Annex A

Design Loads for Yachts of High Speed Type

On the following pages of this Annex we provide an excerpt of the GL Rules, Part 1 – Seagoing Ships, Chapter 5 – High Speed Craft which contains the formulae to determine the design loads for yachts capable of speeds:

$$v \geq 7,2 \cdot \sqrt[6]{\Delta} \;\; [\mathrm{kn}]$$

See Section 2, E.3.1.1.

Note

The passages relevant for design load determination start with C.3.3 of the following page and end with C.3.5.10. Cross references in the following pages aim at the GL Rules, Part 1 – Seagoing Ships, Chapter 5 – High Speed Craft.

Table C3.2.8

	Width or height (mm)	Thickness (mm)	Young's modulus (N/mm^2)	Section (mm^2)
Flange	l_s	t_s	E_s	$S_s = t_s\, l_s$
Core	H	t_a	E_a	$S_a = t_a\, H$
Associated plating	l_b	t_b	E_b	$S_b = t_b\, l_b$

(c) To supplement the symbols defined in Table C3.2.8, the following elements are needed:

z_i : distance from the neutral fibres of the three elements, i.e. core, flange and associated plating (index i refers to each one of them), to the outer face of the associated plating, in mm,

V : distance from the stiffener neutral fibre to the outer face of the associated plating, in mm:

$$V = \frac{\sum E_i \cdot S_i \cdot z_i}{\sum E_i \cdot S_i}$$

V' : distance from the stiffener neutral fibre to the outer face of the flange, in mm:
$V' = H - V + t_s + t_b$

d_i : distances from the neutral fibre of each element to the stiffener neutral fibre, in mm:
$d_i = z_i - V$

I_i : specific inertia of each element, in mm^4.

(d) The rigidity of a stiffener [EI], in $N.mm^2$, is:

$$[EI] = \sum E_i \cdot (I_i + S_i \cdot d_i^2)$$

(e) The inertia of a stiffener [I], in mm^4, is:

$$[I] = \sum (I_i + S_i \cdot d_i^2)$$

(f) The theoretical bending breaking strength of the stiffener σ_{br}, in N/mm^2, is:

$$\sigma_{br} = k \cdot \frac{[EI]}{[I]} \cdot 10^{-3}$$

where:

k :
- 17,0 for stiffeners using polyester resin,
- 25,0 for stiffeners using epoxy resin,
- 12,5 for skins made of carbon reinforcements and epoxy resins.

C3.3 Design acceleration

C3.3.1 Vertical acceleration at LCG

.1 The design vertical acceleration at LCG, a_{CG} (expressed in g), is defined by the designer and corresponds to the average of the 1 per cent highest accelerations in the most severe sea conditions expected, in addition to the gravity acceleration.
Generally, it is to be not less than:

$$a_{CG} = foc \cdot Soc \cdot \frac{V}{\sqrt{L}}$$

where foc and Soc values are indicated in Table C3.3.1. and Table C3.3.2.

Table C3.3.1

Type of service	Passenger, Ferry, Cargo	Supply	Pilot, Patrol	Rescue
foc	0,666	1	1,333	1,666

Table C3.3.2

Sea area	Open sea	Restricted open sea	Moderate environment **(2)**	Smooth sea **(3)**
Soc	C_F **(1)**	0,30	0,23	0,14

(1) For passenger, ferry and cargo craft, their seaworthiness in this condition is to be ascertained. In general, Soc should not be lower than the values given in this Table, where:

$$C_F = 0,2 + \frac{0,6}{V/\sqrt{L}} \geq 0,32$$

(2) Not applicable to craft with type of service "Rescue"
(3) Not applicable to craft with type of service "Pilot, Patrol" or "Rescue"

.2 Lower a_{CG} values may be accepted at the Society's discretion, if justified, on the basis of model tests and full-scale measurements.

.3 The sea areas referred to in Table C3.3.2 are defined with reference to significant wave heights H_s which are exceeded for an average of not more than 10 percent of the year:

- Open-sea service:
  $H_s \geq 4,0$ m
- Restricted open-sea service:
  $2,5 \text{ m} \leq H_s < 4,0$ m
- Moderate environment service:
  $0,5 \text{ m} < H_s < 2,5$ m
- Smooth sea service:
  $H_s \leq 0,5$ m.

.4 If the design acceleration cannot be defined by the designer, the a_{CG} value corresponding to the appropriate values of foc and Soc reported in Table C3.3.1 and Table C3.3.2 will be assumed.

.5 An acceleration greater than a_{CG} = 1,5 · foc may not be adopted for the purpose of defining limit operating conditions.

.6 The longitudinal distribution of vertical acceleration along the hull is given by:

$a_v = k_v \cdot a_{CG}$

where:

k_v : longitudinal distribution factor, not to be less than (see Figure C3.3.1):

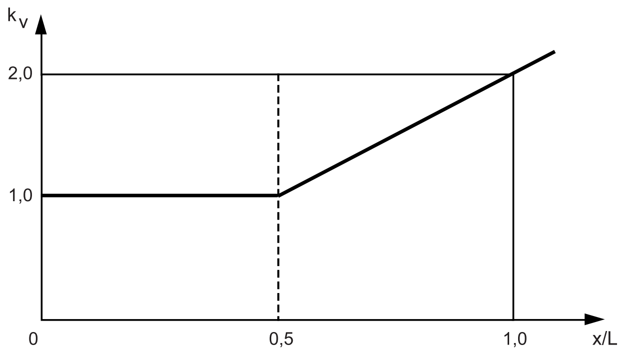
$k_v = 1$ for $x/L \leq 0{,}5$

$k_v = 2 \cdot x/L$ for $x/L > 0{,}5$

Higher values may be requested based on pitch consideration.

a_{CG} : design acceleration at LCG.

Figure C3.3.1



.7 Variation of a_v in the transverse direction may generally be disregarded.

C3.3.2 Transverse acceleration

.1 Transverse acceleration is defined on the basis of results of model tests and full-scale measurements, considering their characteristic value as specified in C3.3.4.1.

.2 In the absence of such results, transverse acceleration, in g, at the calculation point of the craft may be obtained from:

$$a_t = 2{,}5 \cdot \frac{H_{sl}}{L} \cdot \left(1 + 5 \cdot \left(1 + \frac{V/(\sqrt{L})}{6}\right)^2 \cdot \frac{r}{L}\right)$$

where:

H_{sl} : permissible significant wave height at maximum service speed V (see C3.3.3),

r : distance of the point from:

- 0,5 D for monohull craft,
- waterline at draught T, for twin-hull craft.

C3.3.3 Assessment of limit operating conditions

C3.3.3.1 General

.1 "Limit operating conditions" in this paragraph are to be taken to mean sea states (characterized only by their significant wave heights) compatible with the structural design parameters of the craft, i.e. the sea states in which the craft may operate depending on its actual speed.

.2 Limit operating conditions are derived from the restrictions presented in C3.3.3.2, C3.3.3.3 and C3.3.3.4 below.

.3 Other specific design parameters influenced by sea state and speed could be also considered at the discretion of the Society.

.4 It is the designer's responsibility to specify the format and the values of the limit operating conditions. Their format may be for example a relation between speed and significant wave height which ascertains actual loads less than the one used for structural design. They must include the maximum allowed significant wave height H_{sm} consistent with the structural strength. H_{sm} is not to be greater than the value calculated according to C3.3.3.1.7 below.

.5 The limit operating conditions are defined, at the discretion of the Society, on the basis of results of model tests and full-scale measurements or by numerical simulations.

.6 The limit operating conditions, taken as a basis for classification, are indicated in the Classification Certificate and are to be considered in defining the worst intended conditions and the critical design conditions in Section 1.

.7 It is assumed that, on the basis of weather forecast, the craft does not encounter, within the time interval required for the voyage, sea states with significant heights, in m, greater than the following:

$$H_{sm} = 5 \cdot \frac{a_{CG}}{V/(\sqrt{L})} \cdot \frac{L}{6 + 0{,}14 \cdot L}$$

where vertical acceleration a_{CG} is defined in C3.3.1.

.8 For craft with a particular shape or other characteristics, the Society reserves the right to require model tests or full-scale measurements to verify results obtained by the above formula.

C3.3.3.2 Limitation imposed by bottom impact pressure and deck loads

.1 Bottom impact pressure, given in C3.5.3, and deck loads, given in C3.5.8, are explicitly or implicitly depending on the vertical acceleration at LCG. Therefore, the design values of these loads, taken as the basis for the classification, directly impose limitation on vertical acceleration level at LCG.

.2 It is the designer's responsibility to provide for a relation between the speed and the significant wave height that provides a maximum vertical acceleration less than the design value.

.3 Model tests if any are to be carried out in irregular sea conditions with a significant wave height corresponding to the operating conditions of the craft and a clearly specified sea spectrum. The scale effect is to be accounted for with an appropriate margin of safety. The characteristic value of acceleration and global loads to be assumed corresponds to the average of the 1 per cent highest values obtained during tests. The duration of the test is, as far as practicable, to be sufficient to guarantee that results are stationary.

.4 Where model test results or full-scale measurements are not available, the formula contained in C3.3.3.2.5 may be used to define maximum speeds compatible with design acceleration of monohulls, depending on sea states having a significant height H_s.

.5 The significant wave height is related to the craft's geometric and motion characteristics and to the vertical acceleration a_{CG} by the following formula:

$$a_{CG} = \frac{(50 - \alpha_{dCG}) \cdot \left(\frac{\tau}{16} + 0,75\right)}{3555 \cdot C_B} \cdot \left(\frac{H_S}{T} + 0,084 \cdot \frac{B_W}{T}\right) \cdot K_{FR} \cdot K_{HS}$$

- for units for which $V / L^{0,5} \geq 3$ and $\Delta / (0,01 \cdot L)^3 \geq 3500$

  $$K_{FR} = \left(\frac{V_X}{\sqrt{L}}\right)^2$$

  and

  $$K_{HS} = 1$$

- for units for which $V/L^{0,5} < 3$ or $\Delta/(0,01 \cdot L)^3 < 3500$

  $$K_{FR} = 0,8 + 1,6 \cdot \frac{V_X}{\sqrt{L}}$$

  and

  $$K_{HS} = \frac{H_S}{T}$$

where:

H_s : significant wave height, in m,

α_{dCG} : deadrise angle, in degrees, at LCG, to be taken between 10° and 30°,

τ : trim angle during navigation, in degrees, to be taken not less than 4°,

V : maximum service speed, in knots.

V_x : actual craft speed, in knots.

If V_x is replaced by the maximum service speed V of the craft, the previous formula yields the significant height of the limit sea state, H_{sl}. This formula may also be used to specify the permissible speed in a sea state characterised by a significant wave height equal to or greater than H_{sl}.

.6 On the basis of the formula indicated in C3.3.3.2.5, the limit sea state may be defined (characterised by its significant wave height H_{sl}), i.e. the sea state in which the craft may operate at its maximum service speed. During its voyage, whenever the craft encounters waves having a significant height greater than H_{sl}, it has to reduce its speed.

.7 For catamarans, the relation between speed, wave height and acceleration is to be justified by model test results or full-scale measurements (see also C3.3.3.3).

.8 For craft, such as SESs, for which a speed reduction does not necessarily imply a reduction in acceleration, the speed is to be modified depending on the sea state according to criteria defined, at the discretion of the Society, on the basis of motion characteristics of the craft.

.9 The reduction of vertical acceleration a_{CG} induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by bottom impact loads.

C3.3.3.3 Limitation imposed by wet deck impact loads for catamarans

.1 Wet deck impact pressure is given in C3.5.4.

.2 The formula in C3.5.4 may be used to define maximum speeds compatible with actual structure of wet deck, depending on sea states having a significant height H_s.

.3 The reduction of relative impact velocity V_{sl} induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by wet deck impact loads.

C3.3.3.4 Limitation imposed by global loads

.1 For monohulls and catamarans, the longitudinal bending moment and shear forces as given in C3.4.1 and C3.4.2 are explicitly or implicitly depending on vertical acceleration along the ship. Therefore, the design values of these loads, taken as the basis for classification, directly impose limitation on vertical acceleration level at LCG. The requirements of C3.3.3.2.2 to C3.3.3.2.9 apply.

.2 For catamarans, the transverse bending moment, the torsional bending moment and the vertical shear force as given in C3.4.2 are depending on vertical acceleration a_{CG}. Therefore, the requirements of C3.3.3.2.2 to C3.3.3.2.9 apply.

.3 For SWATH craft, the global loads as given in C3.4.3 are not depending on ship motions.

.4 For ships with length greater than 100m, the relation between vertical acceleration along the ship and global loads are to be ascertained on basis of results of model tests and/or full-scale measurements or by numerical simulations, as indicated in C3.3.3.2.

.5 The reduction of vertical acceleration along the ship induced by stabilisation system if any is to be disregarded for the purpose of limit operating conditions imposed by global loads.

C3.3.3.5 Hull monitoring

.1 The Society may require a hull monitoring system to be fitted on board, allowing to monitor and display in real time the vertical acceleration and any other sensitive parameter with respect to the strength.

.2 The information is to be available at the wheelhouse and displayed in a clear format allowing to compare with design values.

.3 When a hull monitoring system is requested, its specification is to be submitted for review.

C3.4 Overall loads

C3.4.1 Monohulls

C3.4.1.1 General

.1 As a rule, only longitudinal vertical bending moment and shear force are to be considered for monohulls.

.2 For large craft, values from model tests, or hydrodynamic calculations, may be taken into account, after agreement of the Society on the methodology, the sea conditions and the loading cases. in such cases, values given in C3.4.1.2 must be considered as short term 1/100° values.

C3.4.1.2 Bending moment and shear force

.1 **General**

.1 The values of the longitudinal bending moment and shear force are given, in first approximation, by the formula in C3.4.1.2.2, C3.4.1.2.3 and C3.4.1.2.4.

.2 The total bending moments M_{blH}, in hogging conditions, and M_{blS}, in sagging conditions, in kN.m, are to be taken as the greatest of those given by the formulae in C3.4.1.2.2 and C3.4.1.2.3.

For ships having L > 100 m, only the formula in C3.4.1.2.3 is generally to be applied; the formula in C3.4.1.2.2 is to be applied when deemed necessary by the Society on the basis of the motion characteristics of the ship. The total shear forces T_{bl}, in kN, is given by the formula in C3.4.1.2.4.

.3 The longitudinal distribution of the total bending moment M_{blH} and M_{blS} is given in C3.4.1.2.5.

.4 If the actual distribution of weights along the craft is known, a more accurate calculation may be carried out according to the procedure in C3.4.1.2.6. the Society reserves the right to require calculation to be carried out according to C3.4.1.2.6 whenever it deems necessary.

.5 Rule requirements are reminded in Table C3.4.1.

Table C3.4.1

Ships		Applicable requirements	
L ≤ 100 m	All cases	Bending moment	C3.4.1.2.2 or C3.4.1.2.3 whichever is the greater
		Shear force	C3.4.1.2.4
L ≤ 100 m	Alternatively, when actual distribution of weights is known	Bending moment and shear force	C3.4.1.2.6
L > 100 m	Normal cases	Bending moment	C3.4.1.2.3
		Shear force	C3.4.1.2.4
L > 100 m	Special cases (when deemed necessary by the Society)	Bending moment	C3.4.1.2.2 or C3.4.1.2.3 whichever is the greater
		Shear force	C3.4.1.2.4
L > 100 m	Alternatively, when actual distribution of weights is known	Bending moment and shear force	C3.4.1.2.6

.2 Bending moment due to still water loads, wave induced loads and impact loads

$$M_{blH} = M_{blS} = 0,55 \cdot \Delta \cdot L \cdot (C_B + 0,7) \cdot (1 + a_{CG})$$

where a_{CG} is the vertical acceleration at the LCG, defined in C3.3.1.

.3 Bending moment due to still water loads and wave induced loads

$$M_{blH} = M_{sH} + 0,60 \cdot Soc \cdot C \cdot L^2 \cdot B \cdot C_B$$
$$M_{blS} = M_{sS} + 0,35 \cdot Soc \cdot C \cdot L^2 \cdot B \cdot (C_B + 0,7)$$

where:

M_{sH} : still water hogging bending moment, in kN.m,

M_{sS} : still water sagging bending moment, in kN.m,

Soc : parameter as indicated in Table C3.3.2, for the considered type of service.

C = 6 + 0,02 L

For the purpose of this calculation, C_B may not be taken less than 0,6.

.4 Total shear force

$$T_{bl} = \frac{3,2 \cdot M_{bl}}{L}$$

where:

M_{bl} : the greatest between M_{blH} and M_{blS}, calculated according to C3.4.1.2.2 and C3.4.1.2.3, as applicable.

.5 Longitudinal distribution of total bending moment

The longitudinal distribution of the total bending moments is given by:

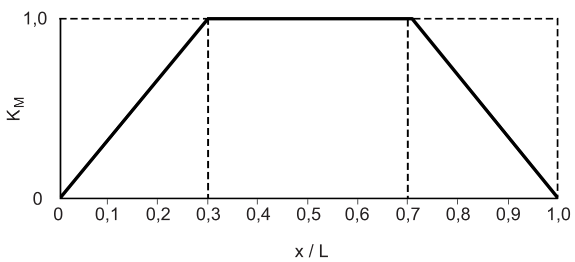
$K_M \cdot M_{blH}$ in hogging

$K_M \cdot M_{blS}$ in sagging

where:

K_M : longitudinal distribution factor as shown on Figure C3.4.1.

Figure C3.4.1



.6 Bending moment and shear force taking into account the actual distribution of weights

.1 The distribution of quasi-static bending moment and shear force, due to still water loads and wave induced loads, is to be determined from the difference in weight and buoyancy distributions in hogging and sagging for each loading or ballast condition envisaged.

.2 For calculation purposes, the following values are to be taken for the design wave:

- wave length, in m:

  $\lambda = L$

- wave height, in m:

  $$h = \frac{L}{15 + \frac{L}{20}}$$

- wave form: sinusoidal.

.3 In addition, the increase in bending moment and shear force, due to impact loads in the fore-body area, for the sagging condition only, is to be determined as specified below. For the purpose of this calculation, the hull is considered longitudinally subdivided into a number of intervals, to be taken, in general, equal to 20. For smaller craft, this number may be reduced to 10 if justified, at the Society's discretion, on the basis of the weight distribution, the hull forms and value of the design acceleration a_{CG}.

For twin-hull craft, the calculation below applies to one of the hulls, i.e. the longitudinal distribution of weight forces g_i and the corresponding breadth B_i are to be defined for one hull.

The total impact force, in kN, is:

$$F_{SL} = \sum q_{SLi} \cdot \Delta x_i$$

where:

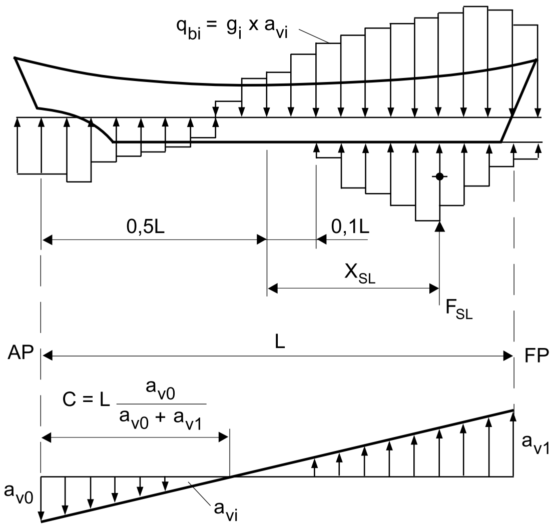
Δx_i : length of interval, in m,

q_{SLi} : additional load per unit length, in kN/m, for x/L ≥ 0,6 (see also Figure C3.4.2), given by:

$$q_{SLi} = p_0 \cdot B_i \cdot \sin\left(2 \cdot \pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right)$$

x_i : distance, in m, from the aft perpendicular,

Figure C3.4.2



B_i : craft breadth, in m, at uppermost deck;

(x_i and B_i to be measured at the centre of interval i),

p_0 : maximum hydrodynamic pressure, in kN/m², equal to:

$$p_0 = \frac{a_{v1} \cdot G \cdot (r_0 - x_W^2)}{f_{SL} \cdot (r_0^2 + 0,5 \cdot L \cdot (x_{SL} - x_W) - x_{SL} \cdot x_W)}$$

a_{v1} : vertical design acceleration at the forward perpendicular, as defined in C3.3,

G : weight force, in kN, equal to:

$$G = \sum g_i \cdot \Delta x_i$$

g_i : weight per unit length, in kN/m, of interval i; for twin-hull craft, g_i is to be defined for one hull,

x_W : distance, in m, of LCG from the midship perpendicular, equal to:

$$x_W = \frac{\sum (g_i \cdot \Delta x_i \cdot x_i)}{\sum (g_i \cdot \Delta x_i)} - 0,5 \cdot L$$

r_0 : radius of gyration, in m, of weight distribution, equal to:

$$r_0 = \left(\frac{\sum g_i \cdot \Delta x_i \cdot (x_i - 0,5L)^2}{\sum g_i \cdot \Delta x_i}\right)^{0,5}$$

normally 0,2 L < r_0 < 0,25 L (guidance value)

x_{SL} : distance, in m, of centre of surface F_{SL} from the midship perpendicular, given by:

$$x_{SL} = \frac{1}{f_{SL}} \sum \Delta x_i \cdot x_i \cdot B_i \cdot \sin\left(2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right) - 0,5L$$

f_{SL} : surface, in m², equal to:

$$f_{SL} = \sum \Delta x_i \cdot B_i \cdot \sin\left(2\pi \cdot \left(\frac{x_i}{L} - 0,6\right)\right)$$

.4 The resulting load distribution q_{si}, in kN/m, for the calculation of the impact induced sagging bending moment and shear force is:

(a) For x/L < 0,6:

$q_{si} = q_{bi} = g_i \cdot a_{vi}$

where:

a_{vi} : total dimensionless vertical acceleration at interval i, equal to:

$$a_{vi} = a_h + a_p \cdot (x_i - 0,5L)$$

a_h : acceleration due to heaving motion, equal to:

$$a_h = \frac{F_{SL}}{G} \cdot \left(\frac{r_0^2 - x_{SL} \cdot x_W}{r_0^2 - x_W^2}\right)$$

a_p : acceleration due to pitching motion, in m⁻¹, equal to:

$$a_p = \frac{F_{SL}}{G} \cdot \left(\frac{x_{SL} - x_W}{r_0^2 - x_W^2}\right)$$

a_h and a_p are relative to g

(b) For x/L ≥ 0,6:

$q_{si} = q_{bi} - q_{SLi}$

.5 The impact induced sagging bending moment and shear force are obtained by integration of the load distribution q_{si} along the hull. They are to be added to the respective values calculated according to C3.4.1.3.1 in order to obtain the total bending moment and shear force due to still water loads, wave induced loads and impact loads.

C3.4.2 Catamarans

C3.4.2.1 General

.1 The values of the longitudinal bending moment and shear force are given by the formulae in C3.4.1.2.

.2 For catamarans, the hull connecting structures are to be checked for load conditions specified in C3.4.2.2 and C3.4.2.3. These load conditions are to be considered as acting separately.

.3 Design moments and forces given in the following paragraphs are to be used unless other values are verified by model tests, full-scale measurements or any other information provided by the designer (see C3.3.4.1, Requirements for model tests).

.4 For craft with length L > 65 m or speed V > 45 knots, or for craft with structural arrangements that do not permit a realistic assessment of stress conditions based on simple models, the transverse loads are to be evaluated by means of direct calculations carried out in accordance with criteria specified in C3.6 or other criteria considered equivalent by the Society.

C3.4.2.2 Longitudinal bending moment and shear force

.1 Refer to C3.4.1.2.

.2 In C3.4.1.2.6, the breadth B_i is defined as below:

B_i : maximum breadth of one hull at the considered longitudinal location x_i, in m.

.3 When slamming of wet-deck is expected to occur (cf. C3.5.4), B_i is to be taken as:

B_i : the maximum breadth of one hull at the considered longitudinal location, in m, without being greater than B/2, multiplied by the coefficient f_B, where:

$f_B = 2 \cdot (1 - B_w/B)$

C3.4.2.3 Transverse bending moment and shear force

.1 The transverse bending moment M_{bt}, in kN.m, and shear force T_{bt}, in kN, are given by:

$$M_{bt} = \frac{\Delta \cdot b \cdot a_{CG} \cdot g}{5}$$

$$T_{bt} = \frac{\Delta \cdot a_{CG} \cdot g}{4}$$

where:

b : transverse distance, in m, between the centres of the two hulls,

a_{CG} : vertical acceleration at LCG, defined in C3.3.1.

C3.4.2.4 Transverse torsional connecting moment

.1 The catamaran transverse torsional connecting moment, in kN.m, about a transverse axis is given by:

$$M_{tt} = 0,125 \cdot \Delta \cdot L \cdot a_{CG} \cdot g$$

where a_{CG} is the vertical acceleration at LCG, defined in C3.3.1, which need not to be taken greater than 1,0 g for this calculation.

C3.4.3 Small waterplane area twin-hull (SWATH) craft - Forces and moments acting on twin-hull connections

C3.4.3.1 Side beam force

.1 The design beam side force, in kN, (see Figure C3.4.3) is given by:

$$F_Q = 12,5 \cdot T \cdot \Delta^{2/3} \cdot d \cdot L_S$$

where:

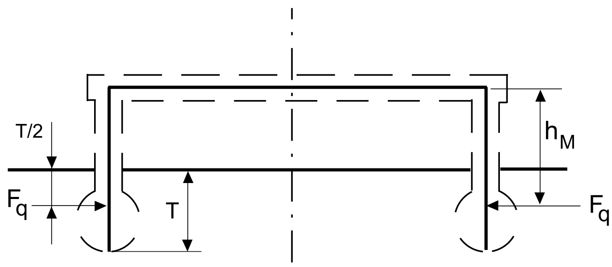
$$d = 1,55 - 0,75 \cdot \tanh\left(\frac{\Delta}{11000}\right)$$

$$L_S = 2,99 \cdot \tanh(\lambda - 0,725)$$

$$\lambda = \frac{0,137 \cdot A_{lat}}{T \cdot \Delta^{1/3}}$$

A_{lat} : lateral area, in m², projected on a vertical plane, of one hull with that part of strut or struts below waterline at draught T.

Figure C3.4.3



.2 The lateral pressure, in kN/m², acting on one hull is given by:

$$p_Q = \frac{F_Q}{A_{lat}}$$

The distribution of the lateral force F_Q can be taken as constant over the effective length $L_e = A_{lat} / T$, in m. The constant lateral force per unit length, in kN/m, is thus given by:

$$q_Q = \frac{F_Q}{L_e}$$

C3.4.3.2 Bending moment

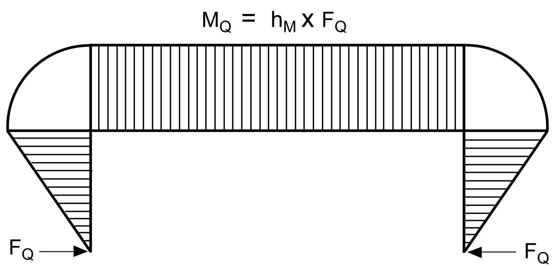
.1 The corresponding design bending moment, in kN.m, is given by:

$$M_Q = h_M \cdot F_Q$$

where:

h_M : half the draught T plus the distance from the waterline at draught T to the midpoint of the cross-deck structure (see Figure C3.4.4), in m.

Figure C3.4.4



C3.5 Local loads

C3.5.1 Introduction

.1 Design loads defined in this Article are to be used for the resistance checks provided for in C3.7 and C3.8 to obtain scantlings of structural elements of hull and deckhouses.

.2 Such loads may be integrated or modified on the basis of the results of model tests or full-scale measurements. Model tests are to be carried out in irregular sea conditions with significant wave heights corresponding to the operating conditions of the craft. The scale effect is to be accounted for by an appropriate margin of safety.

.3 The characteristic value to be assumed is defined as the average of the 1 per cent highest values obtained during testing. The length of the test is, as far as practicable, to be sufficient to guarantee that statistical results are stationary.

C3.5.2 Loads

C3.5.2.1 General

.1 The following loads are to be considered in determining scantlings of hull structures:

- impact pressures due to slamming, if expected to occur,
- sea pressures due to hydrostatic heads and wave loads,
- internal loads.

.2 External pressure generally determines scantlings of side and bottom structures; internal loads generally determine scantlings of deck structures.

.3 Where internal loads are caused by concentrated masses of significant magnitude (e.g. tanks, machinery), the capacity of the side and bottom structures to withstand such loads is to be verified according to criteria stipulated by the Society. In such cases, the inertial effects due to acceleration of the craft are to be taken into account.

Such verification is to disregard the simultaneous presence of any external wave loads acting in the opposite direction to internal loads.

C3.5.2.2 Load points

.1 Pressure on panels and strength members may be considered uniform and equal to the pressure at the following load points:

- for panels:
  - lower edge of the plate, for pressure due to hydrostatic head and wave load
  - geometrical centre of the panel, for impact pressure
- for strength members:
  - centre of the area supported by the element.

.2 Where the pressure diagram shows cusps or discontinuities along the span of a strength member, a uniform value is to be taken on the basis of the weighted mean value of pressure calculated along the length.

C3.5.3 Impact pressure on the bottom of hull

.1 If slamming is expected to occur, the impact pressure, in kN/m^2, considered as acting on the bottom of hull is not less than:

$$p_{sl} = 70 \cdot \frac{\Delta}{S_r} \cdot K_1 \cdot K_2 \cdot K_3 \cdot a_{CG}$$

where:

Δ : displacement, in tonnes (see C3.1.4). For catamaran, Δ in the above formula is to be taken as half of the craft displacement

S_r : reference area, m^2, equal to:

$$S_r = 0,7 \cdot \frac{\Delta}{T}$$

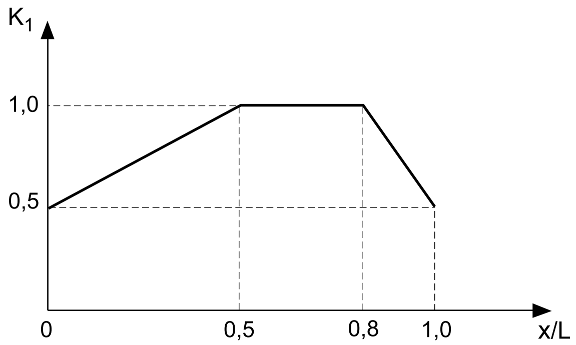
For catamaran, Δ in the above formula is to be taken as half the craft displacement

K_1 : longitudinal bottom impact pressure distribution factor (see Figure C3.5.1):

- for $x/L < 0,5$: $K_1 = 0,5 + x/L$
- for $0,5 \le x/L \le 0,8$: $K_1 = 1,0$
- for $x/L > 0,8$: $K_1 = 3,0 - 2,5 \cdot x/L$

where x is the distance, in m, from the aft perpendicular to the load point

Figure C3.5.1



K_2 : factor accounting for impact area, equal to:

$$K_2 = 0,455 - 0,35 \cdot \frac{u^{0,75} - 1,7}{u^{0,75} + 1,7}$$

with:

- $K_2 \geq 0{,}50$ for plating,
- $K_2 \geq 0{,}45$ for stiffeners,
- $K_2 \geq 0{,}35$ for girders and floors,

$$u = 100 \cdot \frac{s}{S_r}$$

where s is the area, in m², supported by the element (plating, stiffener, floor or girder). For plating, the supported area is the spacing between the stiffeners multiplied by their span, without taking for the latter more than three times the spacing between the stiffeners

K_3 : factor accounting for shape and deadrise of the hull, equal to:

$$K_3 = (70 - \alpha_d)/(70 - \alpha_{dCG})$$

where α_{dCG} is the deadrise angle, in degrees, measured at LCG and α_d is the deadrise angle, in degrees, between horizontal line and straight line joining the edges of respective area measured at the longitudinal position of the load point; values taken for α_d and α_{dCG} are to be between 10° and 30°

a_{CG} : design vertical acceleration at LCG, defined in C3.3.1.

C3.5.4 Impact pressure on bottom of wet-deck of catamarans (including tunnel radius)

.1 Slamming on bottom of the wet deck is assumed to occur if the air gap H_A, in m, at the considered longitudinal position is less than z_{wd},
where:

- for $L \leq 65$ m: $z_{wd} = 0{,}05 \cdot L$
- for $L > 65$ m: $z_{wd} = 3{,}25 + 0{,}0214 \cdot (L - 65)$

In such a case, the impact pressure, in kN/m², considered as acting on the wet deck is not less than:

$$p_{sl} = 3 \cdot K_2 \cdot K_{WD} \cdot V_X \cdot V_{SL} \cdot \left(1 - 0,85 \cdot \frac{H_A}{H_S}\right)$$

where:

V_{sl} : relative impact velocity, in m/s, equal to:

$$V_{sl} = \frac{4 \cdot H_S}{\sqrt{L}} + 1$$

H_S : significant wave height,

K_2 : factor accounting for impact area, as defined in C3.5.3.1,

K_{WD} : longitudinal wet deck impact pressure distribution factor (see Figure C3.5.2):

- for $x/L < 0{,}2$:

$$K_{WD} = 0,5 \cdot \left(1,0 - \frac{x}{L}\right)$$

- for $0{,}2 \leq x/L \leq 0{,}7$:
$K_{WD} = 0{,}4$
- for $0{,}7 < x/L < 0{,}8$:

$$K_{WD} = 6,0 \cdot \frac{x}{L} - 3,8$$

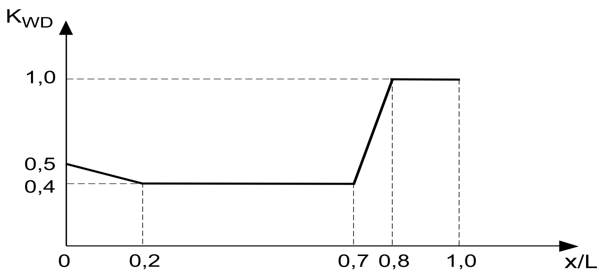
- for $x/L \geq 0{,}8$:
$K_{WD} = 1{,}0$

where x is the distance, in m, from the aft perpendicular to the load point,

V_X : ship's speed, in knots,

H_A : air gap, in m, equal to the distance between the waterline at draught T and the wet deck

Figure C3.5.2



.2 If the wet deck at a transverse section considered is not parallel to the design waterline, the impact pressure p_{sl} will be considered at the discretion of the Society.

C3.5.5 Sea pressures

C3.5.5.1 Sea pressure on bottom and side shell

.1 The sea pressure, in kN/m², considered as acting on the bottom and side shell is not less than p_{smin}, defined in Table C3.5.1, nor less than:

- for $z \leq T$:

$$p_s = 10 \cdot \left(T + 0,75 \cdot S - \left(1 - 0,25 \cdot \frac{S}{T}\right) \cdot z\right)$$

- for $z > T$:

$$p_s = 10 \cdot (T + S - z)$$

where:

z : vertical distance, in m, from the moulded base line to load point. z is to be taken positively upwards,

S : as given, in m, in Table C3.5.1 with C_B taken not greater than 0,5.

Table C3.5.1

	S	p_{smin}
x/L ≥ 0,9	$T \le 0,36 \cdot a_{CG} \cdot \frac{\sqrt{L}}{C_B} \le 3,5 \cdot T$	$20 \le \frac{L+75}{5} \le 35$
x/L ≤ 0,5	$T \le 0,60 \cdot a_{CG} \cdot \sqrt{L} \le 2,5 \cdot T$	$10 \le \frac{L+75}{10} \le 20$

.2 Between midship area and fore end (0,5 < x/L < 0,9), p_s varies in a linear way as follows:

$$p_s = p_{sFP} - (2,25 - 2,5 \cdot x/L) \cdot (p_{sFP} - p_{sM}))$$

where p_{sFP} is the sea pressure at fore end and p_{sM} in midship area.

C3.5.5.2 Stern doors and side shell doors

.1 The sea pressures on stern doors and side shell doors is to be taken according to C3.5.5.1 for scantlings of plating and secondary members.

.2 The design forces, in kN, considered for the scantlings of primary members are to be not less than:

- external force: $F_e = A \cdot p_s$
- internal force: $F_i = F_o + 10 \cdot W$

where:

A : area, in m, of the door opening,

W : mass of the door, in t,

F_p : total packing force in kN. Packing line pressure is normally not to be taken less than 5 N/mm,

F_o : the greater of F_c and $5 \cdot A$ (kN),

F_c : accidental force, in kN, due to loose of cargo etc., to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors, such as bunker doors and pilot doors, the value of F_c may be appropriately reduced. However, the value of F_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental forces due to loose cargoes,

p_s : sea pressure as defined in C3.5.5.1

.3 The design forces, in kN, considered for the scantlings of securing or supporting devices of doors opening outwards are to be not less than:

- external force: $F_e = A \cdot p_s$
- internal force: $F_i = F_o + 10 \cdot W + F_p$

where the parameters are defined in C3.5.5.2.2.

.4 The design forces, in kN, considered for the scantlings of securing or supporting devices of doors opening inwards are to be not less than:

- external force: $F_e = A \cdot p_s + F_p$
- internal force: $F_i = F_o + 10 \cdot W$

where the parameters are defined in C3.5.5.2.2.

C3.5.6 Sea pressures on front walls of the hull

.1 The pressure, kN/m², considered as acting on front walls of the hull (in case of stepped main deck), not located at the fore end, is not less than:

$$p_{sf} = 6 \cdot \left(1 + \frac{x_1}{2 \cdot L(C_B + 0,1)}\right)(1 + 0,045 \cdot L - 0,38 \cdot z_1)$$

where:

x_1 : distance, in m, from front walls to the midship perpendicular (for front walls aft of the midship perpendicular, x_1 is equal to 0),

z_1 : distance, in m, from load point to waterline at draught T.

Where front walls are inclined backwards, the pressure calculated above can be reduced to (p_{sF} sin α), where α is the angle in degree between front wall and deck.
p_{sF} is not less than the greater of:
$3 + (6,5 + 0,06 \cdot L) \cdot \sin\alpha$
$3 + 2,4 \cdot a_{CG}$

.2 For front walls located at the fore end, the pressure p_{sF} will be individually considered by the Society.

C3.5.7 Sea pressures on deckhouses

.1 The pressure, kN/m², considered as acting on walls of deckhouses is not less than:

$$p_{su} = K_{su} \cdot \left(1 + \frac{x_1}{2 \cdot L(C_B + 0,1)}\right)(1 + 0,045 \cdot L - 0,38 \cdot z_1)$$

where:

K_{su} : coefficient equal to:

- for front walls of a deckhouse located directly on the main deck not at the fore end:
  $K_{su} = 6,0$
- for unprotected front walls of the second tier, not located at the fore end:
  $K_{su} = 5,0$
- for sides of deckhouses, b being the breadth, in m, of the considered deckhouse:
  $K_{su} = 1,5 + 3,5$ b/B (with 3 <= K <= 5)
- for the other walls:
  $K_{su} = 3,0$

x_1 : distance, in m, from front walls or from wall elements to the midship perpendicular (for front walls or side walls aft of the midship perpendicular, x_1 is equal to 0),

z_1 : distance, in m, from load point to waterline at draught T.

.2 The minimum values of p_{su}, in kN/m², to be considered are:

- for the front wall of the lower tier:
  $p_{su} = 6,5 + 0,06 \cdot L$
- for the sides and aft walls of the lower tier:
  $p_{su} = 4,0$
- for the other walls or sides:
  $p_{su} = 3,0$

.3 For unprotected front walls located at the fore end, the pressure p_{su} will be individually considered by the Society.

C3.5.8 Deck loads

C3.5.8.1 General

.1 The pressure, in kN/m², considered as acting on decks is given by the formula:

$p_d = p\ (1 + 0,4 \cdot a_v)$

where:

p : uniform pressure due to the load carried, kN/m². Minimum values are given in C3.5.8.2 to C3.5.8.6,

a_v : design vertical acceleration, defined in C3.3.

.2 Where decks are intended to carry masses of significant magnitude, including vehicles, the concentrated loads transmitted to structures are given by the corresponding static loads multiplied by $(1 + 0,4\ a_v)$.

C3.5.8.2 Weather decks and exposed areas

.1 For weather decks and exposed areas without deck cargo:

- if $z_d \leq 2$:
  $p = 6,0$ kN/m²
- if $2 < z_d < 3$:
  $p = (12 - 3\ z_d)$ kN/m²
- if $z_d \geq 3$:
  $p = 3,0$ kN/m²

where z_d is the vertical distance, in m, from deck to waterline at draught T.

p can be reduced by 20% for primary supporting members and pillars under decks located at least 4 m above the waterline at draught T, excluding embarkation areas.

.2 For weather decks and exposed areas with deck cargo:

- if $z_d \leq 2$:
  $p = (p_c + 2)$ kN/m², with $p_c \geq 4,0$ kN/m²
- if $2 < z_d < 3$:
  $p = (p_c + 4 - z_d)$ kN/m², with $p_c \geq (8,0 - 2\ z_d)$ kN/m²
- if $z_d \geq 3$:
  $p = (p_c + 1)$ kN/m², with $p_c \geq 2,0$ kN/m²

where:

z_d : distance defined in C3.5.8.2.1,

p_c : uniform pressure due to deck cargo load, in kN/m², to be defined by the designer with the limitations indicated above.

C3.5.8.3 Sheltered decks

.1 They are decks which are not accessible to the passengers and which are not subjected to the sea pressures. Crew can access such deck with care and taking account of the admissible load, which is to be clearly indicated. Deckhouses protected by such decks may not have direct access to ‘tween-deck below.

For shelter decks:

$p = 1,3$ kN/m²

.2 A lower value may be accepted, at the discretion of the Society, provided that such a value as well as the way of access to the deck are clearly specified by and agreed upon with the Owner.

C3.5.8.4 Enclosed accommodation decks

.1 For enclosed accommodation decks not carrying goods:

$p = 3,0$ kN/m²

p can be reduced by 20 per cent for primary supporting members and pillars under such decks.

.2 For enclosed accommodation decks carrying goods:

$p = p_c$

The value of p_c is to be defined by the designer, but taken as not less than 3,0 kN/m².

C3.5.8.5 Enclosed cargo decks

.1 For enclosed cargo decks other than decks carrying vehicles:

$p = p_c$

where p_c is to be defined by the designer, but taken as not less than 3,0 kN/m².

For enclosed cargo decks carrying vehicles, the loads are defined in C3.5.8.7.

C3.5.8.6 Platforms of machinery spaces

.1 For platforms of machinery spaces:

$p = 15{,}0\ kN/m^2$

C3.5.8.7 Decks carrying vehicles

.1 The scantlings of the structure of decks carrying vehicles are to be determined by taking into account only the concentrated loads transmitted by the wheels of vehicles, except in the event of supplementary requirement from the designer.

.2 The scantlings under racking effects (e.g. for combined loading condition 3 defined in C3.6.1.2.9 and C3.6.2.2.9) of the primary structure of decks carrying vehicles is to be the greater of the following cases:

- scantlings determined under concentrated loads transmitted by the wheels of vehicles,
- scantlings determined under a uniform load pc taken not less than 2,5 kN/m^2. This value of p_c may be increased if the structural weight cannot be considered as negligible, to the satisfaction of the Society.

C3.5.9 Pressures on tank structures

.1 The pressure, in kN/m^2, considered as acting on tank structures is not less than the greater of:

$$p_{t1} = 9,81 \cdot h_1 \cdot \rho \cdot (1 + 0,4 \cdot a_v) + 100 \cdot p_v$$
$$p_{t2} = 9,81 \cdot h_2$$

where:

h_1 : distance, in m, from load point to tank top,

h_2 : distance, in m, from load point to top of overflow or to a point located 1,5 m above the tank top, whichever is greater,

ρ : liquid density, in t/m^3 (1,0 t/m^3 for water),

p_v : setting pressure, in bars, of pressure relief valve, when fitted.

C3.5.10 Pressures on subdivision bulkheads

.1 The pressure, in kN/m^2, considered as acting on subdivision bulkheads is not less than:

$p_{sb} = 9{,}81 \cdot h_3$

where:

h_3 : distance, in m, from load point to bulkhead top.

C3.6 Direct calculations for monohulls and catamarans

C3.6.1 Direct calculations for monohulls

C3.6.1.1 General

.1 Direct calculations generally require to be carried out, in the opinion of the Society, to check primary structures for craft of length L > 65 m or speed V > 45 knots.

.2 In addition, direct calculations are to be carried out to check scantlings of primary structures of craft whenever, in the opinion of the Society, hull shapes and structural dimensions are such that scantling formulas in C3.7 and C3.8 are no longer deemed to be effective.

.3 This may be the case, for example, in the following situations:

- elements of the primary transverse ring (beam, web and floor) have very different cross section inertiae, so that the boundary conditions for each are not well-defined,
- marked V-shapes, so that floor and web tend to degenerate into a single element,
- complex, non-conventional geometries,
- presence of significant racking effects (in general on ferries),
- structures contributing to longitudinal strength with large windows in side walls.

C3.6.1.2 Loads

.1 In general, the loading conditions specified in C3.6.1.2.6 to C3.6.1.2.9 below are to be considered.
Condition C3.6.1.2.9 is to be checked for craft for which, in the opinion of the Society, significant racking effects are anticipated (e.g. for ferries).

.2 In relation to special structure or loading configurations, should some loading conditions turn out to be less significant than others, the former may be ignored at the discretion of the Society. In the same way, it may be necessary to consider further loading conditions specified by the Society in individual cases.

.3 The vertical and transverse accelerations are to be calculated as stipulated in C3.3.

.4 The impact pressure is to be calculated as stipulated in C3.5. For each floor, the K_2-factor which appears in the formula for the impact pressure is to be calculated as a function of the area supported by the floor itself.

.5 In three-dimensional analyses, special attention is to be paid to the distribution of weights and buoyancy and to the dynamic equilibrium of the craft.
In the case of three-dimensional analyses, the longitudinal distribution of impact pressure is to be considered individu-