bsi.

...making excellence a habit.™

Please be aware that this PDF has been created from the original hardcopy document, which might not be in good condition and so the PDF might reflect this.

BSI Group
389 Chiswick High Road
London, W4 4AL
United Kingdom

T: +44 20 845 086 9001
F: +44 20 8996 7400
cservices@bsigroup.com
bsigroup.com

British Standards Limited
Registered in England no: 07864997
Registered address: 389 Chiswick High Road
London, W4 4AL, United Kingdom

AVA Documents
INVESTORS IN PEOPLE
Document Sharing Hub

Full document details: BS 449:1959

Superseded by reprint 1965

BRITISH STANDARD 449 : 1959
(Incorporating British Standard Code of Practice CP 113)
[UDC 669.14 : 624 : 693.814]

+ 8 AMD

THE USE OF STRUCTURAL STEEL IN BUILDING

BRITISH STANDARDS INSTITUTION

AVA Documents
Document Sharing Hub

BRITISH STANDARD SPECIFICATION

THE USE OF STRUCTURAL STEEL IN BUILDING

(incorporating British Standard Code of Practice CP 113, The structural use of steel in buildings)

B.S. 449 : 1959

Price 15/- net

BRITISH STANDARDS INSTITUTION
INCORPORATED BY ROYAL CHARTER
BRITISH STANDARDS HOUSE, 2 PARK ST., LONDON, W.1
TELEGRAMS: STANDARDS, AUDLEY, LONDON TELEPHONE: MAYFAIR 9000

AVA Documents
Document Sharing Hub

THIS BRITISH STANDARD, having been approved by the Building Divisional Council and the Council for Codes of Practice, was published by the authority of the General Council on 27th May, 1959.

First published, April, 1932.
First revision, December, 1935.
Second revision, July, 1937.
Third revision, July, 1948.
Fourth revision (incorporating B.S. C.P. 113), May, 1959

The Institution desires to call attention to the fact that this British Standard does not purport to include all the necessary provisions of a contract.

In order to keep abreast of progress in the industries concerned, British Standards are subject to periodical review. Suggestions for improvements will be recorded and in due course brought to the notice of the committees charged with the revision of the standards to which they refer.

This standard makes reference to the following British Standards and Codes of Practice:

B.S. 4 ~~Dimensions and properties of channels and beams for structural purposes.~~
B.S. 15 ~~Structural steel for bridges, etc., and general building construction.~~
B.S. 153 Steel girder bridges.
B.S. 275 Dimensions of rivets (½ in. to 1¾ in. diameter).
B.S. 499 Glossary of terms (with symbols) relating to the welding and cutting of metals.
~~B.S. 548 High tensile structural steel for bridges, etc., and general building construction.~~
B.S. 592 Carbon steel castings for general engineering purposes (incorporated in B.S. 3100—Steel castings for general engineering).
B.S. 639 Covered electrodes for metal arc welding ~~wrought iron and~~ mild steel.
B.S. 648 Schedule of ~~unit~~ weights of building materials.
B.S. 693 ~~Oxy-acetylene welding as applied to steel structures.~~
B.S. 785 Rolled steel bars and hard drawn steel wire for concrete reinforcement.
B.S. 916 Black bolts, screws and nuts.
B.S. 938 General requirements for the metal arc welding of structural steel tubes. to B.S. 1775

See adt 4

See Amdt 1. page 14

B.S. 968 High-tensile ~~(fusion welding quality)~~ structural steel for ~~bridges, etc.,~~ and general building construction. See Amdt No 3.
B.S. 1083 Precision hexagon bolts, screws, and nuts ~~and plain washers.~~
B.S. 1719 ~~Classification of covered electrodes for the metal-arc welding of mild steel and of medium-high-tensile steels of welding quality.~~
B.S. 1768 Unified precision hexagon bolts, screws, nuts (UNC and UNF threads) ~~and plain washers~~ normal series.
B.S. 1775 Steel tubes for mechanical, structural and general engineering purposes.
B.S. 1856 General requirements for the metal-arc welding of mild steel.
B.S. 1881 Methods of testing concrete.
~~B.S. 2466 Black taper washers.~~
B.S. 2549 Covered electrodes for the metal-arc welding of medium-high tensile structural steel.
B.S. 2642 General requirements for the metal-arc welding of medium tensile weldable structural steels to B.S. 968, Type a.
B.S. 2645 Tests for use in the approval of welders.
B.S. 2708 Unified black square and hexagon bolts, screws and nuts (UNC and UNF threads) ~~and plain washers.~~ Normal series.
B.S. 2762 Notch ductile steel for general structural purposes.
B.S. 3139 High strength friction grip bolts for structural engineering.
CP.3. Chapter IV. Precautions against fire.
CP.3. Chapter V. Loading.

See adt 4.

~~In course of preparation.~~
B.S. 3410, metal washers for general engineering purposes.

British Standards are revised, when necessary, by the issue either of amendment slips or revised editions. It is important that users of British Standards should ascertain that they are in possession of the latest amendments or editions.

B.S. 2994: Cold rolled steel sections
B.S. 3294. Use of high strength friction grip bolts in structural steelwork Part 1. General Grade bolt.

The following B.S.I. references relate to the work on this standard:
Committee reference B/20 Draft for comment CT(B) 9926

B.S. 449. Adtd No 1. [Amdt No 2]

AVA Documents
Document Sharing Hub

CONTENTS

	Page
Co-operating organizations	9
Foreword	10
Economy in design	11
Metric conversions	11
SPECIFICATION	
1. Scope	12
Part 1: DEFINITIONS	
2. Definitions	12
Part 2: MATERIALS	
3. Structural steel and electrodes	14
4. Other materials	15
5. Standard dimensions	15
Part 3: LOADS	
6. Dead loads and imposed loads	16
7. Dynamic loads	16
8. Temperature range	17
Part 4: DESIGN AND DETAILS OF CONSTRUCTION	
A. GENERAL	
9. Steel framework	18
10. Resistance to horizontal forces	19
11. Foundations	20
12. Minimum thickness of metal	20
13. Stresses due to wind forces	21
14. Combined stresses	21
15. Deflection of beams	23
16. Overhang of walls	23
17. Sectional areas	23
18. Separators and diaphragms	24
B. DESIGN OF MEMBERS SUBJECT TO BENDING	
19. Bending stresses (beams other than plate girders)	25
20. Bending stresses (plate girders)	29

	Page
21. Bending stresses (cased beams)	35
22. Bearing stress	36
23. Shear stresses	36
24. Effective span of beams	40
25. Maximum slenderness ratio of compression flanges	41
26. Effective length of compression flanges for beams and girders	41
27. Beams with solid webs including plate girders	45
28. Web stiffeners	48
29. Filler joists	51
C. DESIGN OF COMPRESSION MEMBERS	
30. Axial stresses in struts	53
31. Effective length of compression members	56
32. Design details	57
33. Maximum slenderness ratio of struts	58
34. Eccentricity for stanchions and solid columns	58
35. Lacing and battening	59
36. Battened compression members	61
37. Compression members composed of two components back-to-back	63
38. Stanchions and column bases	63
39. Base plates and bearing plates	65
40. Grillage foundations	65
D. DESIGN OF TENSION MEMBERS	
41. Axial stresses in tension	65
42. Tensile stresses for angles and tees	66
E. CONSTRUCTIONAL DETAILS	
43. Braced frames and trusses	67
44. Roof trusses	67
45. Purlins	68
46. Side and end sheeting rails	68
47. Steel castings	68
48. Connections	69
49. Lug angles	70
F. RIVETING AND BOLTING	
50. Allowable stresses in rivets and bolts	71

AVA Documents
Document Sharing Hub

		Page
51.	Rivets and riveting	72
52.	Bolts and bolting	73

G. WELDING

53.	Allowable stresses in welds	74
54.	Design of welds	77

Part 5: FABRICATION AND ERECTION

55.	Inspection	79

H. WORK OFF SITE

56.	Straightness	79
57.	Clearances	79
58.	Cutting	79
59.	Holing	79
60.	Assembly	80
61.	Riveting	80
62.	Bolting	81
63.	Welding	81
64.	Qualification and testing of welders	81
65.	Flattened ends of tubes	81
66.	Machining of butts, caps and bases	82
67.	Slab bases and caps	82
68.	Solid round steel columns	82
69.	Marking	82
70.	Painting	82

J. WORK ON SITE

71.	Plant and equipment	83
72.	Storing and handling	83
73.	Setting out	83
74.	Security during erection	83
75.	Painting after erection	83
76.	Bedding of stanchion bases, bedding and encasing of grillage beams and bearings of beams and girders	84

Part 6: TESTS FOR USE IN THE APPROVAL OF WELDERS

77.	Tests	86

		Page
78.	Changes of welding procedure requiring re-qualification of welders	86
79.	Extent of qualification of welders	87

APPENDICES

A.	Loading tests	90
B.	Formula from which Table 17 has been derived	92
C.	Determination of the length of the curve of intersection of a tube with another tube or with a flat plate	93
D.	Effective length of stanchions	94
E.	General recommendations for steelwork tenders and contracts	109
F.	Drafting committee for CP 113	113

TABLES

1.	Maximum allowable equivalent stress p_e	22
2.	Allowable stresses in bending	26
3.	Allowable stresses in bending (ton/sq.in.) for beams of steel to B.S. 15 and B.S. 2762	27
4.	Allowable stresses in bending (ton/sq.in.) for beams of steel to B.S. 548 and B.S. 968	28
5.	Values of factor K_1	30
6.	Values of factor K_2	31
7.	Values of A and B to calculate C_s	32
8.	Allowable working stress p_{bc} for different values of C_s	34
9.	Allowable bearing stress	36
10.	Allowable maximum shear stress p_q	37
11.	Allowable average shear stress p_q' in webs	37
12.	Allowable average shear stress p_q' in stiffened webs of steel to B.S. 15 or B.S. 2762	38
13.	Allowable average shear stress p_q' in stiffened webs of steel to B.S. 548 and B.S. 968	39
14.	Maximum outstand of flanges	46
15.	Bending moment values for filler joists	51
16.	Spacing of filler joists	52
17.	Allowable stresses p_c, on gross section for axial compression	54

AVA Documents
Document Sharing Hub

		Page
18.	Assumed eccentricity of loads on stanchions and solid columns	58
19.	Allowable tensile stresses in axial tension	66
20.	Allowable stresses in rivets and bolts	71
21.	Edge distance of holes	72

CO-OPERATING ORGANIZATIONS

The Technical Committee of the Building Divisional Council responsible for the revision of this British Standard (now incorporating the British Standard Code of Practice CP 113: 1948—'The structural use of steel in buildings'), consists of representatives from the following departments and scientific and industrial organizations, and of additional members nominated to represent the Institution of Structural Engineers Committee, under whose supervision CP 113: 1948 was prepared (see Appendix F):—

Admiralty
Air Ministry
Association of Municipal Corporations
British Constructional Steelwork Association
British Iron and Steel Federation
British Railways, The British Transport Commission
British Welding Research Association
Building Committee in Scotland
Crown Agents for Oversea Governments and Administrations
Department of Scientific and Industrial Research
District Surveyors Association
Institute of Builders
Institute of Welding
Institution of Civil Engineers
Institution of Municipal Engineers
Institution of Structural Engineers
London County Council
Ministry of Housing and Local Government
Ministry of Works
National Federation of Building Trades Employers
Royal Institute of British Architects
War Office
Individual manufacturers and consultants

AVA Documents
Document Sharing Hub

BRITISH STANDARD SPECIFICATION FOR

THE USE OF STRUCTURAL STEEL IN BUILDING

(incorporating British Standard Code of Practice CP 113, 'The structural use of steel in buildings')

FOREWORD

B.S. 449 was first issued in 1932 and was revised in December 1935, July 1937 and July 1948. Reconsideration of the standard has since led to numerous amendments which are embodied in the present revised standard, now published under the authority of the Building Divisional Council and the Council for Codes of Practice.

When a programme of Codes of Practice for Buildings was drawn up in 1942 under the aegis of the Ministry of Works, a Code of Practice for the structural use of steel in buildings was included in a series for all types of building construction: this was later (1948) issued as CP 113. Much of the information given in B.S. 449 and in CP 113 was the same and with the formation of the Codes of Practice Council within the B.S.I. it was decided that the two documents should be amalgamated and issued as a single publication under the main reference B.S. 449.

Apart from the alterations necessitated by amalgamation with CP 113, the main differences between the present revised standard and the 1948 issue can be summarized as follows:

(1) The clauses of Part 3 on dead and imposed loads have been omitted, and reference made to the Code of Practice CP 3 : Ch. V—Loading, which covers the loading requirements recommended for structures of all types. This Code of Practice has now been amended to include wind loads on unclad structures.

(2) In Part 4, 'Design and details of construction', the clauses for members subject to *bending*, *axial compression* and *axial tension* have been rearranged in separate groups, each containing the basic information necessary for design.

(3) The use of tubular members in building, covered by Addendum No. 1, PD 1953, is now dealt with within the text of the standard.

(4) The design clauses for welds and welding have been curtailed, and reference has been made instead to the appropriate British Standards. An important addition consists of a section, based on B.S. 2645, specifying the tests to be used for the approval of welders for general and special structural work.

Users of this British Standard should satisfy themselves that effective compliance is secured with local bye-laws and regulations and, for insurance purposes, with any requirements of insurance companies.

The attention of users is also called to the importance of making provision, where necessary, for water, gas, electricity and other services, having particular regard to Clause 21 *e* of this standard for cased beams and Clause 30 *c* (iv) for cased struts.

ECONOMY IN DESIGN

This British Standard stipulates limits of stress and gives rules for design, with the twofold purpose of ensuring normal safety and economy in the use of structural steel. While the stresses and other requirements are to be regarded as limiting values, the purpose in design should be to reach these limits in as many parts of the structure as possible and to adopt a layout such that maximum structural efficiency is attained for a minimum use of steel. Careful consideration should therefore be given to the semi-rigid basis and fully rigid basis of design.

METRIC CONVERSIONS

For the convenience of countries using the metric system, the following conversion factors are provided.

They are calculated from the basic factors:

1 inch (in.)	=	25·4 millimetre (mm) (exactly)
1 pound (lb)	=	0·453 592 37 kilogramme (kg)

and have been rounded to enable converted metric values of sufficient accuracy for general purposes to be obtained.

Conversion tables of greater accuracy are given in B.S. 350, 'Conversion factors and tables'.

1 inch (in.)	=	25·4 millimetre (mm) (exactly)
1 foot (ft)	=	0·3048 metre (m) (exactly)
1 pound (lb)	=	0·4536 kilogramme (kg)
1 ton = 2240 lb	=	1·016 metric tonne
	=	1016 kg
1 lb/sq.in.	=	0·070 kg/mm²
1 ton/sq.in.	=	1·575 kg/mm²

Moment of inertia (inch⁴) × 41·62 = Moment of inertia (cm⁴)

Modulus of section (inch³) × 16·39 = Modulus of section (cm³)

AVA Documents
Document Sharing Hub

SPECIFICATION

SCOPE

1. This British Standard relates primarily to the use in building of hot rolled steel sections and plates, and normalized tubular shapes. ~~An extension to the standard, now in course of preparation, will relate to the use in building of cold rolled sections in light gauge sheet and strip steel.~~ See Amd No 2

The provisions of this standard are not deemed to apply to transmission towers and farm buildings; nor to structures which are designed on an experimental basis, except in so far as provided by Clause 9 *c* and Appendix A.

Part 1: Definitions

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

Beam or girder — Any structural member which supports load primarily by its internal resistance to bending.

Dead load — The weight of all permanent construction.

Effective lateral restraint — Restraint which will produce sufficient resistance in a plane perpendicular to the plane of bending to restrain a loaded beam from buckling to either side at the point of application of restraint.

Filler joists — Rolled steel I-beams or other suitable flanged sections used in combination with structural concrete and forming the skeleton of a floor or roof slab.

Foundation — That part of the building the function of which is to distribute loading direct to the ground. It may include any retaining or other wall, based upon the ground, of sufficient strength and stability to carry its own weight together with the loads and forces imposed upon it.

High strength friction grip bolts — High strength friction grip bolts are bolts of high tensile steel, used in conjunction with high strength nuts and hardened steel washers, which are tightened to a pre-determined shank tension in order that the clamping action thus afforded will transfer loads in the connected members by friction between the parts in contact and not by shear or bearing in the bolts. (See footnote to Clause 48.)

Imposed load — In respect of a building: all loads other than the dead load.

Load factor — The numerical value by which the load which would cause failure of the structure is divided to give the permissible working load on the structure.

Panel wall — A wall built between pillars, stanchions or other members and supported by the steel framework or foundations.

Partition — An internal vertical structure which is employed solely for the purpose of subdividing any storey of a building into sections, and which supports no load other than its own weight.

Strut — A steel pillar, stanchion, column or other compression member.

The 'Engineer' — The person responsible for the design and satisfactory completion of the structure, as covered by this specification.

Welding terms — Except as otherwise defined in this British Standard, the terms used in the welding clauses have the meanings given in B.S. 499, 'Glossary of terms (with symbols) relating to the welding and cutting of metals'.

Wheel loads — The static weights imposed by the wheels when the appliance of which the wheels form part is fully loaded.

Yield stress — The yield stress in tension.

AVA Documents
Document Sharing Hub

Part 2: Materials

See Amdt 1.

STRUCTURAL STEEL AND ELECTRODES

3. *a.* **Structural and rivet steel.** All structural and rivet steel used in building coming within the purview of this British Standard shall, before fabrication, comply with one or other of the following, whichever is appropriate.

See Adt. 4 B.S. 15 ~~'Structural steel for bridges, etc., and general building construction.'~~

B.S. 548 'High tensile structural steel for bridges, etc., and general building construction.'

B.S. 968 'High tensile (~~fusion welding~~ quality) ~~structural~~ steel for bridges, etc., and ~~general building construction.'~~ See Amdt No 3

B.S. 1775 'Steel tubes for mechanical, structural and general engineering purposes.' Grades 13, 16 or 20 of Types HFW, HFS, CDS, ERW or CEW. Types CDS, ERW and CEW shall be supplied in the normalized condition and their classification by grade shall be determined by their mechanical properties in the normalized condition.

NOTE 1. The alteration of mechanical properties resulting from heating, which is mentioned as a possibility in the footnotes to the tables in Clause 33 of B.S. 1775, will not occur in normalized tubes.

NOTE 2. B.S. 1775 refers to steel tubes which are of circular cross section. Tubes of the same material but of rectangular or other cross section may be used provided that the appropriate section properties and form and stress factors, as affecting stress distribution and wind pressure, are used.

B.S. 2762 'Notch ductile steel for bridges and general building construction' (Class B).

NOTE. Welded structures of steel to B.S. 15 are normally satisfactory, but under certain conditions they may become liable to failure due to the brittle fracture of parts subjected to tensile stress. These conditions cannot at present be defined accurately, but the possibility of this type of failure should be considered when there is a combination of low temperature with the following factors: thick plates and large unit sections, connections and details giving rise to severe stress concentrations, and the possibility of certain undetected defects in welding such as cracks, lack of fusion and lack of root penetration.

When the combination of circumstances referred to above cannot be disregarded, the use of Notch Ductile steels, series I to IV, to B.S. 2762 is recommended for parts in tension in excess of 1 in. thickness.

Although steels to B.S. 968 may be superior in notch ductility to those covered by B.S. 15, their suitability under those conditions which may give rise to brittle fracture must be given special consideration.

b. **High tensile steel rivets.** Where high tensile steel is used for rivets, steps shall be taken to ensure that the rivets are so manufactured that they can be driven and the heads formed satisfactorily; and that the physical properties of the steel are not impaired.

c. **Electrodes.** Mild steel electrodes shall comply with the requirements of B.S. 639, 'Covered electrodes for the metal-arc welding of mild steel'. High tensile steel electrodes shall comply with the requirements of B.S. 2549, 'Covered electrodes for the metal-arc welding of medium high tensile structural steel'.

d. **Steel for bolts and nuts.** (i) MILD STEEL. All mild steel bolts and nuts shall have a tensile strength of not less than 28 ton/sq.in. and a minimum elongation of 17 per cent as defined in Clause 2 of B.S. 916, 'Black bolts, screws and nuts, hexagon and square, with B.S.W. threads and partly machined bolts, screws and nuts, hexagon and square with B.S.W. or B.S.F. threads', or in B.S. 2708, 'Unified black bolts, etc. Normal series'.

(ii) HIGH TENSILE STEEL. A. *Structural quality.* The material used for the manufacture of high tensile steel bolts, nuts and washers to B.S. 548, for which permissible stresses are given in Clause 50, Table 20, shall have a minimum tensile strength of 37 ton/sq.in. and other mechanical properties appropriate to B.S. 548, 'High tensile structural steel for bridges, etc.'.

B. *Special quality.* The material used for the manufacture of special quality high tensile steel bolts and nuts as covered by the Note in Clause 50 shall have the mechanical properties appropriate to the particular class of steel, as set out in Appendix A, Tables 9 and 10 of B.S. 1083, 'Precision hexagon bolts, screws, nuts (B.S.W. and B.S.F. threads) and plain washers'; or in B.S. 1768, 'Unified precision hexagon bolts, screws, nuts, etc. Normal series'; or as approved by the Engineer.

e. **Washers.** Plain washers shall be made of steel.

Taper or other specially shaped washers shall be made of steel or malleable cast iron. (See B.S. 2466, 'Black taper washers'.)

OTHER MATERIALS

4. Other materials used in the structure in association with steelwork shall conform to any bye-laws or regulations to which the building has to conform.

Where an appropriate British Standard for a particular material exists the material shall also comply with that British Standard, except where it may conflict with, or differ from, the requirements of any relevant bye-law or regulation.

STANDARD DIMENSIONS

5. The dimensions of all structural rolled shapes, and the form, weight, tolerance, etc., of all rolled shapes and other members used in any structure shall, whenever possible, conform to the latest appropriate standards of the British Standards Institution.

The dimensions or form and the weight, tolerances, etc., of all rivets, bolts, nuts, studs, etc., shall conform to the requirements of the latest appropriate standards of the British Standards Institution.

AVA Documents
Document Sharing Hub

Part 3: Loads

DEAD LOADS AND IMPOSED LOADS

6. Reference should be made to B.S. Code of Practice CP 3—Ch. V—Loading:

a. For recommendations on the determination of the dead load.

b. For recommended values of imposed loads on floors, corridors, balconies, stairs and landings, parapets and balustrades; of snow and other loads; and of wind loads on buildings and unclad structures (including sheeted towers and chimneys).

DYNAMIC LOADS

7. Where loads arising from machinery, runways, cranes and other plant producing dynamic effects are supported by or communicated to the framework, allowance shall be made for these dynamic effects, including impact, by increasing the deadweight values by an adequate percentage.

In order to ensure due economy in design the Engineer shall ascertain as accurately as possible the appropriate dynamic increase for all members affected.

For crane gantry girders the following allowances shall be deemed to cover all forces set up by vibration, shock from slipping of slings, kinetic action of acceleration and retardation and impact of wheel loads:

a. For loads acting vertically, the maximum static wheel loads shall be increased by the following percentages:

For electric overhead cranes	25 per cent
For hand-operated cranes	10 per cent

b. The horizontal force acting transverse to the rails shall be taken as a percentage of the combined weight of the crab and the load lifted as follows:

For electric overhead cranes	10 per cent
For hand-operated cranes	5 per cent

This force shall be taken into account when considering the lateral rigidity of the rails and their fastenings.

c. Horizontal forces acting along the rails shall 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 per cent

The forces specified in either *b* or *c* above shall be considered as acting at the rail level and being appropriately transmitted to the supporting systems.

Gantry girders and their vertical supports shall be designed on the assumption that either of the horizontal forces *b* or *c* may act at the same time as the vertical load.

An increase of 10 per cent on the permissible stresses specified in this standard shall be allowed for the combination of loadings *a* and *b* in respect of the design of the gantry girders and supporting structures. This increase is not however in addition to that permitted in Clause 13.

In special cases, e.g. charging machines, and where more than one crane is in use on the gantry and where high speeds are attained, the above allowances should be reconsidered.

NOTE. For factors applicable to the allowable working stresses, and detailed design under fatigue conditions, see B.S. 153, 'Steel girder bridges', Parts 3B and 4.

TEMPERATURE RANGE

8. Where, in the design and erection of a building, it is necessary to take account of a change of temperature, it shall be assumed that the average temperature of the metal in the structure in Great Britain and Northern Ireland does not vary over a range greater than from 20°F to 120°F. The design range, however, depends on the location, type and purpose of the building. Special consideration will be necessary for structures in special conditions and in localities abroad subject to different temperature ranges.

AVA Documents
Document Sharing Hub

Part 4: Design and Details of Construction

A. GENERAL

STEEL FRAMEWORK

9. *a.* Any part of the structure shall be capable of sustaining the most adverse combination of static and dynamic forces which may reasonably be expected from dead loads and all imposed loads, including snow and wind loads, referred to in Part 3, without the permissible stresses specified in Part 4 being exceeded.

See Annex 1. Page 14

b. The following methods may be employed in the design of the steel framework:

(i) *Simple design.* This method applies to structures in which the end connections between members are such that they will not develop restraint moments adversely affecting the members and the structure as a whole and in which the structure may, for the purposes of design, be assumed to be pin-jointed.

This method of design involves the following assumptions:

Beams are simply supported.

All connections of beams, girders or trusses are proportioned to resist the reaction shear forces applied at the appropriate eccentricity.

Members in compression are subjected to loads applied at the appropriate eccentricities (see Clause 34 for stanchions), with the effective lengths given in Clauses 30 and 31.

Members in tension are subjected to longitudinal loads applied over the net area of the section, as specified in Clause 42.

(ii) *Semi-rigid design.* This method, as compared with the simple design method, permits a reduction in the maximum bending moment in beams suitably connected to their supports, so as to provide a degree of direction fixity and, in the case of triangulated frames, it permits account being taken of the rigidity of the connections and the moment of interaction of members. In cases where this method of design is employed, calculations based on general or particular experimental evidence shall be made to show that the stresses in any part of the structure are not in excess of those laid down in this British Standard. Alternatively, where riveted or bolted connections are employed, the design may be made in conformity with the 'Recommendations for Design'* in the final report of the Steel Structures Research Committee, 1936, provided steel to B.S. 15 or B.S. 2762, or to B.S. 1775, Grade 16, only is used, in which case the requirements of this British Standard in respect of stresses may be deemed to be satisfied.

(iii) *Fully rigid design.* This method, as compared with the method for simple and semi-rigid design, will give the greatest rigidity and economy in weight of steel used when applied in appropriate cases. For this purpose the design shall be carried out in accordance with accurate methods of elastic analysis and to the limiting stresses permitted in this British Standard. Alternatively, it shall be based on the principles of plastic design so as to provide an adequate load factor, and with deflections under working loads not in excess of the limits implied in this British Standard.

* Now issued by British Standards Institution as PD 3343.

c. **Experimental basis.** Where, by reason of the unconventional nature of the construction, calculation is not practicable, or where the methods of design given in *b* above are inapplicable or inappropriate, loading tests shall be made, in accordance with the procedure set out in Appendix A, to ensure that the construction has:

(i) Adequate strength to sustain a total load equal to twice the sum of the dead load and the specified superimposed load.

(ii) Adequate stiffness to resist, without excessive deflection, a total load equal to the sum of the dead load and 1½ times the specified superimposed load.

d. **Curved members and bends.** The design of curved or bent members shall be given special consideration. Allowance shall be made for any thinning of the bent part which may be caused by bending the member.

RESISTANCE TO HORIZONTAL FORCES

10. *a.* **General.** (i) When considering the effect of wind pressure on buildings, due allowance shall be made for the resistance and stiffening effects of floors, roofs and walls.

(ii) When the floors, roof and walls are incapable of transmitting the horizontal forces to the foundation, the necessary steel framework shall be provided to transmit the forces to the foundations. This framework may be in the form of triangulated bracing to members, portal construction or cantilevers which shall comprise all members necessary effectively to transmit the forces to the foundations.

Resistance to the wind forces on the sides and roof of a building shall be provided by horizontal or inclined bracing or beam systems designed to transmit the wind loads direct to the foundations or to intermediate transverse frames or to end frames, and those frames shall be designed to transmit the loads to the foundations.

Resistance to the wind forces on the ends and roof of a building shall likewise be provided by horizontal or inclined bracing or beam systems designed to transmit the wind loads to the side framing, and the side framing shall be braced to transmit these loads to the foundations, or, alternatively, the wind forces on the ends may be taken direct to the foundations by vertical cantilevers.

In buildings where high-speed travelling cranes are supported by the structure

AVA Documents
Document Sharing Hub

or where a building or structure may be otherwise subject to vibration or sway, triangulated bracing or especially rigid portal systems shall be provided to reduce the vibration or sway to a suitable minimum.

b. **Stability.** The stability of the structure as a whole or of any part of it shall be investigated, and weight or anchorage shall be provided so that the least restoring moment, including anchorage, shall be not less than the sum of 1·2 times the maximum overturning moment due to dead loads and 1·4 times the maximum overturning moment due to imposed loads.

Wind loading shall be treated as imposed loading.

To ensure stability at all times account shall be taken of probable variations in dead load during construction, repair or other temporary measures.

In complying with the requirements of this clause it is necessary to ascertain that the resulting pressures and shear forces to be communicated by the foundations to the supporting soil would not produce failure.

All parts of the structure which have been designed for their dead and imposed loads to the permissible stresses in this British Standard shall be deemed to be adequately covered for this margin of stability.

FOUNDATIONS

11. The foundations of a building or other structure shall be so designed as to limit the pressures on the sub-soil to safe bearing values and to ensure such rigidity and restraints as have been allowed for in the design of the superstructure, including resistance to all horizontal forces. Due regard shall be paid to the effects of temperature and seasonal changes generally.

The weight of foundations shall be such as to comply with Clause 10 *b* of this standard.

MINIMUM THICKNESS OF METAL

12. The following provisions shall apply, except in the case of members on which special protection against corrosion is provided:

a. **General.** Steel used for external construction exposed to the weather or other corrosive influences shall be not less than 5/16 in. thick; and in construction not so exposed, not less than ¼ in. thick. These provisions do not apply to the webs of British Standard rolled steel joists and channels, or to packings.

b. **Sealed tubes or sealed box sections.** Sealed tubes or sealed box sections used for external construction exposed to the weather shall be not thinner than 8 S.W.G. (0·160 in.) and for construction not so exposed shall be not thinner than 10 S.W.G. (0·128 in.). In no case, however, shall steel tubes of the diameters shown in Tables 1 and 2 of B.S. 1775 be thinner than the minimum thickness shown for their respective sizes in Table 1 or Table 2 of B.S. 1775, whichever is appropriate.

Tubes of sizes other than those in Tables 1 and 2 of B.S. 1775, and sealed box sections shall have a thickness not less than that given by the formula:

$$t = 0{\cdot}1\sqrt[3]{D}$$

where t = wall thickness in inches.

D = outside diameter of tube, or the diagonal dimension of a rectangular tube, in inches.

See Amdt 1. Page 14.

STRESSES DUE TO WIND FORCES

13. Unless otherwise stated, the allowable stresses specified in the relevant clauses of Part 4 of this standard may be exceeded by 25 per cent in cases where an increase in stress is solely due to wind forces, provided that the steel section shall be not less than that needed if the wind stresses were neglected.

This provision does not apply to grillage beams (see Clause 40).

In the case of any combination of stresses arising from bending and axial loading, including the effects of wind, the values of p_c and p_{bc} in Clause 14 *a* and p_t and p_{bt} in Clause 14 *b* shall be increased by 25 per cent in respect only of the stress ratios which include wind in satisfying the relationship to unity, provided that Clause 14 *a* and *b* shall also apply in respect of any combination of stresses arising from bending and axial loading not due to wind.

See Amdt 1. Page 14

COMBINED STRESSES

14. *a.* **Bending and axial compression.** Members subject to both axial compression and bending stresses shall be so proportioned that the quantity

$$\frac{f_c}{p_c} + \frac{f_{bc}}{p_{bc}}$$

does not exceed unity at any point, where

f_c = the calculated average axial compressive stress.

p_c = the allowable compressive stress in axially loaded struts (see Table 17).

f_{bc} = the resultant compressive stresses due to bending about both rectangular axes.

p_{bc} = the appropriate allowable compressive stress for members subject to bending (see Clause 19).

In cased struts for which allowance is made for the load carried by the concrete in accordance with Clause 30 *b*, the ratio f_c/p_c in the above expression shall be replaced by the ratio of the calculated axial load on the strut to the allowable axial load determined from Clause 30 *b*.

AVA Documents
Document Sharing Hub

b. **Bending and axial tension.** Members subject to both axial tension and bending stress shall be so proportioned that the quantity

$$\frac{f_t}{p_t} + \frac{f_{bt}}{p_{bt}}$$

does not exceed unity at any point, where

f_t = the calculated axial tensile stress.
p_t = the permissible axial tensile stress (see Clause 41).
f_{bt} = the resultant tensile stress due to bending about both principal axes.
p_{bt} = the appropriate allowable tensile stress in bending (see Clause 19).

c. **Bending and shear.** The equivalent stress f_e due to bending and shear shall not exceed the values given of p_e in Table 1.

The equivalent stress f_e is obtained from the following formula:

$$f_e = \sqrt{(f_{bt}^2 + 3f_q^2)} \quad \text{or} \quad \sqrt{(f_{bc}^2 + 3f_q^2)}$$

in which f_{bc} or f_{bt}, and f_q are the numerical values of the co-existent bending and shear stresses.

d. **Combined bearing, bending and shear stresses.** Where a bearing stress is combined with tensile bending and shear stresses under the most unfavourable conditions of loading, the equivalent stress f_e, obtained from the following formulae, shall not exceed the values of p_e given in Table 1.

$$f_e = \sqrt{(f_{bt}^2 + f_b^2 + f_{bt} \cdot f_b + 3f_q^2)}$$
$$\text{or } f_e = \sqrt{(f_{bc}^2 + f_b^2 - f_{bc} \cdot f_b + 3f_q^2)}$$

in which f_{bt}, f_{bc}, f_q and f_b are the numerical values of the co-existent bending, shear and bearing stresses.

TABLE 1. MAXIMUM ALLOWABLE EQUIVALENT STRESS p_e

NOTE. The increases permitted by Clauses 7 and 13 do not apply to these stresses.

Form	Steel to B.S. No.	Thickness or dia.	p_e
		in.	ton/sq.in.
Rolled I-beams and channels	B.S. 15 and B.S. 2762	All	14·5
Plates, bars, Universal beams and columns, and sections other than above	B.S. 15 and B.S. 2762	Up to and including ¾	14·5
		Over ¾	14·0
Plates, sections and bars	B.S. 548	Up to 1¾	20·0
,, ,, ,, ,,	B.S. 548	Over 1¾	17·0
~~,, ,, ,, ,,~~	~~B.S. 968~~	~~Up to 1~~	~~19·0~~
~~,, ,, ,, ,,~~	~~B.S. 968~~	~~Over 1~~	~~17·0~~
Tubes	B.S. 1775, Grade 13	All	12·0
,,	B.S. 1775 Grade 16	All	14·5
,,	B.S. 1775, Grade 20	All	18·5

See Amdt No 3.

See Amdt 4

DEFLECTION OF BEAMS

15. ~~The maximum deflection of any beam shall not exceed 1/325 of the span.~~ However, in cases where greater deflection would not impair the strength and efficiency of the structure lead to damage of finishings or be unsightly, it is permissible to exceed this limit. (See Clauses 45 and 46.)

OVERHANG OF WALLS

16. Where a wall, or leaf of a cavity wall, is placed eccentrically upon the flange of a supporting steel beam, the beam and its connections shall be designed for torsion, unless the beam is encased in solid concrete and reinforced in combination with an adjoining slab in such a way as to prevent the beam deforming torsionally.

SECTIONAL AREAS

17. *a.* **General.** The gross sectional area shall be taken as the area of the cross section as calculated from the specified size.

The net sectional area shall be taken as the gross sectional area less deductions for rivet holes, bolt holes and open holes, or other deductions specified in this standard.

In making deductions for rivet and bolt holes the diameter of the hole shall be assumed to be 1/16 in. in excess of the nominal diameter of the rivet or bolt unless otherwise specified. For countersunk rivets or bolts the appropriate addition shall be made to the diameter of the hole.

Except as required by the following paragraph, the areas to be deducted shall be the sum of the sectional areas of the maximum number of holes in any cross section at right angles to the direction of stress in the member.

For (i) all axially loaded tension members;
(ii) plate girders of steel to B.S. 15 or B.S. 2762 and with d/t greater than 85;
and (iii) plate girders of steel to B.S. 548 or B.S. 968 and with d/t greater than 75, where d and t are as defined in Clause 23 *b*, (Amdt No 2)

the area to be deducted when the holes are staggered shall be that given above or, if greater, the sum of the sectional areas of all holes in any zig-zag line extending progressively across the member or part of the member, less $\frac{s^2t}{4G}$ for each gauge space in the chain of holes.

where s = the staggered pitch, i.e. the distance, measured *parallel* to the direction of stress in the member, centre-to-centre of holes in consecutive lines.

AVA Documents
Document Sharing Hub

t = the thickness of the material.

G = the gauge, i.e. the distance measured *at right angles* to the direction of stress in the member, centre-to-centre of holes in consecutive lines.

For sections such as angles with holes in both legs the gauge shall be measured along the centre of the thickness of the angle.

NOTE. In a built-up member where the chains of holes considered in individual parts do not correspond with the critical chain of holes for the member as a whole, the value of any rivets or bolts joining the parts between such chains of holes shall be taken into account in determining the strength of the member.

b. **Rivets.** The nominal diameter of a rivet shall be the diameter cold before driving.

The gross area of a rivet shall be the cross-sectional area of the rivet hole.

c. **Bolts and screwed tension rods.** The net sectional area of a bolt or screwed tension rod shall be taken as the area at the root of the thread, or as the cross-sectional area of the body of the bolt or tension rod, whichever is the lesser.

SEPARATORS AND DIAPHRAGMS

18. Where two or more rolled steel joists or channels are used side by side to form a girder, they shall be connected together at intervals of not more than 5 ft, except in the case of grillage beams encased in concrete, where it is only necessary to make suitable provision for maintaining correct spacing. Through bolts and separators may be used provided that in beams having a depth of 12 in. or more not less than 2 bolts in the depth are used with each separator. When loads are required to be carried from one beam to the other or are required to be distributed between the beams, diaphragms and their fastenings designed with sufficient stiffness to distribute the load shall be used.

When loads are required to be carried from one tube to another, or are required to be distributed between tubes, diaphragms (which may be tubular) and their fastenings, designed with sufficient stiffness to distribute the load between the tubes, shall be used.

See Add-4.

B. DESIGN OF MEMBERS SUBJECT TO BENDING

BENDING STRESSES (BEAMS OTHER THAN PLATE GIRDERS)

See Amdt 1 Page 14

19. *a.* **Rolled I-beams, ~~broad flange beams~~, rolled channels, rolled Z-beams and compound beams having equal flanges of uniform cross-section throughout or having flanges each of uniform cross-section throughout but where the moment of inertia of the compression flange about the y—y axis of the beam exceeds that of the tension flange about the same axis.** The bending stress in the extreme fibres, calculated on the effective section, shall not exceed:

(i) *for parts in tension.* The appropriate value of p_{bt} in Table 2.

(ii) *for parts in compression.* For steel to B.S. 15 and B.S. 2762, the lesser of the values of p_{bc} given in Tables 2 and 3, as appropriate; *or* for steel to B.S. 548 and B.S. 968, the lesser of the values given in Tables 2 and 4, as appropriate.

In Tables 3 and 4:

l = effective length of the compression flanges (see Clause 26)

r_y = radius of gyration of the beam section about its axis lying in the plane of bending

D = overall depth of beam

T = mean thickness of flange

= area of horizontal portion of flange, divided by width.

For rolled sections, the mean thickness is that given in the appropriate British Standards or other reference book.

b. **Compound girders as noted in Clause 19 *a* but with curtailed flanges.** In assessing D/T, D shall be taken as the overall depth of the girder at the point of maximum bending moment, and T shall be taken as the effective thickness of the compression flange, where

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

Flanges shall not be reduced in breadth to give a value of N lower than 0·25.

Values of K_1 for different values of N are given in Table 5.

d) See Amd No 2.

AVA Documents
Document Sharing Hub

See Addl No 2

TABLE 2. ALLOWABLE STRESSES p_{bc} OR p_{bt} IN BENDING

(See also Clauses 19 and 20, and Tables 3 and 4)

Form	Specification of material	Thickness of material	p_{bc} or p_{bt}
			ton/sq.in.
Rolled I-beams and channels	B.S. 15 and B.S. 2762	All	10·5
Compound girders composed of rolled I-beams or channels plated, with thickness of plate:	B.S. 15 and B.S. 2762	Up to and incl. ¾ in.	10·5
		Over ¾ in.	10·0
Plates, flats, ~~Universal beams and columns~~, rounds, squares, angles, tees and any sections other than above	B.S. 15 and B.S. 2762	Up to and incl. ¾ in.	10·5
		Over ¾ in.	10·0
Plate girders with single or multiple webs	B.S. 15 and B.S. 2762	Up to and incl. ¾ in.	10·0
		Over ¾ in.	9·5
Plates, flats, rounds, squares and other similar sections, rolled I-beams, double channels forming a symmetrical I-section which acts as an integral unit, compound beams composed of rolled I-beams or channels plated, single channels, angles and tees	B.S. 548	Up to 1¾ in.	14·5
		Over 1¾ in. to 2¼ in.	12·5
	~~B.S. 968~~	Up to 1 in.	13·5
		Over 1 in.	12·0
Plate girders with single or multiple webs	B.S. 548	Up to 1¾ in.	13·5
		Over 1¾ in.	12·0
	~~B.S. 968~~	Up to 1 in.	13·0
		Over 1 in.	11·5
Tubes	B.S. 1775: Grade 13	All	9·0
	Grade 16		10·5
	Grade 20		13·0
Plate girders with tubular flanges	B.S. 1775: Grade 13	All	8·5
	Grade 16		10·0
	Grade 20		12·25
Slab bases	All steels		12·0

See Addl No. 3.

See Addl-4.

TABLE 3. ALLOWABLE STRESSES p_{bc} IN BENDING (TON/SQ.IN.) FOR BEAMS OF STEEL TO B.S. 15 AND B.S. 2762

l/r_y	D/T					
	10	15	20	25	30	35
85	10·5	10·5	10·5	10·5	10·5	10·5
90	10·5	10·5	10·5	10·2	10·2	10·2
95	10·5	10·5	10·5	9·9	9·9	9·9
100	10·5	10·5	10·5	9·5	9·5	9·5
105	10·5	10·5	10·2	9·2	9·2	9·2
110	10·5	10·5	9·9	8·9	8·9	8·9
115	10·5	10·5	9·7	8·6	8·6	8·6
120	10·5	10·3	9·4	8·2	8·2	8·2
130	10·5	9·8	8·8	7·6	7·6	7·6
140	10·1	9·3	8·3	6·9	6·9	6·9
150	9·6	8·8	7·7	6·3	6·3	6·3
160	9·2	8·3	7·2	5·9	5·6	5·6
170	8·8	7·9	6·6	5·6	5·2	5·0
180	8·4	7·4	6·1	5·4	5·0	4·7
190	8·0	6·9	5·8	5·2	4·7	4·4
200	7·5	6·4	5·6	4·9	4·5	4·2
210	7·4	6·2	5·4	4·7	4·3	4·0
220	7·2	6·0	5·2	4·6	4·1	3·8
230	7·1	5·9	5·0	4·4	4·0	3·6
240	6·9	5·7	4·9	4·2	3·8	3·5
250	6·8	5·6	4·7	4·1	3·7	3·3
260	6·7	5·5	4·5	4·0	3·5	3·2
270	6·6	5·3	4·4	3·8	3·3	3·0
280	6·5	5·2	4·3	3·7	3·2	2·9
290	6·4	5·1	4·1	3·6	3·1	2·8
300	6·3	4·9	4·0	3·5	3·0	2·7

Intermediate values may be obtained by linear interpolation.

AVA Documents
Document Sharing Hub

See Amdt 4

TABLE 4. ALLOWABLE STRESSES p_{bc} IN BENDING (TON/SQ.IN.) FOR BEAMS OF STEEL TO B.S. 548 AND B.S. 968

l/r_y	D/T					
	10	15	20	25	30	35
50	14·5	14·5	14·5	14·5	14·5	14·5
55	14·5	14·5	14·5	14·2	14·2	14·2
60	14·5	14·5	14·5	13·6	13·6	13·6
65	14·5	14·5	14·2	13·0	13·0	13·0
70	14·5	14·5	13·6	12·4	12·4	12·4
75	14·5	14·2	13·1	11·7	11·7	11·7
80	14·5	13·7	12·[illegible]	11·1	11·1	11·1
85	14·1	13·2	12·1	10·5	10·5	10·5
90	13·7	12·8	11·5	10·2	10·2	10·2
95	13·3	12·3	11·0	9·9	9·9	9·9
100	12·9	11·9	10·5	9·5	9·5	9·5
105	12·5	11·4	10·2	9·2	9·2	9·2
110	12·1	11·0	9·9	8·9	8·9	8·9
115	11·7	10·5	9·7	8·6	8·6	8·6
120	11·3	10·3	9·4	8·2	8·2	8·2
130	10·5	9·8	8·8	7·6	7·6	7·6
140	10·1	9·3	8·3	6·9	6·9	6·9
150	9·6	8·8	7·7	6·3	6·3	6·3
160	9·2	8·3	7·2	5·9	5·6	5·6
170	8·8	7·9	6·6	5·6	5·2	5·0
180	8·4	7·4	6·1	5·4	5·0	4·7
190	8·0	6·9	5·8	5·2	4·7	4·4
200	7·5	6·4	5·6	4·9	4·5	4·2
210	7·4	6·2	5·4	4·7	4·3	4·0
220	7·2	6·0	5·2	4·6	4·1	3·8
230	7·1	5·9	5·0	4·4	4·0	3·6
240	6·9	5·7	4·9	4·2	3·8	3·5
250	6·8	5·6	4·7	4·1	3·7	3·3
260	6·7	5·5	4·5	4·0	3·5	3·2
270	6·6	5·3	4·4	3·8	3·3	3·0
280	6·5	5·2	4·3	3·7	3·2	2·9
290	6·4	5·1	4·1	3·6	3·1	2·8
300	6·3	4·9	4·0	3·5	3·0	2·7

Intermediate values may be obtained by linear interpolation.

BENDING STRESSES (PLATE GIRDERS)

20. The bending stress in the extreme fibres, calculated on the effective section, shall not exceed:

a. for parts in tension. The appropriate value of p_{bt} as given in Table 2.

b. for parts in compression. The lesser of the value of p_{bc} given in Table 2 and of that obtained in accordance with the following requirements:

For plate girders with I_y smaller than I_x

where I_y = Moment of inertia of the whole section about the axis lying in the plane of bending (the y—y axis)

and I_x = Moment of inertia of the whole section about the axis normal to the plane of bending (the x—x axis)

the bending compression stress f_{bc} shall not exceed the value of p_{bc} given in Table 8, corresponding to the critical stress C_s in the compression element, calculated as follows from the values of A and B given in Table 7 for appropriate value of D/T and l/r_y.

In this Table,

l = effective length of compression flange (see Clause 26 *a*)
r_y = radius of gyration about the y—y axis of the gross section of the whole girder, at the point of maximum bending moment
D = overall depth of girder at the point of maximum bending moment
T = as defined below.

The values of C_s given below apply to *all sections with a single web* except when the thickness T of one flange is more than three times the thickness of the other flange.

Case (*I*) Where the flanges have *equal* moments of inertia about the y—y axis of the girder:

$$C_s = A \text{ ton/sq.in.}$$

except that this value of C_s shall be increased by 20 per cent when

T/t is not greater than 2

and d/t is not greater than 85, *for steel to B.S.* 15 *and B.S.* 2762
or d/t is not greater than 75, *for steel to B.S.* 548 *and B.S.* 968

where d is as defined in Clause 23 *b*.

t = web thickness.

AVA Documents
Document Sharing Hub

In assessing D/T,

T = effective thickness of compression flange

= K_1 × mean thickness of the horizontal portion of the compression flange at the point of maximum bending moment. The coefficient K_1 makes allowance for reduction in thickness or breadth of flanges between points of effective lateral restraint and depends on N, the ratio of the total area of both flanges at the point of least bending moment to the corresponding area at the point of greatest bending moment between such points of restraint.

For plate girders with flange angles, the horizontal legs of the angles shall be included in the area of the horizontal portion.

Flanges shall not be reduced in breadth to give a value of N lower than 0·25.

TABLE 5. VALUES OF K_1

N	1·0	0·9	0·8	0·7	0·6	0·5	0·4	0·3	0·2	0·1	0·0
K_1	1·0	1·0	1·0	0·9	0·8	0·7	0·6	0·5	0·4	0·3	0·2

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

Case (II). Where the moment of inertia of the *compression flange* about the y—y axis of the beam *exceeds* that of the tension flange:

$$C_s = A + K_2 B \text{ ton/sq.in.}$$

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

Values of K_2 are given in Table 6.

In assessing D/T,

T = effective thickness of compression flange

= K_1 × mean thickness of the horizontal portion of the flange of greater moment of inertia, about the y—y axis of the girder, at the point of maximum bending moment.

Case (III). Where the moment of inertia of the *tension flange* about the y—y axis of the beam *exceeds* that of the compression flange.

$$C_s = (A + K_2 B)\frac{y_c}{y_t} \text{ ton/sq.in.}$$

where A and B are obtained as in Case (II) above and

y_c = distance from the neutral axis of the girder to the extreme fibre in compression.

y_t = distance from the neutral axis of the girder to the extreme fibre in tension.

TABLE 6. VALUES OF K_2

M	1·0	0·9	0·8	0·7	0·6	0·5	0·4	0·3	0·2	0·1	0·0
K_2	0·5	0·4	0·3	0·2	0·1	0·0	−0·2	−0·4	−0·6	−0·8	−1·0

AVA Documents
Document Sharing Hub

TABLE 7. VALUES OF A AND B TO BE USED FOR CALCULATING VALUES OF C_s IN TON/SQ.IN.

$$\text{where } A = \frac{170\,000}{(l/r_y)^2}\sqrt{\left\{1+\frac{1}{20}\cdot\left(\frac{l}{r_y}\frac{T}{D}\right)^2\right\}}$$

$$B = \frac{170\,000}{(l/r_y)^2}$$

$\frac{l}{r_y}$ \ $\frac{D}{T}$	A															B
	8	10	12	14	16	18	20	25	30	35	40	50	60	80	100	
40	159·4	142·6	132·5	126·1	121·8	118·7	116·3	112·8	110·9	109·7	108·9	108·0	107·4	106·9	106·7	106·3
45	134·9	119·2	109·6	103·4	99·1	96·2	93·9	90·5	88·6	87·3	86·6	85·5	85·1	84·6	84·4	84·0
50	116·9	102·0	93·0	87·0	83·0	80·1	77·9	74·5	72·6	71·4	70·6	69·7	69·2	68·7	68·4	68·0
55	103·1	89·1	80·5	74·8	70·9	68·1	65·9	62·7	60·8	59·6	58·8	57·9	57·4	56·6	56·6	56·2
60	92·2	79·0	70·8	65·4	61·6	58·9	56·8	53·6	51·7	50·6	49·8	48·9	48·4	47·9	47·6	47·2
65	83·5	71·0	63·2	58·0	54·4	51·8	49·7	46·5	44·7	43·6	42·8	41·9	41·4	40·9	40·6	40·2
70	76·2	64·4	57·0	52·0	48·5	46·0	44·1	40·9	39·1	38·0	37·2	36·4	35·9	35·4	35·1	34·7
75	70·2	59·1	51·9	47·2	43·8	41·3	39·4	36·4	34·6	33·5	32·8	31·9	31·4	30·9	30·6	30·2
80	65·1	54·4	47·7	43·1	39·8	37·5	35·6	32·7	30·9	29·8	29·1	28·2	27·7	27·2	27·0	26·6
85	60·7	50·5	44·1	39·7	36·5	34·2	32·5	29·6	27·8	26·8	26·1	25·2	24·7	24·2	24·0	23·5
90	56·8	47·2	41·0	36·8	33·7	31·5	29·8	27·0	25·3	24·2	23·5	22·6	22·1	21·6	21·4	21·0
95	53·5	44·2	38·3	34·3	31·3	29·1	27·5	24·7	23·1	22·0	21·3	20·5	20·0	19·5	19·3	18·8

See Amdt 1 Page 14.

$\frac{l}{r_y}$ \ $\frac{D}{T}$	8	10	12	14	16	18	20	25	30	35	40	50	60	80	100	
100	50·5	41·6	35·9	32·0	29·2	27·1	25·5	22·8	21·2	20·2	19·5	18·6	18·1	17·7	17·4	17·0
110	45·4	37·3	32·0	28·4	25·8	23·8	22·3	19·7	18·2	17·2	16·5	15·7	15·2	14·7	14·5	14·1
120	41·3	33·8	28·9	25·5	23·1	21·2	19·8	17·3	15·9	14·9	14·2	13·4	12·9	12·5	12·2	11·8
130	37·9	30·9	26·4	23·2	20·9	19·1	17·8	15·4	14·0	13·1	12·4	11·6	11·2	10·7	10·5	10·1
140	35·0	28·5	24·2	21·2	19·1	17·4	16·1	13·9	12·5	11·0	10·5	10·2	9·8	9·3	9·1	8·7
150	32·6	26·5	22·5	19·6	17·6	16·0	14·8	12·7	11·3	10·5	9·9	9·1	8·7	8·2	8·0	7·6
160	30·4	24·7	20·9	18·2	16·3	14·8	13·6	11·6	10·3	9·5	8·9	8·2	7·7	7·3	7·1	6·6
170	28·6	23·1	19·5	17·0	15·2	13·7	12·6	10·7	9·5	8·7	8·1	7·4	7·0	6·5	6·3	5·9
180	26·9	21·8	18·4	16·0	14·2	12·8	11·8	9·9	8·8	8·0	7·4	6·7	6·3	5·9	5·7	5·2
190	25·5	20·6	17·3	15·1	13·4	12·1	11·1	9·3	8·2	7·4	6·9	6·2	5·8	5·3	5·1	4·7
200	24·1	19·5	16·4	14·2	12·6	11·4	10·4	8·7	7·6	6·9	6·4	5·7	5·3	4·9	4·7	4·3
210	23·0	18·5	15·6	13·5	12·0	10·8	9·8	8·2	7·2	6·5	6·0	5·3	4·9	4·5	4·3	3·9
220	21·9	17·6	14·8	12·8	11·4	10·2	9·3	7·8	6·7	6·1	5·6	4·9	4·5	4·1	3·9	3·5
230	20·9	16·8	14·1	12·2	10·8	9·7	8·9	7·3	6·4	5·7	5·2	4·6	4·2	3·8	3·6	3·2
240	20·0	16·1	13·5	11·7	10·3	9·3	8·5	7·0	6·1	5·4	4·9	4·3	4·0	3·6	3·4	3·0
250	19·2	15·5	13·0	11·2	9·9	8·9	8·1	6·7	5·8	5·1	4·7	4·1	3·7	3·3	3·1	2·7
260	18·5	14·8	12·4	10·7	9·5	8·5	7·7	6·4	5·5	4·9	4·4	3·9	3·5	3·1	2·9	2·5
270	17·8	14·3	12·0	10·3	9·1	8·2	7·4	6·1	5·2	4·7	4·2	3·7	3·3	2·9	2·7	2·3
280	17·1	13·8	11·5	9·9	8·7	7·9	7·1	5·8	5·0	4·4	4·0	3·5	3·1	2·8	2·6	2·2
290	16·5	13·3	11·1	9·6	8·4	7·6	6·9	5·6	4·8	4·3	3·9	3·3	3·0	2·6	2·4	2·0
300	16·0	12·8	10·7	9·3	8·1	7·3	6·6	5·4	4·6	4·1	3·7	3·2	2·8	2·5	2·3	1·9

TABLE 8. ALLOWABLE COMPRESSION STRESS p_{bc} IN BENDING FOR CALCULATED VALUES OF CRITICAL STRESS C_s (but *see* Table 2)

C_s	p_{bc} for steel to B.S. 15 or B.S. 2762	p_{bc} for steel to B.S. 548 and B.S. 968
ton/sq. in.	ton/sq. in.	ton/sq. in.
2	1·0	1·0
3	1·5	1·5
4	2·0	2·0
5	2·4	2·4
6	2·8	2·8
7	3·2	3·2
8	3·5	3·6
9	3·9	4·0
10	4·2	4·4
12	4·7	5·1
14	5·1	5·7
16	5·5	6·3
17	5·7	6·6
18	5·9	6·9
20	6·3	7·5
22	6·6	8·0
24	7·0	8·4
26	7·2	8·8
28	7·5	9·2
30	7·7	9·5
35	8·2	10 1
40	8·6	10·7
45	8·9	11·1
50	9·1	11·5
55	9·4	11·8
60	9·6	12·1
70	9·9	12·6
80	10·0	13·0
90	10·0	13·3
100	10·0	13·6
110	10·0	13·8
120	10·0	14·0
136	10·0	14·25

BENDING STRESSES (CASED BEAMS)

21. Beams and girders with equal flanges may be designed as cased beams when the following conditions are fulfilled:

a. The section is of single web and I-form or of double open channel form with the webs not less than 1½ in. apart.

b. The beam is unpainted and is solidly encased in ordinary dense concrete, with ⅜ in. aggregate (unless solidity can be obtained with a larger aggregate), and of a works strength not less than 3000 lb/sq.in. at 28 days, when tested in accordance with B.S. 1881, 'Methods for testing concrete', Part 7: 'Making and curing compression test cubes in the field' and Part 8: 'Test for compression strength of moulded cubes'.

c. The minimum width of solid casing is equal to $b + 4$ in. where b is the overall width of the steel flange or flanges in inches.

d. The surface and edges of the flanges of the beam have a concrete cover of not less than 2 in.

e. The casing is effectively reinforced with wire to B.S. 785, 'Rolled steel bars and hard drawn steel wire for concrete reinforcement'. The wire shall be at least 3/16 in. diameter and the reinforcement shall be in the form of stirrups or binding at not more than 6 in. pitch, and so arranged as to pass through the centre of the covering to the edges and soffit of the lower flange.

The compressive stress in bending shall not exceed the value of p_{bc} obtained from Clauses 19 and 20; for this purpose the radius of gyration r_y may be taken as 0·2 (b + 4 in.), and D/T as for the uncased section.

The stress shall not, however, exceed 1½ times that permitted for the uncased section.

See Clauses 29 and 40 for solidly encased filler joists and grillage beams respectively.

NOTE. This clause does not apply to beams and girders having a depth greater than 30 in. or a width greater than 18 in., or to box sections.

AVA Documents
Document Sharing Hub

BEARING STRESS

22. The calculated bearing stress on the net projected area of contact shall not exceed the values of p_b given in Table 9.

TABLE 9. ALLOWABLE BEARING STRESS p_b

Form	Steel to B.S. No.	p_b
		ton/sq.in.
Plates, sections and bars	B.S. 15 and B.S. 2762	12
" " " "	B.S. 548 and B.S. 968	17
Tubes*	B.S. 1775, Grade 13	11
"	B.S. 1775, Grade 16	12
"	B.S. 1775, Grade 20	16

* See Clause 28c for provisions for stiffening tubes subject to bearing pressure.

SHEAR STRESSES

23. *a.* **Maximum shear stress.** The maximum value f_q of the shear stress, having regard to the distribution of stresses in conformity with the elastic behaviour of the member in flexure, shall not exceed values of p_q given in Table 10.

In calculating the resistance of tubes to shear the total shear force resisted at any section shall be taken as the product of half the gross sectional area of the tube and the appropriate maximum shear stress in the table. Where there are holes in the section, calculations shall be made to show that the maximum shear stress given in the table is not exceeded.

TABLE 10. ALLOWABLE MAXIMUM SHEAR STRESS p_q

See Amdt No. 3.

Form	Steel to B.S. No.	Thickness or diameter	p_q
		in.	ton/sq.in.
Plates, sections and bars	B.S. 15 and B.S. 2762	All	7·0
" " " "	B.S. 548	Up to 1¾	10·0
" " " "	B.S. 548	Over 1¾	8·5
" " " "	~~B.S. 968~~	Up to 1	10·0
" " " "	~~B.S. 968~~	Over 1	8·5
Tubes	B.S. 1775, Grade 13	All	6·0
"	B.S. 1775, Grade 16	All	7·0
" " " "	B.S. 1775, Grade 20	All	8·5

See Amdt No 2.

b. **Average shear stress in webs of I beams and plate girders.** The average shear stress f_q' on the gross section of the web shall not exceed the values of p_q' given in Table 11 for unstiffened webs or, for stiffened webs, the values given in Table 12 or Table 13, as appropriate.

The gross section of the web shall be taken as

For rolled I beams and channels	The depth of the beam multiplied by the web thickness.
For plate girders	The depth of the web plate multiplied by its thickness.

Compliance with this sub-clause shall be deemed to satisfy the requirements of sub-clause *a*.

For webs which have tongue plates or which are reinforced by additional plates (see Clause 27 *a* (iv)), the maximum shear stress shall be calculated and the beam designed so as to satisfy both *a* and *b* above.

TABLE 11. ALLOWABLE AVERAGE SHEAR STRESS p_q' IN UNSTIFFENED WEBS

(For stiffened webs see also b above and Tables 12 and 13 below)

Steel to B.S. No.	p_q' for rolled I-beams	p_q' for plate girders and single channels
	ton/sq.in.	ton/sq.in.
B.S. 15—Up to and including ¾ in. thick	6·0	6·0
Over ¾ in. thick	6·0	5·5
B.S. 548—up to 1¾ in. / ~~B.S. 968~~—up to 1 in.	8·5	8·0
B.S. 548—over 1¾ in. / ~~B.S. 968~~—over 1 in.	—	7·0

See Amdt No 3.

AVA Documents
Document Sharing Hub

TABLE 12. ALLOWABLE AVERAGE SHEAR STRESS p_q' IN STIFFENED WEBS OF STEEL TO B.S. 15 OR B.S. 2762

(See also Sub-Clause 23 b and Table 11)

d/t*	Stress p_q' (ton/sq.in.) for different distances between stiffeners											
	0·4d	0·5d	0·6d	0·7d	0·8d	0·9d	d	1·1d	1·2d	1·3d	1·4d	1·5d
100	6·0	6·0	6·0	6·0	6·0	6·0	6·0	6·0	6·0	6·0	5·9	5·8
110	6·0	6·0	6·0	6·0	6·0	6·0	6·0	5·9	5·8	5·8	5·7	5·6
120	6·0	6·0	6·0	6·0	6·0	6·0	5·9	5·8	5·7	5·6	5·5	5·4
130	6·0	6·0	6·0	6·0	5·9	5·8	5·7	5·6	5·5	5·4	5·3	5·3
140	6·0	6·0	6·0	5·9	5·8	5·7	5·6	5·4	5·3	5·2	5·1	5·1
150	6·0	6·0	6·0	5·8	5·6	5·5	5·4	5·3	5·1	5·0	4·9	4·8
160	6·0	6·0	5·8	5·6	5·5	5·3	5·2	5·1	5·0	4·8	4·7	4·7
170	6·0	6·0	5·7	5·5	5·3	5·2	5·1	4·9	4·8	4·7	4·6	4·5
180	6·0	5·9	5·6	5·4	5·2	5·0	4·9	4·7	4·6	4·5	4·4	4·3
190	6·0	5·8	5·5	5·2	5·0	4·9						
200	6·0	5·7	5·4	5·1	4·9	4·7						
210	5·9	5·6	5·2	5·0	4·8							
220	5·8	5·4	5·1	4·8	4·6							
230	5·8	5·4	5·0	4·7								
240	5·7	5·2	4·9	4·6								

The average stress shown in Table 11 shall not be exceeded.

* Defined on p. 40.

TABLE 13. ALLOWABLE AVERAGE SHEAR STRESS p_q' IN STIFFENED WEBS OF STEEL TO B.S. 548 AND B.S. 968

(See also Sub-Clause 23 b and Table 11)

d/t*	Stress p_q' (ton/sq.in.) for different distances between stiffeners												
	0·3d	0·4d	0·5d	0·6d	0·7d	0·8d	0·9d	d	1·1d	1·2d	1·3d	1·4d	1·5d
75	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·4
80	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·4	8·3	8·3
90	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·5	8·3	8·2	8·1	8·0	7·9
100	8·5	8·5	8·5	8·5	8·5	8·5	8·3	8·2	8·0	7·9	7·8	7·7	7·6
110	8·5	8·5	8·5	8·5	8·4	8·2	8·1	7·9	7·7	7·6	7·4	7·3	7·2
120	8·5	8·5	8·5	8·5	8·2	8·0	7·8	7·6	7·4	7·3	7·1	7·0	6·9
130	8·5	8·5	8·5	8·2	7·9	7·7	7·5	7·4	7·1	7·0	6·8	6·7	6·5
140	8·5	8·5	8·4	8·0	7·7	7·4	7·2	7·1	6·8	6·6	6·5	6·3	6·2
150	8·5	8·5	8·2	7·8	7·5	7·2	7·0	6·8	6·5	6·3	6·1	6·0	5·8
160	8·5	8·5	8·0	7·6	7·2	6·9	6·7	6·5	6·2	6·0	5·8	5·6	5·5
170	8·5	8·4	7·8	7·4	7·0	6·7	6·4	6·2	5·9	5·7	5·5	5·3	5·1
180	8·5	8·2	7·7	7·2	6·8	6·4	6·2	6·0	5·6	5·4	5·2	5·0	4·8
190	8·5	8·1	7·5	6·9	6·5	6·2	5·9						
200	8·4	7·9	7·3	6·7	6·3	5·9	5·6						
210	8·3	7·7	7·1	6·5	6·0	5·6							
220	8·1	7·6	6·9	6·3	5·8	5·4							
230	8·0	7·4	6·7	6·1	5·6								
240	7·9	7·3	6·5	5·9	5·3								

The average stress shown in Table 11 shall not be exceeded.

* Defined on p. 40.

AVA Documents
Document Sharing Hub

In Tables 12 and 13:—

d = (i) *for* vertically stiffened *webs without horizontal stiffeners*, the clear distance between flange angles or, where there are no flange angles, the clear distance between flanges, ignoring fillets. Where tongue plates (Fig. 1) having a thickness of not less than twice the thickness of the web plate are used, the depth d shall be taken as the depth of the girder between the flanges less the sum of the depths of the tongue plates or eight times the sum of the thicknesses of the tongue plates, whichever is the lesser.

(ii) *for* vertically stiffened *webs with horizontal stiffeners as described in Clause 28b*, the clear distance between the tension flange (angles, flange plate or tongue plate) and the horizontal stiffener.

t = the thickness of the web.

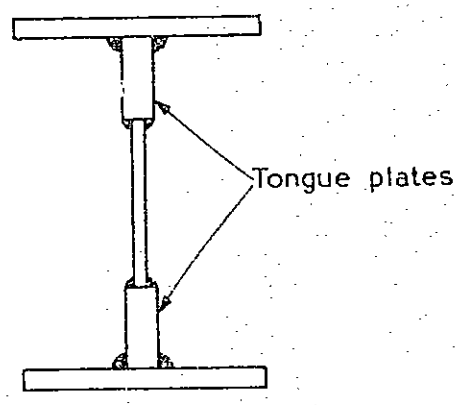

Fig. 1. Tongue plates

For unstiffened webs the ratio d/t shall not exceed 85 for steel to B.S. 15 and B.S. 2762 or 75 for steel to B.S. 548 and B.S. 968.

Where the ratio d/t is greater than the value given above, intermediate stiffeners, designed in accordance with Clause 28*b*, shall be provided throughout the length of the girder at a distance apart not greater than one and a half times, and not less than one third of, d as defined above, subject to the following:

The greater clear dimension of the web in the panel shall not exceed $270t$,

The lesser clear dimension of the web in the panel shall not exceed $180t$.

NOTE. These allowable stresses apply provided any reduction in the web cross-section is due only to rivet holes, etc. Where large apertures are cut in the web a special analysis shall be made to ensure that the stresses laid down in this standard are not exceeded.

EFFECTIVE SPAN OF BEAMS

24. The effective span of a beam shall be taken as the length between the centres of the supports, except for the provision of Clause 9 *b* (iii) and where, under

Clause 34, the point of application of the reaction is taken as eccentric to the support, when it shall be permissible to take the effective span as the length between the assumed points of application of the reactions.

MAXIMUM SLENDERNESS RATIO OF COMPRESSION FLANGES

25. The ratio of the effective length l of the compression flange to the appropriate radius of gyration shall not exceed 300.

EFFECTIVE LENGTH OF COMPRESSION FLANGES FOR BEAMS AND GIRDERS

26. *a.* For simply supported beams and girders where no lateral restraint of the compression flange is provided but where each end of the beam is restrained against *torsion*, the effective length l of the compression flange to be used in Clauses 19, 20 and 21, shall be taken as follows:

(i) With ends of compression flanges unrestrained against lateral bending (i.e. free to rotate in plan at the bearings)

l = span

(ii) With ends of compression flanges partially restrained against lateral bending (i.e. cleated flange connections)

$l = 0{\cdot}85 \times$ span

(iii) With ends of compression flanges fully restrained against lateral bending (i.e. not free to rotate in plan at the bearings)

$l = 0{\cdot}7 \times$ span

Restraint against *torsion* can be provided by
web or flange cleats
or bearing stiffeners acting in conjunction with the bearing of the beam
or lateral end frames or other external supports to the ends of the compression flanges (see Note below)
or their being built into walls.

Where the ends of the beam are not restrained against torsion, or where the load is applied to the compression flange and both the load and flange are free to move laterally, the above values of the effective length shall be increased by 20 per cent.

NOTE. The end restraint element shall be capable of safely resisting, in addition to wind and other applied external forces, a horizontal force acting at the bearing in a direction normal to the compression flange of the beam at the level of the centroid of the flange and having a value equal to not less than 2½ per cent of the maximum force occuring in the flange.

b. For beams which are provided with members giving effective lateral restraint to the compression flange at intervals along the span, in addition to the end torsional restraint required in *a* above, the effective length of the com-

AVA Documents
Document Sharing Hub