

An increase of 10 per cent on the permissible stresses specified in this Code of Practice may be allowed for the combination of loadings specified in 4.2.1 and 4.2.2 above in respect of the design of the gantry girders and supporting structures. This increase is not however in addition to that permitted in 5.4.

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.

Structures or structural components which support hoisting devices with a lifting capacity of 10 tonnes or more, should be designed and constructed in accordance with the relevant provisions of BS 2573: Part 1.

In the event that BS 2573:Part 1 does not adequately cover any particular situation then the structure or structural component should be designed to the satisfaction of the Building Authority.

Note: For factors applicable to the allowable working stresses, and detailed design under fatigue conditions, see BS 153:Parts 3B and 4 and BS 5400:Part 10.

4.3 COMBINED WIND AND DYNAMIC LOADS

A reduction in wind loading may be allowed where the operation of three or more overhead cranes is to be provided in a structure. The supporting structure may be designed for the following load cases:

- (1) the loads due to the operation of the single heaviest crane should be combined with the full wind load appropriate to the height of the structure.
- (2) the loads due to the worst combination of crane loads should be combined with 60 per cent of the wind load appropriate to the height of the structure.

5. DESIGN AND DETAILS OF CONSTRUCTION

5.1 GENERAL

5.1.1 STEEL FRAMEWORK

Any part of a structure should be capable of sustaining the most adverse combination of static and dynamic forces which may reasonably be expected from dead, wind and imposed loads referred to in the Building (Construction) Regulations without the permissible stresses specified in this Code of Practice being exceeded.

Frames may be categorised as braced or unbraced depending on their mode of resistance to lateral load effects. If special structural elements such as shear walls, core walls, truss members etc., are used to resist the lateral loads then the frame is said to be *braced*. It is said to be *unbraced* if only the flexural rigidity of the members is relied upon to provide the lateral resistance.

For a bracing system to be effective the following relationship should be satisfied:

$$T_b/T_u > = 5$$

Where T_b is the stiffness of the braced structure, and

T_u is the stiffness of the structure with the bracing system removed.

If this condition is not fulfilled then the structure must be considered as unbraced.

5.1.2 VERTICAL LOAD—LATERAL DEFLECTION EFFECTS

Where a building is sensitive to the effects of lateral deflection the Engineer should take into account the additional actions induced by the lateral displacements of the points of application of the vertical loads. (P— Δ effects)

5.1.3 DESIGN OF FRAMEWORKS

Steel frameworks may be designed using the following methods:

(1) 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 purposes of design, be assumed to be pin-jointed.

This method involves the following assumptions:

- (a) beams are simply supported,
- (b) all connections of beams girders or trusses are proportioned to resist the shear forces applied at the appropriate eccentricity,

- (c) members in compression are subjected to loads applied at the appropriate eccentricities (refer 7.5 for stanchions), and effective lengths (refer 7.2),
- (d) members in tension are subjected to longitudinal loads applied over the net area of the section (refer to 8.2).

(2) 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 should be made to show that the stresses in any part of the structure are not in excess of those laid down in this Code of Practice.

Alternatively an allowance may be made for the inter-restraint of the connection between a beam and a column by a moment not exceeding 10 per cent of the free-moment applied to the beam, assuming this to be simply supported, provided:

- (a) the beams and columns are designed by the general rules for members of a simply supported frame.
- (b) the beams are designed for the maximum net moment with due allowance for any difference in the restraint moment at each end.
- (c) each column is designed to resist the algebraic sum of the restraint moments from the beams at the same level on each side of the column, in addition to moments due to eccentricity of connection.
- (d) the assumed end restraint moment need not however be taken as 10 per cent of the free moment for all beams, provided that the same value of the restraint moment is used in the design of the column and the beam at each connection.
- (e) the column is fully encased in concrete in accordance with 7.1.2 and the beam to column connection includes a top cleat.

(3) 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 should be carried out in accordance with accurate methods of elastic analysis and to the limiting stresses permitted in this Code of Practice.

5.1.4 EXPERIMENTAL BASIS

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

- (1) adequate strength to sustain a total load equal to twice the sum of the dead, imposed and wind loads, and
- (2) adequate stiffness to resist, without excessive deflection, a total load equal to the sum of the dead load and 1.5 times the imposed and wind loads and, in the case of beams, to satisfy 5.6.

5.1.5 CURVED MEMBERS

The design of curved or bent members should be given special consideration. Allowance should be made for any thinning of the bent part which may be caused by bending the member.

5.2 RESISTANCE TO LATERAL FORCES

Adequate provision should be made to resist the lateral forces that can occur during and after erection of a structure. Where lateral forces cause twisting in a structural frame, provision should be made to resist all the resulting increases in horizontal shear but all resulting decreases in horizontal shear should be neglected in the design.

Where high speed travelling cranes are supported by the structure or where a structure may be otherwise subject to vibration or sway then a bracing system should be provided to reduce the vibration or sway to a suitable minimum.

When considering the effect of the lateral forces, proper allowance should be made for the strength and stiffness of all structural components as follows:

- (1) where structural components such as walls, roofs, floors and other additional bracing structure are capable of transmitting all lateral forces to the substructure, it may be deemed that the structural steelwork is not loaded by such forces.

- (2) where these other structural components are strong enough to transmit only part of the lateral forces to the substructure, the lateral forces should be distributed through the structural system in accordance with the relative stiffnesses of the frame and other components, and the structural steelwork should be designed accordingly.
- (3) where resistance to lateral forces provided by other structural components is obviously low or not ascertainable, the structural steelwork should be designed to resist all the lateral forces and transmit them to the substructure.

5.3 MINIMUM THICKNESS OF METAL

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

- 5.3.1 steel used for external construction exposed to the weather or other corrosive influences should be not less than 8 mm thick; and in construction not so exposed, not less than 6 mm thick. These provisions do not apply to the webs of standard rolled steel joists and channels or packings.
- 5.3.2 sealed tubes or sealed box sections used for external construction exposed to the weather should have walls not less than 4 mm thick and for construction not so exposed should have walls not less than 3 mm thick.

5.4 STRESSES IN FRAMES DUE TO WIND FORCES

Unless otherwise stated, the allowable stresses given in this Code of Practice 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 is not less than that needed if the wind stresses were neglected. This provision does not apply to grillage beams (refer 7.11).

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 5.5.1 and p_t and p_{bt} in 5.5.2 should be increased by 25 per cent in satisfying the relationship to unity, provided that 5.5.1 and 5.5.2 shall also apply in respect of any combination of stresses arising from bending and axial loading not due to wind.

5.5 COMBINED STRESSES

5.5.1 BENDING AND AXIAL COMPRESSION

Members subject to both axial compression and bending should be so proportioned that the following requirements are satisfied

- (1) For the member as a whole and using the maximum value of f_{bc} :

$$\frac{f_c}{p_c} + \frac{C_m f_{bc}}{\left(1 - \frac{f_c}{0.6C_o}\right) p_{bc}} \leq 1.0$$

However where f_c/p_c is less than 0.15, the following expression may be used:

$$\frac{f_c}{p_c} + \frac{f_{bc}}{p_{bc}} \leq 1.0$$

The value of p_{bc} to be used in the above formulas should be the lesser of the values of the maximum permissible stresses, p_{bc} and p_b , given in 6.2.2 and 6.3.3 respectively for bending and about the appropriate axis.

- (2) At a support and using the value of f_{bc} at the support:

$$\frac{f_c}{0.6 Y_s} + \frac{f_{bc}}{p_{bc}} \leq 1.0$$

In cased struts where allowance is made for the load carried by the concrete in accordance with 7.1.2, the ratio f_c/p_{bc} in the above expressions should be replaced by the ratio of the calculated axial load on the strut to the allowable axial load determined from 7.1.2.

In the above expressions the following extra notations are used:

- (a) $C_o = \frac{\pi^2 E}{(L/r)^2}$

where L is the effective length in the plane of bending;

r is the corresponding radius of gyration.

(b) C_m —a coefficient whose value should be taken as follows:—

(i) For members in frames where sidesway is not prevented:

$$C_m = 0.85$$

(ii) For members in frames where sidesway is prevented and not subject to transverse loading between their supports in the plane of bending:

$$C_m = 0.6 - 0.4\beta$$

but not less than 0.4

where β is the ratio of the smaller to the larger moments at the ends of that portion of the unbraced member in the plane of bending under consideration;

β is positive when the member is bent in reverse curvature and negative when bent in single curvature.

(c) For members in frames where sidesway is prevented in the plane of loading and subjected to transverse loading between their supports, the value of C_m may be determined by rational analysis. In the absence of such an analysis the following values may be used

for members whose ends are restrained $C_m = 0.85$

for members whose ends are unrestrained $C_m = 1.00$

5.5.2 BENDING AND AXIAL TENSION

Members subject to both axial tension and bending stresses should be so proportioned that the quantity

$$\frac{f_t}{p_t} + \frac{f_{bt}}{p_{bt}} \leq 1 \text{ is satisfied,}$$

Where f_t is the calculated axial tensile stress,

p_t is the allowable axial tensile stress,

f_{bt} is the resultant tensile stress due to bending about both principle axes;

p_{bt} is the appropriate allowable tensile stress in bending.

5.5.3 BENDING AND SHEAR

The equivalent stress f_e due to bending and shear should not exceed the value given by:

$$f_e = Y_s/1.1$$

Where Y_s is the specified yield stress.

The equivalent stress f_e is obtained from the following formula:

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

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

5.5.4 COMBINED BEARING, BENDING AND SHEAR

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, should not exceed the values of p_e given in Table 1.

$$f_e = \sqrt{(f_{bt}^2 + f_{br}^2 + f_{bt} f_{br} + 3 f_q^2)}$$

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

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

Table 1. Allowable equivalent stress, p_e

Steel Grade	Material Thickness	p_e
250	Up to and including 40 mm	$Y_s/1.1$
	over 40 mm	$Y_s/1.19$
350	all	$Y_s/1.10$
450	up to and including 40 mm	$Y_s/1.16$
	over 40 mm	$Y_s/1.25$

Note: The increase permitted by 4.2 and 5.1 do not apply to these values

5.6 DEFLECTION OF BEAMS

Under the most adverse loading conditions, the deflections of neither a structure as a whole, nor any of its parts, should be such as will impair the strength or serviceability of the structure or part, or lead to damage of other building components, or be unsightly.

Note: Guidance on maximum permissible deflections is given in Appendix B.

5.7 OVERHANG OF WALLS

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 should 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.

5.8 SECTIONAL AREAS

5.8.1 The gross sectional area should be taken as the area of the cross section as calculated from the specified size.

The net sectional area should be taken as the gross sectional area less deductions for bolt holes and open holes, or other deductions specified in this Code of Practice.

In making deductions for bolt holes the diameter of the hole should be assumed to be 2 mm in excess of the nominal diameter of the bolt unless otherwise specified. For countersunk bolts the appropriate addition should be made to the diameter of the hole.

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

- For
- (1) all axially loaded tension members;
 - (2) plate girders with d_1/t greater than $1440/\sqrt{Y_s}$

Where t is the thickness of the web,

d_1 is the depth, defined as the clear distance between flange angles or, where there are no flange angles, the clear distance between flanges, ignoring fillets. Where tongue plates having a thickness of not less than twice the thickness of the web plate are used, the depth d_1 should be taken as the depth of the girder between the flanges less the sum of the depths of the tongue plates;

Y_s is the specified yield stress.

the area to be deducted when the holes are staggered should 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 $s^2t_1/4G$ for each gauge space in the chain of holes.

Where s is 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,

t_1 is the thickness of the holed material;

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

For sections such as angles with holes in both legs the gauge should 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 bolts joining the parts between such chains of holes should be taken into account in determining the strength of the member.

5.8.2 The net sectional area of a bolt or screwed tension rod with ISO metric threads should be taken as the tensile stress area of the threaded part or the cross-sectional area of the unthreaded part, whichever is the lesser.

5.9 SEPARATORS AND DIAPHRAGMS

Where two or more rolled steel joists or channels are used side by side to form a girder, they should be connected together at intervals of not more than 1.5 m 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 300 mm 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 another or are required to be distributed between beams, diaphragms and their fastenings designed with sufficient stiffness to distribute the load should 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, should be used.

6. DESIGN OF MEMBERS SUBJECT TO BENDING

6.1 GENERAL

The bending stress in the extreme fibres of a member should not exceed any of the appropriate maximum permissible stresses given in 6.2, 6.3, 6.4 and 6.5 for bending, in 6.6 for bearing and 6.7 for shear, except that 6.3 should not apply in the following cases:

- (1) a beam bent about its axis of minimum strength,
- (2) an I-beam or channel with equal flanges and with a value of L/r_y less than $940/\sqrt{Y_s}$;
- (3) a rectangular hollow section beam with B/D and t/T both greater than 0.25.

where B is the overall width of section,

D is the overall depth of section,

t is the web thickness;

T is the flange thickness.

6.2 MAXIMUM PERMISSIBLE STRESSES

The bending stress in the extreme fibres, calculated on the effective section, should not exceed:

6.2.1 FOR PARTS IN TENSION

the maximum permissible stress p_{bt} determined by:

$$p_{bt} = 0.66 Y_s$$

for material thickness up to 40 mm, or

$$p_{bt} = 0.60 Y_s$$

for material thickness greater than 40 mm.

6.2.2 FOR PARTS IN COMPRESSION

the maximum permissible compression stress in bending p_{bc} , which should be the lesser of the value determined by the following formulae as appropriate, but not greater than $0.6 Y_s$.

$$p_{bc} = \left[0.72 - \frac{0.12}{256} \frac{b_1}{T_1} \sqrt{Y_s} \right] Y_s$$

$$p_{bc} = \left[0.72 - \frac{0.12}{F_a} \frac{b_2}{T_1} \sqrt{Y_s} \right] Y_s$$