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BRITISH STANDARD 449 : 1948

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THE USE OF STRUCTURAL STEEL IN BUILDING

BRITISH STANDARDS INSTITUTION
STREET, LONDON, W.1

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THIS BRITISH STANDARD, having been approved by the Building Divisional Council, was published by the authority of the General Council on 30th July, 1948.

First published, April, 1932.
First revision, December, 1935.
Second revision, July, 1937.
Third revision, July, 1948.

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.

A complete list of British Standards, numbering over one thousand, indexed and cross-indexed for reference, together with an abstract of each standard will be found in the Institution's Yearbook.

British Standards are revised, when necessary, either by the issue 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 edition.

Users wishing to be kept informed of any alteration to this standard should notify the Sales Department of the Institution, giving the number and title of the standard.

References

This standard requires reference to the following British Standards :—

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. 275. Dimensions of rivets (½ in. to 1¾ in. diameter).
B.S. 499. Nomenclature, definitions and symbols for welding and cutting.
B.S. 538. Metal arc welding as applied to steel structures.
B.S. 548. High tensile structural steel for bridges, etc., and general building construction.
B.S. 592. Carbon steel castings for ships and for marine engine and general engineering purposes.
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. 968. High tensile (fusion welding quality) structural steel for bridges, etc., and general building construction.

CO-OPERATING ORGANIZATIONS

This revised British Standard has been prepared under the supervision of a technical committee of the Building Divisional Council, consisting of representatives of the following Government departments, and scientific and industrial organizations :—

Admiralty
Air Ministry
Association of Municipal Corporations
British Constructional Steelwork Association
British Iron and Steel Federation
British Railways
British Welding Research Association
Building Committee in Scotland
Building Industries National Council
Crown Agents for the Colonies
Department of Scientific and Industrial Research
District Surveyor's Association
Imperial Chemical Industries
Institute of Builders
Institution of Civil Engineers
Institution of Municipal Engineers
Institution of Structural Engineers
London County Council
Ministry of Health
Ministry of Works
National Federation of Building Trades Employers
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BRITISH STANDARD FOR

THE USE OF STRUCTURAL STEEL IN BUILDING

FOREWORD

This British Standard was first issued in April, 1932, and was last revised in 1937. During the war temporary amendments were introduced, giving increased working stresses in steel to B.S. 15, 'Structural steel for bridges, etc., and general building construction' to secure a measure of economy in steel used in building, thus contributing towards the maximum steel output required to meet urgent national demands.

The present revision is based on 'Recommendations for the Design of steel structures made by the Department of Scientific and Industrial Research Steel Structures Committee 1936' and on British Standard Code of Practice CP 4 : 1944, 'Chapter V, Loading,' of the 'Code of functional requirements of buildings.'

Acknowledgments are made to the Codes of Practice Committee for Civil Engineering, Public Works and Building for their co-operation whilst engaged on the preparation of British Standard Code of Practice CP 113 (General series), 'The structural use of steel in buildings,' and to the Institution of Structural Engineers whose 'Report on steelwork for buildings' has proved of assistance.

Users of this British Standard should satisfy themselves that effective compliance is secured with local bye-laws and regulations and, for insurance purposes, with the rules of the Fire Offices Committee.

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 19*d* of this standard and the working stresses employed.

The requirements of the welding clauses in this Standard have been formulated after reference to the British Standard for 'The metal arc welding of mild steel constructions' which is in course of preparation. These clauses may therefore be subject to revision when that standard is published.

ECONOMY IN DESIGN

This British Standard stipulates limits of stress and 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

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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.

SPECIFICATION

SCOPE

1. This British Standard relates primarily to the use of structural steel in building. The requirements of the standard shall be deemed not to apply to structures fabricated from steel tubes, which will be covered by an addition to this British Standard (in course of preparation), nor to structures fabricated from light gauge sheet and strip steel.

PART ONE. DEFINITIONS

2. **Definitions.** For the purposes of this British Standard the following definitions shall apply :—

Beam — Any rolled or pressed section or built-up structural member which supports load primarily by its internal resistance to bending.

Dead load — The weight of all walls, floors, roofs, partitions and other 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 its point of application.

Filler joists — Rolled steel I-beams or other suitable flanged sections forming a floor or roof slab in association with structural concrete.

Foundation — That part of the building which is employed directly to distribute loading 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 all imposed loads and forces.

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

Load factor — The value by which the load causing failure of the structure to unserviceability, is divided to give the permissible working load on the structure.

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

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

Super-imposed load — In respect of a building: all loads other than the dead load.

Welding terms — The terms used in the welding clauses of this British Standard are defined in B.S. 499 'Nomenclature, definitions and symbols for welding and cutting.'

Wheel loads — The equivalent 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.

PART TWO. MATERIALS

STRUCTURAL STEEL

3. *a.* **Structural steel.** All structural steel used in buildings coming within the purview of this British Standard shall before fabrication comply with one or other of the following which is appropriate :—

B.S. 15 : 1948. Structural steel for bridges, etc., and general building construction,

B.S. 548 : 1934. High tensile structural steel for bridges, etc., and general building construction,

B.S. 968 : 1941. High tensile (fusion welding quality) structural steel for bridges, etc., and general building construction.

b. **Electrodes.** Electrodes used for the making of welds shall conform to the requirements of B.S. 639, 'Covered electrodes for metal arc welding wrought iron and mild steel (for hand operation)' Class A.

This British Standard does not at present provide for the use of high tensile steel electrodes (see Clause 24 *b*).

OTHER MATERIALS

4. Other materials used in association with steelwork shall conform to any byelaws 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, any relevant byelaw or regulation.

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PART THREE. LOADS

DEAD LOADS

5. For the purpose of calculating the dead loads, the unit weights of the materials shall be deemed to be those specified in B.S. 648, 'Schedule of unit weights of building materials.'

In all cases of floors where the position and nature of the partitions are definitely shown on the plans, the dead loads of the partitions shall be calculated and provided for, except as allowed in the next paragraph. For all floors in which partitions are intended but are not located on the plans, a uniformly distributed load per square foot of not less than 10 per cent of the weight per foot run of the finished partitions or 20 pounds per square foot, whichever is the greater, shall be provided for as an allowance over the whole of each floor bay upon which the partitions are carried.

If the 10 per cent of the weight per foot run of the finished partition or 20 pounds per square foot, whichever is greater, is less than one-fifth of the superimposed load, the weight of the partition may be neglected.

No partitions shall be erected which will, in effect, result in floor loading greater than that allowed for in the design.

SUPERIMPOSED FLOOR LOADS

6. For the purpose of calculating the loads on slabs, beams, columns, ties, piers, walls and foundations in buildings, the minimum superimposed loads on each floor, given in Table 1, shall be taken as equivalent static loads. These equivalent static loads provide for the effects of normal impact and acceleration.

The minimum loads in Columns 4 and 5 of Table 1 shall be used in place of those in Column 3, where such minimum loads cause higher stresses.

For any given occupancy where the prospective superimposed load exceeds that given in Table 1, provision shall be made for such higher load.

It is recommended that for Classes of loading VI to X inclusively, permanent notices should be displayed at each floor level stating the superimposed load for which the floor has been constructed.

SUPERIMPOSED LOADS ON CORRIDORS, STAIRS AND LANDINGS

7. Corridors, stairs and landings generally shall be designed for the same class of loading as the floor or other space to which they give access, provided that Class VII loadings shall be taken for corridors, stairs and landings leading to places of public assembly with fixed seating. Class VII loadings may be taken as the maximum for any corridor, stair or landing.

Table 1. Superimposed floor loads

1	2	3	4	5
Class of loading	Floor space occupancy	Superimposed floor load per sq. ft.	Minimum* loads on slabs or floorboards per ft. width, uniformly distributed	Minimum* load on beams, uniformly distributed
		lb.	lb.	lb.
I	Private dwellings of not more than two storeys	30	240	1920
II	Rooms in private dwellings of more than two storeys, including flats; hospital rooms and wards; bedrooms and private sitting rooms in hotels and tenement houses; and similar occupancies	40	320	2560
III	Rooms used as offices	50	400	3200
IV	Classrooms in schools and colleges; minimum for light workshops	60	480	3840
V	Banking halls and offices where the public may congregate	70	560	4480
VI	Retail shops; places of assembly with fixed seating†; churches and chapels; restaurants; garages for vehicles not exceeding 2½ tons gross weight (private cars, light vans, etc.); circulation space in machinery halls, power stations, pumping stations, etc., where not occupied by plant or equipment	80	640	5120
VII	Places of assembly without fixed seating (public rooms in hotels, dance halls, etc.); minimum for filing or record rooms in offices; light workshops generally, including light machinery	100	800	6400
VIII	Garages to take all types of vehicles	100	Worst combination of actual wheel loads or, if the slab is capable of effective lateral distribution of load, 1·5 × maximum wheel load, but not less than 2000 lb., considered to be distributed over a floor area 2 ft. 6 in. square	
IX	Light storage space in commercial and industrial buildings; medium workshops	150	—	—
X	Minimum for warehouses and general storage space in commercial and industrial buildings; heavy workshops. (The loads imposed by heavy plant and machinery should be determined and allowed for.)	200	—	—

* Minimum load for slabs becomes operative at spans of less than 8 ft. Minimum load for beams becomes operative on areas less than 64 sq. ft. Beams, ribs and joists spaced at not more than 3 ft. centres may be calculated for slab loadings.

The loadings stated in these columns refer to the design of the slabs and individual beams respectively, including their connections.

† Fixed seating implies that the removal of the seating and the use of the space for other purposes are improbable.

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REDUCTIONS IN SUPERIMPOSED FLOOR LOADS

8. Except in buildings for storage purposes, and as otherwise required in this clause, the following reductions in assumed total superimposed floor loads may be taken in designing all columns, piers, walls, their supports and foundations :—

Table 2

Reductions of total superimposed floor loads on columns, piers, etc.

Number of floors carried by member under consideration	Per cent reduction of superimposed load on all floors carried by the member under consideration
1	0
2	10
3	20
4	30
5 or more	40

Where the single span of a beam or girder supports not less than 500 sq. ft. of floor at one general level, the superimposed load to be carried by the beam or girder may be reduced by 5 per cent for each 500 sq. ft. supported, subject to a maximum reduction of 25 per cent. This reduction or that given in Table 2, whichever is the greater, may be taken into account in the design of columns, etc., supporting such a beam. No reduction shall be made where the floors are used for storage purposes, nor in the weight of any plant or machinery for which specific allowance is made.

PARAPETS AND BALUSTRADES

9. Parapets and balustrades, together with the connections and members which give them immediate structural support shall be designed for the following horizontal static loads which shall be assumed to act at handrail or coping level :—

Light access stairs ; gangways and the like	15 lb/ft. run
Stairways, landings and balconies, private and domestic	25 lb/ft. run
All other stairways, landings and balconies and all parapets and handrails to roofs	50 lb/ft. run (or wind load, if greater).
In places of assembly, where danger would result in the event of panic	200 lb/ft. run

SUPERIMPOSED ROOF LOADS OTHER THAN WIND LOADS

10. *Flat roofs and slightly sloping roofs.* On flat roofs and sloping roofs up to and including 10 degrees, a superimposed load, including a load to

provide for loose snow up to 2 ft. in depth, of 30 lb/sq. ft. measured on plan shall be allowed for, subject to a minimum load of 240 lb. uniformly distributed per foot width on roof slabs or roof covering.

For a light roof where design and location render it in no circumstances likely to be made accessible to persons, other than for maintenance purposes, a value of 15 lb/sq. ft. may be taken, but the load of 240 lb. on slabs or covering shall not be reduced.

Sloping roofs. On roofs having a slope greater than 10 and up to 65 degrees, a snow load of 10 lb/sq. ft. measured on plan shall be allowed for. On roofs having a slope over 65 degrees no allowance need be made.

All roofs. All roof coverings which are required to support loads incidental to maintenance shall be capable of carrying the following loads :—

Where the roof is flat or the slope is such that workmen could stand directly on the roof.	200 lb. concentrated at any point.
Where the slope is such that workmen would have to use a ladder or similar support laid on the covering.	100 lb. concentrated at any point.

The combined effect of snow loads and wind pressure on roofs shall be taken into account as stated in Clause 29.

In localities where abnormal snow loads are experienced, an appropriate additional loading shall be taken.

For localities abroad where no snow load is to be anticipated or conversely, where blown sand or other accidental loading may occur, such adjustments as are appropriate shall be made to the above loadings.

WIND PRESSURE

11. *a. General.* The pressures and suctions specified are given in multiples of the pressure (p) pounds per square foot, which is the equivalent intensity of wind loading in the windward direction.

The term 'pressure' is used in the general sense and is particularized, where necessary, by ' positive ' or ' negative ' ; ' suction ' means negative pressure ; and the appropriate sign is placed before symbols and numerical values.

The effect of wind on the structure as a whole is determined by the combined action of the external pressures and suctions, but the effect at any point on the cladding of the building and locally on the structure is determined by the difference between the external pressure at that point and the air pressure inside the building.

The sensitivity of the structural framework of buildings varies considerably, and whereas in some cases it is sufficient to consider the external pressures, in others—e.g. open sheds, it is essential to take into account the variations of internal pressure.

b. Wind velocities. Table 3 gives wind velocities recommended for use in the application of the formula in Sub-clause *c* to the design of buildings in

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various parts of Great Britain and Northern Ireland, but for buildings in localities abroad subject to winds of very high velocity, special consideration will be necessary.

For open towers, frames, exceptionally large buildings, those of special shape, or those which are so constructed that the distribution of wind pressure is unusual, values based on wind tunnel tests should be used.

'Where natural protection is afforded' means that the site of the building is, as a result of its altitude relative to the surrounding country, shielded from the full effects of the wind.

'Open country inland' means flat or gently undulating country up to a level of about 500 ft. above sea level.

'Conditions of maximum exposure' is intended to cover all exposed sites within five miles of the sea coast or estuary and similar sites inland at an altitude exceeding about 900 ft. above sea level.

For site conditions intermediate between those given, suitable intermediate values of wind speed shall be adopted.

An allowance may be made for the shelter afforded by buildings or other permanent obstacles around and in close proximity to the site such as exists in the built-up areas of towns. This allowance for shelter has been made by introducing into the formula in Sub-clause *c* a factor for the height above general ground level assumed to be sheltered by permanent obstacles. The value assumed for 's' shall not exceed one-half of the value of 'h.'

Table 3

Wind velocities (v) in m.p.h. for use in design

District	Where natural protection is afforded	Open country inland	Conditions of maximum exposure
West Scotland N.W. Ireland N.W. England Wales S.W. England	60	70	80
East Scotland N.E. Ireland N.E England East England South and S.E. England	55	65	75
Central England (including Severn Estuary)	50	60	70

c. Wind pressure on vertical surfaces. The equivalent intensity of wind loading in the windward direction is given by the formula below, which gives values for the unit wind pressure (p) on a building in lb/sq. ft. applied uniformly over the vertical faces (see Table 4) :—

$$p = \frac{v^2}{600}\sqrt{1 + 0{\cdot}06\,(h - s)}$$

where

v = the wind velocity in miles per hour at height of 40 ft. above ground on an open site.

h = the height in feet of the windward vertical face above the general ground level.

s = the height in feet above general ground level assumed to be sheltered by permanent obstacles. The value of 's' should not be taken as more than 0·5 h.

It may be assumed that there is no increase of pressure for heights above 200 ft.

The height of the vertical face 'h' should be measured to one of the following :—

(i) Eaves.

(ii) Top of parapet wall.

(iii) Top of mansard (if slope exceeds 70 degrees).

(iv) Average height of gable ends.

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Table 4

Unit wind pressure (p) lb/sq. ft.

Effective height (h−s) in feet	Wind velocity (v) m.p.h.						
	50	55	60	65	70	75	80
10	5·3	6·4	7·6	8·9	10·3	11·9	13·5
15	5·7	6·9	8·2	9·7	11·2	12·9	14·7
20	6·2	7·5	8·9	10·4	12·1	13·9	15·8
25	6·6	8·0	9·5	11·2	12·9	14·9	16·9
30	7·0	8·4	10·0	11·8	13·7	15·7	17·9
35	7·4	8·9	10·6	12·4	14·4	16·5	18·8
40	7·7	9·3	11·1	13·0	15·0	17·2	19·6
45	8·0	9·7	11·6	13·5	15·7	18·1	20·5
50	8·3	10·1	12·0	14·1	16·3	13·7	21·3
60	9·0	10·8	12·9	15·1	17·3	20·1	22·9
70	9·5	11·5	13·7	16·1	18·4	21·4	24·3
80	10·0	12·1	14·4	16·9	19·6	22·5	25·6
90	10·5	12·7	15·1	17·7	20·6	23·6	26·9
100	11·0	13·3	15·8	18·6	21·6	24·8	28·2
120	11·9	14·4	17·1	20·1	23·4	26·8	30·5
140	12·8	15·4	18·4	21·6	25·0	28·7	32·7
160	13·6	16·4	19·6	22·9	26·6	30·5	34·8
180	14·3	17·3	20·6	24·2	28·0	32·1	36·6
200 and over	15·0	18·2	21·6	25·4	29·4	33·8	38·4

Intermediate values may be determined by interpolation.

WIND PRESSURE ON BUILDINGS AS A WHOLE

12. *a. General.* The supporting framework and foundation of a building shall be designed to resist the wind pressure on vertical surfaces, together with the wind pressure on the roof and the wind pressure on any projections above the roof. Where, however, adequate stiffening is provided by walls or by floors and walls, general stability calculations for wind pressure may be neglected :—

(i) On a building or part of a building of which the height (*h*) does not exceed three times the effective width. (See '*a*' in Cases I, II and III in Fig. 1.) ;

(ii) On a section joining two parts of such a building if the length of the section does not exceed three times its width. (See '*b*' in Case IV, Fig. 1.), and

(iii) On a wing of such a building if it does not project more than its own width. (See '*c*' in Case V, Fig. 1.)

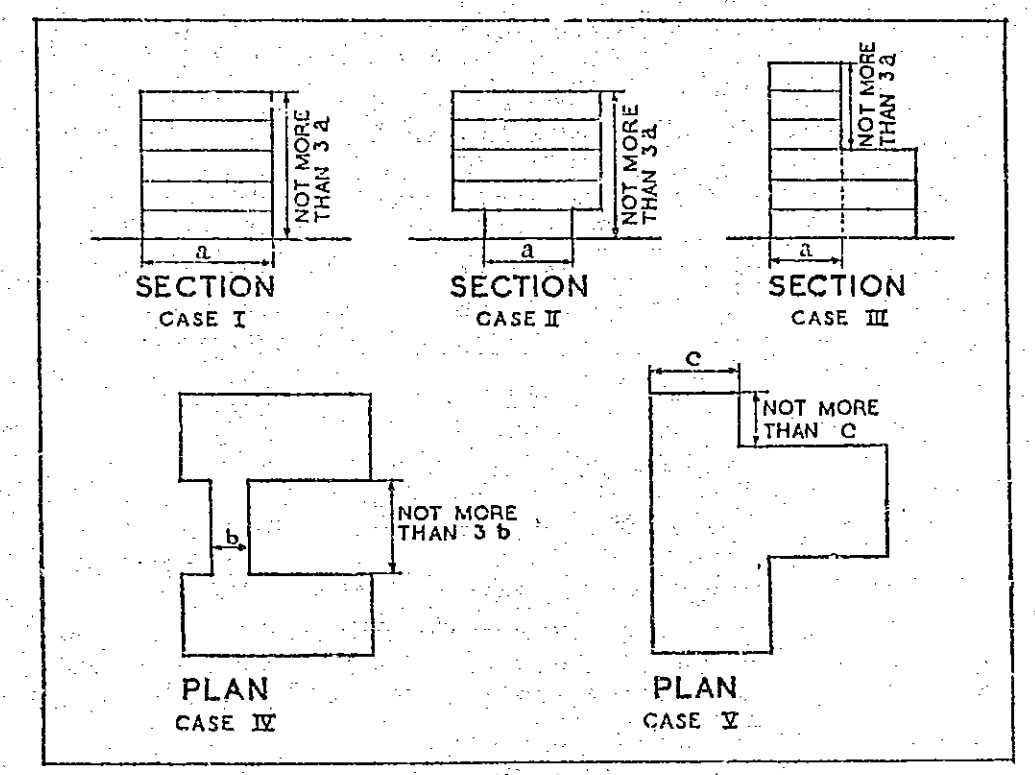

Fig. 1.

b. External wind pressures on vertical surfaces. For the vertical surfaces of buildings, the unit wind pressure (*p*), due to wind blowing at right angles to the surface, shall be taken as divided equally between the windward and leeward surfaces, as a pressure of 0·5*p* on the windward surface and a suction of 0·5*p* on the leeward surface.

A surface inclined at an angle with the horizontal, of 70 degrees or over, shall be deemed to be vertical for the purposes of this clause.

c. External wind pressure on roofs. Flat and pitched roofs. Table 5 gives the wind pressures to be taken on roofs normal to the surface, due to wind blowing at right angles to the eaves, in terms of the unit wind pressure (*p*).

Table 5

External wind pressure on roofs. (Wind normal to eaves)

Slope of roof degrees	Windward slope of pitched roof (or half of flat roof)	Leeward slope of pitched roof (or half of flat roof)
0	− 1·0*p*	−0·5*p*
22½	− 0·25*p*	
30	0	
45	+ 0·25*p*	
70 and over	+ 0·5*p*	

The wind pressures to be assumed on intermediate roof slopes shall be interpolated linearly

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Curved roofs. The wind pressures on the windward and leeward sides of a curved roof, due to wind blowing at right angles to the axis of the roof, shall be taken as equal in intensity to those specified in Table 5 for a pitched roof of the same rise and shall be assumed to act radially inwards and outwards.

Multi-span roofs. In multi-span roofs where all spans are approximately the same height and slope and where the windward span gives shelter to the succeeding spans, and if the spans are connected together, the following reductions of wind pressure may be taken in making the general stability calculations :—

(i) On the span adjoining the windward span, 50 per cent.
(ii) On the next span, 75 per cent.
(iii) On the remaining spans, 87½ per cent.

Wind drag. The dragging effect on surfaces parallel to the wind can normally be neglected, but in the design of very large roofs, etc., provision shall be made for a tangential force of 0·025*p*.

d. Projections above the general roof level. The total wind pressure on projections above the general roof level shall be taken as having the values given in Table 6 ; '*h*' being measured to the top of such projections for the purpose of calculating '*p*.'

Table 6

Intensity of unit wind pressure (*p*) on projected area in wind direction

Plan section of projection	Ratio of height of the projection to base-width of the projection		
	0 to 4	4 to 8	8 to 16
Circular	0·7*p*	0·7*p*	0·7*p*
Octagonal	0·8*p*	0·9*p*	1·0*p*
Square (wind perpendicular to diagonal)	0·8*p*	0·9*p*	1·0*p*
Square (wind perpendicular to face)	1·0*p*	1·15*p*	1·3*p*

INTERNAL AIR PRESSURE

13. Internal air pressure in a building depends upon the degree of permeability of the cladding to the flow of air.

Buildings having a small degree of permeability. In the case of buildings where the cladding is such that the flow of air through the cladding is practically negligible, the structural framework need not be designed for internal air pressure.

Buildings of normal permeability. In the case of buildings where the cladding permits the flow of air but where there are no large openings, the structural framework shall be designed for the alternative conditions of an internal pressure of 0·2*p* and an internal suction of 0·2*p* acting normal to the wall and roof surfaces, in addition to the values given in Clause 12.

Buildings with large openings. In the case of buildings with large openings, such as hangars and sheds, the structural framework shall be designed for an internal pressure of 0·5*p* or an internal suction of 0·5*p* acting normal to the wall and roof surfaces, in addition to the values given in Clause 12, according to the direction of the wind. Positive pressure will be caused by wind blowing into the openings and negative pressure by wind blowing normal to the other face.

LOCAL EFFECTS OF WIND

14. The pressures and suctions specified in the preceding Clauses are average values and are exceeded locally.

Individual panels of wall and roof cladding, together with their immediate supports and fastenings, shall be capable of resisting a local increase of pressure or suction of 0·1*p* in addition to the pressures and suctions computed from the external wind and internal air pressures. Fastenings within a distance of 15 per cent of the span from the eaves in the case of roof cladding, and 15 per cent of the length from the gables in the case of both roof and wall cladding, shall be capable of resisting a suction on the area they support of 1·5*p* for wall cladding, and 2·0*p* for roof cladding.

DYNAMIC LOADS

15. 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 dynamic effects, including impact, by increasing the deadweight value for the plant by an adequate percentage.

The engineer shall ascertain as accurately as possible the appropriate dynamic increase for all members affected so as to ensure due economy in design. It is unnecessary to make any allowance for fatigue over and above that made for dynamic effects.

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, viz. :

(*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*) For horizontal forces acting transversely to the rails, the combined weight of the crab and the load lifted shall be increased by the following percentages :—

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

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One-half of this transverse force shall be considered as acting at the rail level on each of the two lines of rails and transmitted by the gantry girders to the vertical supports.

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

(*c*) For horizontal forces acting along the rails, the static wheel loads which can occur on the rails shall be increased by the following percentages:—

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

These forces are to be considered as acting at the rail level and transmitted to the vertical supports, and shared by all the vertical supports in line in proportion to their relative stiffnesses, unless bracing is provided between the supports to resist this force.

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

An increase of 10 per cent on the permissible bending 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.

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

Care shall be taken to ensure that no part of the supporting structure is seriously overstressed in the event of tests being carried out on the cranes, or other machinery.

TEMPERATURE RANGE

16. 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 temperature in Great Britain and Northern Ireland varies from 30°F. to 90°F. Special consideration will be necessary for buildings in localities abroad subject to different temperature ranges.

PART FOUR. PERMISSIBLE STRESSES

AXIAL STRESSES IN TENSION

17. The direct stress in pure tension on the net area of the section in tons per square inch shall not exceed F_t, where—

F_t = 9 tons/sq. in. for steel to B.S. 15, or

= 0·59 f_y for other steels, where f_y is the guaranteed yield stress in tons/sq. in. For values of F_t for steels to B.S. 548 and 968, see Appendices A and B respectively.

AXIAL STRESSES IN STRUTS

18. *a. Uncased struts, Steel to B.S.* 15. The permissible working stresses on the gross sectional area of struts axially loaded shall not exceed the values F_a in Table 7 * in which l/r = effective length divided by the radius of gyration.

For equivalent values of F_a for steels to B.S. 548 and 968, see Appendix A, Table 19 * and Appendix B, Table 22 * respectively.

Table 7

Permissible working stresses in tons/sq. in. of gross section for axial loads

l/r	F_a tons/sq. in.	l/r	F_a tons/sq. in.	l/r	F_a tons/sq. in.	l/r	F_a tons/sq. in.
0	9·00	70	5·60	140	2·57	210	1·27
10	8·51	80	5·12	150	2·30	220	1·17
20	8·03	90	4·62	160	2·06	230	1·08
30	7·54	100	4·13	170	1·86	240	0·99
40	7·06	110	3·67	180	1·68	250	0·92
50	6·57	120	3·26	190	1·52	300	0·65
60	6·09	130	2·89	200	1·39	350	0·49

Intermediate values may be determined by interpolation.

b. Cased struts. Struts may be designed as cased struts when the following conditions are fulfilled:—

(i) The section is of single web and I-form.

(ii) The steel strut is unpainted and solidly encased in ordinary dense concrete consisting of a 1 : 2 : 4 or richer mix.

(iii) The minimum width of solid casing is equal to $b + 4$ in., where b is the width of the steel flange in inches.

(iv) The surface and edges of the steel strut have a concrete cover of not less than 2 in.

(v) 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 of the edges and outer faces of the flanges.

In selecting the permissible axial stress on the steel section (which shall be deemed to carry the whole load), the radius of gyration r about the weak axis of I-shapes (single web) not exceeding 30 in. deep (over plating where used) may be taken as $0{\cdot}2\,(b+4)$ in. In no case shall this value exceed the stress permitted on the uncased section by more than 50 per cent, nor shall the effective ratio of slenderness of the uncased section exceed 250.

The radius of gyration about the other axis shall be taken as that of the uncased section.

* The formula from which the tables have been derived is given in Appendix C.

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c. Angles as struts, steel to B.S. 15. For single-angle, discontinuous struts connected to gussets or to the leg of a rolled section either by bolting or riveting with not less than 2 bolts or rivets in line along the angle at each end, or by their equivalent in welding, the eccentricity of the connection with respect to the centroid of the strut may be ignored and the strut designed as an axially-loaded member. The permissible working stress shall not exceed the values given in Table 8, in which L is 0·8 of the length of the strut, centre to centre of fastenings at each end, and r is the minimum radius of gyration.

Angle struts with single-bolted or riveted connections shall be treated similarly, but the permissible working stress shall not exceed the values given in Table 9.

For double-angle, discontinuous struts back-to-back connected to both sides of a gusset or to both sides of the leg of a rolled section, by not less than 2 bolts or rivets in line along each angle at each end, or by their equivalent in welding, the load may be regarded as applied axially, the permissible working stress shall not exceed the values obtained from Table 7. The angles shall be connected together by not less than two bolted, riveted or welded packings in the length of the strut, or such other number as will satisfy the requirements of this standard for washer-riveted or welded struts (see Clause 53).

Double-angle discontinuous struts back-to-back connected to one side of a gusset or leg of a rolled section shall be designed as for single angles and the permissible working stress shall not exceed the values in Table 8, whether the angles are connected at each end by one or more rivets or bolts or by welding. The angles, whether in contact or separated, shall be connected together so as to satisfy the above requirements for double angles connected to both sides of a gusset.

Table 8

Permissible working stresses in tons/sq. in. of gross section for discontinuous angle struts. (Double-bolted, double-riveted, or welded at ends)

L/r	$F_c 2$ tons/sq. in.	L/r	$F_c 2$ tons/sq. in.	L/r	$F_c 2$ tons/sq. in.	L/r	$F_c 2$ tons/sq. in.	L/r	$F_c 2$ tons/sq. in.	L/r	$F_c 2$ tons/sq. in.
0	6·00	50	4·55	100	3·12	150	1·95	200	1·25	250	0·86
10	5·71	60	4·26	110	2·85	160	1·77	210	1·16	300	0·62
20	5·42	70	3·97	120	2·60	170	1·61	220	1·08	350	0·47
30	5·13	80	3·68	130	2·37	180	1·47	230	1·00		
40	4·84	90	3·40	140	2·15	190	1·35	240	0·93		

For equivalent values for steels to B.S. 548 and 968, see Tables 20 and 23 in Appendices A and B respectively.

Table 9

Permissible working stresses in tons/sq. in. of gross section for discontinuous angle struts. (Single-bolted or single-riveted at ends)

L/r	$F_c 1$ tons/sq. in.	L/r	$F_c 1$ tons/sq. in.	L/r	$F_c 1$ tons/sq. in.	L/r	$F_c 1$ tons/sq. in.	L/r	$F_c 1$ tons/sq. in.	L/r	$F_c 1$ tons/sq. in.
0	3·00	50	2·42	100	1·85	150	1·32	200	0·96	250	0·71
10	2·88	60	2·31	110	1·73	160	1·24	210	0·90	300	0·53
20	2·77	70	2·19	120	1·62	170	1·16	220	0·84	350	0·43
30	2·65	80	2·08	130	1·51	180	1·09	230	0·79		
40	2·54	90	1·96	140	1·41	190	1·02	240	0·75		

For equivalent values for steels to B.S. 548 and 968, see Appendices A and B respectively. Appendix D gives notes on the derivation of the tables.

BENDING STRESSES

19. *a. General.* In calculating tensile stresses in bending, the moment of inertia of the net cross-section shall be used, and calculations for compressive stresses shall be based on the moment of inertia of the gross cross-section, although for convenience the net cross-section may be used.

Alternatively for plate girders those parts constituting the flanges may be calculated as resisting the whole of the bending (see Clause 48 *b*).

b. In tension.

(i) For beams other than plate girders the bending stress in the extreme fibres in tension shall not exceed F_{bt} where :—

F_{bt} = 10 tons/sq. in. for steel to B.S. 15, or

= 0·65 f_y for other steels, where f_y is the guaranteed yield stress in tons/sq. in.

For values of F_{bt} for steels to B.S. 548 and 968 see Appendices A and B respectively.

(ii) For plate girders, the above values of F_{bt} shall be reduced by 5 per cent.

c. In compression (uncased beams). The bending stress in the extreme fibres in compression shall not exceed the lesser of the values F_{bc} obtained from (i) and (ii) as follows :—

(i) F_{bc} = 10 tons/sq. in. for steel to B.S. 15 ; or

= 0·65 f_y for other steels, where f_y is the guaranteed yield stress in tons/sq. ins. For plate girders the above values of F_{bc} shall be reduced by 5 per cent.

(ii) $F_{bc} = \frac{1000}{l/r} \times K_1$ tons/sq. in., where

l = the length between effective lateral restraints.

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r = the radius of gyration of the beam section perpendicular to the plane of bending.

K_1 = a factor which shall be taken as unity except in the case of rolled steel joists, compounds and plate girders symmetrical about both principal axes and subject to bending about the xx axis (as given in B.S. 4 'Dimensions and properties of channels and beams for structural purposes'). For these conditions the factor may be assumed to have the values given in Table 10, depending upon the ratio of the gross radii of gyration r_{xx} and r_{yy} about the principal rectangular axes.

Table 10
Bending stress factors K_1

r_{xx}/r_{yy}	K_1
5·0	1·000
4·5	1·125
4·0	1·250
3·5	1·375
3·0 or less	1·500

Intermediate values may be determined by linear interpolation.

d. In compression (cased beams). Beams may be designed as cased beams when the following conditions are fulfilled :—

(i) The section is of single web and I-form.

(ii) The beam is unpainted and is solidly encased in an ordinary dense concrete consisting of a 1 : 2 : 4 or richer mix.

(iii) The minimum width of solid casing is equal to $b + 4$ in. where b is the width of the steel flange in inches.

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

(v) 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 of the edges and soffit of the lower flange.

The compressive stress in bending shall not exceed the lesser of the values of F_{bc} obtained from Sub-clauses *c* (i) and (ii) ; for the purpose of Sub-clause *c* (ii) the radius of gyration r_{yy} of cased beams of 'I' shape (single web) not exceeding 30 in. deep (over plating where used) may be taken as $0{\cdot}2\,(b + 4$ in.) ; the radius of gyration r_{xx} being taken as that of the uncased section.

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

See Clause 26 for solidly encased filler joists.

e. Permissible stress for slab bases. The permissible stress for slab bases shall not exceed F_b, where

F_b = 12 tons/sq. in. for steel to B.S. 15 ; or
= $0{\cdot}8\,f_y$ for other steels, where f_y is the guaranteed yield stress in tons/sq. in.

SHEAR STRESSES

20. *a. Simple shear stress.* The shear stress in parts other than webs shall not exceed F_s where

F_s = 6·5 tons/sq. in. for steel to B.S. 15 ; or
= $0{\cdot}42\,f_y$ for other steels, where f_y is the guaranteed yield stress in tons/sq. in.,
For values of F_s for steels to B.S. 548 and 968 see Appendices A and B respectively.

b. Shear stress in webs of beams and girders. The average shear stress F'_s on the gross cross-section of the web shall not exceed the lesser of the values given by (i) and (ii) below for unstiffened webs and by (i) and (iii) below for stiffened webs :—

(i) F'_s = 6·5 tons/sq. in. for steel to B.S. 15 ; or
= $0{\cdot}42\,f_y$ for other steels where f_y is the guaranteed yield stress in tons/sq. in.
For values of F'_s for steels to B.S. 548 and 968 see Appendices A and B respectively.

(ii) $F'_s = \left(\frac{225}{d/t}\right)^2$ tons/sq. in. for unstiffened webs (see Table 11),

where

d = the clear distance between flange angles or where there are no flange angles, the clear distance between flanges ignoring fillets.

t = the thickness of the web.

(iii) $F'_s = \left(\frac{225}{b/t}\right)^2 \cdot \left[1 + \frac{3}{4}\left(\frac{b}{a}\right)^2\right]$ tons/sq. in. for effectively stiffened webs, where

a = the greater unsupported dimension of the web in a panel,

b = the least unsupported dimension of the web in a panel,

c = the thickness of the web.

The stiffeners shall comply with the requirements of Clause 51.

Table 11
Shear stress in webs for steel to B.S. 15

d/t	F'_s tons/sq. in.	d/t	F'_s tons/sq. in.
up to 88	6·50	130	3·00
90	6·25	140	2·58
100	5·06	150	2·25
110	4·18	160	1·98
120	3·52	170	1·75

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These permissible stresses shall 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.

BEARING STRESS

21. The permissible bearing stress on the net area of contact shall not exceed F_p where :—

F_p = 12 tons/sq. in. for steel to B.S. 15 ; or
= $0{\cdot}8 f_y$ for other steels where f_y is the guaranteed yield stress in tons/sq. in.
For values of F_p for steels to B.S. 548 and 968 see Appendices A and B respectively.

COMBINED STRESSES

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

$$\frac{f_a}{F_a} + \frac{f_{bc}}{F_{bc}}$$

does not exceed unity, where

f_a = the axial compressive stress.
F_a = the permissible compressive stress in axially loaded struts. (See Table 7.)
f_{bc} = the sum of the compressive stresses due to bending about both rectangular axes.
F_{bc} = the minimum permissible compressive stress for members subject to bending. (See Clause 19.)
For the purposes of this clause, the allowances made in Clause 19 *c*, Table 10 should not be used where excessive flexibility will result.

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

$$\frac{f_t}{F_t} + \frac{f_{bt}}{F_{bt}}$$

does not exceed unity, where

f_t = the axial tensile stress.
F_t = the permissible axial tensile stress. (See Clause 17.)
f_{bt} = the maximum tensile stress due to bending about both principal axes.
F_{bt} = the permissible tensile stress in bending. (See Clause 19 *b*.)

PERMISSIBLE STRESSES IN RIVETS AND BOLTS

23. The permissible stresses in rivets and bolts shall not exceed the following:—

Table 12

Permissible stresses in rivets and bolts—steel to B.S.15

	Steel to B.S. 15 tons/sq. in.	Remarks
In tension.		
Axial stress on gross area of rivets and net area of bolts :		For gross and net areas, see Clause 38.
Shop-driven rivets	5	
Field-driven rivets	4	
Bolts ¾ in. and over in diameter	6	These stresses are not intended to apply to screwed tension rods.
Bolts less than ¾ in. in diameter	5	
In shear.		
Shear stress on gross area of rivets and bolts :		For gross area see Clause 38. For rivets and bolts in double or quadruple shear, the area to be assumed shall be 2 or 4 times respectively the area as defined.
Shop-driven rivets	6	
Field-driven rivets	5	
Turned and fitted bolts	6	
Black bolts	4	
In bearing.		
Bearing stress on gross diameter of rivets and bolts :		Where the rivets or turned and fitted bolts are in double shear the permissible bearing stress on the central thickness of metal may be increased by 25 per cent.
Shop-driven rivets	12	
Field-driven rivets	10	
Turned and fitted bolts	12	
Black bolts	8	

For permissible stresses in rivets and bolts of steel to B.S. 548 see Appendix A.

PERMISSIBLE STRESSES IN WELDS

24. *a.* **Permissible stresses in welds for mild steel.**

(i) *Butt welds.* The permissible stresses in butt welds, calculated on an area equal to the effective length of the weld multiplied by the throat thickness (or, a reduced throat thickness as specified in Clause 44 *h* for certain butt welds) shall not exceed the permissible tensile compressive and shear stresses in the parent metal.

(ii) *Fillet welds.* The permissible stress in fillet welds, calculated on an area equal to the effective length of the weld multiplied by the throat thickness, shall not exceed the permissible shear stress in the parent metal.

(iii) *Welds subjected to combined bending and direct loading.* When the welds in a connection are subjected to the action of bending combined with direct load, the maximum resultant stress calculated as the vector sum shall not exceed the permissible stress given in (i) and (ii) above for the type of weld under consideration.

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b. **Permissible stresses in welds for high tensile steel.** When electrodes conforming to B.S. 639 (Class A) are used for welding high tensile steel, the permissible stresses in the welds shall not exceed those specified above for mild steel.

STRESSES DUE TO WIND FORCES

25. The stresses, as computed for all loadings excluding wind pressure, may exceed by 25 per cent those specified in Clauses 17 to 24 inclusive, in cases where such increase is solely due to stresses induced by the wind. In no case shall the steel section thus required be less than that needed if the wind stresses were neglected. No increase shall be permitted to the permissible stress specified in Clause 19 *e* for slab bases.

FILLER JOISTS

26. *a. Bending moment.* The bending moments on slabs of which filler joists form part shall be calculated to satisfy the following, viz. :—

(i) As slabs spanning continuously over supports and subject to those combinations of dead and live load producing the maximum positive and negative moments, or

(ii) In the case of three or more approximately equal spans * of continuous filler joists as described in Sub-clause *f*, as slabs designed for uniformly distributed loading, satisfying the bending moment values given in Table 13 :—

Table 13
Bending moment values for filler joists

Near middle of end span	At support next to end support	At middle of interior spans	At other interior supports
$+\frac{w.L^2}{10}$	$-\frac{w.L^2}{10}$	$+\frac{w.L^2}{12}$	$-\frac{w.L^2}{12}$

where

w = the dead plus live load per unit length of span.
L = the span centre to centre of supports.

For single spans the slab shall be assumed to be freely supported.

b. Resistance moment. The resistance moment of the slab shall be calculated from the section properties of the filler joists only, except that where the filler joists are completely embedded in a solid concrete slab the slab may alternatively be calculated as a composite reinforced concrete section.

c. Spacing. The spacing of filler joists centre to centre shall not exceed '*n*' times the minimum thickness of the structural concrete slab or structural concrete topping as given in Table 14, unless the concrete is reinforced to span as a slab or arch between the filler joists.

* Spans may be considered approximately equal when the longest span does not exceed the shortest span by more than 15 per cent.

Where the concrete is designed to arch between the filler joists, the thrust from the arch action shall be taken up by steel ties or by other means so as not to cause appreciable increase of stress in the joists.

Table 14
Spacing of filler joists

Superimposed load per sq. ft.	Up to 50 lb.	Above 50 and up to 100 lb.	Above 100 and up to 150 lb.	Above 150 and up to 200 lb.	Above 200 lb.
Value of '*n*'	9	8	7	6	5

d. Thickness of concrete. Where the underside of the concrete is arched between the filler joists, the thickness at the crown shall be not less than 2 in. The thickness of structural concrete over hollow blocks shall nowhere be less than 1¼ in. when the filler joists do not exceed 18 in. centre to centre and nowhere less than 2 in. when the spacing of the filler joists is greater than 18 in. centre to centre.

e. Stresses. (i) *Bending stress.* The flexural stress in filler joists, other than those designed as forming part of a reinforced concrete slab, shall not exceed 10 + *t* tons/sq. in. for steel to B.S. 15, where '*t*' is an allowance, the value of which is equal to thickness in inches of the structural concrete cover to the compression flanges of the filler joists.

The allowance '*t*' shall apply only in cases where the filler joists are embedded at least flush with the underside of their bottom flanges in a solid concrete slab throughout. Any cover less than 1 in. and in excess of 3 in. shall be neglected.

In cases where the underside of the slab is flush with the bottom flanges of the filler joists, the allowance '*t*' shall not apply in respect of support moments, nevertheless if the top flange is covered the allowance may be made in calculating the resistance to the sagging moments.

(ii) *Shear and bearing stress.* The shear and bearing stresses at end connections shall be calculated as taken entirely on the filler joists, and the stresses shall not exceed those given in Clauses 20 *b* (i) and 21 respectively.

f. Joints in continuous fillers. Continuous fillers shall extend, where possible, over three spans and shall be jointed over supports in such a manner as to preserve a considerable measure of continuity. The joints shall be staggered so that full continuity of the fillers occurs in 50 per cent of those crossing any support.

g. Span depth ratio. The span of filler joists, centre to centre of supports, shall not exceed 35 times the depth from the underside of the joist to the top of the structural concrete or 12 times this depth in the case of cantilever fillers.

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GRILLAGE BEAMS

27. Where grillage beams are enveloped in a solid block of ordinary dense concrete of 1 : 2 : 4 or richer mix, the permissible working stresses specified in this British Standard for uncased beams may be increased by 33⅓ per cent provided that

a. The beams are spaced apart so that the distance between the edges of adjacent flanges is not less than 3 in.

b. The thickness of the concrete cover on the top of the upper flanges, at the ends, and at the outer edges of the sides of the outermost beams is not less than 4 in.

c. The concrete is tamped solid around all beams.

These increased stresses shall not apply to hollow compound girders.

STEEL CASTINGS

28. The use of steel castings shall be limited to bearings and other similar parts and the working stresses shall not exceed the working stresses given in this British Standard for mild steel to B.S. 15.

Steel castings shall conform to B.S. 592 'Carbon steel castings for ships and for marine engine and general engineering purposes,' Grade 1, 28 to 35 tons/sq. in., with a minimum yield stress of 14·75 tons/sq. in.

PART FIVE. DESIGN AND DETAILS OF CONSTRUCTION

STEEL FRAMEWORK

29. All parts of the structure shall be capable of sustaining the most adverse combination of loads to which the building may reasonably be subjected, including the actual dead loads, the prescribed superimposed and wind loads specified in Part Three, and any other forces or loads, without exceeding the permissible stresses specified in Part Four.

The following methods may be employed for the design of the steel framework :—

a. Simple design.
b. Semi-rigid design.
c. Fully rigid design.

a. 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 consequence the structure may, for the purposes of design, be assumed to be pin-jointed.

This method of design involves the following assumptions :—

(i) Beams are simply supported.

(ii) All connections of beams, girders or trusses are virtually flexible and are proportioned for the reaction shears, applied at the appropriate eccentricity.

(iii) Members in compression are subjected to loads applied at the appropriate eccentricities (see Clause 37, for stanchions), with the effective lengths given in Clauses 18 and 35.

(iv) Members in tension are subjected to longitudinal loads applied over the net area of the section, as specified in Clause 39.

b. Semi-rigid design. This method, as compared with that for simple design, permits a reduction in the maximum bending moment on beams suitably connected to stanchions or beams or girders.

In cases where this method of design is used the designs shall be made in complete conformity with the 'Recommendations for Design' in the Final Report of the Steel Structures Research Committee, 1936, except that all connections of beams to stanchions and beams to beams or girders in which restraining moments are taken, shall be riveted.

The method, in so far as this standard is concerned, shall apply only to steel to B.S. 15, and the working stresses, bending moment factors, connection factors, stanchion graphs, tables, details, etc., given in the Recommendations above referred to shall, for the purpose only of semi-rigid design, supersede the requirements of this standard.

c. Fully rigid design. This method, as compared with the methods for simple and semi-rigid design, will give the greatest rigidity and economy in the weight of steel used, when applied in appropriate cases. For the purpose of such design accurate methods of structural analysis shall be employed leading to a load factor of 2, based on the calculated or otherwise ascertained failure load of the structure or any of its parts, and due regard shall be paid to the accompanying deformations under working loads, so that deflections and other movements are not in excess of the limits implied in this British Standard.

RESISTANCE TO HORIZONTAL FORCES

30. *a. General.* (i) When the floors and/or roof and the walls are capable of transmitting the horizontal forces effectively to the foundations, the effect of wind pressure on the stresses in the structural framework may be neglected.

The cases given in Clause 12 may be deemed to satisfy this condition, but other cases shall be examined, and the value of the walls and floors to resist horizontal forces assessed.

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

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