shall be additionally not less than the value, determined by Formula

$$W_{min} = C_W B L^2 (C_b + 0{,}7)\eta. \qquad (3.13.5.4)$$

Restrictions for area of navigation for ships with the distinguishing marks **NAABSA2** and **NAABSA3** shall not be considered in this case.

3.13.6 Dimensions of structural members.

3.13.6.1 Shell Plating.

3.13.6.1.1 Thickness of the bottom and bilge plating s, in mm, in the areas of direct seabed impact, where structural protection is not available shall be at least:

$$s = 15{,}8ak_{\alpha}\sqrt{\frac{k_p p}{k_{\sigma}R_{eH}}}(m_0 - 0{,}05)^{-1}, \qquad (3.13.6.1.1)$$

where a – dimension of the smaller side of the panel (primary frame spacing), in m;
b – dimension of the larger side of the panel, in m;
$\alpha = a/b$ – ratio of panel sides;
$k\alpha = \left(\frac{1-\alpha+\pi\alpha/6}{1-\alpha+\pi\alpha/2}\right)$ – ratio coefficient of panel sides;
k_p – safety factor for panels equal to 1,5;
p – design pressure of seabed, in kPa, according to 3.13.3.9 at $A_t = a \times b$;
$k_{\alpha} = 0{,}95 – 0{,}42L/100$ – for transversal framing in the intermediate hull area and equal to 0,9 – in other cases;
R_{eH} – upper yield stress, in MPa;
m_0 – the allowed residual thickness coefficient for plating in operation equal to 0,80 for areas with special hull strengthened areas.
If such hull area is fitted with external structural protection, the thickness of bottom and bilge plating in this area can be determined by Formula (3.13.6.1.1) at $k_p = 1$ and $m_0 = 0{,}7$.

3.13.6.1.2 In any case, the thickness of the bottom and bilge plating shall comply with the requirement of 2.2.4.8 to the minimum thicknesses.

3.13.6.1.3 The ships with the distinguishing marks **NAABSA2** and **NAABSA3** in the area of impact loads and with no external structural protection shall have the thickness of the bottom and bilge plating of at least

$$s = \frac{k_p pab}{\pi f_0 R_{eH}}(m_0 - 0{,}05)^{-1}, \qquad (3.13.6.1.3)$$

where $f_0 = 0{,}06a$ is the residual buckling allowed by the inspection.

3.13.6.1.4 The thickness of bottom and bilge plating for ships with the distinguishing mark **NAABSA1** instead of calculating by Formula (3.13.6.1.1) can be calculated by Formula (1.6.4.4) at $m = 15{,}8$ and $\sigma_n = R_{eH}$.

3.13.6.2 Primary member parameters.

3.13.6.2.1 The ultimate section modulus W_0, in cm^3, of the beam cross section in the areas of direct seabed impact on the plating shall be no less than the value determined by Formula

$$W_0 = \frac{1000k_p pal^2}{mk_\sigma R_{eH}} k_\alpha k_k (m_0 - 0{,}05)^{-1}, \qquad (3.13.6.2.1)$$

where k_p – safety factor for extreme beam loads, equal to 1,35;
p – design pressure of seabed, in kPa, determined according to 3.13.3.9 at A_i – $2a$ x 1;
a – distance (spacing) between primary members, in m;
l – span length, in m;
$\alpha = a/1$ – spacing to span length ratio;
$k_\alpha = 1 - \alpha^2/2 + \alpha^3/8$ – coefficient;
k_k = 0,914 – load distribution coefficient (concentration around the supports);
m_0 = 0,80 – permissible residual section modulus coefficient;
m = 12 – bending moment coefficient;
k_σ = 0,95–0,42L/100 – for longitudinal beams of the midship area and 0,9 – for the others;
R_{eH} – upper yield stress, in MPa.

If such hull area is fitted with external structural protection, the ultimate section modulus of the beams in this area can be determined by Formula (3.13.6.2.1) at k_p = 1 and m_0 = 0,7.

3.13.6.2.2 The actual ultimate section modulus of beam section can be determined according to 3.10.4.2.6.

3.13.6.2.3 For the ships with the distinguishing mark **NAABSA1** requirements for the minimal section modulus instead of Formula (3.13.6.2.1) can be determined by Formula (1.6.4.1) at m = 12 and $\sigma_n = R_{eH}$.

3.13.6.2.4 In the areas of direct perceiving of seabed loads the area of web cross section of primary bottom member f_c, in cm^2, shall not be less than the value determined by formula

$$f_c = \frac{5k_p pal(1 - \alpha/2)}{0{,}57k_\sigma R_{eH}} (m_0 - 0{,}05)^{-1}. \qquad (3.13.6.2.4)$$

If external structural protection is available in this area, calculation shall be done with at k_p = 1 and m_0 = 0,7.

3.13.6.2.5 The actual area of beam web cross section can be determined in accordance with 3.10.4.2.5.

3.13.6.2.6 For ships with the distinguishing mark **NAABSA1** the requirements for web cross section area of primary members instead of Formula (3.13.6.2.4) can be determined by Formula (1.6.4.3) at $\tau_n = 0{,}57R_{eH}$.

3.13.6.3 Deep member parameters.

3.13.6.3.1 In the areas of direct seabed impact to the bottom shell plating the ultimate section modulus W_0, in cm^3, of a single span deep member cross section shall be determined by Formula (3.13.6.2.1), and the web cross section area of a deep member shall be determined by Formula (3.13.6.2.4) with regard to the following:

k_p = 1,15 – safety factor for extreme loads;

P – the lower design seabed pressure determined by 3.13.3.9 at $A_i = 2al$ (back pressure of cargo shall not be taken in consideration);

a – distance between deep members, in m;

l – span length, in m.

When determining the actual area web cross section area of a deep member, the area of unstiffened notches shall be deducted (net cross section).

3.13.6.3.2 As a rule, bottom deep members (floorings, stringers, center girder) do not refer to single span beams, and provisions of 3.13.6.3.1 do not apply to the mentioned beams.

3.13.6.3.3 Strength of deep framing which does not satisfy the provisions of 3.13.6.3.1 shall be checked on the basis of bottom grillage calculations using beam model. If pillars and struts are available, strength of the grillage shall be checked as a part of the entire hull compartment using beam model. Design static loads on grillage/compartment are determined according to 3.13.3.8. Cross sections with the highest reduced stresses (by von Mises criterion) are determined on the basis of calculation results. In case of field dimensions of the members this stresses, in MPa, shall not exceed:

$(0{,}95–0{,}42L/100)0{,}75R_{eH}$ – for longitudinal framing in area B;

$0{,}68R_{eH}$ – for other structures.

3.13.6.3.4 Strength calculation in 3.13.6.3.3 can be done with consideration of the effect of brackets.

3.13.6.3.5 Compression loads to pillars and struts shall be determined directly by calculations using beam model. Dimensions of the cross sections in this case shall satisfy 2.9. Besides the strength, these members shall satisfy requirements for stability in compression. It is recommended that the struts orientation shall ensure their tensioning in case of hull contact with the seabed.

3.13.6.4 Plate structures.

3.13.6.4.1 Thickness of plate structures – webs of floors, bottom stringers, center girder and plates of transverse and longitudinal bulkheads adjoining the bottom and bilge shell, which participate in accommodating the seabed pressure in the areas, where the hull has no external structural protection, shall satisfy 2.4.4.3.2. In the areas with external structural protection, the thickness shall satisfy 2.4.4.9.

3.13.6.4.2 Plate structures shall be reinforced with stiffeners. The distance between stiffeners, as a rule, shall not exceed the normal spacing, regulated by 1.1.3, in this hull area.

3.13.6.4.3 It is recommended to check plate structures in compliance with 3.10.4.9. Design pressures, in kPa, in this case shall be no less than those, calculated by Formula

$$p_i = 10 d_N (1 + 4/\sqrt{A_i}) k_p, \qquad (3.13.6.4.3)$$

where $A = a^2/2$, in m^2;

a – distance between the stiffeners or the spacing, whichever is less;

k_p – safety factor, taken as 1,5.

3.13.6.5 Stems.

3.13.6.5.1 It is recommended that the lower part of the stem on **NAABSA** ships at the transition area to keel shall protrude beyond the shell surface or shall be made as an outboard bar. The structure shall comply with the requirements of 2.10.

3.13.6.5.2 Stem strength is recommended to be checked as for a curvilinear beam of variable section. The stem is considered to rest on decks, platforms and transverse bulkheads. Stem design load shall be not less than the response of the seabed according to 3.13.3.6 distributed as a triangle along the length, which shall not exceed L_3 according to 3.13.1.3.2. Allowable stresses coefficient shall be taken equal to k_σ = 0,68.

3.13.6.5.3 The lower part of the sternframe on **NAABSA** ships at the transition area to keel shall protrude beyond the shell surface. The sternframe structure shall comply with the requirements of 2.10. The bottom part of the sternframe ahead of propeller post is recommended to be fixed at least to two floorings. It is recommended to arrange the fixing by that sole piece of the sternframe resting upon the propeller post. Starting from the propeller post it is recommended to lift the sternframe in the stern direction at angle of 6° for ships with the distinguishing mark **NAABSA1**, 8° for ships with the distinguishing mark **NAABSA2** and at least 10° for ships with the distinguishing mark **NAABSA3**.

3.13.6.5.4 Strength of sternframe members shall be checked in compliance with 2.10.4.2.6 with the allowable stresses coefficient k_σ = 0,68. The design load shall be taken in compliance with 3.13.3.6 with uniform distribution. With regard to the sternframe's grade to the stern, it is allowed to use a triangular by length load diagram.

3.13.6.6 External structural protection.

3.13.6.6.1 External structural protection of ships operating in NAABSA conditions can include false keels of different configuration of cross-section shapes and in different locations under the bottom (refer to Fig. 3.13.6.6.1). Decisions on structure and location of false keels shall be taken with regard to decreasing the load on hull from contact with seabed. Along the breadth of the bottom, the false keels are recommended to be placed by the boards, near the keel as well as in the places of longitudinal bulkheads and bottom stringers.

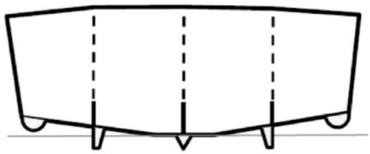


Fig. 3.13.6.6.1

3.13.6.6.2 False keels shall be fastened to external shell plating by means of intermediate members, i.e. flat bars with regard to the practice for fastening of side fenders and bilge keels of ships (for example, according to 2.2.5.3). Flat bars continuous in length and with fair end shape shall be welded to the shell plating with a continuous weld. False keels shall be welded to the flat bars with an all-round continuous fillet weld as well. False keels shall terminate in the stiffened areas of shell plating and shall be gradually tapered at ends in height and width. Welded connection of the false keel in this case shall be relatively weaker than welded connection between the flat bar and the bottom shell plating.

3.13.6.6.3 Design vertical pressure p, in kPa, to false keels shall be at least

$$p = 10d_N(1+4/b_k)k_p, \qquad (3.13.6.6.3)$$

where b_k – false keel width in the place of junction with the hull;

k_p – safety factor, equal to 1 for elastic behavior conditions and equal to 1,5 extreme loads and limit conditions.

3.13.6.6.4 Ultimate loads, which cause false keel damages, shall not induce stresses bigger than 0,8 of the yield stress in welded connections of the flat bars to the shell plating.

3.13.6.6.5 Special attention in the false keel design shall be given to its repairability. As a rule, false keels together with the other strengthening elements shall accommodate at least half of the design load in this hull area.

3.13.6.6.6 Welded flat bars of segment or other cross section can be considered as the additional external strengthening. Such strengthening is usually fitted in order to reduce the rate of shell plating wear.

PART III. EQUIPMENT, ARRANGEMENTS AND OUTFIT

5.7 SPECIAL ARRANGEMENTS ON SHIPS

The Chapter is supplemented with item 5.7.12 reading as follows:

"**5.7.12** It is recommended that ships which are periodically grounded in normal operation and which have the distinguishing marks **NAABSA2** and **NAABSA3**, shall have a special stern anchor and tug arrangement equipment for creation of a force additional to propeller thrust for hauling the ship off the ground, if such arrangements are not available in the places for grounding. If such arrangements are available in the places for grounding, it is then recommended that ships with the distinguishing marks **NAABSA2** and **NAABSA3** shall have arrangements (cable fastening) to ensure that the hauling force is taken up safely."

8.5 EXITS, DOORS, CORRIDORS, STAIRWAYS AND VERTICAL LADDERS

The Chapter is supplemented with item 8.5.7 reading as follows:

"**8.5.7** It is recommended that ships which are periodically grounded in normal operation in **NAABSA** conditions and which do not have a bow ramp shall have stairways or vertical ladders, which shall ensure safe transition of the crew from the upper deck to the ground and back."

PART IV. STABILITY

3. ADDITIONAL REQUIREMENTS TO STABILITY

The Section is supplemented with item 3.13 reading as follows:

"**3.13 Ships which are periodically grounded in normal operation.**

3.13.1 Load distribution on ship while touching the seabed and during emersion in **NAABSA1** conditions shall as far as feasible ensure that the bottom plane is in parallel to the seabed plane in this place.

3.13.2 When rounding with motion in **NAABSA2** or **NAABSA3** conditions the nose-up trim angle of a ship shall be as close as possible to the seabed slope angle.

3.13.3 If conditions don't allow estimating the drafts visually immediately before grounding, the drafts shall be calculated on the basis of the values, recorded to the ship's log book at the last port of departure, with regard to consumption of stores and ballast operations during the voyage.

3.13.4 During cargo handling operations on a ship lying aground, if no reliable data on the exact amount of the notified cargo is available, the stowage rate shall be taken at its maximum value in order not to exceed the load mark.

3.13.5 Before finishing cargo handling operations on a ship lying aground stability calculations shall be performed with regard to the fact, that if no exact data on height of the cargo center of gravity is available, the height of the gravity center is accepted at the top limit level."

Table 1.3.3

RISK ASSESSMENT METHODOLOGY FOR EVALUATION OF LOSS OF STABILITY BY A SHIP UNDER HAZARDOUS DYNAMIC PHENOMENA IN ROLLING SEAS

Assessment of risk assessment for loss of stability by a ship under hazardous dynamic phenomena in rolling seas shall be performed with the use of criteria, which provide for wind and wave conditions, ship loading and its position at wave surface.

Criteria have been developed with regard to research works of Russian authors and via harmonization with proposals of the foreign classification societies, presented in the materials of the International Maritime Organization (IMO).

1. CRITERION FOR LOSS OF STABILITY IN PARAMETRIC ROLLING CONDITIONS

1.1 APPLICATION

1.1.1 Requirements of the present section apply to all ships with the length of $L_1 \geq 24$ m.

1.1.2 For each variant of loading conditions the ship with stability parameters:

.1 complying with the requirement of 1.2 shall be considered as not losing stability under parametric rolling;

.2 not complying with the requirement of 1.2 shall be checked for compliance with 1.3.

1.1.3 The ship with the stability parameters not complying with the requirements of 1.1.2 and 1.1.3 requires introduction of operating limitations for each variant of loading conditions, derived from calculations in compliance with 1.1.3.

1.2 CRITERION FOR LOSS OF STABILITY IN PARAMETRIC ROLLING OF THE 1ST LEVEL

1.2.1. The ship shall be considered as not loosing stability in parametric rolling if

$$\frac{\Delta h}{h} \leqslant R_{PR},$$

where R_{PR} = 1,87 if the ship has sharp bilges,
in other cases:

$$R_{PR} = 0{,}17 + 0{,}425\left(\frac{100A_k}{L_1 B}\right) \quad \text{at} \quad C_m > 0{,}96;$$

$$R_{PR} = 0{,}1R_{PR} = 0{,}17 + (10{,}625 \times C_m - 9{,}775)\left(\frac{100A_k}{L_1 B}\right) \quad \text{at} \quad 0{,}94 < C_m > 0{,}96;$$

$$R_{PR} = 0{,}17 + 0{,}2125\left(\frac{100A_k}{L_1 B}\right) \quad \text{at} \quad C_m > 0{,}94;$$

and

$$\left(\frac{100A_k}{L_1 B}\right) \quad \text{shall not exceed 4;}$$

h – metacentric height for loading in calm water with regard to correction for free liquid surfaces, in m;
Δh – value of metacentric height variation, in m, calculated under one of the following conditions: passing of a longitudinal wave along the ship hull in compliance with 1.2.3; by Formula (1.2.2);
C_m – block coefficient of amidships frame with full load in calm water;
A_k – total area of bilge keels projection (other protruding parts are not available), in m^2;
L_1 – length as defined in the Load Line Rules for Sea-Going Ships, in m;
B – molded breadth of a vessel, in m.

1.2.2. Δh value specified in 1.2.1 can be determined by the formula

$$\Delta h = \frac{I_H - I_L}{2V} \quad \text{only at} \quad \frac{V_D - V}{A_w(D-d)} \geqslant 1{,}0, \qquad (1.2.2)$$

where D – molded height of freeboard to the upper deck, in m;
V_D – volume displacement to waterline, which corresponds to the molded height of freeboard at zero trim angle, in m^3;

V – volume displacement correspondent to the examined loading conditions, in m^3;
A_w – waterline area at the draught of d, in m^2;
d – drought amidships correspondent to the examined loading conditions, in m;

Table 1.3.3

$$\delta d_H = \min\left(D - d\ \frac{L_1 S_W}{2}\right)$$, m;

$$\delta d_L = \min\left(D - 0{,}25 d_{full}\ \frac{L_1 S_W}{2}\right)$$, m; d–0,25d_{full} can't be below the zero;

d_H = d+δd_H, m
d_L = d–δd_L, m
S_W = 0,0167
I_H – moment of inertia of waterline area at draught and at zero trim angle, in m^4,
I_L – moment of inertia of waterline area at draught and at zero trim angle, in m^4;
d_{full} – ship's draft with full load at the beginning of voyage, in m.

1.2.3. Δh value specified in 1.2.1 can be defined as half of the difference between the maximum and the minimum values of metacentric height, calculated for this ship with regard to correction for free liquid surfaces in the examined loading conditions with regard to balance adjustment for sagging and trim on series of waves with the following properties:

wave length $\lambda = L_1$,

weight height $h = L_1 S_W$, where S_W = 0,0167;

wave crest is located amidships and at the points of 0,1L_1, 0,2L_1, 0,3L_1, 0,4 L_1 and 0,5L_1 ahead and 0,1L_1, 0,2L_1, 0,3L_1 и 0,4L_1 astern of it.

1.3 CRITERION FOR LOSS OF STABILITY IN PARAMETRIC ROLLING OF THE 2ND LEVEL

1.3.1. The ship shall be considered as not loosing stability in parametric rolling if one of the following requirements is fulfilled:

.1C1 value, calculated in compliance with 1.3.2, is less than R_{PR0},

or

.2C1 value is higher than R_{PR0}, while C2 value, calculated in compliance with 1.3.3, is less than R_{PR1},

where

R_{PR0} = 0,06;

R_{PR1} = 0,06.

1.3.2. C1 value is calculated as a weighted mean value for a set of sea states, specified in 1.3.2.3:

$$C_1 = \sum_{i=1}^{N} W_i C_i\ ,$$

where W_i – weight coefficient for the corresponding sea state, specified in Table 1.3.2;
C_i = 0 if either condition for variation of metacentric height h in rolling seas, specified in 1.3.2.1, or condition for speed of the ship in rolling seas, specified in 1.3.2.2, is fulfilled;
C_i = 1 in other cases;
N – number of examined sea states from those, given in Table 1.3.2.

1.3.2.1. Condition of metacentric height h variation in rolling seas is fulfilled, if the following inequalities are fulfilled for each wave, specified in 1.3.2.3

$$h(H_i,\ \lambda_i) > 0\ \&\ \frac{\Delta h(h_i,\ \lambda_i)}{h(H_i,\ \lambda_i)} < R_{PR},$$

where R_{PR} is determined in 1.2.1;

$\Delta h(H_i, \lambda_i)$ – half of the difference between the maximum and the minimum values of metacentric height, calculated for this ship, in m, with regard to correction for free liquid surfaces in the examined loading conditions with regard to balance adjustment of the ship for sagging and trim on series of waves characterized by H_i and λ_i;

$h(H_i, \lambda_i)$ – mean value of metacentric height, calculated for this ship, in m, with regard to correction for free liquid surfaces in the examined loading conditions with regard to balance adjustment for sagging and trim on series of waves characterized by H_i and λ_i parameters;

H_i – wave height, in m, specified in 1.3.2.3;

λ_i – wave length, in m, specified in 1.3.2.3.

1.3.2.2. Condition for ship speed in rolling seas is fulfilled, if the following inequality is fulfilled for each wave, specified in 1.3.2.3

$$V_{PR_i} > V_S,$$

Where Vs – operating speed, m/s;

V_{PRi}, – check speed of the ship, correspondent to parametric resonance conditions at $h(H_i, \lambda_i) > 0$:

$$V_{PR_i} = \left|\frac{2\lambda_i}{T\phi}\sqrt{\frac{h(H_i, \lambda_i)}{h}} - \sqrt{g\,\frac{\lambda_i}{2\pi}}\right|;$$

T_φ – natural rolling period of the ship in calm water, in s;

h – metacentric height in calm water, in m;

$h(H_i, \lambda_i)$ – is determined in compliance with 1.3.2.1, in m;

λ_i – wave length, specified in 1.3.2.3, in m;

g – gravity acceleration, equal to 9,81 m/s^2;

$|\ |$ – absolute value (modulus).

Table 1.3.3

1.3.2.3. Specific sea states for assessment of compliance with the requirements of 1.3.2.1 and 1.3.2.2 refer to Table 1.3.2, which contains values of W_i, H_i, λ_i, determined in compliance with 1.3.2 and 1.3.2.1.

Table 1.3.2

Sea state cases for assessment of stability loss risk for a ship in parametric rolling conditions

# sea state	Weight coefficient W_i	Wave length h_i, in m	Wave height H_i, in m
1	0,000013	22,574	0,350
2	0,001654	37,316	0,495
3	0,020912	55,743	0,857
4	0,092799	77,857	1,295
5	0,199218	103,655	1,732
6	0,248788	133,139	2,205
7	0,208699	166,309	2,697
8	0,128984	203,164	3,176
9	0,062446	243,705	3,625
10	0,024790	287,931	4,040
11	0,008367	335,843	4,421
12	0,002473	387,440	4,769
13	0,000658	442,723	5,097
14	0,000158	501,691	5,370
15	0,000034	564,345	5,621
16	0,000007	630,684	5,950

1.3.2.4. For calculation purposes and in 1.3.2.1 the midships shall be at the wave crest and in points $0{,}1\lambda_i$, $0{,}2\lambda_i$, $0{,}3\lambda_i$, $0{,}4\lambda_i$ and $0{,}5\lambda_i$ ahead and $0{,}1\lambda_i$, $0{,}2\lambda_i$, $0{,}3\lambda_i$ and $0{,}4\lambda_i$ astern of it.

1.3.3. C2 value is calculated as a mean of $C2(Fn_i, \beta_i)$, either of which is a weighted mean value for a set of waves, specified in 1.3.4.2, for each given set of Froude numbers and sea directions:

$$C2 = \left[\sum_{i=1}^{3} C2(Fn_i,\ \beta_h) + C2(0,\ \beta_h) + \sum_{i=1}^{3} C2(Fn_i,\ \beta_h)\right]/7,$$

where $C2(Fn_i, \beta_h) = C2(Fn, \beta)$, calculated in compliance with 1.3.3.1 for the ship moving in head seas with the speed of V_i;

$C2(Fn_i, \beta_h) = C2(Fn, \beta)$, calculated in compliance with 1.3.3.1 or the ship moving in following seas with the speed of V_i;

$Fn_i =$ $V_i/\sqrt{Lg}$ Froude number, correspondent to the speed of the ship V_i,

$V_i =$ $V_S K_i$ speed of the ship, in m/s, for corresponding sea direction;

V_S – operating speed of the ship, m/s;

g – gravity acceleration, equal to 9,81 m/s^2;

K_i – from Table 1.3.3;

L_1 – length, in m, in compliance with 1.2.1.

Table 1.3.3

K_i coefficient depending on sea direction

i	K_i	Corresponding sea direction
1	1,0	Head or following seas at V_S
2	0,866	Seas at 30° to CL at V_S
3	0,50	Seas at 60° to CL at V_S

1.3.3.1 The value is calculated as a weighted mean value for a set of sea states, specified in 1.3.4.2, for the given Froude number and sea direction:

$$C2(Fn,\ \beta) = \sum_{i=1}^{N} W_i C_i,$$

where W_i – weight coefficient for the corresponding sea state, specified in 1.3.4.2;

C_i = 1, if the maximum rolling angle, calculated in compliance with 1.3.4, exceeds 25°;

C_i = 0 in other cases;

N – the total number of sea states, for which the maximum rolling angle is calculated for combination of the ship's speed and course.

1.3.4 The maximum rolling amplitude in head and following seas is calculated in compliance with 1.3.4.1 for each speed V_i, determined in 1.3.3.

Calculation of ship's stability in rolling seas for each case shall imply its balance adjustment for sagging and trim on series of waves with the following properties:

wave length $\lambda = L_1$,

wave height $h_j = 0{,}01jL_1$, where $j = 0{,}1, \ldots, 10$.

The maximum rolling amplitude is calculated for each wave height.

The significant wave height and the corresponding value in compliance with 1.3.4.2 are determined for each wave height, for which $Cj = 1$ according to 1.3.3.1.

1.3.4.1 Calculation of the maximum rolling amplitude shall be done by equation of independent rolling with the following components:

inertial term, which provides for the added moment of inertia for rolling in calm water;

linear and nonlinear damping moment for rolling in calm water;

linear and nonlinear righting moment for rolling in calm water;

stability variations in rolling seas due to righting moment variations in rolling conditions.

Calculation of rolling amplitude shall be performed by the method, which is approved by RS.

1.3.4.2 For each case, specified in 1.3.4.2, W_j shall be taken from Table 1.3.2 or a similar data table for the sea states, which correspond to requirements of the Administration. Every cell of the table corresponds to the mean wave period between the zero points T_z and the characteristic wave height H_s, and corresponds to the significant wave height by using of a particular procedure. The maximum rolling amplitude, correspondent to the significant wave height H_r shall be determined by the method of linear interpolation of the maximum rolling amplitudes, correspondent to the wave heights h_j, received in 1.3.4.1.

Table 1.3.4.2

Frequency of sea state cases per 100 000 observations for assessment of the ship's dynamic response during parametric rolling

H_s, m	T_z, s – mean wave period between the zero points															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
0,5	1,3	133,7	865,6	1186,0	634,2	634,2	36,9	5,6	0,7	0,1	0,0	0,0	0,0	0,0	0,0	0,0
1,5	0,0	29,3	986,0	4976,0	7738,0	7738,0	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0,0	0,0	0,0
2,5	0,0	2,2	197,5	2158,8	6230,0	6230,0	4860,4	2066,0	644,5	160,2	33,7	6,3	1,1	0,2	0,0	0,0
3,5	0,0	0,2	34,9	695,5	3226,5	3226,5	5099,1	2838,0	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0,0
4,5	0,0	0,0	6,0	196,1	1354,3	1354,3	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0,0
5,5	0,0	0,0	1,0	51,0	498,4	498,4	2372,7	2008,3	1126,0	463,6	150,9	41,0	9,7	2,1	0,4	0,1
6,5	0,0	0,0	0,2	12,6	167,0	167,0	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1
7,5	0,0	0,0	0,0	3,0	52,1	52,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0,1
8,5	0,0	0,0	0,0	0,7	15,4	15,4	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1
9,5	0,0	0,0	0,0	0,2	4,3	4,3	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1
10,5	0,0	0,0	0,0	0,0	1,2	1,2	37,9	67,5	71,7	51,5	27,3	11,4	4,0	1,2	0,3	0,1
11,5	0,0	0,0	0,0	0,0	0,3	0,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,1
12,5	0,0	0,0	0,0	0,0	0,1	0,1	4,4	9,9	12,8	11,0	6,8	3,3	1,3	0,4	0,1	0,0
13,5	0,0	0,0	0,0	0,0	0,0	0,0	1,4	3,5	5,0	4,6	3,1	1,6	0,7	0,2	0,1	0,0
14,5	0,0	0,0	0,0	0,0	0,0	0,0	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0,0	0,0
15,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0,0	0,0
16,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0

2. CRITERIA FOR LOSS OF STABILITY IN STATIC WAVE RIDING CONDITIONS

2.1 APPLICATION

2.1.1. Requirements of this Section apply to all ships with the length of $L_1 \geq$ 24 m and with Froude number F_n correspondent to the operating speed, exceeding 0,24.

For the purposes of this section shall be determined by the formula

$$F_n = \frac{V_S}{\sqrt{gL_1}} \ ,$$

where V_s – operating speed, m/s;
L_1 – length as defined in the Load Line Rules for Sea-Going Ships;
g – gravity acceleration, equal to 9,81 m/s^2.

2.1.2. For each variant of loading conditions the ship with stability parameters:

.1 complying with the requirement, specified in 2.2, shall be considered invulnerable to

complete loss of stability;

.2 not complying with the requirement, specified in 2.2, shall be checked in compliance with 2.3.

2.1.3. The ship with the stability parameters not complying with the requirements of 2.2 and 2.3, requires introduction of operating limitations for each variant of loading conditions, derived from calculations in compliance with 2.3.

shall be taken with correction for free surfaces of liquid cargos in compliance with 1.4.7, Part IV "Stability", Rules for Classification and Construction of Sea-Going Ships. Application of the simplified assessment, specified in item 2.2.1, as a stricter assessment without the effect of the initial trim shall be allowed for the ships with a trim.

2.2 CRITERION FOR LOSS OF STABILITY OF THE 1ST LEVEL

2.2.1 The ship shall be considered as not loosing stability in static wave riding conditions, if

$$h_{\min} > R_{pLA},$$

where R_{pLA} = 0,05 m;
$h_{\min}$ – the minimum value of metacentric height with regard to correction for free surfaces of liquid cargos, calculated for one of the following conditions: for a longitudinal wave going along the ship's hull, in compliance with 2.2.3; by Formula (2.2.2).

2.2.2 In compliance with 2.2.1 h_{min} can be defined by the formula

$$h_{\min} = z_c + \frac{I_L}{V} - z_c \quad \text{only at} \quad \frac{V_D - V}{A_W(D-d)} \geqslant 1{,}0,$$

where z_c – height of the center of buoyancy for the examined loading conditions, in m;
z_g – height of the center of gravity for the examined loading conditions, in m;
I_L – moment of inertia of waterline area at draught of d_L, in m^4;
V – volume displacement correspondent to the examined loading conditions, in m^3;
d_L= d-δd_L, in m;
d – drought amidships correspondent to the examined loading conditions, in m;

δd_L= min(d-0,24$d_{full}\frac{L_1 S_w}{2}$)> in m;

S_w = 0,0334;
D – molded height of freeboard to the upper deck, in m;
V_D – volume displacement at waterline, which corresponds to the molded height of freeboard D, in m^3;
A_w – waterline area at the draught of d, in m^2.

2.2.3 In compliance with 2.2.1 h_{min} can be defined as the minimum value of metacentric height, calculated for this ship, with regard to correction for free liquid surfaces, in the examined loading conditions with regard to balance adjustment for sagging and trim on series of waves with the following parameters:

wave length $\lambda = L_1$;

wave height $h_E = L_1 S_w$ where $S_w = 0{,}0334$;

wave crest is located amidships and at the points of 0,1L_1, 0,2L_1, 0,3L_1, 0,4L_1 and 0,5L_1, ahead and 0,1L_1, 0,2L_1, 0,3L_1 and 0,4L_1 astern of it.

2.2.4 In compliance with 2.2.2, if $\frac{V_D - V}{A_w(D-d)} < 1{,}0$, then the righting moment lever l shall be positive at heel angle of 30° for each of the specified cases.

2.3 CRITERIA FOR LOSS OF STABILITY OF THE 2ND LEVEL

2.3.1 The ship shall be considered as not loosing stability in static wave riding conditions if the maximum value of the three criteria CR_1, CR_2 and CR_3, calculated in compliance with 2.3.3, 2.3.4 and 2.3.5 for the ship moving with operating speed, is less than R_{pLo}, where R_{pLo} = 0,06.

2.3.2 Each of the three criteria CR_1, CR_2 and CR_3 represents a weighted mean value of some stability parameters of a ship, which is considered as immobile in seas of certain height H_i and length λ_i, taken from Table 2.3.2,

where $CR_1 = \sum_{i=1}^{N} W_i C1_i$ = weighted criterion 1;

$CR_2 = \sum_{i=1}^{N} W_i C2_i$ = weighted criterion 2;

$CR_3 = \sum_{i=1}^{N} W_i C3_i$ = weighted criterion 3;

W_i – weight coefficient; taken from Table 2.3.2;

Table 2.3.2

Frequency of sea state cases per 100 000 observations
for calculation of loss of stability in static wave riding conditions

H_s, m	T_z, s – mean wave period between the zero points															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
0,5	1,3	133,7	865,6	1186,0	634,2	186,3	36,9	5,6	0,7	0,1	0,0	0,0	0,0	0,0	0,0	0,0
1,5	0,0	29,3	986,0	4976,0	7738,0	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0,0	0,0	0,0
2,5	0,0	2,2	197,5	2158,8	6230,0	7449,5	4860,4	2066,0	644,5	160,2	33,7	6,3	1,1	0,2	0,0	0,0
3,5	0,0	0,2	34,9	695,5	3226,5	5675,0	5099,1	2838,0	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0,0
4,5	0,0	0,0	6,0	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0,0
5,5	0,0	0,0	1,0	51,0	498,4	1602,9	2372,7	2008,3	1126,0	463,6	150,9	41,0	9,7	2,1	0,4	0,1
6,5	0,0	0,0	0,2	12,6	167,0	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1
7,5	0,0	0,0	0,0	3,0	52,1	270,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0,1
8,5	0,0	0,0	0,0	0,7	15,4	97,9	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1
9,5	0,0	0,0	0,0	0,2	4,3	33,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1
10,5	0,0	0,0	0,0	0,0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4,0	1,2	0,3	0,0
11,5	0,0	0,0	0,0	0,0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,0
12,5	0,0	0,0	0,0	0,0	0,1	1,0	4,4	9,9	12,8	11,0	6,8	3,3	1,3	0,4	0,1	0,0
13,5	0,0	0,0	0,0	0,0	0,0	0,3	1,4	3,5	5,0	4,6	3,1	1,6	0,7	0,2	0,1	0,0
14,5	0,0	0,0	0,0	0,0	0,0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0,0	0,0
15,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0,0	0,0
16,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0

N – number of rolling seas cases, for which C_1, C_2 and C_3 (272 for variant) are determined;
$C1$ – criterion 1 determined by 2.3.3;
$C2$ – criterion 2 determined by 2.3.4;
$C3$ –criterion 3 determined by 2.3.5.

The following values of wave length and height shall be used for calculation of the righting moment when underway in rolling conditions:

length $\lambda = L_1$,

height $h_E = 0{,}01iL_1$ where $i = 0{,}1, ... , 10$.

Values of the three $C1_i$, $C2_i$ and $C3_i$, criteria shall be calculated by Formulas (2.3.3)–(2.3.5) correspondently with the use of length and height values, taken from Table 2.3.2.

The preset rolling seas cases for assessment of the criteria are given in Table 2.3.2. For application in 2.3.3–2.3.5 N shall be taken equal to 272. For each H_s and T_z combination W_i value is determined by dividing the value, taken from Table 2.3.2, by 100 000, that corresponds to H_i value, calculated below, λ_i in this case is taken equal to L. Values of each of them shall be determined by linear interpolation method from h_E ratios to the above received values.

2.3.3 Criterion 1.

Criterion 1 is preset by the following formula:

$$C1_i = \begin{cases} 1 & \phi_v < R_{PL_1}; \\ 0 & \text{in other cases.} \end{cases} \qquad (2.3.3)$$

The angle of vanishing stability φ_v with regard to correction for free liquid surfaces can be defined as the minimum value, calculated for a ship in the examined loading conditions with regard to balance adjustment of the ship for sagging and trim on series of waves with the parameters, specified in Table 2.3.2.

Wave crest is located amidships and at the points of 0,1L, 0,2L, 0,3L, 0,4L and 0,5L ahead and 0,1L, 0,2L, 0,3L and 0,4L astern of it;

$R_{PLi} = 30°$.

2.3.4 Criterion 2.

Criterion 2 is determined on the basis of the ship's static heel angle by the formula

$$C2_i = \begin{cases} 1 & \phi_v > R_{PL_2a};\ \phi_{loll}\ \text{(in degrees)} > R_{PL_2b}; \\ 0 & \text{in other cases} \end{cases} \qquad (2.3.4)$$

The angle of static heel φ_s. due to heeling moment, preset by R_{PL3}, with regard to correction for free liquid surfaces in case of positive metacentric height h for the ship's position without heel or trim can be defined as the minimum value, calculated for the examined loading conditions and with regard to balance adjustment of the ship for sagging and trim on series of waves with the parameters, specified in Table 2.3.2.

Wave crest is located amidships and at 0,1*L*, 0,2*L*, 0,3*L*, 0,4*L* and 0,5*L* ahead and 0,1*L*, 0,2*L*, 0,3*L* and 0,4*L* astern of it;

$R_{PL_2a} = 15°$;

$R_{PL_2b} = 25°$.

2.3.5 Criterion 3.

Criterion 3 is determined on the basis of the maximum lever of righting lever curve by the formula

$$C3_i = \begin{cases} 1 & l_{\max}(\text{м}) < R_{PL_3}; \\ 0 & \text{in other cases} \end{cases}$$

$l_{\max}$ is defined as the least of the righting lever curves maximums correction for free liquid surfaces in compliance with the examined loading conditions and with regard to balance adjustment of the ship for sagging and trim on series of waves with the parameters, specified in Table 2.3.2.

Wave crest is located amidships and at the points of 0,1*L*, 0,2*L*, 0,3*L*, 0,4*L* and 0,5*L* ahead and 0,1*L*, 0,2*L*, 0,3*L* and 0,4*L* astern of it;

$$R_{PL_3} = 8(H_i/\lambda)dF_n^2 \ .$$

3. CRITERION FOR LOSS OF STABILITY IN BROACHING-TO CONDITIONS

3.1 APPLICATION

3.1.1 Requirements of the present section apply to all ships with the length of $L \geq 24$ m.

3.1.2 In each loading conditions a ship with the stability parameters:

.1 complying with the requirement specified in 3.2, shall be considered as not loosing stability in broaching-to conditions;

.2 not complying with the requirement, specified in 3.2, shall be either: operated in compliance with special steering procedures, aimed at avoiding of hazardous broaching-to situations, recommended in Section 4.2.1 of IMO MSC.l/Circ.1228;

checked in compliance with 3.3.

3.1.3 Each variant of ship loading conditions, which does not comply with the requirements of 3.2 and 3.3, requires introduction of operating limitations derived from calculations in compliance with 3.3.

3.2 CRITERION FOR LOSS OF STABILITY IN BROACHING-TO CONDITIONS OF THE 1ST LEVEL

3.2.1. The ship shall be considered as not loosing stability in broaching-to conditions, if one of the following conditions is fulfilled:

.1 $L_1 > 200$ m;

or

.2 $F_n > 0{,}3$,

where F_n – Froude number = $V_s/\sqrt{L_1 g}$;

V_s = operating speed in calm water, m/s;

L_1 = length as defined in the Load Line Rules for Sea-Going Ships.

3.3 CRITERION FOR LOSS OF STABILITY IN BROACHING-TO CONDITIONS OF THE 2ND LEVEL

3.3.1 The ship shall be considered as loosing stability in broaching-to conditions, if the value, calculated in compliance with 3.3.2, is less than R_{SR},

$$C = \sum_{HS}\sum_{TZ}\left(W2(H_S,\ T)\ \frac{\sum_{i-1}^{N_\lambda}\sum_{j-1}^{N_a} W_{ij}C2_{ij}}{\sum_{i=1}^{N_\lambda}\sum_{j=1}^{N_a} W_{ij}}\right)$$

where R_{SR} = 0,0001;

$W2(H_S, T_Z)$ – weight coefficient for short term rolling seas, preset in 3.3.2 as a function of a considerable wave height H_S, or a wave period between the zero points T_Z;

W_{ij} – static weight coefficient of a wave, determined in compliance with 3.3.3 with steepness $(H/\lambda)_j$, and wave length to ship length ratio $(\lambda/L_{BP})_i$ calculated by joint distribution of steepness and length values of instantaneous waves, i.e. with preset sampling N_λ = 80 and N_a = 100;

$C2_{ij}$ – value, calculated in compliance with 3.3.4.

3.3.2 *$W2(H_S, T_Z)$* value is determined by dividing the value, taken from Table 3.3.2, by 100 000. For short term, rolling seas is equal to 272. Other sources of static data on rolling seas can be used upon approval by the Register.

Table 3.3.2

Frequency of sea state cases per 100 000 observations for assessment of ships response to parametric rolling

H_S, m	T_Z, s – mean wave period between the zero points															
	3,5	4,5	5,5	6,5	7,5	8,5	9,5	10,5	11,5	12,5	13,5	14,5	15,5	16,5	17,5	18,5
0,5	1,3	133,7	865,6	1186,0	634,2	186,3	36,9	5,6	0,7	0,1	0,0	0,0	0,0	0,0	0,0	0,0
1,5	0,0	29,3	986,0	4976,0	7738,0	5569,7	2375,7	703,5	160,7	30,5	5,1	0,8	0,1	0,0	0,0	0,0
2,5	0,0	2,2	197,5	2158,8	6230,0	7449,5	4860,4	2066,0	644,5	160,2	33,7	6,3	1,1	0,2	0,0	0,0
3,5	0,0	0,2	34,9	695,5	3226,5	5675,0	5099,1	2838,0	1114,1	337,7	84,3	18,2	3,5	0,6	0,1	0,0
4,5	0,0	0,0	6,0	196,1	1354,3	3288,5	3857,5	2685,5	1275,2	455,1	130,9	31,9	6,9	1,3	0,2	0,0
5,5	0,0	0,0	1,0	51,0	498,4	1602,9	2372,7	2008,3	1126,0	463,6	150,9	41,0	9,7	2,1	0,4	0,1
6,5	0,0	0,0	0,2	12,6	167,0	690,3	1257,9	1268,6	825,9	386,8	140,8	42,2	10,9	2,5	0,5	0,1
7,5	0,0	0,0	0,0	3,0	52,1	270,1	594,4	703,2	524,9	276,7	111,7	36,7	10,2	2,5	0,6	0,1
8,5	0,0	0,0	0,0	0,7	15,4	97,9	255,9	350,6	296,9	174,6	77,6	27,7	8,4	2,2	0,5	0,1
9,5	0,0	0,0	0,0	0,2	4,3	33,2	101,9	159,9	152,2	99,2	48,3	18,7	6,1	1,7	0,4	0,1
10,5	0,0	0,0	0,0	0,0	1,2	10,7	37,9	67,5	71,7	51,5	27,3	11,4	4,0	1,2	0,3	0,1
11,5	0,0	0,0	0,0	0,0	0,3	3,3	13,3	26,6	31,4	24,7	14,2	6,4	2,4	0,7	0,2	0,1
12,5	0,0	0,0	0,0	0,0	0,1	1,0	4,4	9,9	12,8	11,0	6,8	3,3	1,3	0,4	0,1	0,0
13,5	0,0	0,0	0,0	0,0	0,0	0,3	1,4	3,5	5,0	4,6	3,1	1,6	0,7	0,2	0,1	0,0
14,5	0,0	0,0	0,0	0,0	0,0	0,1	0,4	1,2	1,8	1,8	1,3	0,7	0,3	0,1	0,0	0,0
15,5	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,4	0,6	0,7	0,5	0,3	0,1	0,1	0,0	0,0
16,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,2	0,2	0,2	0,1	0,1	0,0	0,0	0,0

3.3.3 W_{ij} value can be calculated by the formula

$$W_{ij} = \frac{4\sqrt{g}L_1^{5/2}T_{01}}{n\nu(H_s)^3}\, s_j^2 s_i^{3/2}\Big(\frac{\sqrt{1+\nu^2}}{1+\sqrt{1+\nu^2}}\Big)\Delta r\Delta s\, exp\Big[-2\Big(\frac{L_1 r_i s_j}{H_s}\Big)^2 \times$$
$$\times\Big\{1+\frac{1}{\nu^2}\Big(1-\sqrt{\frac{gT_{01}^2}{2\pi r_i L_1}}\Big\}\Big],$$

where $\nu = 0{,}4256 = \sqrt{\frac{m_0 m_2}{m_1^2} - 1}$;

L_1 – length as defined in the Load Line Rules for Sea-Going Ships;
T_{01} = $1{,}086T_Z$,
$s_j = (H/\lambda)_j$ – wave steepness. Varies from 0,03 to 0,15 with increment of Δ_S – 0,0012;
$r_j = (H/\lambda)_i$ – ship length to wave length ratio. Varies from 1,0 to 3,0 with increment of Δ_r = 0,025.

3.3.4 For each sea state $C2_{ij}$value is calculated as follows:

$$C2_{ij} = \begin{cases} 1 & \text{if} \quad F_n > Fn_{cr}(r_j, s_j); \\ 0 & \text{if} \quad F_n \leqslant Fn_{cr}(r_j, s_j), \end{cases}$$

where Fn_{cr} – critical Froude number correspondent to transition into broaching-to conditions in case of regular rolling seas with steepness r_j and wave length to ship length ratio s_j, values of which are determined in compliance with 3.3.4.1.

3.3.4.1 The critical Froude number is calculated by the formula

$$Fn_{cr} = u_{cr}/\sqrt{Lg},$$

where u_{cr} – critical speed of a ship, in m/s, determined by solving of equation in compliance with 3.3.4.2 with critical revolutions of the propulsor n_{cr} by numerical iteration method;
L_1 – length as defined in the Load Line Rules for Sea-Going Ships.

3.3.4.2 Critical ship speed u_{cr} is determined by solving the following equation with critical revolutions of the propulsor n_{cr} by numerical iteration method:

$$T_b(u_{cr}, n_{cr}) - R(u_{cr}) = 0,$$

where $R(u_{cr})$ – ship's drag in calm water when underway with speed u_{cr}, as specified in 3.3.4.3;
$T_b(u_{cr}, n_{cr})$ – thrust produced by the ship's propulsors in calm water, calculated in compliance with 3.3.4.4;
n_{cr} – preset revolutions of the propulsor, corresponding to transition broaching-to conditions.

3.3.4.3 Grad in calm water *R(u)* is approximated on the basis of the available data by the means of a polynom, which can (but not necessarily shall) contain terms of up to the 5th order:

$$R(u) = r_1 u + r_2 u^2 + r_3 u^3 + r_4 u^4 + r_5 u^5 \ ,$$

where u – speed of the ship, in m/s, in calm water;
r_1, r_2, r_3, r_4, r_5 – approximation coefficients for calculation of drag in calm water.

3.3.4.4 If the main propulsor of the ship is represented by a single propeller, its thrust $T_e(u;\, n)$ in calm water can be approximated by a polynom of the second order:

$$T_e(u;\, n) = (1 - t_p)\rho n^2 D_p^4 \{k_0 + k_1 J + k_2 J^2\},$$

where u – speed of the ship (in m/s) in calm water;
n – preset revolutions of the propulsor, in s^{-1};
t_p – approximate thrust decrease coefficient due to suction;
w_p – approximate wake flow coefficient;
D_p – propeller diameter, in m;
k_0, k_1, k_2 – approximation coefficient for calculation of propeller thrust in calm water;

$J = \dfrac{u(1 - w_p)}{nD_p}$ – relative propeller pitch;

ρ – sea water density (1025 kg/m^3).

If case of other, than a propeller, propulsor its thrust can be calculated by the method, correspondent to the nature of the propulsor in use, upon approval by the Register.

3.3.4.5 The value of wave roll-excitation force is calculated by the formula

$$F = \rho g k \frac{H}{2} \sqrt{F_c^2 + F_s^2}(\text{H}),$$

where k_i – wave number = $\dfrac{2\pi}{r_t L^2}$, in m^{-1};

H_{ij} – wave height = $s_j r_i L$, in m;
s_j – determined in 2.12.3.4;
r_i – determined in 2.12.3.4;

$$F_c = \sum_{i-1}^{N} \Delta x_i S(x_i)\ \sin kx_i \exp\left(-0{,}5kd(x_i)\right);$$

$$F_S = \sum_{i-1}^{N} \Delta x_i S(x_i)\ \cos kx_i \exp\left(-0{,}5kd(x_i)\right);$$

F_c and F_S – components of Froude-Krylov force in pitch-excitation wave force;
x_i – longitudinal distance from the ship's center of mass to a particular point, in m, positive in forward direction;
$d(x_i)$ – draught in the point in calm water, in m;
$S(x_i)$ – area of the underwater ship portion in the point in calm water, in m^2;
N – number of such points.

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