International Standard

ISO 12215-9

Small craft — Hull construction and scantlings —

Part 9:
Sailing craft appendages

Petits navires — Construction de coques et échantillons —

Partie 9: Appendices des bateaux à voiles

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 188, *Small craft*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 464, *Small Craft*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 12215-9:2012), which has been technically revised.

The main changes are as follows:

— considerations of canting keel actuator and keel support structure have been added to Table 3;

— Annex A is now required to be completed in all instances;

— a qualified backing plate diameter and thickness treatment in the case of reduced hull thickness has been added to Table D.2;

— a specific caution about bolt proximity to welds has been added in D.4.7;

— in Annex F, the operational life has been doubled to 16 million stress cycles and the associated MSF calculation revised.

A list of all parts in the ISO 12215 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

This document recognizes the importance of adequate scantlings, construction practice and condition assessment for sailing craft appendages, principally the ballast keel.

The loss of a ballast keel leading to craft capsize is one of the major casualty hazards on sailing craft and therefore the structural effectiveness of all elements of the keel and its connection to the craft is paramount.

This document specifies the design loads and their associated stress factors. The user (e.g. the designer or builder) then has a choice of one of the following two options to assess the structural arrangement:

a) Use of computational methods which allow the structure to be modelled three-dimensionally. Methods include finite element analysis, matrix displacement or framework methods, following which Annex A is completed for compliance. General guidance is provided on modelling assumptions in Clause 8.

b) Use of simplified two-dimensional stress formulae. These are presented in Annexes B to F and, if this option is chosen, use of all applicable annexes will be necessary to fulfil the requirements of this document, following which Annex A is completed for compliance.

This document has been developed in consideration of current practice and sound engineering principles. The design loads and criteria of this document may be used with the scantling determination formulae of this document or using equivalent engineering methods as indicated in a) above.

This document reflects current practice, provided the craft is correctly handled in accordance with good seamanship, is well designed and built, maintained, equipped and operated at a speed appropriate to the prevailing sea state. Inspection of all appendages after grounding is essential.

NOTE Compliance with this document will not ensure a satisfactory design in all cases nor absolve the user, such as the designer or builder, of their design responsibilities, with whom such responsibilities are entirely vested.

Racing craft are not the principal focus of the ISO 12215 series. In particular, users are strongly cautioned against attempting to design scantlings for racing craft such that scantlings only just comply.

Small craft — Hull construction and scantlings —

Part 9:
Sailing craft appendages

1 Scope

This document defines the loads and specifies the scantlings of sailing craft appendages on monohull sailing craft with a length of hull (L_H) measured in accordance with ISO 8666 or a load line length (see ISO 12215-5:2019, Clause 1, NOTE 1) of up to 24 m. It gives:

— design stresses;

— the structural components to be assessed;

— load cases and design loads for keel, centreboard and their attachments;

— computational methods and modelling guidance;

— the means for compliance with its provisions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 898-1, *Mechanical properties of fasteners made of carbon steel and alloy steel — Part 1: Bolts, screws and studs with specified property classes — Coarse thread and fine pitch thread*

ISO 3506-1, *Fasteners — Mechanical properties of corrosion-resistant stainless steel fasteners — Part 1: Bolts, screws and studs with specified grades and property classes*

ISO 12215-5:2019, *Small craft — Hull construction and scantlings — Part 5: Design pressures for monohulls, design stresses, scantlings determination*

ISO 12217-1, *Small craft — Stability and buoyancy assessment and categorization — Part 1: Non-sailing boats of hull length greater than or equal to 6 m*

ISO 12217-2, *Small craft — Stability and buoyancy assessment and categorization — Part 2: Sailing boats of hull length greater than or equal to 6 m*

ISO 12217-3, *Small craft — Stability and buoyancy assessment and categorization — Part 3: Boats of hull length less than 6 m*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
design category
description of the sea and wind conditions for which a craft is assessed to be suitable

Note 1 to entry: The design categories are defined in the ISO 12217 series.

Note 2 to entry: The definitions of design categories are in line with the European Recreational Craft Directive 2013/53/EU[11].

3.2
loaded displacement
m_{LDC}
mass of the craft, including all appendages, when in fully loaded ready for use condition

Note 1 to entry: The fully loaded ready for use condition is further defined in ISO 8666.

3.3
sailing craft
craft for which the primary means of propulsion is wind power

Note 1 to entry: It is further defined in ISO 8666.

3.4
mass of keel
m_{KEEL}
mass of the ballast keel, i.e. keel fin plus bulb, where fitted, and, for twin or multiple keels, of a single keel

4 Symbols

For the purposes of this document, unless specifically otherwise defined, the symbols given in Table 1 apply.

Table 1 — Nomenclature

Symbol	Unit	Designation/meaning of symbol	Clause/subclause
A_{CB}	m^2	Area of fully deployed centreboard	7.7.1
A_S	m^2	Reference sail area (mainsail + fore triangle + wing mast) as per ISO 12217-2	7.7.1
a	m	Distance along keel centreline, from centre of gravity (CG) of keel to keel junction with hull or stub	7.2
b_f	mm	Overall breadth of the appendage aerofoil section	E.1
c	m	Distance along keel centreline from keel junction to floor mid-height	7.2
c_a	m	Average value of c for several floors	7.5
d	mm	Selected keel bolt nominal diameter (may exceed d_{req})	B.5.2
d_i	mm	Diameter of ith keel bolt considered (i = 1, 2, etc.)	D.4.4, D.4.5
d_{neck}	mm	Keel bolt neck diameter	D.4.1
d_{ineck}	mm	Neck diameter of ith keel bolt considered (i = 1, 2, etc.)	D.4.4.2
d_{req}	mm	Calculated keel bolt nominal diameter for load case 1 or load case 4	D.4
d_3	mm	ISO-specific designation for d_{neck}	Table D.1
e	—	Proportion of the total side force taken by the centreboard	7.7.1
F_i	N	Design force with i according to load case	7
g	m/s^2	Acceleration of gravity = 9,81 m/s^2	7
h_{CE}	m	Height of centre of area of A_S	7.7.1
h_K	m	Height of keel between its bottom and hull connection	7.5
h_{F4}	m	Height of application of force F_4 (load case 4)	7.5

Table 1 *(continued)*

Symbol	Unit	Designation/meaning of symbol	Clause/subclause
I_L	cm^4	Longitudinal second moment appendage aerofoil section	E.2.2
I_T	cm^4	Transverse second moment of area	E.2.1
k_{DC}	—	Design category coefficient	Table 2
k_f	—	Appendage section shape factor	Table E.1
k_{f1}	—	Appendage section shape factor	Table E.1
k_{LC}	—	Load case coefficient	Table 3
k_{LD}	—	Length displacement coefficient	7.7.1
k_{MAT}	—	Material coefficient	Table 2
L_f	mm	Chord length of appendage aerofoil section	E.1
L_F	m	Transversal length of a floor, which is the distance between points where vertical loads are transferred to the structure	C.1.2
L_{WL}	m	Length of waterline in m_{LDC} conditions	7.7.1
m_{LDC}	kg	See 3.2	3.2, 7
m_{KEEL}	kg	See 3.4	3.4, 7.4
m_{IJ}	N·m	Design bending moment, with index I and J according to load case	7
M_{RUP}	N·m	Righting moment when the craft is sailing upwind, which shall be taken as the moment at 30° heel unless otherwise documented	7.7
n_{PR}	—	Minimal required number of persons for recovering from capsize in accordance with the ISO 12217 series	7.6
P	mm	Keel bolt thread pitch	D.4.1
SM_K	cm^3	Transverse section modulus of the ballast keel about its neutral axis	D.3.1
SM_L	cm^3	Appendage aerofoil shape longitudinal section modulus	E.2.2
SM_T	cm^3	Appendage aerofoil shape transverse section modulus	E.2.1
SM_{To}	cm^3	Torsional section modulus	E.3
st_i	N/mm^2	Stress, which can be σ or τ, and where i can be LIM, d, u, y, yw or uw	5
t_f	mm	Wall thickness of hollow appendage aerofoil section	E.1
V	knots	Maximum speed of the craft in the minimum operation condition, m_{MOC}	7.7
α	°	Angle of attack of centreboard	7.7.1
ε_R	%	Elongation at break	Table B.2
θ	°	Angle between keel axis and centreline for canting keels	7.3.1

5 Design stresses

The maximum stress shall be calculated for each relevant structural component and load case.

The design stress, st_d, expressed in N/mm^2, is the relevant limit stress multiplied by various stress coefficients, as shown by Formula (1):

$$st_d = st_{LIM} \times k_{MAT} \times k_{LC} \times k_{DC} \tag{1}$$

where

st_{LIM} is the limit stress, with st representing either σ, the direct stress, or τ, the shear stress, and index LIM is as follows:

— for metal in the unwelded state or well clear of the heat affected zone (HAZ), min(st_y;0,5 × st_u) where index y is the yield strength and index u is the ultimate strength, i.e. σ_y,σ_u for direct stress, τ_y,τ_u for shear stress and σ_{yb},σ_{ub} for bearing stress;

— for metal within the HAZ, min(st_{yw};0,5 × st_{uw}) where index y is the yield strength and index u is the ultimate strength, i.e. σ_{yw},σ_{uw}, for direct stress, τ_{yw},τ_{uw}, for shear stress and for σ_{ybw},σ_{ubw} bearing stress;

— for wood and fibre-reinforced polymer (FRP), the ultimate strength in tensile σ_{ut}, compressive σ_{uc}, flexural σ_{uf}, bearing, σ_{ub} or shear stress τ_u;

k_{MAT} is the material coefficient as defined in Table 2, with the design stress adjusted according to the material;

k_{LC} is the load case coefficient as defined in Table 3, with the design stress adjusted according to the load case;

k_{DC} is the design category coefficient as defined in Table 2, with allowance for an increase in design stress for lower design categories.

NOTE 1 Table 2 gives details on these variables.

The values of st_{LIM} (i.e. σ_y,σ_u,τ_u for unwelded metals, σ_{yw},σ_{uw},τ_{yw},τ_{uw} for welded metals in a HAZ, or σ_{ut}, σ_{uc}, σ_{uf}, σ_{ub} or τ_u for wood and FRP) shall be taken:

— in accordance with ISO 12215-5:2019, Annexes C, E and F, i.e. according to tests or default values specified for FRP, sandwich core, and laminated wood and plywood, respectively;

— in accordance with ISO 3506-1 for stainless steel fasteners and ISO 898-1 for carbon steel or alloy steel fasteners.

NOTE 2 See Annex B for listed metals.

Table 2 — Design stresses and stress coefficients

Variable	Material/designation	Value
st_{LIM}	Metals, unwelded or well clear of HAZ[a]	min(st_y;0,5 × st_u)[b,c]
	Metals, within HAZ, in welded condition[a]	min(st_{yw};0,5 × st_{uw})[b,c]
	Wood or FRP as dictated by sense of applied stress	σ_{uc}, σ_{ut}, σ_{uf}, σ_{ub} and τ_u as relevant[c]
k_{MAT}	**Stress factor**	
	Metals with elongation at break, $\varepsilon_R \geq 7$ %	0,75
	Metals with elongation at break, $\varepsilon_R < 7$ %	min.(0,062 5ε_R + 0,312 5;0,75)[d]
	Wood and FRP	0,33[e]
k_{LC}	**Stress factor** (see Table 3)	

[a] The heat-affected zone shall be considered as being 50 mm from the weld as specified in F.3.4.3.

[b] For metals, $\tau = 0{,}58 \times \sigma$.

[c] Bearing stress depends on material type (typically, σ_{ub}/σ_{uc} = 2,8 for glass chopped strand mat (CSM) and 0,91 for roving). Metals usually attract 2,4 to 3,0 for bolts (but with restrictions: far from edges, minimum bolt spacing, minimum thickness/bolt d).

[d] The factor gives 0,75 for $\varepsilon_R \geq 7$ %, and 0,375 for $\varepsilon_R = 1$ % and linear interpolation in between. Values of ε_R shall be in accordance with Table B.2.

[e] For wood and FRP, k_{MAT} can be reduced (i.e. design stress reduced and factor of safety increased) and shall be in accordance with the appropriate k_{BB} (FRP only; to avoid doubt, for wood k_{BB} = 1,0) and k_{AM} (FRP and wood) as specified in ISO 12215-5:2019, Table 15 and Table 16, respectively. For example, in an instance where k_{BB} = 0,75 and k_{AM} = 0,9, k_{MAT} would become 0,33 × 0,75 × 0,9 = 0,22. If k_{BB} = 1,0 and k_{AM} = 1,0, k_{MAT} remains 0,33.

Table 2 *(continued)*

Variable	Material/designation	Value
	Stress factor	
k_{DC}	Craft of design categories A and B	1,00
	Craft of design categories C and D	1,25

[a] The heat-affected zone shall be considered as being 50 mm from the weld as specified in F.3.4.3.

[b] For metals, $\tau = 0{,}58 \times \sigma$.

[c] Bearing stress depends on material type (typically, σ_{ub}/σ_{uc} = 2,8 for glass chopped strand mat (CSM) and 0,91 for roving). Metals usually attract 2,4 to 3,0 for bolts (but with restrictions: far from edges, minimum bolt spacing, minimum thickness/bolt d).

[d] The factor gives 0,75 for $\varepsilon_R \geq 7$ %, and 0,375 for $\varepsilon_R = 1$ % and linear interpolation in between. Values of ε_R shall be in accordance with Table B.2.

[e] For wood and FRP, k_{MAT} can be reduced (i.e. design stress reduced and factor of safety increased) and shall be in accordance with the appropriate k_{BB} (FRP only; to avoid doubt, for wood k_{BB} = 1,0) and k_{AM} (FRP and wood) as specified in ISO 12215-5:2019, Table 15 and Table 16, respectively. For example, in an instance where k_{BB} = 0,75 and k_{AM} = 0,9, k_{MAT} would become 0,33 × 0,75 × 0,9 = 0,22. If k_{BB} = 1,0 and k_{AM} = 1,0, k_{MAT} remains 0,33.

Table 3 — Value of k_{LC} stress factor according to load case

Load case	Load case description of keels and appendages	Subclause	Value of k_{LC}
1	Keel bolt[a]	7.2	0,67
	Other elements of fixed keel: metal	—	0,8
	Other elements of fixed keel: FRP[b]	—	0,9
2	Canting keel: metal	7.3	0,8
	Canting keel: FRP	7.3	0,9
	Canting keel: metallic actuator/metallic actuator and keel support structure	7.3	0,8
	Canting keel: FRP actuator/FRP actuator and keel support structure	7.3	0,9
3	Keel vertical pounding	7.4	1
4	Keel longitudinal impact	7.5	1
5	Dinghy capsize recovery (strength of centre/dagger board)	7.6	1,34
6	Centre/dagger board upwind	7.7	1,0

NOTE The design stress of bolts is lower than that of other structural components in recognition of stress concentration effects in bolts, according to long-standing practice.

[a] Load case 1 treats bolts differently from other structural components.

[b] Caution: The requirements of this document are based on strength criteria. In some cases, such as keel fins constructed of lower modulus materials, the need to limit deflections and/or increase natural frequencies can require a substantial increase in scantlings above those requirements. Such cases are outside the scope of this document.

6 Structural components to be assessed

CAUTION — Keel loss can be attributed to insufficient thickness of bottom plating in the keel region. In particular, connecting bolts or inadequately assessed load paths between connecting bolts and the corresponding structure and bolts located too far from the relevant stiffener are causative. It is strongly recommended that the provisions of Clause D.5 and Table D.2 should be followed and, in particular, for bolts located too far from a stiffener, those provisions of Table D.2, item 3.

Keel loss can also be attributed to insufficient fatigue strength. Fabricated (usually welded) metal keel fins are particularly susceptible to fatigue. In such cases, fatigue shall be considered and assessed and the provisions in Annex F or other suitable fatigue design methods shall be followed.

The following shall be considered when assessing or designing the structure covered by this document:

— Keel-to-hull connection (bolts, wedge connection, stub keel, etc.), see Figures 1, C.3, C.4 and D.1.

— Bottom shell plating in respect of the keel bolts and transition arrangements beyond the keel bolting zone into the hull structure. Keels should not be bolted to a hull bottom of sandwich construction. The structural arrangement shall ensure that all loads (keel compression loads, bolt preload, etc.) are safely transferred.

NOTE 1 The terms “pre-stress” and “preload” are used interchangeably.

— Backing plates (usually rectangular steel plates installed on the hull plating inner surface that spread load)/steel washers (annular, placed under securing nuts or bolt heads).

— Floors, girders and associated supporting structure.

— Keel boxes, canting keel actuators and support structure.

— Fins, centreboards, dagger boards of aerofoil cross-section.

NOTE 2 Hydrofoils are not considered.

Assessment shall be conducted either by numerical methods in accordance with Clause 8 or the established practice methods given in Clause 9.

Table 4 describes the step-by-step procedure to establish compliance of the structural components.

Table 4 — Procedure to establish compliance

Step	Subject	Clause/subclause
1	Design stresses	5
2	Structural components to be assessed	6
3	Load cases	7
The structural analysis and scantlings determination shall be achieved using one of the two methods listed in Step 4 or 5:		
4	Calculation by computational 3D numerical procedures including fatigue as required	8.1, 8.2
5	Calculation by simplified strength assessment methods including fatigue as required	8.1, 8.3 and Annexes B to F
6	Compliance and completion of Annex A	9, Annex A

7 Load cases

7.1 General

7.1.1 Status of design load cases

CAUTION — For load cases 1 and 2, where keels have a large sweep angle, the centre of gravity (CG) of the bulb/fin can be located a significant distance aft or forward of the fin or bolt group longitudinal centre at the root. This will induce a torsional moment in addition to the bending moment. In such cases the direct stresses due to bending shall be combined with shear stresses due to torsion (the von Mises equivalent stress) and shall not exceed the design stress given in Formula (1), also noting 7.8.

The design stress shall be assessed for each load case using Formula (1), together with the design stress coefficients given in Table 2 and Table 3, as follows:

— 7.2 defines the fixed keel 90° knockdown load case 1 and corresponding force, F_1, and design bending moment, M_1, at 90° heel, for the keel at its root/bolt level and floor neutral axis, respectively; it shall be used for fixed keels, either vertical or angled as in the case of twin keel craft, and axially lifting or swing ballast keels;

— 7.3 defines canted keel load case 2 and the corresponding force, F_2, and design bending moment, M_2, at 30° steady heel plus a dynamic overload factor; it shall only be used for canting keels;

— 7.4 defines vertical pounding load case 3 and design vertical force, F_3;

— 7.5 defines longitudinal impact load case 4 and design horizontal force, F_4, that considers a longitudinal impact with a fixed or submerged object or marine life;

— 7.6 defines dinghy capsize recovery load case 5 and the design vertical force, F_5, in 90° knockdown, applied on the tip of a centreboard for dinghy capsize recovery;

— 7.7 defines centreboard/dagger board load case 6 and the transverse horizontal force, F_6, applied to centreboard or dagger board used while sailing upwind;

— 7.8 considers other load cases, particularly where specific designs cause combined stresses.

7.1.2 Limitation of load cases

This document is based on the presumption that load magnitudes are set at such a high level of severity that the number of expected occurrences during the lifetime of the craft will be low. Hence, all load cases are considered to be static and used in conjunction with static design stresses according to Tables 2 and 3.

For keels of welded construction, compliance with the static load cases cannot guarantee that fatigue failure due to cyclic loading will not occur. In such cases, an explicit fatigue life assessment and inspection regime shall be implemented.

NOTE 1 See Annexes A and F for fatigue life assessment and inspection regime.

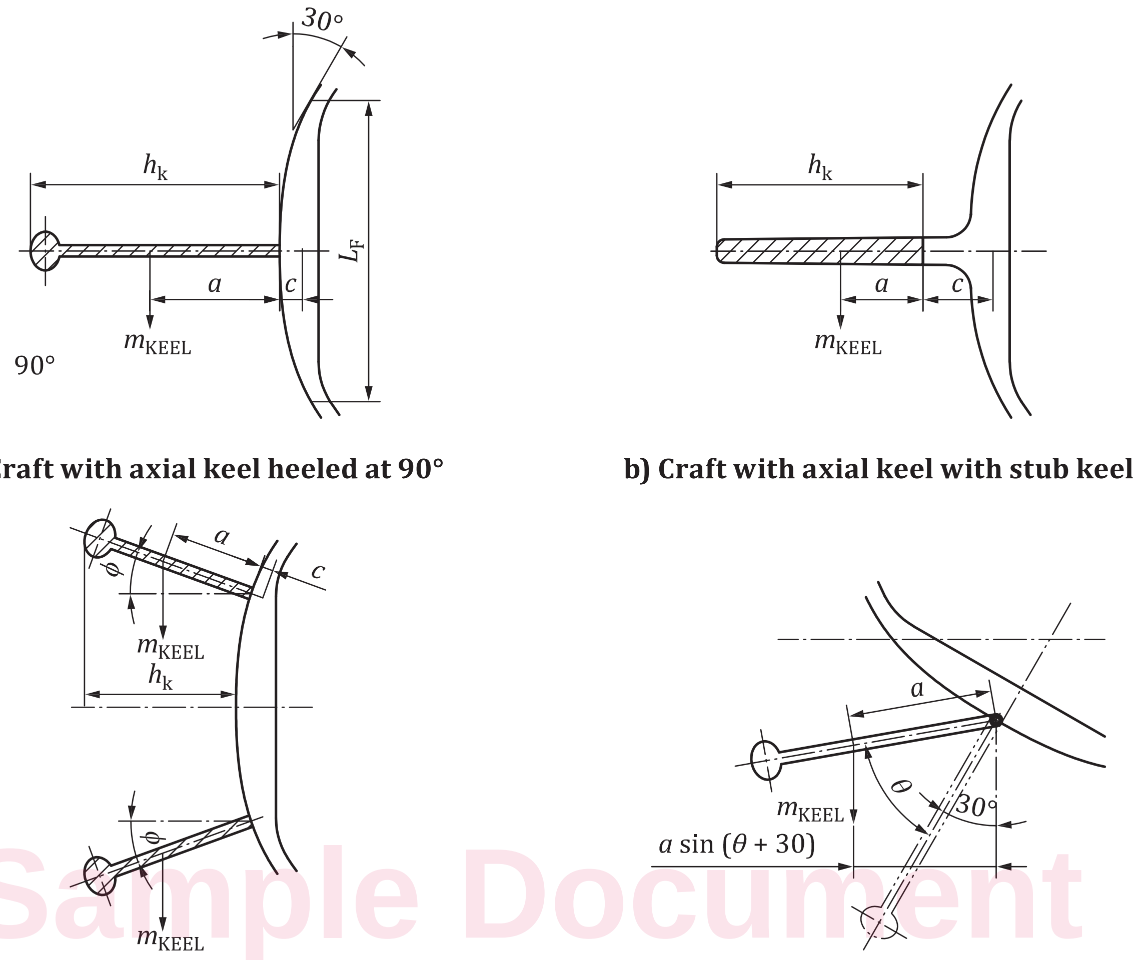
NOTE 2 It is of the utmost importance that the response of structures experiencing cyclic loading is less than the fatigue strength. Fatigue analysis is required when the stresses are high in magnitude and when structures feature welds that require detailed design and documentation.

Keel configurations resembling the types shown in Figure C.4 require case-by-case consideration.

NOTE 3 In addition, the load cases consider that, for bolted connections, the methods for assessing keel bolts are based on the presumption of a broadly uniform distribution of diameter and spacing along the fin root or keel flange (see Clause D.4 for details).

7.2 Load case 1 — Fixed keel at 90° knockdown

7.2.1 This case corresponds to a 90° knockdown case (heeled at 90°) (see Figure 1), which is usually the most severe transverse bending load for fixed ballast keels.



a) Craft with axial keel heeled at 90°

b) Craft with axial keel with stub keel

c) Craft with twin keels heeled at 90°

d) Craft with canting keel heeled at 30°

Figure 1 — Sketch of fixed axial keel, twin keels and laterally canting keel

Calculate the vertical force at 90° knockdown exerted by gravity at the keel CG, F_1, expressed in N, using Formula (2):

$$F_1 = m_{KEEL} \times g \tag{2}$$

Calculate the keel heeling design bending moment at the keel junction, $M_{1.1}$, expressed in N·m, using Formula (3):

$$M_{1.1} = F_1 \times a \tag{3}$$

Calculate the keel heeling design bending moment at floor mid-height, $M_{1.2}$, expressed in N·m, using Formula (4):

$$M_{1.2} = F_1 \times (a + c) \tag{4}$$

where

a	is the distance, in m, along the keel centreline, from the keel CG to the keel's junction with the hull or stub;
c	is the distance, in m, along the keel centreline from the keel junction to the floor at mid-height;
g	is the acceleration due to gravity, taken as 9,81 m/s^2 and used throughout this document.

The craft's structure, keel connection and stiffeners shall be able to withstand this force and moments.

NOTE 1 Annex C provides information on how to calculate the shear force and bending moment on each floor when these are analysed as independent beams.

NOTE 2 For single fixed keels, when considered parallel to the centreline, these bending moments correspond to a heel angle of 90° knock-down. For fixed twin keels [see Figure 1 c)], the cosine of angle ϕ from the horizontal when the craft is knocked down is not considered, as the keels will be parallel to the waterline at some point before or after the craft reaches 90° of heel.

7.2.2 For craft fitted with a fin and stub [see Figure 1 b)], the user should consider a range of values of c to establish the most highly stressed point.

7.3 Load case 2 — Canted keel steady load at 30° heel with dynamic overload factor

7.3.1 General

This case shall only apply to canting keels as illustrated in Figure 1 d) and corresponds to a steady heel at 30° that can be experienced as a long-term load, with an additional dynamic overload factor which represents the additional fluctuating load experienced as the craft responds to the seaway.

Load case 2 represents the normal sailing condition for a craft with canted keel, but is augmented by a 40 % dynamic overload factor to allow for unusual combinations of rigid body motions and accelerations, and is thereby considered to constitute an infrequently occurring case. Fatigue shall be considered and assessed in calculations, in accordance with 7.1.2.

NOTE 1 The dynamic overload factor for normal sailing conditions is in the order of 15 % to 20 % but can be higher.

Calculate the vertical force exerted by gravity at the keel CG, F_2, expressed in N, using Formula (5):

$$F_2 = 1{,}4 \times m_{\text{KEEL}} \times g \quad (5)$$

Calculate the canting keel design bending moment when heeling at the keel junction, $M_{2.1}$, expressed in N·m, using Formula (6):

$$M_{2.1} = F_2 \times a \times \sin(30° + \theta) \quad (6)$$

where θ is the maximum canting angle from axial (vertical) plane. It shall not be taken as greater than 60° or less than 30°.

NOTE 2 The lower limit of 30° ensures a load at least 22 % greater than load case 1.

NOTE 3 Very thin fins of a canting keel, especially those of FRP construction, often require "flutter" (vibration) analysis, but this is considered outside the scope of this document (see 7.1.2 and Annex F).

For calculation of floors,

Calculate the canting keel design bending moment when heeling of supporting structure floors, $M_{2.2}$, expressed in N·m, using Formula (7):

$$M_{2.2} = F_2 \times [a \times \sin(30° + \theta) + 0{,}5c] \quad (7)$$

The craft structure, keel connection and stiffeners shall be able to withstand this force and moments.

NOTE 4 Annex C provides information on how to calculate the shear force and bending moment on each of the two "wet-box" bulkheads when these can be analysed as independent beams.

7.3.2 Specific requirements for canting keel structure

The canting keel system shall be fitted with a box that is watertight.