

Rules for the design of cranes —

Part 1: Specification for classification, stress calculations and design criteria for structures

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Foreword

This Part of BS 2573 has been prepared under the direction of the Mechanical Engineering Standards Committee. It supersedes BS 2573-1:1977 which is withdrawn. The fourth revision of this standard has been prepared having due regard for the work of ISO/TC 96, Cranes, lifting appliances and related equipment, in preparing the International Standard ISO 4301 covering crane classification. The classification requirements have been revised to align with the requirements of the International Standard.

This new edition of BS 2573-1 also aligns the method of classification with that of BS 2573-2 which covers permissible stresses in crane mechanisms and in which account had already been taken of the ISO 4301 requirements.

An approach to classification based on ISO work is considered to provide scope for precise definition of the purchaser's requirements on the one hand and for rational design and economic production on the other. The change in the method of classification will not lead to any substantial change in the design of cranes although it has entailed alterations to related clauses of the standard, notably those dealing with duty and impact factors and fatigue. Because the classification of a crane is determined by the number of hoisting cycles and the state of loading, as defined by the load spectrum factor, comparisons with the four former classes in BS 2573-1:1977 can be readily made.

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Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 86, 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 2573 specifies the basis for computing stresses in crane structures and the way in which permissible stresses in crane structures shall be determined in order to secure economy in design and reliability in operation. For this purpose it specifies a classification system that enables the purchaser and the manufacturer to match a particular crane to the required duty and utilization.

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

1.2 Definitions and applications of terms

1.2.1 Definitions. For the purposes of this British Standard the following definitions apply.

1.2.1.1

dead loads

all the loads of constant magnitude and position that act permanently on the structure or member

1.2.1.2

live loads

any load except wind load that gives rise to variation of stress in a member. Such variation may be due to any change of position or magnitude of an externally applied load or to the movement of the crane structure itself

1.2.1.3

inertia forces

the forces produced by change of velocity

1.2.1.4

wind load

the forces produced by the velocity of the wind, which is assumed to act horizontally

1.2.2 Applications of terms. For the purposes of this British Standard the following terms apply as stated.

1.2.2.1

basic stresses

the stresses as set out in 5.1, 5.2 and section 6

1.2.2.2

permissible working stress

the stress numerically equal to the basic stress multiplied by the relevant duty factor and the factor corresponding to the load combinations as specified in 3.1. Permissible working stresses are specified in 4.3.2

1.2.2.3

permissible fatigue stresses

stresses as set out in section 8

1.2.2.4

service conditions

the crane is deemed to be under service conditions when it is operating without load or with a load up to the maximum safe working load

Section 2. Classification of the crane as a whole

2.1 General

To provide a rational and uniform basis for certain aspects of the design of the crane structure, a group classification for the crane as a whole in the range of A1 to A8 (see Table 3) and based on the requirements of 2.2 to 2.4 shall be established.

NOTE 1 The group classification of the crane as a whole provides a framework of reference between purchaser and manufacturer for contractual and technical purposes by means of which a crane may be matched to the service for which it is required. It also enables a fatigue analysis of the design to be based on the specified life and conditions of service (see section 8).

Cranes shall be classified into groups according to:

- a) *class of utilization*: as determined from the required number of operating cycles for the crane, in accordance with 2.2.
- b) *state of loading*: as determined from the conditions of loading to which the crane will be subjected, in accordance with 2.3.

NOTE 2 It is recommended that the group classification (with the class of utilization and state of loading from which it is derived) are clearly and permanently marked on the crane.

2.2 Class of utilization

2.2.1 General. The class of utilization of the crane shall be determined from its assumed total number of all operating cycles during its intended life. For the purpose of classification, an operating cycle shall be considered to commence when a load is picked up and end at the moment when the crane is ready to pick up the next load.

NOTE Where a crane is fitted with a lifting attachment, the weight of which forms a significant proportion of the crane capacity, the effect of this on fatigue life should be carefully evaluated.

2.2.2 Determining the class of utilization

2.2.2.1 Where sufficient information is available, the number of operating cycles shall be calculated from a knowledge of the duties which the crane will be expected to perform, e.g. for a crane performing part of a continuous, repetitive process the number can readily be derived from the number of operating cycles per hour and the total number of working hours during the intended life.

The class of utilization of the crane shall then be selected from Table 1 according to the tabulated number of operating cycles that is nearest to, but not less than, the number calculated by the procedure outlined in the previous paragraph.

2.2.2.2 Where insufficient information is available for calculating the total number of operating cycles, as may be the case when the crane is used for a variety of duties, a suitable value, estimated on the basis of experience, shall be used. Where there is difficulty in assigning a suitable value, the next highest figure in Table 1 shall be taken.

2.2.2.3 Typical values or ranges of the class of utilization normally associated with particular types of crane and crane applications are given in Appendix A.

2.3 State of loading and nominal load spectrum factor

2.3.1 General. The state of loading of the crane and the corresponding nominal load spectrum factor shall characterize the extent to which the crane lifts the maximum permitted load for the configuration, or smaller loads. They depend both on the magnitudes of the lifted loads relative to the maximum permitted load, and on the number of cycles in which each is lifted relative to the total number of cycles.

Assessment of the state of loading shall be based on the same cycles as are used in 2.2 to determine the class of utilization. Also, the weight of the lifted load shall include the weight of any lifting attachment such as bucket, grab, magnet or lifting beam whether permanently fitted or detachable, and the weights of other suspended components such as the bottom block, hook and of the hoist rope that are lifted together with the load. The maximum permitted load is thus the specified safe working load plus the weights of any such lifted components or attachments that are not included in the specified safe working load.

NOTE Typical values or ranges of the state of loading normally associated with particular types of crane and crane applications are given in Appendix A.

Table 1 — Class of utilization

NOTE The number of cycles used in selecting the class of utilization is a figure used only for classification purposes and as a design parameter. It does not imply a guaranteed life.

Class of utilization	Max. number of operating cycles	Remarks
U1	3.2×10^4	Infrequent use
U2	6.3×10^4	
U3	1.25×10^5	
U4	2.5×10^5	Fairly frequent use
U5	5×10^5	Frequent use
U6	1×10^6	Very frequent use
U7	2×10^6	Continuous or near-continuous use
U8	4×10^6	
U9	Greater than 4×10^6	

2.3.2 Determining the load spectrum factor

2.3.2.1 Where details are available of the magnitudes of the loads and the number of times each will be lifted during the intended life of the crane, the load spectrum factor, K_p' , shall be calculated as follows:

Let: P_i = The magnitudes of the individual lifted loads characteristic of the duty of the crane (i.e. $P_1, P_2, P_3 \dots P_n$);

$P_{\max}$ = The maximum permitted load (see 2.3.1);

C_i = The estimated number of cycles which occur at the individual load level P_i (i.e. $C_1, C_2, C_3 \dots C_n$);

C_t = The total number of all the individual cycles at all load levels

$$\text{Then: } K_p' = \sqrt[m]{\sum \left\{ \frac{C_i}{C_t} \left(\frac{P_i}{P_{\max}} \right)^m \right\}}$$

For the purpose of classification of the crane as a whole, $m = 3$.

Expanded, the above equation becomes:

$$K_p' = \sqrt[3]{\left\{ \frac{C_1}{C_t} \left(\frac{P_1}{P_{\max}} \right)^3 + \frac{C_2}{C_t} \left(\frac{P_2}{P_{\max}} \right)^3 + \frac{C_3}{C_t} \left(\frac{P_3}{P_{\max}} \right)^3 + \dots + \frac{C_n}{C_t} \left(\frac{P_n}{P_{\max}} \right)^3 \right\}}$$

The state of loading shall be selected from Table 2 according to the tabulated value of nominal load spectrum factor K_p , that is the nearest to, but not less than the calculated value of K_p' .

2.3.2.2 Where details of the numbers and weights of the lifted loads during the intended life of the crane are not known, the descriptive definitions in Table 2 shall be used to assist the selection of an appropriate state of loading and corresponding nominal load spectrum factor. Where there is doubt in the selection of appropriate values, the next highest figures in Table 2 shall be used.

2.4 Determination of group classification of the crane

The group classification of the crane shall be determined from Table 3 using the class utilization and state of loading obtained in accordance with 2.2 and 2.3.

No change in the group classification of a crane, or in its combination of state of loading and class of utilization within the same group classification shall be made without reference to the manufacturer or having a thorough design check carried out by a competent person.

Table 2 — State of loading

State of loading	Nominal load spectrum factor K_p	Descriptive definition
Q1 Light	0.5	Cranes which hoist the safe working load very rarely and, normally, light loads.
Q2 Moderate	0.63	Cranes which hoist the safe working load fairly frequently and, normally, moderate loads.
Q3 Heavy	0.8	Cranes which hoist the safe working load frequently and, normally, heavy loads.
Q4 Very heavy	1.0	Cranes which are normally loaded close to safe working load.
NOTE The values of the nominal load spectrum factor as defined in ISO 4301 are equivalent to the cube of those in Table 2 above. This difference from ISO 4301 does not affect the state of loading of the crane or its group classification but results in values that can be applied directly in the simple treatment for fatigue design given in 8.4.		

Table 3 — Group classification of the crane as a whole

State of loading	Nominal load spectrum factor K_p	Class of utilization and maximum number of operation cycles of the crane								
		U1	U2	U3	U4	U5	U6	U7	U8	U9
		3.2×10^4	6.3×10^4	1.25×10^5	2.5×10^5	5×10^5	1×10^6	2×10^6	4×10^6	$> 4 \times 10^6$
Q1 Light	0.5	A1	A1	A2	A3	A4	A5	A6	A7	A8
Q2 Moderate	0.63	A1	A2	A3	A4	A5	A6	A7	A8	A8
Q3 Heavy	0.8	A2	A3	A4	A5	A6	A7	A8	A8	A8
Q4 Very heavy	1.0	A3	A4	A5	A6	A7	A8	A8	A8	A8

Section 3. Loads and load combinations

3.1 Loads and load combinations to be considered in design

3.1.1 General. The structure as a whole and each part of it shall be designed to withstand the load combinations given in 3.1.2 using the loads listed in 3.1.3.

3.1.2 Load combinations

3.1.2.1 Crane in use without wind

$$L_1 + L_3 + H_1$$

3.1.2.2 Crane in use with in-service wind

$$L_1 + L_3 + H_1 + V_1$$

3.1.2.3 Fatigue check for each member in which fluctuating stresses occur

3.1.2.3.1 Each member in which fluctuating stresses occur shall be checked for fatigue in accordance with section 8.

3.1.2.3.2 Where the simple method given in 8.4 is used the following loads shall be taken into account:

$$L_1 + L_4 + H_2$$

3.1.2.3.3 Where the more detailed method of calculation given in the note to 8.4 is used, the following loads shall be taken into account:

$$L_1 + L_3 + H_2$$

3.1.2.4 Crane in out-of-service condition

$$L_1 + V_2$$

3.1.2.5 Crane being erected or dismantled

3.1.2.5.1 During erection and/or dismantling operations

$$L_1 + V_1'$$

3.1.2.5.2 Partially erected or dismantled crane subjected to out-of-service wind

$$L_1 + V_2$$

In calculating the effect of V_2 for the partially erected/dismantled structure, the support provided by temporary erection equipment such as guy ropes or staging shall be taken into account. Where such equipment is not used the structure shall be considered as free standing.

3.1.2.6 Crane in collision with resilient buffers

$$L_1 + B$$

3.1.3 List of loads

- L_1 Dead loads due to dead weight.
- L_2 Live loads, including the hook load.
- L_3 Live loads, including the hook load multiplied by the impact factor (see 3.1.4).
- L_4 Live loads, including the hook load multiplied by the impact factor and the nominal load spectrum factor (see 3.1.4 and 2.3).
- H_1 The combined effect of the two most severe horizontal loads (see 3.1.5).
- H_2 H_1 excluding the skew loads due to travelling.
- V_1 Load due to the service wind acting horizontally in any direction where applicable.
- V_1' Load due to the maximum permissible wind speed for the erection/dismantling operation as specified by the manufacturer. V_1' shall not exceed V_1 .
- V_2 Load due to the out-of-service wind acting horizontally in any direction where applicable.
- B Load due to collision with resilient buffers (see 3.1.6).

3.1.4 Impact factor. The impact factor shall apply to the motion of the hook load in a vertical direction and covers inertia forces including shock. In calculating live loads in members of the structure, the hook load shall be multiplied by the impact factor, given in Table 4 a) to Table 4 g), appropriate to the type of crane and its application.

Table 4 — Impact and duty factors according to crane type and application

NOTE The table does not cover all crane types and duties. Cranes such as floating cranes, breakdown cranes and pedestal cranes for off-shore use, for example, all have special design requirements associated with their particular applications which have to be taken into account when determining appropriate impact and duty factors.

a) Overhead travelling industrial type cranes (O.T.C.)

Type and/or application		Impact factor	Duty factor
Power stations, engine houses, etc.		1.1	0.95
Light work shop duty (maintenance, repairs, assembly, etc.)		1.1	1.0
Light stores duty		1.1	1.0
Medium and heavy warehouse duty		1.3	0.95
Medium and heavy workshop duty		1.3	0.95
Goliath cranes for general hook service		1.3	0.95
Goliath cranes for container handling		1.3	0.95
Goliath and bridge cranes for grabbing work	intermittent duty	1.4	0.90
	continuous duty	1.5	0.85
Shipyard cranes		1.3	0.95
Ladle cranes for foundry work		1.2	0.90
Magnet cranes for steel stockyard		1.4	0.90
Magnet cranes for scrapyard work		1.5	0.85
Forging cranes		2.0 ^a	0.85

b) Overhead travelling steelworks cranes

Type and/or application	Impact factor	Duty factor
Ladle cranes	1.2	0.85
Pig/scrap breaking cranes	1.5	0.85
Ingot strippers	1.2	0.85
Soaking pit mould handling cranes	1.5	0.85
Vertical ingot chargers	^b See below	0.85
Furnace charging cranes	1.5	0.85
Forging cranes	2.0 ^a	0.85
Process cranes: on line	1.5	0.85
Process cranes: off line	1.3	0.9
Heavy mill service	1.4	0.9
Service and maintenance cranes	1.2	0.95

^a This factor may be modified when an overload protection device is fitted.

^b L_3 is taken as $1.2 (W_1 + W_2)$ or $1.5 W_1 + 1.0 W_2$, whichever is the greater, where:

W_1 is the load in the tongs;

W_2 is the weight of the mast and the tongs.

Table 4 — Impact and duty factors according to crane type and application

<i>c) Transporters</i>			
Type and/or application		Impact factor	Duty factor
Medium duty: general use		1.3	0.95
Heavy duty: intermittent grabbing and magnet work		1.4	0.90
Extra heavy duty: continuous grabbing and magnet work		1.5	0.85
<i>d) High pedestal or portal jib cranes and derrick cranes</i>			
Type and/or application		Impact factor	Duty factor
Medium duty in docks and elsewhere: handling general cargo and piece goods		1.3	0.95
Full-time container handling		1.4	0.90
Grabbing or magnet work	intermittent	1.4	0.90
	continuous	1.5	0.85
Shipyards cranes		1.3	0.95
<i>e) Tower cranes</i>			
Type and/or application		Impact factor	Duty factor
Normal duty: general use on building sites		1.2	0.95
Medium duty: general use at a permanent location, etc.		1.3	0.95
<i>f) Freight container cranes</i>			
Type and/or application		Impact factor	Duty factor
Freight container transporters	medium duty	1.3	0.95
	heavy duty	1.4	0.90
Goliath for container handling duty		1.3	0.95
<i>g) Power driven mobile cranes</i>			
Type and/or application		Impact factor	Duty factor
General use		1.2 ^a	0.95
Heavy duty: including intermittent grabbing and magnet work		1.3	0.90
^a For mobile cranes and appliances used for plant erection, lifting hook loads of 75 tonnes up to 100 tonnes, graded impact factors in the range 1.2 to 1.05 may be used where special consideration is given to the duty and the hoist drive characteristics. In this case, for hook loads above 100 tonnes an impact value of 1.05 may be used.			

3.1.5 Horizontal loads

3.1.5.1 Inertia forces. Inertia forces shall be calculated having regard to the linear or angular accelerations produced by the motion drives or brakes.

3.1.5.2 Skew loads due to travelling. When two wheels (or two bogies) roll along a rail, the horizontal forces normal to the rail and tending to skew the structure shall be taken into consideration. The horizontal forces shall be obtained by multiplying the vertical load exerted on each wheel (or bogie) by a coefficient λ (see Figure 1) that depends upon the ratio of the span to the wheel base.

3.1.6 Buffer loads. No design condition is imposed for the crane structure in respect of collision with solid buffers. In cases where adequate resilient buffers are provided for traverse or travel motions and these may come into use at some time in the duty of the crane, when the load is free to swing the buffer force shall be calculated on the assumption that collision takes place with the crane unloaded at 0.7 times the rated speed and that the buffer system is capable of absorbing the energy within its designed stroke. Where the load cannot swing, the buffer effect shall be calculated in the same manner but taking account of the value of the working load. Where a reliable automatic device for slowing down the motion is installed, the appropriate reduced speed shall be used in place of the rated speed.

NOTE Whether buffers should be provided in a particular case is outside the scope of this standard and is usually a matter for decision between the purchaser and the manufacturer having regard to the nature of the duty, dimensional constraints, the size and speed of the crane and the nature of the control and safety devices provided. If resilient buffers are provided, it is recommended that their capacity should be in accordance with the provisions of this clause.

Attention is drawn to the use of buffers with collapsible impact sections for emergency stopping of heavy machines where there is a risk of storm wind forces overcoming the travel brakes or the adhesion of the wheels.

3.1.7 Wind loads

3.1.7.1 Wind action. It shall be assumed that the wind can blow horizontally from any direction at a constant velocity, and that there is a static reaction to the loadings it applies to a crane structure.

3.1.7.2 Wind pressure. The dynamic wind pressure shall be calculated from $q = 0.613 V_s^2$

where

q is the dynamic pressure (in N/m^2)

V_s is the design wind speed (in m/s)

A conversion chart covering V_s in knots, mile/h and m/s , and q in lb/ft^2 , N/m^2 and kgf/m^2 is given in Figure 2.

3.1.7.3 Design wind conditions. Two design wind conditions shall be taken into account in calculating wind loads on cranes as follows.

a) *In-service wind.* This shall be the maximum wind, irrespective of height, in which the crane is designed to operate. The wind loadings shall be assumed to be applied in the least favourable direction in combination with the appropriate service loads specified in 3.1. “In-service” design wind pressures and corresponding speeds shall be in accordance with Table 5.

Action of wind on suspended load. On all cranes, the action of the wind on the suspended load shall be taken into account.

Where a crane is designed to handle only loads of specific shape and size, the wind loading shall be calculated for the appropriate dimensions and configuration. In other cases, the wind force on the suspended load shall be calculated according to Table 6.

b) *Out-of-service wind.* This shall be the maximum (storm) wind that a crane is designed to withstand when in an out-of-service condition. The speed, and thus the pressure, varies with the height of the crane above the surrounding ground level.

For cranes that are to be used in the UK, the minimum out-of-service wind pressures and corresponding velocities to be used as a basis for design shall be those given in Table 7.

Where special precautions are necessary for a crane to withstand the out-of-service wind, e.g. when lowering the jib of a mobile crane, these shall be clearly stated by the manufacturer.

The out-of-service wind pressures on parts of a crane that are between 20 m and 200 m above ground level shall be calculated from the formula:

$$q = 1340 \left(\frac{h}{20} \right)^{0.16}$$

where

q is the wind pressure (in N/m²);

h is the height (in m) above ground level.

NOTE The results of this calculation may also be used as an alternative to the figures given in Table 7 for parts of a crane up to 80 m above ground level.

3.1.7.4 Wind load calculations. For most complete and part structures, and individual members used in crane structures, the wind load shall be calculated from:

$$F = \gamma A q C_f$$

where

F is the wind load (in N);

γ is a factor related to the design application of the calculated wind load;

for structural strength calculations $\gamma = 1.0$;

for anchoring and securing devices $\gamma = 1.2$;

A is the effective frontal area of the part under consideration, i.e. the shadow area of its solid parts projected onto a plane perpendicular to the wind direction (in m²);

q is the wind pressure corresponding to appropriate design condition (in N/m²);

C_f is the force coefficient in the direction of the wind, for the part under consideration.

The total wind load on the structure shall be taken as the sum of the loads on its component parts.

In calculating wind moment for out-of-service conditions, either:

a) the wind pressure at the top shall be taken as constant over the entire height of the structure;

or

b) the structure shall be divided into the horizontal zones of assumed constant pressure given in Table 7 and the appropriate value used for each zone.

3.1.7.5 Individual members, single lattice frames, etc: force coefficients. Force coefficients for individual members, single lattice frames, machinery houses, crabs, etc. shall be in accordance with Table 8.

NOTE The values for individual members vary according to the aerodynamic slenderness and, in the case of large box sections, with the section ratio. Aerodynamic slenderness and section ratio are defined in Figure 3.

Where a frame is made up of flat-sided and circular sections, or of circular sections in both flow regimes ($DV_s < 6 \text{ m}^2/\text{s}$ and $DV_s \geq 6 \text{ m}^2/\text{s}$ where D is the diameter of the section in metres) the appropriate force coefficients shall be applied to the corresponding frontal areas.

3.1.7.6 Multiple members, multiple frames, etc: shielding factors. Where parallel frames or members are positioned so that the windward parts have a shielding effect on those behind them, the wind load on the unsheltered parts shall be calculated from the formula given in 3.1.7.4, taking A as the area in square metres of the windward frame or member plus the unsheltered parts of those behind it. The wind load on sheltered parts shall be calculated from:

$$F_s = \gamma A_s q C_f \phi$$

where

γ , $q C_f$ are as defined in 3.1.7.4;

F_s is the wind load on the sheltered parts (in N);

A_s is the area of the sheltered parts under consideration (in m²);

ϕ is the shielding factor given in Table 9 according to the solidity ratio of the front frame and the spacing ratio. These ratios are defined in Figure 3.

Where there are a number of identical frames or members spaced equidistantly behind each other such that each frame completely shields those behind it, the wind loads shall be calculated (in N) as follows.

On the 1st frame

$$F_1 = \gamma A q C_f$$

On the 2nd frame

$$F_2 = \gamma A q C_f \phi$$

On the n th frame

$$F_n = \gamma A q C_f \phi^{(n-1)}$$

(where n is between 3 and 8)

On the 9th and subsequent frames

$$F_9 = \gamma A q C_f \phi^8$$

where there are up to 9 frames the total wind load

$$\begin{aligned} F_{\text{total}} &= \gamma A q C_f [1 + \phi + \phi^2 + \phi^3 + \dots + \phi^{(n-1)}] \\ (n \leq 9) \\ &= \gamma A q C_f \left(\frac{1 - \phi^n}{1 - \phi} \right) \end{aligned}$$

where there are more than 9 frames the total wind load

$$F_{\text{total}} = \gamma A q C_f \left[\left(\frac{1 - \phi^9}{1 - \phi} \right) + (n-9) \phi^8 \right] \quad (n > 9)$$

where

F, γ, q, C_f are as defined in 3.1.7.4;

A is the area of one frame (in m^2);

ϕ is as defined above.

NOTE For design purposes the value of the term ϕ^n is assumed to have a lower limit of 0.10. It is taken as 0.10 whenever numerically $\phi^n < 0.10$.

3.1.7.7 Lattice towers of square cross section. In calculating the “face-on” wind load on square towers, the solid area of the windward face shall be multiplied by the following overall force coefficients:

for towers composed of flat-sided sections $1.7\gamma q(1 + \phi)$

for towers composed of circular sections

where $DV_s < 6 \text{ m}^2/\text{s}$ $1.2\gamma q(1 + \phi)$

where $DV_s \geq 6 \text{ m}^2/\text{s}$ $1.4\gamma q$

The value of ϕ shall be taken from Table 9 for $a/b = 1$ according to the solidity ratio of the windward face.

The maximum wind load on a square tower, which occurs when the wind blows on to a corner, shall be taken as 1.2 times the face-on load.

3.2 Loads due to climatic conditions and natural phenomena

For conditions of service outside the UK, loads due to wind, snow and temperature variation shall be taken into account as appropriate.

NOTE 1 These should be the subject of agreement between the purchaser and the manufacturer.

NOTE 2 Attention is drawn to the fact that the laws or requirements of a country may require the inclusion of earthquake forces. Such forces should be determined in accordance with those requirements and included in the loads to be considered in design.

Table 5 — In-service design wind pressures

Type of crane	In-service design wind pressure	Approximate equivalent in-service wind speed
a) Cranes that are easily secured against wind action, and are designed for operation in light winds only (e.g. cranes of low chassis height with booms that can be readily lowered to the ground)	N/m ² 125	m/s 14
b) All normal types of crane installed in the open	250	20
c) Transporter-type unloaders that have to continue to work in high winds	450	27

Table 6 — Wind force on suspended load

SWL	Type of crane from Table 5	Wind force on suspended load
up to 1	a) b) c)	N 125 250 450
from 1 to 5	a) b) c)	125 per tonne of SWL 250 per tonne of SWL 450 per tonne of SWL
from 5 to 25	a) b) c)	for SWL ≤ 8 tonne: 125 per tonne of SWL for SWL > 8 tonne: a maximum of 1 000 a further 125 per tonne of SWL a further 225 per tonne of SWL
25 and above	a) b) c)	a maximum of 1 000 a maximum of 3 750 a maximum of 6 750

Table 7 — Out-of-service design wind pressures

Height above ground level	Out-of-service design wind pressure	Approximate equivalent out-of-service wind speed
m	N/m ²	m/s
Parts of crane up to 30	1 340	47
Parts of crane between 30 and 60	1 530	50
Parts of crane between 60 and 80	1 670	52

Table 8 — Force coefficients C_f

Type	Description	Aerodynamic slenderness l/b or l/D^a					
		5	10	20	30	40	50
Individual members	Rolled sections, rectangular hollow sections, flat plates fabricated box sections with b and D not greater than 0.5 m	1.3	1.35	1.6	1.65	1.7	1.8
	Fabricated box sections with b or d greater than 0.5 m	Section ratio b/d^a					
		≥ 2					
		1					
		0.5					
		0.25					
	<i>Circular sections</i>						
	Where $DV_s < 6 \text{ m}^2/\text{s}$	0.75	0.80	0.90	0.95	1.0	1.1
	Where $DV_s \geq 6 \text{ m}^2/\text{s}$	0.60	0.65	0.70	0.70	0.75	0.8
Single lattice frames	Flat-sided sections	1.7					
	<i>Circular sections</i>						
	Where $DV_s < 6 \text{ m}^2/\text{s}$	1.2					
	Where $DV_s \geq 6 \text{ m}^2/\text{s}$	0.8					
Machinery houses, crabs, etc.	Rectangular clad structures on ground or solid base (air flow beneath structure prevented)	1.1					

^a See Figure 3.Table 9 — Shielding factors ϕ

Spacing ratio ^a a/b	Solidity ratio ^a A/A_e					
	0.1	0.2	0.3	0.4	0.5	≥ 0.6
0.5	0.75	0.4	0.32	0.21	0.15	0.1
1.0	0.92	0.75	0.59	0.43	0.25	0.1
2.0	0.95	0.8	0.63	0.5	0.33	0.2
4.0	1	0.88	0.76	0.66	0.55	0.45
5.0	1	0.95	0.88	0.81	0.75	0.68
6.0	1	1	1	1	1	1

^a See Figure 3.

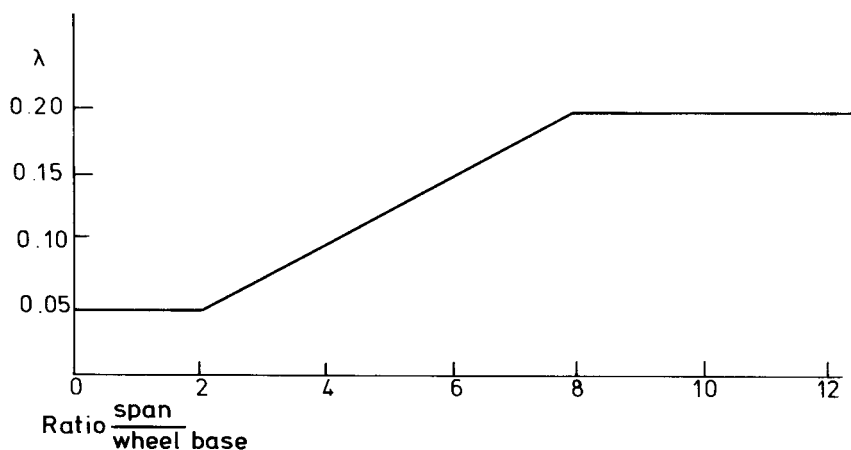


Figure 1 — Skew load coefficients

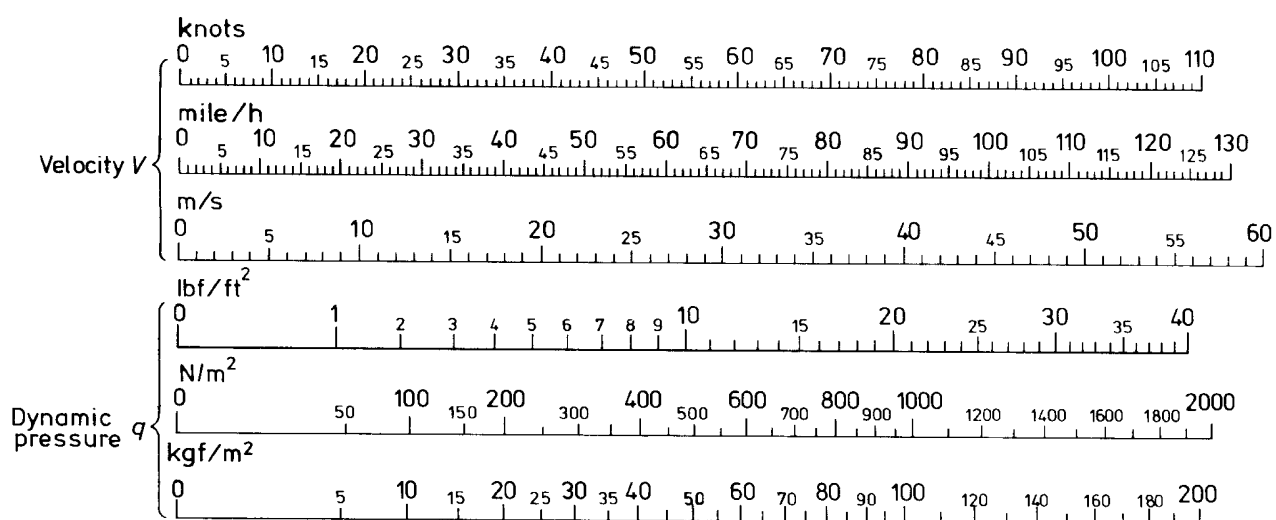
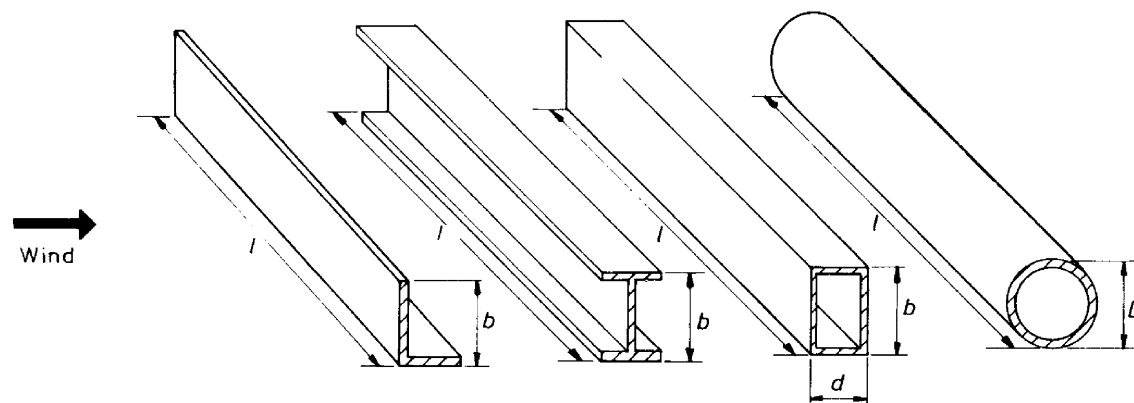


Figure 2 — Conversion chart for wind speed and pressure

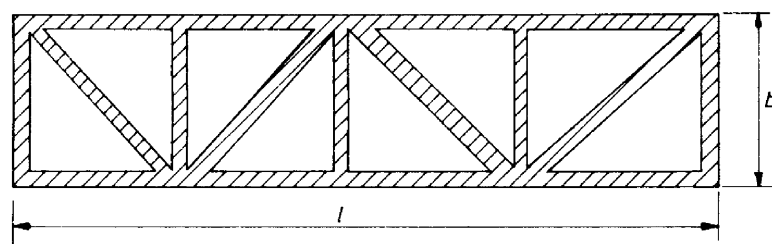
(a) Aerodynamic slenderness and section ratio



$$\text{aerodynamic slenderness} = \frac{\text{length of member}}{\text{breadth of section across wind front}} = \frac{l}{b} \text{ or } \frac{l}{D}$$

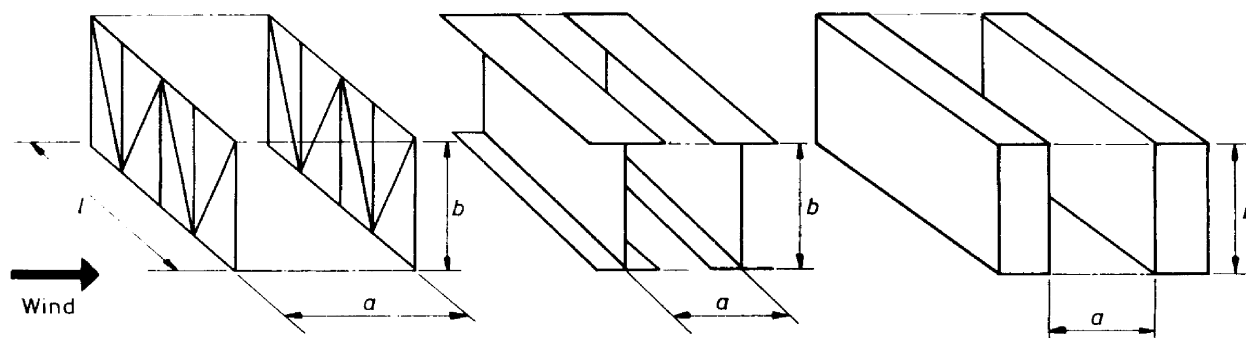
$$\text{section ratio (for box sections)} = \frac{\text{breadth of section across wind front}}{\text{depth of section parallel to wind flow}} = \frac{b}{d}$$

(b) Solidity ratio



$$\text{solidity ratio } \frac{A}{A_e} = \frac{\text{area of solid parts (shown shaded)}}{\text{enclosed area}} = \frac{\sum A_{\text{members}}}{b \times l}$$

(c) Spacing ratio



$$\text{spacing ratio} = \frac{\text{distance between facing sides}}{\text{breadth of member across wind front}} = \frac{a}{b}$$

Figure 3 — Definitions: aerodynamic slenderness, section ratio, solidity ratio and spacing ratio

Section 4. Selection of steel, minimum thickness and working stresses

4.1 Selection of steel

4.1.1 Steel shall be selected from either:

- a) standard structural steels to BS 4360; or
- b) other steels, provided that the crane manufacturer shows that they have comparable properties to steels to BS 4360 and they have been subjected to equivalent tests.

4.1.2 Where thicknesses of steel are specified that exceed the maximum values given in BS 4360 for Charpy V-notch impact tests, the impact test requirements on standard specimens shall not be less than the value given in BS 4360 for the type of steel under consideration on the standard specimen.

4.1.3 Where cranes are to be used at low temperatures such that brittle fracture might occur, the material used for loadbearing members shall have specified low temperature impact properties, adequate to meet the service conditions inherent in the design.

4.1.4 For temperate or tropical conditions, steels having no guaranteed impact test values are acceptable, with the exception of the following, which shall not be used unless impact or other tests show that the material is suitable for service:

- a) plates and sections above 30 mm thickness where brittle fracture might occur under tension loads;
- b) plates and sections above 25 mm thickness where brittle fracture under tension loads would result in major structural collapse.

NOTE For further information regarding selection of steels to counter brittle fracture see chapter 2 of BS 449-2:1969.

4.2 Minimum thickness of plates and sections

The proportioning of members of crane structures shall follow from consideration of the stresses engendered by service conditions, and shall have regard to other practical considerations including the requirements of manufacturing processes, vulnerability to accidental damage, the incidence of corrosion in relation to protective coatings used, etc.

NOTE This standard does not impose minimum thicknesses, but reference should be made to other standards covering specific types of crane. Attention is drawn to the requirements laid down in BS 4395 and BS 4604 for the thicknesses of members at joints made with high strength friction grip bolts.

4.3 Working stresses

4.3.1 **Duty factor.** The duty factors given in Table 4 according to the type of crane and its application shall be applied to all basic stresses set out in 5.1, 5.2 and section 6.

NOTE A duty factor applied to all basic stresses allows for a degree of imperfection in the methods of calculation of stresses and for unforeseen contingencies. In particular, there is a greater probability in high speed and in more intensively used cranes handling loads near their maximum capacity that combined stresses higher than those derived from calculation will occur. It is necessary to take account of this when checking in relation to the elastic limit, even though the separate fatigue calculation also deals with the influence of intensity of service conditions.

4.3.2 **Permissible working stresses.** The calculated stresses in each part of the structure due to the load combinations specified in 3.1 shall not exceed any of the following.

- a) *Under the load combinations specified in 3.1.2.1.* The basic stress multiplied by the duty factor.
- b) *Under the load combinations specified in 3.1.2.2.* The basic stress multiplied by the duty factor and multiplied by a factor of 1.13.
- c) *Under the load combinations specified in 3.1.2.3.* The permissible fatigue stress.
- d) *Under the load combinations specified in 3.1.2.4, 3.1.2.5 and 3.1.2.6.* The basic stress multiplied by a factor of 1.36.

Section 5. Stresses in structural components

5.1 Individual members, rolled sections, hollow sections and members with plated webs: verification relative to the yield stress

5.1.1 Basic stresses. Basic stresses for steels to BS 4360 for use in the application of this standard shall comply with 5.1.2 to 5.1.8.

NOTE 1 In general, the basic stress is expressed as a proportion of the yield stress of the grade of steel under consideration. The formulae for deriving basic stresses and tabulated values are both given.

NOTE 2 *Members subjected to secondary stresses.* Relaxations in some of the requirements of 5.1.2 to 5.1.8 are allowed in cases where secondary stresses are calculated and taken into account in the design (see 5.3).

If steels with higher tensile strengths than those of BS 4360 steels are used, the specific requirements of Appendix B shall be met.

5.1.2 Members subject to simple axial tension. The basic tensile stress $P_{at.bas}$ (in N/mm²) shall not exceed the value

$$P_{at.bas} \text{ (on net section)} = 0.6 Y_s$$

where Y_s is the yield stress of the steel under consideration (in N/mm²).

Tabulated values of $P_{at.bas}$ for the range of steels covered by BS 4360 are given in Table 10.

The maximum widths of tension flange plates with stiffened or unstiffened edges are specified in 7.2.3.

5.1.3 Members subject to simple axial compression. The basic compressive stress $P_{ac.bas}$ shall not exceed $P_{at.bas}$ as defined in 5.1.2 or the value (in N/mm²) obtained from

$$P_{ac.bas} = 0.6 F_{crip}$$

where F_{crip} is the applied stress at failure of a member subjected to overall flexural buckling due to axial compression as given by the equation:

$$F_{crip} = \frac{Y_s + (\eta + 1)C_o}{2} - \sqrt{\left\{ \left(\frac{Y_s + (\eta + 1)C_o}{2} \right)^2 - Y_s C_o \right\}}$$

where

F_{crip} is the applied stress at failure (in N/mm²)

C_o is the Euler critical stress $\left(= \frac{\pi^2 E}{s^2} \right)$

Y_s is the yield stress of the steel under consideration. For sections fabricated from plate by welding, the yield strength Y_s shall be reduced by 25 N/mm².

NOTE This provision need not be applied to welded compound rolled sections or to rolled sections with welded flange cover plates.

E is Young's modulus (= 205 000 N/mm²)

η is the Perry coefficient ($= \alpha(s - s_o) \times 10^{-3}$, but not less than zero)

α is the Robertson constant from Table 11

s is the slenderness ratio ($= l/r$)

s_o is the limiting slenderness ratio for stub columns $= 0.2\pi\sqrt{E/Y_s}$

r is the radius of gyration about the appropriate axis.

l is the effective length relative to the same axis, as defined in 7.1.

Tabulated values of F_{crip} for the range of steels covered by BS 4360 are given in Table 12 for the values of α given in Table 11.

For slenderness ratio less than s_o , $F_{crip} = Y_s$.

The effective and maximum widths of plates in compression are specified in 7.2.1 and 7.2.2 respectively.

The slenderness ratio s for any strut shall be obtained by dividing its effective length l as given in 7.1 by the minimum radius of gyration r of any cross section within the middle third of the length. Where the end fixing conditions of the strut in the X and Y planes are different, its effective lengths in these planes will also differ.

Table 10 — Basic stresses in structural members

All stresses are in newtons per square millimetre.

Description	Basic stress for steels to BS 4360										
	Grade 43 steel with a yield stress of				Grade 50 steel with a yield stress of			Grade 55 steel with a yield stress of			
	215	230	245	280	325	340	355	400	415	430	450
Parts in axial tension On effective sectional area (see 5.1.2)	129	138	147	168	195	204	213	240	249	258	270
Parts in axial compression On effective gross section (see 5.1.3)	129	138	147	168	195	204	213	240	249	258	270
Parts in bending, (tension or compression) (see 5.1.4) On effective sectional area for extreme fibre stress											
a) for plates, flats, tubes, rounds, square and similar sections	140	150	160	182	211	221	231	260	270	280	293
b) for rolled beams, channels angles and tees, and for plate girders with single or multiple webs with:											
d_1/t not greater than 85 for steel of grade 43	133	143	152	174	202	211	220	248	257	267	279
d_1/t not greater than 75 for steel of grade 50											
d_1/t not greater than 65 for steel of grade 55											
c) for plate girders with single or multiple webs with:											
d_1/t greater than 85 for steel of grade 43	127	136	145	165	192	201	209	236	245	254	266
d_1/t greater than 75 for steel of grade 50											
d_1/t greater than 65 for steel of grade 55											
In the above, d_1 is the clear distance between flange angles or, where there are no flange angles, between flanges (ignoring fillets); where, however, tongue plates having a thickness not less than twice the thickness of the web plate are used, d_1 is the depth of the girder between the flanges less the sum of the depths of the tongue plates or eight times the sum of the thickness of the tongue plates, whichever is the lesser t is the web thickness.											
Parts in shear Average shear stress on the gross effective sectional area of webs of plate girders, rolled beams, channels, angles and tees (see 5.1.5)	80	85	91	104	120	126	131	148	154	159	167
Parts in bearing On flat surfaces, fixed axles and pins (see 5.1.6)	172	184	196	224	260	272	284	320	332	344	360
Parts subjected to shear combined with other stresses. Basic equivalent stress (see 5.1.7)	200	214	228	260	302	316	330	372	386	400	419
NOTE 1 Basic stresses corresponding to intermediate values of yield stress may be obtained by interpolation.											
NOTE 2 To obtain the permissible working stress, the appropriate basic stress has to be multiplied by the factors given in 4.3 that correspond to the loading conditions under consideration.											

5.1.4 Members subject to bending

5.1.4.1 Areas in tension. The basic tensile bending stress $P_{bt.bas}$ (in N/mm²) shall not exceed the following values:

- | | | |
|--|---|------------------------|
| a) for plates, flats, tubes, rounds, square and similar sections bending about their minor axis. | } | $P_{bt.bas} = 0.65Y_s$ |
| | | |
| b) for rolled beams, channels angles and tees, and for plate girders with single or multiple webs with | } | $P_{bt.bas} = 0.62Y_s$ |
| d_1/t not greater than 85 for steel of grade 43 | | |
| d_1/t not greater than 75 for steel of grade 50 | | |
| d_1/t not greater than 65 for steel of grade 55 | | |
| c) for plate girders with single or multiple webs with | } | $P_{bt.bas} = 0.59Y_s$ |
| d_1/t greater than 85 for steel of grade 43 | | |
| d_1/t greater than 75 for steel of grade 50 | | |
| d_1/t greater than 65 for steel of grade 55 | | |

where Y_s is as defined in 5.1.2 and d_1 and t are as defined in Table 10 for parts in bending. Tabulated values of $P_{bt,bas}$ for the range of steels covered by BS 4360 are given in Table 10.

The maximum widths of tension flange plates with stiffened or unstiffened edges are specified in 7.2.3.

Table 11 — Values of Robertson constant α for struts of various sections

Type of section	Thickness of flange or plate	Axis of buckling	α
Rolled I section (universal beams, UB)		xx	2.0
		yy	3.5
Rolled H section (universal columns, UC): See note 1	up to 40 mm	xx	3.5
		yy	5.5
	over 40 mm	xx	5.5
		yy	8.0
Welded plate I or H sections: See notes 1, 2, and 3	up to 40 mm	xx	3.5
		yy	5.5
	over 40 mm	xx	3.5
		yy	8.0
Rolled I or H sections with welded flange cover plates: See notes 1 and 4		xx	3.5
		yy	2.0
Welded box sections: See notes 1, 3 and 5	up to 40 mm	any	3.5
	over 40 mm	any	5.5
Rolled channel sections, rolled angle sections and T-bars (rolled or cut from UB or UC)		any	5.5
Hot-rolled structural hollow sections		any	2.0
Rounds, square and flat bars: See note 1	up to 40 mm	any	3.5
	over 40 mm	any	5.5
Compound rolled sections (two or more I, H or channel sections, I section plus channel, etc.)		any	5.5
Two rolled angle, channel or tee sections back-to-back		any	5.5
Two rolled sections laced or battened		any	5.5
Composite members of closed lattice construction		any	2.0
NOTE 1 For thicknesses between 40 mm and 50 mm the value of F_{crip} may be taken as the average of the value for thicknesses less than 40 mm and the value for thicknesses greater than 40 mm. NOTE 2 For welded plate I or H sections where it can be guaranteed that the edges of the flanges will only be flame-cut, $\alpha = 3.5$ may be used for buckling about the y-y axis for flanges up to 40 mm thick and $\alpha = 5.5$ for flanges over 40 mm thick. NOTE 3 Yield strength for sections fabricated from plate by welding reduced by 25 N/mm². NOTE 4 To qualify under the category "rolled I or H section with welded flange cover plates" the widths of the flange and the plate have to be within the greater of 25 mm or 25 % of the larger width. If the smaller width is less than 25 % of the larger, the category "welded plate I or H sections" shall apply, otherwise the category shall be taken as "rolled I section" or "rolled H section" as appropriate. NOTE 5 "Welded box sections" includes those fabricated from four plates, two angles or an I or H section and two plates but not box sections composed of two channels or plates with welded longitudinal stiffeners.			

Table 12 — Values of F_{crip} for steels to BS 4360

All stresses are in newtons per square millimetre

	Grade 43 steel with a yield stress in N/mm ² of				Grade 50 steel with a yield stress in N/mm ² of			Grade 55 steel with a yield stress in N/mm ² of			
	215	230	245	280	325	340	355	400	415	430	450
Slenderness ratio l/r	Limiting slenderness ratio s_0 below which $F_{\text{crip}} = Y_s$										
	19	19	18	17	16	15	15	14	14	14	13
a) $\alpha = 2.0$ (see 5.1.3)											
s_0	215	230	245	280	325	340	355	400	415	430	450
20	213	228	243	277	322	337	350	394	409	424	444
30	208	223	237	271	314	329	342	385	399	413	432
40	203	217	231	264	305	319	331	372	386	399	417
50	197	210	224	254	293	306	317	354	366	378	394
60	190	202	214	242	276	288	297	327	337	346	358
70	180	191	202	226	253	262	268	290	296	302	310
80	168	178	186	205	225	230	234	248	251	255	259
90	155	162	168	181	194	198	200	208	210	212	215
100	139	145	149	158	166	169	170	175	176	178	179
110	124	128	131	137	143	144	145	148	149	150	151
120	110	112	115	119	123	124	124	127	127	128	129
130	97	99	101	104	106	107	108	109	110	110	111
140	86	87	89	91	93	93	94	95	95	96	96
150	77	78	79	80	82	82	83	83	84	84	84
160	68	69	70	71	72	73	73	74	74	74	74
170	61	62	63	64	65	65	65	66	66	66	66
180	55	56	56	57	58	58	58	59	59	59	59
190	50	51	51	52	52	52	53	53	53	53	53
200	46	46	46	47	47	48	48	48	48	48	48
210	42	42	42	43	43	43	43	44	44	44	44
220	38	38	39	39	39	40	40	40	40	40	40
230	35	35	35	36	36	36	36	37	37	37	37
240	32	33	33	33	33	33	33	34	34	34	34
b) $\alpha = 3.5$ (see 5.1.3)											
s_0	215	230	245	280	325	340	355	400	415	430	450
20	211	226	241	275	320	334	346	390	405	419	439
30	204	218	232	265	307	321	332	374	388	402	420
40	195	209	222	253	292	305	316	354	367	380	396
50	186	198	211	239	275	286	295	329	340	351	365
60	175	186	198	223	253	263	270	297	306	314	325
70	163	173	183	203	228	235	241	260	266	272	279
80	150	158	166	182	201	206	210	223	227	231	235
90	136	143	149	161	174	178	181	190	192	195	197
100	123	128	132	141	151	153	155	161	163	164	166
110	110	113	117	124	130	132	133	138	139	140	141
120	98	101	103	108	113	114	115	118	119	120	121
130	87	89	91	95	99	100	100	103	104	104	105
140	78	79	81	84	87	88	88	90	90	91	92
150	70	71	72	75	77	77	78	79	80	80	81
160	63	64	65	67	68	69	69	70	71	71	71
170	57	57	58	60	61	62	62	63	63	63	64
180	51	52	53	54	55	55	56	56	57	57	57
190	47	47	48	49	50	50	50	51	51	51	52
200	43	43	44	44	45	46	46	46	46	47	47
210	39	39	40	41	41	42	42	42	42	42	43
220	36	36	37	37	38	38	38	39	39	39	39
230	33	33	34	34	35	35	35	35	36	36	36
240	31	31	31	32	32	32	32	33	33	33	33

Table 12 — Values of F_{crip} for steels to BS 4360

	Grade 43 steel with a yield stress in N/mm ² of				Grade 50 steel with a yield stress in N/mm ² of			Grade 55 steel with a yield stress in N/mm ² of			
	215	230	245	280	325	340	355	400	415	430	450
Slenderness ratio l/r	Limiting slenderness ratio s_0 below which $F_{\text{crip}} = Y_s$										
	19	19	18	17	16	15	15	14	14	14	13
c) $\alpha = 5.5$ (see 5.1.3)											
S_0	215	230	245	280	325	340	355	400	415	430	450
20	210	224	239	273	317	331	342	358	399	414	433
30	198	211	225	257	298	311	321	361	374	387	405
40	186	198	211	240	277	289	298	334	345	357	373
50	173	185	196	222	254	265	272	303	313	322	335
60	160	170	180	202	230	238	244	268	276	283	293
70	147	155	164	182	204	211	215	233	239	244	251
80	133	140	147	162	179	184	187	200	204	208	213
90	120	126	131	143	156	159	162	171	174	177	180
100	108	112	117	126	135	138	140	147	149	150	153
110	96	100	104	111	118	120	121	126	128	129	131
120	86	89	92	97	103	105	106	109	111	112	113
130	77	80	82	86	91	92	93	96	96	97	98
140	69	71	73	77	80	81	82	84	85	85	86
150	63	64	66	68	71	72	73	74	75	76	76
160	57	58	59	61	64	64	65	66	67	67	68
170	51	52	53	55	57	58	58	59	60	60	61
180	47	48	49	50	52	52	53	54	54	54	55
190	43	44	44	46	47	47	48	49	49	49	49
200	39	40	40	42	43	43	43	44	44	45	45
210	36	37	37	38	39	39	40	40	41	41	41
220	33	34	34	35	36	36	36	37	37	37	37
230	31	31	32	32	33	33	34	34	34	34	34
240	29	29	29	30	31	31	31	31	32	32	32
d) $\alpha = 8.0$ (see 5.1.3)											
S_0	215	230	245	280	325	340	355	400	415	430	450
20	207	222	236	270	313	327	336	378	393	407	426
30	191	204	217	248	287	300	308	346	358	371	388
40	175	187	199	226	261	272	279	312	323	334	348
50	160	170	181	204	234	244	249	277	286	295	306
60	145	154	163	183	208	215	220	242	249	255	264
70	131	139	146	163	182	189	192	209	214	219	225
80	118	124	130	144	159	164	167	179	183	187	191
90	106	111	116	127	139	142	145	154	157	160	163
100	95	99	103	112	121	124	126	133	135	137	139
110	85	88	92	99	106	108	110	115	117	118	120
120	76	79	82	87	93	95	96	100	102	103	104
130	68	71	73	78	82	84	85	88	89	90	91
140	62	64	66	69	73	74	75	78	79	80	80
150	56	58	59	62	66	66	67	69	70	71	71
160	51	52	54	56	59	60	60	62	63	63	64
170	46	47	49	51	53	54	54	56	56	57	57
180	42	43	44	46	48	49	49	50	51	51	52
190	39	40	41	42	44	44	45	46	46	46	47
200	36	37	37	39	40	40	41	42	42	42	43
210	33	34	34	36	37	37	37	38	39	39	39
220	31	31	32	33	34	34	34	35	35	36	36
230	28	29	29	30	31	32	32	32	33	33	33
240	26	27	27	28	29	29	29	30	30	30	31

5.1.4.2 Areas in compression

5.1.4.2.1 Maximum widths of plates. The maximum widths of plates in compression shall be as specified in 7.2.2.

5.1.4.2.2 For sectional shapes with I_y equal to or greater than I_x . Where

I_y is the moment of inertia of the whole section about the axis lying in the plane of bending (the y-y axis), and

I_x is the moment of inertia of the whole section about the axis normal to the plane of bending (the x-x axis),

the basic compressive bending stress shall not exceed the value of $P_{bt,bas}$ given in 5.1.4.1.

5.1.4.2.3 For sectional shapes with I_y smaller than I_x

5.1.4.2.3.1 Where I_y and I_x are as defined in 5.1.4.2.2, the basic compressive bending stress $P_{bc,bas}$ shall not exceed $P_{bt,bas}$ as defined in 5.1.4.1, or the value of $P_{bc,bas}$ corresponding to C_s , the critical stress in the compression element (in N/mm²) calculated as set out in 5.1.4.2.3.2 and 5.1.4.2.3.3.

5.1.4.2.3.2 For sections with a single web, including I sections with stiffened or unstiffened edges, channels, angles, tees, etc., but excluding I sections where the thickness of one flange is more than 3 times the thickness of the other flange.

a) Where the flanges have equal moments of inertia about the y-y axis

$$C_s = \left(1644 \frac{r_y}{l}\right)^2 \sqrt{\left\{1 + \frac{1}{20} \left(\frac{lT}{r_y D}\right)^2\right\}} = A$$

except that the value of C_s calculated above shall be increased by 20 % for rolled beams and channels, and for plate girders provided that:

T/t is not greater than 2 and

d_1/t is not greater than 85, for steel of grade 43 to BS 4360

d_1/t is not greater than 75, for steel of grade 50 to BS 4360

d_1/t is not greater than 65, for steel of grade 55 to BS 4360

where

l is the effective length of compression flange (see 7.1.3);

r_y is the radius of gyration about the y-y axis of the gross section of the member, at the point of maximum bending moment;

D is the overall depth of member, at the point of maximum bending moment;

T is the effective thickness of the compression flange. $T = K_1 \times$ mean thickness of the horizontal portion of the compression flange at the point of maximum bending moment. (For rolled sections, $T = K_1 \times$ thickness given in reference books.) The coefficient K_1 makes allowance for reduction in thickness or breadth of flanges between points of effective lateral restraint and depends on N , the ratio of the total area of both flanges at the point of least bending moment to the corresponding area at the point of greatest bending moment between such points of restraint.

d_1 and t are as defined in Table 10 for parts in bending.

Flanges shall not be reduced in breadth to give a value of N lower than 0.25.

Values of K_1 for different values of N are given in Table 13.

Where the value of N calculated for the compression flange alone is smaller than that when both flanges are combined, this smaller value of N shall be used.

Table 13 — Values of K_1

N	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
K_1	1.0	1.0	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2

b) Where the moment of inertia of the compression flange about the y-y axis exceeds that of the tension flange

$$C_s = \left(1644 \frac{r_y}{l}\right)^2 \sqrt{\left\{1 + \frac{1}{20} \left(\frac{lT}{r_y D}\right)^2\right\}} + K_2 \left(1644 \frac{r_y}{l}\right)^2$$

$$= A + K_2 B$$

where

l , r_y and D are as defined in a) above;

T is the effective thickness of flange; $T = K_1 \times$ mean thickness of the horizontal portion of the flange of greater moment of inertia about the y-y axis of the member at the point of maximum bending moment, where K_1 is obtained from Table 13;

K_2 is a coefficient to allow for inequality of tension and compression flanges, and depends on M , the ratio of the moment of inertia of the compression flange alone to that of the sum of the moments of inertia of the compression and tension flanges, each calculated about its own axis parallel to the y-y axis of the member, at the point of maximum bending moment.

NOTE For flanges of equal moment of inertia $M = 0.5$ and $K_2 = 0$. For tees and angles $M = 1.0$ and $K_2 = 0.5$.

Values of K_2 for different values of M are given in Table 14.

c) Where the moment of inertia of the tension flange about the y-y axis exceeds that of the compression flange

$$C_s = \left[\left(1644 \frac{r_y}{l}\right)^2 \sqrt{\left\{1 + \frac{1}{20} \left(\frac{lT}{r_y D}\right)^2\right\}} + K_2 \left(1644 \frac{r_y}{l}\right)^2 \right] \frac{Y_c}{Y_t}$$

$$= (A + K_2 B) \frac{Y_c}{Y_t}$$

where

l , r_y , D , T and K_2 are as defined above;

Y_c is the distance from the neutral axis of girder to extreme fibre in compression;

Y_t is the distance from the neutral axis of girder to extreme fibre in tension.

Values of K_2 for different values of M are given in Table 14.

NOTE For tees and angles, $M = 0$ and $K_2 = -1$.

Table 14 — Values of K_2

M	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.0
K_2	0.5	0.4	0.3	0.2	0.1	0.0	-0.2	-0.4	-0.6	-0.8	-1.0

Table 15 gives values of A and B for different ratios of l/r and D/T to be used for calculating C_s in newtons per square millimetre.

Table 16 gives values of $P_{bc,bas}$ for different values of C_s .

5.1.4.2.3.3 For sections other than those described in 5.1.4.2.3.2.

a) Where the section is symmetrical about the x-x axis, C_s shall be calculated from the formula given in Appendix D.

b) Where the section is not symmetrical about the x-x axis, C_s shall be calculated using either:

- 1) the formula given in 5.1.4.2.3.2, which will give conservative values; or
- 2) more precise methods.

5.1.4.2.4 *Thin-walled fabricated box sections.* These sections constitute a special design case and, in addition to meeting the requirements of 5.1.4.2.2 and 5.1.4.2.3, shall be given detailed consideration in respect of the following factors.

- a) Residual stresses due to welding.
- b) Distortion and misalignment of panels during fabrication.
- c) Diaphragms need to be of adequate proportions to prevent distortion of the cross section under the applied loads.

d) Panel stiffeners and stub stiffeners used at loading points need adequate restraint at their ends if they are assumed to participate in carrying the reaction loads.

e) Shear stresses due to pure torsion need to be considered in conjunction with the direct compressive stresses.

A suitable method for the design of stiffened compression panels in which factors a), b) and e) are taken into account is given in Appendix E. Where other methods are used, these factors shall be taken into account by detailed calculation or by selecting conservative factors of safety.

5.1.5 Members subjected to shear

5.1.5.1 Rolled beams, channels, angles and tees. The basic average shear stress $P_{q.bas}$ (in N/mm²) on the effective sectional area shall not exceed the value

$$P_{q.bas} = 0.37 Y_s$$

where Y_s is as defined in 5.1.2.

Tabulated values of $P_{q.bas}$ for the range of steels covered by BS 4360 are given in Table 10.

5.1.5.2 Solid web plates. Solid web plates and stiffeners shall be proportioned in accordance with 7.3.

The basic average shear stress $P_{q.bas}$ (in N/mm²) on the effective sectional area of a solid web shall not exceed the value given in 5.1.5.1 or that given by the following equations.

For steel of grade 43 to BS 4360

$$P_{q.bas} = 91 \left[1.3 - \frac{b/t}{250 \left\{ 1 + \frac{1}{2} \left(\frac{b}{a} \right)^2 \right\}} \right]$$

For steel of grade 50 to BS 4360

$$P_{q.bas} = 131 \left[1.3 - \frac{b/t}{200 \left\{ 1 + \frac{1}{2} \left(\frac{b}{a} \right)^2 \right\}} \right]$$

For steel of grade 55 to BS 4360

$$P_{q.bas} = 167 \left[1.3 - \frac{b/t}{180 \left\{ 1 + \frac{1}{2} \left(\frac{b}{a} \right)^2 \right\}} \right]$$

In the above formulae:

a is the greater clear dimension of the web in a panel, not greater than $270t$;

b is the lesser clear dimension of the web in a panel, not greater than $180t$;

t is the thickness of web.

Tabulated values of $P_{q.bas}$ for stiffened webs for varying ratios of depth of panel d to thickness of web t and various spacings of stiffeners are given in Table 17 for the range of steels covered by BS 4360. The depth of panel d is defined as follows.

For webs without horizontal stiffeners, d is the clear distance between flange angles or, where there are no flange angles, between flanges (ignoring fillets); where tongue plates having a thickness not less than twice the thickness of the web plate are used, d is the depth of the girder between the flanges less the sum of the depths of the tongue plates or eight times the sum of the thicknesses of the tongue plates, whichever is the less.

For webs with horizontal stiffeners, d is the clear distance between the tension flange (angles or flange plate or tongue plate) and the horizontal stiffener.

5.1.6 Members subjected to bearing. The basic bearing stress $P_{b.bas}$ (in N/mm²) on flat surfaces and on the projected area of fixed axles and pins shall not exceed the value

$$P_{b.bas} = 0.80 Y_s$$

where Y_s is as defined in 5.1.2.

Tabulated values of $P_{b.bas}$ for the range of steels covered by BS 4360 are given in Table 10.