



BS 6349 : Part 4 : 1985

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British Standard Code of practice for

Maritime structures

Part 4. Design of fendering and mooring systems

Structures maritimes — Code de bonne pratique
Partie 4. Conception des systèmes de défense et d'amarrage

Leitfaden für Bauten im Meer
Teil 4. Ausführung und Anordnung von Fendern und Festmachern

British Standards Institution

Foreword

This Part of BS 6349 has been prepared under the direction of the Civil Engineering and Building Structures Standards Committee.

Following suggestions from the Maritime and Waterways Board of the Institution of Civil Engineers, the Standards Committee for Civil Engineering Codes of Practice set up an ad hoc panel to make further studies. The panel's report, presented in 1975, concluded that existing British codes were inadequate for the special aspects of maritime structures and that there was a need for such a code. A format was proposed that divided the work into two distinct stages.

It has been assumed in the drafting of this British Standard that the execution of its provisions is entrusted to appropriately qualified and experienced people.

The standard will be issued in seven Parts as follows:

- Part 1 General criteria
- Part 2* Design of quay walls, jetties and dolphins
- Part 3* Design of locks, graving docks, shipways, ship lifts, locks and dock gates
- Part 4 Design of fendering and mooring systems
- Part 5* Recommendations for the dredging of waterways and for land reclamation
- Part 6* Design of buoy moorings, floating and buoyant structures and anchorage systems
- Part 7* Design of breakwaters and training walls.

Data from Part 1 that are of particular importance to this Part are reproduced in appendix A.

Information on mooring lines is given in appendix B.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

*In preparation.

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Code of practice. Section one

Section one. General

1 Scope

This Part of BS 6349 gives guidance on types of fenders, fendering systems and layouts, mooring devices and ropes, mooring system layouts for commercial vessels, and recommendations as to their suitability for various applications and locations.

The code is intended principally for use in respect of commercial installations.

NOTE 1. Application of this code to naval bases may require additional data from the relevant naval authorities as regards allowable hull contact pressures, especially for submarines, and as regards the distances at which vessels will be off the quay and the configuration and type of mooring arrangements.

NOTE 2. The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 6349, the following definitions apply.

2.1 elastomeric fender units. Units formed of rubber that absorb berthing energy by virtue of the work required to deform them elastically by compression, bending or shear or a combination of such effects.

2.2 pneumatic fender units. Units comprising rubber bags filled with air under pressure that absorb berthing energy by virtue of the work required to compress the air above the normal pressure obtaining in the bag.

2.3 gross registered tonnage (grt). The gross internal volumetric capacity of the vessel as defined by the rules of the registering authority and measured in units of 2.83 m³ (100 ft³).

2.4 deadweight tonnage (dwt). The total mass of cargo, stores, fuels, crew and reserves with which a vessel is laden when submerged to the summer loading line.

NOTE. Although this represents the load carrying capacity of the vessel it is not an exact measure of the cargo load.

2.5 displacement. The total mass of the vessel and its contents.

NOTE. This is equal to the volume of water displaced by the vessel multiplied by the density of the water.

3 Symbols

The following symbols are used in this Part of BS 6349. More than one meaning is given to some of the symbols and the specific meaning is given in each case in the text where the symbols are used.

<i>B</i>	Beam of vessel
<i>C</i>	Clearance between hull of vessel and face of cope
<i>C_b</i>	Block coefficient of the vessel's hull
<i>C_C</i>	Berth configuration coefficient
<i>C_E</i>	Eccentricity coefficient
<i>C_M</i>	Hydrodynamic mass coefficient
<i>C_S</i>	Softness coefficient
<i>D</i>	Draught of ship
<i>D</i>	Diameter of fender
<i>E</i>	Effective kinetic energy of berthing vessel
<i>H</i>	Height of compressible part of fender
<i>K</i>	Radius of gyration of ship
<i>L</i>	Length of fender parallel to berthing face
<i>L</i>	Length of vessel's hull between perpendiculars
<i>L_S</i>	Length of the smallest vessel using the berth
<i>L_L</i>	Length of the largest vessel using the berth
<i>M</i>	Mass of vessel
<i>M_D</i>	Displacement of vessel
<i>R</i>	Reactive force of fender
<i>R</i>	Distance of the point of contact from the centre of mass of the vessel
<i>V</i>	Velocity of vessel in direction of approach
<i>V_B</i>	Velocity of vessel normal to the berthing face
<i>α</i>	Angle of approach of vessel
<i>γ</i>	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
<i>δ</i>	Deflection of fender unit
<i>Δ</i>	Deflection of fender unit
<i>μ</i>	Coefficient of friction

Section two. Fendering

4 General principles

4.1 Provision of fendering

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. The trend to the use of larger vessels and the siting of berths in more exposed locations such as the outer reaches of rivers and in the open sea has led to the more widespread use of fendering systems.

The decision to fender a berth is a policy matter but wherever possible this policy should only be formulated after due consideration of all the factors involved.

The design should take account of the proposed method of operating the berth with particular reference to the use or non-use of tugs where this can be foreseen. The design should be sufficiently robust to accept without damage relatively small loads in directions or positions not anticipated in the main design analysis.

Berths may be required in a variety of locations ranging from very sheltered to open sea conditions. A range of such categories is given in table 1.

There are also a number of types of vessel having particular requirements for berthing accommodation that may influence the appropriate type of fendering for them (see table 2).

Table 1. Typical categories of berth location

Type	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 ship sizes limited by lock dimensions Usually standard type cargoes related to berth equipment
Tidal basins	Greater range of water levels than impounded basins Limited wave exposure Limited current
Estuarial berths	Maximum tidal range and currents Greater wave exposure than tidal basins Often dedicated berths with single class or type vessels
Coastal berths	Full exposure to wind, wave and currents Usually specialized trades: bulk, coal, ore, oil Single type vessels and handling equipment

The types of berth location given in table 1 cover the various situations that may occur, and the list of features to be taken into account in the design of the fendering system covers aspects which the designer should consider. In particular the range of water level will require a fendering system that is suitable for all possible water levels which may occur, and with large variations this becomes particularly important. Winds, waves and currents will also vary depending on the berth location. Finally with specialized trades, such as bulk coal, ore, oil and petro-chemical products, particular requirements are necessary, and the fendering system should be designed accordingly for particular vessel sizes and characteristics.

4.2 Principles of berthing

A large ship about to berth should be brought, by tugs and/or the use of her engines, to a position in front of her berth and stopped dead a short distance off, parallel to her berth. The layout out of her moorings to the berth mooring points will then commence.

The ship will be pushed or warped slowly into the berth, ideally achieving a gentle contact while making a small angle with the berth.

Since the ship will most frequently come alongside at a slight angle to the berth, it will initially make contact with only one fender. The ship will then rotate round before striking further fenders.

Tugs, launches and other small craft will tend to approach their berths more directly than for large ships.

Ferries and roll-on/roll-off (Ro-Ro) ships approach their berths in a rather different way which is explained in 4.7.6.

The above berthing principles may be assumed when designing fendering systems in accordance with this code of practice.

4.3 Overall design

The function of the fendering system is to protect the berth structure against damage from ships approaching, lying alongside or leaving the berth and to limit the reactive forces on the ship's hull to acceptable values.

The range of available fender systems both of proprietary and purpose-made types is considerable and selection should take account of the following factors.

- Acceptable reactive forces and deflections of both the berth structure and the ship's hull. It is essential that particular attention is paid to deflection limits on berths carrying pipelines, rail mounted cranes and shiploaders.
- Types and hull forms of vessels.
- The energy to be absorbed by the fender having regard to the location and approach conditions of the berth and its method of operation.
- Tidal range and range of freeboards of vessels to be accommodated.
- Acceptable limits to the distance between berth cope and side of hull after the vessel is moored in relation to the outreach of oil loading arms, crane jibs, shiploader booms and similar equipment.

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Table 2. Vessel categories	
Type	Features to be taken into account in the design of the fendering system
Train and vehicle ferries	Quick turn round End berthing High docking velocities Intensive use of berth (see also notes 1, 2 and 4)
Roll on—roll off (Ro-Ro) vessels	Loading ramps, slewed or end loading (vessel mounted or shore based) end berthing (see also notes 1 and 2)
LNG/LPG carriers	Shallow draught even at full load Low berthing pressures on hull Single type vessels using dedicated berth Need to avoid fire hazards from sparking or friction (see also notes 1 and 3)
Coastal tankers	Very low amidships freeboard Intensive use of berth Need to avoid fire hazard from sparking or friction (see also notes 3 and 4)
Container ships	Flared clipper bows with liability to strike shore-side installations (see also note 1)
Bulk carriers	Need to be close to berth to minimize shiploader outreach Possible need to be warped along berth for shiploader to change holds Large change in draught between empty and fully laden conditions (see also note 1)
Passenger liners	Little change of draught between empty and fully laden condition (see also note 1)
Tankers	Need to be close to berth to reduce loading arm length Large change in draught between empty and fully laden conditions Need to avoid fire hazard from sparking or friction (see also note 1)
General cargo vessels	Need to be close to berth to minimize outreach of quayside cranes and/or ship's gear Large change of draught between empty and fully laden conditions Possible long occupancy of berths
Coastal cargo vessels	Short straight run of body (see also note 4)
Miscellaneous tugs, supply boats, barges, lighters and fishing boats	Need very substantial fendering for heavy use Timber fendering usually provided (see also notes 2 and 4)
Yachts	Need for soft fendering which is sometimes provided by the yachts themselves
NOTE 1. The vessels are possibly fitted with bulbous bows. NOTE 2. The vessels are possibly fitted with belting. NOTE 3. The vessels do not necessarily have manifolds at the amidships position. NOTE 4. The vessels may often berth without the aid of tugs.	

The design of the fender system has to be integrated with that of the berth structure as not all types of fender are compatible with all types of structure.

4.4 Materials and workmanship

Fender systems incorporate some or all of the conventional construction materials of steel, iron, concrete and timber together with natural or synthetic rubber, nylon and other man-made fibres. All these materials and the associated workmanship should be in accordance with the relevant British Standards, or other equivalent internationally recognized standards, and with clauses 56, 58, 59, 60, 61, 67 and 68 of BS 6349 : Part 1 : 1984.

4.5 Vessel size

Dimensions and tonnages, etc. relating to fully laden vessels are given in BS 6349 : Part 1.

NOTE. For ease of reference, 17.2 of BS 6349 : Part 1 : 1984 has been reproduced as appendix A in this Part.

Where vessels are berthed in a partially laden condition, reference can be made to builder's plans, load-displacement curves or tables to ascertain draught and displacement values.

For berths dedicated to loading operations it is considered imprudent to design for vessels berthing only in ballast or part laden condition. If contemplating such an approach, the designer should first satisfy himself as to the risk of a more heavily laden vessel having to be accommodated, and the possibility of a fully laden vessel having to return to the berth should not be overlooked.

4.6 Berthing velocities

Suggested values of transverse berthing velocities are given in table 6 of BS 6349 : Part 1 : 1984. Where adequate statistical data on berthing velocities for vessels and conditions similar to those of the berth being designed are available, then the velocity should be derived from this data in preference to the tabulated values.

4.7 Berthing energies

4.7.1 General. Details of the assessment of the total energy of the moving vessel and its associated hydrodynamic mass are given in clause 41 of BS 6349 : Part 1 : 1984.

This value may need to be modified to assess the amount of energy E (in kN·m) to be absorbed by the fender system by the addition of factors C_E , C_S and C_C , giving the following equation:

$$E = 0.5 C_M M_D (V_B)^2 C_E C_S C_C$$

where

C_M is the hydrodynamic mass coefficient;

M_D is the displacement of the ship (in t);

V_B is the velocity of the vessel normal to the berth (in m/s);

C_E is the eccentricity coefficient;

C_S is the softness coefficient;

C_C is the berth configuration coefficient.

Each fender should be designed to absorb the above berthing energy. For this purpose a 'fender' may comprise any one of the following:

- (a) a single elastomeric or pneumatic unit, dolphin pile, or other energy absorbing unit;
- (b) a number of energy absorbing units coupled together to form a composite energy absorbing unit;
- (c) a number of energy absorbing units in sufficiently close proximity that they can be considered to act together if located at the first point of impact of the ship.

4.7.2 Hydrodynamic mass coefficient. The hydrodynamic mass coefficient allows the movement of water around the ship to be taken into account when calculating the total energy of the vessel by increasing the mass of the system.

The hydrodynamic mass coefficient C_M may be calculated from the following equation (see reference [1]):

$$C_M = 1 + \frac{2D}{B}$$

where

D is the draught of the ship (in m),

B is the beam of the ship (in m).

Use of this formula will generally lead to values of C_M in the range 1.3 to 1.8.

4.7.3 Eccentricity coefficient. The eccentricity coefficient C_E allows for the reduction in energy transmitted to the fender system when the point of impact is not opposite the centre of mass of the vessel and may be calculated by means of the following equation:

$$C_E = \frac{K^2 + R^2 \cos^2 \gamma}{K^2 + R^2}$$

where

K is the radius of gyration of the ship (in m) (generally between $0.2L$ and $0.25L$ where L is the length of the ship (in m));

R is the distance of the point of contact from the centre of mass (in m);

γ is the angle between the line joining the point of contact to the centre of mass and the velocity vector (see figure 1).

The above expression is often simplified by assuming $\gamma = 90^\circ$, resulting in:

$$C_E = \frac{K^2}{K^2 + R^2}$$

4.7.4 Softness coefficient. The softness coefficient allows for the portion of the impact energy that is absorbed by the ship's hull. Little research into energy absorption by ships' hulls has taken place, but it has been generally accepted that the value of C_S lies between 0.9 and 1.0. In the absence of more reliable information a figure of 1.0 for C_S is recommended when a soft fendering system is used, and between 0.9 and 1.0 for a hard fendering system. A hard fendering system can be considered as one where

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the deflections of the fenders under impact from ships for which the fenders are designed are less than 0.15 m. A soft fendering system will have fender deflections greater than 0.15 m under the same impacts.

4.7.5 Berth configuration coefficient. The berth configuration coefficient allows for the portion of the ship's energy which is absorbed by the cushioning effect of water trapped between the ship's hull and quay wall. The value of C_C is influenced by the type of quay construction, and its distance from the side of the vessel, the berthing angle, the shape of the ship's hull, and its underkeel clearance. A value of 1.0 for C_C should be used for open piled jetty structures, and a value of C_C of between 0.8 and 1.0 is recommended for use with a solid quay wall.

4.7.6 Berthing energies in ferry and Ro-Ro berths

4.7.6.1 General. The three modes of berthing for ferries and Ro-Ro ships in common use are as follows:

- (a) making a transverse approach to berth alongside a quay and using the ship's own ramps for vehicle access;
- (b) making a transverse approach to a row of breasting dolphins and after coming to rest then moving slowly longitudinally to berth end-on against a shore ramp structure;
- (c) making a direct longitudinal approach to berth end-on against a shore ramp structure but using side breasting dolphins as a guide.

These three modes of berthing are illustrated in figures 2(a), 2(b) and 2(c).

The berth layouts for modes (b) and (c) are similar and therefore both types of approach could occur at the same berth.

Mode (a) is most likely to be adopted by the larger Ro-Ro vessels where bow and stern are not specifically designed for berthing forces. Mode (c) is most likely to be adopted by ferries where bow or stern are designed for end berthing. It is important that the berthing provision is conformable with the ship's characteristics and the appropriate method of approach.

4.7.6.2 Mode (a). The fendering should be designed to absorb energies calculated in accordance with 4.7.1 except that the value of the radius of gyration K used in the calculation of C_E should be found from the equation:

$$K = (0.19 C_b + 0.11) L$$

where

- L is the length of hull between perpendiculars (in m);
- C_b is the block coefficient of the hull (0.54 to 0.63 for Ro-Ro ships and ferries).

4.7.6.3 Mode (b)

4.7.6.3.1 Side fenders. Berthing energy for the side fenders should be calculated as in mode (a).

4.7.6.3.2 End fenders. The end fenders should be designed to absorb the total energy E (in kN·m) of the ship. This energy is calculated from the following equation:

$$E = 0.5 MV^2$$

where

V is the velocity of the vessel in the direction of approach (in m/s);

M is the mass of the vessel (in t).

NOTE 1. In the absence of factual data, V may be taken as 0.15 m/s.

NOTE 2. The values C_M , C_S , C_C and C_E may each be taken as unity for end-on berthing.

4.7.6.4 Mode (c)

4.7.6.4.1 Side fenders. The energy E (in kN·m) to be absorbed by the side fenders should be calculated from the equation:

$$E = 0.5 M_D C_M C_S C_C C_E (V \sin \alpha)^2$$

where

M_D is the displacement of the vessel (in t);

C_M is the hydrodynamic mass coefficient;

C_S is the softness coefficient;

C_C is the berth configuration coefficient;

C_E is the eccentricity coefficient, calculated in accordance with mode (a);

V is the velocity of the vessel in the direction of approach (in m/s);

α is the angle of approach (see figure 2(c)).

A minimum value of 15° is recommended for α except in cases where the berth geometry restricts the vessel to a less angled approach.

Due to the high power of most ferries and rapid turn-round times, operating speeds are generally higher than for other vessels. It is therefore recommended that the velocity V should be taken as follows (see figure 2(c)):

outer end dolphin 2.0 m/s to 3.0 m/s

inner end dolphin 0.5 m/s to 1.0 m/s

4.7.6.4.2 End fenders. The end fenders should be designed to absorb the total energy E (in kN·m) of the ship. This energy is calculated from the following equation:

$$E = 0.5 M (V \cos \alpha)^2$$

where

M is the mass of the vessel (in t);

V is the velocity of the vessel in the direction of approach (in m/s);

α is the angle of approach.

NOTE 1. In the case of ferries V should be taken in the range 0.5 m/s to 1.0 m/s.

NOTE 2. The values C_M , C_S , C_C and C_E may each be taken as unity for end-on berthing.

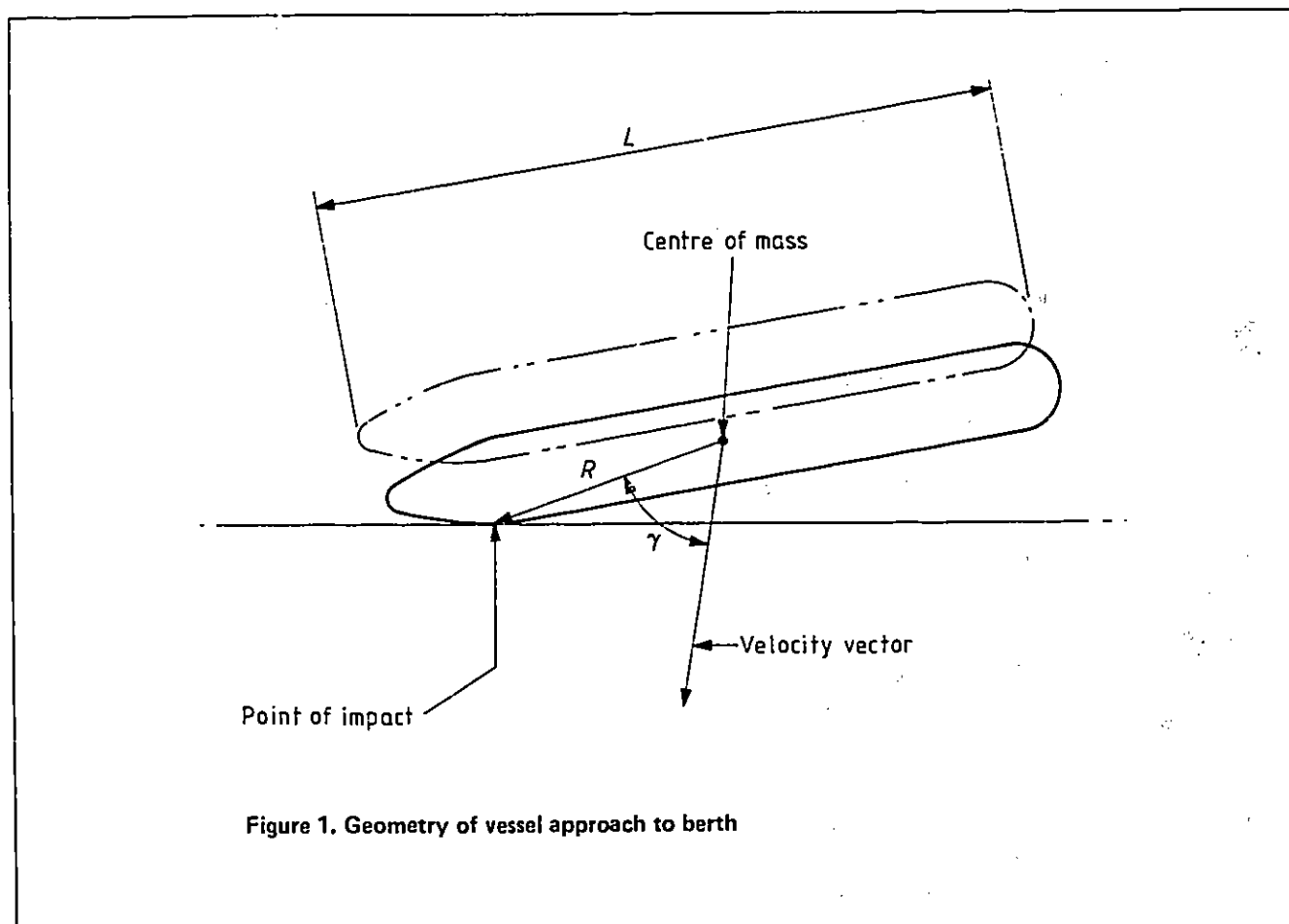


Figure 1. Geometry of vessel approach to berth

4.8 Berthing reactions and load distribution

4.8.1 General. Berthing reactions are a function of the berthing energy and the deformation characteristics of the fender system. Typical reaction/deformation curves for fender types are given in clause 5. Berthing loads should be distributed in such a manner that:

- (a) contact pressures on the ship's hull are kept within acceptable limits;
- (b) direct contact between hull and berth structure is prevented;
- (c) the capacity of the fender is not exceeded.

4.8.2 Hull pressures. The maximum acceptable contact pressure between the hull and fender is influenced by many factors, including the type and size of ship, nature of the fender bearing surface (i.e. rigid or flexible) and the position of the contact area relative to the hull frames.

For LNG/LPG tankers and very large crude carriers (VLCC's), acceptable contact pressures will generally be between 15 t/m² and 20 t/m².

4.8.3 Fender reaction due to angular berthing. Unless the point of impact is on the straight run of the hull and the vessel is parallel to the berth at impact the fender unit will

receive an angular loading. The hull geometry over the impact area should therefore be considered in both horizontal and vertical planes (see figures 3 and 4) to establish:

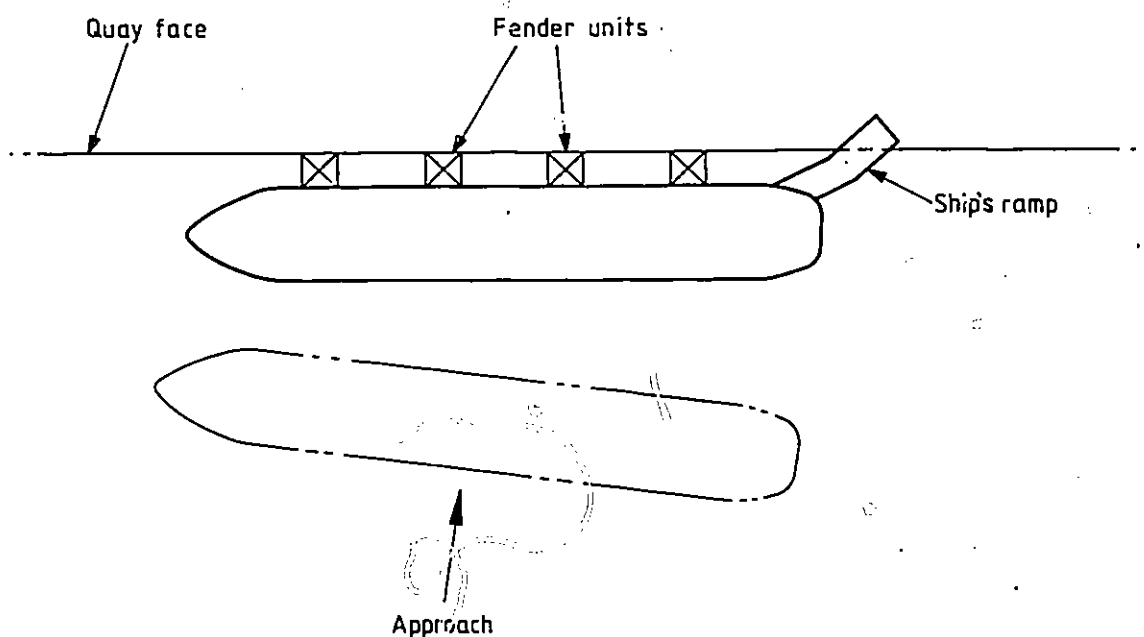
- (a) the angle of application of load to individual fenders;
- (b) deflection of individual energy absorbing units within the fender and hence the aggregate amount of energy absorbed by the complete fender;
- (c) clearance between hull and berth structure.

Most manufacturers of proprietary elastomeric units and pneumatic fenders supply correction factors to the performance data of their units for use under angular berthing conditions. For flexible elastic dolphins, gravity fenders, etc., the effects of angular berthings should be analysed from first principles.

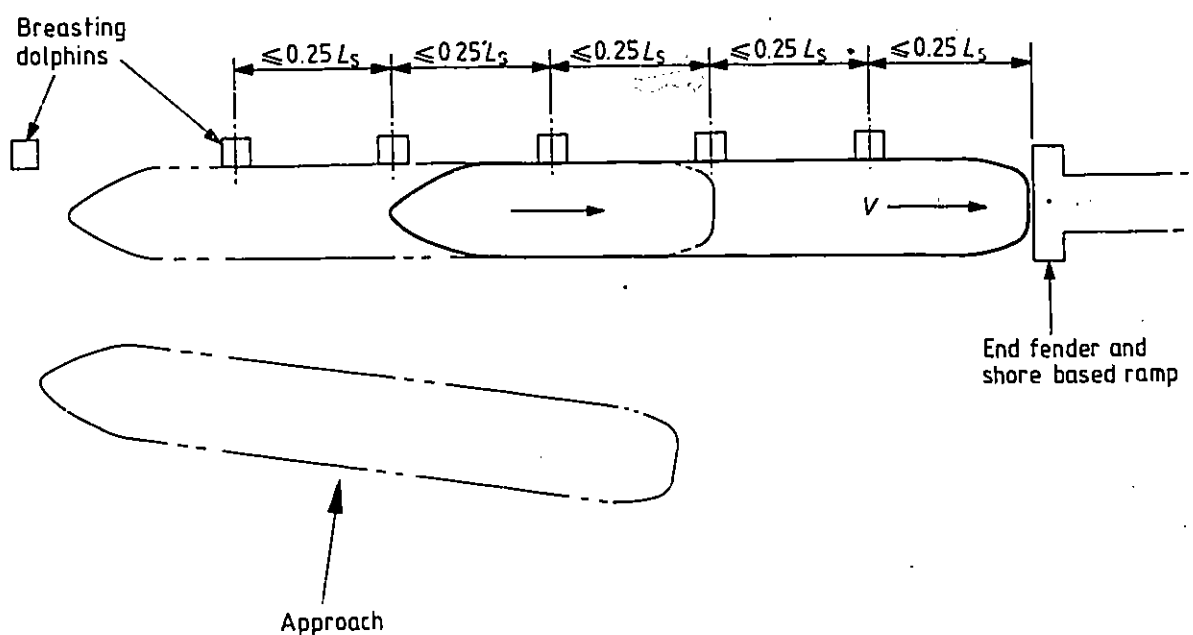
Where circumstances dictate that angled approaches will be the general practice at a particular berth, consideration may be given to angling the individual fender elements relative to the berth in order to create a closer approximation to parallel berthing conditions and hence more efficient performance of the fender (see figure 5).

4.8.4 Fender frames. Where a fender frame is used to reduce the contact pressure, or to couple a series of units

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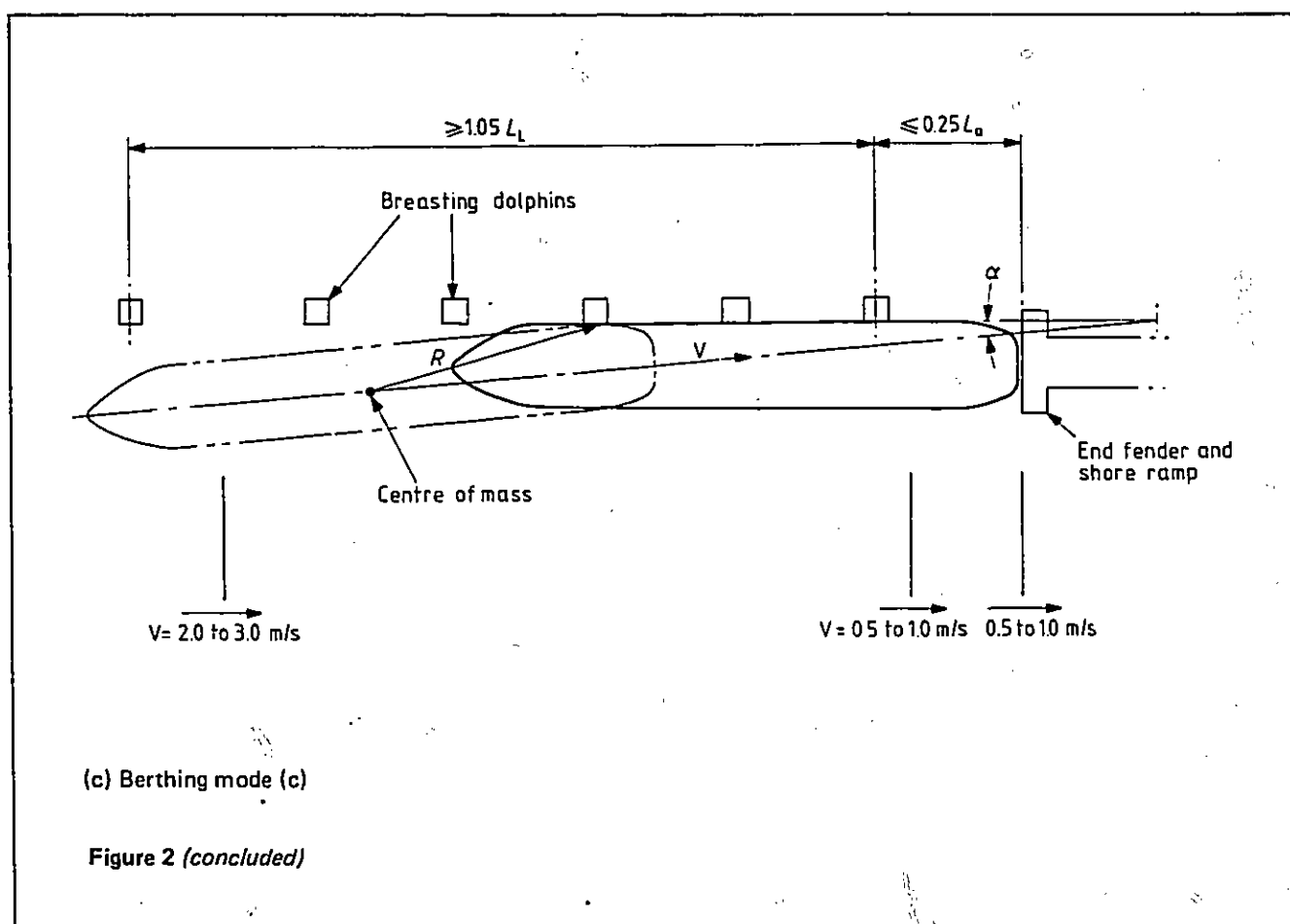


(a) Berthing mode (a)



(b) Berthing mode (b)

Figure 2. Ferry and Ro-Ro vessel berthing



into a single fender, the fender frame should be one of the following:

- (a) a proprietary type as produced by the fender manufacturer and demonstrated by him as being adequate to carry the applied loads;
- (b) a purpose designed steel frame with stresses and constructional details in accordance with BS 449;
- (c) a purpose designed timber frame with stresses in accordance with CP 112, treating berthing impacts as short term loadings (see 3.12.1.1 of CP 112 : Part 2 : 1971).

Steel frames should be faced with suitable materials to minimize abrasive contact with the hull of the vessel. Facing materials may be of timber or polymers. In cases of particularly high wear the use of steel plate facing may be considered. Fixings should be such that worn or damaged facing panels can be easily and rapidly replaced. The heads of fixing bolts, set screws, etc. should be recessed into the wearing face to avoid direct contact with the hull plating, with an allowance for wear of the facing panels.

4.8.5 Shear capacity of fenders. Vessels moving longitudinally or vertically induce friction forces at the contact surface between fender and hull. These forces will induce shear deformations in the fender and these should be kept within acceptable limits. (Shear deflections may be limited by chains connecting appropriate parts of the fender

assembly.) In the absence of information from a fender manufacturer, shear forces can be calculated using the relevant coefficient of friction, μ , multiplied by the normal force at the fender face. Typical values of μ are given in table 3.

Table 3. Coefficients of friction of fender facing materials in dry conditions

Material	Coefficient of friction μ
Polyethylene	0.2
Nylon	0.2
Rubber	0.5
Timber	0.3

NOTE. The above coefficients of friction only apply where smooth contact surfaces are present. Hence they will not apply where the ships using the berth have rusty hulls or protrusions on their hulls as is the case, for example, with the rivets and plate ends of older vessels. In the latter cases the designer should consider higher values.

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4.9 Factors of safety and design stresses

4.9.1 General. Two levels of impact energy, normal and abnormal, should be established for the design of the fender system and the supporting berth structure.

The berthing energy as computed in accordance with 4.7 is based on normal operations and may be exceeded for accidental occurrences such as:

- (a) engine failure of ship or tug;
- (b) breaking of mooring or towing lines;
- (c) sudden changes of wind or current conditions;
- (d) human error.

To provide a margin of safety against such unquantifiable risks it is recommended that, unless a lower value can be shown to have been satisfactory in similar circumstances, the ultimate energy capacity of each fender should be up to double that calculated for normal impacts (see 4.7.1).

Because of the non-linear energy/deflection and reaction/deflection characteristics of most fender systems the effects of both normal and abnormal impacts on the fender system and berth structures should be examined.

4.9.2 Compressible fender on rigid structure. Where there is a compressible fender on a rigid structure, all the energy has to be absorbed by the fender, the structure being assumed to have zero or negligible energy absorbing capacity.

There is little information available on compressible fenders loaded beyond their maximum energy absorption value. The fender unit should therefore be selected with a maximum value not less than the design abnormal energy level.

This may be achieved either by using a compressible fender of this rating, or by using a compressible fender to absorb the normal impact energy, in series with a collapsible steel fender to protect against abnormal loading, which should be easily replaceable.

The reactions corresponding to given energy absorption may be obtained directly from the performance curves for a given fender. The normal and abnormal reactions should be taken as the maximum reactions occurring over the ranges zero to normal and zero to abnormal respectively.

The fender manufacturer may state a tolerance on the figures quoted for reactions and energies. If not, the tolerance of $\pm 10\%$ should be taken into account in the design of the fendering system.

Under the normal reaction, stresses in the steel components of the fender system should not exceed the normal permissible stresses given in BS 449 associated with elastic design of the system. Under the abnormal reaction, such stresses in the system should not exceed 0.8 of the yield stresses.

It should be noted that the maximum permitted stress levels at normal and abnormal energies cannot always both be realized.

NOTE. For the allowable elastic stresses in the berth structure under the action of the berthing forces and the load factors to be applied

to the berthing forces for limit state design of the berth structure, reference should be made to BS 6349 : Part 2*.

4.9.3 Flexible steel pile dolphins. In the case of flexible steel pile dolphins all the energy of impact has to be absorbed by lateral deflection of the piles. Energy absorption is a function of the square of the bending stress.

The pile section should be selected to operate at 0.8 yield stress under abnormal energy conditions. For the recommended ratio between abnormal and normal energies of 2.0, this gives the normal energy bending stress as 0.57 yield stress.

4.9.4 Flexible steel pile dolphins with compressible fenders. In certain circumstances requiring large energy absorption, compressible fenders may be mounted on flexible dolphins. The assessment of safety factors becomes complex and should be carried out from first principles, taking into account the value of the compressible fender at the load compatible with the limiting stresses in the steel as discussed in 4.9.2 and 4.9.3.

4.9.5 Flexible pre-cast concrete pile dolphins. It is recommended that concrete piles for use in flexible dolphins are pre-stressed.

4.9.6 Flexible timber pile dolphins. For small dolphins in locations such as yacht marinas, timber, generally greenheart or pitch pine, may be used in-lieu of steel. Working stresses should be in accordance with CP 112, treating berthing impacts as short term loadings (see 5.12.1.1 of CP 112 : Part 2 : 1971).

4.9.7 Berthing beams. Berthing beams may be provided in the following situations.

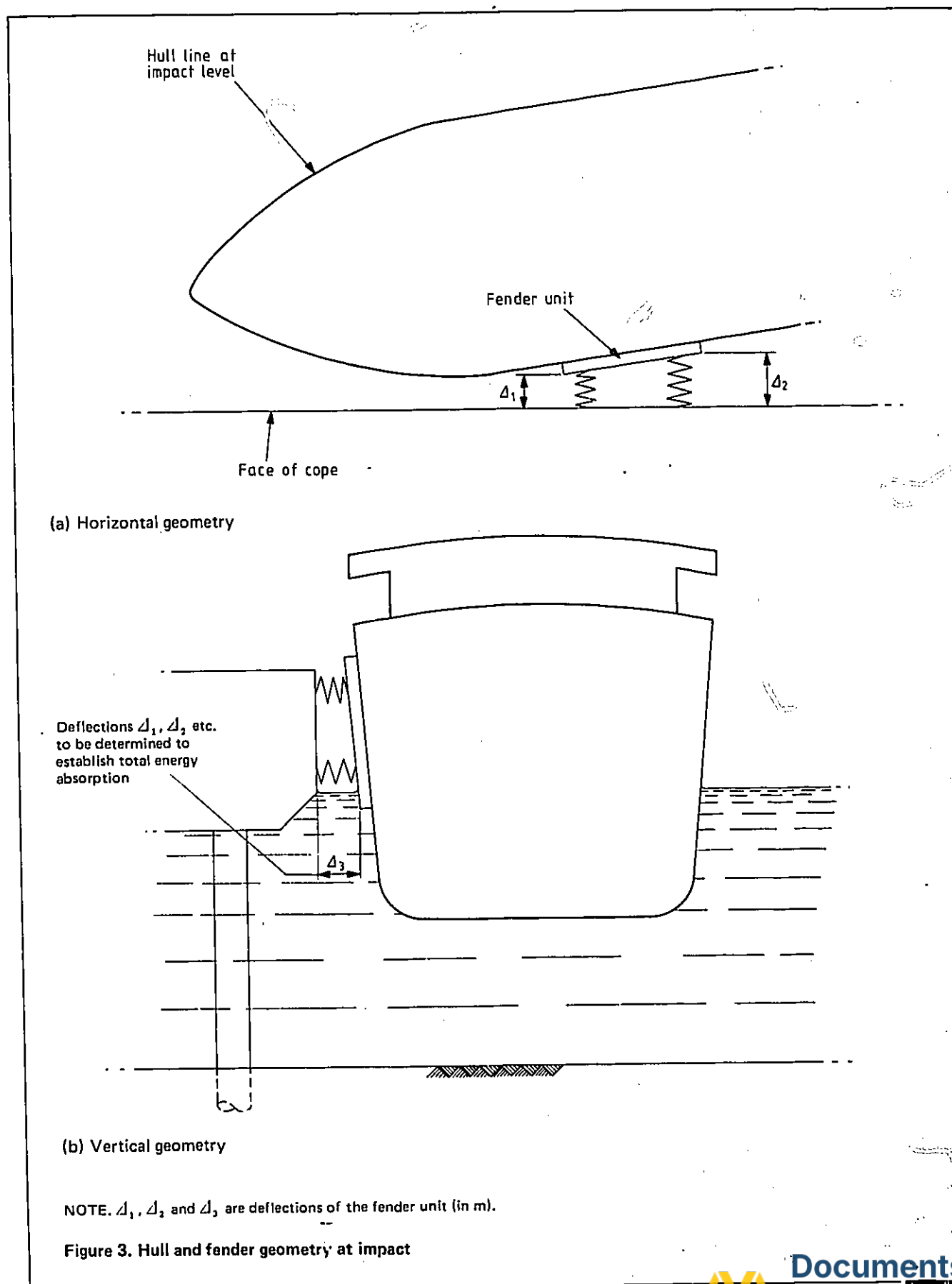
- (a) As a fendering structure for a piled jetty, generally in locations where a large range of vessel sizes is to be accommodated or where it is advantageous not to design the jetty itself for large horizontal forces. Inclined berthing beams are generally used in these cases.
- (b) To prevent vessels from running aground or causing damage to existing installations as, for example, at difficult approaches to locks.

Berthing beams generally consist of a fendered steel or concrete beam above water level supported by steel cantilever piles. The cantilever piles may be vertical or outward raking; in the latter case the structure is known as an inclined berthing beam. Some berthing beams are partially supported against horizontal forces by elastomeric units braced against piled strong points; the strong points are generally located near the ends of the berthing beam.

The following points are important in the design of all berthing beams.

- (c) The spacing of the piles should be such that they carry similar dead load working stresses.
- (d) Unless strong points are being used in the design, more slender or more widely spaced piles should generally be used at the ends of the berthing beam than in the middle. The choice and arrangement of the piles should be such that under an abnormal impact near the

* In preparation.



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Section two

