

Maritime works –

Part 4: Code of practice for design of fendering and mooring systems

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Contents

Foreword *iii*

Section 1: General 1

- 1 Scope 1
- 2 Normative references 1
- 3 Terms, definitions and symbols 2

Section 2: Fendering 4

- 4 General principles 4
 - 4.1 Provision and overall design of fendering systems 4
 - 4.2 Selection and design of fenders 7
 - 4.3 Vessel characteristics 7
 - 4.4 Fender layout for berths and other locations 9
 - 4.5 Berthing procedure 13
 - 4.6 Berthing reactions and load distribution 15
 - 4.7 Moored reactions 18
- 5 Calculation of berthing energies 18
 - 5.1 Characteristic and design berthing energy 18
 - 5.2 Calculation of characteristic berthing energies for alongside berthing 19
 - 5.3 Calculation of berthing energies for ferry and Ro-Ro berths 22
- 6 Selection of fenders and fender types 23
 - 6.1 General 23
 - 6.2 Materials and workmanship 23
 - 6.3 Fenders using elastomeric units 23
 - 6.4 Torsion arm fenders 25
 - 6.5 Pneumatic and foam-filled fenders 25
 - 6.6 Flexible dolphins 26
 - 6.7 Shear capacity of fenders 29
 - 6.8 Fender panels 29
 - 6.9 Mounting and suspension 30

Section 3: Mooring 32

- 7 Principles of good mooring 32
 - 7.1 General 32
 - 7.2 Mooring lines 32
 - 7.3 Mooring layouts 33
- 8 Actions acting on the moored vessel 36
 - 8.1 General 36
 - 8.2 Wind and currents 36
 - 8.3 Hydrodynamic forces 36
 - 8.4 Tidal rise and fall and change in draught or trim due to cargo operations 38
 - 8.5 Ice 38
- 9 Loads on mooring points 39
 - 9.1 General 39
 - 9.2 Calculation methods 39
 - 9.3 Design of mooring point structure 41
- 10 On-shore mooring equipment 41
 - 10.1 Materials 41
 - 10.2 Mounting and fixing 41
 - 10.3 Bollards 42
 - 10.4 Quick release mooring hooks 43
 - 10.5 Capstans 43
 - 10.6 Vacuum mooring systems 44

Bibliography 45

List of figures

- Figure 1 – Geometry of vessel with bulbous bow 8
Figure 2 – Hull and cope geometry at impact 10
Figure 3 – Fender layout on a continuous quay 10
Figure 4 – Fender layout for three island berth 11
Figure 5 – Fender layout for five island berth 12
Figure 6 – Geometry of vessel approach to berth 13
Figure 7 – Ferry and Ro-Ro vessel berthing 14
Figure 8 – Hull and fender geometry at impact 17
Figure 9 – Design berthing velocity as function of navigation conditions and size of vessel 20
Figure 10 – Flexible dolphins 28
Figure 11 – Typical mooring pattern for continuous quay 34
Figure 12 – Optimum angles of mooring lines for island tanker berth 35
Figure 13 – Vessel under influence of stand-off force 37
Figure 14 – Effect of rise and fall of tide and change in draught or trim 39

List of tables

- Table 1 – Typical fendering locations 5
Table 2 – Vessel categories 6
Table 3 – Guidance on hull pressure 16
Table 4 – Coefficients of friction of fender facing materials in dry conditions 29
Table 5 – Mooring point loads for general cargo vessels and bulk carriers 41
Table 6 – Mooring bollards 42

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 46, an inside back cover and a back cover.

Foreword

Publishing information

This part of BS 6349 is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 June 2014. It was prepared by Technical Committee CB/502, *Maritime works*. A list of organizations represented on this committee can be obtained on request to its secretary.

Supersession

This part of BS 6349 supersedes BS 6349-4:1994, which is withdrawn.

Relationship with other publications

BS 6349 is published in the following parts ¹⁾:

- Part 1-1: *General – Code of practice for planning and design for operations*;
- Part 1-2: *General – Code of practice for assessment of actions*; ²⁾
- Part 1-3: *General – Code of practice for geotechnical design*;
- Part 1-4: *General – Code of practice for materials*;
- Part 2: *Code of practice for the design of quay walls, jetties and dolphins*;
- Part 3: *Code of practice for the design of shipyards and sea locks*;
- Part 4: *Code of practice for design of fendering and mooring systems*;
- Part 5: *Code of practice for dredging and land reclamation*;
- Part 6: *Design of inshore moorings and floating structures*;
- Part 7: *Guide to the design and construction of breakwaters*;
- Part 8: *Code of practice for the design of Ro-Ro ramps, linkspans and walkways*.

Information about this document

This is a full revision of the standard, and introduces the following principal changes:

- reduction of informative content, with informative guidance separated from recommendations;
- general updating to reflect latest practice;
- change in definitions of berthing mode and navigation conditions.

Use of this document

As a code of practice, this part of BS 6349 takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

¹⁾ A new part 9 is in preparation.

²⁾ In preparation.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

Section 1: General

1 Scope

This part of BS 6349 gives recommendations and guidance on the design of fendering systems and layouts, mooring devices and mooring system layouts, principally for commercial vessels with a minimum displacement of 1 000 t.

NOTE Some of the provisions in this part of BS 6349 might be applicable to other type of vessels such as naval vessels, provided that the particular vessel characteristics and berthing/mooring procedures are taken into account.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Standards publications

ASTM F2192/05, *Standard test method for determining and reporting the berthing energy and reaction of marine fenders*

BS 6349-1:2000, *Maritime structures – Part 1: Code of practice for general criteria*

BS 6349-1-1:2013, *Maritime works – Part 1-1: General – Code of practice for planning and design for operations*

BS 6349-1-4, *Maritime works – Part 1-4: General – Code of practice for materials*

BS 6349-2, *Maritime works – Part 2: Code of practice for the design of quay walls, jetties and dolphins*

BS EN 1993 (all parts), *Eurocode 3 – Design of steel structures*

BS EN 1995 (all parts), *Eurocode 5 – Design of timber structures*

BS EN 60079-10-1, *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres*

BS ISO 17357 (all parts), *Ships and marine technology – Floating pneumatic rubber fenders*

Other publications

[N1] US ARMY CORPS OF ENGINEERS (USACE), NAVAL FACILITIES ENGINEERING COMMAND (NAVFAC), AIR FORCE CIVIL ENGINEER CENTER (HQ AFCEC) and NATIONAL AERONAUTICS AND SPACE ADMINISTRATION (NASA). *Unified facilities guide specifications – Division 35: Waterway and marine construction – Section 35.59.13.16: Marine fenders*. USACE/NAVFAC, 2011.³⁾

[N2] EUROPEAN ORGANISATION FOR TECHNICAL APPROVALS. *Design of bonded anchors*. TR 029. Brussels: EOTA, 2007.

³⁾ Available from <http://www.wbdg.org/ccb/DOD/UFGS/UFGS%2035%2059%2013.16.pdf> [last accessed 25 June 2014].

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this part of BS 6349, the terms and definitions given in BS 6349-1-1:2013 and the following apply.

3.1.1 berth

area in a port dedicated to the mooring of a vessel and typically equipped with fenders and mooring equipment

NOTE A berth for a large vessel can be used to moor two or more smaller vessels.

3.1.2 berthing line

seaward face of a berth including the uncompressed fendering system

3.1.3 cope

top edge of a quay or jetty adjacent to a berth

3.1.4 design vessel

vessel for which the fendering and mooring systems are designed to permit it to safely berth and be moored under the environmental operating limits

NOTE Where a berth is to accommodate a range of vessels, there will be several design vessels, including as a minimum both the largest and smallest.

3.1.5 fender

item of port equipment designed to keep a vessel from touching the berth structure without damaging itself or the vessel or the berth structure

NOTE The components of a fender can include one or more of the following:

- *energy absorbing unit(s), e.g.:*
 - *elastomeric unit(s);*
 - *pneumatic unit(s);*
 - *foam-filled unit(s);*
- *fender panel;*
- *facing material;*
- *fender pile;*
- *timber sections;*
- *fender chains:*
 - *to assist in supporting the static weight of fender panels;*
 - *to control movement of fender panel;*
 - *to prevent movement of panels out from berthing line.*

3.1.6 fendering system

all the fenders provided for a berth

3.1.7 flat side of vessel

part of the side of a vessel between the bow and stern that is flat, vertical and parallel to the axis of the vessel

NOTE Sometimes also referred to as parallel midships or parallel mid-body.

3.2 Symbols

For the purposes of this part of BS 6349, the following symbols apply.

B	beam of vessel, in metres (m)
C_b	block coefficient of the vessel hull
C_C	berth configuration coefficient
C_E	eccentricity coefficient
C_M	hydrodynamic mass coefficient
C_S	softness coefficient
D_v	draught of vessel, in metres (m)
d	deflection at the level of the application of the load, in metres (m)
E_C	characteristic energy to be absorbed by the fendering system, in kilonewton metres (kN·m)
E_D	design energy to be absorbed by the fendering system, in kilonewton metres (kN·m)
E_F	energy absorbed by the fender, in kilonewton metres (kN·m)
K	radius of gyration of vessel
L_{OA}	overall length of vessel, in metres (m)
L_{BP}	length of vessel hull between perpendiculars, in metres (m)
L_L	overall length of largest design vessel, in metres (m)
L_S	overall length of smallest design vessel, in metres (m)
M_D	displacement of vessel, in tonnes (t)
R	distance of the point of contact from the centre of mass of the vessel, in metres (m)
R_F	fender reaction, in kilonewtons (kN)
V	characteristic velocity of vessel in direction of approach, in metres per second (m/s)
V_B	characteristic velocity of vessel normal to the berthing line at the point of impact, in metres per second (m/s)
α	angle of approach of vessel
γ	angle between the line joining the point of contact to the centre of mass of the vessel and the normal to the axis of the vessel
μ	coefficient of friction

Section 2: Fendering

4 General principles

4.1 Provision and overall design of fendering systems

Berths should be provided with a suitable fendering system to protect berth structures and vessels from damage, taking into account operating conditions as defined in BS 6349-1-1:2013 and stated in the facility operating manual, unless a clear justification can be made that such a system is not required.

NOTE 1 Historically it has been the practice in some ports not to provide fendering to berths other than simple timber rubbing strips, particularly where they are situated in sheltered locations such as impounded dock basins. For commercial vessels, and where berths are situated in more exposed locations such as the outer reaches of rivers and in the open sea, fendering systems are widespread.

The fendering system should be designed taking account of:

- a) the range of vessels berthing;
- b) the methods used to berth the vessel;

NOTE 2 Where a vessel berthing alongside is manoeuvred by tugs and/or the use of thrusters, it is generally stopped a short distance off and parallel to the berth. The vessel is then pushed or warped slowly onto the berth, ideally achieving a gentle contact as near as parallel to the berthing line as possible.

NOTE 3 Tugs, launches and other small vessels tend to approach their berths more directly than large vessels.

NOTE 4 Ferries and roll-on/roll-off (Ro-Ro) vessels approach their berths in a different way, which is explained in 4.5.2.

- c) vessels moored during cargo handling operations;
- d) vessels moored during extreme events caused by adverse metocean or other conditions;
- e) the normal operating conditions of the berth;
- f) the risks and consequences as a result of an extreme or accidental event occurring;
- g) the features appropriate to the location of the berth, as shown in Table 1;
- h) the features appropriate to the characteristics of the vessels that are expected to use the berth, as shown in Table 2;
- i) the intended service life of the system, making due allowance for degradation and wear and tear during operations.

NOTE 5 The fendering system might need to be designed to work with the mooring system to reduce vessel movements.

NOTE 6 Fendering systems are required to be suitable for all operational water levels that might occur, and with large variations this becomes particularly important. Winds, waves, current and other factors also vary depending on the berth location.

Table 1 Typical fendering locations

Location	Features to be taken into account in the design of the fendering system
Impounded basins	Approximately constant water level Usually sheltered from high winds Limited fetch for local wave generation Negligible current Range of vessel sizes limited by lock dimensions
Tidal basins	Greater range of water levels than impounded basins Limited wave exposure Limited current
River berths	Variable water level due to changes in river discharge and possibly tide Limited wave exposure Variable current Possible restricted area available for manoeuvring of vessels
Estuarial and coastal berths	Maximum tidal range and currents Greater wave exposure than tidal basins Often dedicated berths with single class or type vessels
Exposed coastal berths	Full exposure to wind, wave and currents Usually specialized trades, e.g. bulk coal, ore, oil (products), LNG, LPG Single type vessels and handling equipment
Locks and lock entrances	Variable water level Limited lateral movement of vessels within the lock Large longitudinal movement of vessels

Table 2 Vessel categories

Category	Features to be taken into account in the design of the fendering system
Bulk carriers	Possible need to be warped along berth for shiploader to change holds Large change in draught between empty and fully laden conditions
Car carriers	Loading ramps, slewed or end loading (vessel mounted or shore based) High windage areas Vessels might have recessed bollards in hull End berthing
Container vessels	Extensive flared bows and sterns with liability to strike shore-side installations Particularly the larger vessels can have a relatively short length of flat side Potential high windage areas
General cargo vessels	Large change of draught between empty and fully laden conditions Possible long occupancy of berths
LNG/LPG carriers	Low allowable hull pressure Single type vessels using dedicated berth Need to avoid fire hazards from sparking or friction Relatively short length of flat side High windage areas
Miscellaneous tugs, supply boats, barges, lighters and fishing boats	Need robust fenders for heavy use Vessels are usually fitted with belting
Passenger liners	Little change of draught between empty and fully laden condition High windage areas Low allowable hull pressure
Roll on-roll off (Ro-Ro) vessels	Loading ramps, slewed or end loading (vessel mounted or shore based) End berthing High windage areas Vessels are usually fitted with belting Vessels usually berth without the aid of tugs
Tankers	Very low amidships freeboard for coastal tankers Large change in draught between empty and fully laden conditions Need to avoid fire hazards from sparking or friction
Train and vehicle ferries	Quick turnaround End berthing High berthing velocities Intensive use of berth High windage areas Vessels are usually fitted with belting Vessels usually berth without the aid of tugs

NOTE Most vessels have bulbous bows. Vessels from all categories could be fitted with belting, particularly smaller vessels.

4.2 Selection and design of fenders

NOTE 1 If the vessel comes alongside at a slight angle to the berth, it usually makes initial contact with one or two fenders. The vessel then rotates before impacting on further fenders.

NOTE 2 Generally, the fender loads during berthing are the controlling influence on the fender selection. However, for offshore ports and for ports with entrances in exposed locations, vessels might berth only during relatively benign conditions, and the greatest fender loading could occur when the vessel remains at the berth during storm events.

The fenders should be designed to protect the berth structure against damage from vessels and to limit the reactive forces on the vessel hull to acceptable values.

The range of available fenders of both proprietary and purpose-made types is considerable. Selection and design should take account of the factors listed in 4.1 together with:

- a) types and hull forms of the vessels that are expected to use the berth;
- b) velocity and angle at which the vessels berth;
- c) range of water levels and range of freeboards of vessels to be accommodated;
- d) offset of fender face to protect quayside equipment;
- e) limits to the distance between berth cope and side of hull after vessels are moored in relation to the outreach of oil loading arms, crane jibs, shiploader booms and similar equipment;
- f) spacing between fenders;
- g) movement of vessels while moored;
- h) number of energy absorbing units that absorb the initial impact energy;
- i) energy to be absorbed by the fenders, having regard to the location and approach conditions of the berth and its method of operation;
- j) reactive forces and deflections on both the berth structure and the vessel hull;
- k) acceleration and deflection limits on berths carrying quay equipment such as pipelines, rail-mounted cranes and shiploaders;
- l) number of fenders that resist the loads from a vessel when moored alongside;
- m) ease with which the berth can be accessed for the maintenance, repair and replacement of fenders and fender components, including facing materials;
- n) metocean actions on the fenders, including from ice and debris.

The design of the fenders should be integrated with that of the berth structure as not all types of fender are compatible with all types of structure.

4.3 Vessel characteristics

4.3.1 General

The characteristics of the design vessels for a particular berth should be established.

NOTE 1 Where specific data is not available, the data relating to appropriate vessels for the proposed berth as given in BS 6349-1-1:2013, Annex D or similar data sources may be used.

The design should allow for the vessel's hull form, e.g. large container vessels might have relatively short flat sides and fast ferries might have high sides with low allowable hull pressure.

NOTE 2 The vessel plans might be available to determine the vessel characteristics.

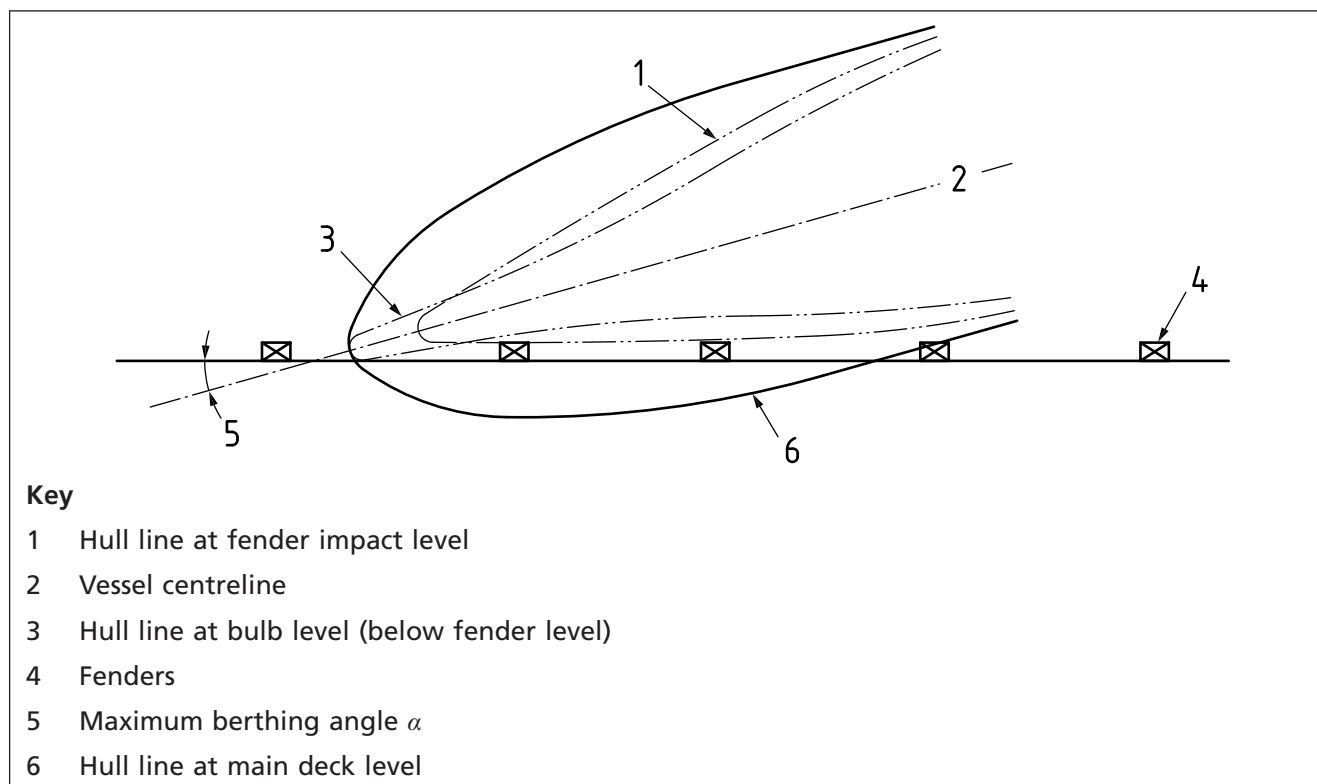
Where vessels are berthed in a partially laden condition, reference should be made to vessel plans, load-displacement curves or tables to ascertain the hull form and other vessel characteristics such as draught and displacement values.

Where the fendering system is designed primarily for a partially laden or in ballast design vessel, the designer should establish the risk of berthing a more heavily laden vessel, and should take into account the possibility of a fully laden vessel having to return to the berth.

4.3.2 Vessels with bulbous bows

Vessels with bulbous bows pose a greater collision hazard to most berth structures than vessels with a conventionally shaped bow. Where such vessels are to be berthed, the underwater geometry of the bow section should be taken into account in addition to that at the level of contact with the fendering system. The fender spacing, fender outstand after compression and relationship of the berth's substructure to the cope face should also be assessed (see Figure 1), to establish a maximum berthing angle α which is acceptable without impact between the bow and the berth structure.

Figure 1 Geometry of vessel with bulbous bow



It is generally impracticable to provide a fendering system to safeguard the berth structure against accidental head-on or steeply-angled impacts. The designer should therefore establish a maximum safe value of the berthing angle that can be achieved whilst optimizing both the fendering system and the substructure layout.

4.3.3 Belting

The design of the fendering system should if appropriate take account of belting. Fender panels should be sufficiently long to avoid belting catching the top or bottom of the panel.

NOTE 1 Ferries, and small craft such as tugs and launches, are often fitted with belting that consists of one or more timber, rubber or steel rubbing strips around the vessel. Occasionally this belting is discontinuous and might be in poor condition. On some vessels it might occur at more than one level, particularly towards the stern of the vessel.

NOTE 2 Belting might give highly concentrated loads, catch on edges, giving large vertical loads, and cause localized compression of the fender.

4.4 Fender layout for berths and other locations

4.4.1 General

The design of the fendering system should take into account the berth layout.

NOTE Fendering systems can be classified into three general categories, i.e. those for continuous quays, those for island berths and those for lead-in jetties and locks. Other systems are generally variants of or combinations of these three categories. Fendering systems might be formed of groups of individual fenders or a combination of differing types of fenders.

4.4.2 Continuous quays

NOTE 1 For the purposes of this subclause, a continuous quay is one that provides a straight continuous berthing line for more than one berth.

On continuous quays there is often no precise delineation of individual berths in order to give flexibility of operation and the accommodation of a wide range of vessels. In such cases the fendering system should allow a vessel to berth at any position along the length of the quay. The fendering system usually consists of a series of individual fenders, the positioning of which should be in accordance with the following recommendations.

- a) The fendering system should prevent the vessel striking the berth structure and cargo handling equipment when berthing on the bow or stern quarters (see Figure 2), and allow sufficient fenders to be mobilized for energy absorption. Positioning of equipment during berthing should be discussed with port operations and included in the facility operating manual.

NOTE 2 A typical minimum clearance (see item 5 in Figure 2) is 250 mm at the design deflection.

- b) The fendering system should allow vessels to lie alongside with adequate support from the fenders along the flat side of the vessel hull.
- c) The fender spacing should not exceed $0.15L_s$ (see Figure 3). This is based on conventional hull shapes. Where less conventional hull shapes are to be catered for, such as Ro-Ro vessels with a square stern or any vessels with a large bow and/or stern flare, the spacing should allow for the specific vessel profiles.

NOTE 3 Bow and stern vertical flare varies depending upon the vessel type and design. Vertical flare up to 15° is common on container vessels.

On continuous quays, varying fendering systems could be used where vessels and dredge depths vary, and this should be set out in the facility operating manual.

Figure 2 Hull and cope geometry at impact

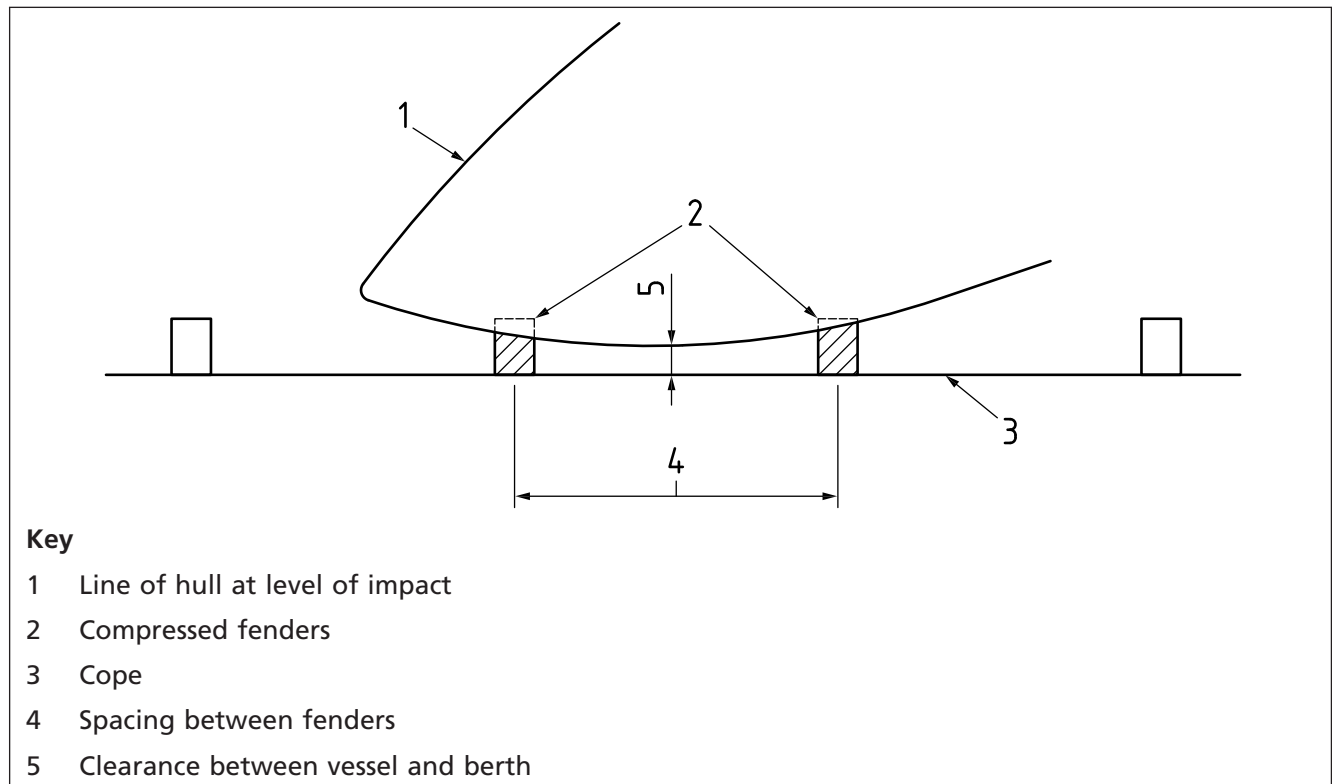
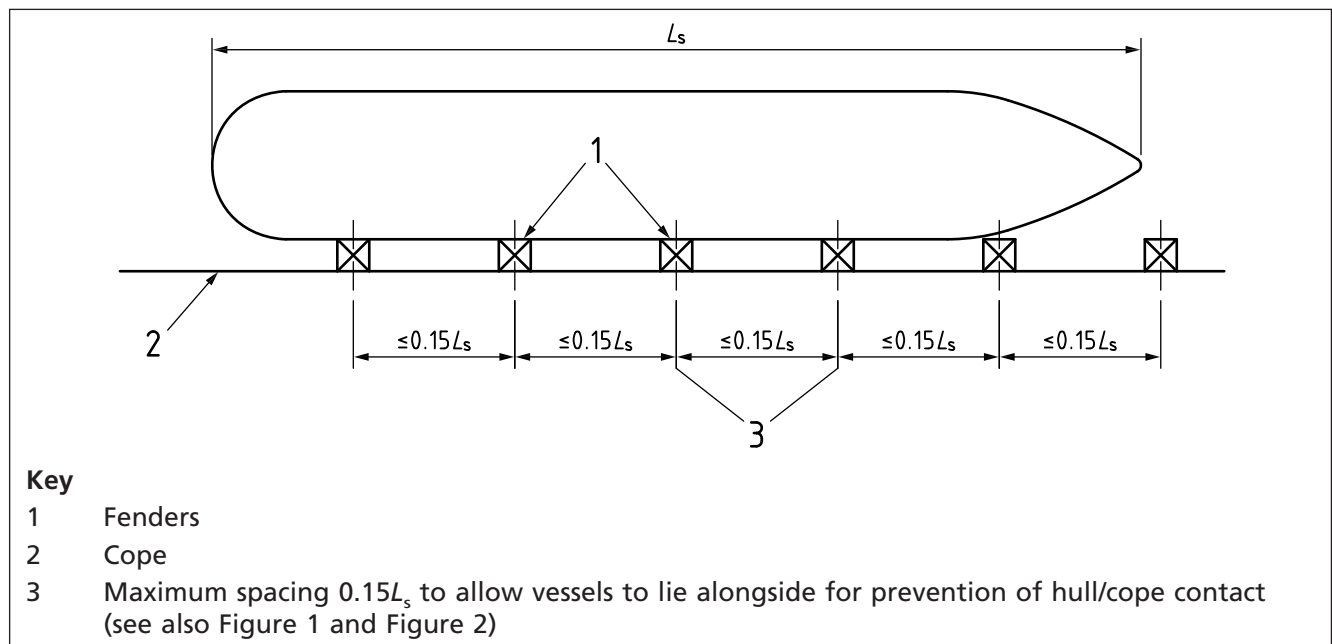


Figure 3 Fender layout on a continuous quay



4.4.3 Island berths

COMMENTARY ON 4.4.3

Where vessels are berthed about a fixed point such as oil loading arms, the primary fenders can be concentrated at two or more points depending on the range of vessels to be accommodated.

The spacing of primary fenders should take account of the actual geometry of the vessels to be berthed. At least two fenders (one at either side of the platform) should make full face contact with the flat side of the vessel hull to provide a sufficient lever arm in the horizontal plane.