

A single copy of this
Steel Construction Institute
publication is licensed to

GLAMORGAN

on

07/04/2020

This is an uncontrolled copy

University of South Wales

**This is an uncontrolled copy. Ensure use of the most current version of this document
by searching the Construction Information Service at <http://uk.ihs.com>.**

Steelwork Design Guide to BS 5950

Volume 4 Essential Data for Designers

Published in association with the following:

British Steel General Steels - Sections

British Steel General Steels - Plates

British Steel General Steels - Welded Tubes

British Steel Strip Products

The British Constructional Steelwork Association Limited

The Steel Construction Institute





is The Steel Construction Institute. Its aim is to promote the proper and effective use of steel in construction.

Membership is open to all organisations and individuals that are concerned with the use of steel in construction, and members include clients, designers, contractors, suppliers, fabricators, academics and government departments. SCI is financed by subscriptions from its members, revenue from research contracts, consultancy services and by the sales of publications.

SCI's research and development activities cover many aspects of steel construction including multi-storey construction, industrial buildings, use of steel in housing and development of design guidance on the use of steel.

The Steel Construction Institute, Silwood Park, Ascot, Berkshire, SL5 7QN.

Tel: 01344 623345; Fax: 01344 622944; Email: reception@steel-sci.com; Website: www.steel-sci.org

This guide has been published in association with the following:

British Steel General Steels - Sections

British Steel Sections produces and markets structural steel sections to BS4 and BS4848, Parts 4 and 5 i.e. principally universal beams, columns and piles, joists, channels, angles and T sections. A Regional Advisory Structural Engineering Service is maintained to help specifiers with any problems relevant to structural steelwork design and to provide a point of contact with the sales functions and Technical Services. A series of publications are available dealing with the steel products and their use.

British Steel General Steels - Sections, PO Box 24, Steel House, Redcar, Cleveland TS10 5QL. Telephone: 0642 474111 Fax: 0642 489466.

British Steel General Steels -Plates

British Steel Plates manufactures plates in a wide range of carbon and low alloy steels for a variety of applications in structural steelwork. Also, through close collaboration with designers and fabricators, the needs of the newer and developing industries are being met. These include offshore oil and gas production, nuclear power generation and the manufacture of mining, earth-moving and mechanical handling equipment.

British Steel General Steels - Plates. PO Box 30, Motherwell, Lanarkshire ML1 1AA. Telephone: 0698 66233 Fax: 0698 66233 Ext 214.

British Steel General Steels -Welded Tubes

British Steel Welded Tubes produces and markets structural hollow sections to BS4848 Part 2. Regional Advisory Structural Engineers provide information and advice to specifiers on all aspects of the use of hollow sections in construction and relevant publications are available.

British Steel General Steels - Welded Tubes, PO Box 101, Corby, Northamptonshire NN17 1UA. Telephone: 0536 402121 Fax: 0536 404111.

British Steel Strip Products

British Steel Strip Products produces wide steel strip in various sizes and thicknesses for manufacture into a very wide range of construction products. Although some use is made of hot rolled coil in this connection, the majority of the production is supplied for construction purposes as metal (zinc, aluminium) coated, pre-finished paint coated or laminated with PVC film. The Technical Advisory Services gives information and advice on the products of BS Strip Mill Products.

British Steel Strip Products, PO Box 10, Newport, Gwent NP9 0XN. Telephone: 0633 290022 Fax: 0633 272933.

The British Constructional Steelwork Association Limited

The British Constructional Steelwork Association Limited (BCSA) is the officially recognised Trade Association for steelwork companies engaged in the design, fabrication and erection of constructional steelwork in the fields of building and civil engineering. The Association represents the interests of the constructional steelwork industry, ensures the capabilities and activities of the industry are widely understood and provides members with professional services in technical, commercial and contractual matters.

The British Constructional Steelwork Association Limited, 4 Whitehall Court, Westminster, London SW1A 2ES.

Telephone: 020 7839 8566 Fax: 020 7976 1634

Although care has been taken to ensure, to the best of our knowledge, that all data and information contained herein are accurate to the extent that they relate to either matters of fact or accepted practice or matters of opinion at the time of publication, the Steel Construction Institute and the organisations listed above assume no responsibility for any errors in or misinterpretations of such data and/or information or any loss or damage arising from or related to their use.

Publications supplied to the Members of the Institute at a discount are not for resale by them.

Steelwork Design Guide to BS 5950

Volume 4

Essential Data for Designers

British Library Cataloguing in Publication Data

Steelwork design guide to BS 5950
Volume 4: Essential data for designers
1. Steel structures. Design
I. Steel Construction Institute
624.1821

ISBN 1 870004 00 0 (set)
ISBN 1 870004 61 2 (vol 4)

© The Steel Construction Institute 1991

The Steel Construction Institute
Silwood Park
Ascot
Berkshire SL5 7QN

Tel: 01344 623345
Fax: 01344 622944

FOREWORD

This volume, one of the series of SCI Steelwork Design Guides to BS 5950, presents essential design data, not readily available elsewhere, that is useful to steelwork designers and fabricators.

A single volume could not possibly contain all the supplementary information that would be required to cover the full range of structural steelwork design. To assist the reader, a list of the relevant British Standards and other publications have been included where appropriate. These, together with the addresses of product manufacturers provided in this guide will enable users to obtain quickly all the information they require. An effort has been made to keep detailed description of the background to the data to a minimum.

This guide has been compiled mainly from various publications of The British Standards Institution, British Constructional Steelwork Association, Building Research Establishment, British Steel General Steels, and from technical literature supplied by manufacturers; the source of some of the material included is not clearly identifiable. Acknowledgements have been included, where possible, in the relevant Sections. Details of advisory bodies are contained in Section 20 of this publication.

Extracts from British Standards are reproduced with the permission of the British Standards Institution. Copies of the Standards can be obtained by post from BSI Sales, Linford Wood, Milton Keynes, MK14 6LE; telephone: 0908 221166; Fax: 0908 322484.

The publication has been made possible by sponsorship from British Steels General Steels, which is gratefully acknowledged.

The publication was edited by Mr D M Porter of the University of Wales College of Cardiff and Mr A S Malik of the Steel Construction Institute.

CONTENTS

	Page
1. LOADS	1-1
1.1 Dead loads	1-1
1.2 Other design data	1 -5
1.3 Imposed and wind loads on buildings	1 -7
1.4 Member capacities	1-7
1.5 References	1 -8
2. WELDABLE STEELS	2-1
2.1 Performance requirements of structural steels	2-2
2.2 Mechanical properties	2-3
2.3 Chemical properties	2-3
2.4 Rolling tolerances	2-10
2.5 References	2-17
3. COLD FORMED STEEL PRODUCTS	3-1
3.1 Manufacturers of roof and wall external and internal cladding	3-1
3.2 Manufacturers of roof purlins and wall sheeting rails	3-2
3.3 Manufacturers of roof decking	3-3
3.4 Manufacturers of lintels	3-3
3.5 Manufacturers of profiled decking for composite floors	3-5
3.6 References	3-5
4. COMPOSITE CONSTRUCTION	4-1
4.1 Composite beams	4-1
4.2 Profiled steel decking	4-1
4.3 Shear connectors	4-2
4.4 Welded steel fabric - BS 4483:1985	4-5
4.5 References	4-6
5. STEEL SLAB BASES AND HOLDING DOWN SYSTEMS	51
5.1 Design of slab column bases	5-1
5.2 Concentric load capacity of slab bases for universal columns	5-3
5.3 Holding down systems	5-3
5.4 Drawings	5-3
5.5 References	5-7

	Page
6. BUILDING VIBRATIONS	6-1
6.1 Introduction	6-1
6.2 Vibration of buildings	6-1
6.3 Vibration of floors	6-2
6.4 Human reaction	6-2
6.5 References	6-3
7. EXPANSION JOINTS	7-1
7.1 Background	7-1
7.2 Basics	7-1
7.3 Practical factors - industrial buildings	7-3
7.4 Practical factors - commercial buildings	7-4
7.5 Cladding and partitions	7-5
7.6 Detailing of expansion joints	7-5
7.7 Recommendations	7-6
7.8 Summary	7-8
7.9 References	7-9
8. DEFLECTION LIMITATIONS OF PITCHED ROOF STEEL PORTAL FRAMES	8-1
8.1 British Standard recommendations	8-1
8.2 Types of cladding	8-1
8.3 Deflections of portal frames	8-2
8.4 Behaviour of sheeted buildings	8-3
8.5 Behaviour of buildings with external walls	8-3
8.6 Analysis at the serviceability limit state	8-4
8.7 Building with overhead crane gantries	8-5
8.8 Ponding	8-6
8.9 Visual appearance	8-6
8.10 Indicative values	8-6
8.11 References	8-9
9. ELECTRIC OVERHEAD TRAVELLING CRANES AND DESIGN OF GANTRY GIRDERS	9-1
9.1 Crane classification	9-1
9.2 Design of crane gantry girders	9-1
9.3 Design and detailing of crane rail track	9-11
9.4 Gantry girder end stops	9-12
9.5 References	9-12
10. FASTENERS	10-1
10.1 Mechanical properties and dimensions	10-1
10.2 Strength grade classification	10-1
10.3 Protective coatings	10-10

	Page
10.4 Minimum length of bolts	10-10
10.5 Designation of bolts	10-10
10.6 References	10-10
11. WELDING PROCESSES AND CONSUMABLES	11-1
11.1 Basic requirements	11-1
11.2 Manual metal-arc (MMA) welding	11-1
11.3 Submerged arc (SA) welding	11 -2
11.4 Gas metal arc welding (GMA)	11-3
11.5 Gas shielded flux-cored arc welding (FCAW)	11-3
11.6 Consumable guide electrosag welding (ESW)	11 -4
11.7 Stud welding	11-5
11.8 Manual metal arc (MMA) electrodes	11 -7
11.9 BS 7084:1988 carbon and carbon manganese steel tubular cored welding electrodes	11-12
11.10 BS 4165:1984 electrode wires and fluxes for the submerged arc welding of carbon steel and medium-tensile steel	11-14
11.11 References	11-15
12. STEEL STAIRWAYS, LADDERS AND HANDRAILING	12-1
12.1 Stairways and ladders	12-1
12.2 Handrailing	12-1
12.3 Detailed design	12-1
12.4 List of manufacturers	12-3
12.5 References	12-3
13. CURVED SECTIONS	13-1
13.1 General	13-1
13.2 Minimum bend radii	13-1
13.3 Material properties of curved members	13-1
13.4 Bending of hollow sections for curved structures	13-3
13.5 Accuracy of bending	13-5
13.6 References	13-5
14. STAINLESS STEEL IN BUILDING	14-1
14.1 Introduction	14-1
14.2 Stainless steel types	14-1
14.3 Corrosion	14-1
14.4 Staining	14-2
14.5 Surface finish	14-2
14.6 Fabrication	14-2
14.7 Applications and design considerations	14-2
14.8 Material grades	14-4
14.9 References	14-5

	Page
15. FIRE PROTECTION OF STRUCTURAL STEELWORK	15-1
15.1 Section factors	15-1
15.2 Forms of protection	15-1
15.3 Performance of proprietary fire protective materials	15-2
15.4 Amount of protection	15-3
15.5 Calculation of Hp/A values	15-3
15.6 Half-hour fire resistant steel structures, free-standing block-filled columns and stanchions	15-11
15.7 Fire resistant of composite floors with steel decking	15-14
15.8 Concrete filled hollow section columns	15-16
15.9 Water cooled structures	15-16
15.10 References	15-16
16. BRITISH STEEL - SPECIALISED PRODUCTS	16-1
16.1 Durbar floor plates	16-1
16.2 Bridge and crane rails	16-5
16.3 Bulb flats	16-7
16.4 Round and square bars	16-10
16.5 References	16-10
17. BRITISH STEEL - PLATE PRODUCTS	17-1
17.1 Plate products - range of sizes	17-1
17.2 References	17-8
18. TRANSPORTATION, FABRICATION AND ERECTION OF STEELWORK	18-1
18.1 Transportation of steelwork	18-1
18.2 Fabrication tolerances	18-3
18.3 Accuracy of erected steelwork	18-3
18.4 References	18-3
19. BRITISH STANDARDS	19-1
20. ADVISORY BODIES	20-1
APPENDIX - Metric conversion tables	A-1

1. LOADS

This Section contains essential design data on dead loads, other design data, imposed loads and wind loads for normal design situations.

1.1 Dead loads

Information on dead loads is given below.

Table 1.1 contains general data on the unit weight of bulk materials. More detailed information is given in BS 648⁽¹⁾. However, for final design purposes, reference should be made to the manufacturers' publications.

Table 1.2 provides information on packaged materials; Table 1.3 pertains to building materials; and Table 1.4 to floors, walls and partitions.

Table 1.1 Bulk materials: approximate unit weights

Material	kN/m ³	Material	kN/m ³
Ashes, coal	7.05	Brass, rolled	83.84
Asphalt, paving	22.64	Bronze	82.27
Ballast, brick, gravel	17.54	Copper, cast	86.34
		Copper, rolled	87.60
Cement, portland loose	14.11	Iron, cast	70.66
Cement, mortar	16.46	Iron, wrought	75.36
Clay, damp, plastic	17.54	Lead, cast	111.13
Concrete, breeze	15.09	Lead, sheet	111.42
Concrete, brick	18.82	Nickel, monel metal	87.27
Concrete, stone	22.64	Steel, cast	77.22
Earth, dry, loose	11.30	Steel, rolled	77.22
Earth, moist, packed	15.09	Tin, cast	71.44
Earth, dry, rammed	17.54	Tin, rolled	72.52
Glass, plate	27.34	Zinc	68.60
Glass, sheet	24.50		
Gravel	18.82	NATURAL STONE	
Lime mortar	16.17	Slate	28.22
		Flint	25.90
MASONRY		Granite	26.70
Artificial stone	22.60	Limestone	25.13
Freestone, dressed	23.52	Macadam	23.57
Freestone, rubble	21.95	Marble	25.92
Granite dressed	25.92	Sandstone	23.57
Granite, rubble	24.30		
METALS		Pitch	10.98
Aluminium, cast	27.15	Plaster	15.09
Brass, cast	82.71	Plaster of Paris, set	12.54

Continued.....

Table 11 (Continued)

Material	kN/m ³	Material	kN/m ³
REINFORCED CONCRETE		TIMBER	
2% steel	23.55	Softwoods:	
3% steel	24.55	Pine, Spruce,	
		Douglas Fir	4.72
Sand, dry	15.68	Redwood	5.50
Sand, wet	19.60	Pitchpine	6.60
		Hardwoods:	
Steel	77.22	Teak, Oak	7.07
Tar	10.05		
Terra-cotta	17.60		

For further information refer to BS 648⁽¹⁾: Weights of building materials.

Table 12 Packaged materials: approximate unit weights

Material	kN/m ³	Material	kN/m ³
CEREALS ETC.			
Barley, in bags	5.65	Lime, in barrels	7.85
Barley, in bulk	6.28	Oils, in bulk	8.79
Flour, in bags	7.07	Oils, in barrels	5.65
Hay, in bales, compressed	3.77	Oils, in drums	7.07
Hay, not compressed	2.20	Paper, printing	6.28
Oats, in bags	4.24	Paper, writing	9.42
Oats, in bulk	5.02	Petrol	6.59
Potatoes, piled	7.07	Plaster, in barrels	8.32
Straw, in bales compressed	2.98	Potash	32.14
Wheat, in bags	6.12	Red Lead, dry	20.72
Wheat, in bulk	7.07	Rosin, in barrels	7.54
		Rubber	9.42
MISCELLANEOUS		Saltpetre	10.52
Bleach, in barrels	5.02	Screw nails, in packages	15.70
Cement, in bags	13.19	Soda ash, in barrels	9.73
Cement, in barrels	11.46	Soda, caustic, in drums	13.82
Clay, china, kaolin	21.67	Snow, freshly fallen	0.94
Clay, potters, dry	18.84	Snow, wet, compact	3.14
Coal, loose	8.79	Starch, in barrels	3.93
Coke, loose	4.71	Sulphuric acid	9.42
Crockery, in crates	6.28	Tin, sheet, in boxes	43.65
Glass, in crates	9.42	Water, fresh	9.81
Glycerine, in cases	8.16	Water, sea	10.05
Ironmongery, in packages	8.79	Whitelead, dry	13.50
Leather, in bundles	2.51	White lead paste, in drums	27.32
Leather, hides compressed	3.61	Wire, in coils	11.62

Table1.3 *Building materials: approximate unit weights*

Material	kN/m ²
ALUMINIUM ROOF SHEETING 1.2 mm THICK	0.04
ASBESTOS CEMENT SHEETING	
Corrugated 6.3 mm thick as laid	0.16
Flat 6.3 mm thick as laid	0.11
ASPHALT	
Roofing, 2 layers, 19 mm thick	0.41
25 mm thick	0.58
Bitumen, built up felt roofing	
3 layers including chippings	0.29
BLOCKWORK (excludes weight of mortar)	
Concrete, solid, per 25 mm	0.54
Concrete, hollow, per 25 mm	0.34
Lightweight, solid, per 25 mm	0.32
BRICKWORK (excludes weight of mortar)	
Clay, solid, per 25 mm thick	0.45
Low density	0.49
Medium density	0.54
High density	0.58
Clay, perforated, per 25 mm thick	
Low density 25% voids	0.38
15% voids	0.42
Medium density 25% voids	0.40
15% voids	0.46
High density 25% voids	0.44
15% voids	0.48
BOARDS	
Cork, compressed, per 25 mm thick	0.07
Fibre insulating, per 25 mm thick	0.07
Laminated blockboard, per 25 mm thick	0.11
Plywood, 12.7 mm thick	0.09
GLASS	
Clear float, 4 mm	0.09
6 mm	0.14
GLASS FIBRE	
Thermal insulation, per 25 mm thick	0.005
Acoustic insulation, per 25 mm thick	0.01
GLAZING, PATENT (6.3 mm Glass)	
Lead covered bars at 610 mm centres	0.29
Aluminium alloy bars at 610 mm centres	0.19
LEAD, SHEET PER 3 mm THICK	0.34
PLASTER	
Gypsum 12.5 mm thick	0.22
PLASTERBOARD GYPSUM	
9.5 mm thick	0.08
12.5 mm thick	0.11
19.0 mm thick	0.17
ROOF BOARDING	
Softwood rough sawn 19 mm thick	0.10
Softwood rough sawn 25 mm thick	0.12
Softwood rough sawn 32 mm thick	0.14

Continued...

Table 1.3 (Continued)

Material	kN/m ²
RENDERING	
Portland cement: sand 1:3 mix, 12.5 mm thick	0.29
SCREEDING	
Portland cement: sand 1:3 mix, 12.5 mm thick	0.29
Concrete, per 25 mm thick	0.58
Lightweight, per 25 mm thick	0.32
STEEL ROOF SHEETING	
0.70 mm thick (as laid)	0.07
1.20 mm thick (as laid)	0.12
TILING, ROOF	
Clay or concrete, plain, laid to 100 mm gauge	0.62-0.70
Concrete, interlocking, single lamp	0.48-0.55
TILING, FLOOR	
Asphalt 3 mm thick	0.06
Clay 12.5 mm thick	0.27
Cork, compressed 6.5 mm thick	0.025
PVC, flexible 2.0 mm thick	0.035
Concrete 16 mm thick	0.38
WOODWOOL SLABS, per 25 mm thick	0.15

Table 1.4 Floors, walls and partitions: approximate unit weights

(a) Reinforced concrete floors

Thickness mm	Dense concrete kN/m ²	Lightweight concrete kN/m ²
100	2.35	1.76
125	2.94	2.20
150	3.53	2.64
175	4.11	3.08
200	4.70	3.52
225	5.30	3.96
250	5.88	4.40

Dense concrete is assumed to have natural aggregates and 2% reinforcement with a mass of 2400 kg/m³. Lightweight concrete is assumed to have a mass of 1800 kg/m³.

(b) Steel floors

Durbur non-slip		Open steel flooring		
Thickness on plain mm	kN/m ²	Thickness mm	kN/m ²	
			Light	Heavy
4.5	0.37	20	0.29	0.38
6.0	0.49	25	0.38	0.46
8.0	0.64	30	0.44	0.56
10.0	0.80	40	0.60	0.74
12.5	0.99	50	0.74	0.90

Open steel floors are available from various manufacturers to particular patterns and strengths. The above average figures are for guidance in preliminary design. Manufacturers' data should always be used for final design.

Continued.....

Table 1.4 (Continued)

(c) Timber floors (solid timber, joist sizes, mm), unit weight kN/m²

Joist centres	Decking	Joist sizes					
		75x50	100x50	150x50	200x50	225x50	275x50
400 mm	19 mm Softwood	0.16	0.18	0.21	0.25	0.27	0.30
	19 mm Chipboard	0.19	0.21	0.24	0.28	0.30	0.33
	22 mm Chipboard	0.21	0.23	0.26	0.30	0.32	0.35
600 mm	19 mm Softwood	0.14	0.16	0.18	0.20	0.21	0.24
	19 mm Chipboard	0.17	0.19	0.21	0.23	0.24	0.27
	22 mm Chipboard	0.19	0.21	0.23	0.25	0.26	0.29

The solid timber joists are based on a density of 5.5 kN/m³.

(d) Wall: approximate unit weights for design

Construction	kN/m ²		
	Brick	Block	Brick + Block
102.5 mm thick			
Plain	2.17	1.37	
Plastered one side	2.39	1.59	
Plastered both sides	2.61	1.81	
215 mm thick			
Plain	4.59	2.99	3.79
Plastered one side	4.81	3.21	4.01
Plastered both sides	5.03	3.43	4.23
255 mm Cavity wall			
Plain	4.34	2.74	3.54
Plastered one side	4.56	2.96	3.76
Plastered both sides	4.78	3.18	3.98
Assumed unit weight of brickwork 21.2 kN/m ³			
Assumed unit weight of clockwork 13.3 kN/m ³			

(e) Partitions

Timber partition (12.5 mm plasterboard each side)	0.25 kN/m ²
Studding with lath and plaster	0.76 kN/m ²

For specific types and makes of walls and partitions, reference should be made to the manufacturers' publications.

1.2 Other design data

Details about the angle of repose of bulk materials, coefficient of active pressure for cohesionless materials and coefficients of linear thermal expansion of building materials are given below.

1.2.1 Angle of repose of bulk materials

For preliminary design, the angle of repose values given in Table 1.5 could be used. In final design a more accurate value of the actual material should always be obtained and used.

Table 1.5 *Angle of repose*

Material	Unit weight kN/m ³	Angle of repose, θ
Ashes	6.3 - 7.9	40°
Cement	14.1	20°
Cement (clinker)	14.1	30°
Chalk (in lumps)	11.0 - 12.6	35° - 45°
Clay (in lumps)	11.0	30°
Clay (dry)	18.8 - 22.0	30°
Clay (moist)	20.4 - 25.1	45°
Clay (wet)	20.4 - 25.1	15°
Clinker	10.2	40°
Coal (in lumps)	8.8	35°
Coke	5.5	30°
Copper ore	25.1 - 28.3	35°
Crushed brick	12.6 - 15.7	35° - 40°
Crushed stone	17.3 - 20.4	35° - 40°
Granite	17.3 - 31.0	35° - 40°
Gavel (clean)	14.1 - 17.3	35° - 40°
Gravel (with sand)	15.7 - 17.3	25° - 30°
Haematite iron ore	36.1	35°
Lead ore	50.2	35°
Limestones	12.6 - 18.8	35° - 45°
Magnetite iron ore	39.3	35°
Manganese ore	25.1 - 28.3	35°
Mud	16.5 - 18.8	0°
Rubblestone	17.3 - 18.8	45°
Salt	9.4	30°
Sand (dry)	15.7 - 18.8	30° - 35°
Sand (moist)	18.1 - 19.6	35°
Sand (wet)	18.1 - 20.4	25°
Sandstones	12.6 - 18.8	35° - 45°
Shale	14.1 - 18.8	30° - 35°
Shingle	14.1 - 17.3	30° - 40°
Slag	14.1	35°
Vegetable earth (dry)	14.1 - 15.7	30°
Vegetable earth (moist)	15.7 - 17.3	45° - 50°
Vegetable earth (wet)	17.3 - 18.8	15°
Zinc ore	25.1 - 28.3	35°

1.2.2 Coefficient of active pressure

The coefficient of active pressure for cohesionless materials is given in Table 1.6

Table 1.6 *Values of K_a (coefficient of active pressure) for cohesionless materials*

Wail	K_a for values of angle of repose (θ)				
μ	25°	30°	35°	40°	45°
0°	0.41	0.33	0.27	0.22	0.17
10°	0.37	0.31	0.25	0.20	0.16
20°	0.34	0.28	0.23	0.19	0.15
30°		0.26	0.21	0.17	0.14

This table may be used to determine the horizontal pressure, P_a , in kN/m², exerted by stored material.

$P_a = \text{unit weight} \times \text{depth of stored material} \times K_a$

The effect of wall friction μ on active pressures is small and is usually ignored. The above values of K_a assume vertical walls with horizontal ground surface.

The above data should not be used in the design calculations for silos, bins, bunkers and hoppers.

1.2.3 Coefficients of linear thermal expansion

The coefficients of linear thermal expansion for some common building materials is given in Table 1.7.

Table 1.7 Coefficients of linear thermal expansion for some common building materials

Material		(per deg. C.x 10 ⁻⁴)	
Aluminium			0.24
Brass			0.19
Copper			0.17
Glass (flat)			0.08
Iron (cast)		0.10	- 0.13
Iron (wrought)			0.12
Mild Steel			0.12
Lead			0.29
Wood-hard or soft	(par. to grain)	0.04	- 0.06
	(across grain)	0.30	- 0.70
Zinc - high purity			0.4
Die-cast alloy to BS 1004			0.27
Zn-Ti alloy sheeting			0.21

1.3 Imposed and wind loads on buildings

1.3.1 Imposed loads

The imposed loads which have to be considered when designing floors, ceilings, stairways and walkways for the various categories of buildings such as domestic, commercial and industrial are given in *BS 6399: Part 1:1984⁽¹⁾*. Given also in the above standard are the imposed loads for designing vehicle barriers, balustrades etc.

Also included are the design loads for crane gantry girders and for dynamic effects other than that of wind loads.

1.3.2 Wind loads

At present the code of practice for wind loading is *CP3, Chapter V, Part 2:1972⁽¹⁾* but this standard will be replaced by *BS 6399: Part 2*.

1.3.3 Roof and snow loads

Minimum imposed loads and snow loads on roofs are given in *BS 6399: Part 3:1988⁽¹⁾*:

Section 1	Minimum imposed roof loads
Section 2	Snow loads

1.4 Member capacities

Steelwork design guide to BS 5950: Part 1:1985 Volume 1(2) published by the Steel Construction Institute, provides section properties and member capacities of all steel sections manufactured in the United Kingdom. This guide contains Member Capacity Tables classified as given below:

- I and H section struts
- Hollow section struts
- Channel struts
- Angle struts
- Angle ties
- I and H sections subject to bending

I and H sections: bearing and buckling
Hollow sections subject to bending
Hollow sections: bearing and buckling
Channels subject to bending
Channels: bearing and buckling
I and H sections: axial load and bending
Hollow sections: axial load and bending
Channels: axial load and bending
Bolt capacities
Weld capacities
Floor plates

1.5 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)
2. THE STEEL CONSTRUCTION INSTITUTE
Steelwork design guide to BS 5950: Part 1:1985, Volume 1 - Section properties and member capacities, 2nd Edition
SCI, Ascot, 1987

2. WELDABLE STEELS

This Section covers chemical and mechanical properties of weldable structural steels to *BS 4360: 1990*⁽¹⁾, *BS EN 10 025:1990*⁽¹⁾ (grades Fe 360, Fe 430 and Fe 510) and rolling tolerances for plates, bars and all structural sections.

In relation to the EC Commission's Construction Products Directive and the material requirements of the draft European Standard for Design of Steel Structures (Eurocode 3), the European Committee for Iron and Steel Standardisation is preparing a series of European Standards for structural steels. EN 10 025 is the first in the series to be made available and was published in the UK by the British Standards Institution during the summer of 1990. The British version of this standard (*BS EN 10 025*⁽¹⁾), together with *BS 4360:1990*⁽¹⁾ supersede *BS 4360:1986* which is withdrawn. The requirements for those products and grades not within the scope of *BS EN 10 025* are simultaneously republished unchanged as *BS 4360:1990*⁽¹⁾. The grades of *BS 4360: 1986* superseded by *BS EN 10 025* are:

40 A, B, C,D;
43 A, B, C, D and
50 A, B, C, D, DD.

Other grades not listed above are incorporated in *BS 4360:1990*⁽¹⁾. Table 2.1 gives a comparison between *BS 4360:1986* nomenclature and *BS EN 10 025* nomenclature.

Table 2.1 *Comparison of BS 4360:1986 and BS EN 10 025 nomenclature*
(Figures in parentheses refer to the notes following this table)

BS EN 10 025 grades	BS 4360:1986 grades
Fe 310-0(1)(4)	
Fe 360 A(2) Fe 360 B Fe 360 B (FU) Fe 360 B (FN) Fe 360 C Fe 360 D1 Fe 360 D2	40A 40B 40C 40D 40D
Fe 430 A(2) Fe 430 B Fe 430 C Fe 430 D1 Fe 430 D2	43A 43B 43C 43D 43D
Fe 510 A(2) Fe 510 B Fe 510 C Fe 510 D1 Fe 510 D2 Fe 510 DD1(3) Fe 510 DD2(3)	50A 50B 50C 50D 50D 50DD 50DD
Fe 490-2(1)(4) Fe 590-2(1)(4) Fe 690-2(1)(4)	— — —

- (1) There is no equivalent BS 4360:1986 grade.
(2) The "A" subgrades only appear in Annex D of the UK edition of the European Standard.
(3) The Charpy V-notch acceptance criteria for Fe 510 DD1/DD2 are different from those of BS 4360:1986 grade 50DD.
(4) These grades are not suitable for use as weldable structural steels.

(FU) Rimming steel
(FN) Rimming steel not permitted

The main differences between *BS EN 10 025* and *BS 4360:1986* are as follows:

- . Different nomenclature for the various grades.
- Omission of certain grade: (e.g. E, EE, F) which are covered separately in *BS 4360:1990*.
- The scope of the standard with reference to tensile properties for plates, wide flats and sections has been increased to 250 mm from 150 mm, 63 mm and 100 mm respectively.
- * The scope of the standard with reference to impact properties for plates and wide flats has been increased to 250 mm from 100 mm and 50 mm respectively. A limiting thickness of 100 mm has been introduced for sections.

Fuller information on the comparison between *BS EN 10 025* and *BS 4360:1986* is given in an information brochure entitled *BS EN 10 025 vs BS 4360:1986 - Comparisons and Comments* ⁽²⁾ which is available from the British Steel General Steels.

2.1 Performance requirements of structural steels

BS 4360:1990⁽¹⁾ and *BS EN 10 025:1990*⁽¹⁾ (grades Fe 360, Fe 430 and Fe 510) together specify the requirements for weldable structural steels for general structural and engineering purposes in the form of hot rolled plates, flats, bars and for the structural sections complying with *BS 4: Part 1*⁽¹⁾ and *BS 4848 Parts 2,4 and 5*⁽¹⁾. For hollow sections formed from plate and with metal-arc welded seams only the plate material is covered by *BS 4360: 1990*⁽¹⁾.

BS 5950: Part 2⁽¹⁾ requires that all structural steels shall comply with *BS 4360*⁽¹⁾ or *BS EN 10 025*⁽¹⁾ (grades Fe 360, Fe 430 and Fe 510) unless otherwise specified by the engineer.

The performance requirements listed in Table 2.2 must be specified for steels not complying with *BS 4360*⁽¹⁾ or *BS EN 10 025*⁽¹⁾ and compliance with these requirements (Table 2.2) must be determined by the test procedures of *BS 4360*⁽¹⁾ (or *BS EN 10 025*⁽¹⁾).

Where structural steelwork is designed using plastic theory then the steels must be grades 43,50,55 and WR50 of *BS 4360*⁽¹⁾ (or grades Fe 360, Fe 430 and Fe 510 of *BS EN 10 025*⁽¹⁾). For other steels it must be demonstrated that the additional requirements for plastic theory in Table 2.2 have been determined in accordance with the test procedures of *BS 4360*⁽¹⁾ (or *BS EN 10 025*⁽¹⁾).

Table 2.2 Performance requirements for structural steelwork

Performance requirement	Specified by	Additional requirements for steel in structures designed by the plastic theory
Yield strength	Upper yield strength - R_{eH}	$R_m/R_{eH} \geq 1.2$
Minimum tensile strength	Tensile strength - R_m	
Notch toughness	Minimum average Charpy V-notch impact test energy at specified temperature (see BS 4360)	None
Ductility	Elongation in a specified gauge length	Stress-strain diagram to have a plateau at yield stress extending for at least six times the yield strain. The elongation on a gauge length of 5.65 $\sqrt{S_0}$ is not to be less than 15% where S_0 is as given in BS EN 10 002-1: 1990 ⁽¹⁾
Weldability	Maximum carbon equivalent value	None
Quality of finished steel	BS 4360 and BS EN 10 025	None

As far as design to BS 5950: Part 1⁽¹⁾ is concerned, designers now need to understand all references to "BS 4360 grades" as references to "BS 5950 design grades". Table 2.3 given below is used to translate the "design grades" as used in BS 5950: Part 1 into the relevant grades in BS EN 10 025 or BS 4360: 1990 as relevant.

Table 2.3 Appropriate product grades corresponding to BS 5950 design grades
(Figures in parentheses refer to the notes following this table)

Design grade	Product form			
	Sections (other than hollow sections)(1,5)	Plates, wide flats, strip (1,5)	Flats, round and square bars (1,5)	Hollow sections
43A	Fe 430 A (2) or Fe 430 B	Fe 430 A (2) or Fe 430 B	Fe 430 A (2) or Fe 430 B	(4)
43B	Fe 430 B	Fe 430 B	Fe 430 B	(4)
43B(T)	Fe 430 B (6)	Fe 430 B (6)	Fe 430 B (6)	(4)
43C	Fe 430 C	Fe 430 C	Fe 430 C	43C (3)
43D	Fe 430 D	Fe 430 D	Fe 430 D	43D (3)
43DD	43DD (3)	(4)	(4)	(4)
43E	(4)	(4)	43E (3)	(4)
43EE	(4)	43 EE (3)	(4)	43EE (3)
50A	Fe 510 A (2) or Fe 510 B	Fe 510 A (2) or Fe 510 B	Fe 510 A (2)(5) or Fe 510 B	(4)
50B	Fe 510 B	Fe 510 B	Fe 510 B	(4)
50B(T)	Fe 510 B (6)	Fe 510 B (6)	Fe 510 B (6)	(4)
50C	Fe 510 C	Fe 510 C	Fe 510 C	50C (3)
50D	Fe 510 D	Fe 510 D	Fe 510 D	53D (3)
50DD	Fe 510 DD	Fe 510 DD	Fe 510 DD	(4)
50E	55E (3)	(4)	50E (3)	(4)
50EE	(4)	50EE (3)	(4)	50EE (3)
50F	(4)	50F (3)	(4)	(4)
55C	55C (3)	55C (3)	55C (3)	55C (3)
55EE	(4)	55EE (3)	55EE (3)	55EE (3)
55F	(4)	55F (3)	(4)	55F (3)
WR50A	WR50A (3)	WR50A (3)	WR50A (3)	WR50A (3)
WR50B	WR50B (3)	WR50B (3)	WR50B (3)	WR50B (3)
WR50C	WR50C (3)	WR50C (3)	WR50C (3)	WR50C (3)

- (1) Unless shown otherwise, grades in this product form are supplied in accordance with BS EN 10 025
(2) These grades are supplied in accordance with BS EN 10 025 Annex D, Non-conflicting national additions.
(3) These grades are supplied in accordance with BS 4360:1990.
(4) Grades in this product form are not included in either BS EN 10 025 or BS 4360:1990.
(5) Products certified as complying with BS 4360:1986 having the same grade designation as the BS 5950 design grade designation are permitted alternatives.
(6) For design grades 43B(T) and 50B(T), verification of the impact properties of quality B by testing shall be specified under Option 7 of BS EN 10 025 at the time of enquiry and order.

2.2 Mechanical properties

The mechanical properties of BS 4360⁽¹⁾ steels including weather resistant (WR) grades are given in Tables 2.4 to 2.9. For the steels within the scope of BS EN 10 025⁽¹⁾, the mechanical properties are given in Tables 2.10 to 2.11.

2.3 Chemical properties

The chemical properties of BS 4360 steels including weather resistance (WR) grades are given in the Tables 12,14,16,18,20 and 22, of BS 4360:1990⁽¹⁾. The chemical properties of steels within the scope of BS EN 10 025 are given in Tables 2 and 3 of BS EN 10 025.

Tensile strength, R _m (1)	Minimum yield strength, R _e , for thicknesses (in mm) (2)					Minimum elongation, A, on a gauge length of (1)			Minimum Charpy V-notch impact test value			Grade
	Up to and including 16	Over 16 up to and including 40	Over 40 up to and including 63	Over 63 up to and including 100	Over 100 up to and including 150	80 mm (3)	200 mm (4)	5.65 VS ₀	Temp.	Energy min. value	Thickness (5)	
N/mm ² (6) 340/500	N/mm ² 260	N/mm ² 245	N/mm ² 240	N/mm ² 225	N/mm ² 205	% 25	% 22	% 25	°C -50	J 27	mm 75	40EE
430/580(7)	275	265	255	245	225	23	20	22	-50	27	75	43EE
490/640(8)(9) 490/640	355 390	345 390	340	325	305	20 20	18 18	20 20	-50 -60	27 27	75(10) 40	50EE 50F
	Up to and including 16	Over 16 up to and including 25	Over 25 up to and including 40	Over 40 up to and including 63								
550/700 550/700 550/700	450 450 450	430 430 430	415 415	400		19 19 19	17 17 17	19 19 19	0 -50 -60	27 27 27	25 63 40	55C 55EE 55F

- (1) The specified tensile strength and elongation values apply up to the maximum thickness for which minimum yield strength values are specified.
- (2) For wide flats up to and including 63 mm thick and for continuous mill products up to and including 16 mm thick.
- (3) Up to and including 9 mm thick, 17% for grades 40EE, 43EE and 16% for grades 50EE.
- (4) Up to and including 9 mm thick, 16% for grades 40EE, and 43EE and 15% for grades 50EE, 50F, 55C, 55EE and 55F.
- (5) For wide flats up to and including 50 mm thick.
- (6) 1 N/mm² = 1 MPa.
- (7) Minimum tensile strength 410 N/mm² for material over 100 mm thick.
- (8) Minimum tensile strength 460 N/mm² for material over 100 mm thick.
- (9) Minimum tensile strength 480 N/mm² for material over 16 mm thick up to and including 100 mm thick.
- (10) For wide flats up to and including 30 mm thick.

Table 2.5 Mechanical properties for sections (other than hollow sections) (As per Table 15 of BS 4360:1990)
(Figures in parentheses refer to the notes following this table)

Tensile strength,	Minimum yield strength, R _e , for thicknesses (in mm)				Minimum elongation, A, on a gauge length of		Minimum Charpy V-notch impact test value		Grade
	Up to and including 16	Over 16 up to and including 40	Over 40 up to and including 63	Over 63 up to and including 100	200 mm (1)	5.65 S ₀	Temp.	Energy min. value	
N/mm ² (2) 340/500	N/mm ² 260	N/mm ² 245	N/mm ² 240	N/mm ² 225	% 22	% 25	°C -30	J 27	40DD
430/580	275	265	255	245	20	22	-30	27	43DD
490/640(3)	355	345	340	325	18	20	-40	27	50E
	Up to and including 16	Over 16 up to and including 25	Over 25 up to and including 40						
500/700	450	430	415	-	17	19	0	27(4)	55C

- (1) Up to and including 9 mm thick. 16% for grades 40 and 43 and 15% for grades 50 and 55.
 (2) 1 N/mm²=1MPa.
 (3) Minimum tensile strength 480 N/mm² for material over 16 mm thick up to and including 100 mm thick.
 (4) To maximum thickness of 19 mm.

Table 2.6 Mechanical properties for flats and round and square bars (As per Table 17 of BS 4360:1990)
(Figures in parentheses refer to the notes following this table)

Tensile strength,	Minimum yield strength, R _e , for thicknesses (in mm)				Minimum elongation, A, on a gauge length of 5.65 S ₀	Minimum Charpy V-notch impact test value		Grade
	Up to and including 16	Over 16 up to and including 40	Over 40 up to and including 63	Over 63 up to and including 100		Temp.	Energy min. value	
N/mm ² (1) 340/500	N/mm ² 260	N/mm ² 245	N/mm ² 240	N/mm ² 225	% 25	°C -40	J 27(2)	40E
430/580	275	265	255	245	22	-40	27(2)	43E
490/640(3)	355	345	340	325	20	-40	27(2)	50E
	Up to and including 16	Over 16 up to and including 25	Over 25 up to and including 40	Over 40 up to and including 63				
550/700 550/700	450 450	430 430	415 415	400	19 19	0 -50	27(4) 27(4)	55C 55EE

- (1) 1 N/mm²=1 MPa.
 (2) To a maximum thickness of 75 mm.
 (3) Minimum tensile strength 480 N/mm² for material over 16 mm thick up to and including 100 mm thick.
 (4) To maximum thickness of 19 mm.

Table 2.7 Mechanical properties for hollow sections (1) (As per Table 19 of BS 4360:1990)
(Figures in parentheses refer to the notes following this table)

Tensile strength, R_m	Minimum yield strength, R_e , for thicknesses > (in mm)		Minimum elongation, A, on a gauge length of $5.65\sqrt{S_0}$	Minimum Charpy V-notch impact test value			Grade
	Up to and including 16	Over 16 up to and including 40(2)		Temp.	Energy min. value	Thickness max.	
N/mm ² (3) 430/580 430/580 430/580	N/mm ² 275 275 275	N/mm ² 265 265 265	% 22 22 22	°C 0(4) -20 -50	J 27 27 27	mm 40 40 40	43C 43D 43EE
490/640 490/640 490/640	355 355 355	345 345 345	21 21 21	0 -20 -50	27 27 27	40 40 40	50C 50D 50EE
	Up to and including 16	Over 16 up to and including 25(2)					
550/700 550/700 550/700	450 450 450	430 430 430	19 19 19	0 -50 -60	27 27 27	25 25 25	55C 55EE 55F

- (1) For details of flattening test see Clause 28, of BS 4360.
 (2) Only circular hollow sections are available in thicknesses over 16 mm.
 (3) 1 N/mm² = 1 MPa.
 (4) Verification of the specified impact value to be carried out only when option specified in BS 4360 is invoked by the purchaser.

Table 2.8 Mechanical properties for plates, strip, wide flats, flats, sections (other than hollow sections) and round and square bars: weather resistant grades (As per Table 21 of BS 4360:1990)
(Figures in parentheses refer to the notes following this table)

Minimum tensile strength, R_m	Minimum yield strength, R_e , for thicknesses (in mm)				Minimum elongation, A, on a gauge length of		Minimum Charpy V-notch impact test value			Grade
	Up to and including 12	Over 12 up to and including 25	Over 25 up to and including 40	Over 40 up to and including 50	200 mm (1)	$5.65\sqrt{S_0}$	Temp.	Energy min. value	Thickness max.	
N/mm ² (2) 480	N/mm ² 345	N/mm ² 325	N/mm ² 325	N/mm ²	% 19	% 21	°C 0	J 27	mm 12(3)	WR50A
480	345	345	345	340	19	21	0	27	50	WR50B
480	345	345	345	340(4)	19	21	-15	27	50	WR50C

- (1) Minimum elongation of 17% for material under 9 mm.
 (2) 1 N/mm² = 1 MPa.
 (3) For round and square bars, maximum thickness is 25 mm.
 (4) Up to and including 63 mm.

Table 2.9 Mechanical properties for hollow sections: weather resistant grades (1) (As per Table 23 of BS4360:1990)
(Figures in parentheses refer to the notes following this table)

Tensile strength, Rm	Minimum yield strength, Re, for thicknesses (in mm)			Minimum elongation, A, on a gauge length of 5.65 S ₀	Minimum Charpy V-notch impact test value			Grade
	Up to and including 12	Over 12 up to and including 25(2)	Over 25 up to and including 40		Temp.	Energy min.	Thickness max.	
N/mm ² (3) 480	N/mm ² 345	N/mm ² 325	N/mm ² 325	% 21	°C 0	J 27	mm 12	WR50A
480	345	345	345	21	0	27	40	WR50B
480	345	345	345	21	-15	27	40	WR50C

- (1) For details of flattening test see Clause 28 of BS 4360.
 (2) Only circular hollow sections are available in thicknesses over 16 mm.
 (3) 1 N/mm²=1 MPa.

Table 2.10 Mechanical properties for flat and long products (As per Table 4 of BS EN 10 025:1990)
(Figures in parentheses refer to the notes following this table)

Designation		Type of deoxidation(6)	Sub-group(4)	Minimum yield strength R _{eH} in N/mm ² (1)								Tensile strength R _m in N/mm ² (1)			
New according EN 10 027-1(2)	According EU 25-72			Nominal thickness in mm								Nominal thickness in mm			
				≤16	>16 ≤40	>40 ≤63	>63 ≤80	>80 ≤100	>100 ≤150	>150 ≤200	>200 ≤250	< 3	> 3 £100	>100 £150	>150 >250
	Fe 310-0 (3)	opt.	BS	185	175	-	-	-	-	-	-	310-540	290-510	-	-
	Fe 360 B (3)	opt.	BS	235	225							360-510	340-470		
	Fe 360 B (3)	FU	BS	235	225							360-510	340-470		
	Fe 360 B	FN	BS	235	225	215	215	215	195	185	175	360-510	340-470	340-470	340-470
	Fe 360 C	FN	QS	235	225	215	215	215	195	185	175	360-510	340-470	340-470	340-470
	Fe 360 D1	FF	QS	235	225	215	215	215	195	185	175	360-510	340-470	340-470	340-470
	Fe 360 D2	FF	QS	235	225	215	215	215	195	185	175	360-510	340-470	340-470	340-470
	Fe 430 B	FN	BS												
	Fe 430 C	FN	QS	275	265	255	245	235	225	215	205	430-580	410-560	400-540	380-540
	Fe 430 D1	FF	QS												
	Fe 430 D2	FF	QS												
	Fe 510 B	FN	BS												
	Fe 510 C	FN	QS												
	Fe 510 D1	FF	QS	355	345	335	325	315	295	285	275	510-680	490-630	470-630	450-630
	Fe 510 D2	FF	QS												
	Fe 510 DD1	FF	QS												
	Fe 510 DD2	FF	QS												
	Fe 490-2 (5)	FN	BS	295	285	275	265	255	245	235	225	490-660	470-610	450-610	440-610
	Fe 590-2 (5)	FN	BS	335	325	315	305	295	275	265	255	590-770	570-710	550-710	540-710
	Fe 690-2 (5)	FN	BS	360	355	345	335	325	305	295	285	690-900	670-830	650-830	640-830

(1) The values in the table apply to longitudinal test pieces for the tensile test. For plate, strip and wide flats with widths £ 600mm transverse test pieces are applicable.

(2) At the moment of publication of the European Standard, the transformation of EURONORM 27 (1974) into a European standard (EN 10 027-1) is not complete and may be subject to changes (see BS EN 10 025).

(3) Only available in nominal thickness ≤25mm.

(4) BS = base steel; QS = quality steel.

(5) These steels are normally not used for channels, angles and sections.

(6) Method at the manufacturer's option: FU=rimming steel; FN=rimming steel not permitted; FF=fully killed steel containing nitrogen binding elements in amount sufficient to bind the available nitrogen.

Table 2.10 Mechanical properties for flat and long products (continued)
(Figures in parentheses refer to the notes following this table)

Designation		Type of deoxi- dation(6)	Sub- group(4)	Position of test pieces (1)	Minimum percentage elongation (1)									
New according EN10 027-1(2)	According EU 25-72				L ₀ = 80 mm Nominal thickness in mm					L ₀ = 5.65√S ₀ Nominal thickness in mm				
					≤1	>1 ≤1.5	>1.5 ≤ 2	>2 ≤ 2.5	>2.5 <3	≤3 ≤40	>40 ≤63	>63 ≤100	>100 ≤150	>150 ≤250
	Fe 310-0 (3)	opt.	BS	1 t	10 8	11 9	12 10	13 11	14 12	18 16	-	-	-	-
	Fe 360 B (3) Fe 360 B (3) Fe 360 B Fe 360 C Fe 360 D1 Fe 360 D2	opt. FU FN FN FF FF	BS BS BS QS QS QS	1 t	17 15	18 16	19 17	20 18	21 19	26 24	25 23	24 22	22 22	21 21
	Fe 430 B Fe 430 C Fe 430 D1 Fe 430 D2	FN FN FF FF	BS QS QS QS	1 t	14 12	15 13	16 14	17 15	18 16	22 20	21 19	20 18	18 18	17 17
	Fe 510 B Fe 510 C Fe 510 D1 Fe 510 D2 Fe 510 DD1 Fe 510 DD2	FN FN FF FF FF FF	BS QS QS QS QS QS	1 t	14 12	15 13	16 14	17 15	18 16	22 20	21 19	20 18	18 18	17 17
	Fe 490-2 (5)	FN	BS	1 t	12 10	13 11	14 12	15 13	16 14	20 18	19 17	18 16	16 15	15 14
	Fe 590-2 (5)	FN	BS	1 t	8 6	9 7	10 8	11 9	12 10	16 14	15 13	14 12	12 11	11 10
	Fe 690-2 (5)	FN	BS	1 t	4 3	5 4	6 5	7 6	8 7	11 10	10 9	9 8	8 7	7 6

- (1) The values in the table apply to longitudinal test pieces (1) for the tensile test. For plate, strip and wide flats with widths ≤ 600 mm transverse test pieces (t) are applicable.
- (2) At the moment of publication of the European Standard, the transformation of EURONORM 27 (1974) into a European standard (EN 10 027-1) is not complete and may be subject to changes (see BS EN 10 025).
- (3) Only available in nominal thickness ≤ 25 mm.
- (4) BS = base steel; QS = quality steel.
- (5) These steels are normally not used for channels, angles and sections.
- (6) Method at the manufacturer's option: FU = rimming steel; FN = rimming steel not permitted; FF = fully killed steel containing nitrogen binding elements in amount sufficient to bind the available nitrogen.

Table 2.11 Mechanical properties - impact strength (KV longitudinal) for flat and long products (1)
(As per Table 5 of BS EN 10 025:1990) (Figures in parentheses refer to the notes following this table)

Designation New according	According	Type of Type of deoxi- dation(7)	Sub- group(3)	Temperature °C	Min. energy (J)	
					> 10(4) ≤ 150	>150(4) ≤ 250
EN 10 027-1(27)	EU 25-72					
	Fe 310-0 (5)	opt.	BS	-	-	-
	Fe 360 B (5)(6)	opt.	BS	20	27	
	Fe 360 B (5)(6)	FU	BS	20	27	
	Fe 360 B (6)	FN	BS	20	27	23
	Fe 360 C	FN	QS	0	27	23
	Fe 360 D1	FF	QS	-20	27	23
	Fe 360 D2	FF	QS	-20	27	23
	Fe 430 B (6)	FN	BS	20	27	23
	Fe 430 C	FN	QS	0	27	23
	Fe 430 D1	FF	QS	-20	27	23
	Fe 430 D2	FF	QS	-20	27	23
	Fe 510 B (6)	FN	BS	20	27	23
	Fe 510 C	FN	QS	0	27	23
	Fe 510 D1	FF	QS	-20	27	23
	Fe 510 D2	FF	QS	-20	27	23
	Fe 510 DD1	FF	QS	-20	40	33
	Fe 510 DD2	FF	QS	-20	40	33
	Fe 490-2	FN	BS	-	-	-
	Fe 590-2	FN	BS	-	-	-
	Fe 690-2	FN	BS	-	-	-
(1) For subsize test pieces Figure 1 in BS EN 10 025 applies. (2) At the moment of publication of the European Standard the transformation of EURONORM 27 (1974) into a European standard (EN 10 027-1) is not complete and may be subject to changes (see BS EN 10 025). (3) BS = base steel; QS = quality steel. (4) For sections with a nominal thickness > 100 mm the values shall be agreed. Option 24 (see BS EN 10 025, Clause 11) (5) Only available in nominal thickness > 25mm. (6) The impact properties of quality B products are verified only when specified at the time of the enquiry and order. Option 7 (see BS EN 10 025, Clause 11). (7) Method at the manufacturer's option: FU= rimming steel; FN=rimming steel not permitted; FF=fully killed steel containing nitrogen binding elements in amount sufficient to bind the available nitrogen.						

2.4 Rolling tolerances

BS 5950: Part 2⁽¹⁾ requires that all plates, bars, flats etc., and hot rolled sections must comply with the rolling tolerances specified in BS 4360, BS 4 and BS 4848⁽¹⁾ as appropriate. These tolerances are set out in the sub-sections which follow.

2.4.1 Rolling tolerances for plates, strip, wide flats, rounds and square bars

(a) Plates and strip

The dimensional and shape tolerances for plates and strip produced on continuous mills shall comply with BS 1449: Part 1⁽¹⁾. Tolerances for plates produced on non-continuous mills shall comply with BS 4360⁽¹⁾ Clauses 14.2 to 14.6. The length tolerance on ordered length shall comply with Table 2 of BS 4360⁽¹⁾ and the width tolerance on ordered width with Tables 3 (BS 4360); thickness tolerance shall comply with Table 4 (BS 4360) and flatness tolerance with Table 5 (BS 4360).

The specific tolerance requirement for edge camber is given in Clause 14.5 of BS 4360⁽¹⁾

(b) Wide flats

For wide flats (widths of 150 mm and above) the tolerances shall comply with BS 4360 Clauses 15.1 to 15.5. The length tolerances on ordered length for wide flats shall be -0, +50 mm.

The width tolerances on ordered width for wide flats shall be $\pm 2\%$ of ordered width but shall not exceed ± 5 mm.

The thickness tolerances on ordered thickness for wide flats are given in Table 6 of BS 4360⁽¹⁾.

The edge camber tolerance shall be a nominal straightness edge camber not exceeding 0.25% of the length of the wide flat (see Clause 15.4 of BS 4360⁽¹⁾).

The tolerances of squareness of ends, angular accuracy and flatness shall comply with BS 4360⁽¹⁾ Clauses 15.5, 15.6 and 15.7 respectively. For flats of widths of 0-150 mm, the width tolerances on ordered width shall comply with BS 4360⁽¹⁾ Table 9 and thickness tolerances on ordered thickness with Table 10.

(c) Round and square bars

For round and square bars, the size tolerances on ordered size shall comply with BS 4360⁽¹⁾ Clauses 17.1 to 17.2 and Table 11.

The length tolerances on ordered length for round and square bars shall be -0, +600 mm.

2.4.2 Rolling tolerances for hot rolled structural steel sections

Hot rolled sections following BS 4: Part 1:1980⁽¹⁾, (viz beams, columns, joists, channels and tees) are covered below. A hot rolled section is designated by the serial size (nominal size) in millimetres and the mass per unit length in kilograms per metre; this form of designation shall be used in any enquiry and order.

(a) Mass and length tolerances

Mass: If the order does not state that the actual mass per unit length is a minimum, the rolling tolerance shall be $\pm 2.5\%$ of the actual mass per unit length.

If the order states that the actual mass per unit length is a minimum, the rolling tolerance (5%) shall be wholly over the actual mass per unit length.

Length: Sections ordered as "specified" or as "exact" lengths shall be supplied as follows:

- (i) "Specified" lengths; when a section is to be cut to a specified length, it shall be cut to within ± 25 mm of that length. When a minimum length is specified it shall be cut to within +50, -0 mm of that minimum length.
- (ii) "Exact" length; when a section is to be cut to an exact length, it shall be cold sawn to within ± 3 mm of that length.

(b) Dimensional rolling tolerances for universal beams and columns

(i) Cross-section

The variations from the specified dimensions and the correct cross-section shall not exceed those shown in Figure 2.1 and Tables 2.12 and 2.13.

(ii) Straightness

The variation from straightness shall not exceed those tolerances given in Table 2.14.

- (iii) The variations from the nominal thickness of web and flange shall not exceed the tolerances given in Table 2.12(c).
- (c) Tolerances on specified depth of joists and channels

The tolerances on specified depth of joists and channels are given in Table 2.15.

- (d) Cambering of universal beams from the mill

Camber will approximate to a simple regular curve nearly the full length of the beam, and is customarily specified by the ordinate at the mid-length of the beam to be curved. Ordinates at other points, or reverse or other compound curves are not considered practicable.

Small amounts of camber may not be permanent because release of the stresses put into the beam during the cambering operation may subsequently cause the camber to be lost.

It will be appreciated that with such a wide range of sections available, with each size and weight having different cambering characteristics, it is not feasible to state precise amounts or limitations of camber.

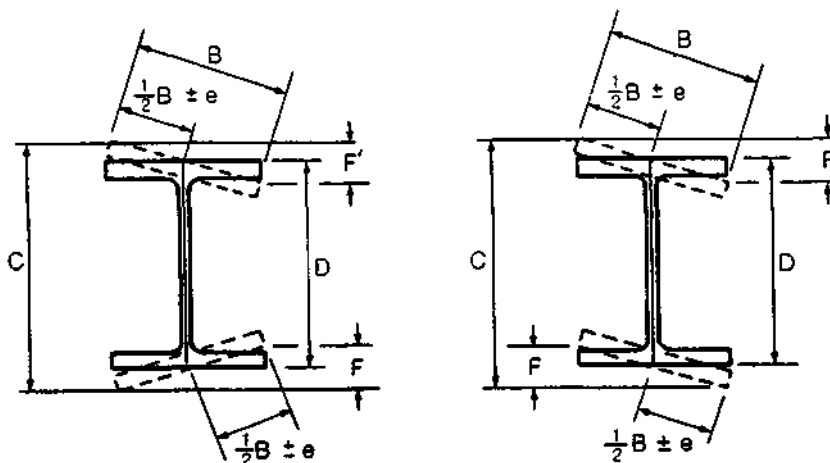


Figure 2.1 Key to Tables 2.12 and 2.13

Table 2.12 Tolerances on dimensions and cross-section for universal beams and columns
(As per Table 1 of BS 4: Part 1:1980)

(a) Tolerances on depth and off-centre of web for universal beams and columns

Serial size depth	Tolerances on depth D	Tolerances on cross-section	
		Off-centre of web e, max	Maximum depth at any cross section C
Up to and including 305 mm	mm ± 3	mm 3.0	mm D+5.0
Over 305 mm	± 3	5.0	D+6.5

(b) Tolerances on flange width for universal beams and columns

Serial size width	Tolerances on flange width B
mm	mm
Up to and including 130	+3 -2
Greater than 130 up to and including 210	±3
Greater than 210 up to and including 235	±4
Greater than 235	+6 -5

(c) Tolerances on thickness for web and flange of universal beams and columns

Thickness	Tolerances	
	Web t	Flange T
mm	mm	mm
Up to but excluding 10	±0.7	±1.0
10 up to but excluding 20	±1.0	±1.5
20 up to but excluding 30	±1.3	±2.0
30 up to but excluding 40	±1.7	±2.5
40 up to but excluding 50	±2.2	±3.0
50 and over		±4.0

Table 2.13 Tolerances on out-of-squareness of flanges for universal beams and columns (As per Table 2 of BS 4: Part 1:1980)

Serial size width	Out-of-squareness of flanges F + F
mm	mm
Up to and including 102	1.5
Greater than 102 up to and including 203	3.0
Greater than 203 up to and including 305	5.0
Greater than 305	6.5

Table 2.14 Tolerances on straightness of universal beams and columns (As per Table 3 of BS 4: Part 1:1980)

Section type	Length, L		Straightness tolerance
	Over	Up to and including	
Universal beams Universal columns	m	m	mm
		All lengths	1.04 L
	9	9 13.5	1.04L 9.5
	13.5		1.04(L-4.5)

Table 2.15 *Tolerances on specified depth of joists and channels (As per Table 4 of BS 4: Part 1: 1980)*

Nominal depth		Maximum permissible variation from specified depth	
Over	Up to and including		
	mm	mm	mm
305	305	+3.2	-0.8
381	381	+4.0	-1.6
	432	+4.8	-1.6

2.4.3 Rolling tolerances for equal and unequal angles to BS 4848: Part 4:1972 (1986)

(a) Mass tolerance - individual angle

- (i) up to and including 4 mm thick $\pm 5\%$
- (ii) over 4 mm thick +5%,-2½%.

(b) Dimensional tolerances

The dimensional tolerances for leg length and section thickness and straightness are given in Tables 2.16, 2.17 and 2.18 respectively.

Table 2.16 *Leg length (As per Table 1 of BS 4848: Part 4:1972 (1986))*

Leg length A	Tolerance on leg lengths A and B
mm	mm
Up to and including 50	± 1
Over 50 up to and including 100	+ 3-1.5
Over 100 up to and including 150	+ 4-2.0
Over 150	+ 5-3.0

Table 2.17 *Section thickness*

Section thickness	Tolerance
mm	mm
Up to and including 5	± 0.50
Over 5 up to and including 10	± 0.75
Over 10 up to and including 15	± 1.00
Over 15	± 1.20

Table 2.18 Straightness

Leg Length A	Tolerance		
	Over full bar length	Over any part bar length	
	Deviation q	Length considered	Deviation q
mm		m	mm
Up to and including 80	0.4% L	1.5	6.0
Over 80 up to and including 150	0.3% L	1.5	4.5
Over 150 up to and including 200	0.2% L	2.0	3.0
Over 200	0.1% L	3.0	3.0

Straightness is measured in the plane of each leg, that leg being horizontal.
 Deviation between ends of bars not to exceed q above.
 Limits apply to each plane of the angle.

- (c) Bar length L
 - (i) +100 mm, - 0 mm for normal tolerance
 - (ii) ±3 mm for "fine" tolerance i.e. when exact length ordered.
- (d) Out of squareness
 - (i) Angular tolerance ±1 °
 - (ii) Linear deviation from squareness not greater than 2.0 mm.

2.4.4 Rolling tolerances for hot finished structural hollow sections (SHS) to BS 4848: Part 2

- (a) Mass

The rolling tolerance on mass shall be: ±6% on individual lengths, +6%, -4% on lots of 10 tonnes and over.

- (b) Length

- (i) Mill Lengths; the tolerances for the standard and special mill lengths are given in Table 2.19 for CHS and Table 2.20 for RHS.
- (ii) Exact Lengths; unless otherwise specified exact lengths are supplied to a tolerance of +6 mm, -0 mm.

- (c) Straightness tolerance

Unless otherwise arranged, structural hollow sections shall not deviate from straightness by more than 0.2% of the total length, as produced, measured at the centre of the length.

- (d) Dimensional tolerances

The dimensional tolerances are as follows:

- (i) Circular hollow sections
 - Outside diameter. ±0.5 mm or ±1 % whichever is the greater

Table 2.19 Length ranges and tolerances for circular hollow section (CHS)

Size mm		Welded		Seamless	Length tolerance mm
O.D.	Thickness	Standard mill lengths m	Special mill lengths m	Standard mill lengths m	
21.3&26.9	all	6.0 & 6.4	5.4 - 7.5		+150-0
33.7-48.3	all	6.0, 6.4 & 7.5	5.4 - 7.5		+150 - 0
60.3-114.3	all	6.0,6.4,7.5 & 10	5.4-12		+150-0
139.7-168.3	all	7.5,10 & 12	6.1 -14.6		+150-0
193.7	up to 12.5	7.5,10 & 12	6.1 -14.6		+150-0
	16.0			8,10 & 12	+300 - 0
219.1	up to 12.5	10 & 12	9-14.8		+300 - 0
	16.0 20.0			8,10 6, 8, &10	
244.5	6.3-16 8-12.5	10 & 12	9-14.8	8,10 & 12 10, 12 & 14	+300 - 0
	20.0			6, 8 &10	
273	6.3-16.0	10&12	9-14.8		+300 - 0
	20.0 25.0			6, 8 &10 4, 6 & 8	
323.9	6.3-16.0	10 & 12	9-14.8		+300-0
	20.0 25.0			6, 8 &10 4, 6 & 8	
355.6	8.0-16.0	10 & 12	9-14.8		+300 - 0
	20.0 25.0			6, 8 &10 4, 6 & 8	
406.4	10.0-16.0	10&12	9-14.8		+300 - 0
	20.0 25.0 32.0			8,10 & 12 4, 6 & 8 2, 4 & 6	
457	10.0-16.0	10&12	9-14.8		+300 - 0
	20.0 25.0 32.0 40.0			8,10 & 12 6, 8 &10 4, 6 & 8 2,4 & 6	
508	10.0-16.0	10&12	9-14.8		+300 - 0
	20&25 32 40 50			6, 8 &10 4, 6 & 8 2,4 & 6 3, 4 & 5	

Table 2.20 Length ranges and tolerances for rectangular hollow sections (RHS)

Size		Welded		Seamless		Length tolerance mm
Square mm	Rectangular mm	Standard mill lengths m	Special mill lengths m	Standard lengths m	Maximum exact lengths m	
20 x 20	-	6.4	5.4 - 7.5			+150 - 0
25 x 25 & 30 x 30	-	6.4 & 7.5				
	50 x 25	7.5				
40 x 40 up to 100 x 100 x 8	50 x 30 up to 120 x 80 x 8	7.5,10 & 12	5.4 - 13.7			
100 x 100 x 10 up to 150 x 150 x 12.5	120 x 80 x 10 up to 200 x 100 x 12.5	7.5,10 & 12	6.1 - 14.6			
150 x 150 x 16	200 x 100 x 16			10-11.2	5.6-11.2	+300 - 0
180 x 180 up to 400 x 400 x 16	250 x 150 up to 500 x 300 x 16	10 & 12	9-14.8			+300 - 0
400 x 400 x 20	500 x 300 x 20	8.5-9.0 random				

- (ii) Rectangular hollow sections

Outside dimensions of sides:

Squareness of sides:

Radii of comers:

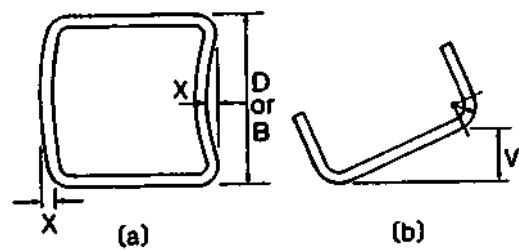
$\pm 0.5\text{ mm}$ or $\pm 1\%$ whichever is the greater

$90^\circ \pm 1^\circ$

outside - between the limits of $0.5t$ and $2.0t$
inside- between the limits of $0.5t$ and $1.5t$
where, t is the specified thickness of the section.
- Concavity/convexity, X:

$\pm 1\%$ of the length of the side D or B. (This tolerance is measured independently of the tolerance on outside dimension) See Figure 2.2(a).
- Angular twist:

$2\text{ mm} + (0.5\text{ mm per metre})$ maximum. Twist is measured by laying the section, as produced, on a horizontal surface with the face at one end pressed flat against the surface and measuring the difference in height, V, above the surface between the two comers at the opposite end, see Figure 2.2(b).



Figures 2.2 Tolerance parameters

2.5 References

1. BRITISH STANDARD INSTITUTION
(see Section 19)
2. BRITISH STEEL GENERAL STEELS
Technical information brochure, BS EN 10 025 vs BS 4360:1986 - Comparisons and comments
BRITISH STEEL GENERAL STEELS, Motherwell, 1990

3. COLD FORMED STEEL PRODUCTS

The following categories of cold formed steel products are used extensively in buildings, in association with structural steelwork:

- (1) Roof and wall external cladding
- (2) Roof and wall internal cladding
- (3) Roof purlins and wall sheeting rails
- (4) Roof decking
- (5) Lintels
- (6) Composite floor decking

Design of cold formed steel products and the specifications for their material and workmanship are covered by *BS 5950: Parts 5,6 and 7⁽¹⁾*.

The manufacturers listed below should be contacted for details of their product range, capacity tables, information regarding fixing details and any technical advice needed. Their products generally conform to the requirements of *BS 5950, Parts 5,6 or 7⁽¹⁾*.

3.1 Manufacturers of roof and wall external and internal cladding

Atlas Coated Steels Limited
2-6 Rock Street
Ashton under Lyme
Lancs OL7 9AZ

Telephone: 061 3432060
Fax: 061 3431542

Ayrshire Metal Products (Daventry) Limited
Royal Oak Way
Daventry
Northants NN1 15NR

Telephone: 0327 300990
Fax: 0327 300885

British Steel Profiles
Newton Aycliffe Works
Aycliffe Industrial Estate
Newton Aycliffe
Co. Durham DL5 6AZ

Telephone: 0325 312343
Fax: 0325 313358

Conder Gadding
Shaw Street
Hill top
West Bromwich
West Midlands B70 0TX

Telephone: 021 556 4211
Fax: 021 505 1228/502 5385

412 Glasgow Road
Clyde Bank
Dunbartonshire G81 1PP

Telephone: 041 952 7831
Fax: 041 952 7720

Corrugated Sheets and Profiles Limited
Ridgacre Road
Black Lake
West Bromwich
West Midlands B71 1BB

Telephone: 021 553 6771
Fax: 021500 6133

Euroclad (South Wales) Limited Wentloog Industrial Estate Wentloog Cardiff CF3 8ER	Telephone: 0222 790722 Fax: 0222 793149
European Profiles Limited Llandybie Ammanford Dyfed SA18 3JG	Telephone: 0269 850691 Fax: 0269 851081
Grenge Industries Limited Houston Industrial Estate Livingston West Lothian EH54 5DH	Telephone: 0506 32551 Fax: 0506 34386
Huurral Limited Greenfield Business Park Number 2 Greenfield Holywell Clywd CH8 7EP	Telephone: 0352 714545 Fax: 0352 710760
Kingspan Building Products Limited New Road Dudley West Midlands DY2 9AZ	Telephone: 0384 456501 Fax: 0384 259343
Precision Metal Forming Limited Swindon Road Cheltenham Gloucester GL51 9LS	Telephone: 0242 527511 Fax: 0242 518929
Stramit Industries Limited Yaxley Eye Suffolk IP23 8BW	Telephone: 037 983 465 Fax: 037 983 659
Ward Building Systems Limited Widespan Works Sherburn Malton North Yorkshire YO17 8PQ	Telephone: 0944 70421 Fax: 0944 70512

3.2 Manufacturers of roof purlins and wall sheeting rails

Ayrshire Metal Products (Daventry) Limited Royal Oak Way Daventry Northants NN11 5NR	Telephone: 0327 300990 Fax: 0327 300885
Hi-Span Limited Ayton Road Wymondham Norfolk NR18 0RD	Telephone: 0953 603081 Fax: 0953 607842

Kingspan Building Products Limited New Road Dudley West Midlands DY2 9AZ	Telephone: 0384 456501 Fax: 0384 259343
---	--

Metal Sections Limited Birmingham Road Oldbury Warley West Midlands B69 4HE	Telephone: 021 552 1541 Fax: 021 544 5520
---	--

Millpac CRS Limited Albion Road West Bromwich West Midlands B70 8BD	Telephone: 021 553 1877 Fax: 021 553 5507
--	--

Structural Sections Limited PO Box 92 Downing Street Smethwick Warley West Midlands B66 2PA	Telephone: 021 555 5918 Fax: 021 555 5659
--	--

Ward Building Systems Limited Widespan Works Sherburn Malton North Yorkshire YO17 8PQ	Telephone: 0944 70421 Fax: 0944 70512
---	--

3.3 Manufacturers of roof decking

British Steel Profiles Newton Aycliffe Works Aycliffe Industrial Estate Newton Aycliffe Co. Durham DL5 6AZ	Telephone: 0325 312 343 Fax: 0325 312343 Ext 217
--	---

Precision Metal Forming Limited Swindon Road Cheltenham Gloucester GL51 9LS	Telephone: 0242 527511 Fax: 0242 518929
--	--

Ward Building Systems Limited Sherburn Malton North Yorkshire YO17 8PQ	Telephone: 0944 70421 Fax: 0944 70512
---	--

3.4 Manufacturers of lintels

Birtley Lintels Halesfield 9 Halesfield Industrial Estate Telford Shropshire TF7 4LD	Telephone: 0952 684763 Fax: 0952 684764
--	--

Birtley Building Products Limited
Mary Avenue
Birtley
Co. Durham DH3 1JF

Telephone: 091 410 6631
Fax: 091 410 0650

CATNIC Components Limited
Pontygwindy Estate
Caerphilly
Mid Glamorgan CF8 2WJ

Telephone: 0222 885955
Fax: 0222 867796 (Sales)
0222 863178 (Reception)

Clarksteel Limited
Station Road
Yaxley
Peterborough PE7 3EG

Telephone: 0733 240811
Fax: 0733 240201

Cleveland Structural Engineering Limited
Post Box 27
Yarm Road
Darlington DL1 4DE

Telephone: 0325 381188
Fax: 0325 382320

Hill and Smith Group of Companies
PO Box 4
Canal Street
Brierley Hill
West Midlands DY5 1JL

Telephone: 0384 480084
Fax: 0384 480543

IG Lintels Limited
Avondale Road
Cwmbran
Gwent NP44 1XY

Telephone: 0633 366811
Fax: 0633 876222

Jones of Oswestry
Whittington Road
Oswestry
Shropshire SY11 1HZ

Telephone: 0691 653251
Fax: 0691 658222

Redpath Dorman Long (Manchester) Limited
32 Longwood Road
Trafford Park
Manchester M17 1PZ

Telephone: 061 873 7266
Fax: 061 873 5539

ROM Limited
Eastern Avenue
Trent Valley
Lichfield
Staffordshire WS13 6RN

Telephone: 0543 414111
Fax: 0543 268221

Stressline Limited
Station Road
Stoney Stanton
Leicester LE9 6LX

Telephone: 0455 272457
Fax: 0455 274564

3.5 Manufacturers of profiled decking for composite floors

Alpha Engineering Services Limited Redcliffe Road Cheddar Bristol BS27 2PN	Telephone: 0934 743720 Fax: 0934 744131
Precision Metal Forming Limited Swindon Road Cheltenham Gloucestershire GL51 9LS	Telephone: 0242 527511 Fax: 0242 518929
Quikspan Construction Limited Forelle House Upton Road Poole Dorset BH17 7AA	Telephone: 0202 666699 Fax: 0202 665311
Richard Lees Limited Weston Underwood Derbyshire DE6 4PH	Telephone: 0335 60601 Fax: 0335 60014
H H Robertson (UK) Limited Cromwell Road Ellesmere Port Cheshire L65 4DS	Telephone: 051 355 3622 Fax: 051 355 276
Structural Metal Decks Limited Mallard House Christchurch Road Ringwood Hants BH24 3AA	Telephone: 0425 471088 Fax: 0425 471408

3.6 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)

4. COMPOSITE CONSTRUCTION

4.1 Composite beams

For the design of simply supported composite beams with a composite slabs, reference should be made to the SCI publication, *Design of composite slabs and beams with steel decking*⁽¹⁾. In this publication some 71 Design Tables are presented which aid the selection of beam size for various plans and loadings. The natural frequency of the beams is restricted to a lower limit of 4 Hz and this often influences the design of the longer span beams.

The following sections highlight some important aspects of composite construction. Details of design are covered in other SCI Publications.

4.1.1 Long span composite beams

There is a strong demand in commercial building for longer-span column-free construction to cater for open planning or greater flexibility in use. Such long span construction will often require deeper beams than the conventional rolled sections and in these cases automatically fabricated composite beams could be the solution. Moreover, since service trunking etc., can be accommodated either in web openings or in the case of simple construction in the reduction of beam depth at the supports, it is often found that there is little or no overall increase in floor depth by the use of such techniques.

Reference (2) describes modern methods of manufacture of automatically fabricated sections and gives general guidance on their likely range of application, their erection and economic construction. Design charts are presented and guidance given to assist initial sizing of the structure.

Reference (3) describes salient features of haunched composite beams and puts forward a design method consistent with *BS 5950: Parts 1 and 3*⁽⁵⁾. Other long span systems which may be used are lattice girders, and stub girders. A novel system is the parallel beam approach⁽⁶⁾ which utilizes a two layer grillage providing continuity in orthogonal directions.

4.2 Profiled steel decking

4.2.1 Deck types

Modern deck profiles are in the range of 45 to 75 mm height and 150 to 300 mm trough spacing. There are two well known generic types: the dovetail profile and the trapezoidal profile with web indentations. A selection of the profiles available from the listed suppliers are (see 4.3.5) shown in Figures 4.1 and 4.2

4.2.2 Slab span and depth

The most efficient use of composite slabs with permanent profiled steel decking is for the slab to span between 2.7 and 3.6 m. Slab depths largely depend upon fire resistance requirements and are usually between 100 and 150 mm⁽⁴⁾. In most situations deflection serviceability limits are catered for if the slab span to depth ratio for continuous slabs does not exceed 35 for normal concrete and 30 for lightweight concrete. For single span slabs these ratios should be reduced to 30 and 25 respectively.

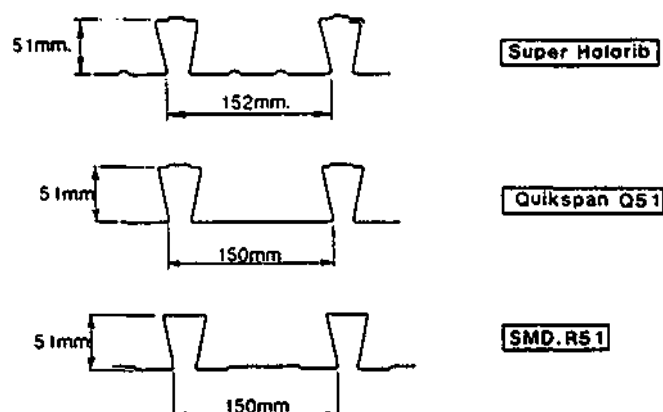


Figure 4.1 Dovetailed deck profiles used in composite slabs

4.2.3 Steel grades and thicknesses

Galvanised sheet steel is typically 0.9 to 1.5 mm thick. Z28 steel (280 N/mm² yield strength) is generally specified, although Z35 steel is used for some of the deeper, longer-span profiles. The thickness of galvanising is approximately 0.02 mm per face, equivalent to 275 g/m² total coverage.

4.3 Shear connectors

4.3.1 Shear studs

The modern form of welded shear connection is the headed stud. The most popular size is 19 mm diameter and 100 mm height. Studs are often welded onto the top flange of the beam through the steel decking using a hand tool connected via a control unit to a power generator. In the case of through deck welding, the top flange of the beam should not be painted or, alternatively, the paint should be removed from the zone where the shear connectors are to be welded. Also, the galvanised steel of the decking should be less than 1.25 mm thick and free from moisture.

4.3.2 Shot fired connectors

The shot-fired connector shown in Figure 4.3 is often used where site power may be a problem.

The design strength of shot-fired connectors marketed by Hilti Ltd is typically 31 kN for standard 110 mm height connector. No reduction is made for concrete type and grade as failure is largely controlled by the shear or pull-out capacity of the pins fired into the steel beam.

4.3.3 Design strength of headed stud shear connectors

The strength of shear connectors is a function of the concrete strength and type, and is determined from the standard push-out test. The design strengths of stud shear connectors in accordance with BS 5950 Part 3⁽⁵⁾ are presented in Table 4.1. The use of high

strength concrete is not recommended, because of its effect on the deformation capacity of the shear connectors. In accordance with BS 5950: Part 3⁽⁵⁾ the ultimate tensile strength of the steel used in the shear connectors (before forming) should be not less than 450 N/mm² and the elongation at failure not less than 15%⁽²⁾.

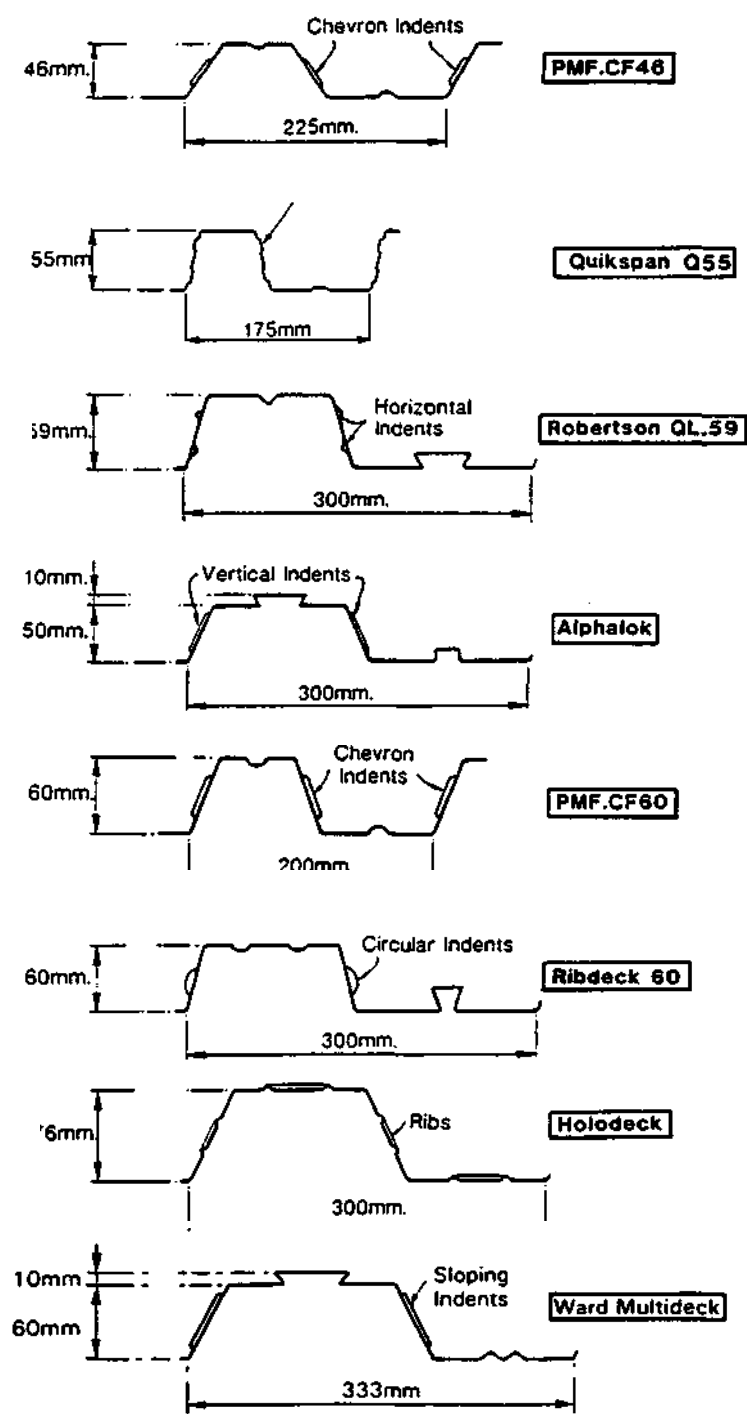


Figure4.2 Trapezoidal deck profiles used in composite slabs

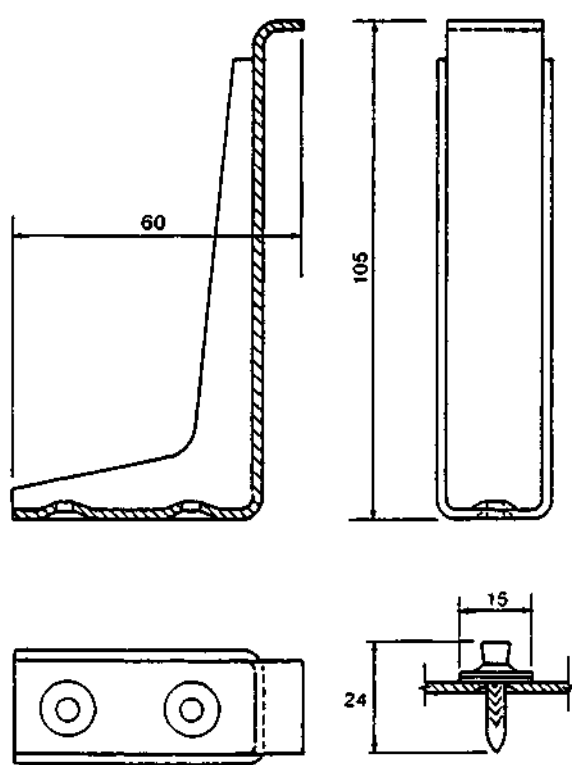


Figure 4.3 The Hilti shot-fired shear connector

Table 4.1 Design strengths in kN of headed studs in normal weight concrete

Dimensions of stud shear connectors (mm)			Characteristic strength of concrete (N/mm ²)			
Dia.	Nominal height	As-welded height	25	30	35	40
25	100	95	117	123	129	134
22	100	95	95	111	106	111
19	100	95	76	80	83	87
19	75	70	66	70	73	77
16	75	70	56	59	62	66
13	65	60	35	38	39	42

For connectors of heights greater than 100 mm use the tabulated values for the 100 mm high studs.

4.3.4 Lightweight concrete slabs

For shear studs in lightweight concrete (density > 1750 kg/m³) the design strengths are 12.5% less than those given in Table 4.1 above.

4.3.5 Suppliers and manufacturers

Deck manufacturers

Alpha Engineering Services Ltd Redcliffe Road Cheddar Bristol BS27 3PN	Telephone: 0934 743720 Fax: 0934 744131
Precision Metal Forming Ltd Swindon Road Cheltenham Gloucestershire GL51 9LS	Telephone: 0242 527511 Fax: 0242 518929
Quikspan Construction Ltd Forellel House Upton Road Poole Dorset BH17 7AA	Telephone: 0202 666699 Fax: 0202 665311
Richard Lees Ltd Weston Underwood Derbyshire DE6 4PH	Telephone: 0335 60601 Fax: 0335 60014
H H Robertson (UK) Ltd Cromwell Road Ellesmere Port Cheshire L65 4DS	Telephone: 051 3553622 Fax: 051 355276
Structural Metal Decks Ltd Mallard House Christchurch Road Ringwood Hants BH24 3AA	Telephone: 0425 471088 Fax: 0425 471408
Ward Building Components Sherburn Malton North Yorkshire YO17 8PQ	Telephone: 0944 70591 Fax: 0944 70777

Shear connector manufacturers

Haywood Engineering Ltd 17 Lower Willow Street Leicester LE1 2HP	Telephone: 0533 532025 Fax: 0533 514602
Hilti (GB) Ltd 1 Trafford Wharf Road Manchester M17 1BY	Telephone: 061 873 8444 Fax: 061 848 7107
T R W - Nelson Stud Welding Ltd Buckingham Road Aylesbury Bucks HP19 3QA	Telephone: 0296 26171 Fax: 0296 22583

4.4 Welded steel fabric - BS 4483:1985⁽⁵⁾

Welded steel fabric for concrete reinforcement is manufactured from plain or deformed wires complying with *BS 4449*, *BS 4461* or *BS 4482*⁽⁵⁾. It is normally produced from grade 460 cold reduced wire complying with *BS 4482*⁽⁵⁾. Grade 250 steel is permitted for wrapping mesh. Dimensional details of the preferred range of fabrics are given in Table 4.2.

Table 4.2 Dimensional details of preferred range of welded steel fabric

Fabric references	Longitudinal wires			Cross wires			Mass
	Nominal wire size	Pitch	Area	Nominal wire size	Pitch	Area	
	mm	mm	mm ² /m	mm	mm	mm ² /m	kg/m ²
Square mesh							
A393	10	200	393	10	200	393	6.16
A252	8	200	252	8	200	252	3.95
A193	7	200	193	7	200	193	3.02
A142	6	200	142	6	200	142	2.22
A98	5	200	98	5	200	98	1.54
Structural mesh							
B1131	12	100	1131	8	200	252	10.9
B785	10	100	785	8	200	252	8.14
B503	8	100	503	8	200	252	5.93
B385	7	100	385	7	200	193	4.53
B283	6	100	283	7	200	193	3.73
B196	5	100	196	7	200	193	3.05
Long mesh							
C785	10	100	785	6	400	70.8	6.72
C636	9	100	636	6	400	70.8	5.55
C503	8	100	503	5	400	49	4.34
C385	7	100	385	5	400	49	3.41
C283	6	100	283	5	400	49	2.61
Wrapping mesh							
D98	5	200	98	5	200	98	1.54
D49	2.5	100	49	2.5	100	49	0.77
Stock sheet size	Length			Width			Sheet area
	4.8 m			2.4 m			11.52 m ²

4.4.1 Bond and lap requirements

The anchorage lengths and lap lengths of welded fabric must be determined in accordance with Clauses 3.12.8.4 and 3.12.8.5 of BS 8110: Part 1⁽⁵⁾.

4.5 References

1. LAWSON, R.M.
Design of composite slabs and beams with steel decking
The Steel Construction Institute, Ascot, 1989
2. OWENS, G.W.
Design of fabricated composite beams in buildings
The Steel Construction Institute, Ascot, 1989
3. LAWSON, R.M. and RACKHAM, J.W.
Design of haunched composite beams in buildings
The Steel Construction Institute, Ascot, 1989
4. NEWMAN, G.M.
The fire resistance of composite floors with steel decking
The Steel Construction Institute, Ascot, 1989
5. BRITISH STANDARDS INSTITUTION
(see Section 19)
6. BRETT, P. and RUSHTON, J.
Parallel beam approach - A design guide
The Steel Construction Institute, Ascot, 1990

5. STEEL SLAB BASES AND HOLDING DOWN SYSTEMS

5.1 Design of slab column bases

The design of steel slab column bases must be in accordance with *BS 5950: Part 1*⁽¹⁾ Clause 4.13 which allows the use of the following empirical method for a rectangular slab base concentrically loaded by I, H, channel, box or RHS. The minimum thickness is given by:

$$t_p = \left[\frac{2.5}{p_{yp}} w (a^2 - 0.3b^2) \right]^{\frac{1}{2}}$$

but not less than the flange thickness of the column supported, where:

- a = the greater projection of the plate beyond the column
- b = the lesser projection of the plate beyond the column
- w = the pressure on the underside of the plate assuming a uniform distribution
- p_{yp} = the design strength of the plate but not greater than 270 N/mm²

Base plates of grade 43A steel subject to compression only should not be limited in thickness by the brittle fracture requirements.

Gussets need not be provided to columns with slab bases but the fastenings (welds or bolted cleats) must be sufficient to transmit the forces developed at the column base connection due to all realistic combinations of factored loads (see *BS 5950: Part 1*⁽¹⁾ Clause 2.2.1) plus those arising during transit unloading and erection; the exception to this is provided in Clause 4.13.3 of *BS 5950: Part 1*⁽¹⁾.

The maximum pressure produced by the factored column loads must not exceed the design bearing strength of the bedding material or the concrete base which is normally taken as $0.4f_{cu}$ where f_{cu} is the 28 day cube strength. The bedding materials normally used are:

Grout:	A fluid suspension of cement with water usually of the proportion of 2:1 by weight. The fluid suspension can be poured into holes and under narrow gaps between base plates and foundations.
Sanded grout:	A mixture of cement, sand and water in approximately equal proportions by weight. It has a higher strength than grout but with a lower shrinkage.
Mortar:	A mixture of cement, sand and water in proportions of about 1:3:0.4 by weight. It is intended for placing or packing.
Fine concrete:	A mixture of cement, sand, coarse aggregate and water in proportions of about 1:1¼:2:0.4 by weight. The coarse aggregate has a maximum size of 10 mm.

Table 5.1 provides suggested design bearing strengths of bedding material.

Unless proper provision is made for the placing and compaction of good quality mortar or concrete, the bearing strengths appropriate to grout or sanded grout should be adopted in the design. In the common case where grout is required to be introduced into bolt pockets under a column base plate, the access space is often between 25 and 50 mm; thus placing conditions are poor and correspondingly low bearing strengths should be assumed.

Detailed guidance on manufacture and placing procedures to achieve the values given in Table 5.1 is given in Reference (2).

Table 5.1 Design bearing strengths of bedding material

Bedding material	Cube strength at 28 days f_{cu}	Design bearing strength at 7 days $0.4 f_{cu}$
	N/mm ²	N/mm ²
Grout	12.0-15.0	4.8- 6.0
Sanded grout	15.0-20.0	6.0- 8.0
Mortar	20.0 - 25.0	8.0-10.0
Fine concrete*	30.0 - 50.0	12.0-20.0

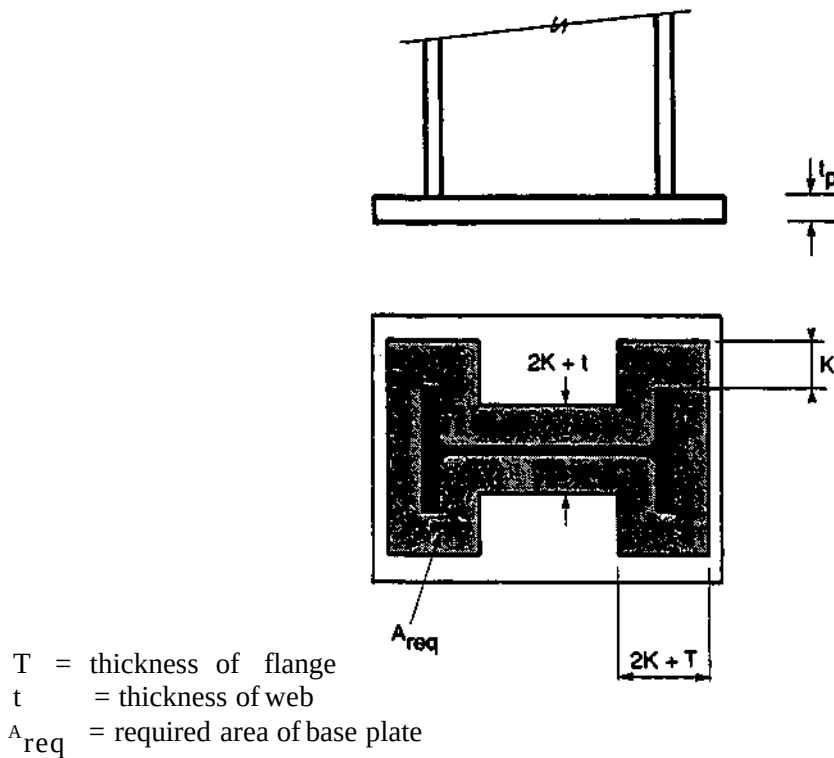
*The strength of fine concrete depends critically on the degree of compaction which can be achieved. Higher bearing strengths up to 30.0 N/mm² can be obtained using hammered or dry packed fine concrete.

Further information and detailed guidance for the design of column bases is given in *Manual on connections, 2nd edition*⁽³⁾.

An alternative method of checking the adequacy of the thickness of base plate is given in a recent publication by SCI/BCSA, *Joints in simple construction, Volume 1: Design methods*⁽⁴⁾. The minimum thickness is given by:

$$t_p = K \left[\frac{3 (0.6 f_{cu})}{p_{yp}} \right]^{1/2}$$

but not less than the flange thickness of the supported column, where K is defined in Figure 5.1, being the distance from the edge of the column section to provide the required minimum base plate area.



T = thickness of flange
 t = thickness of web
 A_{req} = required area of base plate

Figure 5.1 Required minimum area of base plate

5.2 Concentric load capacity of slab bases for universal columns

The load capacities for grade 43 steel slab bases with universal columns are given in Tables 5.2 to 5.8 inclusive. The tables are based on *BS 5950: Part 1*⁽¹⁾ Clause 4.13.2.2. In using the tables, note that:

- (i) F = the factored column axial load in kN
- (ii) W = pressure (N/mm^2) produced by the factored load F on the underside of slab base
- (iii) Plate projections a and b are for the lightest section in any particular column serial size
- (iv) It is important to check that the thickness of the slab is not less than the thickness of the flange of the respective universal column as this restriction could not be considered in the preparation of the tables.

5.3 Holding down systems

The design of the holding down system and the foundation is best prepared under the direction of a single engineer who has an appreciation of the steelwork design, erection problems and civil engineering foundation construction. If this unified approach is not possible then it is essential that the steelwork designer and concrete foundation designers work in close co-operation.

The design of the holding down system must cater for:

- (i) the transmission of the service loads from the column to the foundations
- (ii) the stabilisation of the column during erection
- (iii) the provision of sufficient movement to accommodate the fabrication and erection tolerances
- (iv) the system of packing, filling and bedding
- (v) the provision of protective methods which ensure the achievement of the design life of the holding down system.

Full information with regard to the design of holding down systems is given in Reference (2).

5.4 Drawings

It is essential that all the information needed both by the steelwork erection and civil engineering foundation contractors should be given in the drawings with all the assumptions clearly stated.

Table 5.2 *Grade 43 steel base plate concentric load and bearing capacity for universal columns 152 x 152 UC series*

Slab	300x300 mm		350 x 350 mm		400x400 mm		450 x 450 mm		500 x 500 mm	
thickness mm	W N/mm2	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN
10	2.36	212								
15	5.31	478	2.96	363						
20	9.27	834	5.17	633	3.29	527				
25	14.5	1300	8.08	990	5.15	823	3.56	721		
30			11.6	1430	7.41	1190	5.13	1040	3.76	940
35					10.1	1610	6.98	1410	5.12	1280

Table 5.3 *Grade 43 steel base plate concentric load and bearing capacity for universal columns 203 x 203 UC series*

Slab	400X400 mm		450 x 450 mm		500 x 500 mm		600 x 600 mm		700 x 700 mm	
thickness mm	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN
15	2.99	478								
20	5.21	834	3.31	671						
25	8.15	1300	5.18	1050	3.58	895				
30	11.7	1880	7.46	1510	5.16	1290				
35	16.0	2550	10.2	2060	7.02	1750	3.93	1410		
40	20.9	3340	13.3	2690	9.17	2290	5.13	1850		
45			15.5	3140	10.7	2680	6.00	2160		
50					13.2	3310	7.41	2670	4.73	2320
55							8.97	3230	5.72	2800
60									6.81	3340

Table 5.4 *Grade 43 steel base plate concentric bad and bearing capacity for universal columns 254 x254 UC series*

Slab	500x500 mm		550x550 mm		600 x 600 mm		700X700 mm		800X800 mm	
thickness mm	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN
20	3.34	834								
25	5.21	1300	3.60	1090						
30	7.51	1880	5.18	1570	3.79	1370				
35	10.2	2550	7.06	2130	5.17	1860				
40	13.3	3340	9.22	2790	6.75	2430				
45	15.6	3900	10.8	3260	7.89	2840	4.75	2330		
50	19.3	4820	13.3	4030	9.75	3510	5.87	2870		
55	23.3	5830	16.1	4870	11.8	4250	7.10	3480	4.74	3030
60			19.2	5800	14.0	5050	8.45	4140	5.64	3610
65			22.5	6810	16.5	5930	9.91	4860	6.61	4230
70					19.1	6880	11.5	5630	7.67	4910
75							13.2	6470	8.81	5640

Table 5.5 *Grade 43 steal base plate concentric bad and bearing capacity for universal columns 305 x 305 UC series*

Slab	550x550 mm		600x600 mm		700 x 700 mm		800x800 mm		900x900 mm		1000 x 1000 mm	
thickness mm	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm2	F kN	W N/mm ²	F kN
20	3.32	1010										
25	5.19	1570	3.59	1290								
30	7.48	2260	5.17	1860								
35	10.2	3080	7.03	2530	3.93	1930						
40	13.3	4020	9.19	3310	5.14	2520						
45	15.6	4710	10.8	3870	6.01	2950						
50	19.2	5810	13.3	4780	7.42	3640	4.73	3030				
55	23.2	7030	16.1	5780	8.98	4400	5.73	3670				
60			19.1	6880	10.7	5240	6.82	4360	4.72	3820		
65			22.4	8080	12.5	6150	8.00	5120	5.54	4490		
70					14.5	7130	9.28	5940	6.43	5210	4.71	4710
75					16.7	8180	10.6	6820	7.38	5980	5.41	5410
80					19.0	9310	12.1	7750	8.39	6800	6.16	6160
85					21.4	10500	13.7	8750	9.48	7680	6.95	6950
90							15.3	9810	10.6	8610	7.79	7790

Table 5.6 Grade 43 steel base plate concentric toad and bearing capacity for universal columns 356 x 368 UC series

Slab	600x600 mm		700 x 700 mm		800 x 800 mm		900 x 900 mm		1000 x 1000 mm		1100 x 1100 mm	
thickness mm	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN
20	3.24	1170										
25	5.06	1820										
30	7.29	2620	3.71	1820								
35	9.92	3570	5.06	2480								
40	13.0	4670	6.60	3240								
45	15.2	5460	7.73	3790	4.67	2990						
50	18.7	6740	9.54	4670	5.77	3690						
55	22.7	8150	11.5	5660	6.98	4470	4.67	3780				
60			13.7	6730	8.31	5320	5.56	4500				
65			16.1	7900	9.75	6240	6.52	5280	4.67	4670		
70					11.3	7240	7.57	6130	5.42	5420		
75					13.0	8310	8.69	7040	6.22	6220	4.67	5650
80							9.88	8000	7.07	7070	5.31	6430
85									7.99	7990	6.00	7260
90											6.72	8140

Table 5.7 Grade 43 steel base plate concentric load and bearing capacity for universal columns 356 x 406 UC series (up to 393 kg/m)

Slab	700x700 mm		800 x 800 mm		900x900 mm		1000 x 1000 mm		1100x1100 mm		1200 x 1200 mm	
thickness mm	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN
35	5.86	2870										
40	7.65	3750	4.47	2860								
45	8.96	4390	5.24	3350								
50	11.1	5420	6.46	4140	4.23	3430						
55	13.4	6560	7.82	5010	5.12	4150						
60	15.9	7800	9.31	5960	6.10	4940	4.30	4300				
65	18.7	9160	10.9	6990	7.16	5800	5.05	5050				
70	21.7	10600	12.7	8110	8.30	6720	5.86	5860	4.35	5270		
75			14.5	9310	9.53	7720	6.72	6720	5.00	6040		
80			16.5	10600	10.8	8780	7.65	7650	5.68	6880	4.39	6320
90			20.9	13400	13.7	11100	9.68	9680	7.19	8700	5.55	8000
100					16.9	13700	12.0	12000	8.88	10700	6.86	9870

Table 5.8 Grade 43 steel base plate concentric load and bearing capacity for universal columns 356 x 406 UC series (above 393 kg/m)

Slab	900 x 900 mm		1000 x 1000 mm		1100 x 1100 mm		1200 x 1200 mm		1300 x 1300 mm	
thickness mm	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN	W N/mm ²	F kN
60	6.78	5500	4.70	4700						
65	7.96	6450	5.52	5520						
70	9.23	7480	6.40	6400	4.70	5680				
75	10.6	8590	7.35	7350	5.39	6520				
80	12.1	9770	8.36	8360	6.14	7420	4.69	6760		
90	15.3	12400	10.6	10600	7.76	9400	5.94	8550	4.69	7930
100	18.8	15300	13.1	13100	9.59	11600	7.33	10600	5.79	9790

5.5 References

- BRITISH STANDARDS INSTITUTION
(see Section 19)
- "Holding down systems for steel stanchions"
Concrete Society, BCSA and Constrado, London, 1980
- PASK,J.W
Manual on connections
Volume 1 - Joints in simple construction (conforming with the requirements of BS 5950:
Part 1:1985)
The British Construction Steelwork Association, Publication No. 19/88, London, 1988
- THE STEEL CONSTRUCTION INSTITUTE/BCSA
Joints in simple construction, volume 1: Design methods
SCI, Ascot, 1991

6. BUILDING VIBRATIONS

6.1 Introduction

The dynamic response of vibrations in buildings has increased in recent years with the greater use of lightweight materials and more economic design, and large forces acting on tall structures. Vibration problems can be divided into two main categories; those in which the occupants or users of the building are inconvenienced, and those in which the integrity of the structure may be prejudiced. Vibration can also have a serious effect on laboratory work and trade processes.

6.2 Vibration of buildings

There are three aspects to consider when vibrations of a building are of concern; the source causing the forces which induce vibration, the response of the building, or elements of the building, to those forces, and the acceptable response level.

6.2.1 Vibration sources

Sources which cause buildings to vibrate fall into two main categories; those which are repetitive (and very often caused by some man-made agency), and those which are random (and often caused by natural sources). Typical sources of man-made vibration are machinery, compressors, piledrivers, road and rail traffic, and aircraft; natural sources include wind, earthquakes and wave action. In the United Kingdom wind is by far the most common source of naturally occurring vibration energy. The occurrence of repetitive loading, such as that caused by machinery is rarely a problem for the integrity of a structure, unless the frequency coincides with a natural frequency of some element of the building. The effect on occupants, however, may be unacceptable as this may occur at response levels well below that causing structural damage.

6.2.2 Building response

The response of buildings to a vibration source is governed by the following factors:

- (a) the relationship between the natural frequencies of the building (and/or elements of the building) and the frequency characteristics of the vibration source;
- (b) the damping of the resonances of the building or elements;
- (c) the magnitude of the forces acting on the building;

Some guidance on natural frequencies of building elements is available in References (1) and (2).

Damping values are more difficult to evaluate; generally, in the absence of measurement, specialist advice should be sought. Some guidance on values applicable to taller structures is available in References (3) and (4).

Specialist advice on stiffness, the magnitude of forces and the interaction of buildings with the medium transmitting the forces should be sought. Some information can be found in the literature, References (4) to (8).

6.3 Vibration of floors

The problem of floor vibration due to pedestrian traffic is adequately covered in the *Design guide on the vibration of floors*⁽⁹⁾. This publication presents guidance for the design of floors in steel framed structures against unacceptable vibrations caused by pedestrian traffic with particular relevance to composite floors with steel decking.

6.4 Human reaction

Human reaction to the levels of accelerations that are typical in buildings and floors is a rather fuzzy subject, not due to lack of data but because reaction is almost entirely related to psychological factors rather than physiological factors. Individuals vary greatly in their assessments and there may be differences between nationalities. It also varies according to the task that the person is engaged upon and to other environmental stimuli (e.g. sight and sound) which may or may not be connected with the source of vibration.

The most relevant UK specification is *BS 6472: Evaluation of human exposure to vibration in buildings (1 Hz to 80 Hz)*⁽¹⁰⁾. It defines a root-mean-square (r.m.s.) acceleration base curve for continuous vibration and multipliers to apply in specific circumstances.

The qualitative description of human reaction to sustained steady oscillation is given in Figure 6.1

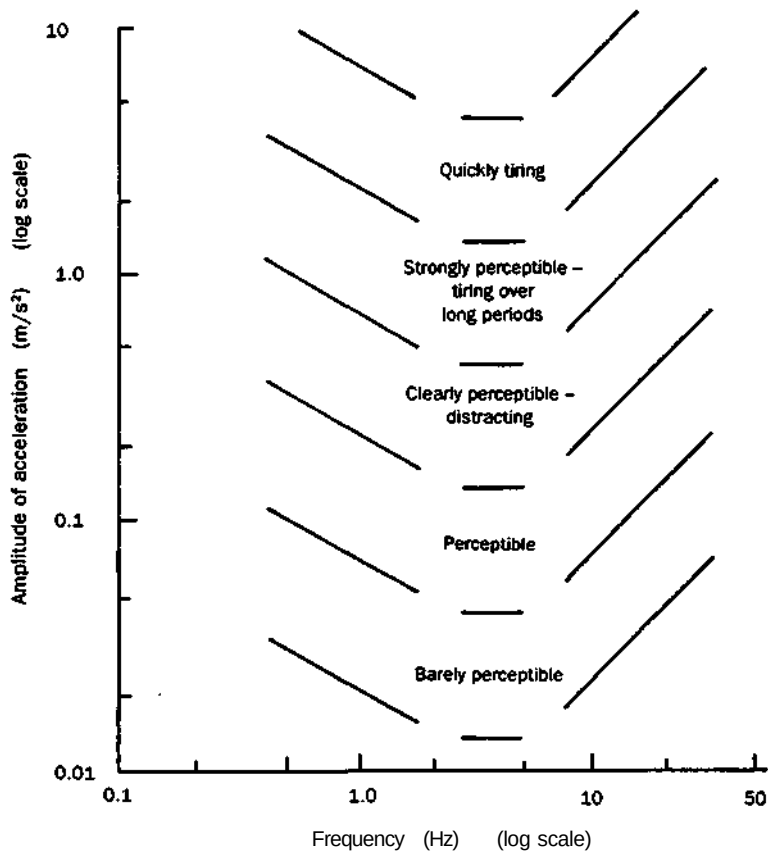


Figure 6.1 Human sensitivity, vortical vibrations (persons standing)

6.5 References

1. ELLIS, B.R.
An assessment of the accuracy of predicting the fundamental natural frequencies of buildings and the implication concerning the dynamic analysis of structures
Proceedings Institution of Civil Engineers Part 2, London, 1980,69, pp763-776
2. STEFFENS.R.J.
Structural vibration and damage
Building Research Establishment, Watford, 1974
3. JEARY, A.P. & ELLIS, B.R.
Recent experience of induced vibration of structures at varied amplitudes
Proc. ASCE/EMD Conference on Dynamic response of structures,
Atlanta, GA, January 1981. Available in Reference (4)
4. HART, G.C.
Dynamic response of structures: experimentation, observation, prediction and control
American Society of Civil Engineers, 345 E47 Street, New York, NY,
USA, 10017 1980
5. ENGINEERING SCIENCES DATA UNIT
Item 76001, Response of flexible structures to atmospheric turbulence
ESDU, 251-259, Regent Street, London, 1976
6. ENGINEERING SCIENCES DATA UNIT
Item 79005, Undamped natural vibration of shear buildings
ESDU, 251-259, Regent Street, London, 1979
7. JEARY, A.P.
The dynamic behaviour of the Arts Tower, University of Sheffield and its implications
to wind loading and occupant reaction
BRE Current Paper CP48 78
Building Research Establishment, Watford, 1978
8. BUILDING RESEARCH ESTABLISHMENT
Vibrations: building and human response
BRE Digest 278
BRE, Watford, 1983
9. WYATT, T.A.
Design guide on the vibration of floors
The Steel Construction Institute, Ascot, 1989
10. BRITISH STANDARDS INSTITUTION
(see Section 19)

7. EXPANSION JOINTS

7.1 Background

Three points are noteworthy concerning the provision of expansion joints in steel-framed buildings:

- They are potential sources of problems.
- The advice circulating on their provision and spacing is variable and conflicting.
- It is widely reported that they do not move anyway.

Varying advice is given in References (2) to (7), so the basics of the problem will first be considered before giving any recommendations.

7.2 Basics

7.2.1 General

When temperatures change, materials expand and contract, generally expanding as temperatures increase. Steel has a positive coefficient of linear thermal expansion, which is quoted in *BS 5950: Part 1:1990*⁽¹⁾ (Clause 3.1.2) as 12×10^{-6} per °C.

This code also recommends (in Clause 2.3) that, where it is necessary to take account of temperature effects, the temperature range to be considered for internal steelwork in the UK can be taken as from -5°C to +35°C, that is a total range of 40°C or a variation from the mean of ±20°C. It is commonly assumed that the foundations do not move and thus there is a differential movement problem, with the steel frame trying to expand but the column bases remaining static. Simple analysis methods or computer programs can most readily be used to account for this by solving the reverse problem, in which the steelwork tries to remain the same length but the bases are displaced horizontally (see Figure 7.1) so the expansion of the frame is treated as a reversed imposed displacement of the bases.

Theoretically there are two alternative approaches:

- Free expansion
- Restraint of thermal expansion

In practice an intermediate situation often actually occurs, which is generally advantageous. But before moving on to such practical factors, it is useful to examine these two limiting cases and the calculations involved.

7.2.2 Free expansion

For simple construction, in which all the joints are assumed to be pinned, the analysis described above does not provide any forces or moments and the calculated expansion is simply treated as a deflection, which is greatest at the columns furthest from the braced bay.

For both simple and continuous construction, the non-verticality of columns (other than at the centre of expansion) will lead to additional forces, moments also arising in continuous construction, though both the forces and the moments due to displacement are often neglected as "secondary effects". To justify this the overall length of structure is limited, or broken down into separate sections separated by expansion joints. In simple construction, each such section needs its own (central) braced bay.

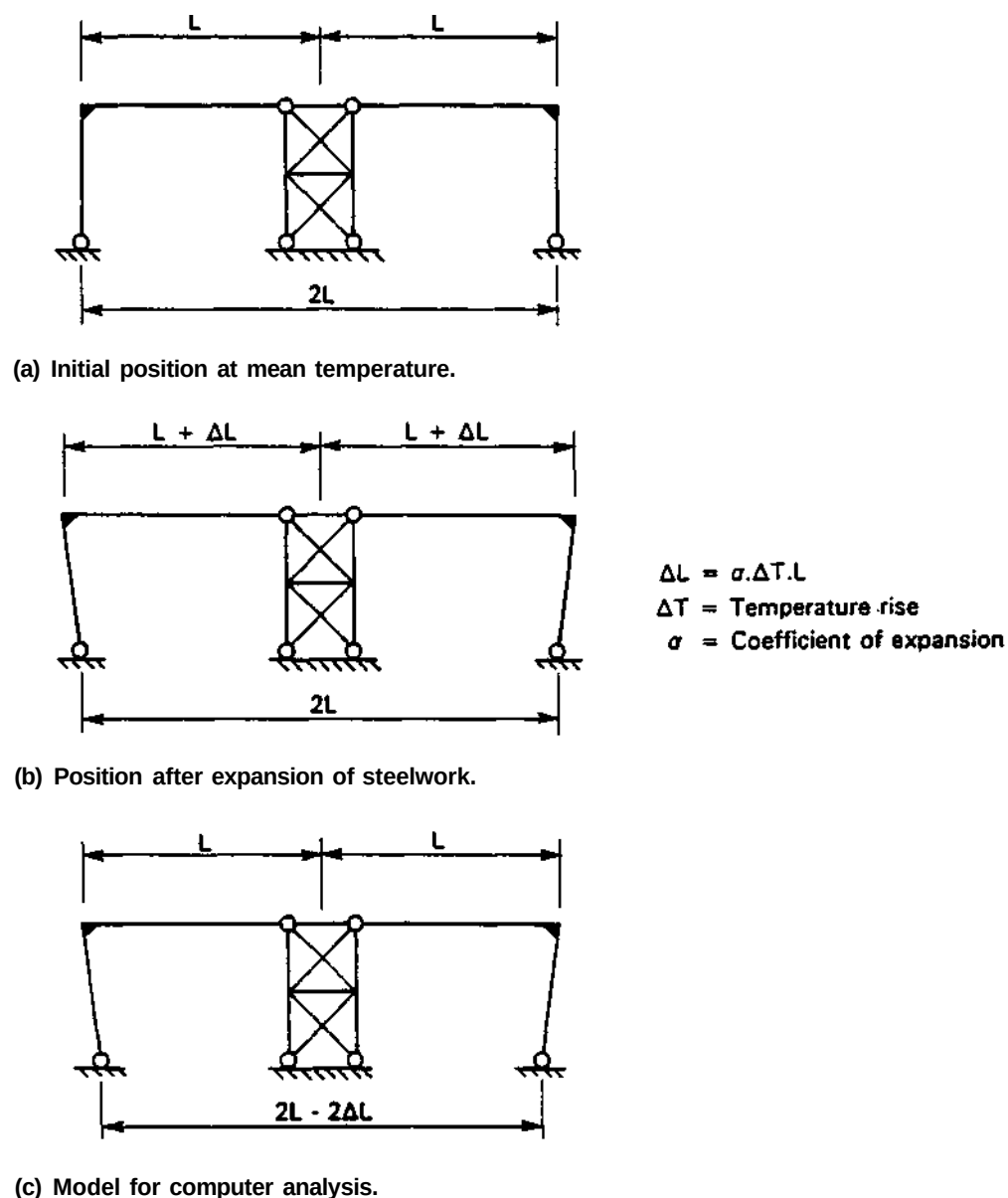


Figure 7.1 Assumptions for calculating expansion effects

For a 20°C temperature change, the expansion per metre length is $20 \times 12 \times 10^{-6} \times 10^3 = 0.24$ mm per metre length. For a building length (overall or between expansion joints) of 100 m, the free expansion length would be taken as 50 m (neglecting any constraint within the braced bay) so each end would move $0.24 \times 50 = 12$ mm, or pro rata for other lengths.

In an industrial building with a height of (say) 6 m, this represents a displacement of 1 in 500. In a commercial building with a storey height of (say) 3.6 m the displacement would be 1 in 300.

Of course in either case the total calculated movement in an expansion joint would be double the maximum movement of one section, that is 24 mm for a spacing of 100 m. Considerations of acceptable movements in expansion joints or floors have thus lead to recommendations to introduce expansion joints every 50 m, thus limiting theoretical joint movements to ± 12 mm and theoretical displacements in a 3.6 m storey height to 6 mm i.e. 1 in 600.

On the other hand expansion joints in the cladding of industrial buildings can be devised with larger movement capacities. For industrial buildings, recommended spacings of expansion joints from 80 m to 150 m have been proposed, representing expansion joint movements of about 19 to 36 mm and theoretical displacements in a 6 m height of 1 in 632 to 1 in 333. For higher buildings the slope will be less.

This discussion indicates how various "rule-of-thumb" recommendations have arisen and why they vary so much. It also serves to warn against applying rules devised for one situation to entirely different circumstances, without proper consideration of what actually happens.

But the real situation is different, as will be explained in the following sections.

7.2.3 Constraint of thermal expansion

If instead of allowing free expansion, it is prevented by some appropriate means, a stress is induced. Using the value of the elastic modulus of steel E from *BS 5950: Part 7*⁽¹⁾ Clause 3.1.2 of 205 kN/mm² the stress for a 20°C temperature change is $20 \times 12 \times 10^{-6} \times 205 \times 10^3 = 49.2$ N/mm² or about 50 N/mm².

BS 5950: Part 1⁽¹⁾ (Table 2) recommends a Y_f factor of 1.2 for forces due to temperature effects, giving a factored load stress of 60 N/mm². Thus even where expansion is almost completely inhibited, the stress induced is well within the range that can be resisted by steel members, provided they are not so slender that they buckle.

The Code is not clear on combining thermal effects and imposed loads, but it is considered that a Y_f factor of 1.2 could also be applied to the imposed loads when considering combined effects. It should also be noted that whilst including imposed roof loads due to snow may be necessary for thermal contraction (i.e. negative thermal expansion), it is not usually a realistic load case for positive thermal expansion!

Buckling due to thermal expansion is self-limiting because the force dissipates as the member deforms. The resulting deformation is clearly unacceptable in crane rails, crane girders, runway beams and valley beams, and is probably not acceptable in eaves beams.

However it does not lead directly to failure and may be tolerable where the appearance is unaffected.

7.3 Practical factors - industrial buildings

7.3.1 Description

The term "industrial building" is used here to describe a single storey factory or storage building with a steel frame and a sheeted roof. The sides may be either sheeted, brick clad or a mixture of both. It may also possibly have an overhead crane gantry or runway beams.

7.3.2 Examination of assumptions

The assumptions mentioned in Section 7.2.1 are worth examining critically. For example if the steel columns are supported on concrete bases which are jointed by "ground beams" or even just by a floor slab (let alone cases where a raft foundation is used), why should the frame expand but the bases remain unmoved? Assuming they do, there must be restraint from the ground, producing stresses in the foundations. If this is acceptable, why not accept thermal stresses in the superstructure?

Moving up a sheeted building, the lowest line of sheeting rails is quite close to ground level. So if the bases do not move, this line of sheeting rails must be heavily restrained, even if the roof steelwork can expand freely. If this is acceptable, why not accept restraint of sheeting rails at other levels?

7.3.3 Pitched rafters

Modern industrial buildings often have pitched roof portal frames or similar types of roof framing which do not include horizontal members. If thermal expansion of these frames is resisted at ground level, the effect is to increase the horizontal thrust and the apex of the frame rises; for a temperature drop it falls. Thus in the plane of such frames, expansion joints in the steelwork are unnecessary. Provided that the roof sheeting is able to expand, the most that needs consideration is the additional stresses in the frames.

7.3.4 Clearance holes

Holes for bolts are normally 2 mm larger than the nominal bolt diameter, more for large sizes. Theoretically this allows a total of 4 mm relative movement between a member and a cleat or gusset plate which attaches it to supporting members, that is ± 2 mm. However bolt holes are not necessarily precisely spaced and in practice the available movement is less, say ± 1 mm. Purlins and sheeting rails are often continuous over 2 bays for spans up to 5 m; so the likely movement is ± 1 mm at each end of a 10 m length, that is a total of 2 mm in a 10 m length, compared to a thermal expansion for $\pm 20^\circ\text{C}$ of $\pm 20 \times 12 \times 10^{-6} \times 10 \times 10^3 = \pm 2.4$ mm.

The force generated in a typical purlin or sheeting rail at 60 N/mm^2 is also of a similar magnitude to the force needed to cause slip in a typical bolted connection, so it is not clear-cut whether the available movement gets utilised or not, even where free expansion is prevented. However, it can be seen that the available movement should generally be sufficient to avoid significantly higher stresses being generated for any reason.

7.3.5 Provision of braced bays

To permit free expansion, the logical arrangement would be to provide a vertical braced bay at mid-length, with bracing in end bays restricted to roof bracing. However in practice the end bays have frequently been braced vertically for convenience, and this is now the usual practice recommended for safety during erection. Even where such bracing is thought of as temporary bracing, it is rarely removed in practice.

The result is that most such buildings do in fact constrain thermal expansion, even though this might not always have been consciously intended or explicitly allowed for in the calculations. In recent years buildings several hundred metres long have been constructed with braced bays at intervals, but with no expansion joints.

7.4 Practical factors - commercial buildings

7.4.1 Description

The term "commercial building" is used here to describe a multi-storey office block or similar building used as a retail shop, school, hospital etc. The floors are generally concrete, or more likely nowadays, composite slabs. The external cladding may be brickwork or various kinds of panels, such as precast concrete, composites or curtain walling. Internal partition walls are likely to include brickwork or clockwork as well as moveable lightweight partitions.

7.4.2 Examination of assumptions

As discussed in Section 7.3.2 there is no reason to prefer free expansion rather than restraint of expansion. Also for a commercial building, once the building is completed the range of temperature change experienced by the internal steelwork is unlikely to exceed $\pm 15^\circ\text{C}$ and while the building is in normal use the variation is not likely to exceed $\pm 10^\circ\text{C}$.

7.4.3 Continuous construction

In structures of continuous construction free expansion is not possible due to the rigidity of continuous members and the joints. The result is a condition intermediate between free expansion and full constraint of expansion, with reduced movements due to the moments generated in the frame. The extent of this partial constraint depends on the bending stiffnesses of the members, particularly the columns, and the cross-section areas of longitudinal members and floor slabs constrained.

7.5 Cladding and partitions

7.5.1 Sheeting

Sheeting, particularly metal sheeting, can easily experience a larger temperature change than the internal steelwork. The maximum temperature depends largely on the colour and other heat absorption characteristics. The minimum temperature depends on environmental and climatic factors.

For profiled steel sheeting, expansion transverse to the span can readily be accommodated by "concertina" or "breathing" action. Parallel to the span, care needs to be taken where long lengths of sheeting are used. Some movement can be accommodated by the fixings to the purlins and by movement of the purlins, depending on the nature of the purlin-to-rafter connections.

7.5.2 Brickwork and clockwork

Brickwork and blockwork have a different coefficient of thermal expansion to steelwork and reinforced concrete, so the main problem is differential expansion. There are also significant differences between different types of brickwork.

Expansion joints have to be provided in the brickwork at relatively close centres, as recommended in Clause 20 and Appendix A of BS 5628: *Part 3*⁽¹⁾. These also allow for shrinkage effects.

Provided that expansion joints are provided in supported brickwork at the recommended centres, there is no need for expansion joints in the steel frame.

External brickwork cladding to single-storey or low-rise buildings is often supported vertically by foundations but supported horizontally against wind forces by the steel frame, with horizontal deflections of the steelwork accommodated by a flexible damp-proof layer at the foot, see Clause 20 of BS 5628: *Part 3*⁽¹⁾ and also Section 8.5.2. In this case the free expansion of the steelwork may need to be either limited or constrained.

7.5.3 Floor slabs

In modern steel-framed buildings, the floor slabs are often composite slabs. No particular need for expansion joints in such floors has been reported, but joints are usually introduced at suitable points such as locations of significant changes in the shape of the building on plan or in the overall height or in the floor levels, or in the type of foundation. Similar considerations also apply to reinforced or precast concrete floors, see BS 8110: *Part 2*⁽¹⁾.

7.6 Detailing of expansion joints

7.6.1 Joints in external sheeting

The precise details of such joints depends on the type of sheeting and the internal and external conditions.

What should be noted is that the provision of a satisfactory expansion joint is neither cheap nor simple. This is why it is often better to spend more on the structure to avoid the need for a joint. Where one is provided it is a false economy to try to make savings in its construction.

7.6.2 Joints in brickwork and blockwork

Reference should be made to *BS 5628: Part 3*⁽¹⁾ and to specialist recommendations⁽⁴⁾.

7.6.3 Joints In floor slabs

Once a joint in a floor slab is provided, it may tend to act as a focus or collecting point for movements due to a variety of causes, such as creep and settlement and may also need to take up the effects of construction tolerances and differential sways. Such joints should therefore permit more than the maximum theoretical expansion movement and a minimum of 22 mm is suggested.

7.6.4 Joints in sheeting rails and purlins

Where expansion joints are provided in sheeting rails and purlins, slotted holes may be used but special bolts designed to permit free movement without the nut coming loose (such as shouldered bolts) should be used and care should be taken to ensure that slots are smooth enough to permit free movement.

7.6.5 Joints in crane girders and runway beams

Where it is necessary for overhead crane gantries to cross expansion joints, special details are necessary both to permit free movement and to avoid rail wear. The two adjacent girders are best supported separately, though a halving-joint with a sliding bearing is also possible. The rail should have a long scarving joint - and where crane utilisation is high it is wise to make provision for easy replacement of the expansion joint in the rail, as wear is likely to be high at this point.

Runway beams should preferably not cross expansion joints, unless they have flexible support arrangements which can accommodate support movements without the need for a break in the runway beam itself.

7.6.6 Other joints in steelwork

In steel members larger than sheeting rails and purlins, simple slotted hole joints are unlikely to work and sliding bearings are unlikely to be economic except perhaps in crane girders.

Articulated joints can sometimes be used in lattice girder roof construction, but in most cases the most practical solution is a complete break in the framing. Double columns close together are best avoided but can be used where there is no alternative. But by arranging joints at changes in layout or level of the building, it is generally possible to have separate structures which are sufficiently far apart not to cause problems but sufficiently close to enable the gap to be bridged by cantilevering.

7.7 Recommendations

7.7.1 General

Expansion joints should be used only where they are really necessary. The alternative of resisting expansion should be considered as an alternative. Where expansion joints are provided, they should be properly detailed to ensure they can move and also to ensure they cannot cause leaks in the cladding or problems in floors etc.

7.7.2 Steel frames - industrial buildings

Unless longitudinal members such as eaves beams and crane girders are designed to resist stresses due to restraint of expansion, provide expansion joints in the steel frame at a maximum of 150 m centres, or 125 m centres in buildings subject to high internal temperatures due to plant⁽⁵⁾.

Vertical braced bays should be positioned mid-way between expansion joints, but plan bracing can be located at gables. If vertical braced bays are needed at the ends, allow for stresses in main longitudinal members due to restraint of expansion (and also in bracing except where deformation by self-limiting buckling can be accepted).

In the transverse direction, expansion joints should be provided where the roof construction includes horizontal members, but may be omitted where flexure of pitched rafters permits horizontal movement, though the associated thrust should be accounted for in the analysis.

Expansion joints should pass through the whole structure above ground level without offsets so as to divide the structure into individual sections. These sections should be designed to be structurally independent without relying on stability of adjacent sections.

To prevent unsightly damage and rain penetration, the joint should be designed and detailed to be properly incorporated in the finishes and external cladding.

7.7.3 Steel frames - commercial buildings

Expansion joints should be considered where the width or length of the building exceeds 100 m in the case of simple construction or 50 m for continuous construction⁽²⁾.

They should also be considered in buildings of lesser overall dimensions, where there are significant changes in shape on plan or in the overall height or in the floor levels.

In simple construction, vertical bracing systems must be provided for each portion when the building is split by expansion joints. These should preferably be located midway across the relevant portion.

The effects of differential horizontal displacements causing non-verticality of columns remote from bracing systems should be considered and the resulting forces in connected horizontal members should be catered for. If these are excessive, closer joint spacing may be preferable.

In continuous construction the steel frame is subjected to forces due to restraint of the thermal expansion of the floor slabs. The coefficient of thermal expansion of reinforced concrete can be assumed to be 10×10^{-6} per °C. A value of the modular ratio for concrete a_e of 7 for normal weight concrete or 11 for lightweight aggregate structural concrete (see *BS 5950: Part 3: Section 3.1*⁽¹⁾) is appropriate for thermal effects. A reduced temperature variation of $\pm 10^\circ\text{C}$ is adequate during normal use, but should be combined with imposed load effects using $Y_f = 1.6$ for the imposed loads in this case, rather than 1.2.

Where the provision of expansion joints is impractical or uneconomic (such as in the case of a tall multi-storey building) the resulting forces, including those due to expansion of the floor slabs, need to be accounted for. However, in a tall building, it is usually only the lower storeys that are significantly affected.

In the case of flat roofs where significant solar heating of the structure supporting the roof is possible, additional expansion joints should be considered in the top storey. Where they are needed, simple construction should be considered for the top storey, even if the lower storeys are of continuous construction. If this is not convenient, other possibilities are either to introduce nominally pin-jointed simple connections between the columns and the roof beams, even if the beams are continuous, or else to use nominal pin joints in the columns at top floor level.

Expansion joints should pass through the whole structure above ground level without offsets, so as to divide the structure into individual sections. These sections should be designed to be structurally independent without relying on stability of adjacent sections.

Expansion joints should be at least 22 mm wide, or larger where necessary. The expansion and contraction characteristics of the joint filler material is usually such that only movements of $\pm 30\%$ of the overall joint width can be accommodated.

To prevent unsightly damage and rain penetration, the joint should be designed and detailed to be properly incorporated in the finishes and external cladding.

7.7.4 Roof sheeting

Continuous lengths of steel roof sheeting of up to 20 m, measured down the slope, can be used without special provisions. However, for longer lengths it is advisable to make provision for expansion of the sheeting relative to the supporting frame. This can be done either by allowing for minor ovaling of the holes in the sheeting by using special enlarged neoprene washers, or by providing more flexible purlin-to-rafter connections, or else by making use of "standing seam" type roof sheeting. However when standing seam sheeting is used it is necessary to ensure that adequate lateral restraint is given to the purlins by other means.

7.7.5 Brick or block walls

Expansion joints must be introduced into all brick or block walls, whether internal or external, at the spacings recommended in Clause 20 of *BS 5628: Part 3*⁽¹⁾. These vary from 6 m to 15 m according to the type of brick or block.

7.8 Summary

A summary of the recommendation outlined in Section 7.7 is given in Table 7.1.

Table 7.1*Maximum spacing of expansion joints*

Steel frames - industrial buildings	generally	150 m [1]
	buildings subject to high internal temperatures due to plant	125 m [1]
Steel frames - commercial buildings	simple construction	100 m [1]
	continuous construction	50 m [2]
Roof sheeting	down the slope	20m [3]
	along the slope	no limit
Brick or block walls	clay bricks	15 m [4]
	calcium silicate bricks	9 m [4]
	concrete masonry	6 m [4]

Notes:

[1] Where the stress due to constraint of thermal expansion can be catered for by the members, no limit is necessary in simple construction.

[2] Larger spacings are possible where the stresses due to constraint of thermal expansion can be catered for by the members.

[3] Longer lengths are possible where provision for expansion is made.

[4] For more detail see Clause 20 and Appendix A of BS5628: Part3, see Reference (1).

7.9 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)
2. BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION
Multi-storey steel structures: A study on performance criteria
Publication No 13/84
BCSA, London, 1984
3. LAWSON, R.M. and ALEXANDER, S.J.
Design for movement in buildings
CIRIA Technical Note 107
CIRIA, London, 1981
4. BRICK DEVELOPMENT ASSOCIATION/BRITISH STEEL
Brick cladding to steel framed buildings
Brick Development Association and British Steel Corporation Joint Publication, London,
September 1986
5. AMERICAN INSTITUTE OF STEEL CONSTRUCTION
Engineering for steel construction: A source book on connections, Chapter 7, page 7-8
AISC, Chicago, 1984
6. THE INSTITUTION OF STRUCTURAL ENGINEERS & THE INSTITUTION OF
CIVIL ENGINEERS
Manual for the design of steelwork building structures
The Institution of Structural Engineers, London, 1989
7. FISHER, J.M. and WEST, M.A.
Serviceability design considerations for low-rise buildings
Steel Design Guide Series No 3
American Institute of Steel Construction, Chicago, 1990

8. DEFLECTION LIMITS FOR PITCHED ROOF PORTAL FRAMES

8.1 British Standard recommendations:

BS 5950: Part 1: 1990⁽¹⁾ recommends in Clause 2.5.1 that:

"The deflection under serviceability loads of a building or part should not impair the strength or efficiency of the structure or its components or cause damage to the finishings.

When checking for deflections the most adverse realistic combination and arrangement of serviceability loads should be assumed, and the structure may be assumed to be elastic.

Table 5 gives recommended limitations for certain structural members. Circumstances may arise where greater or lesser values would be more appropriate. Other members may also need a deflection limitation to be established, eg. sway bracing.

Generally the serviceability loads may be taken as the unfactored imposed loads. When considering dead load plus imposed load plus wind load only 80% of the imposed load and wind load need be considered. In the case of crane surge and wind, only the greater effect of either need be considered in any load combination."

The first paragraph gives the basic criteria, applicable to all structures. Generally, more specific criteria are then given in Table 5.

However, Table 5 specifically excludes portal frames. This is due to the fact that the deflections of portal frames have no direct significance for the serviceability of the portal frame itself, whereas their implications for the serviceability of the cladding depend on the type of cladding and other constructional details outside the scope of the code.

Guidance has therefore been included in this publication to assist designers in providing suitably serviceable steel portal frames to satisfy the basic criteria given in paragraph one of Clause 2.5.1.

It should be noted that portal frames which give large deflections may also have problems with frame stability at the ultimate limit state, but this is covered separately in the code.

8.2 Types of cladding

8.2.1 Side cladding

A distinction must be drawn, first of all, between buildings with their sides clad with sheeting and those with walls comprising brick, block or stone masonry or precast concrete panels. It is to be recognised of course that various combinations of cladding are also possible.

For sheeted buildings it is also necessary to distinguish between:

- steel (or other metal) sheeting
- fibre reinforced cladding panels
- curtain walling
- other forms of glazing.

and for buildings with masonry cladding between:

- . masonry which is supported against wind loads by the steelwork
- . free-standing masonry
- . precast concrete units.

and again for supported masonry, between walls with or without damp-proof courses made of compressible material.

8.2.2 Roof cladding

The type of roof cladding is also significant and a distinction needs to be made between:

- . corrugated or profiled sheeting
- . felted metal decking or other felted construction
- . tiled roofs
- . concrete roof slabs.

8.3 Deflections of portal frames

8.3.1 Types of deflection

Under gravity loads, the principal deflections of a pitched roof portal frame are:

- outward horizontal spread of the eaves
- downward vertical movement of the apex.

Under side loads due to wind the frame will sway so that both eaves deflect horizontally in the same direction. Positive and negative wind pressure on the roof will also modify the vertical deflections due to gravity loads.

8.3.2 Loads to be considered

Depending on the circumstances, it may be necessary to consider:

- dead load
- imposed load
- all gravity loads (i.e. dead & imposed)
- wind load
- wind load plus dead load
- 80% of (wind load plus imposed load)
- 80% of (wind plus imposed) plus 100% of dead load.

Only the imposed load and the wind load are included in the serviceability loads. The dead load need normally only be considered where its effects are not already compensated for by the initial precamber of the frame.

8.3.3 Effects of cladding

The cladding itself often has the effect of reducing the deflection of the frame. It may do this in three different ways as follows:

- composite action with the frame
- "stressed-skin" diaphragm action
- independent structural action.

As a result, deflection limits and deflection calculations are normally related to nominal deflections based on the behaviour of the bare steel frame, unless otherwise stated.

The actual deflections are generally less than the nominal values.

8.4 Behaviour of sheeted buildings

8.4.1 Composite action

Although composite action of the sheeting undoubtedly reduces deflections in many cases, the effect is very variable due to differences between types and profiles of sheeting, behaviour of laps, behaviour of fixings, flexibility of purlin cleats etc. Data is not widely available and in some cases the behaviour of the more recent systems with over-purlin lining, double skin sheeting etc is probably different

It is normal to ignore this effect in the calculations, but the recommended limits are based on experience and make some allowance for the difference between nominal and actual deflections.

8.4.2 Stressed-skin action

Designs taking account of stressed-skin diaphragm action in the strength and stability of the structure at the ultimate limit state, should also take advantage of this behaviour in the calculation of deflections at the serviceability limit state.

Where stressed skin action is not taken explicitly into account in the design, it will nevertheless be present in the behaviour of the structure. Neglecting it is apparently on the safe side, but there is an important exception to this, as follows.

Where significant stressed skin diaphragm action develops due to the geometry of the building, but the fixings of the sheeting are not designed to cope with the resulting forces, the fixings will be over-strained, including localised hole elongation and tearing of the sheeting. To keep this within acceptable limits at the serviceability limit state, differential deflections between adjacent frames have to be limited, otherwise in service the sheets may leak at their fixings.

8.4.3 Gable ends

Sheeted gable ends are generally so stiff, in their own plane, that their in-plane deflections can be neglected. The result of this is that it is generally the difference in deflections between the gable end and the next frame which is critical - at least for uniform spacing of frames. However this may be affected by the presence of bracing, see Figure 8.1.

This applies both to the horizontal deflection at the eaves and to the vertical deflection at the ridge.

It should be noted that where sheeted internal division walls are constructed like gable ends and not separated from the building envelope, the same relative deflection criteria apply.

8.5 Behaviour of buildings with external walls

8.5.1 Free-standing side walls

When the side walls are designed free-standing, to resist the wind loads acting upon them independently of the frame, the only requirement is to ensure that, allowing also for construction tolerances, the horizontal deflections of the eaves are not such as to close the gap between the frame and the wall.

The wall should either not contain a horizontal damp-proof course, or else have one composed of engineering bricks or other material which is capable of developing the necessary flexural resistance (see *BS 5628: Part 3*⁽¹⁾: Clause 18.4.1).

8.5.2 Side walls supported by steel frames

When the side walls are designed on the assumption that they will be supported horizontally by the steel frame when resisting wind loads, then they should be detailed such that they can deflect with the frame, generally by using a compressible damp-proof course at the base of the wall as a hinge.

The base hinge should also be taken into account when verifying the stability of the wall panels (see *BS 5628: Part 3*⁽¹⁾: Clauses 18.4.2 and 20.2.3).

8.5.3 Walls and frames sharing load

If a base hinge is not provided, but the side walls are nevertheless attached to the steel frame, their horizontal deflections will be equal and both the horizontal and the vertical loading will be shared between the frame and the walls according to their flexural stiffnesses.

In such cases the walls should be designed in accordance with *BS 5628*⁽¹⁾ at both the ultimate and the serviceability limit states, for all the loading to which they are subject

This procedure is only likely to be viable where either the steel frame is so rigid that it attracts virtually all the load, or the construction of the brick walls is of a cellular or diaphragm layout, capable of resisting relatively large horizontal forces. In both cases the design is outside the scope of these recommendations.

8.6 Analysis at the serviceability limit state

8.6.1 Serviceability loads

Although *BS 5950*⁽¹⁾ only defines a single level of serviceability loading, this is a simplification.

In the case of the deflection of a floor beam, leading to cracking of a plaster ceiling or other brittle finish, it is appropriate to consider the maximum value of the imposed load, or wind load, that is anticipated to occur within the design life of the building, even though its occurrence is rare.

For many other serviceability conditions it would be more logical to consider values of imposed and wind loads that occur more frequently, as is envisaged in *Eurocode 3*⁽²⁾. However for simplicity only the maximum values are considered in *BS 5950*⁽¹⁾, with the limiting values adjusted accordingly.

8.6.2 Base fixity

Base fixity is covered in Clause 5.1.2.4 of *BS 5950: Part 1*⁽¹⁾, which requires use of the same value of base stiffness "for all calculations". This clause is intended to apply to the ultimate limit state and the requirement relates to consistency between the assumptions made for elastic frame analysis and those applied when checking frame or member stability and designing connections.

When accurate values are not available, it permits the assumption of a base stiffness of 10% of the column stiffness for a nominal base, but not more than the column stiffness for a nominally rigid base.

It is a principle of limit state design that the verifications of the ultimate and serviceability limit states can be completely independent. At lower load levels, the base stiffness will generally be more than at ultimate, particularly for cases where it is as low as 10% at ultimate. Further, since *BS 5950*⁽¹⁾ was drafted, the requirements of the Health and Safety Executive in relation to erection, have changed the normal detailing of nominal base connections from 2 to 4 holding-down bolts.

Accordingly, it is recommended that a base stiffness of 20% of the column stiffness be adopted for nominally connected bases, in analysis at the serviceability limit state.

Similarly, for nominally rigid bases, it is recommended that full fixity be adopted in analysis at the serviceability limit state, even though Clause 5.1.2.4 requires the adoption of partial fixity at the ultimate limit state.

8.6.3 Plastic analysis

Plastic analysis is commonly used in the design of portal frames for the verification of the ultimate limit state.

Serviceability loading is less, typically 65-70% of ultimate, and the frame is assumed to remain elastic. Depending on the geometry, this is not necessarily the case under the rarely occurring maximum serviceability loads, but for many serviceability criteria the frequently occurring values are more relevant and the assumption is adequate.

However for such criteria as a portal frame hitting a free-standing masonry wall, or any other criterion related to damage to brittle components or finishes, any deformations due to the formation of plastic hinges under serviceability loading should also be allowed for.

Such allowance should also be made where the elastic moments under serviceability loading exceed $1.5 M_p$

8.7 Building with overhead crane gantries

Where a portal frame supports gantry girders for overhead travelling cranes, not only will deflections be produced in the frames by crane loads, but deflections of the crane girders will be produced by wind and gravity loads on the building envelope.

Although vertical deflections may also be produced, the most significant parameter is variation in the horizontal dimension across the crane track from one rail to the other.

Standard overhead cranes can only tolerate a limited variation in this gauge dimension, whereas with crane brackets added to a otherwise standard pitched roof portal frame the relative horizontal deflections of the two crane girders will be relatively large.

It is therefore a question of deciding, on the merits of each individual case, whether it will be more cost-effective to have a special crane with greater gauge dimension tolerances, or whether to design a special suffer form of frame. Horizontal ties at eaves level help reduce spread of the crane track. Base fixity is also beneficial, especially with stepped crane columns. The use of stepped columns, rather than cantilever brackets, to provide supports for the crane girders, will also reduce deflections, provided that the upper part of the column is not too slender.

Crane manufacturers are often very reluctant to provide crane gantries with more than a very limited play in the gauge and it is important to ascertain what is available at the earliest possible stage.

In any case, it is advisable to use relatively rigid frames where cranes are carried, otherwise significant horizontal crane forces may be transferred to the cladding. Unless the cladding fixings have been designed accordingly, damage to cladding or fixings may result

It is also advisable to limit the differential lateral movements between the columns in adjacent frames, measured at crane rail level.

8.8 Ponding

To ensure the correct discharge of rainwater from a nominally flat or low-pitched roof, the design of all roofs with a slope of less than 1 in 20 should be checked to ensure that rainwater cannot collect in pools.

In this check, due allowance should be made for construction tolerances, for deflections of roofing materials, deflections of structural components and the effects of precamber and for possible settlement of foundations.

Precambering may reduce the possibility of ponding, but only if the rainwater outlets are appropriately located.

Where the roof slope is 1 in 33 or less, additional checks should be made to ensure that collapse cannot occur due to the weight of water collected in pools formed by the deflections of structural members or roofing materials, or due to the weight of water retained by snow.

Attention should be paid to deflections of members or roofing materials spanning at right angles to the slope as well as those spanning parallel to the roof slope.

8.9 Visual appearance

Deflection limits based on visual appearance are highly subjective. As noted in Section 8.6 the values under frequently occurring loads are actually relevant, but equivalent values under maximum serviceability loads are used.

The main criterion concerned is verticality of columns, expressed as a limit on lateral deflection at the eaves. However for frames supporting false ceilings, limits on vertical deflection at the ridge are also relevant

8.10 Indicative values

Values for limiting deflections appropriate for pitched roof portal frames without cranes, or other significant loads supported from the frame, are given in Table 8.1 for a range of the more common side and roof cladding materials. In this table, side cladding comprising brickwork, hollow concrete blockwork or precast concrete units is assumed to be seated on a damp-proof layer and supported against wind by the steel frame.

In using this table for horizontal deflections, the entries for both the side cladding and the roof cladding should be inspected and the more onerous adopted. For the vertical deflection at the ridge two criteria are given; both should be observed.

The values for differential deflection relative to adjacent frames apply particularly to the frame nearest each gable end of a building and also to the frames adjacent to any internal gables or division walls attached to the external envelope. Note however that differential deflections may be reduced by roof bracing, see Figure 8.1.

The symbols used in Table 8.1 are defined in Figure 8.1

Table 8.1 Indicative deflection limits for pitched roof steel portal frames

a. Horizontal deflection at eaves level - due to unfactored wind load or unfactored imposed roof load or 80% of unfactored (wind & imposed) loads		
Type of cladding	Absolute deflection	Differential deflection relative to adjacent frame
Side cladding:		
Profiled metal sheeting	$\leq \frac{h}{100}$	-
Fibre reinforced sheeting	$\leq \frac{h}{150}$	-
Brickwork	$\leq \frac{h}{300}$	$\leq \frac{\sqrt{h^2 + b^2}}{660}$
Hollow concrete blockwork	$\leq \frac{h}{200}$	$\leq \frac{\sqrt{h^2 + b^2}}{500}$
Precast concrete units	$\leq \frac{h}{200}$	$\leq \frac{\sqrt{h^2 + b^2}}{330}$
Roof cladding:		
Profiled metal sheeting	-	$\leq \frac{b}{200}$
Fibre reinforced sheeting	-	$\leq \frac{b}{250}$
Felted metal decking	-	$\leq \frac{b}{400}$
b. Vertical deflection at ridge (for rafter slopes $\geq 3^\circ$) - due to unfactored imposed roof load or unfactored wind load or 80% of unfactored (imposed & wind) loads		
Type of roof cladding	Differential deflection relative to adjacent frame	
Profiled metal sheeting	$\leq \frac{b}{100}$	and $\leq \frac{\sqrt{b^2 + s^2}}{125}$
Fibre reinforced sheeting	$\leq \frac{b}{100}$	and $\leq \frac{\sqrt{b^2 + s^2}}{165}$
Felted metal decking:		
- supported on purlins	$\leq \frac{b}{100}$	and $\leq \frac{\sqrt{b^2 + s^2}}{250}$
- supported on rafter	$\leq \frac{b}{200}$	and $\leq \frac{\sqrt{b^2 + s^2}}{250}$



Steelwork Design Guide to BS 5950

Volume 4 : Essential Data for Designers

SPECIAL NOTE CONCERNING CHAPTER 8 : TABLE 8.1

"INDICATIVE DEFLECTION LIMITS FOR PITCHED ROOF PORTAL FRAMES"

The indicative values given in Table 8.1 of Chapter 8 "Deflection limits for pitched roof portal frames" also appeared in "Steel Construction Today" Volume 5, No 4, July 1991, as item AD 090 of the "Advisory Desk" feature.

Early feedback on this table has suggested that some of the values given may be more stringent than necessary. Pending the outcome of a wider consultation on this subject, the indicative numerical values given in this table should be regarded as only provisional.

Readers wishing to submit evidence of satisfactory or unsatisfactory experience on this subject, or to make constructive suggestions on the further development of Chapter 8, should please write to "Advisory Desk" at the SCI.

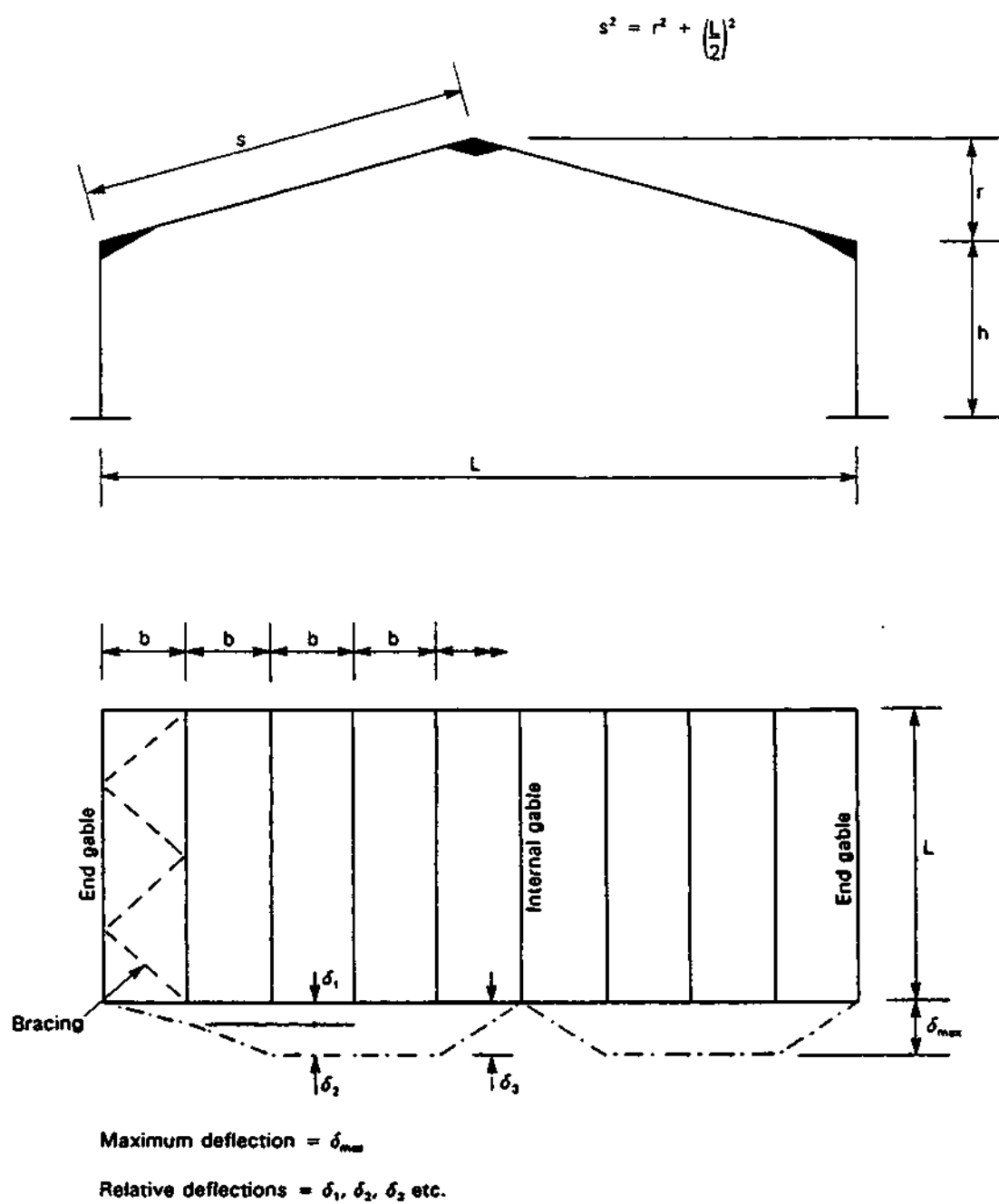


Figure8.1 Portal frame - definitions

8.11 References

1. **BRITISH STANDARDS INSTITUTION**
(see Section 19)
2. **COMMISSION OF THE EUROPEAN COMMUNITIES**
Eurocode No. 3: Design of steel structures
Part 1: General rules and rules for buildings (Final draft)

Further reading

3. **DAVIES J. M. and BRYAN E.R.**
Manual on stressed skin diaphragm design
Granada, 1982
4. **BRICK DEVELOPMENT ASSOCIATION/BRITISH STEEL**
Brick cladding to steel framed buildings
Brick Development Association and British Steel Corporation Joint Publication,
London, September 1986
5. **WOOLCOCK S.T. and KITIPORNCHAIS.**
Survey of deflection limits for portal frames in Australia
Journal of Constructional Steel Research Vol 7, No 6, Australia, 1987
6. **FISHER, J.M and WEST, M.A.**
Serviceability design considerations for low-rise buildings
Steel Design Guide Series No 3
American Institute of Steel Construction, Chicago, 1990

9. ELECTRIC OVERHEAD TRAVELLING CRANES AND DESIGN OF GANTRY GIRDERS

9.1 Crane classification

BS 466⁽¹⁾ and *BS 2573*⁽¹⁾ are the standards which apply to the design of overhead travelling cranes. The structural aspects of overhead crane design is covered by *BS 2573:Part1*⁽¹⁾

The above standards place overhead travelling cranes into four loading classes, Q1, Q2, Q3 and Q4 according to the frequency with which the safe working load is lifted. Q4 is the heaviest duty. Cranes are further categorized according to their degree of utilization into one of nine classes U1 to U9 inclusive. Cranes in class U9 would be in continuous use with a high frequency of lifting operations.

9.2 Design of crane gantry girders

Figure 9.1 and Tables 9.1,9.2 and 9.3 give dimensions and static wheel loads of typical class Q2 cranes and these are suitable for preliminary design. For the final design the actual dimensions and static wheel loads must be obtained from the manufacturer of the crane to be installed.

Inadequate design and installation of gantry girders and rail track could effect the smooth running and safe operation of the crane. The attention of designers and erectors is drawn to Appendix F of *BS 466*⁽¹⁾ which gives a comprehensive set of geometrical and dimensional tolerances to which the rail track should be constructed.

9.2.1 Crane loading effects

(i) Ultimate limit states

The relevant Yf factors for the limit state of strength and stability which apply to the design of crane gantry girders are given in Table 9.4. It should be noted for the vertical loads that the Yf factors are applied to the dynamic crane loads, i.e. the static vertical wheel loads increased by the appropriate allowance for dynamic loads.

(ii) Dynamic and impact effects

For canes of loading class Q3 and Q4 as defined in *BS 2573: Part 1*⁽¹⁾ the dynamic effect values for vertical and horizontal surge loading should be established in consultation with the crane manufacturers.

For other cranes the following allowances should be taken to account for all forces set up by vibration, shock from slipping of slings, kinetic action of acceleration and retardation and impact of wheel loads.

(a) For vertical loads the maximum static wheel loads should be increased by the following percentages:

Electric overhead cranes	25%
Hand operated cranes	10%

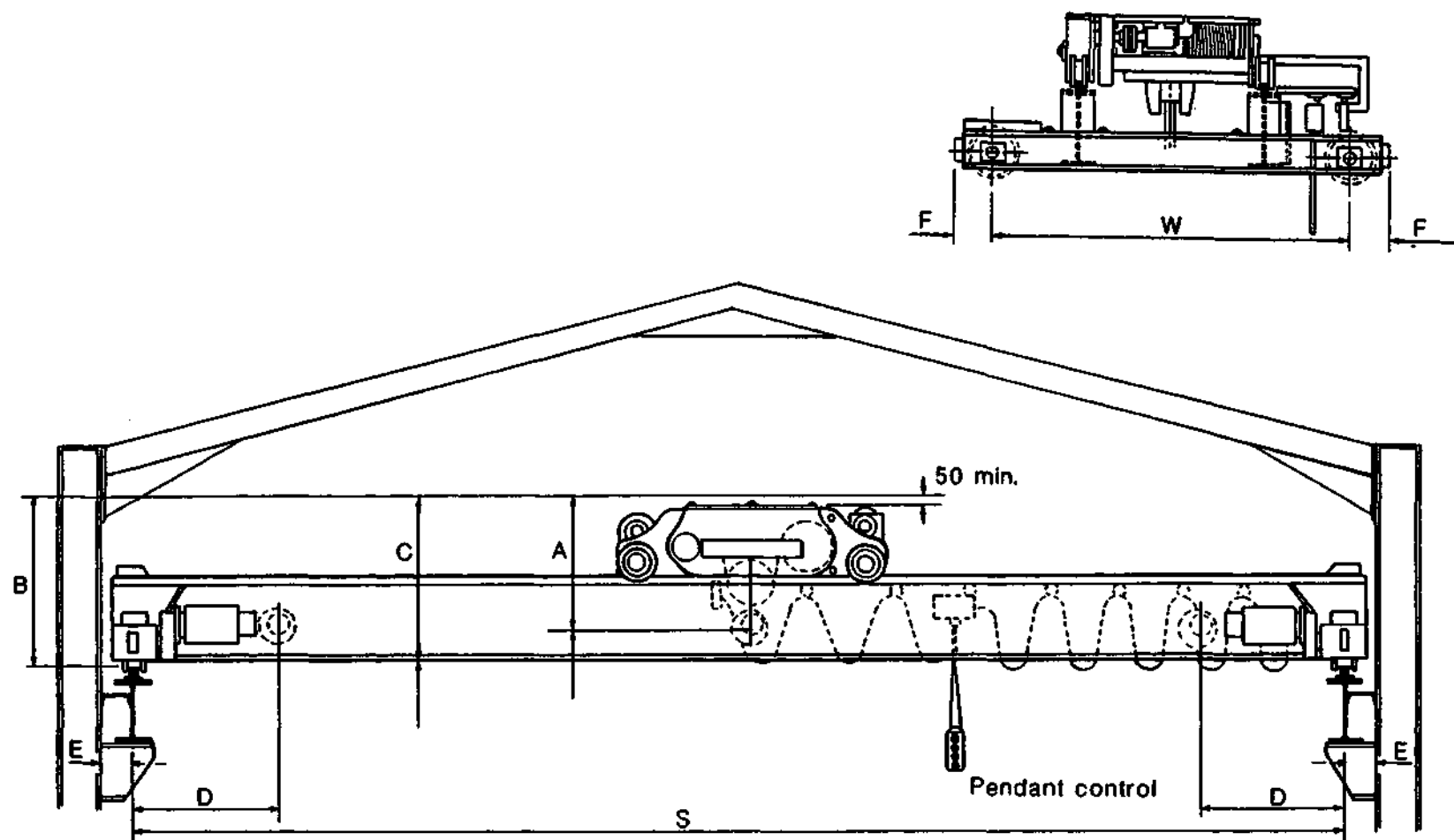


Figure 9.1 Double girder pendant controlled cranes for loading class 02 to BS 446 and BS 2573: Part 1⁽¹⁾

Table 9.1 Double girder pendant controlled cranes for loading class Q2 to BS 466 and BS 2573: Part 1⁽¹⁾

(See Figure 9.1)

Capacity tonnes	Span S metres	A mm	B mm	C mm	D mm	E mm	F mm	H mm	W mm	Crab wt. tonnes	Crane wt. tonnes	Wheel load tonnes
2	8	590	920	895					2500		2.52	1.69
	10	590	970	945					2500		3.41	1.94
	12	590	1040	1015					2500		4.20	2.15
	14	590	1120	1095					3100		5.56	2.49
	16	590	1120	1095					3700		6.87	2.83
	18	590	1120	1095	660	200	260	7900	3700	0.55	7.50	2.98
	20	620	1380	1355					3700		8.91	3.33
	22	620	1380	1355					3700		10.43	3.71
	24	620	1380	1355					4300		11.23	3.91
	26	620	1545	1520					4300		12.95	4.34
3	8	640	970	945					2500		2.96	2.27
	10	640	1040	1015					2500		3.77	2.50
	12	640	1120	1095					2500		4.66	2.73
	14	640	1120	1095					3100		6.22	3.14
	16	640	1120	1095					3700		6.86	3.32
	18	640	1135	1110	660	200	260	7300	3700	0.55	9.16	3.86
	20	670	1380	1355					3700		8.91	3.82
	22	670	1380	1355					3700		10.43	4.20
	24	670	1380	1355					4300		11.23	4.40
	26	670	1545	1520					4300		12.95	4.83
5	8	700	1070	1045					2500		3.68	3.44
	10	700	1140	1115					2500		4.65	3.73
	12	700	1140	1115					2500		5.64	4.01
	14	700	1140	1115					3100		6.62	4.28
	16	700	1170	1145					3700		8.85	4.80
	18	700	1170	1145	760	200	260	9700	3700	0.95	9.69	5.03
	20	730	1420	1395					3700		9.29	4.93
	22	730	1420	1395					3700		10.81	5.32
	24	730	1420	1395					4300		11.61	5.55
	26	730	1585	1560					4300		13.33	5.98
7½	8	870	1250	1225			260		2500		4.88	4.92
	10	870	1250	1225			260		2500		5.84	5.27
	12	870	1250	1225			260		2500		6.45	5.49
	14	870	1280	1255			260		3100		8.77	6.07
	16	870	1280	1255			260		3700		9.57	6.30
	18	870	1350	1325	970	200	260	11250	3700	1.70	11.21	6.74
	20	900	1510	1485			260		3700		10.01	6.44
	22	900	1510	1485			260		3700		11.53	6.82
	24	900	1675	1650			260		4300		13.17	7.28
	26	900	1850	1800			430		4300		14.73	7.67
10	8	920	1250	1225					2500		5.18	6.19
	10	920	1250	1225					2500		5.84	6.47
	12	920	1278	1255					2500		7.98	6.98
	14	920	1280	1255					3100		8.82	7.26
	16	920	1375	1325					3700		10.68	7.77
	18	920	1375	1325	970	200	430	9700	3700	1.70	11.60	8.04
	20	950	1535	1485					3700		11.11	7.91
	22	950	1715	1665					3700		12.67	8.30
	24	950	1715	1665					4300		13.65	8.61
	26	950	1865	1815					4300		15.17	8.99

Continued.....

Table 9.1(continued)

(See Figure 9.1)

Capacity tonnes	Span S metres	A mm	B mm	C mm	D mm	E mm	F mm	H mm	W mm	Crab wt. tonnes	Crane wt. tonnes	Wheel load tonnes
15	8	1415	1420	1370	970	200	430	7300	3700	2.40	6.30	8.72
	10		1420	1370		200	430		3700		6.93	8.96
	12		1575	1525		200	430		3700		8.17	9.44
	14		1575	1525		200	430		3700		9.26	9.81
	16		1575	1525		200	430		3700		10.58	10.23
	18		1740	1690		200	430		3700		12.02	10.59
	20		1740	1690		200	430		3700		12.86	10.89
	22		1890	1840		200	430		3700		14.34	11.26
	24		1890	1780		220	500		4300		20.59	13.15
	26		1890	1780		220	500		4300		21.76	13.48
20	8	1440	1757	1525	970	200	430	6700	3700	2.40	7.12	11.16
	10		1575	1525		200	430		3700		7.70	11.41
	12		1575	1525		200	430		3700		9.02	11.96
	14		1740	1690		200	430		3700		10.30	12.40
	16		1740	1690		200	430		3700		11.14	12.72
	18		1890	1840		200	430		3700		12.50	13.06
	20		1890	1780		200	500		3700		18.32	14.90
	22		1890	1780		220	500		3700		19.48	15.24
	24		2035	1925		220	520		4300		22.07	15.93
	26		2035	1925		220	520		4300		23.35	16.29
25	8	1650	1650	1540	1150	220	500	8000	4300	4.00	11.40	14.90
	10		1650	1540		220	500		4300		11.97	15.04
	12		1650	1540		220	500		4300		13.14	15.62
	14		1800	1690		220	500		4300		14.36	16.13
	16		1800	1690		220	500		4300		15.22	16.49
	18		1950	1840		220	500		4300		18.83	17.52
	20		1950	1840		220	500		4300		20.03	17.92
	22		2100	1990		220	520		4900		22.54	18.64
	24		2100	1990		235	600		4900		24.53	19.20
	26		2125	2035		235	600		4900		27.78	20.08
32	8	1650	1650	1540	1150	220	500	8000	4300	4.00	11.00	17.65
	10		1650	1540		220	500		4300		12.33	18.24
	12		1800	1690		220	500		4300		13.49	18.87
	14		1800	1690		220	500		4300		14.14	19.37
	16		1950	1840		235	600		4900		18.45	20.57
	18		1950	1840		235	600		4900		19.61	21.00
	20		2100	1990		235	600		4900		21.99	21.71
	22		2100	1990		235	600		4900		23.26	22.14
	24		2210	2035		250	620		4900		26.69	23.07
	26		2210	2035		250	620		4900		28.11	23.51

(1) Dimension B is based upon construction where end carriages are built into bridge members for maximum rigidity and compact headroom dimension. Alternative end constructions can be provided to either increase or reduce dimension B to suit existing building conditions.

(2) The height of lift, H or hook path dimension, is based upon a standard crab unit. Alternative crabs are available in all capacities for extended heights of lift.

(3) Crane weight includes the weight of the crab.

(4) Weights of crane and crab are with unloaded hooks.

(5) Wheel loads are for static conditions with maximum working load and minimum crab approach.

(6) Above information is approximate only and is intended for guidance. Exact information should be obtained from manufacturers' publication.

Table 9.2 Single hoist cranes for handling class Q2 to BS466 and BS2573: Part 1⁽¹⁾
(See Figure 9.2)

Capacity tonnes	Span A m	B mm	C m	D m	E m	F m	G m	H m	K m	L m	Crab wt. tonnes	Crane wt. tonnes	Wheel load tonnes	Wheels in end carriage
5	10	240	1.6	0.9	0.8	16	0	0.8	3.0	4.1	1.76	5.0	3.9	2
	12.5	240	1.6					1.0	3.7	4.7		6.5	4.7	
	16	250	1.6					1.1	3.8	4.9		8.5	5.7	
	20	250	1.7					1.3	4.1	5.2		11.0	6.7	
	25	270	1.7					1.4	4.6	5.6		14.0	7.8	
	32	270	1.7					1.4	5.1	6.1		17.5	9.6	
8	10	240	1.7	0.9	0.8	16	0.27	0.8	3.0	4.1	2.6	6.9	5.6	2
	12.5	240	1.7					1.0	3.7	4.7		8.8	6.3	
	16	250	1.7					1.1	3.7	4.9		11.4	7.4	
	20	250	1.8					1.3	4.1	5.2		15.0	8.6	
	25	270	1.8					1.4	4.6	5.6		19.4	9.8	
	32	270	1.8					1.5	5.1	6.1		24.5	11.5	
10	10	250	1.8	1.0	0.8	16	0.3	0.8	3.0	4.1	2.8	7.5	6.8	2
	12.5	250	1.8					1.0	3.7	4.7		10.0	7.7	
	16	270	1.8					1.1	3.9	4.9		12.9	8.7	
	20	270	1.9					1.3	4.1	5.2		17.0	9.8	
	25	280	1.9					1.4	4.6	5.6		21.7	11.5	
	32	280	1.9					1.5	5.1	6.1		27.5	12.7	
12.5	10	270	2.0	1.0	1.0	16	0.3	0.8	3.2	4.6	2.8	8.5	8.2	2
	12.5	270	2.0					1.0	3.8	4.9		10.7	9.3	
	16	280	2.0					1.1	4.0	5.0		13.8	10.3	
	20	280	2.1					1.3	4.1	5.2		18.0	11.5	
	25	290	2.1					1.4	4.6	5.8		22.8	12.7	
	32	290	2.1					1.5	5.1	6.2		28.8	14.5	
16	10	270	2.0	1.1	1.0	16	0.4	0.8	3.4	4.6	3.0	9.4	9.8	2
	12.5	270	2.0					1.0	3.8	4.9		11.9	11.0	
	16	280	2.0					1.1	4.0	5.0		15.0	11.8	
	20	280	2.1					1.3	4.1	5.2		19.3	13.0	
	25	290	2.1					1.4	4.6	5.8		24.0	14.5	
	32	290	2.1					1.5	5.1	6.2		30.5	16.0	
20	10	280	2.1	1.2	1.1	16	0.5	0.8	3.4	4.6	4.0	11.0	12.0	2
	12.5	280	2.1					1.0	3.8	4.9		13.6	13.3	
	16	290	2.1					1.1	4.0	5.0		16.6	14.5	
	20	290	2.2					1.3	4.1	5.2		21.3	16.0	
	25	300	2.2					1.4	4.6	5.8		26.3	14.5	
	32	300	2.2					1.5	5.1	6.2		32.5	19.5	
25	10	290	2.2	1.4	1.1	16	0.6	0.8	3.4	3.4	4.5	12.5	15.0	2
	12.5	290	2.2					1.0	3.8	3.8		15.0	16.0	
	16	300	2.2					1.1	4.0	4.0		18.5	17.5	
	20	300	2.2					1.3	4.1	4.1		23.0	19.0	
	25	300	2.3					1.4	4.6	4.6		28.0	20.3	
	32	300	2.3					1.6	5.1	6.2		34.0	22.0	

(1) Crane weight includes the weight of the crab.
 (2) Weights of crane and crab are with unloaded hooks.
 (3) Wheel loads are for static conditions with maximum working bad and minimum crab approach.
 (4) Above information is approximate only and is intended for guidance. Exact information should be obtained from manufacturers' publication.

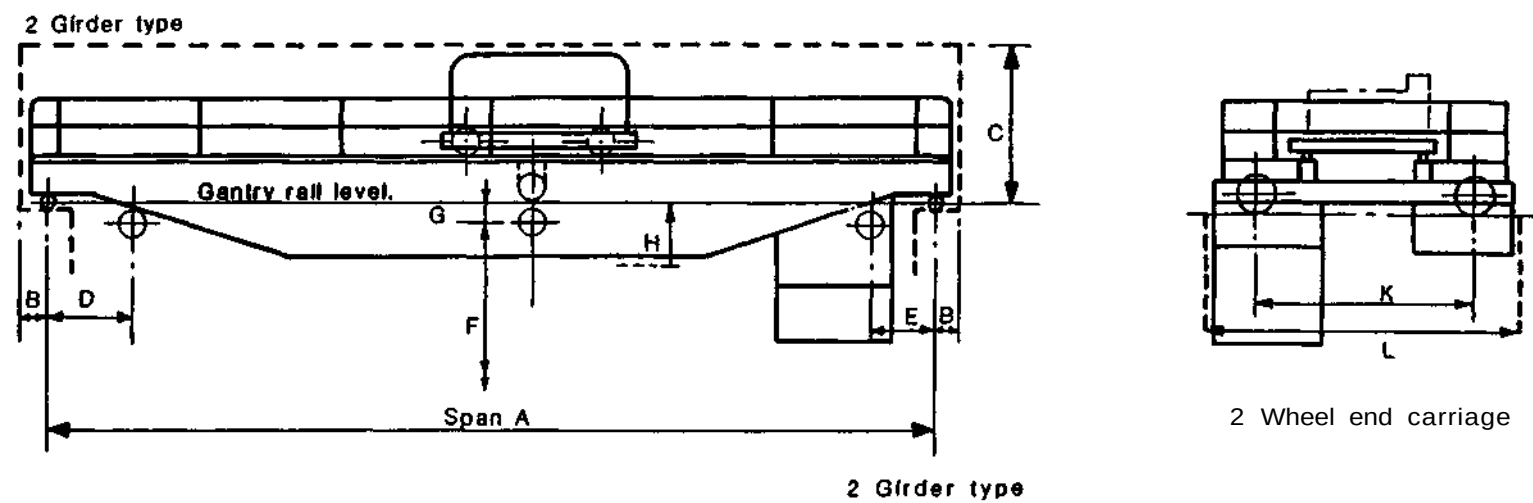


Figure 9.2 Single hoist cranes for loading class Q2 to BS 466 and BS 2573: Part 1⁽¹⁾

Table 9.3 Double hoist cranes for loading class Q2 to BS 466 and BS 2573: Part 1⁽¹⁾

(See Figure 9.3)

Capacity tonnes	Span A m	B mm	C m	D m	E m	F m	G m	H m	K m	L m	M m	Crab wt. tonnes	Crane wt. tonnes	Wheel load tonnes	Wheels in end carriage
20/5	10	280	2.1	0.2	1.7	16	0.5	0.8	3.5	4.6	0.8	8.0	12.5	13.0	2
	12.5	280	2.1					1.0	3.8	4.9			16.0	14.0	
	16	290	2.1					1.1	4.0	5.0			17.5	15.5	
	20	290	2.2					1.3	4.1	5.2			23.0	17.0	
	25	300	2.2					1.4	4.6	5.8			28.0	18.5	
	32	300	2.2					1.6	5.1	6.2			36.0	20.0	
25/5	10	300	2.3	1.4	1.8	16	0.5	0.8	4.0	5.0	0.9	12	15.0	20.0	2
	12.5	300	2.3					1.0	4.2	5.2			18.0	22.0	
	16	300	2.4					1.1	4.3	5.3			22.0	23.5	
	20	300	2.4					1.3	4.4	5.5			26.5	25.0	
	25	300	2.4					1.4	4.6	5.8			32.5	27.0	
	32	300	2.4					1.6	5.1	6.2			41.0	30.0	
32/5	10	320	2.5	1.4	1.9	16	0.5	0.8	4.0	5.0	1.0	14	17.0	24.0	2
	12.5	320	2.5					1.0	4.2	5.2			20.0	25.0	
	16	320	2.5					1.1	4.3	5.3			24.0	27.0	
	20	330	2.6					1.3	4.4	5.5			28.5	28.5	
	25	330	2.6					1.4	4.6	5.8			35.0	30.5	
	32	330	2.6					1.6	5.1	6.4			43.0	33.0	
40/10	10	320	2.5	1.4	1.9	16	0.6	0.8	4.2	5.3	1.1	15	18.5	24.0	2
	12.5	320	2.5					1.0	4.4	5.5			22.0	26.0	
	16	320	2.5					1.1	4.5	5.6			26.0	27.8	
	20	330	2.6					1.3	4.7	5.7			30.5	30.0	
	25	330	2.6					1.4	4.8	6.0			37.0	32.0	
	32	330	2.6					1.6	5.1	6.4			45.0	34.5	
50/10	10	330	2.6	1.5	2.0	16	0.6	0.8	4.3	5.5	1.1	20	21.0	30.0	2
	12.5	330	2.6					1.0	4.6	5.8			35.0	32.0	
	16	330	2.6					1.1	4.7	5.9			30.0	34.2	
	20	340	2.7					1.3	4.9	6.1			35.0	37.0	
	25	340	2.7					1.4	5.0	6.2			41.0	40.0	
	32	340	2.7					1.6	5.2	6.4			50.0	43.0	
63/10	10	380	3.0	1.7	2.1	16	0.6	0.8	4.6	5.8	1.1	25	28.0	36.0	2
	12.5	380	3.0					1.0	4.7	5.9			33.0	38.0	2
	16	380	3.0					1.1	4.9	6.1			38.0	42.0	2
	20	380	3.0					1.3	5.0	6.2			44.0	45.0	2
	25	380	3.0					1.4	5.1	6.2			51.0	23.9	4
	32	380	3.0					1.6	5.2	6.4			60.0	26.0	4

(1) Crane weight includes the weight of the crab.

(2) Weights of crane and crab are with unloaded hooks.

(3) Wheel loads are for static conditions with maximum working load and minimum crab approach.

(4) Above information is approximate only and is intended for guidance. Exact information should be obtained from manufacturers' publication.

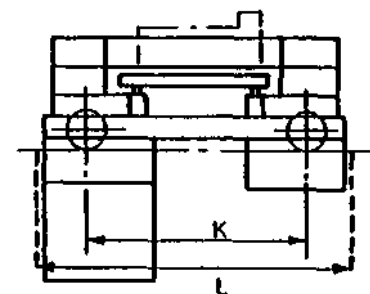
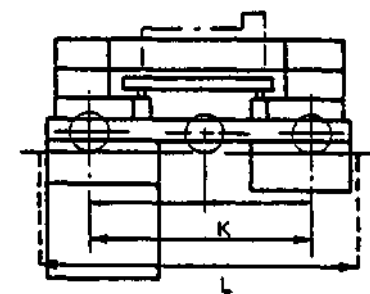
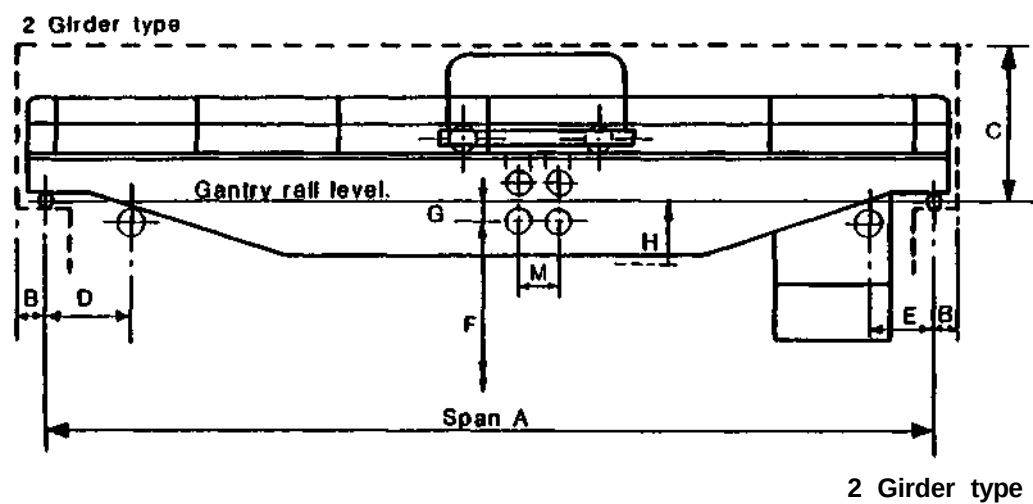


Figure 9.3 Double hoist cranes for loading class Q2 to BS 466 and BS 2573: Part 1⁽¹⁾

(b) The horizontal surge force acting transverse to the rails should be taken as a percentage of the combined weight of the crab and load lifted as follows:

For electric overhead cranes	10%
For hand operated cranes	5%

(c) Longitudinal horizontal forces acting along the rails should be taken as a percentage of the static wheel loads which can occur on the rails as follows:

For overhead cranes either electric or hand operated	5 %
--	-----

Table 94Crane loading effects

Loading	Factor-yf
Vertical load	16
Vertical load acting with horizontal loads (crabbing or surge)	14
Horizontal load	16
Horizontal load acting with vertical	14
*Crane load acting with wind load	12
*When considering wind or imposed load and crane loading acting together, the value of yf for dead load may be taken as 12	

(iii) Crabbing of trolley

Gantry girders intended to carry cranes of loading class Q1 and Q2 as defined in *BS 2573: Part 1*⁽¹⁾ need not be designed for the effects of crabbing action.

Gantry girders intended to carry cranes of class Q3 and Q4 as defined in *BS 2573: Part 1*⁽¹⁾ should be designed for the following couple due to the crabbing action of two wheels or bogies comprising two equal and opposite forces, F_R , acting transverse to the rail, one at each end of the wheelbase.

$$F_R = \frac{L_c W_w}{40 a_w} \text{ but } \geq \frac{W_w}{20}$$

where L_c is the span of the crane
 W_w is the factored maximum load on a wheel or bogie pivot
 a_w is the distance between the centres of the two end wheels or between the pivots of the bogies (where horizontal guide rails are used a_w is the wheelbase of the guide rails).

(iv) Wind loading on outdoor gantries

The wind loads on the gantry girders and supporting structures in the case of outdoor gantries are obtained from:

- (a) *BS 2573: Part 1*⁽¹⁾ for cranes in working condition.
- (b) *CP3: Chapter V: Part 2*⁽¹⁾ for cranes which are not working.

(v) Deflection limits for gantry girders

Vertical deflection due to unfactored static wheel loads	$\frac{\text{Span}}{600}$
---	---------------------------

Horizontal deflection due to unfactored crane surge (Calculated on the top flange assembly properties alone)	$\frac{\text{Span}}{500}$
---	---------------------------

(vi) Failure

Only those gantry girders and supporting structures of cranes of utilization classes U7 to U9 as defined in BS 2573⁽¹⁾ are required to be checked for fatigue by reference to the fatigue design clauses of that standard.

9.2.2 Design notes

The top flange of crane gantry girders are normally reinforced with channel sections or plates in order to resist the horizontal loads.

These gantry girders are usually designed on the basis that the vertical load effects are resisted by the combined section and the horizontal loads are resisted by the top flange assembly only; the horizontal loads being deemed to act at the centroidal axis of the top flange assembly. Further, notwithstanding that the horizontal loads are applied at rail level, the torsional effects on the gantry girder are ignored.

Gantry girders can be simply supported or continuous. The deflections of continuous girders are much reduced as compared with simply supported.

For many situations gantry girder will be fabricated using Universal Beams but for high capacity crane loadings welded plate girders may be required. When designing plate girders attention must be given to Clauses 4.11.4 and 4.11.6 of BS 5950: Part 1⁽¹⁾.

Additional provisions for gantry girders, Clause 4.11 of BS 5950: Part 1⁽¹⁾ requires that in addition to the fulfilling the general rules for beams, gantry girders should be capable of resisting the local compression under the wheel.

(i) Local compression under wheels

Local compression on the web may be obtained by distributing the crane wheel load over a length x_R where:

$$x_R = 2(H_R + T)$$

where $\frac{H_R}{T}$ is the rail height;
is the flange thickness.

Alternatively where the properties of the rail are known:

$$x_R = K_R \left[\frac{I_f + I_R}{t} \right]^{\frac{1}{3}}$$

where t is the web thickness
 I_f is the second moment of area of the flange about its horizontal centroidal axis

I_R is the second moment of the area of the crane rail about its horizontal centroidal axis
 K_R is a constant taken as:

- (a) when the crane rail is mounted directly on the beam flange $K_R = 3.25$
- (b) where a suitable resilient pad not less than 5 mm thick is interposed between the crane rail and the beam flange $K_R = 4.0$.

The stress obtained by dispersing the load over this length should not be greater than p_{yw} (the design strength of the web).

(ii) Lateral torsional buckling

In the case of lateral torsional buckling no account should be taken of the effect of moment gradient, i.e. n and m should be taken as 1.0 (see Clause 4.3 of *BS 5950: Part 1*⁽¹⁾).

(iii) Universal beam top flange reinforcement

It is recommended that only plates > 10 mm thick shall be used to act as top flange reinforcement for universal beam gantry girders. Plates < 10 mm thick tend to bend in the transverse direction on welding. For example plates 10 mm, 12 mm and 15 mm thick by 250 mm or 300 mm wide are suitable for UB serial sizes 457 x 152, 457 x 191, 533 x 210 and 610 x 229.

(iv) Gantry girder support structures

The gantry girder support structures and fixings must be designed taking into account that the horizontal forces defined in Sections 9.2.1 (ii) and (iv) above act at the level of the rails.

9.3 Design and detailing of crane rail track

The transverse horizontal loads defined in Sections 9.2.1 (ii) and (iv) above must be taken into account in considering the lateral rigidity of the rails and their fastenings.

The main functions of rail fixing bolts or clips are to prevent overturning and lateral displacement of the rail and by adequately holding down the rail to prevent the formation of a "bow wave" ahead of the crane wheel. Fixing systems should permit easy realignment and replacement of rails. However, the adjustment allowed should be limited (say 5 mm each way) so as to avoid large eccentric vertical loading on the girder.

Any further movement should be obtained by adjusting the girder on the column cap. The use of fixings that permit "longitudinal float" of the rail should cater for the relative movement between the rail and the top flange of a simply supported girder due to the shortening of the flange under load.

For this situation fully continuous rails have to be used. Continuous rails are obtained by using bolted fish plate splices with the rail ends closely butted or by site welding in the case of rails for heavy duty cranes. Site welding of crane rails is a highly specialized technique.

A major advantage of continuous rails is the avoidance of the discontinuities at the joints with the accompanying wheel flange and rail wear and loosening of fixings.

If the rails or simply supported girders are not fully continuous as described above then it is recommended that the rail lengths are the same as the girders and the joints coincide with the gantry girder joints.

It is again emphasized that the safe operation of the crane depends upon the rail track being designed for and erected to the comprehensive set of dimensional and geometrical tolerances given in Appendix F of BS466⁽¹⁾. There is a wide range of proprietary rail fixings available and the manufacturers literature should be consulted before finalizing design details.

Details of available crane rails are given in Section 16.

9.4 Gantry girder end stops

The end stops must be designed to withstand the impact of the crane travelling at full speed. Typical stops are shown in Figure 9.4.

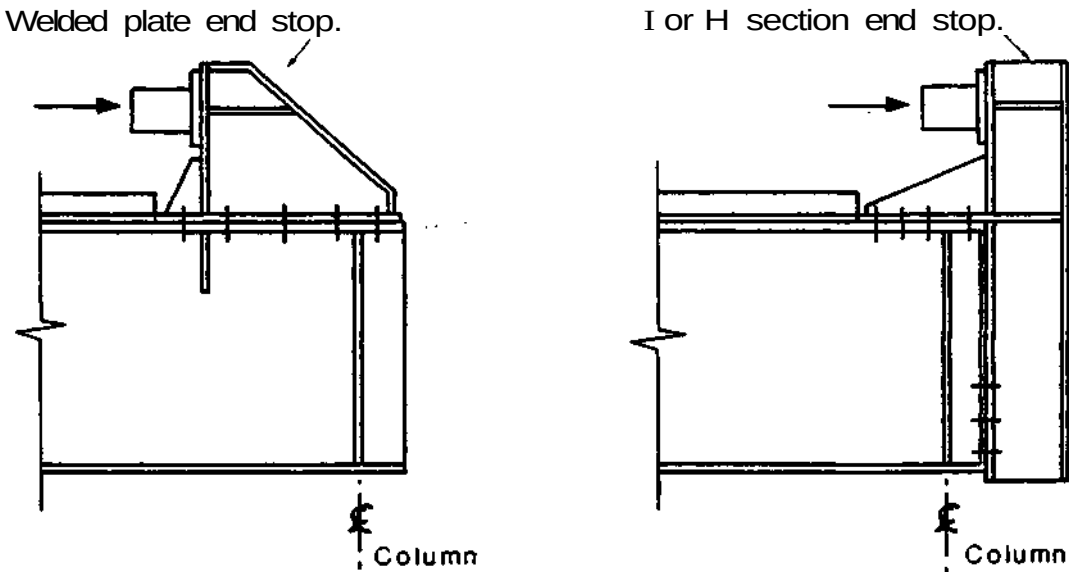


Figure 9.4 Gantry girder end stops

9.5 References

1. BRITISH STANDARD INSTITUTION
(see Section 19)

Acknowledgement

The information in Tables 9.1 to 9.3 was obtained from "The Sections Book" which is produced by British Steel General Steels - Sections in association with British Constructional Steelwork Association.

10. FASTENERS

Fasteners used in structural steelwork will conform to one of the following standards (see Section 19):

Bolts:

BS 4190:1967 ISO	Metric black hexagon bolts, screws and nuts
BS 4933 :1973 ISO	Metric black cup and countersunk head bolts and screws with hexagonal nuts
BS 3692 :1967 ISO	Metric precision hexagon bolts, screws and nuts
BS 4395 :	High strength friction grip bolts and associated nuts and washers
Part 1:1969	General grade
Part2:1969	High grade

Washers:

BS 4320:1968	Metal washers for general engineering purposes metric series (washers for HSFG bolts are included in <i>BS 4395⁽¹⁾</i>).
--------------	--

10.1 Mechanical properties and dimensions

Details of the mechanical properties, dimensions and mass for the range of bolts, both in size and strength grade, that are normally used in structural steelwork are given in the Tables 10.1 to 10.11. For details of bolts outside this range and for fuller information, the original British Standards should be consulted.

Note that the term "black" in the case of bolts does not refer to the colour but implies the comparative wider tolerances to which these bolts are normally manufactured.

10.2 Strength grade classification

The ISO (International Organisation of Standardisation) system of strength grading has been adapted in the above British Standards. In the ISO System the strength grade for bolts is given by two figures separated by a point. The first figure is one tenth of the minimum ultimate stress in kgf/mm² and the second figure is one tenth of the percentage of the ratio of minimum yield stress to minimum ultimate stress.

The single grade number for nuts indicates one tenth of the proof load stress as kgf/mm² and corresponds with the bolt ultimate stress to which it is matched e.g. an 8 grade nut is used with an 8.8 grade bolt. It is permissible to use a higher strength grade nut than the matching bolt number. Grade 10.9 bolts are suggested with grade 12 nuts since there is no grade 10 nut in the BS series.

To minimise the risk of thread stripping at high loads, BS 4395⁽¹⁾ high strength friction grip bolts are matched with nuts one class higher than the bolt.

Table 10.1 Mechanical properties and dimensions for grade 4.6 black bolts and nuts to BS 4190 and grade 8.8 bolts and nuts to BS 3692

ISO Metric coarse threads	M12	M16	M20	(M22)	M24	(M27)	M30	(M33)	M36
Pitch (mm)	1.74	2.00	2.50	2.50	3.00	3.00	3.50	3,50	4.00
Tensile stress area (mm ²)	84.3	157	245	303	353	459	561	694	817
Basic effective diameter (Pitch diameter) (mm)	10.863	14.701	18.376	20.376	22.051	25.051	27.727	30.727	33.402
Grade 4.6 Ultimate load kN	33.1	61.6	96.1	118.8	138	180	220	272	321
Grade 4.6 Proof load kN	18.7	34.8	54.3	67.3	78.2	102	124	154	181
Grade 8.8 Ultimate load kN	66.2	123	192	238	277	360	439	544	641
Grade 8.8 Proof load kN	48.1	89.6	140	173	201	262	321	396	466
Length of threads									
BS 4190 (Up to and inc. 125mm and (Over 125mm up to and (inc. 200mm	30	38	46	50	54	60	66	72	78
BS 3692 (Over 200mm	36	44	52	56	60	66	72	78	84
BS 4190 (Up to and inc. 125mm (Short thread length)	49	57	65	69	73	79	85	91	97
	-	24	30	33	36	40	-	-	-
Dimensions (mm)									
Maximum width across flats	19.0	24.0	30.0	32.0	36.0	41.0	46.0	50.0	55.0
Maximum width across corners	21.9	27.7	34.6	36.9	41.6	47.3	53.1	57.7	63.5
Nominal head depth of bolts	8.0	10.0	13.0	14.0	15.0	17.0	19.0	22.0	23.0
Nominal depth of nuts	10.0	13.0	16.0	18.0	19.0	22.0	24.0	26.0	29.0

Sizes shown in brackets are non-preferred.

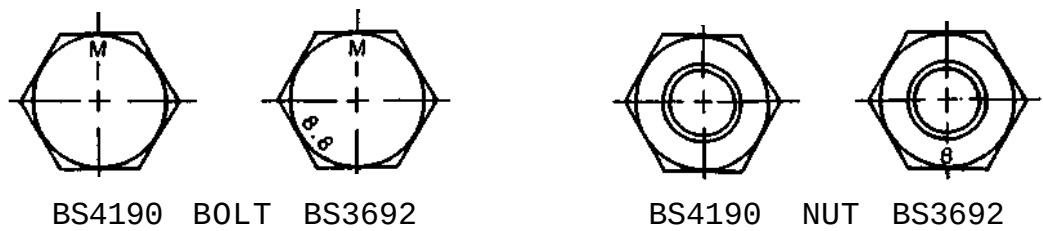


Table 10.2 Manufacturers recommended range for black hexagon bolts and screws to BS 4190 grade 4.6 metric coarse thread

Thread lengths for BS 4190 (and BS 3692) bolts

Nominal bolt length	Standard thread length	Short thread length
Up to and inc. 125 mm	2d + 6 mm	1.5d
Over 125, up to and inc. 200 mm	2d + 12 mm	
Over 200 mm	2d + 25 mm	

d = nominal bolt diameter

Hexagon head bolts and nuts - standard and short thread lengths, mm

	Length mm]																							
	25	30	35	40	45	50	55	60	65	70	75	80	90	100	110	120	130	140	150	160	180	220	260	300
M12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X
M16		0	0	0	0	X0	X0	X0	X0	X0	X0	X0	X0	X0	X	X	X	X		X	X	X	X	X
M20				0	0	0	0	X0	X0	X0	X0	X0	X0	X0	X	X	X	X	X		X	X	X	X
M24								0		X0		X0	X0	X0	X	X		X		X	X	X	X	X

X = Standard thread lengths

0 = Short thread lengths

Continued...

Table 10.2 (Continued)
Hexagon head screws

Diameter	Length (mm)										
	25	30	35	40	45	50	60	70	80	90	100
M12	X	X	X	X	X	X	X	X	X	X	X
M16		X	X	X	X	X	X	X	X	X	X
M20				X	X	X	X	X	X	X	X

X = Standard thread lengths

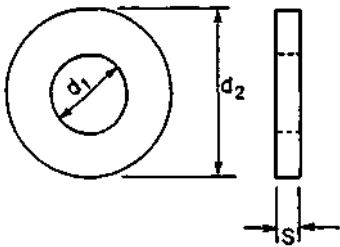


Table 10.3 Dimensions for black washers to BS 4320

All dimensions in mm

Nom. Bolt Dia.	Inside diameter, d ₁			Outside diameter, d ₂			Thickness, S		
	Nom.	Max.	Min.	Nom.	Max.	Min.	Nom.	Max.	Min.
	Normal diameter (Form E)								
M6	6.6	7.0	6.6	12.5	12.5	11.7	1.6	1.9	1.3
M8	9.0	9.4	9.0	17	17	16.2	1.6	1.9	1.3
M10	11.0	11.5	11.0	21	21	20.2	2.0	2.3	1.7
M12	14	14.5	14	24	24	23.2	2.5	2.8	2.2
M16	18	18.5	18	30	30	29.2	3	3.6	2.4
M20	22	22.6	22	37	37	35.8	3	3.6	2.4
(M22)	24	24.6	24	39	39	37.8	3	3.6	2.4
M24	26	26.6	26	44	44	42.8	4	4.6	3.4
(M27)	30	30.6	30	50	50	48.8	4	4.6	3.4
M30	33	33.8	33	56	56	54.5	4	4.6	3.4
(M33)	36	36.8	36	60	60	58.5	5	6.0	4.0
M36	39	39.8	39	66	66	64.5	5	6.0	4.0
Large diameter (Form F)									
M8	9	9.4	9	21	21	20.2	1.6	1.9	1.3
M10	11	11.5	11	24	24	23.2	2	2.3	1.7
M12	14	14.5	14	28	28	27.2	2.5	2.8	2.2
M16	18	18.5	18	34	34	32.8	3	3.6	2.4
M20	22	22.6	22	39	39	37.8	3	3.6	2.4
(M22)	24	24.6	24	44	44	42.8	3	3.6	2.4
M24	26	26.6	25	50	50	48.8	4	4.6	3.4
(M27)	30	30.6	30	56	56	54.5	4	4.6	3.4
M30	33	33.8	33	60	60	58.5	4	4.6	3.4
(M33)	36	36.8	36	66	66	64.5	5	6.0	4.0
M36	39	39.8	39	72	72	70.5	5	6.0	4.0
Extra large diameter (Form G)									
M6	6.6	7.0	6.6	18	18	17.2	2	2.3	1.7
M8	9	9.4	9.0	24	24	23.2	2	2.3	1.7
M10	11	11.5	11.0	30	30	29.2	2.5	2.8	2.2
M12	14	14.5	14.0	36	36	34.8	3	3.6	2.4
M16	18	18.5	18	48	48	46.8	4	4.6	3.4
M20	22	22.6	22	60	60	58.5	5	6.0	4
(M22)	24	24.6	24	66	66	64.5	5	6.0	4
M24	26	26.6	26	72	72	70.5	6	7	5
(M27)	30	30.6	30	81	81	79	6	7	5
M30	33	33.8	33	90	90	88	8	9.2	6.8
(M33)	36	36.8	36	99	99	97	8	9.2	6.8
M36	39	39.8	39	108	108	106	10	11.2	8.8

Sizes shown in brackets are non-preferred.

Table 10.4 Approximate mass in kg per 1000 for black bolts and nuts to BS 4190

Length under head	Diameter of bolt in mm											
mm	6	8	10	12	16	20	(22)	24	(27)	30	(33)	36
25	8.97	18.7	36.6	52.5								
30	10.1	20.7	39.1	56.1	113							
35	11.2	22.7	42.2	59.7	121							
40	12.3	24.7	45.3	64.1	129	214						
45	13.4	26.7	48.4	68.5	137	227						
50	14.5	28.7	51.5	72.9	144	239	294	377				
55	15.6	30.7	54.6	77.3	153	251	309	395				
60	16.7	32.7	57.7	81.7	160	264	324	412				
65	17.8	34.7	60.8	86.1	168	276	339	429				
70	18.9	36.7	63.9	90.5	176	288	354	447	621			
75	20.0	38.7	67.0	95.0	184	300	369	464	643			
80	21.1	40.7	70.1	100	192	313	384	481	666			
90		44.7	76.3	109	207	337	414	516	710	930	1162	
100		48.7	82.5	118	223	362	444	550	755	986	1229	1371
110			88.7	127	239	387	474	585	800	1042	1295	1451
120			94.9	136	255	411	504	620	845	1098	1362	1531
130			101	145	270	436	534	654	890	1154	1429	1610
140			107	154	286	460	564	689	935	1210	1495	1690
150			113	163	302	485	594	723	980	1266	1562	1770
160			119	172				758	1025	1322	1628	1850
170			125	181					1070	1378	1695	1930
180			131	190						1434	1762	2009
190			137	199						1490	1828	2089
200			143	208								2169
Extra per 10 mm	2.22	3.95	6.17	8.88	15.7	24.6	30.0	34.6	44.9	56.0	66.6	79.8
Approximate mass of nuts	2.32	4.82	10.9	15.9	32.9	59.8	74.4	104	157	209	279	352

Masses include one nut per bolt but make no allowance for washers
Sizes shown in brackets are non-preferred.

Table 10.5 Approximate mass in kg per 1000 for black washers to BS 4320

Type of washer	Diameter of bolt in mm											
	6	8	10	12	16	20	(22)	24	(27)	30	(33)	36
Flat Form E	11	21	40	59	11	17	18	32	40	50	71	87
Flat Form F		3.5	5.6	9.1	16	20	26	45	55	60	95	112

Sizes shown in brackets are non-preferred.
Because of thickness tolerances, mass may vary by as much as 30%.

Table 10.6 Mechanical properties for high strength friction grip bolts and nuts to BS 4395

Bolts - General grade Part 1

Nominal diameter	Tensile stress area	Proof load minimum (Min. shank tension)	Yield load (minimum)	Ultimate load (minimum)
mm	mm ²	kN	kN	kN
(M12)	84.3	49.4	53.3	69.6
M16	157	92.1	99.7	130
M20	245	144	155	203
M22	303	177	192	250
M24	353	207	225	292
M27	459	234	259	333
M30	561	286	313	406
M36	817	418	445	591

Minimum elongation after fracture for all diameters is 12% on the test specimen described in Appendix B of BS 4395: Part 1.

Size shown in brackets is non-preferred. Only to be used for the lighter type of construction where practical conditions, such as material thickness, do not warrant the usage of a larger size bolt than M12.

Bolts - Higher grade Part 2

Nominal diameter	Tensile stress area	Proof load minimum	0.85 of Proof load (Min shank tension)	1.15 of Proof load (Max shank tension)	Yield load minimum	Ultimate load minimum
mm	mm ²	kN	kN	kN	kN	kN
M16	157	122.2	103.9	140.5	138.7	154.1
M20	245	190.4	161.8	219.0	216	240
M22	303	235.5	200.2	270.8	266	269.5
M24	353	274.6	233.4	316	312	346
M27	459	356	303	409	406	450
M30	561	435	370	500	495	550
M33	694	540	459	621	612	680

Minimum elongation after fracture for all diameters is 9% on the test specimen described in Appendix B of BS 4395: Part 2.

Nuts

Nominal size of nut	Proof load	
	General grade Part 1	Higher grade Part 2
mm	kN	kN
(M12)	84.3	
M16	157	184.4
M20	245	288.4
M22	303	356.9
M24	353	415.4
M27	459	540.0
M30	561	660.0
M33		817.0
M36	817	-

Size shown in brackets is non-preferred.

Table 10.7 Dimensions for high strength friction grip bolts and nuts to BS 4395 Parts 1 and 2

See Figure 10.1 for the definition of dimensions shown in the table

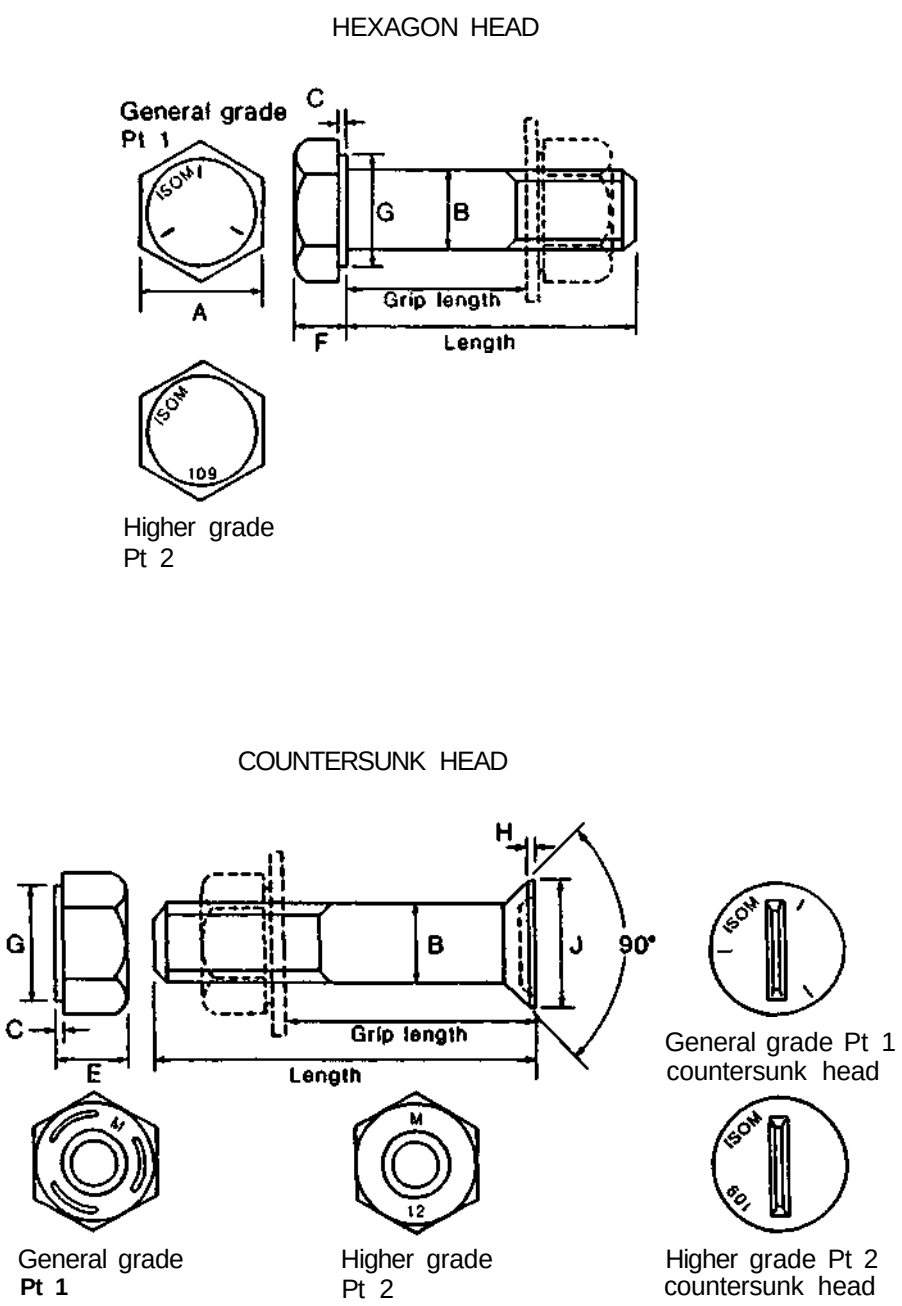
Nominal diameter	Diameter of unthreaded shank		Pitch (coarse pitch series)	Width across flats		Depth of washer face	Thickness of hexagon head		*Dia. of Csk. head	Diameter of washer face		'Depth of Csk. flash	Thickness of nuts		Addition to grip length to give length of bolt required"
	B			A		C	F		J	G		H	I		
	Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.		Max.	Min.	
mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
(M12)	12.70	11.30	1.75	22	21.16	0.4	8.45	7.55	24	22	19.91	2.0	11.55	10.45	22
M16	16.70	15.30	2.0	27	26.16	0.4	10.45	9.55	32	27	24.91	2.0	15.55	14.45	26
M20	20.84	19.16	2.5	32	31.00	0.4	13.90	12.10	40	32	29.75	3.0	18.55	17.45	30
M22	22.84	21.16	2.5	36	35.00	0.4	14.90	13.10	44	36	33.75	3.0	19.65	18.35	34
M24	24.84	23.16	3.0	41	40.00	0.5	15.90	14.10	48	41	38.75	4.0	22.65	21.35	36
M27	27.84	26.16	3.0	46	45.00	0.5	17.90	16.10	54	46	43.75	4.0	24.65	23.35	39
M30	30.84	29.16	3.5	50	49.00	0.5	20.05	17.95	60	50	47.75	4.5	26.65	25.35	42
M33	34.00	32.00	3.5	55	53.80	0.5	22.05	19.95	66	55	52.55	5.0	29.65	28.35	45
M36	37.00	35.00	4.0	60	58.80	0.5	24.05	21.95	72	60	57.75	5.0	31.80	30.20	48

Size shown in brackets is non-preferred.
*Countersunk head.
*Allows for nut, one flat round washer and sufficient thread protrusion beyond nut.

Thread lengths

Nominal length of bolt	Length of thread	
	BS4395 Part 1	BS4395 Part 2
Up to and including 125 mm	2d + 6 mm	2d + 12 mm
Over 125 mm up to and including 200 mm	2d + 12 mm	2d + 18 mm
Over 200 mm	2d + 25 mm	2d + 30 mm

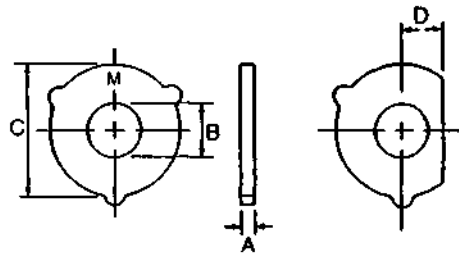
d = thread diameter i.e. nominal bolt diameter.



THE SYMBOL "M" MAY BE USED AS AN ALTERNATIVE TO 'ISOM*' ON BOLT HEADS

Figure 10.1 High strength friction grip bolts and nuts

Table 10.8 Flat round washers for use with high strength friction grip bolts



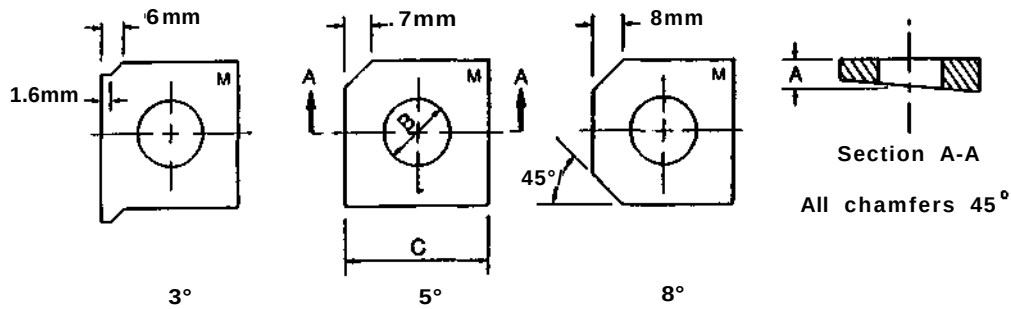
Nominal size	Inside diameter B(mm)		Outside diameter C(mm)		Thickness A (mm)		*D (mm)
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	
(M12)	13.8	13.4	30	29	2.8	2.4	11.5
M16	17.8	17.4	37	36	3.4	3.0	14
M20	21.5	21.1	44	43	3.7	3.3	17.5
M22	23.4	23.0	50	48.5	4.2	3.8	19
M24	26.4	26.0	56	54.5	4.2	3.8	21
M27	29.4	29.0	60	58.5	4.2	3.8	22.5
M30	32.8	32.4	66	64.5	4.2	3.8	26
M33	35.8	35.4	75	73.5	4.6	4.2	29
M36	38.8	38.4	85	83.5	4.6	4.2	32

The symbol 'M' appears on the face of all Metric Series washers.

* When required washers clipped to this dimension.

Sizes shown in brackets are non-preferred.

Table 10.9 Square taper washers for use with high strength friction grip bolts



Nominal size	Inside diameter B (mm)		Overall size C (mm)	Mean thickness A	
	Maximum	Minimum		3° and 5° Taper (mm)	8° Taper (mm)
(M12)	14.2	13.4	31.75	4.76	6.35
M16	18.2	17.4	38.10	4.76	6.35
M20	21.9	21.1	38.10	4.76	6.35
M22	23.8	23.0	44.45	4.76	6.35
M24	26.8	26.0	57.15	4.76	6.35
M27	29.8	29.0	57.15	4.76	6.35
M30	33.2	32.4	57.15	4.76	6.35
M33	36.2	35.4	57.15	4.76	6.35
M36	39.2	38.4	57.15	4.76	6.35

The symbol 'M' appears on the face of all Metric Series washers.

Size shown in brackets is non-preferred.

Table 10.10 Approximate mass in kg per 1000 for HSFG bolts and nuts to BS4395: Part1, Part2

Length under head	Diameter of bolt in mm								
mm	(12)	16	20	22	24	27	30	33	36
30	70	136							
35	74	144							
40	79	152	248						
45	82	160	260						
50	87	168	272	360	491				
55	91	176	285	375	509				
60	95	184	297	389	527				
65	100	192	310	404	545				
70	104	199	322	419	562				
75		207	334	434	580	756			
80		215	346	449	598	779			
85		223	359	464	615	801	1022	1337	
90		231	371	479	633	824	1050	1371	
100				508	669	869	1106	1393	1791
110					704	914	1161	1415	1871
120					739	958	1217	1572	1950
130						999	1269	1635	2024
140						1045	1325	1702	2104
150						1089	1380	1769	2184
160							1436	1836	2264
170							1491	1903	2343
180								1970	2423
190									2503
200									2583
Extra per 10mm	8.88	15.7	24.6	30.0	35.6	44.9	56.0	67.1	79.8
Approximate mass of nuts	26.4	50.7	83.0	112	174.1	242	287	409.8	525

Masses include one nut per bolt but make no allowance for washers.
Size shown in brackets is non-preferred.

Table 10.11 Approximate mass in kg per 1000 for HSFG washers to BS4395: Part1

Type of washer	Diameter of bolt in mm								
	(12)	16	20	22	24	27	30	33	36
Flat round	12.5	22.0	32.8	46.0	60.0	66.6	76.6	96.6	133.3
Square taper 3° and 5°	32	51	41	58	102	97	90	-	78
Square taper 8°	43	68	54	78	136	129	121	-	104

Size shown in brackets is non-preferred.

10.3 Protective coatings

When required, bolts, nuts and washers should be spun galvanised, sherardised or electro-plated with zinc or cadmium.

Note that electro-plated finishes may not provide the same degree of protection as metal sprayed or galvanised steelwork.

10.4 Minimum length of bolts

The length of the bolt must be such that at least one thread shows above the nut after tightening, and at least one thread plus the thread run out is clear between the nut and the unthreaded shank of the bolt.

10.5 Designation of bolts

When designating ISO Metric bolts, screws or nuts the following information should be given.

- (i) General product description, e.g. high tensile or black, head shape, bolts, screws or nuts, as appropriate.
- (ii) The letter "M" before the nominal thread diameter in mm.
- (iii) The nominal length in mm, if applicable.
- (iv) The appropriate British Standard, e.g. *BS3692*⁽¹⁾.
- (v) The strength grade symbol.
- (vi) Details of the protective coating.

Examples

- (a) Black hexagon head bolts 16 mm diameter, 70 mm long, strength grade 4.6, galvanised, would be designated:

Black hexagon head bolts M16 x 70 to *BS 4190*, grade 4.6, galvanised to *BS 729*⁽¹⁾.
- (b) Hexagon head bolts 24 mm diameter, 90 mm long, strength grade 8.8, zinc plated with coating of intermediate thickness, would be designated:

High tensile hexagon head bolts M24 x 90 to *BS 3692*, grade 8.8, zinc-plated to *BS1706*⁽¹⁾.

10.6 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)

11. WELDING PROCESSES AND CONSUMABLES

A brief description is given below of the various welding processes followed by a review of the requirements, classification and purchasing of the welding consumables. Further information can be found in SCI publication, *Introduction to the welding of structural steelwork*⁽¹⁾.

11.1 Basic requirements

The process and/or consumables must:

- (a) supply heat to effect fusion of the parts to be joined
- (b) make a joint such that the properties of the join are adequate to cater for the design load and fracture toughness requirements; this necessarily includes satisfactory metallurgical properties
- (c) enable the process to be made efficiently in any required position; both vertical and overhead welds may be made by some processes but not all.

11.2 Manual metal-arc (MMA) welding

This process, as the name suggests, is a manual operation and is solely dependent on the skill of the operator. It is the oldest of all the processes and is widely used by all fabricators.

The electrode consists of a core wire with a flux extruded around it (Figure 11.1). The flux can consist of ingredients such as cellulose, silicates, titanium, iron oxides, manganese oxides, calcium carbonate, fluoride, etc. These constituents are made into a stiff paste with a sodium silicate binder for extrusion around the core wire; the flux should perform several functions when it is melted in the arc, viz:

- (a) stabilise the arc
- (b) provide the arc and molten weld pool with a gaseous envelope to prevent the pick-up of oxygen and nitrogen from the atmosphere - such contaminants would produce a weld of inferior mechanical and metallurgical properties
- (c) produce a slag over the hot deposited weld bead to protect it from the atmosphere
- (d) produce a slag to form the acceptable weld bead shapes in the welding position (flat, horizontal, vertical, overhead) required with adequate slag detachability
- (e) add alloys where necessary to the weld metal
- (f) provide the necessary slag/weld metal reactions
- (g) control the deposition rate.

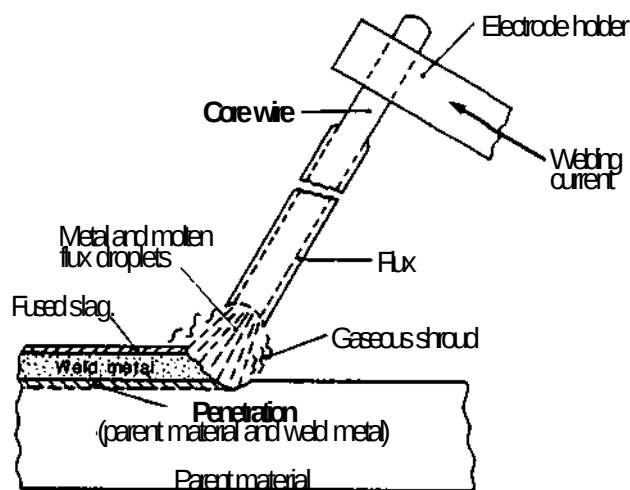


Figure 11.1 Manual metal-arc welding (MMA)

11.3 Submerged arc (SA) welding

This is an automatic welding process in which a continuous bare wire (electrode) is fed from a drum through a welding nozzle into a bed of granulated flux automatically dispensed along the joint to be welded. This is shown schematically in Figure 11.2. The heat of the arc melts some of the flux and, as in the manual metal-arc process, provides a gaseous envelope around the arc. The fused flux forms a cover to the deposited molten metal which prevents oxidation, or other contamination from the atmosphere.

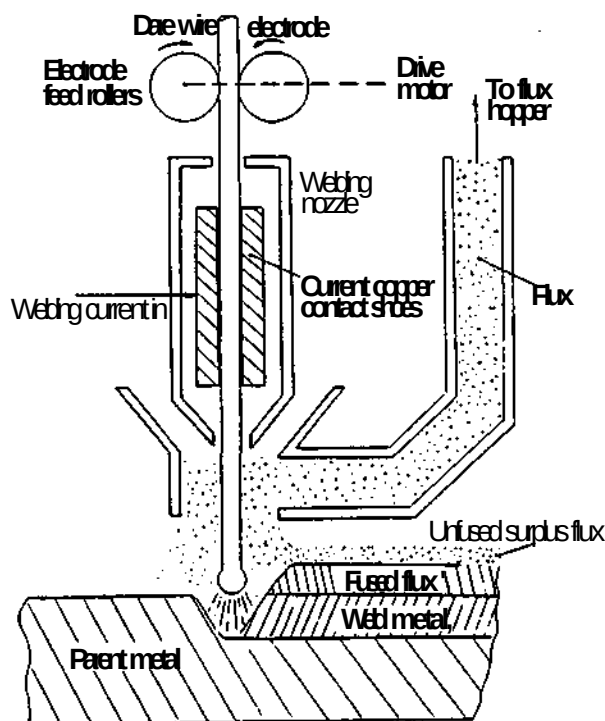


Figure 11.2 Submerged arc welding (SA)

The arc being completely enclosed by flux, spatter and radiation losses are minimal and high welding currents can be employed resulting in deep penetration welds. The consequent high heat inputs together with the fluid type molten flux, produce weld beads of smooth surface appearance.

Fluxes are of three main types, fused, bonded (agglomerated) and mechanically mixed. They consist of mixtures of various forms of silicon, metal oxides and arc stabilisers. The particular make-up can decide deposition rates, slag detachability, necessary cleanliness of the plate surface and weld metal non-metallic inclusions. The latter has a significant effect on weld metal fracture toughness and in general, the more basic the flux, the fewer the inclusions in the weld metal.

The electrode wire can also have alloying elements added to it which transfer to the weld metal when it is deposited.

The fact that high input currents can be employed means that this process is capable of high deposition rates. Even higher rates can be achieved by the use of multiple arcs for which two or three electrodes operating from suitable power sources are fed into the same joint. It should be noted, however, that the high heat input will naturally result in a decreased rate of cooling of the weld metal which, because of its resultant metallurgical microstructure, can suffer a reduction in fracture toughness.

11.4 Gas metal arc welding (GMA)

In this process a small diameter solid electrode is continuously fed into the weld with the arc and molten weld pool shielded by a gas which prevents the pick up of oxygen and nitrogen from the atmosphere. Welding with an inert gas, helium or argon is not suitable for the welding of steel since they form an irregular weld pool but the addition of oxygen or carbon dioxide to argon achieves a more stable arc with improved bead shape, better penetration and reduced undercut. To counter the effect of oxygen from the above added gases in the weld metal, deoxidants are added to the electrode filler wire. As more carbon dioxide is added (commonly up to 20 per cent) to the argon, the mode of metal transfer from the electrode changes from a spray type to a globular one. This is very evident when the shielding gas is entirely carbon dioxide, where the globules occasionally short circuit the arc; spatter increases and the arc sounds harsher.

Gas terminology is not exact. The term MIG welding (metal inert gas welding) should strictly apply to the inert gases only, such as helium and argon. The additions of oxygen and carbon dioxide i.e. active gases, to argon is sometimes known as MAG (metal active gas), but in some quarters it is still termed as MIG. When carbon dioxide only is used as a shielding gas the expression MAG (CO₂) is sometimes employed.

The electrode is fed by means of a speed controlled motor through the nozzle or gun and the gas through the gun orifice (Figure 11.3).

11.5 Gas shielded flux-cored arc welding (FCAW)

In this process, which can be either semi-automatic or automatic, the electrode contains a flux within its periphery i.e. a flux cored wire. The flux contains arc stabilisers, deoxidants and alloying elements, and as in the previous section, gases are used as a shielding medium. The addition of the flux offers better deoxidation of the weld metal with improved chemical composition and hence better physical properties particularly notch toughness. Basic fluxes give low hydrogen weld deposits with good impact values and subsequent improved resistance to cracking. Small diameter wires, typically 1.2 mm diameter, are used for all positional welding and diameters 2.0 mm to 2.4 mm for high downhand depositions increased by the additions of iron powder to the flux. Shielding gases used are CO₂ and Ar/CO₂ mixtures.

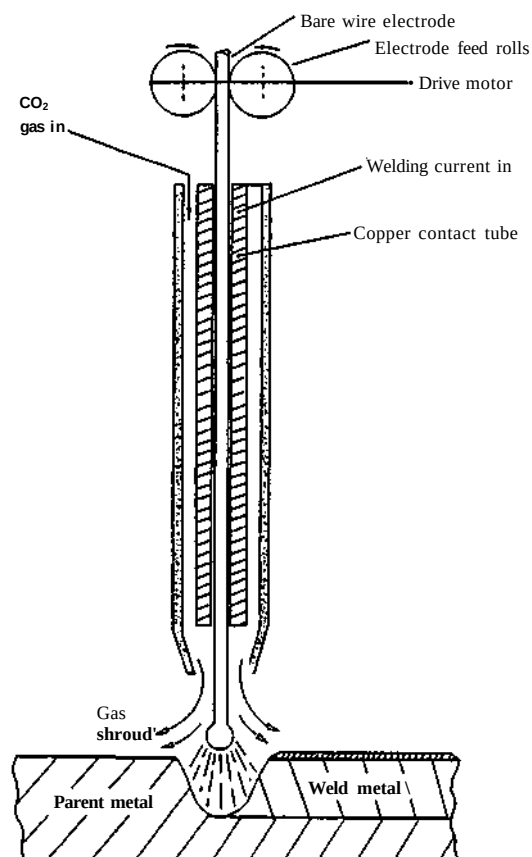


Figure 11.3 Gas shielded metal arc welding (MAG)

11.5.1 Self shielded flux-cored arc welding

In this process no shielding gas is required since the cored flux contains constituents which vaporize in the arc to prevent the pick-up of oxygen and nitrogen by the weld metal. The flux provides good fusion properties and a quick freezing slag permits positional welding and without an external shielding gas the welding equipment is less bulky permitting easy access to all plate preparations. Welding is unaffected by windy site conditions since no external gas shroud is employed. Low hydrogen content wires are available as with FCAW consumables. Fast depositions are possible in the flat positions but care is necessary to employ optimum welding conditions with respect to arc voltage and electrode feed rate.

11.6 Consumable guide electroslog welding (ESW)

The process originated in Russia and consists of feeding a continuous bare wire electrode through a flux coated metal guide tube centred between the vertical plates being welded. The edges of the plate are square, requiring no preparation which is necessary for welding thick plates by other processes. The consumable guide is held in a clamp situated on a small platform fixed above the weld gap which also holds the feed motor and reel containing the electrode. Both sides of the weld aperture are enclosed by two full-length water cooled copper shoes to contain the weld metal (Figure 11.4). The arc is initiated under some flux on the start plate and when the flux melts it becomes electrically conductive and after certain equilibrium conditions are achieved, the arc is extinguished. The electrode is then melted off by resistance heating produced by the welding current in the wire and

also the molten slag. To prevent contact with the plates, the guide tube is insulated with an extruded flux around it and is melted off by the heat of the molten slag and thus added to the weld metal and slag pools. Very little flux is consumed by the process although during the operation it may become necessary to add a little flux to the slag. Up to 4 mm diameter electrode wires are popularly used with alloying additions to obtain mechanical properties in the weld metal. Oscillation as shown in the figure may be applied and more than one electrode and guide employed, enabling thicknesses in excess of 400 mm to be welded. The welding is continuous with a high heat input and slow cooling rate and is virtually a casting process with a coarse grain structure near the fusion line boundary and in the heat affected zone resulting in a low notch toughness in these areas; this can be improved by a post-weld normalising heat treatment. It is, however, an economical method of welding very thick plates and may be used in situations where notch ductility is not important.

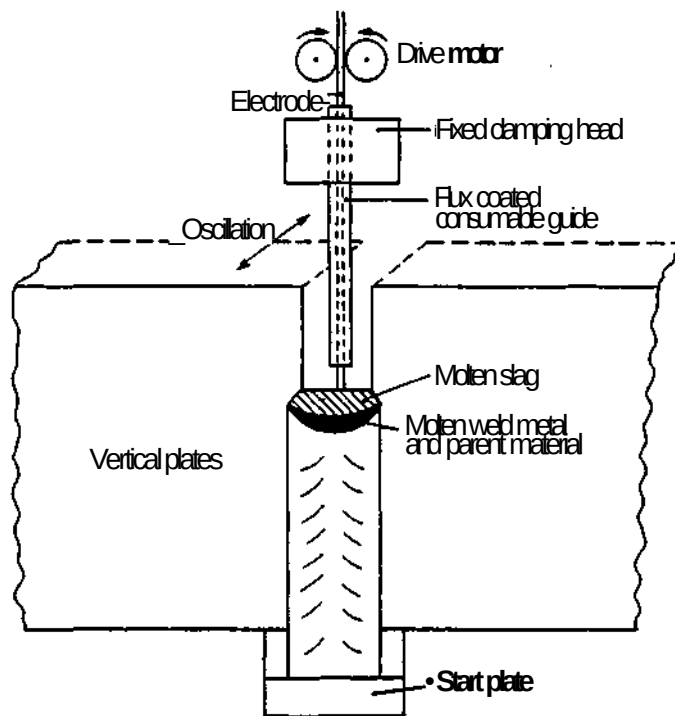


Figure 11.4 Consumable guide electroslog welding (ESW)

11.7 Stud welding

This is an arc welding process and is extensively used for fixing stud shear connectors to beams.

The equipment consists of a gun hand tool, DC power source, auxiliary contactor and controller (Figure 11.5). The stud is mounted into the chuck of the hand tool and the conical tip of the stud is held in contact with the work piece by the pressure of a spring on the chuck. The weld is initiated by depressing the trigger on the gun when a solenoid within the hand tool comes into operation and causes the stud to lift about 2 mm off the surface of the work piece; this gap is preset and can be varied within certain limits. A small current pilot arc is then drawn between the stud tip and the work piece. This is followed by the main power arc which melts the end of the stud and the adjacent part of the work piece. Whilst the arc is still burning, the solenoid is de-energised and the spring loaded stud plunges into the molten crater, the duration of the current flow and the timing of the plunge is controlled by a timer in the control unit. High transient welding currents, in the region of 2000 amps for a 25 milli-second duration for a 19 mm diameter stud are used and such high currents necessitate the use of an auxiliary contactor which limits the current rise at the end of the cycle by switching in a resistance in series with the power unit.

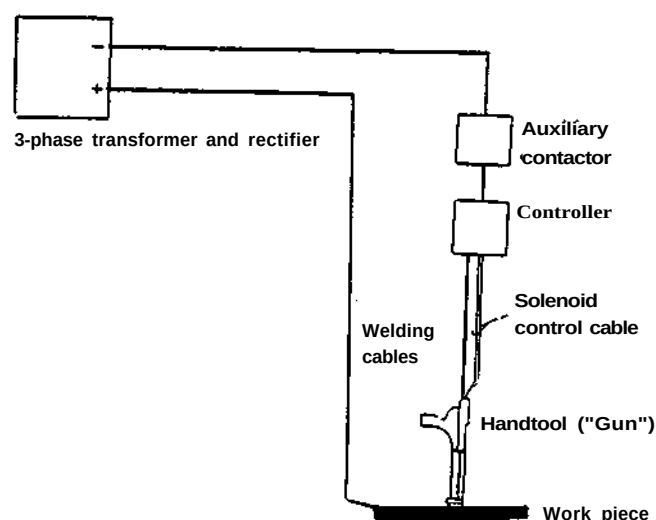


Figure 11.5 Schematic circuit for arc stud welding

The stages of the welding operation are shown in Figure 11.6. A ceramic ferrule placed around the stud foot is shaped so that an all round fillet is formed. The ferrule also prevents ejection of weld metal and helps to reduce arc glare. To reduce oxidation of the weld metal by the atmosphere, the conical surface at the end of the stud is treated with a deoxidant in the form of aluminium metal spray or a "slug" of aluminium inserted at the tip; this also improves the mechanical properties of the stud weld.

Composite beam construction in floors of large buildings often utilises a thin profiled steel deck spanning the girders; this deck, which is invariably galvanised, is used as permanent shuttering and bottom reinforcement to the concrete. To provide for composite action, shear stud connectors are welded to the beams and a problem can arise when the studs have to be welded through the galvanised sheet. Zinc will volatilise in the arc drawn between stud and beam and when the weld is made it can exhibit gross porosity and fusion defects. One method of reducing these defects and to produce a satisfactory weld is to increase the arcing time of the stud and thus remove the zinc from the arc before the weld is made. Another method, which produces satisfactory welds, is to use actual current process in which a preliminary arc is made first to bum off the zinc on the profiled sheet and then a higher arc current is developed to make the stud-to-beam weld through the sheet.

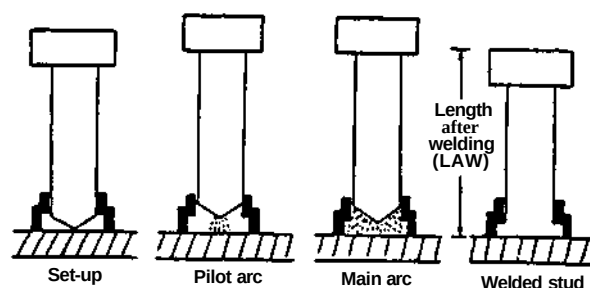


Figure 11.6 Sequence in welding shear stud connectors

11.8 Manual metal arc (MMA) electrodes

MMA electrodes should comply with BS 639⁽¹⁾ *Specification for covered carbon and carbon manganese steel electrodes for manual metal-arc welding*.

It is not possible to grade electrodes on the basis of mechanical results which relate directly to practice because of the very many different ways in which the electrodes are used, e.g. welding position, electrode size, run sequence, welding current and the great variety of parent material upon which the electrodes are deposited. At best therefore an electrode standard can provide a system by which various types of electrodes can be graded in accordance with a specified manner of weld depositions and testing which is free from the effects of variations present in practical welding. By this means electrodes of different type or manufacture can be compared. Whilst such grading of electrodes can never indicate the results which will be obtained in any given welding procedure test, in practice they form a useful guide to the welding engineer as to what type of electrode he will need to adopt to achieve satisfactory mechanical test results.

Ordering electrodes complying with this standard gives an assurance of electrode quality and the classification has significance to the fabricator. The user is advised to carry out welding procedure tests if notch toughness criteria have to be satisfied and these tests should be representative of the appropriate production joints as specified in BS 4870: Part 1⁽¹⁾. Furthermore if a fabrication is to be heat treated after welding a similar post-weld heat treatment should be applied to the welding procedure test pieces because heat treatment can affect both the tensile and impact strength.

Different manufacturers may have a number of electrodes with identical or very similar classifications and the user's choice may depend upon other factors such as ease of use, deslagging or welder appeal (weldability). Electrodes bearing identical codings may be expected to have generally similar characteristics and properties, even if made by different manufacturers, but some differences may exist between such electrodes. The selection of electrodes should be made on the basis of the particular application and the user should consult the electrode manufacturers or other appropriate authoritative sources for guidance.

If the classifications of the standard are used for purchasing it should be made clear that they represent minimum requirements since electrodes with higher toughness properties than the minimum required may also be appropriate for use on a production joint. Furthermore the manufacturer's brand name or identification number should also be quoted.

For electrodes of a given type to be classified the manufacturer must test two sizes - a 4 mm and the largest size he wishes to have classified. The results of the two sets of tests are considered.

In accordance with the standard, the classification of an electrode is indicated as follows:

(a) Strength, toughness and covering code (STC code)

- (1) The letter "E" for a manual electrode.
- (2) Two digits indicating the strength (tensile, yield and elongation properties of the weld metal).
- (3) A digit indicating the temperature for a minimum average impact value of 28 J.
- (4) A digit indicating the temperature for a minimum average impact value of 47 J.
- (5) A letter or letters indicating the type of covering.

(b) Additional coding

The following additional coding has to be provided in manufacturers' literature:

- (1) When appropriate, three digits indicating the nominal electrode efficiency.
- (2) A digit indicating the recommended welding positions for the electrode.
- (3) A digit indicating the power supply requirement.
- (4) When appropriate a letter "H" indicating a Hydrogen controlled electrode.

A guide to the coding system is given in Table 11.1.

The following examples illustrate the way in which the coding is expressed and the use of the complete classification or only the compulsory part.

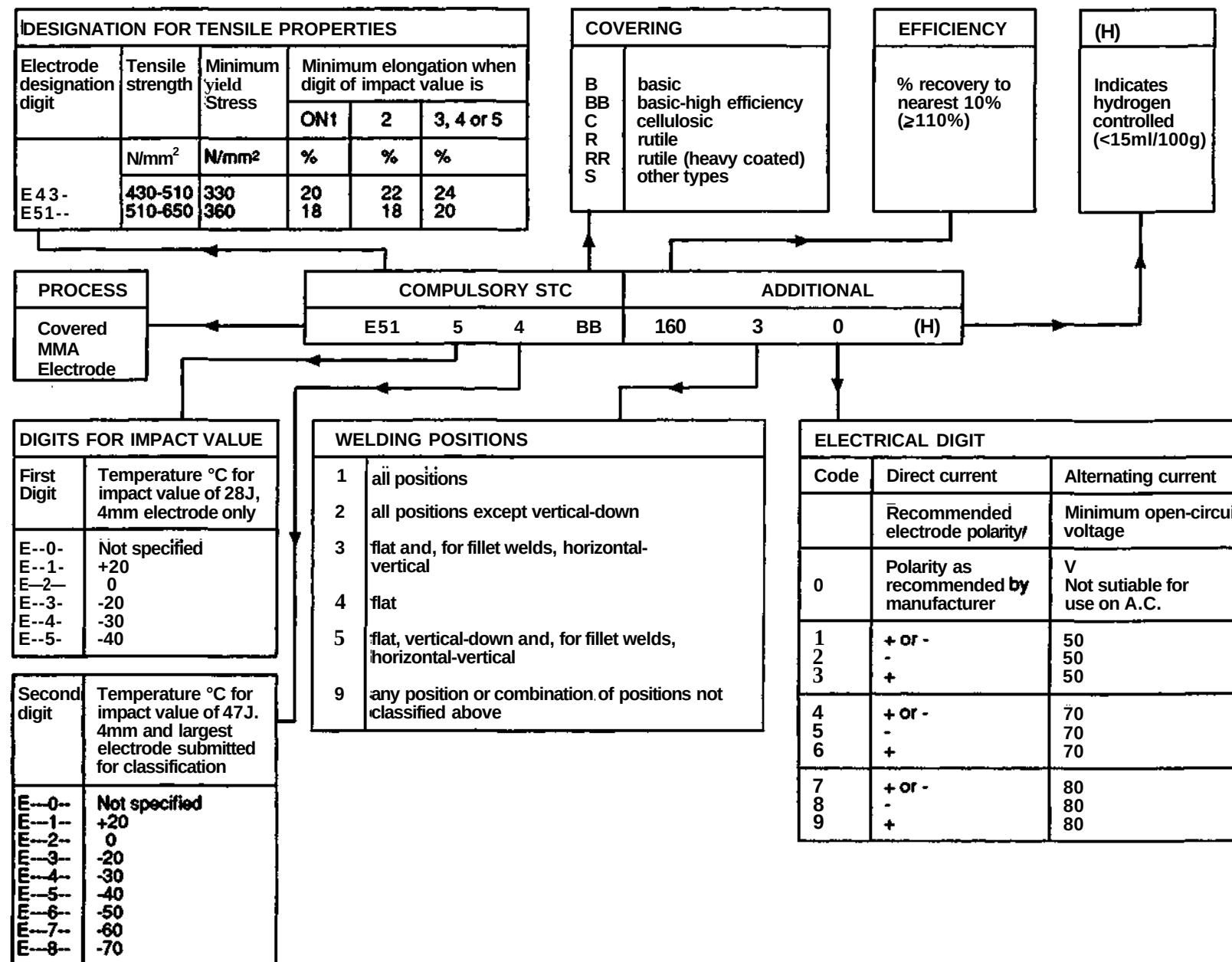
Example (a)

Covered electrodes for manual metal-arc welding having a rutile covering (R) but not designated as a high efficiency electrode.

The electrode may be used for welding in all positions and it welds satisfactorily on alternating current with a minimum open circuit voltage of 50 V and on direct current with positive polarity. The electrode is not designed to give hydrogen controlled weld metal.

The electrode deposits weld metal with the properties given in Table 11.2 when tested in accordance with this standard and when the manufacturer submits 8 mm diameter electrodes as the maximum size to be classified. The table of results shows that the manufacturer carried out sets of impact tests at 0°, at -20°C and at -30°C in order to determine the appropriate classification.

Table 11.1 Guide to coding system



Example(b)

An electrode for manual metal-arc welding having a basic covering, with a nominal efficiency of 158% and depositing weld metal containing 8 mL of diffusible hydrogen per 100 g of deposited weld metal.

The electrode deposits weld metal with the properties given in Table 11.3 when tested in accordance with this standard and when the manufacturer submits 6 mm electrodes as the maximum size to be classified. The table of results shows that the manufacturer carried out sets of impact tests at -30°C and at -40°C.

Table 11.3 Test results for example (b)

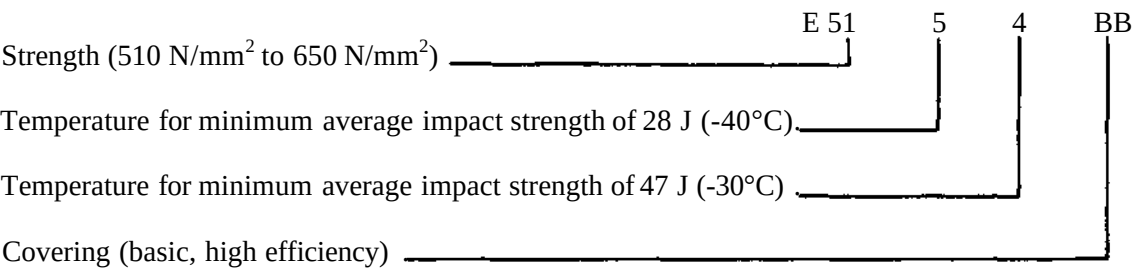
Property	Test plates for 4 mm electrode	Test plates for 6 mm electrodes	Classification E51 — equivalent	Result
Tensile strength (N/mm ²)	565	560	510 to 650	Satisfactory
Yield stress (N/mm ²)	400	395	360 min.	Satisfactory
Impact value at -40°C (J)	46 20) 40 31) average 43 42) 37	Not required (see 7.3.1)	Temperature for impact value of 28 J average but no one value less than 16 J	This result is greater than both 35 J and 28 J and the results are satisfactory for classification of first digit at -40°C
Impact value at -30°C (J)	120) 110) average 106)112	60) 68) average 70)66	Temperature for impact value of 47 J average but no one value less than 20 J	Satisfactory results for classification of second digit at -30°C
Impact value at -40°C (J)	Results from previous test give average 37* (see above). No need to repeat test	4 mm electrode failed so no need to test 6 mm electrode	Temperature for impact value of 47 J average but no one value less than 20 J	Failed requirements of 7.3.2
Elongation %	24	23	20 min. +	Satisfactory

'Only three values are in fact required but whichever three values out of the six are taken the average is less than the required minimum of 47 J.

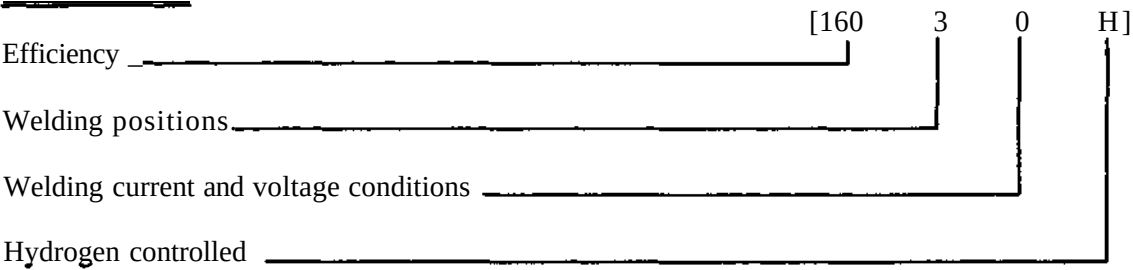
+Elongation determined from Table 1 of BS 639⁽¹⁾ after establishment of first impact digit

The classification for the electrode is therefore:

STC code



Additional code



Complete classification

The complete classification is therefore E51 54 BB [160 30 H]

11.9 BS 7084:1988 Carbon and carbon manganese steel tubular cored welding electrodes

The cored wire welding process uses tubular electrodes which are filled with flux or with a mixture of flux and metal powder. They are either used in the self-shielded mode or with an auxiliary shielding gas, usually carbon dioxide or argon/carbon dioxide.

Although there are applications in all branches of industry the cored wire welding process has found more favour in the heavier branches of industry. The self-shielding characteristics of some electrodes have made them ideal for use outdoors for the offshore and shipbuilding industries. Wires which use an additional gas shield have found favour in work-shop situations, not only for the welding of carbon and carbon-manganese steels, but also for stainless steels. The development of small diameter flux cored electrodes suitable for welding in all positions has helped the process gain popularity in general fabrication.

BS 7084⁽¹⁾ includes requirements for continuous tubular metal-cored or flux-cored electrodes for arc welding with and without shielding gas, and gives details of the system by which they are to be classified.

It may not be possible to select an electrode which is suitable for a particular weldment without carrying out an appropriate welding procedure test but the standard will enable the fabricator to make the first step in consumable selection. These electrode wires can be used in a wide variety of situations, e.g. different steels, welding parameters, types of power supply and welding position and width of weld weave. The foreword to the Standard emphasises this problem and advises tests to *BS 4870: Part 1*⁽¹⁾.

It is not possible for suppliers to carry out tests on every coil of electrode they supply to prove its compliance and therefore the purchaser is advised to ensure that the supplier operates a quality system in compliance with the appropriate part of BS 5750⁽¹⁾

When ordering to the standard the purchaser should specify the standard number, the electrode classification or trade designation and the test certification documentation required. Any particular requirements for temper, cast and helix may also be specified.

The classification system is as follows:

The process identification letter is "T" for tubular cored electrode and this is followed by a digit indicating strength - "4" for a tensile range of 430-550 N/mm² with a minimum yield of 330 N/mm² and minimum elongation of 20% and "5" for a tensile range of 510-650 N/mm² and minimum yield of 360 N/mm² with minimum elongation of 18%.

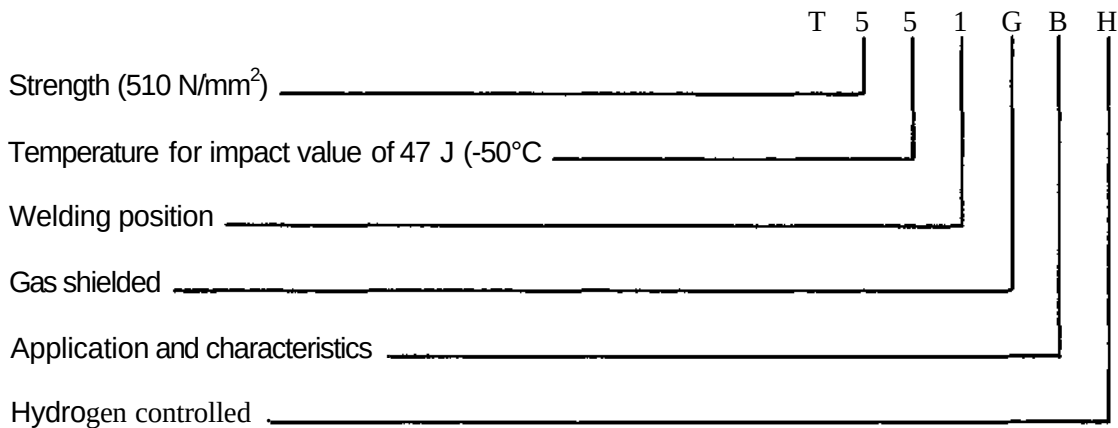
This is followed by a digit which relates to the test temperature at which the electrode deposited weld metal in accordance with the method given and achieved a minimum average impact value of 47 Joules.

Unlike some other consumable standards it was felt to be more logical for the digit for toughness to correlate with the temperature of testing and hence digit 2 relates to -20 C and digit 3 to -30°C and so on.

The next digit in the classification relates to the recommended welding position and this is followed by a letter either "G" for a gas shielded electrode or "N" for a self-shielded.

There is then a further letter which indicates the application and characteristics of the electrode in accordance with the detailed table. The final letter "H" of the classification is only written if the consumable can be classed as hydrogen controlled i.e. the weld metal has less than 15 ml of diffusible hydrogen per 100 g when determined in accordance with BS 6693: Part 5⁽¹⁾ at welding currents and at arc voltage and electrode extension as specified in BS 7084⁽¹⁾.

The classification for the electrode is therefore:



11.10 BS 4165:1984 Electrode wires and fluxes for the submerged arc welding of carbon steel and medium-tensile steel

This British Standard specifies requirements for solid electrode wires and for fluxes of the submerged arc welding of carbon steel and medium - tensile steel having a tensile strength of not more than 700 N/mm^2 , and sulphur and phosphorous contents not greater than 0.06% each such as those in BS 4360⁽¹⁾ and includes weld impact values appropriate to these steels. The Standard specifies general requirements for all wires and fluxes.

Charpy V-notch impact tests are affected by many factors such as the composition of the welding wire and the type of welding flux, the effect of diluting from the parent material, the heat input for the weld which in turn is affected by the welding current, arc voltage and travel speed, and the deposition of the weld runs in a multi-run weld. For this reason it is usual to carry out tests to assess the mechanical properties on all-weld metal test pieces deposited under defined parameters and thus unaffected by the parent metal used in the preparation of the tests.

The submerged arc process can be used to make butt welds by a two-run technique, one run from each side of the joint, with either square or partially bevelled edges with a generous root face. Such are the penetrating properties with this process that sound weld can be obtained without resort to back gouging. The weld metal deposited in this manner is heavily diluted with parent plate and is likely to provide significantly different properties to that deposited by a multi-run technique which results in low dilution and provides essentially all-weld metal results. To cater for these differences in technique, this standard specifies initial weld tests for both multi-run and two-run deposition. These tests are carried out using specified wire sizes and conditions with an appropriate grade of BS 4360 plate. Testing of these welded joints comprises tensile, bend and Charpy V-notch tests and chemical analysis.

It is important to appreciate that, whilst the tests using the two-run technique give results which approximate to those obtained in practice when welds are carried out under the same conditions with equivalent plate material, the test results obtained from the all-weld metal test pieces with the multi-run technique may not relate to a production type joint. Nevertheless, the tests specified are suitable for grading the results obtained from various wire/flux combinations and enable the fabricator to select a combination which may be appropriate to his production requirements. However, one should be aware of the fact that Charpy results from the approval tests may not be representative of those obtained from production joints.

In view of the factors which affect the results obtained from a production situation, it will be advisable for the fabricator to carryout a welding procedure test and reference should be made to BS 4870: Part 1⁽¹⁾.

On completion of testing, the wire/flux combination is assigned the appropriate grading code which takes the form of a prefix number related to the impact test temperature, followed by the letters "M" and/or "T" to indicate multi-run, two-run or both and finally a three figure number related to tensile properties of the weld metal. For example, a wire/flux combination giving weld metal in a two-run test with an average impact value better than 35 J at -40°C , a tensile strength in the range 400 N/mm^2 to 600 N/mm^2 and yield stress above 300 N/mm^2 , would have the grading 4T300.

Manufacturers usually supply a range of wires and fluxes. This standard includes a table of the commonly used wire analyses and a descriptive table of the various types of welding flux. Fluxes are based on various combinations of compounds and the ratio of basic to acidic components in a flux is known as the Basicity Index.

Generally high basicity fluxes tend to give the best impact properties, other factors being equal. This is a complex subject and in all cases where weld metal toughness is important, the user is advised to consult the consumable supplier since the notch toughness of weld metal is a function not only of the flux chemistry but also of the weld metal chemistry and the weld micro-structure.

Although combinations of wires and fluxes supplied by individual companies may have the same grading, the individual wires and fluxes from different companies are not necessarily interchangeable.

11.10.1 Testing and grading

The wires and fluxes are to be capable of complying in all respects with the appropriate requirements and tests in the standard. In particular wire and flux combinations which are suitable for multi-run, two-run techniques or both shall be tested initially as appropriate. Wire-flux combinations suitable for use on either a.c or d.c are tested on a.c. In all cases the type of current used in the tests shall be reported. On satisfactory completion of these test the flux and wire combinations are graded.

The grade number is made up of three parts: a prefix number related to impact testing temperature, the letters "M" or "T" indicating multi- or two-run techniques and a three figure suffix related to minimum yield stress in N/mm², e.g:

Grade 2	M	350
Test temperature of 0°C	Multi-run	Minimum yield stress of 350 N/mm ² (tensile strength 460 N/mm ² to 650 N/mm ²)

Where both "M" and "T" gradings are approved for a particular wire/flux combination, the grade number shall be given separately, e.g. 3M 450/IT450.

11.11 References

- 1. PRATT, J.L.
Introduction to the welding of structural steelwork (3rd revised edition)
The Steel Construction Institute, Ascot, 1989
- 2. BRITISH STANDARDS INSTITUTION
(see Section 19)

12. STEEL STAIRWAYS, LADDERS AND HANDRAILING

12.1 Stairways and ladders

The design and dimensioning of stairways will generally be determined by their intended purpose and anticipated volume and frequency of usage. Important aspects to be considered will be safety in use, ease of access and adequate clearances.

Figure 12.1 illustrates the terms used in stairway construction.

The available space and slope will be a controlling factor in deciding the type of stairway to be used. Figure 12.2 is a chart giving useful recommendations for stairway type suitable for a given slope.

Stairways should be designed to withstand a load of 5 kN/m^2 on the plan area of the stair. Such a load will be sufficient to allow for normal impact and dynamic load effects. The design load may be reduced to 3 kN/m^2 minimum providing this load is not less than the load on the floor to which the stairway gives access. Further details of floor and stairway loading are given in *BS 6399: Part 1*⁽¹⁾.

The design and construction details of stairways must be in accordance with the appropriate part of *BS 5395*⁽¹⁾ which is the code of practice for the design of stairways and walkways; *BS 4211*⁽¹⁾ covers the design of fixed ladders for permanent access.

12.2 Handrailing

Handrails and guardrails are produced to give safety and reassurance for users of stairways and walkways. As a general rule, any unprotected edge of a walkway, platform and staircase from which a person may fall more than 0.5 m must be protected by a guardrail.

Handrails must be designed to withstand a lateral load which will depend on the type of use. *BS 6399: Part 1*⁽¹⁾ gives the design load for light access stairs and the loading for handrails in industrial locations are given in *BS 5395: Part 3*⁽¹⁾. If there is a possibility of vehicular impact then the recommendations in Appendix C of *BS 6180*⁽¹⁾ should be followed.

12.3 Detailed design

Guidance and detailed information with regard to the design of stairways, ladders and handrailing can be obtained from the references at the end of this Section.

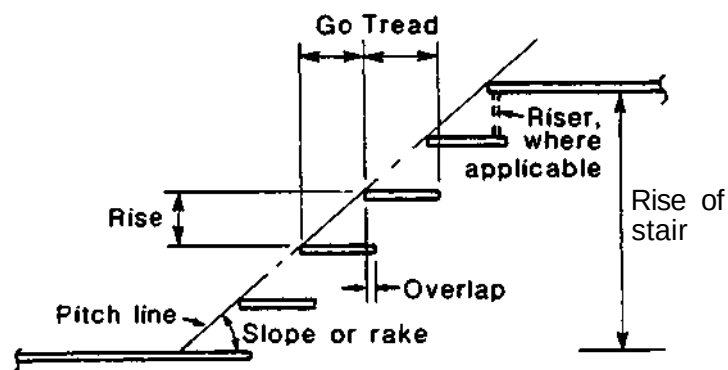


Figure 12.1 Stairway terms

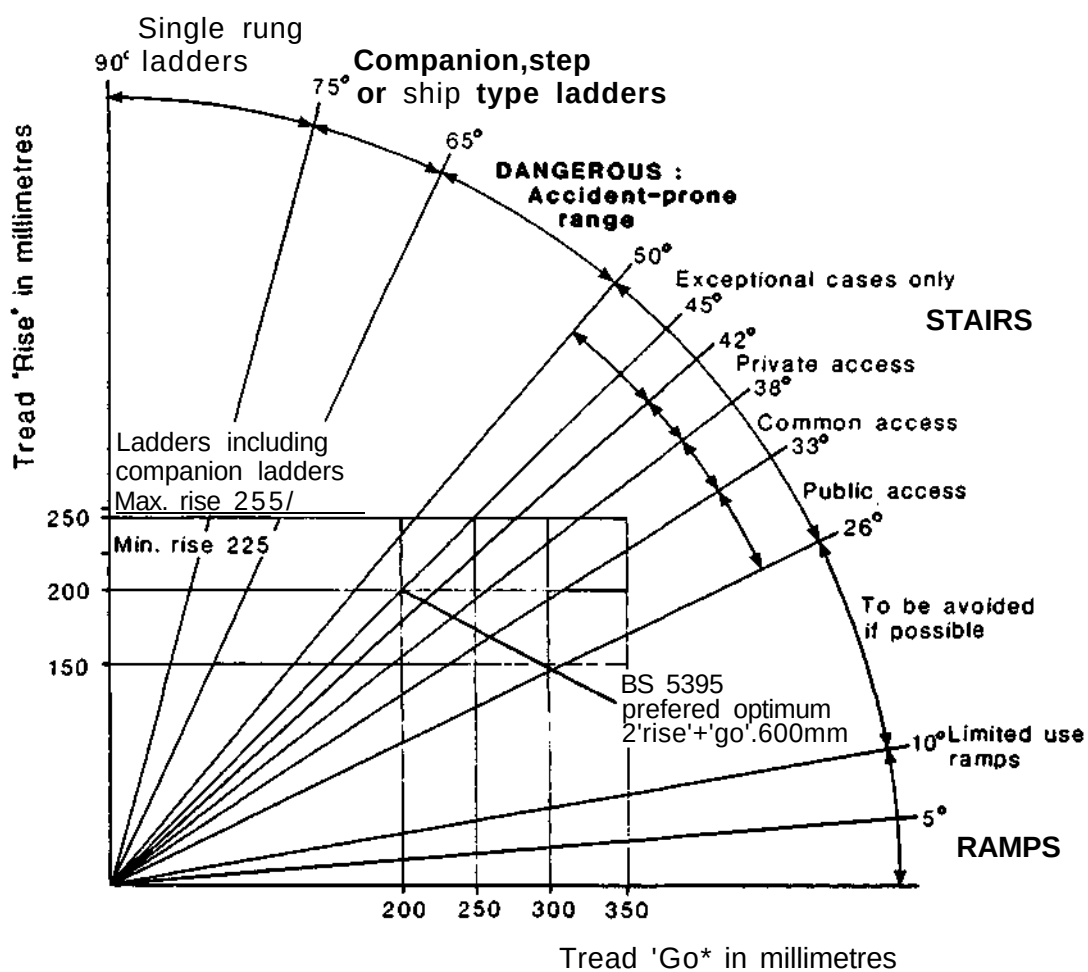


Figure 12.2 Stairway type recommendations

12.4 List of manufacturers

Stairs, handrails and ladders

Allan Kennedy & Co Ltd					
Riverside					
Stockton-on-Tees					Telephone: 0642 245151
Cleveland	TS18	1TQ			Fax: 0642 224710

Steelway-Fensecure (Glynwed Engineering Ltd)					
Queensgate Work					
Bilston		Road			Telephone: 0902 451733
Wolverhampton	WV2 2NJ				Fax: 0902 452256

Guardrails

Abacus Municipal Ltd					
Sutton in Ashfield					Telephone: 0623 511111
Notts	NG17 5FT				Fax: 0623 552133

Orsogril UK Ltd					
Prudential Buildings					
95-101 Above Bar Street					Telephone: 0703 638055
Southampton	SO1 0FG				Fax: 0703 636975

Optimum Safety Fencing Ltd					
The Coal Wharf					
Highfields Road					Telephone: 0902 403197
Bilston	WV14	OSF			Fax: 0902 402104

12.5 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)

Further Reading

2. Catalogue and Technical Guide, Steelway and Fenscure
Glynwed Engineering Ltd, Wolverhampton
3. HAYWARD, A.ANDWEARE,F.
Steel detailer's manual
BSP Professional Books, Oxford 1989
4. Engineering Equipment Users Association (E.E.U.A.) Handbook No 7, London
(Now E.E.M.U.A. Engineering Equipment and Manufacturers Users Association
Handbook No 7)

13. CURVED SECTIONS

13.1 General

The development of powerful cold-rolling equipment capable of accurately bending the larger sizes of structural sections has greatly increased the possible uses of curved members in structural steelwork. The availability of large size curved structural sections opens up new scope for the design of domed and vaulted roofs, splayed columns, glazed atria and malls and for specific features such as, arched lintels etc. They are of particular value for curved facades since it is usually more economical to fix cladding panels directly to curved perimeter beams or rails than to use a series of straight members with complex connectors. Universal beams pre-cambered with great accuracy, can be used in the construction of graceful footbridges.

The capacity chart (Figure 13.1) lists the main profiles which can be curved by "cold-rolling".

13.2 Minimum bend radii

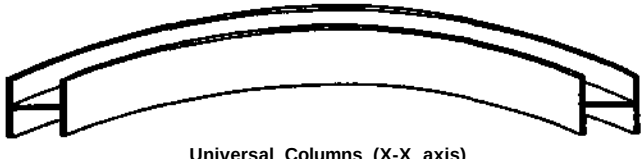
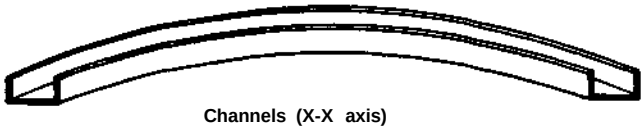
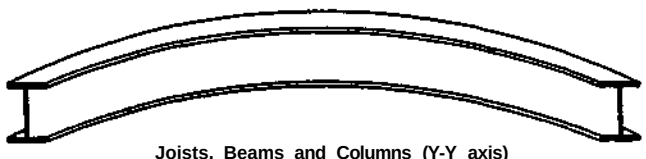
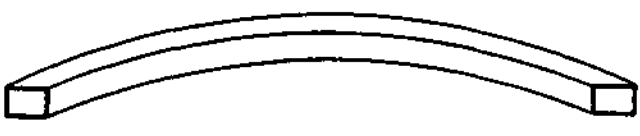
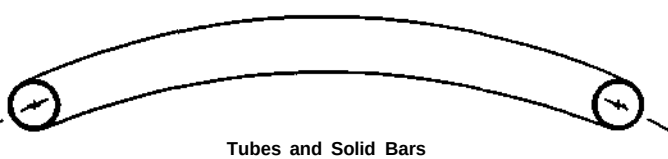
The minimum radius to which any section can be curved depends on its metallurgical properties, particularly its ductility, cross-sectional geometry and its end use. Table 13.1 gives some typical radii to which a range of sections can be curved. This information is provided as a guide to scale only, as the bending specialists should always be consulted when the design of curved members is being considered. There are wide variations in the "bendability" of different sections. Even within one serial size, the heavier sections can usually be curved to a smaller radii than the lighter sections. Similarly sections can usually be rolled to smaller radii on the y-y axis than on the x-x axis. Generally, the radii to which hollow sections can be cold-rolled are much larger than those for I sections of similar size. However, it is possible by the use of hot or cold bending by mandrels to bend hollow sections to very small radii, e.g. circular tubes up to 139.7 mm. o.d. (outer diameter) can be bent to 3 x o.d., but the process is inevitably more expensive than cold-rolling.

13.3 Material properties of curved members

The cold-rolling process deforms the material through the yield point into the plastic range and the material becomes work hardened. Compared with the original material, the work hardened material of the curved section will have a higher effective yield and ultimate stress but at the expense of some loss of ductility. The extent of work-hardening depends mainly on the section geometry and the degree of bending. For most structural steelwork applications, stress relieving will not be required. The non-fatigue "elastic" behaviour of the curved members can be taken as that of the original straight member but it would be wise to limit the design moment capacity to M_y (i.e. Elastic modulus x Design strength).

It is important when dealing with cold-worked sections to the normal good steelwork design to detailing practice, avoiding for example, multiaxial stresses complicated joints, notches etc.

Figure 13.1 *Bending capacity data*

I-Sections, Channels & Hollow Sections (Other profiles - angles, tees, rails etc. - can also be curved)	
 Joists and Universal Beams (X-X axis)	Joists & Universal Beams (X-X axis) All sizes up to *914 x 419 x 388 kg/m
 Universal Columns (X-X axis)	Universal Columns (X-X axis) All sizes up to *356 x 406 x 634 kg/m
 Channels (X-X axis)	Channels (X-X axis) All sizes up to 432 x 102 x 6.54 kg/m
 Joists, Beams and Columns (Y-Y axis)	Joists, Beams & Columns (Y-Y axis) All sizes up to *914 x 419 x 388 kg/m
 S.H.S R.H.S and Solid Bars	Square Hollow Sections (SHS) All sizes up to 300 x 300 x 16 Rectangular Hollow Sections (RHS) All sizes up to 450 x 250 x 16
 Tubes and Solid Bars	Circular Hollow Sections (CHS) Most sizes up to 406.4 o.d. x 32

**Most Euronorm Sizes can also be accommodated.*

Table 13.1 Typical recommended bend radii

Serial size	Typical possible bend radii	
	XX Axis (metres)	Y-Y Axis (metres)
533 x 210 x 122 UB	25	2.5
406 x 178 x 74 UB	18	2.25
305 x 165 x 54 UB	7	2
254 x 146 x 43 UB	5	1.75
203 x 133 x 30 UB	4	1.5
178 x 102 x 19 UB	4	1.25
152 x 89 x 16 UB	2.5	1
127 x 76 x 13 UB	2	1
254 x 203 x 81.85 RSJ	4	2.25
203 x 152 x 52.09 RSJ	2.5	1.75
152 x 127x 37.20 RSJ	1.5	1.5
305 x 305 x 283 UC	6	3.5
254 x 254 x 167 UC	4.5	3
203 x 203 x 86 UC	3	2.25
152 x 152 x 37 UC	2	1.75
250 x 250 x 16 SHS	10	10
200 x 200 x 12.5 SHS	7	7
200 x 100 x10 RHS	4	6
150 x 100 x 10 RHS	2.5	4
120 x 80 x 10 RHS	2	3
219.1 mm x 12.5 mm CHS	3	3
168.3 mm x 10 mm CHS	1.5	1.5
114.3 mm x 6.3 mm CHS	1.25	1.25
60.3 mm x 5 mm CHS	0.75	0.75

The examples shown are not the minimum radii possible.

13.4 Bending of hollow sections for curved structures

There are all manner of means and equipment available today for the bending of hollow sections. There is today very little need for "fire bending" a process used until quite recently for the larger diameter tubes (CHS). By this process the tube is filled with silver sand, rammed home hard, and the ends plugged with a clay compound to hold the sand firm and tightly packed. The tube is heated to 950°C by coke-fired or gas-fired ovens in whatever manageable lengths can be accommodated. The process is highly skilled and labour intensive, often requiring several re-heats and water dousing operations to produce a bend with acceptable tolerances. Fabricators using the "fire bending" technique have to beware of wrinkles on the inside radius, wall thinning and ovality.

13.4.1 Induction process for large radius bending of tubes

These problems do not occur with the induction process, which is now used extensively for bending large diameter tubes.

By this process the tube to be bent is passed through an induction coil where a narrow band of the tube, approximately 13 mm wide, is raised to a forging temperature while the remainder is kept cool by air and water cooling coils.

If required, it is a simple matter to produce a series of multiple bends without the need for intervening straight sections.

The narrowness of the heated zone eliminates pipe wrinkling and no formers or supporting mandrels are required, since the cold tube on either side of the heated zone provides adequate support.

Because of the very high speed of induction heating, neither the outside nor inside wall of the tube develops scaling during bending.

As the tube is pushed rather than pulled round the bend, tubes of different wall thicknesses present no difficulties but do need different heating temperatures and bending rates.

13.4.2 Cold bending process for large radius bending of tubes

Cold bending by section bending rolls is another very satisfactory process for forming bends in tubes or hollow sections. Because there is no cost involved to heat the tube it is often a more economical process than alternatives.

Forming bends by this process is achieved by passing the tube to and fro between three rollers, two of which drive the tube along while the third pinches it to form the bend. The force required to produce the bend is applied in the same manner as a point load in the centre of a simply supported beam.

The minimum radius to which any tube or hollow section can be bent depends on the ductility of the material, cross-section geometry and its end use. The last-named is often the determining factor when the appearance of the work has to be of a very high quality.

Tube becomes oval when bending by this process and, as the radius becomes tighter, wrinkling starts to occur along the inside edge of the radius, and wall thickness thinning occurs along the outer edge of the radius. The stage at which ovality and wrinkling is unacceptable varies with each application.

Some guidelines for the minimum radius for any particular diameter, that can be achieved are:

O/D Tube	Min. radius
76 mm	600 mm
114 mm	800 mm
127 mm	1000 mm
168 mm	1500 mm
178 mm	2000 mm
219 mm	3000 mm

In cold rolling process the material is deformed through the yield stress into the plastic range. As a result it becomes "work hardened" which in turn changes the mechanical properties. In particular it loses the yield plain characteristics and some ductility. However, within the elastic range the stress strain performance is not altered significantly. The change in properties can be important however where there is a fatigue stress or a low temperature condition.

13.4.3 Small radius bending of tubes

Rotary Draw Bending Process is accepted as the most satisfactory process for small radius bending of tubes and hollow sections.

In this process the tube is locked to the former die by the clamp die; a mandrel is inserted to a position where bending takes place. As the former die rotates the pressure die advances with the tube; this supports the back of the tube as it is being drawn off the mandrel during the bending operation.

Machines are available to bend tubes by this process up to and including 114 mm diameter, the limitation to this process is only in the range of former dies available which establishes the centre line radius that can be achieved for every size of tube or hollow section.

13.5 Accuracy of bending

It should be noted that in accordance with Clause 7.2.7 of *BS 5950: Part 2*⁽¹⁾ the deviation from the specified camber ordinate at the mid-length of the portion to be curved should not exceed the greater of 12 mm or 1 mm/m length of curved member. Modern bending machines usually allow greater accuracy than this.

The above information was supplied by:
 The Angle Ring Company Limited
 Barnshaw Section Benders Limited
 Westbury Tubular Structures Limited

13.6 References

1. BRITISH STANDARDS INSTITUTION
 (see Section 19)

14. STAINLESS STEEL IN BUILDING

14.1 Introduction

The term stainless steel covers a range of corrosion and heat resistant iron-based materials which contain at least 12 percent chromium in addition to one or more other alloying elements. Most metals are attacked by oxygen which first forms an oxide film on the surface and then continues to attack deeper into the metal. On some materials, and stainless steel is one of them, the oxide film formed is under compression and provides an invisible self-healing protection for the metal at any temperature to which a building material is likely to be subjected.

14.2 Stainless steel types

Most stainless steels may be classified as austenitic, ferritic or martensitic according to their basic metallurgical structure. Certain stainless steels contain a mixture of these phases and these are the duplex stainless steels. The austenitic group of stainless steels is the most widely used both in building and engineering.

Austenitic stainless steels are alloys of chromium, nickel and iron, and can be welded easily, usually with no preheat or postheat treatments. They are non-magnetic in the fully annealed state, but become slightly magnetic during cold-working. The materials are ductile and are hardened by cold-working but not by heat treatment.

Nickel is the most expensive alloying addition, so the most commonly used alloys are those which contain low percentages of nickel and still remain austenitic, i.e. 18 percent chromium and 8 percent nickel (known as 18-8 or 304) and 18 percent chromium, 10 percent nickel and 3 percent molybdenum (known as 18-10-3 or 316). The low carbon variants (e.g. 304L or 316L) are particularly suitable where welding is to be used.

14.3 Corrosion

There are a number of corrosion mechanisms which, given appropriate circumstances, can attack stainless steel. In buildings, consideration should be given to the possibility of four types of corrosion: galvanic attack, pitting corrosion, crevice corrosion and, occasionally, stress corrosion cracking. All types require the presence of moisture for corrosion to occur, for example continued condensation.

Pitting and crevice corrosion are avoided by using the appropriate grade of stainless steel. Type 316 is more resistant than type 304 and is thus recommended for use in polluted atmospheric environments, see (a) below. Stress corrosion cracking is generally considered not to be a problem at temperatures below about 50°C. It is exacerbated by certain chemical species, particularly halide ions of which chloride is the most prevalent. Ferritic stainless steels are not affected by stress corrosion cracking.

Mild steel in contact with stainless steel may suffer accelerated corrosion by galvanic attack. Attack can be avoided by separating the two materials with bituminous or zinc chromate paint, or washers of impervious, non-porous materials. Galvanic attack depends also on the size ratio of the adjacent components; if the ratio of the size of the stainless steel component to the size of the other component is small, e.g. an aluminium sheet secured by stainless steel fasteners, the effects of galvanic attack is much reduced.

(a) Atmospheric environments

Stainless steels are not affected by clean, moist air, but some may be attacked by polluted air with high sulphur or chloride contents, such as will be found in industrial areas or in marine and coastal environments. The higher alloyed steels offer better resistance to corrosion, but are also more expensive. For most conditions outdoors in the United Kingdom, if surface finish and appearance are important, the 316 type should be used. Further guidance is given in Reference (1).

(b) Swimming pool environments

Special care should be taken in the use of stainless steel in swimming pool or similar environments and in particular, with roof and ceiling fixings. Under certain conditions of stress, elevated temperatures and presence of chlorides, the protective oxide film is broken down giving rise to "stress corrosion cracking". See Reference (2).

(c) Chemicals

Stainless steel is resistant to attack from many chemical agents but expert advice should always be sought. Stainless steel producers are often willing to provide such advice.

14.4 Staining

Stainless steel is compatible with most building materials; it can be used safely in contact with or embedded in concrete or plaster, and will not cause staining of marble or other light-coloured material with which it is in contact. The wash from it will not cause staining of adjacent materials.

14.5 Surface finish

Dependent on the finishing processes of the sheet, the material can be given a dull, matt or bright finish, and it can be polished. Complex shapes can be polished electro-chemically. Textured finishes can be produced by rolling or pressing although care must be exercised in planning the cutting of sheets to use the material economically.

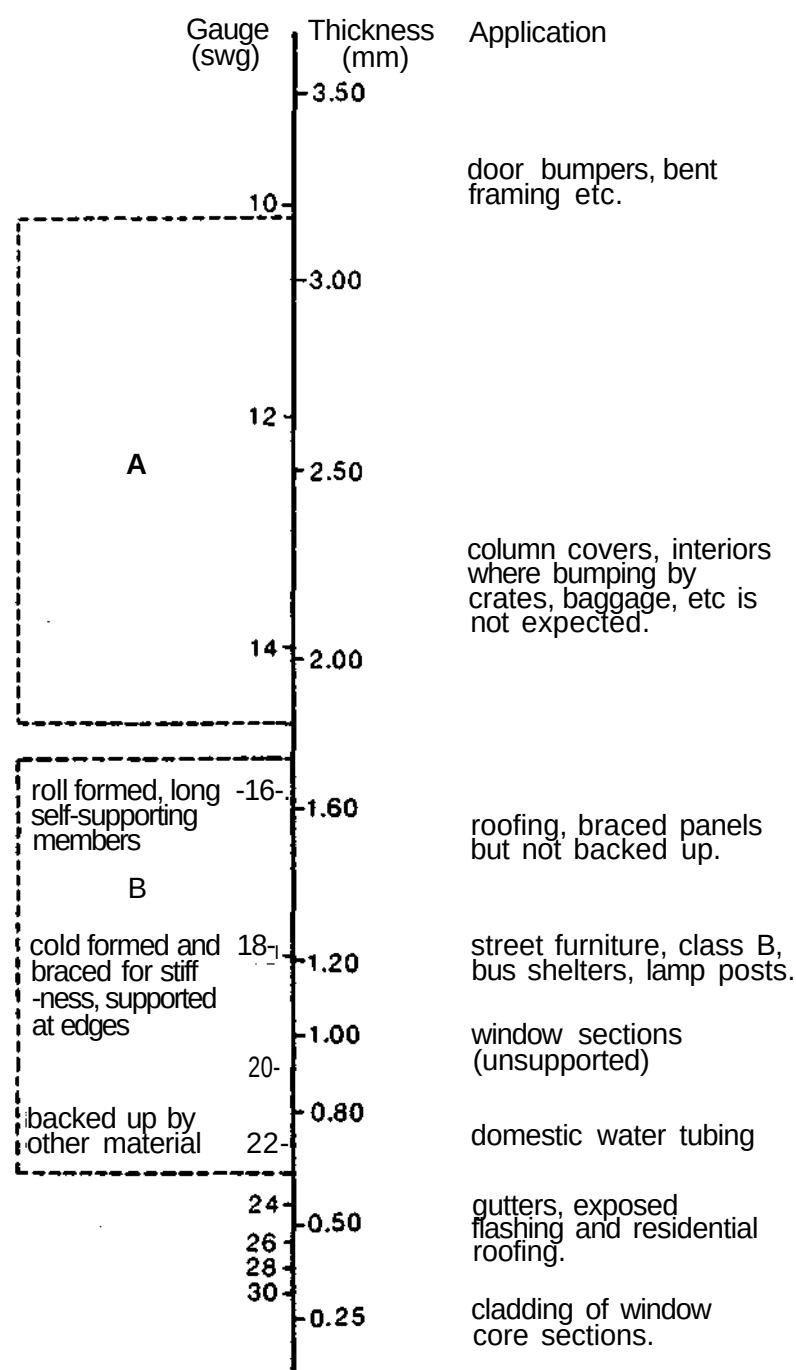
14.6 Fabrication

The high ductility of austenitic steel allows it to be bent to very small radii, but because it work hardens, much greater loads are required for forming and pressing than are required for mild steel, and annealing may be necessary after fabrication. Joints can be made by lock-seaming, soldering, brazing, welding and adhesives, but for brazing and fusion welding thick materials it may be necessary to use either low carbon steel or steels stabilised by the addition of titanium or niobium.

The choice of joining method must be made with regard to service as well as fabrication conditions, and requires expert advice. Note that it is important to use separate fabrication areas and tools for mild steel and stainless steel to avoid possible contamination of the stainless steel.

14.7 Applications and design considerations

Compared weight for weight with other building materials, stainless steel is expensive, but its properties of strength and corrosion resistance should be considered in relation to the weight that can be saved. For economy, components should be as thin as possible (Figure 14.1 shows suggested thicknesses for various applications) and the least expensive alloy and form (usually roll-finished) suitable for the application should be selected. Its low thermal expansion makes it particularly useful in the design of large panels or sections, but very large, flat areas can suffer from optical distortion unless the sheets are supported by battens. If continuous backing is not feasible, the use of patterned rather than polished sheets should be considered; care should be taken to use a pattern that does not retain dirt.



A. includes street level column covers, fascia panels, mullions and transoms, pilasters - stiffened with braces but not completely backed up.

B. includes curtain walls, spandrels, mullions and transoms above street level.

Figure 14.1 Suggested thicknesses for various applications

The steels are available in the following forms: plate, sheet, strip, bar, sections (hot-rolled, extruded, drawn, and especially cold formed), forgings, tubes (solid drawn and welded), wire and castings.

The durability of stainless steel could be used in the reduction of maintenance costs. Little advantage would be gained in applications of simple and cheap replacement or where occasional changes are required for aesthetic or decorative purposes. The advantages lie in applications of permanent strength, function or appearance such as nails, fixings and ties, especially those positioned out of sight, embedded in building materials or underground. Externally the material is used in roofing generally, and for flashings and weatherings, where failure could lead to troublesome internal damage, particularly with buildings not subjected to routine inspection. Attention is again drawn to the need for special care in the use of stainless steel in swimming pools or similar environments.

14.8 Material grades

As stated above in Section 14.2, the austenitic grades of stainless steel are the most appropriate for building applications, and types 304 and 316 are the most generally specified. In plate, sheet and strip form, these materials are produced to *BS 1449: Part 2:1983*⁽³⁾, the mechanical properties are given in Table 14.1.

Stainless steels with a 0.2% proof stress approximately 40% higher are produced to *BS 1501: Part 3:1990*⁽³⁾; the higher level being attained by the inclusion of nitrogen. The mechanical properties of this plate material are given in Table 14.2.

Table 14.1 Mechanical properties of stainless steel to BS1449: Part2⁽³⁾

Grade	0.2% Proof Stress N/mm ² (min.)	Tensile Strength N/mm ² (min.)	Elongation %	Condition
304S11*	180	480	40	Softened
304S15 304S16	195	500	40	*
304S31	195	500	40	*
316S11* 316S13*	190	490	40	*
316S31 316S33	205	510	40	*

* Denotes Stainless Steels with a Low Carbon Content

Table 14.2 Mechanical properties of stainless steel to BS1501:Part3⁽³⁾

Grade	0.2% Proof stress N/mm ² (min.)	1% Proof stress N/mm ² (min.)	Tensile strength N/mm ² (min.)	Elongation %
304S61	(270)	305	550	35
316S61	(280)	315	580	35

14.9 References

1. NICKEL DEVELOPMENT INSTITUTE
An architect's guide on corrosion resistance
Nickel Development Institute, Toronto, January 1990
2. PAGE, C.L., and ANCHOR, R.D.
Stress corrosion cracking of stainless steels in swimming pools
The Structural Engineer. Volume 66, No. 24., p.416, December 1988, London
3. BRITISH STANDARDS INSTITUTION
(see Section 19)

Acknowledgment

Information for the above section was obtained from the BRE Digest 121 September 1970
"Stainless Steel as a Building Material".

15. FIRE PROTECTION OF STRUCTURAL STEELWORK

Structural sections used in buildings may or may not require fire protection depending upon the situations in which they are used. If fire protection is needed, the requirement is that the steel is kept below the limiting temperature as defined in *BS 5950: Part 8*⁽¹⁾⁽²⁾. Traditionally this has been assumed to be 550°C but in Part 8 the limiting temperature is defined as a function of the load on the member. Many proprietary materials (boards, sprays, intumescent and preformed systems) are available to protect structural steelwork (see Section 15.3).

Filling hollow steel sections with water or concrete to provide fire protection can eliminate or reduce the need for additional protection.

Fire protection of columns can also be eliminated or reduced by positioning them outside the shell of the building.

Designers should refer for fuller details of fire protection requirements, methods of fire protection, and fire protection materials to the publications listed in Section 15.10.

15.1 Section factors

The performance of a structural steel member in fire depends on the relative proportion of the steel surface exposed, i.e. its heated perimeter (H_p) and the thickness of steel, which is related to its cross-sectional area (A). The ratio H_p/A is the section factor.

H_p = Perimeter of the section exposed to fire (m)

A = Cross-sectional area of the steel member (m²)

The lower the H_p/A value, the slower will be the rate of heating in a fire.

15.2 Forms of protection

There are three main types of fire protection that should be considered (Figure 15.1) and they are described below.

Profile protection is where the fire protection follows the surface of the member. Therefore the section factor relates to the proportions of the steel member.

Box protection is where there is an outer casing around the member. The heated perimeter is defined as the sum of the inside dimensions of the smallest possible rectangle, around the section, neglecting air gaps etc. (refer to Figure 15.1). The cross-sectional area, A , is that of the steel section. The thermal conductivity of the protection material is assumed to be much lower than that of steel and therefore, the temperature conditions within the area bounded by the box protection are assumed to be uniform.

Solid protection is where the member is encased (typically by concrete). This is a more complex case because of the non-uniform thermal profile through the concrete. If only part of the member is exposed (for example the lower flange), then the heated perimeter may be taken around the portion that is exposed. This assumes that the passage of heat through the concrete relative to the steel is small.

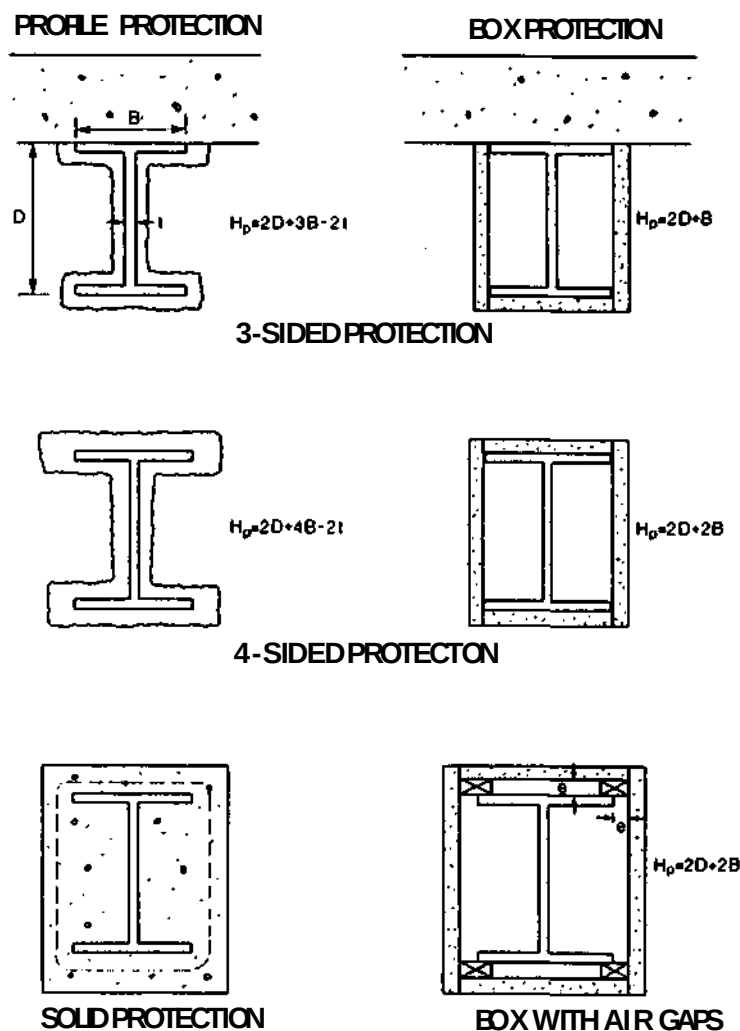


Figure 15.1 Different forms of fire protection to I section members

15.3 Performance of proprietary fire protective materials

A number of different forms of proprietary fire protective materials are marketed. In simple terms these are:

- cementitious-type sprays, such as perlite-cement, vermiculite, vermiculite-cement, glass or mineral fibre-cement sprays
- fire boards, such as fibro-silicate, gypsum and vermiculite
- mineral fibre and other similar mat materials
- intumescent coatings.

There are a number of different manufacturers of each of these systems. Sprayed fire protection appears to be currently popular in commercial steel buildings where the floor soffit is hidden and where additional cladding is provided around the steel columns. Box or board systems are more popular where the protection to the beams and columns is left exposed.

Sprayed systems are usually applied in a number of layers. A priming coat applied to the steel section may be recommended by the manufacturer. The main advantage of sprayed systems is that they can easily protect complicated beam-column junctions, trusses and secondary elements. Their main disadvantage is the mess and dust created during spraying.

Board systems often use additional noggings and filler pieces between the flanges of the beam which the boards are attached. Their method of jointing is important in order to prevent gaps opening up. Pre-formed box systems are also used.

Intumescent coatings are those which expand or "intumesce" on heating, thereby offering protection to the steelwork. They are generally used for architectural reasons where the steelwork is left fully exposed. Thin intumescent coatings (1 to 2 mm thick) can provide up to 1 % hour fire resistance.

15.4 Amount of protection

The amount of fire protection required depends upon the configuration of protection, fire resistance period, and the H_p/A value of the section involved. Information in manufacturers literature is presented in either graphical or tabular formats and a knowledge of the H_p/A value of the section involved is essential to decide the protection thickness.

The method of determining the thickness of fire protection in *BS 5950: Part 8*⁽¹⁾ is based on the European approach where temperature dependent properties of the protection are inserted into a design formula. Traditionally, the "Yellow Book", *Fire protection for structural steel in buildings*⁽⁴⁾ has been used. In this publication, tables are presented which are derived from a semi-empirical approach based on the results of fire tests. Information on the use of traditional material such as concrete, blockwork and brick, may be obtained from the BRE publication⁽¹⁴⁾.

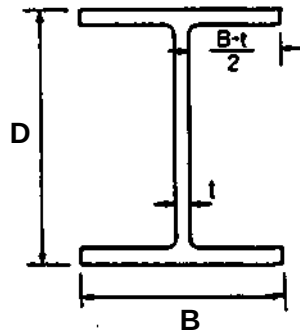
15.5 Calculation of H_p/A values

The section factor H_p/A is not a constant for a given section but will vary according to whether the protection forms a box encasement or follows the profile of the section for both 3 sided or 4 sided attack from fire.

The value of H_p , the exposed perimeter, depends upon the configuration of the fire protection. In the case of box protection, H_p is measured as the perimeter of shortest length which will enclose the section, whilst for profile protection the H_p value is taken as the perimeter of the steel. The equations given in Section 15.5.1 demonstrate how H_p is calculated for various steel sections in different situations. No account is taken of the radii at the corners of the sections.

In all situations, values of A , the cross-sectional area of the section, are taken from tables for the various serial sizes and weights per metre. H_p/A values for universal beams, universal columns and hollow sections are given in the Tables 15.1 to 15.5. It is normal in published tables to quote the section factor to the nearest 5 units.

15.5.1 Universal beams, columns and Joists



Box protection

Boxed (4 sided exposure)

$$H_p = 2B + 2D$$

Profile protection

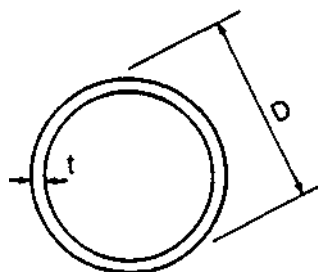
Profile (4 sided exposure)

$$H_p = 2B + 2D + \frac{4(B - t)}{2}$$

Boxed (3 sided exposure)
 $H_p = B + 2D$

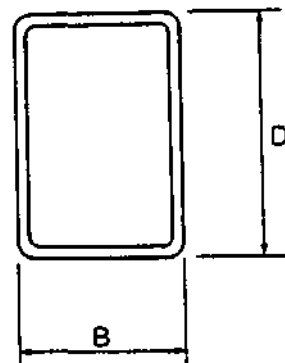
Profile (3 sided exposure)
 $H_p = B + 2D + \frac{4(B - t)}{2}$

15.5.2 Hollow sections



Circular hollow section

$$H_p \approx \pi D$$



Rectangular hollow section

$$H_p = 2B + 2D \text{ (4 sided)}$$

$$H_p = B + 2D \text{ (3 sided) or } 2B + D \text{ (3 sided)}$$

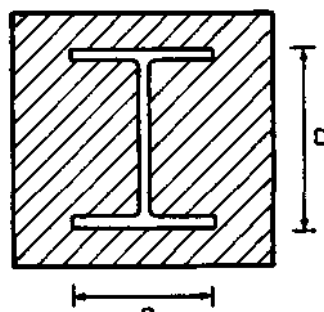
The shape of hollow section is such that the perimeter is the same for both profile and box protection.

A similar approach should be used for channels, angles and tees. Detailed advice is given in the Reference (4).

Specific examples are presented below to show how H_p/A values are estimated for different situations to demonstrate the principles.

(i) Solid or hollow box protection

Consider a 203 mm x 203 mm x 52 kg/m universal column, solid or box exposed on four sides, as an example.



$H_p \text{ (4-sided)} = 2D + 2B \text{ in m}$
 $A = \text{Cross-sectional area of steel element in m}^2$

In this case:

$$B = 203.9 \text{ mm}$$

$$D = 206.2 \text{ mm}$$

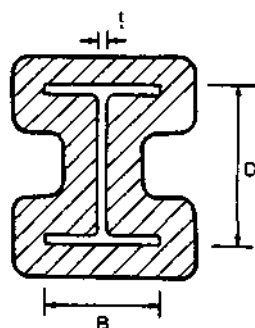
$$H_p = (2 \times 206.2) + (2 \times 203.9) = 820.2 \text{ mm} = 0.8202 \text{ m}$$

$$A = 66.4 \text{ cm}^2 = 0.00664 \text{ m}^2$$

$$H_p / A = \frac{0.8202 \text{ m}}{0.00664 \text{ m}^2} = 124 \text{ m-l}$$

(ii) Profile protection

Consider a 406 mm x 178 mm x 60 kg/m universal beam, profile exposed on four sides, as an example.



$$H_p, (4\text{-sided}) = 2B + 2D + 2(B - t) \text{ in m}$$

$$A = \text{Cross-sectional area of steel element in } \text{m}^2$$

In this case:

$$B = 177.8 \text{ mm}$$

$$D = 406.4 \text{ mm}$$

$$t = 7.8 \text{ mm}$$

$$H_p = (2 \times 406.4) + (2 \times 177.8) + \frac{4(177.8 - 7.8)}{2} = 1508.4 \text{ mm} = 1.5084 \text{ m}$$

$$A = 76.0 \text{ cm}^2 = 0.0076 \text{ m}^2$$

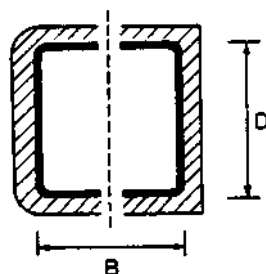
$$H_p/A = \frac{1.5084 \text{ m}}{0.0076 \text{ m}^2} = 198 \text{ m}^{-1}$$

(iii) Rectangular hollow sections

Consider a 300 x 300 x 10 RHS, exposed on four sides, as an example.

For rectangular hollow sections there is no distinction between box and profile protection.

Profile
Protection



Box
Protection

$$H_p = 2B + 2D \text{ (4 sided exposure)}$$

$$A = \text{Cross-sectional area from tables.}$$

In this case:

$$D = B = 300 \text{ mm}$$

$$H_p = (2 \times 300) + (2 \times 300) = 1200 \text{ mm} = 1.2 \text{ m}$$

$$A = 116 \text{ cm}^2 = 0.0116 \text{ m}^2$$

$$H_p/A = \frac{1.2 \text{ m}}{0.0116 \text{ m}^2} = 103 \text{ m}^{-1}$$

For concrete filled RHS, please refer to *Design manual for SHS concrete filled columns*⁽¹¹⁾ from British Steel General Steels - Welded Tubes.

Table 15.1 H_p/A values for universal beams.

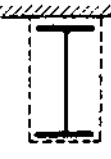
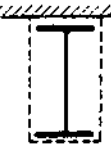
Universal beams							Section factor H_p/A			
							Profile		Box	
							3 sides	4 sides	3 sides	4 sides
										
Designation		Depth of section D	Width of section B	Thickness		Area of section				
Serial size	Mass per metre			Web t	Flange T					
mm	kg	mm	mm	mm	mm	cm ²	m ⁻¹	m ⁻¹	m ⁻¹	m ⁻¹
914x41 9	388	920 5	420 5	21.5	36.6	494.4	60	70	45	55
	343	911 4	418 5	19.4	32.0	437.4	70	80	50	60
	289	926 6	307 8	19.6	32.0	388.8	75	80	60	65
	253	918 5	305 5	17.3	27.9	322.8	85	95	65	75
	224	910 3	304 1	15.9	23.9	285.2	95	105	75	85
888 x 29.2	201	903	308 4	15.2	20.2	256.4	105	115	80	95
	226	880 9	298 8	16.1	26.8	288.7	85	95	70	80
	194	840 7	292 4	14.7	21.7	247.1	100	115	80	90
	176	834 9	291 6	14	18.8	224.1	no	125	90	100
	197	789 6	268	15.6	25.4	250.7	90	100	70	85
762x26 7	173	762	266 7	14.3	21.6	220.4	105	115	80	95
	147	753 9	265 3	12.9	17.5	188.0	120	135	95	110
	170	692 9	255 8	14.5	23.7	216.5	95	no	75	90
	152	687 6	254 5	13.2	21.0	198.8	110	120	85	95
686x25 4	140	683 5	253 7	12.4	19.0	178.6	115	130	90	105
	125	677 9	253	11.7	16.2	159.6	130	145	100	115
	238	633	311 5	18.6	31.4	303.7	70	80	50	60
	179	617 5	307	14.1	23.6	227.9	90	105	70	80
610x30 5	149	609 6	304 8	11.9	19.7	190.1	no	125	80	95
	140	617	230 1	13.1	22.1	178.3	105	120	80	95
	125	611 9	229	11.9	19.6	159.5	115	130	90	105
	113	607 3	228 2	11.2	17.3	144.4	130	145	100	115
610x22 9	101	602 2	227 6	10.6	14.8	129.1	145	160	110	130
	122	544 6	211 9	12.8	21.3	155.7	110	120	85	95
	109	539 5	210 7	11.6	18.8	138.5	120	135	95	110
	101	536 7	210 1	10.9	17.4	129.7	130	145	100	115
533x21 0	92	533 1	209 3	10.2	15.6	117.7	140	160	110	125
	82	528 3	208 7	9.6	13.2	104.4	155	175	120	140
	98	467 4	192 8	11.4	19.6	125.2	120	135	90	105
	89	463 6	192	10.6	17.7	113.9	130	145	100	115
457 x 19.1	82	460 2	191 3	9.9	16.0	104.5	140	160	105	125
	74	457 2	190 5	9.1	14.5	94.8	155	175	115	135
	67	453 6	189 9	8.5	12.7	85.4	170	190	130	150
	82	465 1	153 5	10.7	18.9	104.4	130	145	105	120
457 x 15.2	74	461 3	152 7	9.9	17.0	94.9	140	155	115	130
	67	457 2	151 9	9.1	15.0	85.4	155	175	125	145
	60	454 7	152 9	8.0	13.3	75.9	175	195	140	160
	52	449 8	152 4	7.6	10.9	66.4	200	220	160	180
406 x 17.8	74	412 8	179 7	9.7	16.0	94.9	140	160	105	125
	67	409 4	178 8	8.8	14.3	85.4	155	175	115	140
	60	406 4	177 8	7.8	12.8	76.0	175	195	130	155
	54	402 6	177 6	7.6	10.9	68.4	190	215	145	170
406 x 14.0	46	402 3	142 4	6.9	11.2	58.6	205	230	160	185
	39	397 3	141 8	6.3	8.6	49.4	240	270	190	220
356 x 17.1	67	364	173 2	9.1	15.7	85.4	140	160	105	125
	57	358 6	172 1	8	13.0	72.1	165	190	125	145
	51	355 6	171 5	7.3	11.5	64.5	185	210	135	165
	45	352	171	6.9	9.7	56.9	210	240	155	185
356 x 12.7	39	352 8	126	6.5	10.7	49.4	215	240	170	195
	33	248 5	125 4	5.9	8.5	41.8	250	280	195	225
305 x 16.5	54	310 9	166 8	7.7	13.7	68.3	160	185	115	140
	46	307 1	165 7	6.7	11.8	58.9	185	210	130	160
	40	303 8	165 1	6.1	10.2	51.5	210	240	150	180
305 x 12.7	48	310 4	125 2	9.9	14.0	60.3	160	180	125	145
	42	306 6	124 3	8	12.1	53.1	180	205	140	160
	37	303 8	123 5	7.2	10.7	47.4	200	225	155	180
305 x 10.2	33	312 7	102 4	6.6	10.8	41.7	215	240	175	200
	28	308 9	101 9	6.1	8.9	36.3	245	275	200	225
	25	304 8	101 6	5.8	6.8	31.3	285	315	225	260
254 x 14.6	43	259 6	147 3	7.3	12.7	55.1	170	195	120	150
	37	256	146 4	6.4	10.9	47.4	195	225	140	170
	31	251 5	146 1	6.1	8.6	40.0	230	265	160	200
	28	250 4	102 1	6.4	10.0	36.1	220	250	170	200
254 x 10.2	25	257	101 9	6.1	8.4	32.1	245	280	190	225
	22	254	101 6	5.8	6.8	28.4	275	315	215	250
203 x 13.3	30	206 8	133 8	6.3	9.6	38.0	210	245	145	180
	25	203 2	133 4	5.5	7.8	32.3	240	285	165	210
203 x 10.2	23	203 2	101 6	5.2	9.3	29	235	270	175	210
	178 x 10.2	177 8	101 6	4.7	7.9	24.2	265	305	190	230
152 x 8.9	16	152 4	88 9	4.6	7.7	20.5	270	310	190	235
	13	127	76 2	4.2	7.6	16.8	275	320	195	240

Table 15.2 H_p/A values for universal columns

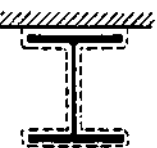
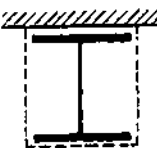
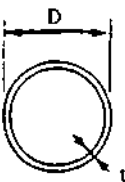
Universal columns							Section factor H_p/A			
							Profile		Box	
							3 sides	4 sides	3 sides	4 sides
										
Designation		Depth of section D	Width of section B	Thickness		Area of section				
Serial size	Mass per metre			Web t	Flange T					
mm	kg	mm	mm	mm	mm	cm ²	m ⁻¹	m ⁻¹	m ⁻¹	m ⁻¹
356 x 406	634	474.7	424.1	47.6	77.0	808.1	25	30	15	20
	551	455.7	418.5	42.0	67.5	701.8	30	35	20	25
	467	436.6	412.4	35.9	58.0	595.5	35	40	20	30
	393	419.1	407.0	30.6	49.2	500.9	40	45	25	35
	340	406.4	403.0	26.5	42.9	432.7	45	55	30	35
	287	393.7	399.0	22.6	36.5	366.0	50	65	30	45
	235	381.0	395.0	18.5	30.2	299.8	65	75	40	50
356 x 368	202	374.7	374.4	16.8	27.0	257.9	70	85	45	60
	177	368.3	372.1	14.5	23.8	225.7	80	95	50	65
	153	362.0	370.2	12.6	20.7	195.2	90	110	55	75
	129	355.6	368.3	10.7	17.5	164.9	105	130	65	90
305 x 305	283	365.3	321.8	26.9	44.1	360.4	45	55	30	40
	240	352.6	317.9	23.0	37.7	305.6	50	60	35	45
	198	339.9	314.1	19.2	31.4	252.3	60	75	40	50
	158	327.2	310.6	15.7	25.0	201.2	75	90	50	65
	137	320.5	308.7	13.8	21.7	174.6	85	105	55	70
	118	314.5	306.8	11.9	18.7	149.8	100	120	60	85
	97	307.8	304.8	9.9	15.4	123.3	120	145	75	100
254 x 254	167	289.1	264.5	19.2	31.7	212.4	60	75	40	50
	132	276.4	261.0	15.6	25.3	167.7	75	90	50	65
	107	266.7	258.3	13.0	20.5	136.6	90	110	60	75
	89	260.4	255.9	10.5	17.3	114.0	110	130	70	90
	73	254.0	254.0	8.6	14.2	92.9	130	160	80	110
203 x 203	86	222.3	208.8	13.0	20.5	110.1	95	110	60	80
	71	215.9	206.2	10.3	17.3	91.1	110	135	70	95
	60	209.6	205.2	9.3	14.2	75.8	130	160	80	110
	52	206.2	203.9	8.0	12.5	66.4	150	180	95	125
	46	203.2	203.2	7.3	11.0	58.8	165	200	105	140
152 x 152	37	161.8	154.4	8.1	11.5	47.4	160	190	100	135
	30	157.5	152.9	6.6	9.4	38.2	195	235	120	160
	23	152.4	152.4	6.1	6.8	29.8	245	300	155	205

Table 15.3 H_p/A values for circular hollow sections

Circular hollow sections						Section factor H_p/A	
				Profile or Box			
Designation		Mass per metre	Area of section				
Outside diameter D	Thickness t						
mm	mm	kg	cm ²	m ⁻¹			
21.3	3.2	1.43	1.82	370			
26.9	3.2	1.87	2.38	355			
33.7	2.6	1.99	2.54	415			
	3.2	2.41	3.07	345			
	4.0	2.93	3.73	285			
42.4	2.6	2.55	3.25	410			
	3.2	3.09	3.94	340			
	4.0	3.79	4.83	275			
48.3	3.2	3.56	4.53	335			
	4.0	4.37	5.57	270			
	5.0	5.34	6.80	225			
60.3	3.2	4.51	5.74	330			
	4.0	5.55	7.07	270			
	5.0	6.82	8.69	220			
76.1	3.2	5.75	7.33	325			
	4.0	7.11	9.06	265			
	5.0	8.77	11.2	215			
88.9	3.2	6.76	8.62	325			
	4.0	8.38	10.70	260			
	5.0	10.3	13.2	210			
114.3	3.6	9.83	12.5	285			
	5.0	13.5	17.2	210			
	6.3	16.8	21.4	170			
139.7	5.0	16.6	21.2	205			
	6.3	20.7	26.4	165			
	8.0	26.0	33.1	135			
168.3	10.0	32.0	40.7	110			
	5.0	20.1	25.7	205			
	6.3	25.2	37.1	165			
193.7	8.0	31.6	40.3	130			
	10.0	39.0	49.7	105			
	5.0	23.3	29.6	205			
219.1	6.3	29.1	37.1	165			
	8.0	36.6	46.7	130			
	10.0	45.3	57.7	105			
244.5	12.5	55.9	71.2	85			
	16.0	70.1	89.3	70			
	5.0	26.4	33.6	205			
273.0	6.3	33.1	42.1	165			
	8.0	41.6	53.1	130			
	10.0	51.6	65.7	105			
323.9	12.5	63.7	81.1	85			
	16.0	80.1	102	65			
	20.0	98.2	125	55			

continued

				Section factor H_p/A			
				Profile or Box			
Designation		Mass per metre	Area of section				
Outside diameter D	Thickness t						
mm	mm	kg	cm ²	m ⁻¹			
244.5	6.3	37.0	47.1	165			
	8.0	46.7	59.4	130			
	10.0	57.8	73.7	105			
	12.5	71.5	91.1	85			
	16.0	90.2	115	65			
	20.0	111	141	55			
273.0	6.3	41.4	52.8	160			
	8.0	52.3	66.6	130			
	10.0	64.9	82.6	105			
	12.5	80.3	102	85			
	16.0	101	129	65			
	20.0	125	159	55			
323.9	25.0	153	195	45			
	6.3	49.3	62.9	160			
	8.0	62.3	79.4	130			
	10.0	77.4	98.6	105			
	12.5	96.0	122	85			
	16.0	121	155	65			
355.6	20.0	150	191	55			
	25.0	184	235	45			
	8.0	68.6	87.4	130			
	10.0	85.2	109	100			
	12.5	106	135	85			
	16.0	134	171	65			
406.4	20.0	166	211	55			
	25.0	204	260	45			
	10.0	97.8	125	100			
	12.5	121	155	80			
	16.0	154	196	65			
	20.0	191	243	55			
457.0	25.0	235	300	45			
	32.0	295	376	35			
	10.0	110	140	105			
	12.5	137	175	80			
	16.0	174	222	65			
	20.0	216	275	50			
508.0	25.0	266	339	40			
	32.0	335	427	35			
	40.0	411	524	25			
	10.0	123	156	100			
	12.5	153	195	80			
	16.0	194	247	65			

Rectangular hollow sections (square)				Section factor H_p/A	
				3 sides	4 sides
Designation		Mass per metre	Area of section		
Size D x D	Thickness t				
mm	mm	kg	cm ²	m ⁻¹	m ⁻¹
20x20	2.0	1.12	1.42	425	565
	2.5	1.35	1.72	350	465
25x25	2.0	1.43	1.82	410	550
	2.5	1.74	2.22	340	450
	3.0	2.04	2.60	290	385
	3.2	2.15	2.74	275	365
30x30	2.5	2.14	2.72	330	440
	3.0	2.51	3.20	280	375
	3.2	2.65	3.38	265	355
40x40	2.5	2.92	3.72	325	430
	3.0	3.45	4.40	275	365
	3.2	3.66	4.66	260	345
	4.0	4.46	5.68	210	280
50x50	5.0	5.40	6.88	175	235
	2.5	3.71	4.72	320	425
	3.0	4.39	5.60	270	355
	3.2	4.66	5.94	255	335
60x60	4.0	5.72	7.28	205	275
	5.0	6.97	8.88	170	225
	6.3	8.49	10.8	140	185
	3.0	5.34	6.80	265	355
	3.2	5.67	7.22	250	330
70x70	4.0	6.97	8.88	205	270
	5.0	8.54	10.9	165	220
	6.3	10.5	13.3	135	180
	8.0	12.8	16.3	110	145
	3.0	6.28	8.00	260	350
80x80	3.6	7.46	9.50	220	295
	5.0	10.1	12.9	165	215
	6.3	12.5	15.9	130	175
	8.0	15.3	19.5	110	145
	3.0	7.22	9.20	260	350
90x90	3.6	8.59	10.9	220	295
	5.0	11.7	14.9	160	215
	6.3	14.4	18.4	130	175
	8.0	17.8	22.7	105	140
	3.6	9.72	12.4	220	290
100x100	5.0	13.3	16.9	160	215
	6.3	16.4	20.9	130	170
	8.0	20.4	25.9	105	140
	4.0	12.0	15.3	195	260
	5.0	14.8	18.9	160	210
	6.3	18.4	23.4	130	170
	8.0	22.9	29.1	105	135
	10.0	27.9	35.5	85	115

continued				Section factor H_p/A	
				3 sides	4 sides
Designation		Mass per metre	Area of section		
Size D x D	Thickness t				
mm	mm	kg	cm ²	m ⁻¹	m ⁻¹
120 x 120	5.0	18.0	22.9	155	210
	6.3	22.3	28.5	125	170
	8.0	27.9	35.5	100	135
	10.0	34.2	43.5	85	110
	12.5	41.6	53.0	70	90
140 x 140	5.0	21.1	26.9	155	210
	6.3	26.3	33.5	125	165
	8.0	32.9	41.9	100	135
	10.0	40.4	51.5	80	110
	12.5	49.5	63.0	65	90
150 x 150	5.0	22.7	28.9	155	210
	6.3	28.3	36.0	125	165
	8.0	35.4	45.1	100	135
	10.0	43.6	55.5	80	110
	12.5	53.4	68.0	65	90
180 x 180	16.0	66.4	84.5	55	70
	6.3	34.2	43.6	125	165
	8.0	43.0	54.7	100	130
	10.0	53.0	67.5	80	105
	12.5	65.2	83.0	65	85
200 x 200	16.0	81.4	104	50	70
	6.3	38.2	48.6	125	165
	8.0	48.0	61.1	100	130
	10.0	59.3	75.5	80	105
	12.5	73.0	93.0	65	85
250 x 250	16.0	91.5	117	50	70
	6.3	48.1	61.2	125	165
	8.0	60.5	77.1	95	130
	10.0	75.0	95.5	80	105
	12.5	92.6	118	65	85
300 x 300	16.0	117	149	50	65
	10.0	90.7	116	80	105
	12.5	112	143	65	85
	16.0	142	181	50	65
	10.0	106	136	75	105
350 x 350	12.5	132	168	65	85
	16.0	167	213	50	65
400 x 400	10.0	122	156	75	105
	12.5	152	193	60	85
	16.0	192	245	50	65

Table 155 H_p/A values for rectangular hollow

Rectangular hollow sections				Section factor H_p/A		
				3 sides		4 sides
Designation		Mass per metre	Area of section			
Size D x B	Thickness t					
mm	mm	kg	cm ²	m ⁻¹	m ⁻¹	m ⁻¹
50x25	2.5	2.72	3.47	360	290	430
	3.0	3.22	4.10	305	245	365
	3.2	3.41	4.34	290	230	345
50x30	2.5	2.92	3.72	350	295	430
	3.0	3.45	4.40	295	250	365
	3.2	3.66	4.66	280	235	345
	4.0	4.46	5.68	230	195	280
	5.0	5.40	6.88	190	160	235
60x40	2.5	3.71	4.72	340	295	425
	3.0	4.39	5.60	285	250	355
	3.2	4.66	5.94	270	235	335
	4.0	5.72	7.28	220	190	275
	5.0	6.97	8.88	180	160	225
80x40	3.0	8.49	10.8	150	130	185
	3.0	5.34	6.80	295	235	355
	3.2	5.67	7.22	275	220	330
	4.0	6.97	8.88	225	180	270
	5.0	8.54	10.9	185	145	220
90x50	6.3	10.5	13.3	150	120	180
	8.0	12.8	16.3	125	100	145
	3.0	6.28	8.00	290	240	350
	3.6	7.46	9.50	240	200	295
	5.0	10.1	12.9	180	145	215
100x50	6.3	12.5	15.9	145	120	175
	8.0	15.3	19.5	120	95	145
	3.0	6.75	8.60	290	235	350
	3.2	7.18	9.14	275	220	330
	4.0	8.86	11.3	220	175	265
100x60	5.0	10.9	13.9	180	145	215
	6.3	13.4	17.1	145	115	175
	8.0	16.6	21.1	120	95	140
	3.0	7.22	9.20	285	240	350
	3.6	8.59	10.9	240	200	295
120x60	5.0	11.7	14.9	175	150	215
	6.3	14.4	18.4	140	120	175
	8.0	17.8	22.7	115	95	140
	3.0	9.72	12.4	240	195	290
	3.6	13.3	16.9	180	140	215
120x80	6.3	16.4	20.9	145	115	170
	8.0	20.4	25.9	115	95	140
	5.0	14.8	18.9	170	150	210
	6.3	18.4	23.4	135	120	170
	8.0	22.9	29.1	110	95	135
150x100	10.0	27.9	35.5	90	80	115
	5.0	18.7	23.9	165	145	210
	6.3	23.8	29.7	135	120	170
	8.0	29.1	37.1	110	95	135
	10.0	35.7	45.5	90	75	110
160x10	12.5	43.6	55.5	70	65	90
	5.0	18.0	22.9	175	140	210
	6.3	22.3	28.5	140	110	170
	8.0	27.9	35.5	115	90	135
	10.0	34.2	43.5	90	75	110
200x100	12.5	41.6	53.0	75	60	90
	5.0	22.7	28.9	175	140	210
	6.3	28.3	36.0	140	110	165
	8.0	35.4	45.1	110	90	135
	10.0	43.6	55.5	90	70	110
250x150	12.5	53.4	68.0	75	60	90
	16.0	66.4	84.5	60	45	70
	6.3	38.2	48.6	135	115	165
	8.0	48.0	61.1	105	90	130
	10.0	59.3	75.5	85	75	105
300x200	12.5	73.0	93.0	70	60	85
	16.0	91.5	117	55	45	70
	6.3	48.1	61.2	130	115	165
	8.0	60.5	77.1	105	90	130
	10.0	75.0	95.5	85	75	105
400x200	12.5	92.6	118	70	60	85
	16.0	117	149	55	45	70
	10.0	90.7	116	85	70	105
	12.5	112	143	70	55	85
	16.0	142	181	55	45	70
450x250	10.0	106	136	85	70	105
	12.5	132	168	70	55	85
	16.0	167	213	55	45	70

15.6 Half-hour fire resistant steel structures, free-standing blockwork-filled columns and stanchions

As a result of tests carried out to *BS 476: Part 8*⁽¹⁾ it has been shown that large universal sections with small section factors (H_p/A) have inherent half-hour fire resistance and this can be used in the fully exposed state To satisfy the minimum requirements of building regulations. For smaller universal section sizes, half-hour fire resistance can be achieved by fitting light weight concrete blocks between the section flanges as shown in Figure 15.2. This form of protection shields the web and inner surfaces of the flanges from radiant and convected heat so that the section will heat up much more slowly than the unprotected section.

The main advantages are reduced costs, avoidance of the need for specialist fire protection contractors on site, occupation of less floor space and good resistance to mechanical impact or abrasion.

Blockwork-filled sections can be used for free-standing columns in buildings with half-hour fire ratings. The half-hour fire rating commonly applies in England and Wales for ground and upper storeys in office, shop, factory, assembly and storage buildings up to 7.5 m in height, and to a range of other multi-storey buildings in residential, assembly, industrial and storage occupancy groups.

Blockwork-filled sections are also suitable for single-storey buildings where the proximity to the site boundary may require the external wall to have half-hour fire resistance. Another ideal use is for the supporting columns for mezzanine floors in industrial buildings.

(Acknowledgement. The information in Tables 15.6 and 15.7 was obtained from BRE Digest 317⁽¹²⁾.)

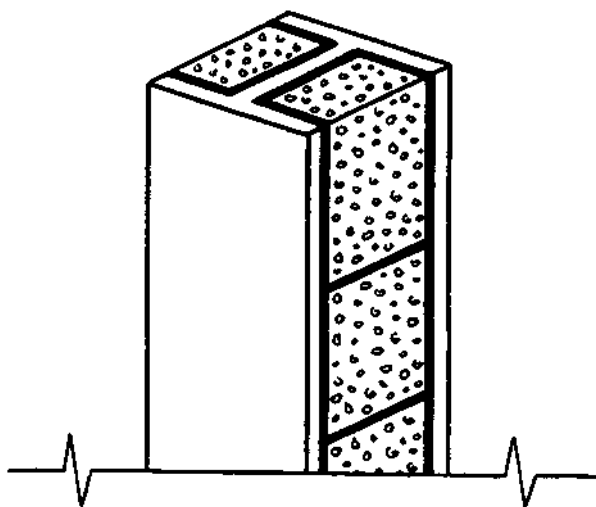


Figure152 *Small size universal column with aerated block penetration*

Table 15.7 *Methods of achieving half-hour fire resistance in universal beam sections acting as stanchions (provided load factor (g') does not exceed 1.5 for normal design)⁽³⁾*

Serial size mm	Mass per metre kg	Exposed Hp/A ⁽²⁾ m ⁻¹	Recommended protection method
and larger 457 x 191	98 89 82 74 67	37 40 43 46 50	Blocking in the webs with autoclaved aerated concrete blocks gives a minimum of 30 min fire resistance (minimum block density = 475 kg/m ³).
457 x 152	82 74 67 60	37 39 43 47	
406 x 178	74 67 60	45 49 54	
356 x 171	67 57	48 55	
350 x 165	54	57	
305 x 127	48	50	
254 x 146	43	63	
457 x 152	52		Apply fire protection (boards, sprays or intumescent) as per manufacturers' recommendations, or blockwork box ⁽¹⁾ .
406 x 178	54		
406 x 140	46 39		
356 x 171	51 45		
356 x 127	39 33		
305 x 165	46 40		
305 x 127	42 37		
305 x 102	33 28 25		
254 x 146	37 31		

(1) See Fire protection for structural steel in buildings⁽⁴⁾
(2) Exposed Hp = (2 x flange width) + (4 x flange thickness)
(3) This table is based on limiting exposed Hp/A value to 69 m⁻¹ and flange thickness to not less than 12.5 mm.

15.7 Fire resistance of composite floors with steel decking

The fire resistance of composite floor is inherently good and soffit fire protection is rarely necessary. Any floor properly designed for normal conditions may be assumed to have 30 minutes fire resistance without soffit fire protection. For longer periods two design methods have been developed, viz the fire engineering method and the simplified method.

15.7.1 Fire engineering method

In this method the strength of the section in both hogging and sagging is calculated. Any arrangement of reinforcement may be used. The method is fully described in Reference (10).

15.7.2 Simplified design for the fire resistance of composite floors

Tests (see References (8) and (10)), have shown that the strength of composite floors with steel deckings in fire is ensured by the inclusion of sufficient mesh reinforcement in the concrete slab. The reinforcement can be that required for the ambient temperature design and is not necessarily additional reinforcement included solely for the fire condition. A simplified design method for fire resistance has been derived from the results of the fire testing and is presented in the form of Design Tables, viz. Table 15.8⁽¹⁵⁾ and Table 15.9⁽¹⁵⁾. These Tables can be used provided that:

(i) Loading

The imposed loads or the floor (live load and finishings, etc) do not exceed 6.7 kN/m^2 .

(ii) Mesh reinforcement

The reinforcement must have a top cover of between 15 mm and 45 mm and be adequately supported over the entire area of the floor.

(iii) Support conditions

The floors and mesh reinforcement must be continuous over at least one support.

15.7.3 Design tables

Table 15.8 gives the simplified design data for composite floors with trapezoidal profiled decking and applies to deck profiles of 45 to 60 mm depth (see Figure 15.3). For deck profiles of depth D less than 55 mm and spans not greater than 3 m, slab depths may be reduced by 55-D up to a maximum reduction of 10 mm. For deck profiles greater than 60 mm slab depths should be increased by D-60.

For composite decks with dovetail deck sheeting the design data is given in Table 15.9. The data applies to deck profiles of 38 to 50 mm depth. For deck profiles greater than 50 mm the slab depth should be increased by D-50. In the design tables a minimum deck thickness, t , is given this thickness if not critical as in fire the deck heats up very quickly and loses much of its strength. It should not be considered as mandatory but as a practical limit. The benefit of using greater slab depths can be taken into account in some circumstances (see Reference (10)).

15.7.4 Minor variations

In given circumstances minor increases in maximum loading and spans may be taken into account (see Reference (10)).

Table15.8Simplified design for composite slabs with trapezoidal decks

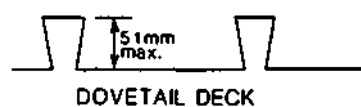
Maximum span (m)	Fire rating (hours)	Minimum dimensions			
		t (mm)	Slab depth (mm)		Mesh size
			NW	LW	
2.7	1	0.8	130	120	A142
3.0	1	0.9	130	120	A142
	1½	0.9	140	130	A142
	2	0.9	155	140	A193
3.6	1	1.0	130	120	A193
	1½	1.2	140	130	A193
	2	1.2	155	140	A252



NW = Normal weight concrete
LW = Lightweight concrete
t = Minimum sheet thickness
Imposed load not exceeding 5 kN/m² (+1.7 kN/m² ceiling and services)

Table15.9Simplified design for composite slabs with dovetail decks

Maximum span (m)	Fire rating (hours)	Minimum dimensions			
		t (mm)	Slab depth (mm)		Mesh size
			NW	LW	
2.5	1	0.8	100	100	A142
	1½	0.8	110	105	A142
3.0	1	0.9	120	110	A142
	1½	0.9	130	120	A142
	2	0.9	140	130	A193
3.6	1	1.0	125	120	A193
		1.2	135	125	A193
	2	1.2	145	130	A252



NW = Normal weight concrete
LW = Lightweight concrete
t = Minimum sheet thickness
Imposed load not exceeding 5 kN/m² (+1.7 kN/m² ceiling and services)



D_s = overall slab depth
D = deck depth

Figure 15.3 Overall slab depth and deck depth

15.8 Concrete filled hollow section columns

The filling of structural hollow sections manufactured in accordance with *BS 4848: Part 2*⁽¹⁾, with concrete will enhance their fire resistance. The hollow sections can be filled with normal weight concrete with and without reinforcement which may be either conventional high yield bar reinforcement to *BS 4449*⁽¹⁾ or drawn steel fibre reinforcement.

Full information with regard to design and fire resistance of concrete filled columns is given in Reference (11).

15.9 Water cooled structures

The principle of water cooling of structural elements to provide fire resistance, particularly of columns, is now well established and there are many buildings mainly in Europe and the USA, which employ this method of fire protection. Water cooling works by the water absorbing the heat applied to the structure and carrying it away from the heat source by convection, either to a cooler part of the structure or to be expelled to atmosphere. The heat can be transmitted by the water remaining as a liquid or by changing to steam. Much more heat will be absorbed by converting the water to steam due to the latent heat of vapourisation. However, when steam forms, care must be taken to ensure that the steam can be efficiently removed from the structure. Many tests have demonstrated that provided the structure remains filled with water, the steel temperatures will not rise sufficiently to endanger the stability of the structure.

For further information with regard to use of water cooled structures, see Reference (5).

15.10 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)
2. LAWSON, R.M. and NEWMAN, G.M.
Fire resistant design of steel structures - A handbook to BS 5950: Part 8
The Steel Construction Institute, Ascot, 1990
3. EUROPEAN CONVENTION FOR STRUCTURAL STEELWORK
European recommendations for the fire safety of steel structures
ECCS Technical Committee 3, 1981 (also Design Manual, 1985)
4. Fire protection for structural steel in buildings (2nd Edition)
Jointly published by The Association of Structural Fire Protection Contractors and Manufacturers Limited, The Steel Construction Institute and Fire Test Study Group, 1989
5. BOND, G.V.L.
Fire and steel construction: water cooled, hollow columns
Constrado, Croydon, 1974
6. LAW, M. and O'BRIEN, T.
Fire and steel construction: Fire safety of bare external steel
The Steel Construction Institute, Ascot, 1989
7. NEWMAN, G.M.
Fire and Steel Construction: The behaviour of steel portal frames in boundary conditions (2nd Edition)
The Steel Construction Institute, Ascot, 1990

8. CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION
Fire resistance of ribbed concrete floors
CIRIA, Report 107, London, 1985
9. CONSTRUCTION INDUSTRY RESEARCH AND INFORMATION ASSOCIATION
Fire resistance of composite slabs with steel decking; Data sheet
CIRIA, Special Publication 42, London, 1986
10. NEWMAN, G.M.
The fire resistance of composite floors with steel decking
The Steel Construction Institute, Ascot, 1989
11. BRITISH STEEL
Design manual for SHS concrete filled columns
BSC Tubes Division, Corby, 1986
12. BUILDING RESEARCH ESTABLISHMENT
Fire resistant steel structures: Free-standing blockwork-filled columns and stanchions
BRE Digest 317
BRE, Watford, 1986
13. LAWSON, R.M.
Enhancement of fire resistance of beam by beam to column connections - Technical Report
The Steel Construction Institute, Ascot, 1990
14. MORRIS, W.A., READ, R.E.H. and COOK, G.M.E.
Guidelines for the construction of fire resisting structural elements
Building Research Establishment, Watford, 1988
15. BRITISH STEEL GENERAL STEELS
Fire resistant design of structural steelwork information sheets
British Steel General Steels, Redcar, January 1991

16. BRITISH STEEL - SPECIALISED PRODUCTS

This Section provides data on special products manufactured by British Steel and covers:

- (i) Durbar floor plates
- (ii) Bridge and crane rails
- (iii) Bulb flats
- (vi) Round and square bars

16.1 Durbar floor plates

Non-slip raised pattern steel plates

Durbar steel plates provide increased anti-slip properties, the studs being distributed to give maximum resistance from any angle. The absence of enclosed surface areas makes the plates self-draining and easy to clean thereby minimising corrosion and ensuring longer life (see Figure 16.1). Standard sizes and mass of durbar plate are given in Tables 16.1 and 16.2 respectively.

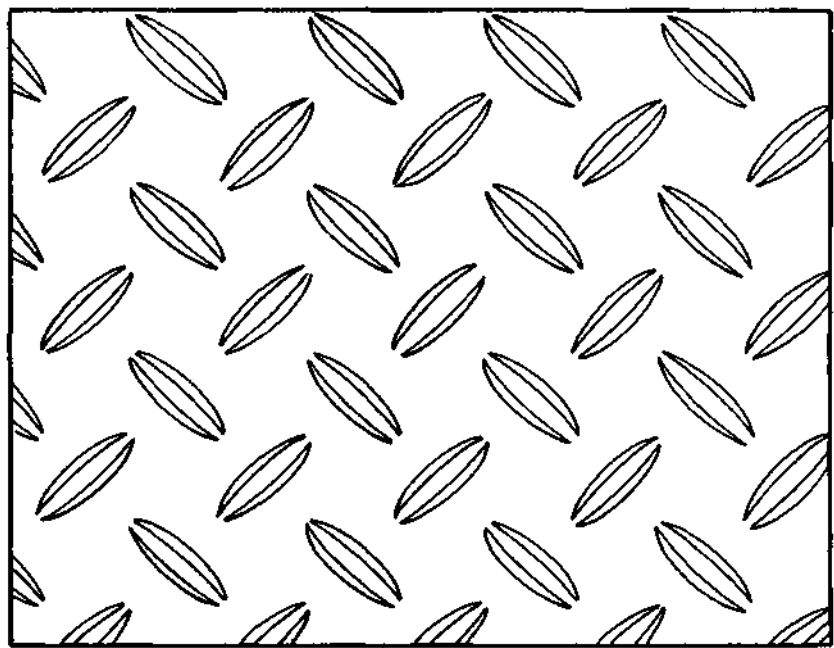


Figure 16.1 *Durbar floorplate*

Table 16.1 Standard sizes

Width mm	Thickness range on plain mm				
1000	4.5	6.0	8.0	10.0	12.5
1250	4.5	6.0	8.0	10.0	12.5
1500	4.5	6.0	8.0	10.0	12.5
1750	4.5	6.0	8.0	10.0	12.5
1830	-	6.0	8.0	10.0	12.5

Consideration will be given to requirements other than standard sizes where they represent a reasonable tonnage per size, i.e. in one length and one width. Lengths up to 10 metres can be supplied for plate 6 mm thick and over.

Table 16.2 Mass per square metre of durbar plates

Thickness on Plain mm*	kg/m ²
4.5	37.97
6.0	49.74
8.0	65.44
10.0	81.14
12.5	100.77

Depth of pattern ranging from 1.9 mm to 2.4 mm.
*Thickness as measured through the body of the plate, i.e. exclusive of pattern.

16.1.1 Ultimate distributed load capacity

The ultimate distributed load capacity including self weight (kN/mm²) for durbar floor plate with various support conditions are given in Tables 16.3 to 16.5 (maximum stress = 275 N/mm²)

Table 16.3 Ultimate load capacity (kN/mm²) for plates simply supported on two sides stressed to 275 N/mm²

Thickness on plain mm	Span (mm)							
	600	800	1000	1200	1400	1600	1800	2000
4.5	20.48	11.62	7.45	5.17	3.80	2.95	2.28	1.87
6.0	36.77	20.68	13.28	9.20	6.73	5.20	4.07	3.30
8.0	65.40	36.87	23.48	16.38	11.97	9.23	7.23	5.93
10.0	102.03	57.42	36.67	25.55	18.70	14.45	11.30	9.25
12.5	159.70	89.85	57.40	39.98	29.27	22.62	17.68	14.50

Stiffeners should be used for spans in excess of 1100 mm to avoid excessive deflections.

Table 16.4 Ultimate toad capacity (kN/mm²) for plates simply supported on all four edges stressed to 275 N/mm²

Thickness on plain mm	Breadth B mm	600	800	1000	Length (mm)		1600	1800	2000
					1200	1400			
4.5	600	34.9	25.5 19.6	22.7 15.1 12.6	21.7	21.2	21.0	20.8	20.8
	800				13.4	12.6	12.2	12.0	11.8
	1000				10.0	8.8	8.3	7.9	7.7
	1200				8.7	7.1	6.3	5.9	5.6
	1400					6.4	5.3	4.8	4.4
	1600						4.9	4.1	3.7
	1800							3.8	3.3
6.0	600	62.1	45.3 34.9	40.4 26.8 22.4	38.5	37.7	37.3	37.0	36.9
	800				23.7	22.3	21.7	21.3	21.1
	1000				17.8	15.8	14.8	14.2	13.9
	1200				15.5	12.7	11.3	10.6	10.1
	1400					11.4	9.5	8.5	7.9
	1600						8.7	7.4	6.7
	1800							6.9	5.9
8.0	600	110	80.6 62.1	71.1 47.7 39.7	68.4	67.0	66.2	65.8	65.6
	800				42.2	39.7	38.5	37.8	37.4
	1000				31.7	28.1	26.2	25.2	24.6
	1200				27.6	22.6	20.1	18.8	17.9
	1400					20.3	17.0	15.2	14.1
	1600						15.5	13.3	11.9
	1800							12.3	10.6
10.0	600	172*	126* 97.0	112* 74.5 62.1	107*	105*	103*	103*	103*
	800				65.9	62.1	60.1	59.1	58.5
	1000				49.5	43.9	41.0	39.4	38.5
	1200				43.1	35.4	31.5	29.3	28.0
	1400					31.7	26.6	23.8	22.1
	1600						24.3	20.7	18.6
	1800							19.2	16.6
12.5	600	269*	197* 152	175* 116* 97.0	167*	163*	162*	161*	160*
	800				103*	97.0*	94.0*	92.3*	91.4*
	1000				77.4	68.5	64.1	61.6	60.1
	1200				67.4	55.3	49.2	45.8	43.8
	1400					49.5	41.5	37.1	34.5
	1600						37.9	32.4	29.1
	1800							29.9	25.9

Values without an asterisk caused deflection greater than B/100 at serviceability, assuming that the only dead toad present is due to self-weight.

Values obtained using Pounder's formula allowing the comers to lift. See note 4.16 in Steelwork design guide to BS5950: Part 1:1985 Volume 1⁽¹⁾.

Table 16.5 Ultimate load capacity (kNmm⁽²⁾) for plates encastered on all four edges stressed to 275 N/mm²

Thickness on plain mm	Breadth B mm	Length mm)							
		600	800	1000	1200	1400	1600	1800	2000
4.5	600	47.7*	36.8*	33.5*	32.2*	31.6*	31.4*	31.2*	31.1*
	800		26.8	21.5*	19.5*	18.6*	18.1*	17.9*	17.7*
	1000			17.2*	14.2*	12.9*	12.2*	11.8*	11.6*
	1200				11.9	10.1	9.1	8.6	8.3
	1400					8.7	7.5	6.9	6.5
	1600						6.7	5.8	5.3
	1800							5.3	4.7
6.0	600	84.8*	65.4*	59.5*	57.3*	56.2*	55.7*	55.5*	55.3*
	800		47.7*	38.3*	34.7*	33.1*	32.2*	31.7*	31.5*
	1000			30.5*	25.3*	22.9*	21.7*	21.0*	20.6*
	1200				21.2*	18.0*	16.3*	15.4*	14.9*
	1400					15.6*	13.4*	12.3*	11.6
	1600						11.9	10.4	9.5
	1800							9.4	8.3
8.0	600	151	116*	106*	102*	100*	99.1*	98.6*	98.3*
	800		68.1*	61.7*	58.8*	57.3*	56.4*	55.9*	
	1000			54.3*	44.9*	40.7*	38.6*	37.4*	36.7*
	1200				37.7*	31.9*	29.0*	27.4*	26.5*
	1400					27.7*	23.9*	21.8*	20.6*
	1600						21.2*	18.6*	17.0*
	1800							16.9*	14.8*
10.0	600	236*	182'	165*	159*	156*	155*	154*	154*
	800		132*	106*	96.4*	91.8*	89.5*	88.2*	87.4*
	1000			84.8*	70.2*	"63.7*	60.3*	58.4*	57.3*
	1200				58.9*	49.9*	45.4*	42.9*	41.3*
	1400					43.3*	37.3*	34.1*	32.2*
	1600						33.1*	29.0*	26.6*
	1800							26.2*	23.2*
12.5	600	368*	284*	258*	249*	244*	242*	241*	240*
	800		207*	166*	151 *	144*	140*	138*	137*
	1000			132*	110*	99.5*	94.2*	91.2*	89.5*
	1200				92.0*	77.9*	70.9*	67.0*	64.6*
	1400					67.6*	58.3*	53.3*	50.3*
	1600						51.8*	45.3*	41.6*
	1800							40.9*	36.2'

Values without an asterisk caused deflection greater than B/100 at serviceability, assuming that the only dead load present is due to self-weight.

16.1.2 Durbar floor plate fixings

The recommended size and spacing of bolts and welds are given in Table 16.6.

Table 16.6 Recommended size and spacing of bolts and welds

Thickness on plain mm	Bolt diameter mm	Weld size mm	Spacing mm
Up to 8	12	3	600
Over 8	16	5	750

Where floor plates have not been designed to resist horizontal loading through diaphragm action, holes in clips and holes in support beams (see Figure 16.2) should be made 4 mm larger than bolt diameter. Where a curb is provided on top of floor plates (see Figure 16.2), bolt spacing can be increased by up to one third.

Where plates will be manhandled sizes should be kept within the limits of a two man lift, about 2.0 m² for 8 mm plate and 1.5 m² for 10 mm plate.

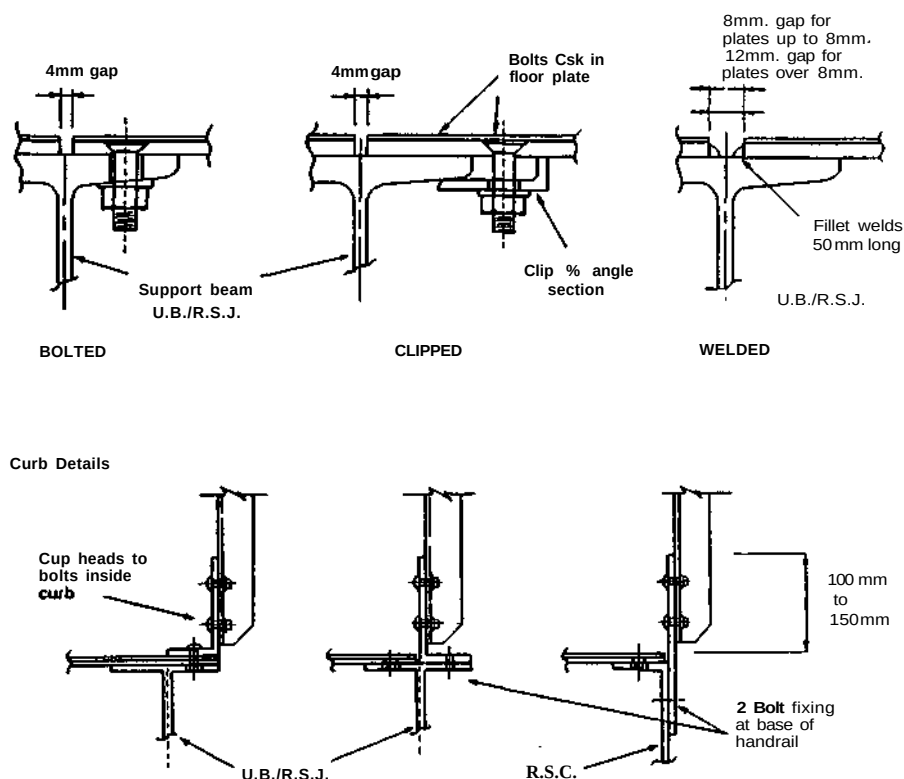


Figure 16.2 Durbar floor plate fixings

16.2 Bridge and crane rails

The principal section dimensions and properties of British Steel Bridge and Crane Rails are given in Table 16.7. (The profiles of the available Bridge and Crane Rails are shown in Figure 16.3)

Further details are available from British Steel on request (see Section 16.2.3).

Table 16.7 Bridge and crane rails; section properties

Section	Mass/unit length kg/m	Dimension mm			Area cm ²	Y mm	I _{xx} cm ⁴	I _{yy} cm ⁴	Z _{xx} cm ³	Z _{yy} cm ³
		Head width A	Base width B	Height C						
13 Bridge	13.31	36.0	92	47.5	16.95	21.5	39.01	74.38	14.70	16.17
16 Bridge	15.97	44.5	108	54.0	20.34	24.3	64.01	116.34	21.55	21.54
20 Bridge	19.86	50.0	127	55.5	25.30	25.8	82.10	192.76	27.66	30.36
28 Bridge	28.62	50.0	152	67.0	36.46	28.9	167.45	371.37	44.05	48.86
35 Bridge	35.38	58.0	160	76.0	45.06	34.4	265.67	505.23	63.79	63.15
50 Bridge	50.18	58.5	165	76.0	63.92	29.3	325.83	719.67	69.81	87.23
56 Crane	55.91	76.0	171	102.0	71.22	43.8	794.38	685.90	141.24	80.67
89 Crane	88.93	102.0	178	114.0	113.29	53.3	1493.04	1415.91	245.91	159.09
101 Crane	100.38	100.0	165	155.0	127.88	73.9	3410.78	1266.34	420.47	153.50
164 Crane	165.92	140.0	230	150.0	211.37	67.7	4776.95	5121.70	580.59	445.37

For A, B and C see Figure 16.4

Y = height of centroid above base

I_{xx} = moment of inertia about horizontal axis through centroid

I_{yy} = moment of inertia about vertical axis through centroid

Z_{xx} = section modulus about horizontal axis through centroid

Z_{yy} = section modulus about vertical axis through centroid

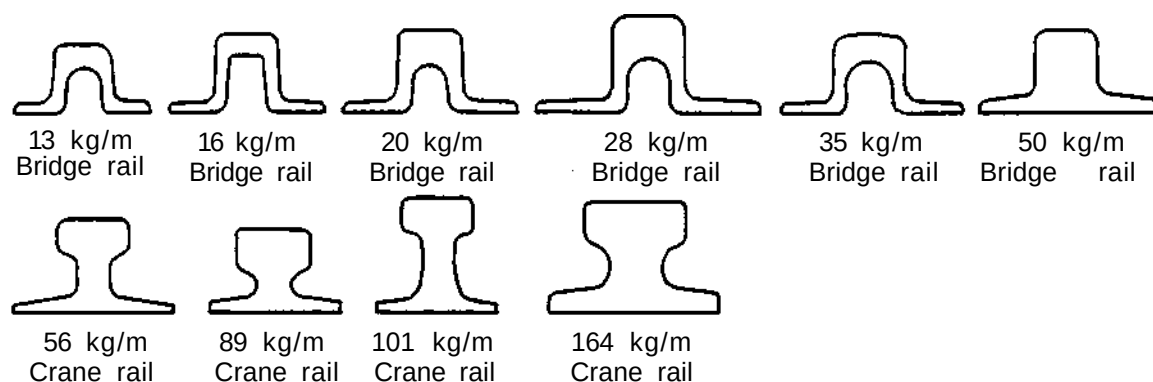


Figure 16.3 Profiles of bridge and crane rails

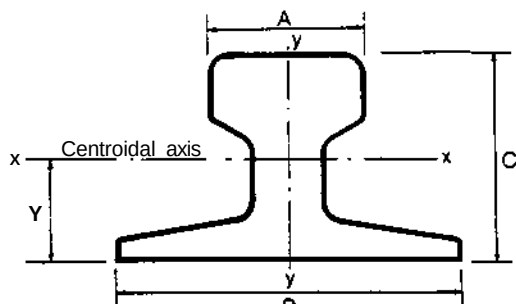


Figure 16.4 Rail dimensions

16.2.1 Rail fixings

There is a wide range of proprietary fixings available. Manufacturers' literature should be consulted before finalising design details.

16.2.2 Form of supply

(i) Rail length and tolerance

The maximum lengths normally supplied for individual bridge and crane rail sections is given in Table 16.8

Table 16.8 The maximum lengths for individual bridge and crane rail sections

Section	Length (m)
13 Bridge	9.144
16 Bridge	9.144
20 Bridge	9.144
28 Bridge	15.000
35 Bridge	15.000
50 Bridge	15.000
56 Crane	15.000
89 Crane	15.000
101 Crane	12.192
164 Crane	9.144

Sections 13,16,20 (Bridge) and 164 (Crane) can be supplied with hot sawn ends and to a length tolerance of either ± 25 mm or $-0, + 50$ mm, as specified.

Where length accuracy is important, e.g. for welding, rails should be specially ordered as cold sawn to close length tolerance, ± 3 mm. All other sections will be supplied cold sawn to a tolerance of ± 5 mm.

(ii) End straightness

For continuously welded track applications, bridge and crane rails should be ordered specially end straightened for welding when all rail ends will be specially end straightened and checked against a 750 mm straight edge to a maximum ordinate deviation of 1 mm in both planes.

16.2.3 Technical advice

A technical advisory service is available from British Steel Track Products on section and material selection, metallurgical, welding and design. When utilising the technical advisory service, the following information should be provided:

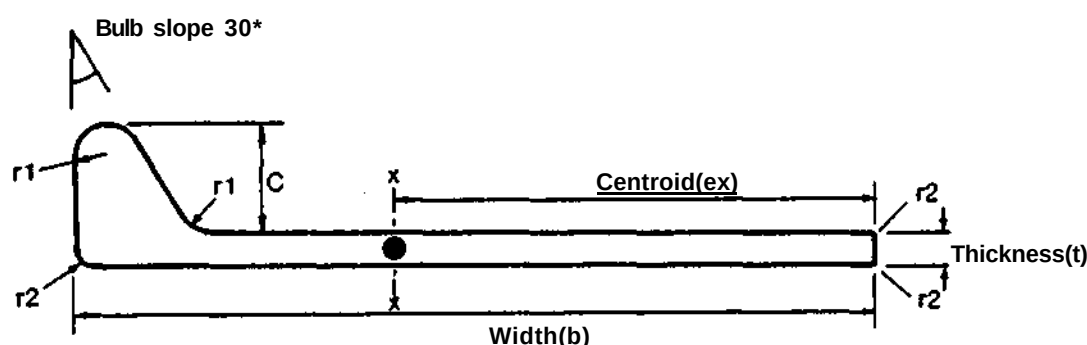
- (i) Maximum wheel load
- (ii) Maximum dynamic loading
- (iii) Number of wheels and minimum diameter
- (iv) Crane suspension and type (if any)
- (v) Details of wheel profile
- (vi) Method of joining and fixing to gantry
- (vii) Class of crane and application
- (viii) Any dimensional or design limitations

British Steel Track Products
Moss Bay
Derwent Howe
Workington
Cumbria CA14 5AF

Telephone: 0900 604321

16.3 Bulb flats

Hot rolled bulb flats with bulb on one side are available in sizes ranging from 120 mm x 6 mm to 430 mm x 20 mm. Table 16.9 shows the preferred widths and thicknesses.



- r1 = bulb radius
- r2 = radius of curvature at comers

Figure 16.5 Bulb flat dimensions

Table 16.9 *Bulb flats*

Preferred thicknesses. Properties about x-x axis (see Figure 16.5)

Size	Width	Thickness	Bulb height	Bulb radius	Area of section	Mass per unit length	Surface area per unit length	Position of centroid	Moment of inertia	Elastic modulus
	b	t	c	r1	A			ex	Ixx	Zxx
mm	mm	mm	mm	mm	cm ²	kg/m	m ² /m	cm	cm ⁴	cm ³
120x6	120	6	17	5	9.31	7.31	0.276	7.20	133	18.4
7		7	17	5	10.5	8.25	0.278	7.07	148	21.0
8		8	17	5	11.7	9.19	0.280	6.96	164	23.6
140x6.5	140	6.5	19	5.5	11.7	9.21	0.319	8.37	228	27.3
7		7	19	5.5	12.4	9.74	0.320	8.31	241	29.0
8		8	19	5.5	13.8	10.83	0.322	8.18	266	32.5
10		10	19	5.5	16.6	13.03	0.326	7.92	316	39.8
160x7	160	7	22	6	14.6	11.4	0.365	9.66	373	38.6
8		8	22	6	16.2	12.7	0.367	9.49	411	43.3
9		9	22	6	17.8	14.0	0.369	9.36	448	47.9
11.5		11.5	22	6	21.8	17.3	0.374	9.11	544	59.8
180x8	180	8	25	7	18.9	14.8	0.411	10.9	609	55.9
9		9	25	7	20.7	16.2	0.413	10.7	663	61.8
10		10	25	7	22.5	17.6	0.415	10.6	717	67.8
11.5		11.5	25	7	25.2	19.7	0.418	10.4	799	76.8
200x8.5	200	8.5	28	8	22.6	17.8	0.456	12.2	902	74.0
9		9	28	8	23.6	18.5	0.457	12.1	941	77.7
10		10	28	8	25.6	20.1	0.459	11.9	1020	85.0
11		11	28	8	27.6	21.7	0.461	11.8	1090	92.3
12		12	28	8	29.6	23.2	0.463	11.7	1160	99.6
220x9	220	9	31	9	26.8	21.0	0.501	13.6	1296	95.3
10		10	31	9	29.0	22.8	0.503	13.4	1400	105
11		11	31	9	31.2	24.5	0.505	13.2	1500	113
12		12	31	9	33.4	26.2	0.507	13.0	1590	122
240x9.5	240	9.5	34	10	31.2	24.4	0.546	14.8	1800	123
10		10	34	10	32.4	25.4	0.547	14.7	1860	126
11		11	34	10	34.9	27.4	0.549	14.6	2000	137
12		12	34	10	37.3	29.3	0.551	14.4	2130	148
260x10	260	10	37	11	36.1	28.3	0.593	16.2	2477	153
11		11	37	11	38.7	30.3	0.593	16.0	2610	162
12		12	37	11	41.3	32.4	0.595	15.8	2770	175
280x10.5	280	10.5	40	12	41.2	32.4	0.636	17.5	3223	184
11		11	40	12	42.6	33.5	0.637	17.4	3330	191
12		12	40	12	45.5	35.7	0.639	17.2	3550	206
13		13	40	12	48.4	37.9	0.641	17.0	3760	221
300x11	300	11	43	13	46.7	36.7	0.681	18.9	4190	222
12		12	43	13	49.7	39.0	0.683	18.7	4460	239
13		13	43	13	52.8	41.5	0.685	18.5	4720	256
320x11.5	320	11.5	46	14	52.6	41.2	0.727	20.2	5370	266
12		12	46	14	54.2	42.5	0.728	20.1	5530	274
13		13	46	14	57.4	45.0	0.730	19.9	5850	294
14		14	46	14	60.6	47.5	0.732	19.7	6170	313
340x12	340	12	49	15	58.8	46.1	0.772	21.5	6760	313
13		13	49	15	62.2	48.8	0.774	21.3	7160	335
14		14	49	15	65.5	51.5	0.776	21.1	7540	357
15		15	49	15	69.0	54.2	0.778	20.9	7920	379
370x12.5	370	12.5	53.5	16.5	67.8	53.1	0.839	23.6	9213	390
13		13	53.5	16.5	69.6	54.6	0.840	23.5	9470	402
14		14	53.5	16.5	73.3	57.5	0.842	23.2	9980	428
15		15	53.5	16.5	77.0	60.5	0.844	23.0	10490	455
16		16	53.5	16.5	80.7	63.5	0.846	22.8	10980	481
400x13	400	13	58	18	77.4	60.8	0.907	25.8	12280	476
14		14	58	18	81.4	63.9	0.908	25.5	12930	507
15		15	58	18	85.4	67.0	0.910	25.2	13580	537
16		16	58	18	89.4	70.2	0.912	25.0	14220	568
430x14	430	14	62.5	19.5	89.7	70.6	0.975	27.7	16460	594
15		15	62.5	19.5	94.1	73.9	0.976	27.4	17260	628
17		17	62.5	19.5	103	80.6	0.980	26.9	18860	700
20		20	62.5	19.5	115	90.8	0.986	26.3	21180	804

16.3.1 Rolling tolerances for bulb flats

(i) Dimensional tolerance

The permitted dimensional tolerances are given in Table 16.10 below.

Table 16.10 Dimensional tolerances

Width b(mm)			Thickness t (mm)			Radius of curvature at corners r2 (mm) for thicknesses (See Figure 16.5)		
over	up to	Permitted tolerance	over	up to	Permitted tolerance	over	up to	Max r2
	120	±1.5		8	+ 0.7, - 0.3		6	1.5
120	180	±2.0	6.5	11.5	+ 1.0,-0.3	6	9	2.0
180	300	±3.0	8.5	13	+ 1.0,-0.4	9	13	3.0
300	430	±4.0	11.5	20	+ 1.2, -0.4	13	20	4.0

(ii) Variation in mass

The masses shown in the Table 16.9 have been calculated from the cross-section with a density of 0.785 kilogram per square centimetre per metre run.

Permitted tolerance in mass:

- +6.0%, - 2.0% of the total mass for consignments of 5 tonnes and over
- +8.0%, - 2.7% of the total mass for consignments of under 5 tonnes.

(iii) Straightness variation

Permitted tolerance from straight when measured over the entire length of the bar are given below:

- For widths b up to 200 mm, permitted tolerance = 0.0030 x length
- For widths b from 200 mm to 430 mm, permitted tolerance = 0.0025 x length

16.4 Round and square bars

Sizes and masses of the full range of available round and square bars are given in Table 16.11

Table 16.11 *Mass per metre length (kg/m)*

Diameter or side	Round	Square	Diameter or side	Round	Square	Diameter or side	Round	Square
mm	kg/m	kg/m	mm	kg/m	kg/m	mm	kg/m	kg/m
10	0.62	0.79	45	12.48	15.90	100	61.65	78.50
11	0.75	0.95	46	13.05	16.61	105	67.97	86.55
12	0.89	1.13	47	13.62	17.34	110	74.60	94.90
13	1.04	1.33	48	14.21	18.09	115	81.54	103.82
14	1.21	1.54	49	14.80	18.85	120	88.78	113.04
15	1.39	1.77	50	15.41	19.63	125	96.33	122.66
16	1.58	2.01	51	16.04	20.42	130	104.19	132.67
17	1.78	2.27	52	16.67	21.23	135	112.36	143.07
18	2.00	2.54	53	17.32	22.05	140	120.84	153.86
19	2.23	2.83	54	17.98	22.89	145	129.63	165.05
20	2.47	3.14	55	18.65	23.75	150	138.72	176.63
21	2.72	3.46	56	19.33	24.62	155	148.12	188.60
22	2.98	3.80	57	20.03	25.50	160	157.83	200.96
23	3.26	4.15	58	20.74	26.41	165	167.85	213.72
24	3.55	4.52	59	21.46	27.33	170	178.18	226.87
25	3.85	4.91	60	22.20	28.26	175	188.81	240.41
26	4.17	5.31	61	22.94	29.21	180	199.76	254.34
27	4.49	5.72	62	23.70	30.18	185	211.01	268.67
28	4.83	6.15	63	24.47	31.16	190	222.57	283.39
29	5.19	6.60	64	25.25	32.15	195	234.44	298.50
30	5.55	7.07	65	26.05	33.17	200	246.62	314.00
31	5.92	7.54	66	26.86	34.19	205	259.10	329.90
32	6.31	8.04	67	27.68	35.24	210	271.89	346.19
33	6.71	8.55	68	28.51	36.30	215	284.99	362.87
34	7.13	9.07	69	29.35	37.37	220	298.40	379.94
35	7.55	9.62	70	30.21	38.47	225	312.12	397.41
36	7.99	10.17	71	31.08	39.57	230	326.15	415.27
37	8.44	10.75	72	31.96	40.69	235	340.48	433.52
38	8.90	11.34	73	32.86	41.83	240	355.13	452.16
39	9.38	11.94	74	33.76	42.99	250	385.34	490.63
40	9.86	12.56	75	34.68	44.16	260	416.78	530.66
41	10.36	13.20	80	39.46	50.24	270	449.46	572.27
42	10.88	13.85	85	44.54	56.72	280	483.37	615.44
43	11.40	14.51	90	49.94	63.59	290	518.51	660.19
44	11.94	15.20	95	55.64	70.85	300	554.88	706.50

Suppliers should be consulted regarding availability of sizes.

16.5 References

1. THE STEEL CONSTRUCTION INSTITUTE
Steelwork design guide to BS 5950: Part 1:1985, Volume 1 - Section properties and member capacities, 2nd Edition
SCI, Ascot, 1987

17. BRITISH STEEL - PLATE PRODUCTS

17.1 Plate products - range of sizes

British Steel General Steels supplies plate to a wide range of industries worldwide. The products meet the requirements of British, other National and International standards. These specifications cover steels for structural, shipbuilding, boiler and pressure vessel applications as well as more specialised specifications including line pipe and proprietary brands of quenched and tempered plate. The sizes and masses of full range of available plate are given in Tables 17.1 to 17.8.

Table 17.1 Mass of plates (kg per m length)

Thickness	Width (mm)												
mm	1000	1250	1500	1750	2000	2250	2500	2750	3000	3250	3500	3750	4000
5	39	49	59	69	79	88	98	108	118	128	137	147	157
6	47	59	71	82	94	106	118	130	141	153	165	177	188
7	55	69	82	96	110	124	137	151	165	179	192	206	220
8	63	79	94	110	126	141	157	173	188	204	220	235	251
9	71	88	106	124	141	159	177	194	212	230	247	265	283
10	79	98	118	137	157	177	196	216	235	255	275	294	314
12.5	98	123	147	172	196	221	245	270	294	319	343	368	393
15	118	147	177	206	235	265	294	324	353	383	412	442	471
20	157	196	235	275	314	353	393	432	471	510	550	589	628
25	196	245	294	343	393	442	491	540	589	638	687	736	785
30	235	294	353	412	471	530	589	648	707	765	824	883	942
35	275	343	412	481	550	618	687	756	824	893	962	1030	1099
40	314	393	471	550	628	707	785	863	942	1020	1099	1178	1256
45	353	442	530	618	707	795	883	971	1060	1148	1236	1325	1413
50	393	491	589	687	785	883	981	1079	1178	1276	1374	1472	1570
60	471	589	707	824	942	1060	1178	1295	1413	1531	1648	1766	1884
65	510	638	765	893	1020	1148	1276	1403	1531	1658	1786	1913	2041
70	550	687	824	962	1099	1236	1374	1511	1648	1786	1923	2061	2198
75	589	736	883	1030	1178	1325	1472	1619	1766	1913	2061	2208	2355
80	628	785	942	1099	1256	1413	1570	1727	1884	2041	2198	2355	2512
90	707	883	1060	1236	1413	1590	1766	1943	2120	2296	2473	2649	2826
100	785	981	1178	1374	1570	1766	1962	2159	2355	2551	2748	2944	3140
120	942	1178	1413	1648	1884	2120	2355	2591	2826	3062	3297	3532	3768
140	1099	1374	1648	1923	2198	2473	2748	3022	3297	3572	3846	4121	4396
160	1256	1570	1884	2198	2512	2826	3140	3454	3768	4082	4396	4710	5024
180	1413	1766	2120	2473	2826	3179	3532	3886	4239	4592	4946	5299	5652
200	1570	1962	2355	2748	3140	3532	3925	4318	4710	5103	5495	5888	6280
250	1962	2453	2944	3434	3925	4416	4906	5397	5888	6378	6869	7359	7850
300	2355	2944	3532	4121	4710	5299	5888	6476	7065	7654	8243	8831	9420
350	2748	3434	4121	4808	5495	6182	6869	7556	8243	8929	9616	10303	10990

Values in the table are based on the density of steel = 7850 kg/m³

Table 17.2 Typical size range of carbon steel plates

THICKNESS mm	WIDTH mm																			
		>1220 <1250	>1250 «1300	>1300 <1500	>1500 1600	>1600 <1750	>1750 « 1800	>1800 <2000	>2000 <2100	>2100 ^2250	>2250 2500	>2500 <2750	>2750 <3000	>3000 4 3050	>3050 <3250	>3250 (3460	>3460 <3500	>3500 <3750	>3750 <3960	
5	12	12	12	12	12	12	12	12	12	12										
6	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	12.5	12.5								
7	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5							
8	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	11						
9	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3						
10	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	10					
12.5	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19			
15	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
20	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
25	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
30	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
35	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
40	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19		
45	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17		
50	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17		
60	15.3	17	17	17	17	17	17	17	17	17	17	16.9	15.6	15.6	14.6	14.6	13.6	12.8		
65	13.1	17	17	17	17	17	17	17	17	17	15.9	14.6	13.4	13.4	12.5	12.5	11.6	11		
70	13.1	17	17	17	17	17	17	17	17	17	15.9	14.6	13.4	13.4	12.5	12.5	11.6	11		
75	8.4	17	17	16.8	16.8	17	17	17	17	15.3	13.9	12.7	11.6	11.6	10.9	10.9	10.2	9.7		
80	7.9	17	17	16.8	16.8	17	17	17	17	15.3	13.9	12.7	11.6	11.6	10.9	10.9	10.2	9.7		
90		17	17	15	15	17	17	15.1	15.1	13.6	12.4	11.3	10.5	10.5	9.7	9.7	9.1	8.6		
100		15.7	15.7	13.5	13.5	15.3	15.3	13.6	13.6	12.2	11.1	10.2	9.4	9.4	8.7	8.7	8.2	7.7		
120		13.1	13.1	11.2	11.2	12.7	12.7	11.3	11.3	10.2	9.3	8.5	7.8	7.8	7.3	7.3	6.8	6.4		
140		11.2	11.2	9.6	9.6	10.9	10.9	9.7	9.7	8.7	7.9	7.3	6.7	6.7	6.2	6.2	5.8			
160		9.8	9.8	8.4	8.4	9.6	9.6	8.5	8.5	7.6	6.9	6.4	5.9	5.9	5.5	5.5	5.1			
180		8.7	8.7	7.5	7.5	8.5	8.5	7.5	7.5	6.8	6.2	5.7	5.2	5.2	4.9	4.9	4.5			
200		7.9	7.9	6.7	6.7	7.6	7.6	6.8	6.8	6.1	5.6	5.1	4.7	4.7	4.4	4.4	4.1			
250		4	4	4	4	4	4	4	4	3.9	3.5	3.2								
300		4	4	4	4	4	4	3.6	3.6	3.2										
350	4	4	4	4	3.5	3.5	3.1	3.1												

19 Maximum length in metres

 Not available

Typical specifications Include:

Structural Steels

BS EN 10025:1990-Fe 360A, Fe 360B

BS EN 10025:1990-Fe 430A, Fe 430B

Boiler and Pressure Vessel Steels

BS 1501 -151/360, 400, 430

BS 1501 -161/360, 400, 430

Ship Qualities

Lloyd's Grade A

Note 1 Carbon steel plates for structural applications and boiler and pressure vessel applications are also available to the requirements of ISO, Euronorm, ASME, ASTM, Canadian, French, German, Japanese, Swedish and other national standards.

Note 2 Carbon steel plates for ship construction are also available in accordance with the requirements of other major Classification Societies such as American Bureau of Shipping, Bureau Veritas and Det norske Veritas.

Table 17.3 Typical size range of carbon-manganese steel plates

THICKNESS mm	WIDTH mm																	
	>1220 ≤1250	>1250 ≤1300	>1300 ≤1500	>1500 ≤1600	>1600 ≤1750	>1750 ≤1800	>1800 ≤2000	>2000 ≤2100	>2100 ≤2250	>2250 ≤2500	>2500 ≤2750	>2750 ≤3000	>3000 ≤3050	>3050 ≤3250	>3250 ≤3460	>3460 ≤3500	>3500 ≤3750	>3750 ≤3960
5	12	12	12	12	12	12	12	12	12	12								
6	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	12.5	12.5						
7	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5					
8	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	11				
9	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3				
10	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	10			
12.5	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17	17	
15	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17	17	
20	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17.5	17	17	17
25	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17.6	17	17	17	17	17	17	17
30	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	17.9	17	17	17	17	17	17	17	17	17
35	18.1	18.1	17	18.1	17	17	17.3	17	17	17	17	17	17	17	17	17	17	17
40	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
45	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
50	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	16.3	15.4
60	10.6	17	17	17	17	17	17	17	17	17	17	16.9	15.6	15.6	14.6	14.6	13.6	12.8
65	9.7	17	17	17	17	17	17	17	17	17	15.9	14.6	13.4	13.4	12.5	12.5	11.6	11
70	9	17	17	17	17	17	17	17	17	17	15.9	14.6	13.4	13.4	12.5	12.5	11.6	11
75	8.4	16	16	16	16	16	16	16	16	15.3	13.9	12.7	11.6	11.6	10.9	10.9	10.2	9.7
80	7.9	16	16	16	16	16	16	16	16	15.3	13.9	12.7	11.6	11.6	10.9	10.9	10.2	9.7
90		16	16	15	15	16	16	15.1	15.1	13.6	12.4	11.3	10.5	10.5	9.7	9.7	9.1	8.6
100		15.7	15.7	13.5	13.5	15.3	15.3	13.6	13.6	12.2	11.1	10.2	9.4	9.4	8.7	8.7	8.2	7.7
120		13.1	13.1	11.2	11.2	12.7	12.7	11.3	11.3	10.2	9.3	8.5	7.8	7.8	7.3	7.3	6.8	6.4
140		11.5	11.5	9.9	9.9	8.6	8.6	7.7	7.7	8.1	6.3	5.8	5.3	5.3	4.9	4.9	4.6	
160		10.1	10.1	8.6	8.6	7.6	7.6	6.7	6.7	6.1	5.5	5.0	4.7	4.7	4.3	4.3	4.0	
180		9	9	7.7	7.7	6.7	6.7	6.0	6.0	5.4	4.9	4.5	4.1	4.1	3.8	3.8	3.6	
200		8.1	8.1	6.9	6.9	6.1	6.1	5.4	5.4	4.8	4.4	4.0	3.7	3.7	3.5	3.5	3.2	
250		4	4	4	4	4	4	4	4	3.9	3.5	3.2	3	3				
300		4	4	4	4	4	4	3.6	3.6	3.2								
350		4	4	4	4	3.5	3.5	3.1	3.1									

Typical specifications Include:

Structural Steels

BS 4360: 1990 - 40EE, 43EE, 50EE
55C, 55EE,
WR grades
BS EN 10 025 - Fe 360C, Fe 360D
Fe 430C, Fe 430D
Fe 510A, Fe 510B
Fe 510C, Fe 510D
Fe 510DD

CORTEN A,B1

Hyplus 29

Boiler and Pressure Vessel Steels

BS 1501 - 164/360, 400
BS 1501 - 223/460, 490
BS 1501 - 224/400, 430, 460, 490
BS 1501 - 225/460, 490

Ship Qualities

Lloyd's Grades, B, D, E
AH32, DH32, EH32,
AH34S, DH34S, EH34S
AH36, DH36, EH36

Note 1 Carbon-manganese plates for structural applications and boiler and pressure vessel applications are also available to the requirements of ISO, Euronorm, ASME, ASTM, Canadian, French, German, Japanese, Swedish and other national standards.

Note 2 C-Mn plates for ship construction are also available in accordance with the requirements of other major Classification Societies such as American Bureau of Shipping, Bureau Veritas and Det norske Veritas.

Table 17.4 Typical size range of low alloy steel plates

WIDTH mm		≤1250	≤1500	≤1750	≤2000	≤2250	≤2500	≤2750	≤3000	≤3250	≤3500	≤3750	≤3960
THICKNESS mm	5	13.5	13.5	13.5	13.5	12.5	12.5						
	6	13.5	13.5	13.5	13.5	12.5	12.5						
	7	13.5	13.5	13.5	13.5	12.5	12.5						
	8	13.5	13.5	13.5	13.5	12.5	12.5						
	9	18	18	18	18	18	18	18	18	18			
	10	18	18	18	18	18	18	18	18	18			
	12.5	17	17	17	17	17	17	17	17	17	17	17	
	15	17	17	17	17	17	17	17	17	17	17	17	
	20	17	17	17	17	17	17	17	17	17	17	17	17
	25	17	17	17	17	17	17	17	17	17	17	17	17
	30	17	17	17	17	17	17	17	17	17	17	17	17
	35	17	17	17	17	17	17	17	17	17	17	17	17
	40	17	17	17	17	17	17	17	17	17	17	17	17
	45	17	17	17	17	17	17	17	17	17	17	16.6	15.7
	50	17	17	17	17	17	17	17	17	17	16.0	14.9	14.2
	60		17	17	17	17	17	17	15.6	14.4	13.3	12.5	11.8
	70		17	17	17	17	17	14.6	13.3	12.3	11.4	10.7	10.1
	80		16.0	15.5	16.0	15.6	14.0	12.7	11.6	10.8	10.0	9.3	8.8
	90		16.0	13.7	15.6	13.8	12.5	11.3	10.4	9.6	8.9	8.3	7.9
	100		14.4	12.4	14.0	12.5	11.2	10.2	9.3	8.6	8.0	7.5	7.1
	120		12.0	10.3	11.7	10.4	9.3	8.5	7.8	7.2	6.7	6.2	5.9
	140		11.5	9.9	8.6	7.7	8.1	6.3	5.8	5.3	4.9	4.6	
	160		10.1	8.6	7.6	6.7	6.1	5.5	5.0	4.7	4.3	4.0	
	180		9.0	7.7	6.7	6.0	5.4	4.9	4.5	4.1	3.8	3.6	
	200		8.1	6.9	6.1	5.4	4.8	4.4	4.0	3.7	3.5	3.2	

18

Maximum length in metres

Not available

Typical specifications Include:

Boiler and Pressure Vessel Steels

BS 1501: Part 2 - all grades, except those which are supplied in the quenched and tempered condition. (See appropriate table).

ASTM (ASME) - selected grades form A203, A204, A353 and A387.

Low alloy boiler and pressure vessel steel plates are also available to meet the requirements of ISO, Euronorm, Canadian, French, German, Swedish and other national standards.

Table 17.5 Typical size range of quenched and tempered steel plates

THICKNESS mm	WIDTH mm	≤1250	≤1300	≤1500	≤1600	≤1750	≤1800	≤2000	≤2100	≤2250	≤2500	≤2750	≤3000	≤3050
		5	15	15	15	15	15	15	15	15	15	15	15	15
6		15	15	15	15	15	15	15	15	15	15			
7		15	15	15	15	15	15	15	15	15	15			
8		15	15	15	15	15	15	15	15	15	15			
9		15	15	15	15	15	15	15	15	15	15	15	15	15
10		15	15	15	15	15	15	15	15	15	15	15	15	15
12.5		15	15	15	15	15	15	15	15	15	15	15	15	15
15		15	15	15	15	15	15	15	15	15	15	15	15	15
20		15	15	15	15	15	15	15	15	15	15	15	15	15
25		15	15	15	15	15	15	15	15	15	15	15	15	15
30		12	12	12	12	12	12	12	12	12	12	12	12	12
35		12	12	12	12	12	12	12	12	12	12	12	12	12
40		12	12	12	12	12	12	12	12	12	12	12	11	11
45		12	12	12	12	12	12	12	12	12	11.9	10.9	9.7	9.7
50		12	12	12	12	12	12	11.9	11.9	10.7	9.7	8.8	8.8	8.8
55		12	12	12	12	12	12	11.5	10.8	9.7	8.8	8.0	8.0	8.0
60		12	12	12	12	12	11.1	10.6	9.9	8.9	8.1	7.3	7.3	7.3
65		12	12	12	11.8	11.4	10.3	9.8	9.1	8.2	7.5	6.7	6.7	6.7
70														
80														
90														
100														



Maximum length in metres



Not available



May be available for some qualities with dimensions and properties by arrangement

Typical specifications Include:

Structural Steel (high strength roller quenched and tempered)

BS 4360:1990 - Grades 50F and 55F

QT445 - Grades A and B

RQT501, RQT601, RQT701

ASTM A514

SS 14 26 24

Wear Resistant Steels

A-R-COL

ARQ 280, 300, 320, 340, 360

Boiler and Pressure Vessel Steels

BS 1501:510 (9% nickel)

ASTM A553 Type 1 (9% nickel)

ASTM A517

Note: Quenched and Tempered plates are available with specified properties in thicknesses up to and including 40 mm with the exception of:

- QT445 Grade A which is only available to 32 mm maximum
- RQT501, BS 1501:510, ASTM A553 Type 1 which are available up to 50 mm maximum
- QT445 Grade B which is available from 32 to 63 mm

Table 17.6 Typical size range of carbon and carbon-manganese wide flats

THICKNESS mm		10	12	15	20	25	30	35	40	45	50	55	60	65	70	75	80	90	100
WIDTH mm																			
150					13	13	13	15	15	15	15	15	15						
180			12	13	13	15	15	15	15	15	15	15	16	16	16	16			
200			12	13	14	15	15	15	15	15	16	16	16	16	16	16			
220			12	13	14	15	15.5	16.5	17	17	17.5	18	18	18	18	18			
250			12	13.5	14	15	15.5	16	16.5	17.5	17.5	17.5	18	18	18	18			
275			12	14	14	15	15.5	16.5	17	17	17.5	18	18	18	18	18			
300			12	14	15	16	18	18	18	18	18	19	19	19	19	19			
325			12	12	15	16	18	18	18	18	18	19	19	19	19	19			
350				12	15	16	18	18	18	18	20	20	20	20	20	20			
375				12	16	16.5	20	20	20	20	20	20	21	21	21	21			
400				12	16	17	21	21	22	22	22.5	22.5	23	23	23	23			
425				12	16	18	21	23	23	23	23	23	23	23	23	23			
450					16	18	21	23	23	23	23	23	23	23	23	23			
475					15	18	21	23	23	23	23	23	23	23	23	23			
500					15	18	21	23	23	23	23	23	23	23	23	23			
525						18	21	23	23	23	23	23	23	23	23	22			
550						18	21	23	23	23	23	23	23	23	22	20			
575						18	21	23	23	23	23	23	23	23	21	19			
600						18	21	23	23	23	23	23	23	22	21	19			
625						18	21	23	23	23	23	23	23	21	20	19			
650						18	21	23	23	23	23	23	22	21	19	18			

23

Maximum length in metres

Not available

Development range-
Please consult

May be available with dimensions
and material properties by
arrangement

Not normally available except by
special arrangement on straightness
and flatness tolerances

Typical specifications Include:

Structural Steels

BS 4360:1990- all grades (including weather resistant steels) except grades 50F, 55EE and 55FF.

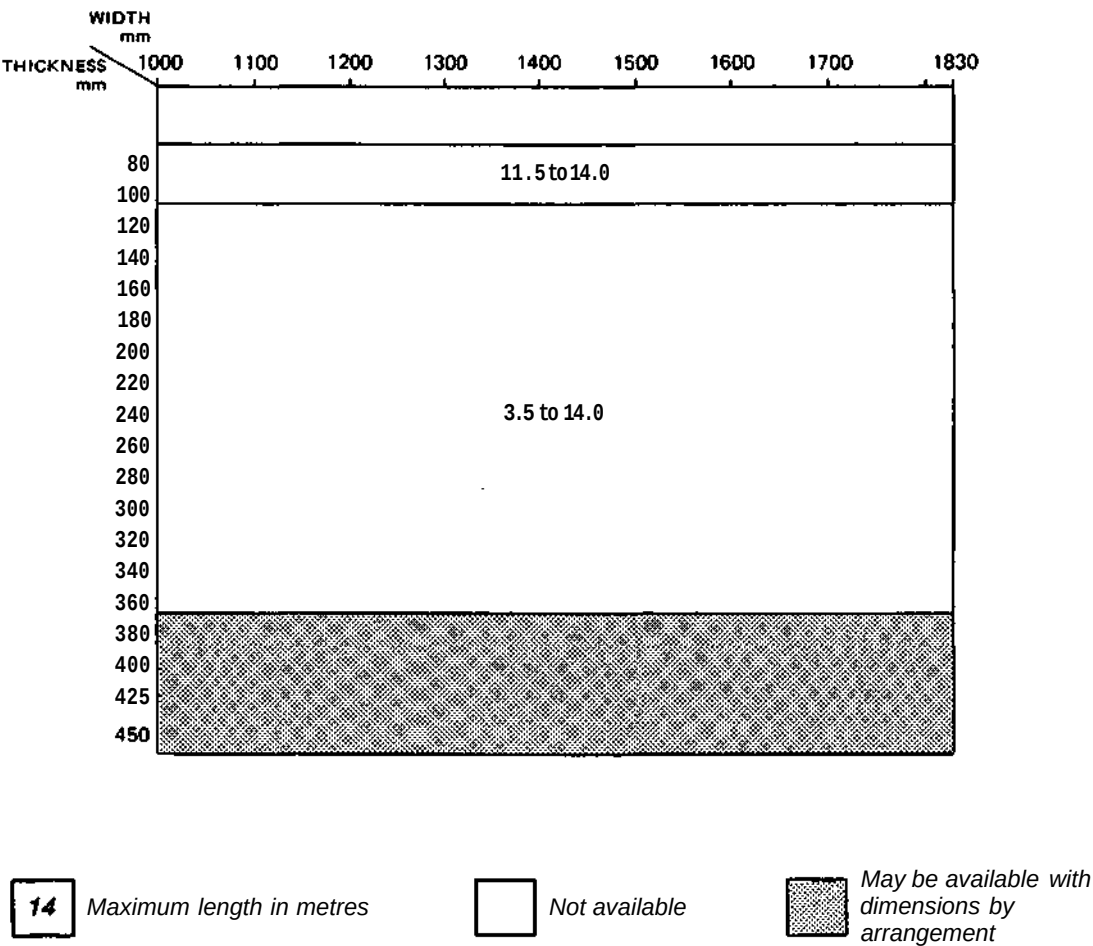
Equivalent structural steel in accordance with foreign national standards are available on application.

Ship

Qualities

Wide Flats in normal and high strength structural grades are available in accordance with the requirements of the major Classification Societies such as Lloyds, American Bureau of Shipping, Bureau Veritas and Det norske Veritas.

Table 17.7 Typical size range of profiling slabs



Typical specifications Include:

BS EN 10025:1990 - Fe 430A, Fe 510A

EN 8 (BS 970 080 A40)

ASTM A36, A572 - 50

DIN 17100 RSt 37-2, St 44- 2, St 42 - 3

Profiling slab up to 16.0 m may be available depending upon width/thickness combination

Table 17.8 Typical size range of linepipe

Wall Thickness		OUTSIDE DIAMETER (examples)					
		20 in 506 mm	24 in 610 mm	28 in 711 mm	30 in 762 mm	36 in 914 mm	44 in 1117 mm
.250	6.4						
.281	7.1						
.312	7.9						
.344	8.7						
.375	9.5						
.406	10.3						
.438	11.1						
.469	11.9						
.500	12.7						
.562	14.3						
.625	15.9						
.688	17.5						
.750	19.1						
.812	20.6						
.875	22.2						
.938	23.8						
1.000	25.4						
1.062	27.0						
1.25	31.8						



Size range for pipe grades up to, and including, API 5L X65.
For API 5L X70 the maximum thickness is 22.2 mm.



Specific combinations of diameter/thickness/quality/quantity may be available beyond 27 mm up to 31.8 mm and below 7.9 mm down to 6.4 mm.

17.2 References

- 1. BRITISH STANDARDS INSTITUTION
(see Section 19)

Acknowledgement

The information in Tables 17.2 to 17.8 was obtained from British Steel General Steels catalogue titled "Plate Products".

18. TRANSPORTATION, FABRICATION AND ERECTION OF STEELWORK

This Section provides guidance to designers, fabricators and erectors on transportation of steel to site and allowable tolerances in fabrication and erection.

18.1 Transportation of steelwork

The size of structural units that can be transported will form the upper boundary of size for a particular structural member. This limitation will therefore form one of the parameters of design. Where the distance to be transported is particularly long or expensive, care should be taken in designing members so that they can be stacked in the minimum space and where possible nested together.

18.1.1 Road transport

The UK Road Traffic Regulations permit a gross weight for rigid vehicles of 30 tons and 32 tons for articulated vehicles. The maximum permitted axle load is 10 tons. There are also regulations concerning the length, width, marking, lighting and police notification for large loads. These requirements have been published by Motor Transport Journal and reproduced in Figure 18.1. This chart shows the requirements of the law concerning police notice and mates, when long, wide and projecting loads are carried. This chart was published in *Motor transport journal* June 1988. For fuller details, reference should be made to this issue of the Journal. The requirements are contained in the following legislation to which reference may be made for classification:

- (1) Motor vehicles (construction & use) regulations 1986
- (2) Motor vehicles (authorization of special types) general order 1979
- (3) Road traffic act 1972

The official clearance height for new bridges over roads in the UK is 5.0 m. Minimum clearance for service roads is 4.5 m. However, for a given project it would be wise to check existing bridge clearances, as not all of the older bridges meet these requirements.

Also important is the limiting width which should be checked at the same time.

18.1.2 Rail transport

The normal limitations of size that can be transported by British Rail are 21 m long x 2.4 m wide x 2.75 m high. For this type of freight, weight is not normally a problem, but all aspects of the journey should be cleared in advance with the appropriate rail authority.

18.1.3 Air transport

Delivery of prefabricated steelwork by air is more complicated due to different types of aircraft in use. For the normal side loading type of cargo aircraft, loads have to be palletised in crates approximately 3.0 m x 21 m x 1.4 m with serious limitations on weight

There are however larger front loading aircraft available. It is recommended that one of the cargo charter companies be contacted for up-to-date limitations of size and weight.

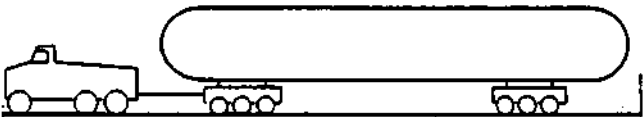
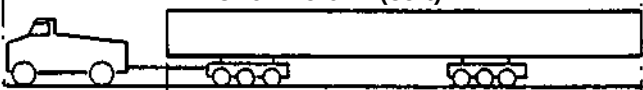
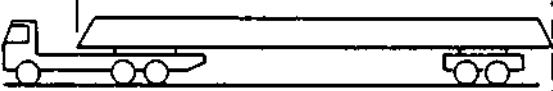
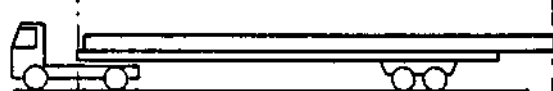
Police Notice required	Vehicle Mate required	
✓	✓	
✓	✓	
✓	✓	Over 25.9m (85ft) 
✓	✓	
✓	✓	
✓	✓	Over 18.3m (60ft) 
		
✓		Over 305mm (12in) or over 2.9m (9ft 6in) Construction & Use (C. and U.)
✓		Over 2.9m (9ft 6in) Special types
✓	✓	Over 3.5m (11ft 5 3/4in) Both CC. & U. and special types
✓	✓	Over 4.3m (14ft) Indivisible load on C. and U. vehicle
✓	✓	Over 5m (16ft 4 3/4in) Abnormal indivisible load

Figure 18.1 Law requirements at a glance

18.1.4 Transport by ship

This presents no problem. Any structural member which can be transported to the dockside can be accommodated aboard ship.

18.2 Fabrication tolerances

BS 5950:Part 2⁽¹⁾, specifies the dimensional tolerances to which steelwork members and components are to be fabricated and the steelwork structure is to be erected. These tolerances have been taken into account in the provisions of *BS5950:Part1*⁽¹⁾ and it is essential that these tolerances are achieved so that subsequent difficulties in the location and/or use of the steelwork components do not arise.

Additional and/or different tolerances may be specified to cater for special requirements of a particular building or problem but such tolerances should be compatible with the design recommendations and product standards.

The permitted maximum deviation from design dimensions after fabrication of steelwork members and the erection of the steelwork structure are set out in unambiguous illustrated format in the *National structural steelwork specification for building construction*⁽²⁾.

The above specification covers permitted deviations after fabrication in respect of:

- (i) Rolled components (including Structural Hollow Sections)
- (ii) Elements of fabricated members
- (iii) Plate girder sections
- (iv) Box sections

The permitted deviations refer to cross-section squareness, length, camber etc. after fabrication.

18.3 Accuracy of erected steelwork

Designs are carried out on the basis of implicit assumptions on the level of workmanship achievable. Any deviation from permitted workmanship tolerances could influence the performance of the building.

Permitted deviations in foundations, walls, foundation bolts and erected components are contained in the *National structural steelwork specifications for building construction*⁽²⁾.

18.4 References

1. BRITISH STANDARDS INSTITUTION
(see Section 19)
2. BRITISH CONSTRUCTIONAL STEELWORK ASSOCIATION
National structural steelwork specifications for building construction
BCSA Publication No 1/89
BCSA, London, 1989

19. BRITISH STANDARDS

A basic list of British Standards covering the Design and Construction of Steelwork
(correct as at 31 December 1990)

Bolts

- BS 3692 1967 Specification for ISO metric precision hexagon bolts, screws and nuts. Metric units
- BS 4190 1967 Specification for ISO metric black hexagon bolts, screws and nuts
- BS 4320 1968 Specification for metal washers for general engineering purposes. Metric series
- BS 4395 Specification for high strength friction grip bolts and associated nuts and washers for structural engineering. Metric series
Part 1:1969 General grade
Part 2:1969 Higher grade bolts and nuts and general grade washers
- BS 4604 Specification for the use of high strength friction grip bolts in structural steelwork. Metric series
Part 1:1970 General grade
Part 2:1970 Higher grade (parallel shank)
Part 3:1973 Higher grade (waisted shank)
- BS 4933 1973 Specification for ISO metric black cup and countersunk head bolts and screws with hexagon nuts

Corrosion

- BS 729 1986 Specification for hot dip galvanised coatings on iron and steel articles
- BS 1501 Steels for pressure purposes: plates, sheet and strip
Part 3:1990 Specification for corrosion and heat-resisting steels
- BS 1706 1990 Method for specifying electroplated coatings of zinc and cadmium on iron and steel.
- BS 4232 1967 Specification for surface finish of blast cleaned steel for painting
- BS 5493 1977 Code of practice for the protective coating of iron and steel structures against corrosion

Design

- BS 466 1984 Specification for power driven overhead travelling cranes, semi-goliath and goliath cranes for general use
- BS 449 Specification for the use of structural steel in building
Part 2:1969 Metric units
Addendum No. 1 (1975) to BS 449: Part 2 1969 The use of cold formed steel sections in building (withdrawn, replaced by BS 5950: Part 5)

- BS 2573 Rules for the design of cranes
Part 1:1983 Specification for classification, stress calculations and design criteria for structures
- BS 2853 1957 Specifications for the design and testing of steel overhead runway beams
- BS 4211 1987 Specification for ladders for permanent access to chimneys, other high structures, silos and bins
- BS 5395 Stairs, ladders and walkways
Part 1:1977 (1984) Code of practice for the design of straight stairs
Part 2:1984 Code of practice for the design of helical and spiral stairs
Part 3:1985 Code of practice for the design of industrial type stairs, permanent ladders and walkways
- BS 5400 Steel, concrete and composite bridges
Part 3:1982 Code of practice for design of steel bridges
Part 5:1979 Code of practice for design of composite bridges
Part 6:1980 Specification for materials and workmanship: steel
Part 10:1980 Code of practice for fatigue
- BS 5502 Code of practice for the design of buildings and structures for agriculture
Part 1 Section 1.1:1986 Materials
Part 22:1987 Code of practice for design, construction and loading
- BS 5628 Code of practice for use of masonry
Part 3:1985 Material and components, design and workmanship
- BS 5950 Structural use of steelwork in building
Part 1:1990 Code of practice for design in simple and continuous construction: hot rolled sections
Part 2:1985 Specification for materials fabrication and erection: hot rolled sections
Part 3: Section 3.1:1990 Codes of practice for design of simple and continuous composite beams
Part 4:1982 Code of practice for design of floors with profiled steel sheeting
Part 5:1987 Code of practice for design of cold formed sections
Part 6: Code of practice for design of light gauge sheeting, decking and cladding (in preparation)
Part 7: Specification for materials and workmanship: cold formed section (in preparation)
Part 8:1990 Code of practice for fire resistance design
- BS 6180 1982 Code of practice for protective barriers in and about buildings
- BS 8110 Structural use of concrete
Part 1:1985 Code of practice for design and construction
Part 2:1985 Code of practice for special circumstances

Erection

- BS 5531 1988 Code of practice for safety in erecting structural frames

Fire

- BS 476 Part 8:1972 Test methods criteria for the fire resistance of elements of building construction
- BS 5950 Part 8:1990 Code of practice for fire resistance design

Loading

- BS 648 1964: Schedule of weights of building materials
- BS 5400 Steel, concrete and composite bridges
Part 2:1978 Specification for loads
- BS 6399 Loading for buildings
Part 1: 1984 Code of practice for dead and imposed loads
Part 2: Code of practice for wind loading (to be published and will replace CP3 Chapter V Part 2)
Part 3: 1988 Code of practice for imposed roof loads
- CP3 Code of basic data for the design of buildings
Chapter V Part 2: 1972 Wind load

Quality Assurance

- BS 5750 1989: Quality systems (various parts)

Steel

- BS 4 Structural steel sections
Part 1:1980 Specification for hot rolled sections
- BS 970 Specification for wrought steels for mechanical and allied engineering purposes
Part 1: 1983 General inspection and testing procedures and specific requirements of carbon, carbon manganese, alloy and stainless steels
- BS 1449 Steel plate, sheet and strip
Part 1:1983 Specification for carbon and carbon-manganese plate, sheet and strip
Part 2:1983 Specification for stainless and heat-resisting steel plate, sheet and strip
- BS 1501 Steel for pressure purposes: plates, sheet and strip
Part 1:1980 Specification for carbon and carbon manganese steels
Part 2:1988 Specification for alloy steels
Part 3:1990 Specification for corrosion and heat-resisting steels
- BS 2989 1982 Specification for continuously hot-dip zinc coated and iron-zinc alloy coated steel: wide strip, sheet/plate and slit wide strip
- BS 4360 1990 Specification for weldable structural steels
- BS4461 1978 Specification for cold worked steel bars for reinforcement of concrete
(withdrawn, replaced by BS 4449:1988)
- BS 4449 1988 Specification for carbon steel bars for the reinforcement of concrete
- BS 4482 1985 Specification for cold reduced steel wire for the reinforcement of concrete
- BS 4483 1985 Specification for steel fabric for the reinforcement of concrete
- BS 4848 Specification for hot-rolled structural steel sections
Part 2:1975 Hollow sections
Part 4:1972 (1986) Equal and unequal angles
Part 5:1980 Bulb flats

- BS EN 10 002-1 Tensile testing of metallic materials
Part 1:1990 Method of test at ambient temperature
- BS EN 10 025 1990 Specification for hot rolled products of non-alloy structural steels and their technical delivery conditions

Vibration

- BS 6472 1984 Guide to evaluation of human exposure to vibration in buildings (1Hz to 80 Hz)

Welding

- BS 639 1986 Specification for covered carbon and carbon manganese steel electrodes for manual metal-arc welding
- BS 4165 1984 Specification for electrode wires and fluxes for the submerged arc welding of carbon steel and medium tensile steel
- BS 4870 Specification for approval testing of welding procedures
Part 1:1981 Fusion welding of steel
- BS 4871 Specification for approval testing of welders working to approved welding procedures
Part 1:1982 Fusion welding of steel
- BS 4872 Specification for approval testing of welders when welding procedure approval is not required
Part 1:1982 Fusion welding of steel
- BS 5135 1984 Specification for process of arc welding of carbon and carbon manganese steels
- BS 6693 Diffusible hydrogen
Part 5: 1988 Primary method for the determination of diffusible hydrogen in MIG, MAG, TIG or cored electrode ferritic steel weld metal
- BS 7084 1989 Specification for carbon and carbon manganese steel tubular cored welding electrodes

Weld Testing

- BS 2600 Radiographic examination of fusion welded butt joints in steel
Part 1:1983 Methods for steel 2 mm up to and including 50 mm thick
Part 2:1973 Methods for steel over 50 mm thick up to and including 200 mm thick
- BS 2910 1986 Methods for radiographic examination of fusion welded circumferential butt joints in steel pipes
- BS 3923 Methods for ultrasonic examination of welds
Part 1:1986 Methods for manual examination of fusion welds in ferritic steels
- BS 5289 1976 Code of practice for visual inspection of fusion welded joints
- BS 6072 1981 Method for magnetic particle flaw detection

20. ADVISORY BODIES

The reader may wish to contact one of the Advisory Bodies listed below for additional and/or current information and advice on most of the topics covered by this publication. However, please note that most of these Advisory Bodies give free advice only to their members; membership details can be obtained on request.

1. The British Constructional Steelwork Association (BCSA)

The British Constructional Steelwork Association Ltd (BCSA) is the national representative organisation for the constructional steelwork industry; its Member companies undertake the design, fabrication and erection of steelwork for all forms of construction in building and civil engineering. Associate Members are those principal companies involved in the purchase, design or supply of components, materials, services, etc. related to the industry. The principal objectives of the Association are to promote the use of structural steelwork; to assist specifiers and clients; to ensure that the capabilities and activities of the industry are widely understood and to provide members with professional services in technical, commercial, contractual and quality assurance matters.

The British Constructional Steelwork Association Ltd
4 Whitehall Court
Westminster
London SW1A2ES
Telephone: 071 839 8566 Fax: 071 976 1634

2. The Building Research Establishment (BRE)

The Building Research Establishment is the principal organisation in the United Kingdom carrying out research into building and construction and the prevention and control of fire. BRE is part of the Department of the Environment. Its main role is to advise DOE and other Government Departments on technical aspects of buildings and fire and on related subject, such as some aspects of environmental protection.

The Establishment's unique range of specialist skills and technical facilities is made available to the construction industry and its suppliers and clients through BRE Technical Consultancy, launched in October 1988.

BRE operates from four sites: its main site at Garston, near Watford; the Fire Research Station at Borehamwood and Cardington; and the BRE Scottish Laboratory at East Kilbride, Glasgow.

Building Research Establishment
Garston
Watford WD2 7JR
Telephone: 0923 894040 Fax: 0923 664010

3. British Steel plc

British Steel operates various centres of professional and technical advice for the construction industry. They are listed below by product.

(a) Sections

The Structural Advisory Service comprises a team of regionally-based engineers specialising in all aspects of structural steelwork.

The service offers confidential advice free of charge to designers and specifiers either in-house or over the telephone. It also offers a computer-based feasibility study facility to produce scheme designs of structures for comparison purposes with other framing materials.

British Steel General Steels
Commercial Division - Sections
PO Box 24, Steel House
Redcar
Cleveland TS10 5QL
Telephone: 0642 474111 Fax: 0642 489466

(b) Plates

For information and advice on all aspects of selection and use of carbon, carbon manganese and low alloy steel plates, including structural and pressure vessel steels. The service is the focal point for all the expertise and research effort required to answer any query relating to the use of steel plates.

British Steel General Steels
Commercial Division - Plates
PO Box 30
Motherwell
Lanarkshire ML1 1AA
Telephone: 0698 66233 Fax: 0698 66233 Ext 214

(c) Tubes

For information and advice on all aspects of Structural Hollow Sections (SHS) both Rectangular (RHS) and Circular (CHS) - including design, fabrication and welding, budget pricing, fire protection, corrosion prevention and metallurgical aspects.

Regionally based Structural Engineers are available to call at customers' offices to advise on design and usage.

British Steel General Steels - Welded Tubes
PO Box 101
Corby
Northamptonshire NN17 1UA
Telephone: 0536 402121 Fax: 0536 404111

(d) Strip products

The Technical Advisory Service gives information and advice on the products of BS Strip Mill Products. This includes dimensional ranges, steel qualities, suitability of products for particular applications, conformity to British and International Standards, and interpretation of specifications.

British Steel Strip Products
Commercial
PO Box 10
Newport
Gwent NP9 0XN
Telephone: 0633 290022 Fax: 0633 272933

(e) Stainless steel

The Stainless Steel Advisory Centre offers advice on the selection of stainless steels, properties and performance, fabrication, manipulation, surface finishing etc.

The Centre has a comprehensive index of fabricators, finished components, mill quantities, and stockholders, which will help with any source of supply queries.

It is the focal point for all the expertise and research effort required to answer any question relating to the use of stainless steel.

Stainless Steel Advisory Centre
 PO Box 161
 Shepcote Lane
 Sheffield S9 1TR
 Telephone: 0742 440060 Fax: 0742 448280

4. Construction Industry Research and Information Association (CIRIA)

The Construction Industry Research and Information Association is an independent non-profit-distributing body which initiates and manages research and information projects on behalf of its members. CIRIA projects relate to all aspects of design, construction, management and performance of buildings and civil engineering works. Details of other CIRIA publications, and membership subscription rates, are available from CIRIA at the address below.

CIRIA
 6 Storey's Gate
 London SW1P 3AU
 Telephone: 071 222 8891 Fax: 071 222 1708

5. The Steel Construction Institute (SCI)

The Steel Construction Institute aims to promote the proper and effective use of steel in construction.

SCI's work is initiated and guided through the involvement of its members on advisory groups and technical committees. A comprehensive advisory and consultancy service is available to members on the use of steel in construction.

SCI's research and development activities cover many aspects of steel construction including multi-storey construction, industrial buildings, use of steel in housing, development of design guidance on the use of stainless steel, behaviour of steel in fire, fire engineering, use of steel in barrage schemes, bridge engineering, offshore engineering, development of structural analysis systems and the use of CAD/CAE.

The Steel Construction Institute
 Silwood Park
 Ascot
 Berkshire SL5 7QN
 Telephone: 0344 23345 Fax: 0344 22944

SCI offices also at:

Unit 820		B-3040 Huldenberg
Birchwood Boulevard	52	De Limburg Stirumlaan
Warrington		Belgium
Cheshire WA3 7RZ		

Telephone: 0925 838655	Telephone: International + 32 2 687 8532
Fax: 0925 838676	

6. The Fire Test Study Group (UK) (FTSG)

FTSG is a forum for technical discussions and liaisons between consulting fire test laboratories involved in producing information for the purposes of building control.

Members of the FTSG participate on all relevant BSI committees, the equivalent ISO technical committees and are involved in the EEC Commission technical discussions on harmonisation.

The Fire Test Study Group (UK) (FTSG)

First Floor

72 High Street

Portishead,

Bristol

Avon BS20 9EH

Telephone: 0272 846262

APPENDIX: Metric conversion tables

Equivalents of SI units are given in Imperial and, where applicable, metric technical units.

MEASUREMENTS

Metric	Imperial	Imperial	Metric
1 mm	= 0.03937 in	1 in	= 25.4 mm
1 m	=3.28 1 ft	1 ft	=0.3048m
	=1.094 yd	1 yd	= 0.9144 m
1 km	= 0.6214 mile	1 mile	= 1.609 km
1 mm ²	= 0.00155 in ²	1 in ²	=645.2mm ²
1 m ²	=10.76 ft ²	1 ft ²	= 0.0929m ²
1 m ²	= 1.196yd ²	1 yd ²	= 0.8361m ²
1 hectare	= 2.471 acres	1 acre	= 0.4047 hectares
1 mm ³	= 0.00006102in ³	1 in ³	=16390 mm ²
1 m ³	= 35.31 ft ³	1 ft ³	=0.02832 m ³
	= 1.308 yd ³	1 Yd ³	=0.7646 m ³
(Moment of Inertia)		(Moment of Inertia)	
1 mm ⁴	=0.000002403 in ⁴	1 in ⁴	= 416200 mm ⁴

FORCE

N	lbf	kgf	kN	tonf	tonne f
1.0	=0.2248	=0.1020	1.0	=0.1004	=0.1020
4.448	=1.0	=0.4536	9.964	=1.0	=1.016
9.807	=2.205	=1.0	9.807	=0.9842	=1.0

FORCE PER UNIT LENGTH

N/m	lbf/ft	kgf/m	kN/m	tonf/ft	tonne f/m
1.0	=0.06852	=0.1020	1.0	=0.0306	=0.1020
14.59	=1.0	=1.488	32.69	=1.0	=3.333
9.807	=0.672	=1.0	9.807	=0.3000	=1.0

FORCE PER UNIT AREA

N/mm ²	lbf/in ²	kgf/cm ²	N/m ²	lbf/ft ²	kgf/m ²
1.0	=145.0	=10.20	1.0	=0.02089	=0.102
0.006895	=1.0	=0.0703	47.88	=1.0	=4.882
0.09807	=14.22	=1.0	9.807	=0.2048	=1.0
N/mm ²	tonf/in ²	kgf/cm ²	N/min ²	tonf/ft ²	kgf/cm ²
1.0	=0.06475	=10.20	1.0	=9.324	=10.20
15.44	=1.0	=157.5	0.1073	=1.0	=1.094
0.09807	=0.006350	=1.0	0.09807	=0.9144	=1.0

Continued.....

continued.....

UNIT WEIGHT

N/m³	lbf/ft³	kgf/m³	kN/m³	tonf/ft³	tonne f/m³
10	=0.006366	=0.102	10	=0.002842	=0.1020
157.1	=1.0	=16.02	351.9	=1.0	=35.88
9.807	=0.0624	=1.0	9.807	=0.02787	=1.0
kN/m³	lbf/in³	tonne f/m³			
10	=0.003684	=0.1020			
271.4	=1.0	=27.68			
9.807	= 0.03613	= 10			

MOMENT

N-m	lbf-in	lbf-ft	kgf-m
10	=8.851	=0.7376	=0.1020
0.1130	=1.0	=0.08333	=0.01152
1356	=12.0	=1.0	=0.1383
9.807	=86.80	=7.233	=1.0

FLUID CAPACITY

litres	Imp. gallons	USA gallons
10	=0.22	=0.2642
4.546	=1.0	= 1.201
3.785	=0.8327	=1.0