

Specification for

Design and construction of electric hoists for both passengers and materials

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- BEAMA Ltd.
- Building Employers Confederation
- Construction Health and Safety Group
- Construction Plant-hire Association
- Department of Trade and Industry, Mechanical and Electrical Engineering Division
- Federation of Civil Engineering Contractors
- Federation of Manufacturers of Construction Equipment and Cranes
- Federation of Master Builders
- Federation of Wire Rope Manufacturers of Great Britain
- Health and Safety Executive
- Independent Engineering Insurers' Committee
- Institution of Mechanical Engineers

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Contents

	Page
Committees responsible	Inside front cover
Foreword	iii
Section 1. General	
1 Scope	1
2 Definitions	1
3 Design considerations	2
Section 2. Structural design and construction	
4 Loads and load combinations	3
5 Selection of steel, minimum thickness and working stresses	7
6 Stresses in structural components	8
7 Basic stresses in connections	29
8 Proportions of structural components, plates and web stiffeners	34
9 Fluctuating loads: permissible fatigue stresses	42
Section 3. Mechanical design and construction	
10 Hoist cage and enclosure	50
11 Hoistway enclosure and gates	51
12 Interlocking of gates	51
13 Rope suspension	51
14 Rack and pinion suspension system	53
15 Driving machinery	54
16 Brake	54
17 Counterweights	55
18 Safety gear	55
19 Overspeed governors	56
20 Buffers	56
21 Hoist cage overrun	57
22 Safety switches	57
23 Guarding	58
24 Notices	58
Section 4. Electrical design and construction	
25 Mains supply isolating switch	59
26 Cables and wiring	59
27 Protection against the effects of external influences	60
28 Earthing	60
29 Control circuits, panels, equipment and systems	60
30 Suppression of radio and television interference	62
Section 5. Testing	
31 General	63
Section 6. Instruction manual	
32 General	65
Appendix A Legislation and related documents	66
Appendix B <i>Text deleted</i>	66
Appendix C Derivation of design wind pressures	66
Appendix D The use of steels of higher tensile strengths than those of steels complying with BS 4360	67
Appendix E Basic formula for calculation of C_s	67
Appendix F <i>Text deleted</i>	69
Appendix G Certificate of type test for safety gear	70

Index	Page
Figure 1 — Conversion chart for wind speed and pressure	7
Figure 2 — Definitions: aerodynamic slenderness, section ratio, solidity ratio and spacing ratio	9
Figure 3 — Design throat thickness of fillet welds	32
Figure 4 — Design throat thickness of deep-penetration fillet welds	33
Figure 5 — Effective length with lateral bracing	35
Figure 6 — Typical class E weld details	46
Figure 7 — Typical class F weld details	47
Figure 8 — Typical class F and class G weld details	48
Figure 9 — Typical class G weld details	49
Figure 10 — Angle of fleet	52
Table 1 — List of loads	3
Table 2 — Load combinations	3
Table 3 — Impact factors	3
Table 4 — Design wind pressures	5
Table 5 — Force coefficients C_f	6
Table 6 — Shielding factors σ	7
Table 7 — Basic stresses in structural members	12
Table 8 — Values of Robertson constant α for struts of various sections	13
Table 9 — Values of F_{crip} for steels complying with BS 4360	16
Table 10 — Values of K_1	17
Table 11 — Values of K_2	18
Table 12 — Values of A and B to be used for calculating values of C_s	21
Table 13 — Basic stress $P_{bc,bas}$ for different values of critical stress C_s	22
Table 14 — Basic average shear stress $P_{q,bas}$ in stiffened webs of steel complying with BS 4360	24
Table 15 — Basic stresses in welds	31
Table 16 — Basic stresses in rivets as a percentage of $Y_{R 0.2}$	33
Table 17 — Effective lengths of parts in compression	34
Table 18 — Effective length with no lateral bracing	37
Table 19 — Maximum width of plates in compression	38
Table 20 — Projection of unstiffened compression flange plates	38
Table 21 — Values of P for fluctuating stresses for various classes of constructional details	45
Table 22 — Size of perforation or opening in cage enclosure related to clearance	50
Table 23 — Clearance between turns of rope on helically grooved drums	53
Table 24 — Type of safety gear for counterweights	56
Table 25 — Governor tripping speeds	56
Publications referred to	Inside back cover

Foreword

This British Standard, prepared under the direction of the Mechanical Handling Standards Policy Committee at the request of the Health and Safety Executive, is a new edition of BS 4465:1986, which is withdrawn. This edition introduces technical changes to bring the standard up-to-date but it does not reflect a full review of the standard, which will be undertaken in due course. It specifies requirements for hoists carrying both passengers and materials used in construction work and applies to machines employing rope suspended cages driven by drum and traction, and also to rack and pinion drive machines.

The primary object of the standard is to promote reliability and safety without placing undue restrictions on the general design of hoists or methods employed in their construction and erection.

The standard follows closely the requirements specified in draft European Standard prEN 109. It was originally envisaged that EN 109 would be directly implemented as the revision of this British Standard but, owing to administrative problems, final publication of the European Standard cannot be anticipated for some considerable time. However, upon the publication of EN 109 this standard may be revised to implement that European Standard.

The design practice in this specification is based upon that for cranes and thus the structural requirements specified in this standard are similar to those specified in BS 2573-1.

Account has also been taken of BS 5655-1 for electric lifts. There are however some radical departures from lift design practice in this standard, these being necessitated by such factors as the open air environment of the hoist, and the need for its periodic dismantling, re-erection and extension in service.

It is assumed that a base structure and other supports will be provided on the construction site which will support and resist all loads, moments and overturning forces which may develop due to the use of the hoist, wind forces and other incidental forces on the mast or tower.

It is acknowledged that a hoist designed to carry both passengers and materials may have a cage larger than that required for passengers only in order to carry bulky but not necessarily heavy objects. It is essential, therefore, that users of these hoists exercise adequate control over their loading. Consideration should be given to the installation of overload warning devices. It is anticipated that a code of practice will be prepared on the safe installation and use of the hoists covered by this standard.

BS 7212 makes recommendations for the selection of appropriate types of hoist, for laying down safe systems of work and for the management and planning of the installation, testing, examination, operation and maintenance of all construction hoists as well as giving guidance on the selection and training of erectors and operators.

Appendix A lists legislation, regulations and related documents that may be applicable to electric hoists.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

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

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 72, 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 Scope

This British Standard specifies requirements for the design and construction of hoists that are intended to be used as temporary installations during construction work. They are primarily intended for the carriage of personnel but may also carry materials. The hoist cage is restrained against lateral movement by a guide or guides and is suspended or supported by either steel wire ropes or a rack and pinion(s). The maximum speed of travel of the hoist cage is 2 m/s.

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

2 Definitions

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

2.1

in service

a condition when the cage(s) is in any position other than at the lowest landing position of its travel (whether it is laden or unladen), and when the cage(s) is at the lowest landing position and laden

2.2 *text deleted*

2.3

mast

a structure that supports and guides the cage (and the counterweight when provided) outside of the mast structure

2.4

out of service

a condition when the cage(s) is at the lowest landing position and unladen

2.5

passenger

any person, including the driver, transported by a hoist

2.6

progressive safety gear

a safety gear in which deceleration is effected by a braking action, and for which special provisions are made so as to limit the forces on the suspended part to a permissible value

2.7

rated load

the load for which the equipment has been built and for which normal operation is guaranteed by the vendor

2.8

rated speed

the speed of the hoist cage for which the equipment has been built and for which normal operation is guaranteed by the vendor

2.9

safety gear

a mechanical device for stopping and maintaining stationary on the guides the hoist cage or counterweight in the case of overspeeding in the downward direction

2.10

stopping distance

the distance the cage will fall during a safety gear test, measured from the point of release of the stationary cage to the point of arrest

2.11

terminal stopping switch

a switch or combination of switches arranged to bring the cage to rest automatically at or near a terminal landing, independently of the functioning of the operating control device

2.12

tower

a structure that supports and guides the cage (and the counterweight when provided) within the tower structure

2.13

ultimate limit switch

an emergency switch arranged to stop the hoist automatically, in the event of the cage travelling a predetermined distance beyond a terminal landing

3 Design considerations

3.1 Design features

All components shall be correctly designed and of sound construction using materials that are free from patent defects and that are of adequate strength and suitable quality. The construction and reliability of the equipment, in whole or part, shall be appropriate to its intended use, operating environment and design life.

Materials used in the construction of the hoist shall not support combustion.

3.2 Accessibility

The hoist shall be designed, constructed and installed in such a manner that periodic examination, testing, maintenance or repairs may be readily and safely carried out.

Section 2. Structural design and construction

4 Loads and load combinations

4.1 Loads and load combinations to be considered in design

4.1.1 General. The structure as a whole and each part of it including ties shall be designed to withstand the loads listed in Table 1 in the combinations given in Table 2.

Table 1 — List of loads

Symbol	Description of load
L_1	Loads due to static components, e.g. masts, ties and other appendages
L_2	Loads due to moving components, e.g. cage, counterweight, ropes, moving cables
L_3	Rated load
L_4	$(L_2 + L_3) \times \text{impact factor}$
L_5	$(L_2 \times \text{impact factor}) + (L_3 \times \text{impact factor} \times \text{load spectrum factor})$
L_6	Load due to in-service wind acting horizontally in any direction on the mast or tower, cage and auxiliary items when applicable
L_7	Load due to out-of-service wind acting horizontally in any direction on the mast or tower, cage and auxiliary items when applicable

Table 2 — Load combinations (see 5.3)

1) Hoist in use without wind	$L_1 + L_4$
2) Hoist in use with in-service wind	$L_1 + L_4 + L_6$
3) Hoist in out-of-service condition	$L_1 + L_2 + L_7$
4) Hoist being erected or dismantled	$L_1 + L_4 + L_6$
5) Hoist cage in collision with overrun buffers	$L_1 + L_4 + L_6$
6) Hoist with application of safety gear	$L_1 + L_4 + L_6$
7) Fatigue check (for each member in which fluctuating stresses occur when tested in accordance with clause 9)	$L_1 + L_5 + L_6$

4.1.2 Impact factor. In calculating live loads in members of the structure, forces due to moving masses, inertia forces and shock shall be multiplied by an impact factor (see Table 1). The appropriate impact factor shall be as given in Table 3.

4.1.3 Load spectrum factor. The load spectrum factors K_p required to take account of the state of loading of the hoist throughout its lifetime, as used in the treatment for fatigue design as specified in clause 9, shall be as follows:

- | | |
|--|-----|
| a) masses of constant magnitude, e.g. cages, | 1.0 |
| b) masses of variable magnitude, e.g. payload, | 0.6 |

Table 3 — Impact factors

Rope suspended masses	1.25
Progressive safety gear application	1.40
Rack and pinion suspended masses	1.40
Collision with resilient buffers:	
a) rope suspended cages	2.0
b) rack and pinion supported cages	see note
NOTE Take into account the kinetic energy of the drive unit when calculating the impact factor. Such factors can be in excess of 10.	

4.1.4 Wind loads

4.1.4.1 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 hoist structure.

4.1.4.2 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 1.

4.1.4.3 Design wind conditions. Two design wind conditions shall be taken into account in calculating wind loads on hoists, as follows.

a) *In-service wind.* This is the wind pressure, irrespective of height, in which the hoist is designed to operate.

The wind loadings, which shall be assumed to be applied in the least favourable direction in combination with the appropriate service loads specified in 4.1.1, shall be not less than the pressures specified in Table 4.

b) *Out-of-service wind.* This is the wind pressure that a hoist is designed to withstand when in an out-of-service condition.

For hoists used in the UK, the out-of-service wind pressures specified in Table 4 shall be used as the basis of design.

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

$$F = AqC_f$$

where

F is the wind load (in N);

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 m^2);

q is the wind pressure corresponding to appropriate design condition (in N/m^2);

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

NOTE It is acceptable for A and C_f for specific designs to be determined by full scale experimental testing.

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 4 and the appropriate value used for each zone.

4.1.4.5 Individual members, single lattice frames, etc: force coefficients. Force coefficients for individual members, single lattice frames, machinery houses, cages, etc. shall be as given in Table 5.

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 2.

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.

4.1.4.6 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 4.1.4.4, 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:

$$F_s = A_s q C_f \phi$$

where

q and C_f are as defined in 4.1.4.4;

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 6 according to the solidity ratio of the front frame and the spacing ratio; these ratios are defined in Figure 2.

Table 4 — Design wind pressures

Height	Wind pressure				
	In-service ^a	Out-of-service ^a			
	All zones ^b	Zone 1 ^b	Zone 2 ^b	Zone 3 ^b	Zone 4 ^b
	N/m ²	N/m ²	N/m ²	N/m ²	N/m ²
Parts of hoist under 30 m from ground level	250	731	1 167	1 370	1 588
Parts of hoist over 30 m and up to 60 m from ground level	250	868	1 384	1 625	1 884
Parts of hoist over 60 m and up to 90 m from ground level	250	940	1 500	1 760	2 041
Parts of hoist over 90 m and up to 120 m from ground level	250	998	1 593	1 869	2 168
Parts of hoist over 120 m and up to 150 m from ground level	250	1 041	1 661	1 950	2 261
Parts of hoist over 150 m and up to 200 m from ground level	250	1 102	1 759	2 064	2 394
^a See Appendix C for details of the in-service and out-of-service wind speeds and the methods used to calculate the design pressures. ^b Zone 1: Greater London. Zone 2: Remainder of England and most of Wales and the southern half of Northern Ireland (see also zone 3). Zone 3: Lowlands of Scotland, the extreme south-western tip of Wales and most of the northern half of Northern Ireland (see also zone 4). Zone 4: Highlands and Islands of Scotland and the extreme northern tip of Northern Ireland.					

Table 5 — 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 $b/d^a \geq 2$						
		1	1.55	1.75	1.95	2.1	2.2	
		0.5	1.40	1.55	1.75	1.85	1.9	
		0.25	1.0	1.2	1.3	1.35	1.4	
		0.25	0.8	0.9	0.9	1.0	1.0	
	Circular sections:							
	where $D V_s < 6 \text{ m}^2/\text{s}$		0.75	0.80	0.90	0.95	1.0	1.1
	where $D V_s \geq 6 \text{ m}^2/\text{s}$		0.60	0.65	0.70	0.70	0.75	0.8
Single lattice frames	Flat-sided sections		1.7					
	Circular sections:							
	where $D V_s < 6 \text{ m}^2/\text{s}$		1.2					
	where $D V_s \geq 6 \text{ m}^2/\text{s}$		0.8					
Cages and counter weights, etc.	Rectangular clad structures		1.0					

^a See Figure 2.

4.1.4.7 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 $1.7q (1 + \phi)$

for towers composed of circular sections

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

where $D V_s \geq 6 \text{ m}^2/\text{s}$ $1.4q$

The value of ϕ shall be taken from Table 6 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.

4.2 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 6 — Shielding factors ϕ

Spacing ratio ^a a/b	Solidity ratio ^a A/A_s					
	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

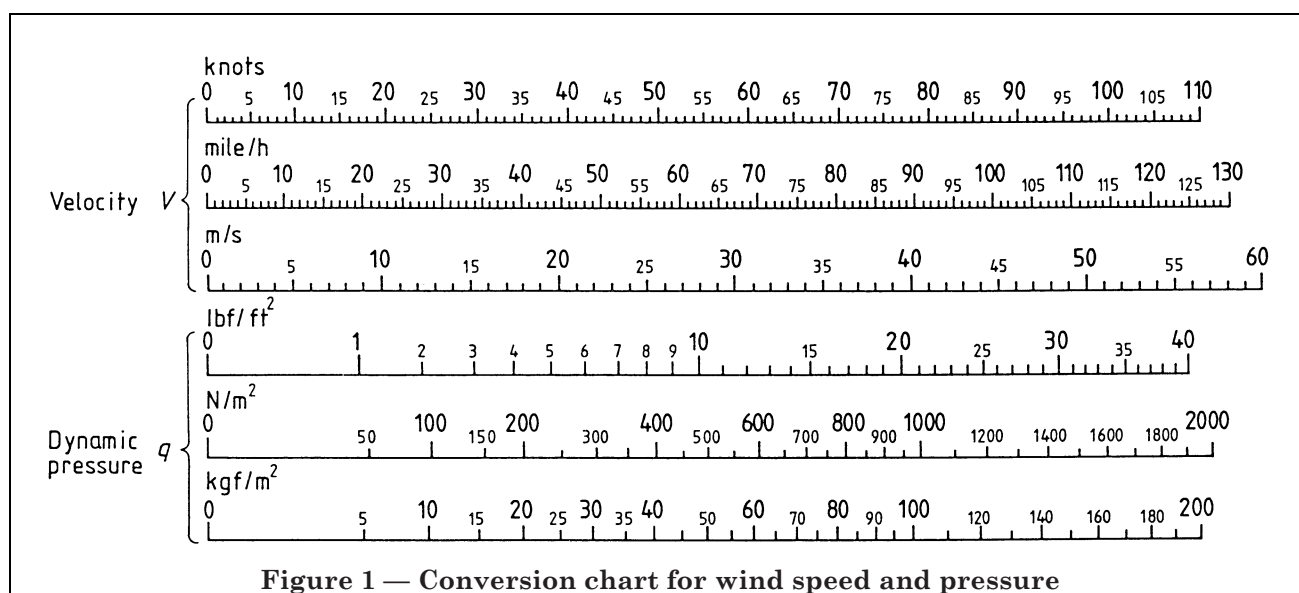
^a See Figure 2.

Figure 1 — Conversion chart for wind speed and pressure

5 Selection of steel, minimum thickness and working stresses

5.1 Selection of steel

5.1.1 Steel shall be selected from either:

- structural steels complying with BS 4360; or
- other steels, provided that the hoist manufacturer shows that they have comparable properties to steels complying with BS 4360 and they have been subjected to equivalent tests.

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

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

5.1.4 For temperate or tropical conditions, steels having no specified impact properties 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:

- plates and sections above 30 mm thickness where brittle fracture might occur under tension loads;
- 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.

5.2 Minimum thickness of plates and sections

The proportioning of members of hoist 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. Attention is drawn to the requirements laid down in BS 4395 for the thicknesses of members at joints made with high strength friction grip bolts.

5.3 Permissible working stresses

The calculated stresses in each part of the structure due to the load combinations listed in Table 2 shall not exceed any of the following.

- a) *Under load combination 1*). The basic stress multiplied by the duty factor 0.95.
- b) *Under load combination 2*). The basic stress multiplied by the duty factor 1.07.
- c) *Under load combination 7*). The permissible fatigue stress.
- d) *Under separate load combinations 3*), 4), 5) and 6). The basic stress multiplied by the duty factor 1.36.

6 Stresses in structural components

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

6.1.1 Basic stresses. Basic stresses for steels complying with BS 4360 for use in the application of this standard shall comply with **6.1.2** to **6.1.8**.

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 **6.1.2** to **6.1.8** are allowed in cases where secondary stresses are calculated and taken into account in the design [see **6.3**].

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

6.1.2 Members subject to simple axial tension [see **5.3**]. The basic tensile stress $P_{at,bas}$ (in N/mm^2) shall not exceed the value

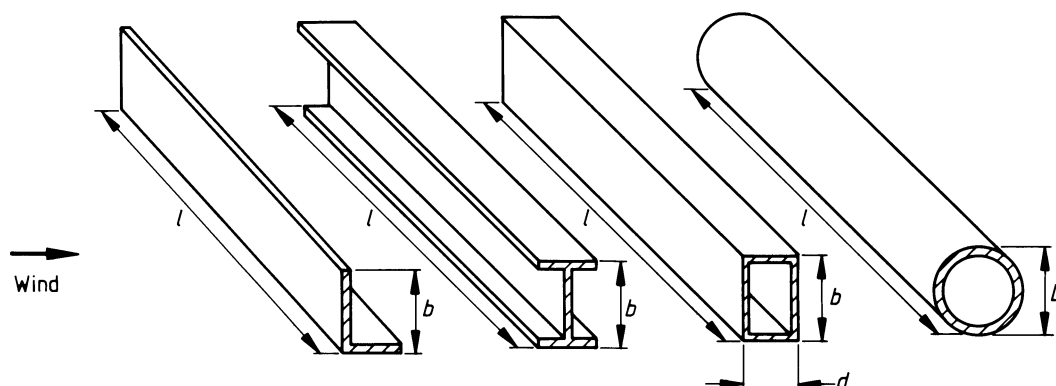
$$P_{at,bas} \text{ (on net section)} = 0.6Y_s$$

where

Y_s is the yield stress of the steel under consideration (in N/mm^2).

Tabulated values of $P_{at,bas}$ for the range of steels covered by BS 4360 are given in Table 7.

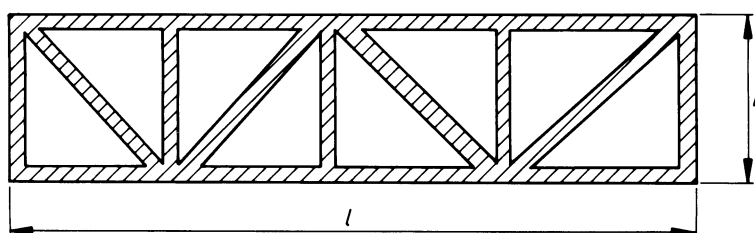
The maximum widths of tension flange plates with stiffened or unstiffened edges are specified in **8.2.3**.



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

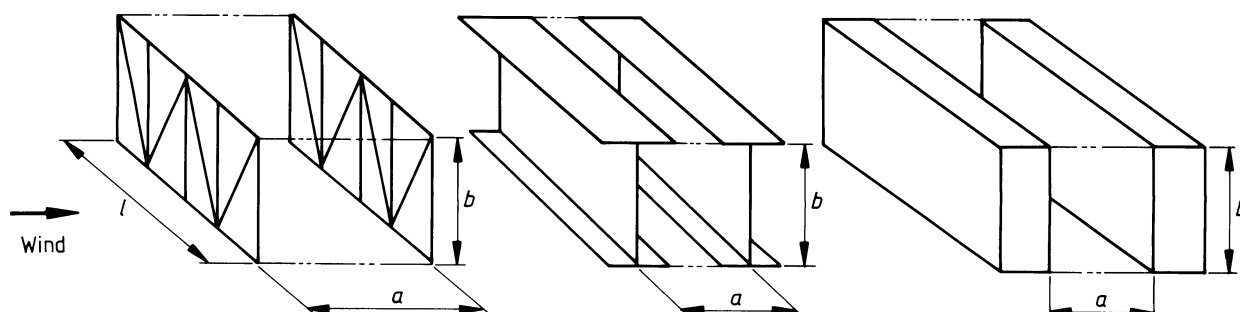
$$\text{Section ratio (for box sections)} = \frac{\text{breadth of section across wind front}}{\text{depth of section parallel to wind flow}} = \frac{b}{d}$$

(a) Aerodynamic slenderness and section ratio



$$\text{Solidity ratio } \frac{A}{A_s} = \frac{\text{area of solid parts (shown shaded)}}{\text{enclosed area}} = \frac{\Sigma A_{\text{members}}}{b \times l}$$

(b) Solidity ratio



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

(c) Spacing ratio

Figure 2 — Definitions: aerodynamic slenderness, section ratio, solidity ratio and spacing ratio

6.1.3 Members subject to simple axial compression [see 5.3]. The basic compressive stress $P_{ac,bas}$ shall not exceed $P_{at,bas}$ as defined in 6.1.2 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 (in N/mm²) 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

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

Y_s is the yield stress of the steel under consideration; for sections fabricated from plate by welding, the yield stress Y_s is 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 8;

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 8.1.

Tabulated values of F_{crip} for the range of steels covered by BS 4360 are given in Table 9 for the values of α given in Table 8.

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

The effective and maximum widths of plates in compression are specified in 8.2.1 and 8.2.2 respectively.

The slenderness ratio s for any strut shall be obtained by dividing its effective length l as given in 8.1 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.

6.1.4 Members subject to bending [see 5.3]

6.1.4.1 Areas in tension. The basic tensile bending stress $P_{bt,bas}$ (in N/mm^2) shall not exceed the following values:

for plates, flats, tubes, rounds, square and similar sections bending about their minor axis; $\left. \vphantom{\begin{array}{l} \text{for plates, flats, tubes, rounds, square and similar sections bending} \\ \text{about their minor axis;} \end{array}} \right\} P_{bt,bas} = 0.65 Y_s$

for rolled beams, channels angles and tees, and for plate girders with single or multiple webs with: $\left. \vphantom{\begin{array}{l} \text{for rolled beams, channels angles and tees, and for plate girders with} \\ \text{single or multiple webs with;} \end{array}} \right\} P_{bt,bas} = 0.62 Y_s$

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;

for plate girders with single or multiple webs with: $\left. \vphantom{\begin{array}{l} \text{for plate girders with single or multiple webs with;} \end{array}} \right\} P_{bt,bas} = 0.59 Y_s$

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 6.1.2 and d_1 and t are as defined in Table 7 for parts in bending. Tabulated values of $P_{bt,bas}$ for the range of steels covered by BS 4360 are given in Table 7.

The maximum widths of tension flange plates with stiffened or unstiffened edges are specified in 8.2.3.

6.1.4.2 Areas in compression

6.1.4.2.1 Maximum widths of plates. The maximum widths of plates in compression shall be as specified in 8.2.2.

Table 7 — Basic stresses in structural members

Description	Basic stress for steels complying with 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
Parts in axial tension On effective sectional area (see 6.1.2)	N/mm ² 129	N/mm ² 138	N/mm ² 147	N/mm ² 168	N/mm ² 195	N/mm ² 204	N/mm ² 213	N/mm ² 240	N/mm ² 249	N/mm ² 258	N/mm ² 270
Parts in axial compression On effective gross section (see 6.1.3)	129	138	147	168	195	204	213	240	249	258	270
Parts in bending, (tension or compression) (see 6.1.4) 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. The value 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 6.1.5)	80	85	91	104	120	126	131	148	154	159	167
Parts in bearing On flat surfaces, fixed axles and pins (see 6.1.6)	172	184	196	224	260	272	284	320	332	344	360
Parts subjected to shear combined with other stresses Basic equivalent stress [see 6.1.7]	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 5.3 that correspond to the loading conditions under consideration.											
NOTE 3 The factors in 5.3 which tend to increase the permissible working stress <i>do not apply</i> to the basic equivalent stress ($P_{e,bas}$) but the factor which decreases the permissible working stress <i>does apply</i> .											

Table 8 — 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” include 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.

6.1.4.2.2 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 **6.1.4.1**.

6.1.4.2.3 For sectional shapes with I_y smaller than I_x .

6.1.4.2.3.1 Where I_y and I_x are as defined in **6.1.4.2.2**, the basic compressive bending stress $P_{bc,bas}$ shall not exceed $P_{bt,bas}$ as defined in **6.1.4.1**, 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 **6.1.4.2.3.2** and **6.1.4.2.3.3**.

6.1.4.2.3.2 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, the critical stress C_s shall be calculated as follows.

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

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

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

l/t is not greater than 2;

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

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

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

where

l is the effective length of the compression flange (see **8.1.3**);

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; i.e. $K_1 \times$ mean thickness of the horizontal portion of the compression flange at the point of maximum bending moment.

NOTE 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 7 for parts in bending.

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

Table 9 — Values of F_{crip} for steels complying with BS 4360

Slenderness ratio l/r	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
	Limiting slenderness ratio so below which $F_{\text{crip}} = Y_s$										
	19	19	18	17	16	15	15	14	14	14	13
a) $\alpha = 2.0$ (see 6.1.3)	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
s_o	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 6.1.3)											
s_o	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 9 — Value of F_{crip} for steel complying with BS 4360

Slenderness ratio l/r	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
	Limiting slenderness ratio so below which $F_{crip} = Y_s$										
	19	19	18	17	16	15	15	14	14	14	13
c) $\alpha = 5.5$ (see 6.1.3)	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2	N/mm^2
s_o	215	230	245	280	325	340	355	400	415	430	450
20	210	224	239	273	317	331	342	385	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 6.1.3)											
s_o	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

Values of K_1 for different values of N are given in Table 10.

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 10 — 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);

T is the effective thickness of flange; i.e. $K_1 \times$ 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 10;

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 11.

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

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

$$\left. + K_2 \left(1644 \frac{r_y}{l}\right)^2 \right] \frac{Y_c}{Y_t} = (A + K_2 B) \frac{Y_c}{Y_t}$$

where

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

T and K_2 are as defined in b);

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 11.

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

Table 11 — 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 12 gives values of A and B for different ratios of l/r and D/T to be used for calculating C_s (in N/mm^2).

Table 13 gives values of $P_{bc,bas}$ for different values of C_s .

6.1.4.2.3.3 For sections other than those described in **6.1.4.2.3.2**:

- where the section is symmetrical about the x-x axis, C_s shall be calculated from the formula given in Appendix E;
- where the section is not symmetrical about the x-x axis, C_s shall be calculated using either:
 - the formula given in **6.1.4.2.3.2**, which will give conservative values; or
 - more precise methods.

6.1.5 *Members subjected to shear* (see **5.3**)

6.1.5.1 *Rolled beams, channels, angles and tees.* The basic average shear stress $P_{q,bas}$ (in N/mm^2) on the effective sectional area shall not exceed the value

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

where

Y_s is as defined in **6.1.2**.

Tabulated values of $P_{q,bas}$ for the range of steels covered by BS 4360 are given in Table 7.

6.1.5.2 *Solid web plates.* Solid web plates and stiffeners shall be proportioned in accordance with **8.3**.

The basic average shear stress $P_{q,bas}$ (in N/mm^2) on the effective sectional area of a solid web shall not exceed the value given in **6.1.5.1** or that given by the following equations.

For grade 43 steel complying with 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 grade 50 steel complying with 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 grade 55 steel complying with BS 4360

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

where

- 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.