

Code of practice for

Maritime structures —

**Part 6: Design of inshore moorings and
floating structures**

UDC [624.034.3/.4 + 69.034.3/.4]

Confirmed December 2011

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- Association of Consulting Engineers
- British Ports Association and the National Association of Ports Employers
- British Steel Industry
- Concrete Society
- Department of the Environment (Property Services Agency)
- Department of Transport (Marine Directorate)
- Federation of Civil Engineering Contractors
- Health and Safety Executive
- Institution of Civil Engineers
- Institution of Structural Engineers
- Oil Companies International Marine Forum

This British Standard, having been prepared under the direction of the Civil Engineering and Building Structures Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 30 June 1989

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The following BSI references relate to the work on this standard:
Committee reference CSB/17
Draft for comment 86/12351 DC

ISBN 0 580 16761 5

Amendments issued since publication

Amd. No.	Date of issue	Comments

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Foreword

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

This code of practice contains material which is both for the information and guidance of engineers and material which forms recommendations on good practice. As such conformity with its recommendations is not obligatory and variations from its recommendations may well be justified in special circumstances and engineering judgement should be applied to determine when the recommendations of the code should be followed and when they should not.

A code of practice is intended for the use of engineers having some knowledge of the subject. It embodies the experience of engineers successfully engaged on the design and construction of a particular class of works so that other reasonably qualified engineers may use it as a basis for the design of similar works.

It is not intended that it should be used by engineers who have no knowledge of the subject nor that it should be used by non-engineers.

A code of practice represents good practice at the time it is written and, inevitably, technical developments may render parts of it obsolescent in time. It is the responsibility of engineers concerned with the design and construction of works to remain conversant with developments in good practice, which have taken place since the publication of the code.

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.

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 dry docks, locks, slipways and shipbuilding berths, shiplifts and dock and lock gates¹⁾;*
- *Part 4: Design of fendering and mooring systems;*
- *Part 5: Recommendations for the dredging of waterways and for land reclamation¹⁾;*
- *Part 6: Design of inshore moorings and floating structures;*
- *Part 7: Design of breakwaters and training walls¹⁾²⁾.*

The full list of the organizations which have taken part in the work of the Technical Committee is given on the inside front cover. The Chairman of the Committee is Mr J T Williams OBE, C Eng, FICE, F I Struct E and the following were members of the Technical Committee.

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²⁾ To be issued initially as a draft for development.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 52, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1.1 Scope

This Part of BS 6349 gives guidance and recommendations on the design of moorings and floating structures at inshore locations. The mooring of ships alongside fixed structures is included in BS 6349-4.

Information on wave, wind and current loads which is specific to moored floating structures is contained in section 2. It should be used in conjunction with the general information for all maritime structures, contained in BS 6349-1.

The selection, design and analysis of moorings is covered in section 3 which also includes information on anchors, mooring equipment and maintenance and inspection of moorings. Detailed information on the design of deepwater mooring structures for the offshore industry is beyond the scope of the code, and is not included.

Design criteria which are specific to floating structures are covered in section 4. Loads, codes and classification society rules are considered together with fundamental information and criteria on stability, motion response and longitudinal strength.

General information on pontoons, floating docks and floating breakwaters is provided in section 5. Information on the detailed design of such structures is not included since specific codes and rules already exist (see 4.3 for guidance).

NOTE The titles of the publications referred to in this standard are listed on the inside back cover. The numbers in square brackets used throughout the text relate to the bibliographic references given in Appendix A.

1.2 Definitions

For the purposes of this Part of BS 6349, the definitions given in BS 6349-1 apply together with the following.

1.2.1

intact stability

the stability that covers the non-damaged condition of a vessel

1.2.2

damage stability

the stability with one or more watertight compartments flooded as a result of damage (collision)

1.2.3

displacement (of a vessel)

the mass of water displaced by a vessel

NOTE Displacement is sometimes expressed as the volume of water displaced.

1.2.4

centre of buoyancy

the centroid of the underwater volume of the vessel; it is the point through which the total buoyancy force acts

1.2.5

metacentre

the point at the intersection of vertical lines through the centres of buoyancy in the initial and slightly inclined positions

1.2.6

metacentric height

the distance between the centre of gravity and the metacentre

1.2.7

free surface effect

the reduction in the value of the metacentric height resulting from the presence of liquid in any tanks in the vessel

1.3 Symbols

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

A	Waterplane area
A_n	Area normal to flow
A_x	Effective wind area normal to x axis
A_x	Effective current area normal to x axis
A_y	Effective wind area normal to y axis
A_y	Effective current area normal to y axis
B	Breadth
B	Beam of vessel or structure
(BM)	Distance between centre of buoyancy and metacentre
b	Dimension normal to wind
C	Damping force
C_D	Drag force coefficient
C_f	Wind force coefficient
C_x	Wind force coefficient for x axis
C_x	Current force coefficient for x axis
C_y	Wind force coefficient for y axis
C_y	Current force coefficient for y axis
D	Draught of vessel or structure
d	Distance

d	Still water depth	P	Amplitude of the harmonic force (maximum wave force)
d	Dimension measured in direction of wind	P_y	Maximum hydrodynamic pressure at elevation y
F	Chain tension at fairlead	q	Wind pressure
F	Trochoidal wave profile factor	q	Proportion of critical damping
f	Wave frequency	q	Submerged unit mass of chain
f_c	Frequency of cyclic loading	$R^2(f)$	Drift force coefficient at wave frequency f
F_D	Drag force	$S_\eta(f)$	One-dimensional spectral density function of surface elevation, at wave frequency f
$F_{\max}$	Maximum wave force per unit length of structure	t	Time variable
f_N	Natural frequency of structure or member	V	Displaced volume of water
F_{RW}	Resultant wind force	V	Incident current velocity
F_{WD}	Mean wave drift force	V	Basic wind speed
F_x	Wind force acting along x axis	V_w	Design wind speed
F_x	Current force acting along x axis	w	Mass
F_y	Wind force acting along y axis	w	Lesser horizontal dimension
F_y	Current force acting along y axis	x	Horizontal displacement
f_y	Characteristic strength of reinforcement	y	Vertical displacement
g	Acceleration due to gravity (9.81 m/s ²)		Maximum wave slope
(GM)	Metacentric height		Angle of wind or current to the axis
(GZ)	Righting lever	β	Phase angle
H	Wave height	γ_{FL}	Load factor
H	Horizontal component of chain tension	η	Instantaneous height of water surface above still water level
H_{inc}	Incident wave height	θ	Angle of heel
H_s	Significant wave height	θ	Angle of chain to horizontal, at fairlead
h	Horizontal distance from fairlead to chain touch down point on seabed	ξ	Wave particle horizontal amplitude
I	Second moment of area	π	Ratio of circumference to diameter of circle
k	Radius of gyration	ρ	Mass density of water
K	Stiffness of mooring system	ρ_1	Mass density of a liquid
(KB)	Vertical distance of centre of buoyancy above keel	ϕ	Angular displacement
(KG)	Vertical distance of centre of gravity above keel	ϕ_0	Amplitude of natural angular displacement
(KM)	Vertical distance of metacentre above keel		
L	Length of vessel or structure		
L	Wavelength		
L	Length of chain from fairlead to touch down point		
l	Greater horizontal dimension		
M	Mass of water displaced		
m_D	Displacement of vessel		

Section 2. Environmental loads

2.1 General

The various environmental phenomena which should be considered for investigation at a coastal site and methods of data collection are included in section 2 of BS 6349-1:1984. Information on sea states is contained in section 4 of BS 6349-1:1984 and general information on loads, movements and vibrations is contained in section 5 of BS 6349-1:1984.

The purpose of this section is to provide information on wave, wind and current loads which is specific to vessels and floating structures. For ships moored alongside a quay or jetty the information contained in clauses 30, 31 and 42 of BS 6349-1:1984 should be used.

2.2 Return period and limiting conditions

A floating structure should normally be designed for extreme environmental conditions having a return period of not less than 50 years.

The moorings for a vessel or floating structure may be designed for conditions having an average return period of less than 50 years provided that there are contingencies which allow the vessel or structure to be safely removed before the design limits of the mooring are reached. For example, procedures may be laid down for a vessel to leave a mooring under its own power, and/or with tug assistance. In such instances the procedures should reflect the operational limits of tugs and/or line boats.

2.3 Combined loading

The environmental conditions assumed to occur simultaneously should be not less severe than the following:

- a) the still water levels over a range equal to the range of the highest annual spring tide plus positive and negative storm surges;
- b) the 1 min mean wind speed for the return period being considered⁴⁾;
- c) the 10 min mean current for the return period being considered;
- d) the wave condition corresponding to the return period being considered.

Combinations of wind, current and waves should be considered for all directions.

2.4 Wave loading

2.4.1 Wave climate

The wave climate and design wave properties should be estimated in accordance with section 4 of BS 6349-1:1984. The range of conditions considered should reflect the characteristics of the vessel or structure, and the moorings. It should be noted that the response of moored vessels and structures to waves is highly dependent on wave period and wave length. For example, maximum response may occur when a wave period coincides with the natural frequency of motion of a structure, or when a wave length coincides with the structure length.

2.4.2 Description of wave loading

The primary wave-induced forces on a vessel or structure are oscillatory and have, in general, the same frequency characteristics as the waves themselves. They are usually defined as “first order” forces, which are proportional to wave amplitude. In addition to the oscillatory forces there are slowly varying drift forces which act on the vessel or structure and are primarily due to non-linear second order terms in the pressure field associated with the waves. These drift forces are proportional to the square of the wave amplitude and have a much smaller frequency than the first order forces. The magnitude of the forces is small compared to first order forces. There is a resulting mean value, commonly called the mean drift force. This mean drift force is similar to the wave “set-up” observed when a wave reflects off a fixed wall or shoreline.

Most floating structures are of sufficient size to cause disturbance of the waves incident on the structure. Physical models, and computational models based on diffraction theory can be used to simulate wave disturbances and hence the forces and resulting motions of a structure. Simple estimates of wave loading can be made for the two limiting cases of:

- a) no disturbance of the waves;
- b) complete reflection of the waves.

2.4.3 Basic design principles

2.4.3.1 First order forces and resultant motions.

Vertical motions (pitch, roll and heave) cannot normally be suppressed by a mooring or restraining system and should be allowed to exist unimpeded.

⁴⁾ Loads due to gusts of less than 1 min will usually be damped out in water. However, the effect of gusts should be checked for taut line mooring systems, small structures and small vessels.

Horizontal motions (surge, sway and yaw) can be suppressed by stiff restraining systems such as dolphins. However, significant wave action (of the order of 2 m height or over) will cause large first order forces. These forces can be avoided by providing a soft system, e.g. a chain or wire mooring, such that the structure moves freely.

In the case of a stiff restraining system, e.g. sets of dolphins, the stiffness of the system can be used in theory to predict the response of the vessel or floating structure to waves. However, in practice the softness or slackness of guide systems and fendering will allow motion which will generally be erratic and unpredictable. As a consequence, a stiff restraining system should be designed with an allowance for impact load added to the force required to hold the structure rigid.

For sheltered locations it may be sufficient to make simple estimates of forces and motions, as outlined in 2.4.4. The use of physical or mathematical models should be considered for exposed locations.

2.4.3.2 Drift forces and slowly varying motions. The mean drift force acting on a vessel or structure should be considered as a steady force which acts in combination with steady forces due to wind and current. For locations where the significant wave height is less than 2 m, it is sufficient to make a simple estimate of mean drift force as outlined in 2.4.4. Slowly varying drift forces and resultant motions may be neglected provided that the mean drift force is shown to be small.

For exposed locations, or locations where long waves are known to exist, mean and slowly varying drift forces should be estimated by taking account of the wave climate, the motions of the structure and the stiffness of the moorings. Physical or computational models which input irregular waves can be used to obtain estimates.

2.4.4 Simple estimates of forces and motions

2.4.4.1 First order forces. When a vessel or structure is small or slender it will have little effect on wave form, and forces may be estimated by the use of Morison's equation as described in 39.4.4 of BS 6349-1:1984.

When a vessel or structure is of a shape such that waves impinging on it are reflected, forces can be estimated as for a standing wave. The maximum pressure on the structure elevation γ , relative to still water level P_γ (in kN/m²), is then given by the equation:

$$P_\gamma = \rho g \gamma + \rho g H_{\text{inc}} \cosh[2\pi(\gamma + d)/L] / \cosh(2\pi d/L) \quad (1)$$

where

- ρ is the mass density of water (in t/m³);
- g is the acceleration due to gravity (9.81 m/s²);
- γ is the elevation relative to still water level, measured positively upward (in m);
- H_{inc} is the incident wave height (in m);
- d is the still water depth (in m);
- L is the wavelength (in m).

Equation (1) neglects the set-up of the wave due to the presence of the vessel or structure.

For a structure extending to the seabed the maximum wave force for unit length of the structure (in a horizontal direction), F_{max} (in kN/m), is given by the equation:

$$F_{\text{max}} = \rho g H_{\text{inc}} L \tanh(2\pi d/L) / 2\pi \quad (2)$$

For deep water equation (2) reduces to:

$$F_{\text{max}} = \rho g H_{\text{inc}} L / 2\pi \quad (3)$$

For shallow water the equivalent equation is:

$$F_{\text{max}} = \rho g H_{\text{inc}} d \quad (4)$$

2.4.4.2 Response to first order forces. The response of a vessel or floating structure to regular waves can be described in terms of response amplitude operators (RAOs) which give the ratio

$$\frac{\text{amplitude of motion of vessel or structure}}{\text{amplitude of wave motion}}$$

for a defined wave frequency or period, or length. Simple estimates of RAOs can either be made from known estimates for similar vessels or structures, or recourse can be made to physical or mathematical modelling.

In deep water the horizontal amplitude of motion of a wave particle at the surface is equal to the vertical amplitude. As the water depth decreases, horizontal particle motions increase, as indicated in Figure 1. This increase should be allowed for when assessing horizontal motions.

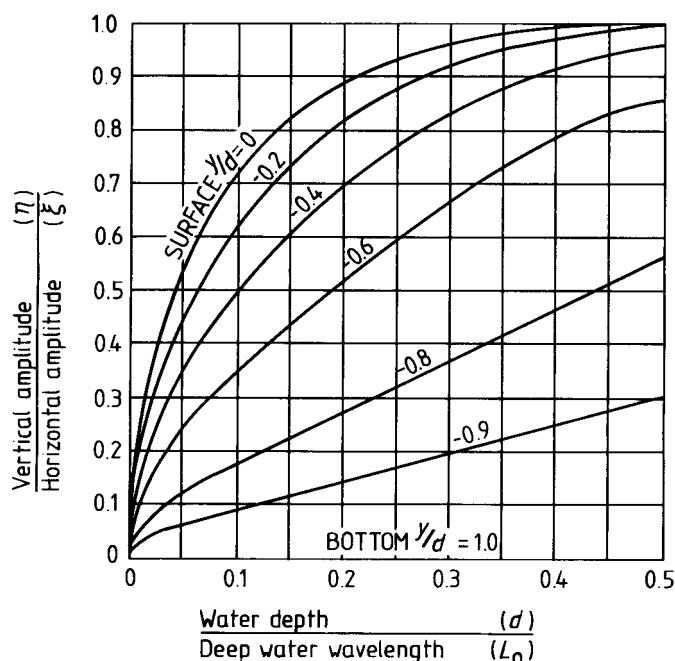


Figure 1 — Wave particle amplitude of motion versus water depth

2.4.4.3 Mean wave drift. The mean wave drift force, F_{WD} (in kN), in an irregular sea is given by the equation:

$$F_{WD} = 2g\rho \int_0^\infty S_\eta(f) R^2(f) df \quad (5)$$

where

- ρ is the mass density of water (in t/m^3);
- g is the acceleration due to gravity (9.81 m/s^2);
- L is the length of the vessel or structure normal to the wave;
- $S_\eta(f)$ is the one-dimensional spectral density function of surface elevation, at wave frequency f ;
- $R^2(f)$ is the drift force coefficient at wave frequency f .

The mean wave drift force in a regular sea is given by the equation:

$$F_{WD} = \rho g L R^2(f) (H/2)^2 \quad (6)$$

where H is the height of the regular wave (in m).

Physical and mathematical models have been used to determine values of drift force coefficient $R^2(f)$ for tankers, semi-submersible vessels and barges [1, 2, 3, 4]. Various definitions of drift force coefficient exist, and care should be taken when interpreting results.

For a motionless structure the value of $R^2(f)$ tends to a maximum of 0.5 for waves of large frequency (small period). This value indicates full reflection of waves off the structure.

A simple conservative estimate of mean drift force can be made, without recourse to the modelling of a structure, by assuming that all waves are fully reflected off the structure, i.e. the value of $R^2(f)$ is 0.5. The mean drift force in an irregular sea is then given by the equation:

$$F_{WD} = \frac{\rho g L H_s^2}{16} \quad (7)$$

where H_s is the significant wave height (in m).

Similarly the mean drift force for a regular sea is given by the equation:

$$F_{WD} = \frac{\rho g L H^2}{8} \quad (8)$$

where H is the regular wave height (in m).

The equations for an irregular sea will generally apply. However, in certain instances, such as when a steady swell of almost invariant height exists, it may be more appropriate to consider the more conservative regular sea equation.

2.4.5 Physical models

Guidance on the use of physical models is contained in 31.3.2 of BS 6349-1:1984 and [5]. Tests are performed either in a narrow wave tank or a wave basin of large plan area. Tests in wave tanks normally allow accurate modelling of the vessel or structure and moorings. However, the wave climate is simplified in that it is essentially two-dimensional. The tests are often performed in order to calibrate mathematical models. Tests in wave basins often allow modelling of changes in wave climate due to topography, coastline and harbour features. However, care should be taken that the inclusion of these details does not lead to problems of scale when modelling a vessel or structure and moorings.

Model tests should be conducted by experienced personnel. The accuracy of tests will depend on the ability to satisfy scaling laws, the ability to model vessel or structure properties, the method of wave generation and the accuracy to which waves, vessel motions and mooring forces can be measured. The degree of accuracy of tests should be stated in test reports. Particular care should be taken when applying results to conditions which are different from those modelled, such as for instance when results are “scaled up” to represent more severe sea states.

The load factors and factors of safety normally applied in design should not be reduced as a consequence of model tests.

2.4.6 Computational models

Computational models are described briefly in 31.3.4 of BS 6349-1:1984. Most models use a three-dimensional source technique to account for the incident waves, diffraction of the waves by a vessel or structure, and the radiation of the waves due to the motions. The basic theory is usually referred to as “diffraction theory” [6].

In order to model vessels or structures they have to be divided into a number of small elements. Waves can be treated as either regular or irregular. However, irregular waves have to be modelled in order to calculate slowly varying drift forces.

Computational models are complex and should be run by personnel experienced in their calibration and operation. Where possible, results should be checked against those obtained from physical model tests or other calculations. Particular care should be taken to ensure that the most severe load cases are considered when evaluating factors of safety for moorings.

2.5 Wind loading

2.5.1 General

This clause covers factors considered to be of particular relevance to vessels and floating structures in coastal waters. It is intended to supplement CP 3:Chapter V-2. It should generally be used in conjunction with CP 3:Chapter V-2. However, sufficient information is included in this clause to allow loads on simple structures in “open” locations to be calculated without reference to CP 3:Chapter V-2. The information contained herein is also intended to supplement other codes applying to locations outside the British Isles.

2.5.2 Basic wind speed (3 s gust)

In CP 3:Chapter V-2 the basic wind speed is defined as the 3 s gust speed estimated to be exceeded, on the average, once in 50 years. A map of basic wind speeds at 10 m above ground in an open situation is provided in CP 3:Chapter V-2. A wind map for offshore locations is contained in Appendix B and has been derived by extending the wind map in CP 3:Chapter V-2 from the coast. These maps are compatible, and either may be used for coastal sites in the British Isles. However, the accuracy of the data and the availability of further data should be checked where necessary using expert advice such as that provided by the Meteorological Office.

Where local data is used to calculate basic wind speeds, care should be taken in converting wind speed to differing duration and height above sea level to the basic speed. If data from offshore locations such as weather ships or light vessels are to be used, the use of expert advice should be considered. The following information is a guide for data at the standard height of 10 m above sea or ground level:

a) *for data from offshore sites:*

3 s gust speed = 1.30×10 min mean speed;

3 s gust speed = $1.37 \times$ hourly mean speed;

b) *for data from coastal or land station:*

3 s gust speed = $1.5 \times$ hourly mean speed.

This information is based on the fact that gust speeds over the open sea are similar to those over open land. However, mean speeds over the open sea are higher than over land.

2.5.3 Design wind speeds

2.5.3.1 General. The design wind speed should be calculated by taking account of the type of structure, the height above sea level and the return period being used.

2.5.3.2 Type of structure and height above sea level. The height above sea level and type of structure can be accounted for by applying the factors given in Table 1 to basic wind speeds of 3 s duration.

Categories A, B and C (see Table 1) should be used for the design of individual members or substructures. Category D (see Table 1), which is based on a 1 min mean speed, should be used to derive the total loads on a vessel or floating structure. These recommendations are based on the fact that very short gust loads (less than 1 min) have little effect on the moorings of most floating vessels or structures unless they are small and are on taut lines.

Wind speed factors for “open” country (contained in CP 3:Chapter V-2) are similar to those contained in Table 1, except for heights of less than 10 m. The factors in CP 3:Chapter V-2 can be used but are not generally applicable to floating structures at heights of less than 10 m due to the fact that the wind is influenced less by the sea than by the ground. CP 3:Chapter V-2 does not contain information on 1 min mean speeds. A study of land based data for open sites provides an approximate relationship between the 1 min mean speed 10 m above ground level and the 3 s gust speed, as follows:

$$1 \text{ min mean speed} = 0.82 \times 3 \text{ s gust speed.}$$

This information should be used with caution. The use of Table 1 to calculate 1 min mean speeds will lead to more generous estimates. For example, for the open sea at 10 m above sea level:

$$1 \text{ min mean speed} = 0.85 \times 3 \text{ s gust speed.}$$

Table 1 — Wind speed factors for use over the open sea

Height	Category ^a			
	A	B	C	D
	3 s gust speeds	5 s gust speeds	15 s mean speeds	1 min mean speeds
	Individual members, etc.	Small structures	Large structures	For use with maximum wave
m				
5	0.95	0.93	0.88	0.78
10	1.00	0.98	0.93	0.85
20	1.05	1.03	0.99	0.93
30	1.09	1.07	1.02	0.97
40	1.11	1.09	1.05	1.00
50	1.13	1.11	1.08	1.03
60	1.14	1.13	1.09	1.05
80	1.17	1.16	1.12	1.09
100	1.19	1.18	1.14	1.12
120	1.21	1.20	1.16	1.15
150	1.23	1.22	1.19	1.17

^a The four categories are as follows:

- a) Category A refers to individual members, and equipment secured to them on open decks for which the 3 s gust speed applies with a factor for increase of speed with height according to a power-law equation having an exponent of 0.075.
- b) Category B refers to parts or the whole of the superstructure above the lowest still water level whose greatest dimension horizontally or vertically, does not exceed 50 m, for which a 5 s gust applies using a power-law exponent of 0.08.
- c) Category C refers to parts or the whole of the superstructure above the lowest still water level whose greatest dimension, horizontally or vertically exceeds 50 m, for which a 15 s mean speed applies using a power-law exponent of 0.09.
- d) Category D refers to the exposed superstructure, regardless of dimension, to be used when determining the wind forces associated with maximum wave or current force which predominates, for which a 1 min mean speed applies using a power-law exponent of 0.12.

2.5.3.3 Return period. A factor S_3 (defined in 5.6 of CP 3:Chapter V-2:1972) based on statistical concepts can be applied to take account of the degree of security required and the period of time, in years, during which there will be exposure to waves. A factor of 1 should normally be applied, equivalent to a period of 50 years. For periods of exposure other than 50 years the factors presented in Figure 2 of CP 3:Chapter V-2:1972 and described in Appendix C of CP 3:Chapter V-2:1972 should be applied.

2.5.4 Force coefficient

Information on coefficients for ships is contained in clause 42 of BS 6349-1:1984. Coefficients are provided for longitudinal, transverse and rotational forces for winds in any direction.

Information on coefficients for individual structural members is contained in CP 3:Chapter V-2. Coefficients for the forces along the major axis of the members are provided for intervals of wind direction of 45° .

Information on coefficients for "box like" structures is provided in Table 2. The coefficients have been derived from Table 10 of CP 3:Chapter V-2:1972 and apply to winds acting normal to surfaces. For winds acting at an angle to the surface, forces may be evaluated as described in 2.5.6.

2.5.5 Trim and heel

Trim or heel of a vessel or structure is usually only significant in open seas. Increases in wind loading due to trim or heel of a moored structure can usually be ignored.

2.5.6 Simplified method of evaluating wind loading

A detailed evaluation of wind loading cannot always be justified. A simplified approach may be sufficient for the following:

- temporary moorings;
- mooring of vessels, where contingencies exist for leaving the mooring;
- mooring where large factors of safety apply;
- locations where limited wind data exist;
- feasibility studies.

A simple method for evaluating wind loads is provided below. The following assumptions are made:

- 1) the site is "open";
- 2) the height of the vessel or structure is small (< 20 m);
- 3) the structure is predominantly solid.

The design wind speed V_w may be taken as the 1 min mean speed, and can be related to the basic wind speed (3 s gust) V by

$$V_w = 0.85 V.$$

The wind pressure q (in kN/m^2) may be taken as:

$$q = 0.613 \times 10^{-3} \times V_w^2 \quad (9)$$

where V_w is the design wind speed (in m/s).

The wind forces on the structure are as follows:

$$F_x = qA_x (C_x \cos \alpha) \quad (10)$$

$$F_y = qA_y (C_y \sin \alpha) \quad (11)$$

$$F_{RW} = \sqrt{(F_x^2 + F_y^2)} \quad (12)$$

where

x and y are the major axes of the structures;

F_x is the wind force acting along the x axis (in kN);

F_y is the wind force acting along the y axis (in kN);

q is the wind pressure (in kN/m^2);

A_x is the effective wind area normal to the x axis (in m^2);

A_y is the effective wind area normal to the y axis (in m^2);

C_x is the wind force coefficient for the x axis;

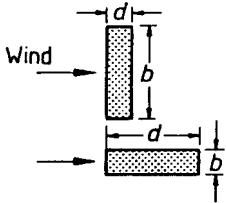
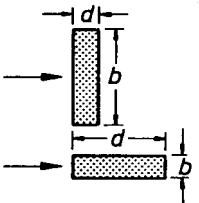
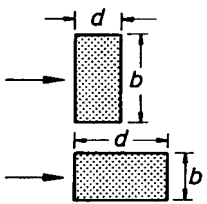
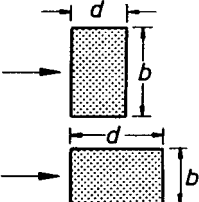
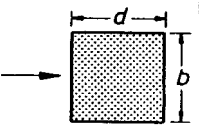
C_y is the wind force coefficient for the y axis;

α is the angle of the wind to the x axis;

F_{RW} is the resultant wind force (in kN).

The use of this method for loads on ships gives reasonable agreement with the method described in clause 42 of BS 6349-1:1984. The application of force coefficients of 1.0 to barge and pontoon hulls is standard practice, i.e. $C_x = C_y = 1.0$. The simplified approach outlined above should be used to check more detailed calculations.

Table 2 — Wind force coefficient C_f for rectangular bodies

Plan shape	l w (see note)	b d (see note)	Height/breadth ratio						
			Up to $\frac{1}{2}$	1	2	4	6	10	20
			Wind force coefficient C_f						
	≥ 4	≥ 4	1.2	1.3	1.4	1.5	1.6	—	—
		$\leq \frac{1}{4}$	0.7	0.7	0.75	0.75	0.75	—	—
	3	3	1.1	1.2	1.25	1.35	1.4	—	—
		$\frac{1}{3}$	0.7	0.75	0.75	0.75	0.8	—	—
	2	2	1.0	1.05	1.1	1.15	1.2	—	—
		$\frac{1}{2}$	0.75	0.75	0.8	0.85	0.9	—	—
	$1\frac{1}{2}$	$1\frac{1}{2}$	0.95	1.0	1.05	1.1	1.15	—	—
		$\frac{2}{3}$	0.8	0.85	0.9	0.95	1.0	—	—
	1	1	0.9	0.95	1.0	1.05	1.1	1.2	1.4
NOTE b is the dimension normal to the wind; d is the dimension measured in the direction of the wind; l is the greater horizontal dimension; w is the lesser horizontal dimension.									

2.6 Current loading

2.6.1 General

This clause complements clause 42 of BS 6349-1:1984.

2.6.2 Design speed

The design speed should be assessed taking account of the most unfavourable combinations of tide, surge and wind-induced currents for the return period being considered. It is normal to correlate current measurements with tide records. The assessment of maximum currents should reflect the accuracy and detail of the data on tide elevations and current speeds available. A simple assessment from chart data or Admiralty Sailing Directions (Pilots) should allow for the fact that values quoted are often typical rather than proven maxima.

The calculation of wind induced currents should be based on a wind of 12 h duration. The surface current speed is generally found to be 2 % to 3 % of the wind speed, and a linear decay of the wind induced current with depth is usually assumed.

It is recommended that a 10 min mean current speed is used in design.

2.6.3 Force coefficients

The nature of the forces on floating bodies is considerably complex and not fully understood. In theory, the forces depend on factors such as speed of flow, area normal to the flow, total wetted area, roughness, detailed form or shape, and the proximity of the seabed or other boundaries and bodies. In practice, simplifications are made when describing forces. For bodies where areas normal to the flow are small compared to their length parallel to the flow, such as the longitudinal forces on ships, the forces are usually described by a coefficient which relates the force to the current speed and the wetted area (usually defined in terms of length and draught). Coefficients for ships are given in clause 42 of BS 6349-1:1984.

For bodies presenting significant cross-sectional area to the flow (compared with length parallel to the flow), the force is usually described by a coefficient which relates the force to the current speed and the cross-sectional area of the body. Such an example is transverse loading on a ship. Coefficients for transverse loading are given in clause 42 of BS 6349-1:1984.

For a body where width normal to the flow is similar to the length parallel to the flow, the governing factor is usually assumed to be width not length. For forces on structural members such as cylinders or piles the following equation is used:

$$F_D = \frac{1}{2} (C_D \rho V^2 A_n) \quad (13)$$

where

F_D is the steady drag force (in kN);

C_D is the drag force coefficient;

ρ is the mass density of water (in t/m³);

V is the incident current velocity (in m/s);

A_n is the area normal to the flow (in m²).

Drag coefficients for common pile shapes are contained in 38.2 of BS 6349-1:1984.

There is very little data on forces or coefficients for floating structures such as barges and pontoons. However, towing tests on barges have been performed, and graphs of typical drag coefficients are reproduced in Figure 2 to Figure 5 [7]. Towing tests on wall-sided boxes have also been performed and results are reproduced in Table 3 [4].

The coefficients in Figure 2 and Figure 3 and Table 3 apply when the water is deep (depth/draught ≥ 5). The coefficients in Figure 4 and Figure 5 apply in shallow water. The correction factor for ships in shallow water, given in Figures 29 and 30 of BS 6349-1:1984 may be used in place of the data in Figure 4 and Figure 5.

The following equations should be used when applying the coefficients given in Figure 2 to Figure 5.

$$F_x = \frac{1}{2} (C_x \rho V^2 A_x) \quad (14)$$

$$F_y = \frac{1}{2} (C_y \rho V^2 A_y) \quad (15)$$

where

F_x is the current force along the longitudinal (x) axis (in kN);

F_y is the current force along the transverse (y) axis (in kN);

C_x is the longitudinal current force drag coefficient;

C_y is the transverse current force drag coefficient;

ρ is the mass density (in t/m³);

A_x is the effective current area normal to the longitudinal (x) axis (in m);

A_y is the effective current area normal to the transverse (y) axis (in m);

V is the incident current velocity (in m/s).

Table 3 — Typical current drag coefficients for wall-sided boxes

Shape of model	Breadth/draught ratio B/D	Drag force coefficient C_D
Square	8.1	0.72
	3.4	0.70
	1.6	0.86
Octagon (face leading)	8.1	0.57
	3.4	0.52
	1.6	0.60
Octagon (corner leading)	1.8	0.58
Cylinder	8.1	0.47
	3.4	0.39
	1.6	0.45

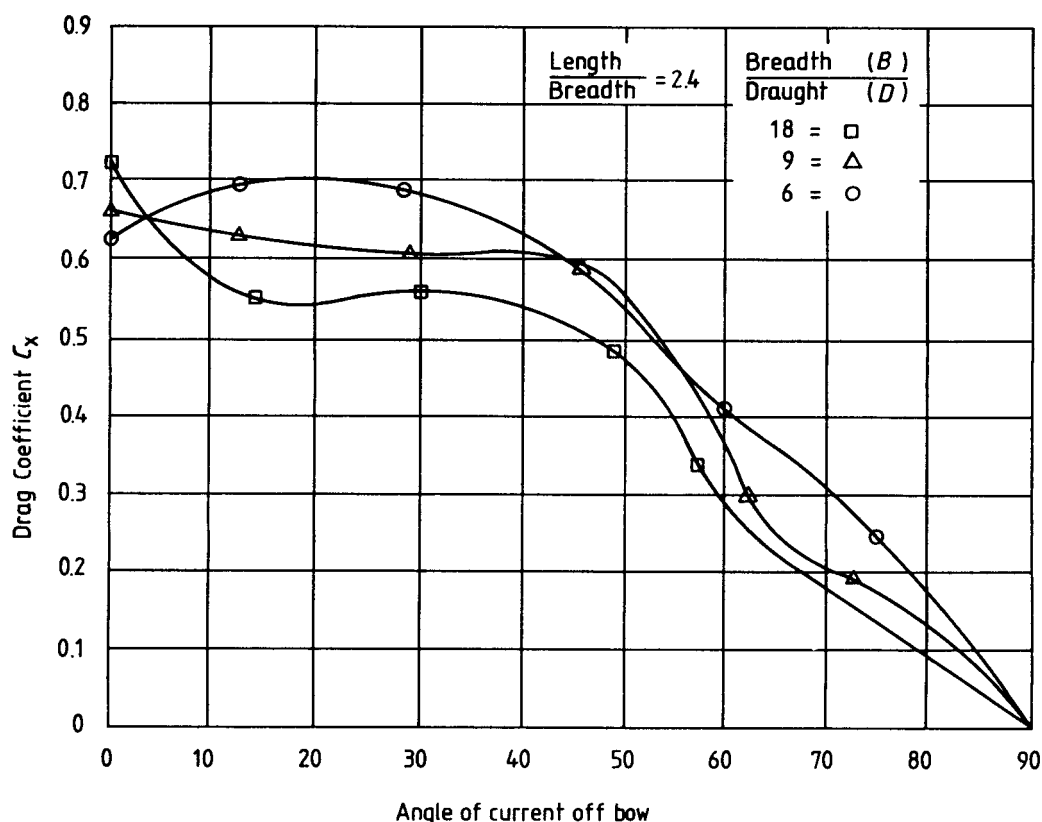
NOTE 1 A drag coefficient of 1.0 should be used unless more reliable values can be obtained.

NOTE 2 The data source for this table is reference [4].

2.6.4 Evaluation of model tests and theoretical formulae

Considerable care is required when interpreting model tests and theoretical equations due to difficulties in defining and scaling the various components contributing to the force or resistance of a body.

The drag force coefficient C_D is usually referred to as a “total” drag coefficient, since in theory it is composed of several components such as “pressure drag”, “skin friction drag” and “wave making resistance”. The total drag coefficient may not have been “corrected” to allow for depth or width limitations in the model tests. The use of “corrected” values of coefficients implies that no boundaries exist near the body. If boundaries such as the seabed do exist near the body, the coefficients may be factored to allow for the boundary.

**Figure 2 — Longitudinal drag coefficient for rectangular pontoon in deep water**