General Notes on Design

1

1·1. Introduction

The design of a steel structure is governed by the layout of the structure. The layout depends on the different functions to be performed by the structure. The planning and proportioning of a structure to satisfy functional, economical and aesthetic requirements is known as structural design.

For most economical design, it becomes necessary to make preliminary designs and cost estimates for various structural schemes, which in turn are influenced by the availability of materials and labour.

1·2. Factors Governing Layout

The following are some of the factors which will govern the layout of various structures :

Office Buildings

(*a*) Satisfactory natural and artificial lighting.

(*b*) Unobstructed areas required for various users.

(*c*) Adequate provision of staircases and lifts.

(*d*) Circulation space.

(*e*) Space required for services like heating, air-conditioning etc.

(*f*) Provision of toilets and other conveniences.

Industrial Buildings

(*a*) Transport and hoisting services.

(*b*) Protection from the weather.

(*c*) Planning out working areas around the machinery.

(*d*) Layout of machinery.

(*e*) Satisfactory natural and artificial lighting.

(*f*) Satisfactory natural and artificial ventilation.

(*g*) Adequate facilities and conveniences of the employees.

(*h*) Facilities for storage and movement of raw materials as well as finished products.

(*i*) Protection from dangerous operations and successful removal of obnoxious gases to satisfy requirements of environmental protection agency.

(*j*) Shock absorption for vibrating equipments.

Bridges

(*a*) Location should be convenient for the traffic.

(*b*) Adequate capacity for future use.

(*c*) Provision for drainage.

(*d*) Provision of crash barrier and median.

(*e*) If it crosses a navigable river, either the bridge in some portion should be sufficiently high to allow the water borne traffic unobstructed, or movable span should be provided.

(*f*) If it crosses railway or road, proper clearance must be provided.

(*g*) Provision for carrying water pipes, electric cables etc. should be made.

(*h*) Pedestrian walkway if needed.

1·3. Structural Design

Some of the factors which will govern the design are :

(*a*) Adequate strength, rigidity and flexibility.

(*b*) Should not interfere with the functions for which the structure is intended.

(*c*) Be economical in initial cost and maintenance.

(*d*) Should have durability for the period of service for which it is designed.

(*e*) Be readily adaptable to future extension.

(*f*) Should be easy for inspection of damage.

1·4. Steps in Design

The designing will consist of :

(*a*) Working out the loads which the structure has to carry.

(*b*) Arrangement and choice of various structural elements like beams, columns, etc. to support the structure.

(*c*) Computation of stresses, shears, etc. in the members of the frame.

(*d*) Providing adequate economic sections to resist the stresses in the members.

1·5. Load Analysis

Structures have to carry different types of loading. Estimation of the loads to which the structure is likely to be subjected is one of the most difficult problems in design. The designer has to assess the loads which structure has to carry throughout the life span. It is also necessary to consider the combinations of loads for worst effect on structures.

The loads which can come on the structure can be classified as :

(*i*) Dead loads
(*ii*) Live loads (Imposed)
(*iii*) Impact loads
(*iv*) Wind loads
(*v*) Seismic force
(*vi*) Snow loading
(*vii*) Earth pressure
(*viii*) Loads due to water currents
(*ix*) Centrifugal forces
(*x*) Upthrust or buoyancy
(*xi*) Temperature stresses
(*xii*) Erection stresses
(*xiii*) Secondary stresses
(*xiv*) Deformation stresses
(*xv*) Blast loading.
(*xvi*) Longitudinal forces due to breaking and accelerating

1·5·1. Dead Load

The weight of all the permanent fixtures in a structure including self-weight is called the dead load. The dead weight will consist of weight of all walls, partition walls, floors and roofs, and all other permanent constructions attached to it. The materials going into the building will be bricks, concrete, stone, glass, timber, steel, etc. The unit weights of these are given in Table 1·1.

Table 1·1. Unit Weight of Materials

Material	Weight kN/cu metre
1. Granite stone	27
2. Sandstone-ashlar	24
3. Granite stone setts	26
4. Basalt stone setts	27
5. Ballast loose of granite 2·5 to 7·5 cm	14
6. Ballast loose of basalt 2·5 to 7·5 cm	16
7. Common bricks	16 to 19
8. Bricks engineering	21 to 23
9. Bricks pressed	17·5 to 18·5
10. Brick work (pressed) in cement mortar	22
11. Brick work (common) in cement mortar	19
12. Brick work (common) in lime mortar	18
13. Ordinary cement	14·4
14. Rapid hardening cement	12·8
15. Concrete asphalt	22
16. Concrete breeze	14
17. Concrete (cement plain)	22
18. Concrete (cement plain with plums)	23
19. Concrete (cement reinforced)	
1% steel	23·1 to 24·7
2% steel	23·7 to 25·3
5% steel	25·6 to 27·2
20. Prestressed concrete	25
21. Concrete (lime-brick aggregate)	19
22. Concrete (lime-stone aggregate)	21
23. Earth compacted	18
24. Gravel	18
25. Macadam (binder premix)	22
26. Macadam rolled	26
27. Sand loose	14
28. Sand (wet compressed)	19
29. Coursed rubble stone masonry in cement	26
30. Stone masonry in lime mortar	24
31. Water	10
32. Timber	08
33. Cast iron	72
34. Wrought iron	77
35. Steel rolled or cast	78

Loads of partitions should be calculated on the basis of construction details and position of partitions. In case the position of the partitions is not known and details of partitions are not known, a uniformly distributed load per sq. metre of $\frac{1}{3}$rd partition load per metre run should be taken. In case of office floors a load 1 kN per square metre of floor area should be taken.

1·5·2. Imposed live loads. Live loads on floors and roofs as recommended by I.S. are given in Tables 1·2 and 1·3.

Table 1·2. Live Load on Floors

Loading class number	*Type of floors*	*Minimum live load in kN/m²*	*Alternate minimum live load*
1—200	Floors in dwelling houses, tenements, hospital wards, bed rooms and private sitting rooms in hostels and dormitories.	2	
2—250	Office floors other than entrance halls and floors of light workrooms.	2·5 to 4	
3—300	Floors of banking halls, office entrance halls and reading rooms.	3	
4—400	Shop floors used for the display and sale of merchandise, floors of work-rooms generally, floors of class-rooms in schools, floors of assembly with fixed seating, restaurants and circulation space in machinery halls, power stations, etc. were not occupied by plant or equivalent.	4	Subject to a minimum total load of 2·5 times the value given for minimum live load for any given slab panel and 6 times the value for minimum live load for any given beam.
5—500	Floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for light weight loads, office floors for storage and filing purposes, floors of places of assembly without fixed seating, public rooms in hotels, dance halls, waiting halls etc.	5	This total load shall be assumed uniformly distributed on the entire area of the slab panel or the entire length of the beam in case of buildings 1, 2, 3, 4 and 5.
6—750	Floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for medium-weight loads.		
7—1000	Floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for heavy-weight loads, floors of book stores and libraries, roofs and pavement over basements projecting under the public footpath.	7·5	
8—Garage light	Floors used for garage for vehicles not exceeding 2·5 tonnes gross weight :	10	
	1. Slabs	4	The worst combi-nation of actual wheel loads, whichever is greater.
	2. Beams	2·5	

Table contd...

Table contd...

Loading class number	*Type of floors*	*Minimum live load in kN/m²*	*Alternate minimum live load*
9—Garage heavy	Floors used for garage for vehicles not exceeding 4 tonnes gross weight.	7·5	Subject to a minimum or one and a half time maximum wheel load but not, less than 900 kg considered to be distributed over 75 cm squre.
10—Stairs	Stairs, landings and cooridors for class 200 loading but not liable to over-crowding.	3	Subject to a minimum of 130 kg connected load at the supported end of each step for stairs constructed out of structurally indepen-dent cantilever steps.
	Stairs, loadings and corridors for class 200 loading but liable to over crowding, and for all other classes.	5	
11—Balcony	Balconies not liable to over-crowding.		
	For class 200 loading.	3	
	For all other classes.	5	
	Balconies liable to over-crowding.	5	

In case of large floor areas, it is likely that the same intensity of loading may not occur simultaneously on whole area. Similarly in case of multi-storey buildings it will be very much oversafe to assume that the same uniform load will occur simultaneously on all the floors. Taking this in account, the reductions in floor live loads for design of columns as suggested in IS : 875 are given in Table 1·4. This reduction is applied to walls, piers and foundations.

Table 1·3. Live Loads on Roofs

Type of roof	*Live load measured on plan*	*Minimum live load measured on plan*
1. Flat, sloping or curved roof with slopes upto and including 10°		
(*a*) Access provided	1·5 kN/m²	3·75 kN uniformly distributed over any span of one metre width of the roof slab and 9 kN uniformly distributed over the span in the case of all beams.
(*b*) Access not provided except for maintenance.	0·75 kN/m²	1·9 kN uniformly distributed over any span of one metre width of the roof slab and 4·50 kN uniformly distributed over the span in the case of beams.

Table contd...

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Type of roof	*Live load measured on plan*	*Minimum live load measured on plan*
2. Sloping roof with slope greater than 10°	(*a*) For roof membrane, sheets or purlins—0·75 kN/m^2 less than 0·02 kN/m^2 for every degree in slope over 10°. (*b*) For members sup-porting the roof membrane and roof purlins, such as trusses, beams, girders, etc.—2/3 of loads as in (*a*) (*c*) Loads in (*a*) and (*b*) do not include loads due to snow, rain, dust collection etc. and the effects of such loads shall be appropriately considered.	Subject to a minimum of 0·4 kN/m^2
3. Curved roofs with slope at springing greater than 10°	(0·75—3·45 γ^2) kN/m^2, where $\gamma = h/l$ h = height of the highest point of structure measured from its springing, and l = chord width of the roof if singly curved and shorter of the two sides, if doubly curved.	Subject to a minimum of 0·4 kN/m^2.

Table 1·4. Reduction in Floor Live Loads

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

1·5·3. Impact Load

The instantaneous effect of a suddenly applied load is known as impact. The deformations caused due to impact are much larger than due to a gradually applied load. The impact effect is expressed as a percentage of the static load. The equation for impact is of the form $I = \dfrac{C_1}{L + C_2}$ where I is the impact factor, L is the span and C_1 and C_2 are constants. Table 1·5 gives the values of impact factors.

Table 1·5. Impact factors

Moving loads	Impact factor
1. For frames supporting lifts and cranes	100% of live load
2. For foundations, footings and piers supporting lifts and hoisting apparatus	40% of live load
3. For light machinery, shaft or motor units	20% of live load
4. For reciprocating machinery or power units	50% of live load
5. Vertical loads of electric overhead travelling cranes	25% of wheel load
6. Vertical loads of hand operated cranes	10% of wheel load
7. Horizontal forces due to the rails at rail level	
(*a*) Electric overhead travelling crane	10% weight of crab plus weight lifted on the crane.
(*b*) Hand operated cranes	5% of weight of crab plus weight lifted on the crane

1·5·4. Wind Load

Wind exerts pressure on the obstruction in its path and varies as $\frac{1}{2}\rho V^2$, where ρ is the density of air and V is the velocity of wind. The variation depends on the shape of obstruction. The wind pressure can be presented by equation $p = K (\frac{1}{2}\rho V^2)$, where K is a constant depending on the shape and size of obstruction and direction of wind. The density of air at sea level is taken as 0·006, therefore $p = 0{\cdot}003\ KV^2$.

Table 1·6. Live Load for Power House

Sl. No. (1)	*Area of Location* (2)	*Live Load* (3)
	PART A	
	(The indicated loads include equipment load)	
(*i*)	Roofs : Accessible	1500
	Inaccessible	750
(*ii*)	Stairways	5000
(*iii*)	Office and corridors	5000
(*iv*)	Reception rooms	5000
(*v*)	Circuit breaker rooms	20000
(*vi*)	Control room	10000
(*vii*)	Cable spreading room	10000
(*viii*)	Equipment and storage rooms	10000
(*ix*)	Maintenance shop	15000
(*x*)	Fan room (air-conditioning, heating and ventilating equipment)	5000
(*xi*)	Auxiliary electric equipment room	10000

Table contd...

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Sl. No. (1)	Area of Location (2)	Live Load (3)
(*xii*)	Steel grating/chequered plate	5000
(*xiii*)	Tool room	10000
(*xiv*)	Galleries with light or no equipment, namely, carbon dioxide, drainage (no pump), heat exchanger, pipe, dewatering (no pump), ventilating, battery rooms, motor generator room, operating floors (other than generator floor and telephone room)	10000
(*xv*)	Water—treatment room	750
	PART B	
(*i*)	**Erection floor**	**50000**
(*ii*)	Generator floor	10000
(*iii*)	Turbine floor	15000
(*iv*)	Pump rooms and oil purification rooms	10000
(*v*)	Transformer beck	10000
(*vi*)	Gantry deck (outdoor power house), intake deck (general), power house access and draft tube deck	10000
(*vii*)	Air compressor room, penstock and valve floor, generator-protective equipment gallery and switch gear room	10C00

Notes : 1. If the power house is located in snow-bound areas, suitable snow load should be taken into account.

2. The above loading is for preliminary design only. The final design should be checked for the actual equipment load.

1·5·5. Seismic Force

The earthquake shock causes vibrations in a structure. The response of a structure depends on its location with respect to direction of wave motion, the distance from epicentre and natural period of vibration of structure. The vibrations in the horizontal direction are most important. The horizontal acceleration is taken 8 to 12 per cent of the gravitation force. The general equation is $F = CW$, where F is the shear force at base, C is a constant and W is the total weight of the building above the base. This total lateral force F is distributed over the height of the building so that the force P is given by $P = FC_1$, where

$C_1 = \dfrac{W_h h^2}{\Sigma wh^2}$ where W_h is the weight of all floors above a level h from base, w is the weight of floor at h level.

It should be noted that for less important and small structures design is not done as given in code but certain constructional details such as diagonal bracing in vertical panels of framed structures, strengthening of openings in walls, jambs, corners of returns of walls, and provision of continuous **band** at lintel level, are provided.

For important structures located in highly seismic zones and very tall buildings, dynamic analysis is attempted.

IS : 4326—1977 has suggested salient features of earthquake resistant construction as given below :

(*i*) Since earthquake force is proportional to mass of structure, the building shall be as light as possible.

(*ii*) As far as possible, the parts of the building should be tied together so that whole building should act as one unit.

(*iii*) Building should have a symmetrical rectangular shape in plan both for mass and rigidity and the centres of mass and rigidity should coincide to avoid torsional forces.

(*iv*) There should be no projection as far as possible.

(*v*) There should be proper connection between non-structural parts to structural framing to avoid any damage to the non-structural elements due to deformations of structural elements.

1·5·6. Snow Load

Structures should be designed for snow load, where snow is likely to occur. Snow loads will depend on the slope of roof. In case of slopes of greater than 50°, snow load is not taken. In absence of any information snow load may be taken as 0·25 kN/m^2 per centimetre of depth of snow.

1·5·7. Earth Pressure

Structures like counterforts, abutments, gravity walls which have to support earth on one side are subjected to earth pressure.

Piers and abutments for bridges over rivers are subjected to pressure due to water currents. Structures which are built on soils having high underground water quite high, are subjected to upthrust or buoyancy.

Braking Loads. When moving objects are braked or accelerated, they cause longitudinal forces in structures on which they move, like wheels of crane moving on crane girder or vehicles moving on bridges.

Temperature Loads. In case, structures subjected to temperature variation are restrained they will be subjected to normal loading as normal expansion or contraction is stopped. The co-efficient of expansion for steel may be taken as $1{\cdot}2 \times 10^{-5}$ °C per unit length.

Erection Loads. Erection loads are caused due to storing of construction materials on the structure during erection. The loads are of temporary nature and, therefore, usually temporary strengthening measures are taken. If proper arrangements are not made, there is likelihood of structure falling in case of large construction materials being stored on it.

Secondary Loads. It is difficult to provide ideal end conditions for which the structure is analysed. For example in case of trusses, joints are assumed to be pin joints. As riveting or welding will provide fixity in joints, the stresses caused due to this are called secondary stresses.

Vibration Loads. These loads are caused by movement in heavy machinery like turbines and pumps.

Blast Loads. The burst of a bomb generates strong pressure waves resulting in increased pressure on structure known as blast loading. This effect is dynamic in nature. For purposes of design equivalent static load may be taken. Seismic forces also produce a dynamic load on structure which produces dynamic response. Pseudo static analysis is done for these structures.

1·6. Minimum Thickness

Where the steel is directly exposed to weather and is fully accessible for cleaning and repainting, the thickness shall not be less than 6 mm, and where the steel is directly exposed to weather and is not accessible for cleaning and repainting, the thickness shall not be less than 8 mm. These restrictions do not apply to rolled I-sections and channel sections.

Where the steel is not directly exposed to weather the thickness for primary members shall not be less than 6 mm and for secondary members the thickness shall not be less than 4·5 mm.

1·7. S.I. Units

1 kgf = 9·81 N (Newton)

Newton is defined as a force to produce acceleration of 1 metre/sec^2 in a mass of 1 kg.

Pascal (Pa) is a unit of stress and is equal to 1 Newton per sq. metre

$$1 \text{ N/mm}^2 = 10^6 \text{ Pascals} = \text{MPa (Mega Pascal)}$$

$$1 \text{ N/mm}^2 = 10{\cdot}19 \text{ kgf/cm}^2$$

$$1 \text{ kgf/cm}^2 = 0{\cdot}0981 \text{ MPa}$$

For convenience 1 kgf may be taken equal to 10 Newtons, *i.e.* 0·01 kN.

1·8. Plans and Drawings

(1) Plans, drawings and stress sheets shall be prepared according to latest Indian Standard specifications.

(2) *Plans*. The plans (design drawings) shall show the complete design with sizes, sections, and the relative locations of the various members. Floor levels, column centres, and offsets shall be dimensioned. Plans shall be drawn to a scale large enough to convey the information adequately. Plans shall indicate the type of construction to be employed; and shall be supplemented by data on the assumed loads, shears, moments and axial forces to be resisted by all members and their connections. Any special precaution to be taken in the erection of structure from the design consideration, shall also be indicated in the drawing.

(3) *Shop drawings*. Shop drawings, giving complete information necessary for the fabrication of the components of the structure including the location, type, size, length and detail of all welds, shall be prepared in advance of the actual fabrication. They shall clearly distinguish between shop and field rivets, bolts and welds. For additional information to be included on drawings for designs, based on the use of welding, reference shall be made to appropriate Indian Standards. Shop drawings shall be made in conformity with IS : 696-1972 and IS : 962-1967. A marking diagram allotting distinct identification marks to each separate part of steel work shall be prepared. The diagram shall be sufficient to ensure convenient assembly and erection at site.

(4) Symbols for welding used on plans and shop drawings shall be according to IS : 813-1961.

1·9. Design Considerations

(1) *General*. All parts of the steel framework of the structure shall be capable of sustaining the most adverse combination of the dead loads, prescribed imposed loads, wind loads, earthquake loads where applicable, and any other forces or loads to which the building may reasonably be subjected without exceeding the permissible stresses specified in this standard.

(2) *Load Combinations* 10000

Load combinations for design purposes shall be the one that produces maximum forces and effects and consequently maximum stresses from the following combinations of loads : 10000

(*a*) Dead load + imposed loads,

(*b*) Dead load + imposed loads + wind or earthquake loads, and

(*c*) Dead load + wind or earthquake loads.

Note. In case of structures bearing crane loads, imposed loads shall include the crane effect as given below in (5).

(3) Wind load and earthquake loads shall be assumed not to act simultaneously. The effect of both the forces shall be given separately.

(4) The effect of cranes to be considered under imposed loads shall include the vertical loads, eccentricity effects induced by the vertical loads, impact factors, lateral (surge), and the longitudinal horizontal thrusts acting across and along the crane rail.

(5) The crane loads to be considered shall be as indicated by the customer. In the absence of any specific indications the load combination shall be as follows :

(*a*) Vertical loads with full impact from one loaded crane or two cranes in case of tandem operation together with vertical loads, without impact, from as many loaded cranes as may be positioned for maximum effect, alongwith maximum horizontal thrust (surge) from one crane only or two cranes in case of tandem operation;

(*b*) For multibay multicrane gantries—loads as specified in (*a*) above, subject to consideration of cranes in maximum of any two bays of the building cross section;

(*c*) The longitudinal thrust on a crane track rail shall be considered for a maximum of two loaded cranes on the track; and

(*d*) Lateral thrust (surge) and the longitudinal thrust acting respectively across and along the crane rail shall not be assumed to act simultaneously. The effect of both the forces shall, however, be investigated separately.

(6) While investigating the effect of earthquake forces the resulting effect from dead loads of all cranes, parked in each bay positioned for maximum effect, shall be considered.

(7) The crane runway girders supporting bumpers shall be checked for bumper impact loads.

(8) Stresses developed due to secondary effects such as handling, erection, temperature effects, settlement of foundations shall be appropriately added to the stresses calculated from the combination of loads stated in (2). The total stresses thus cal-culated shall be within the permissible limits as specified in Art. 1·19.

1·10. Methods of Design

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

(*a*) Simple design, (*b*) Semi-rigid design, and (*c*) Fully rigid design.

1·11. Simple Design

This method applies to structures in which the end connect-ions between members are such that they will not develop restraining moments adversely affecting the members and the structure as a whole and as a consequence the structure may, for the purpose of design, be assumed to be pin-jointed.

The method of simple design involves the following assumpt-ions :

(*a*) Beams are simply supported;

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

(*c*) Members in compression are subjected to forces applied at the appropriate eccentricities with the effective length; and

(*d*) Members in tension are subjected to longitudinal forces applied over the net area of the section, as specified under Art. 1·16·(6).

1·12. 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 accounts for the rigidity of the connections and the movement 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 the code. Stress investigations may also be done on the finished structure for assurance that the actual stresses under specific design loads are not in excess of those laid down in the standard.

1·13. Fully Rigid Design

This method as compared to the methods of simple and semi-rigid designs gives the greatest rigidity and economy in the weight of steel used when applied in appropriate cases. The end connections of members of the frame shall have sufficient rigidity to hold the original angles between such members and the members they connect virtually unchanged. Unless otherwise specified, the design shall be based on theoretical methods of elastic analysis and the calculated stresses shall conform to the relevant provisions of this standard. Alternatively, it shall be based on the principles of plastic design as given in Section 9 of the code.

1·14. Experimentally Based Design

Where structure is of non-conventional or complex nature, the design may be based on full scale or model tests subject to the following conditions :

(*a*) A full scale test of prototype structure may be done. The prototype shall be accurately measured before testing to determine the dimensional tolerance in all relevant parts of the structure; the tolerances then specified on the drawing shall be such that all successive structures shall be in practical conformity with the prototype. Where the design is based on failure loads, a load factor of not less than 2·0 on the loads or load combinations given in 1·9(2) shall be used. Loading devices shall be previously calibrated and care shall be exercised to ensure that no artificial restraints are applied to the prototype by the loading systems. The distribution and duration of forces applied in the test shall be representative of those to which the structure is deemed to be subjected.

(*b*) In the case where design is based on the testing of a small scale model structure, the model shall be constructed with due regard for the principles of dimensional similarity. The thrusts, moments and deformations under working loads shall be determined by physical measurements made when the loadings are applied to simulate the conditions assumed in the design of the actual structure.

1·15. Geometrical Properties

(1) *General* : The geometrical properties of the gross and the effective cross sections of a member or part thereof shall be calculated on the following basis :

(*a*) The properties of the gross cross section shall be calculated from the specified size of the member or part thereof.

(*b*) The properties of the effective cross section shall be calculated by deducting from the area of the gross cross section the following :

(*i*) The sectional area in excess of effective plate width, as given below in (2), and

(*ii*) The sectional areas of all holes in the section, except that for parts in compression (*see* Sec. 1·16).

(2) *Plate Thickness* : If the projection of a plate or flange beyond its connection to a web, or other line of support or the like, exceeds the relevant values given in (*a*), (*b*) and (*c*) below, the area of the excess flange shall be neglected when calculating the effective geometrical properties of the section.

(*a*) Flanges and plates in compres sion with unstiffened edges $\dfrac{256\,T_1}{\sqrt{f_y}}$ subject to a maximum of 16 T_1

(*b*) Flanges and plates in compression with face stiffened edges	20 T_1 to the innermost face of the stiffening
(*c*) Flanges and plates in tension	20 T_1

Note 1. Stiffened flanges shall include flanges composed of channels or I-sections or of plates with continuously stiffened edges.

Note 2. 'T_1' denotes the thickness of the flange of a section or of a plate in compression, or the aggregate thickness of plates, if connected together in accordance with the provisions of Section 8, as appropriate.

f_y is material yield stress in MPa.

Note 3. The width of the outstand of members referred above shall be taken as shown in Table 1·7 :

Table 1·7. Width of Outstand

Type	*Width of Outstand*
Plates	Distance from the free edge to the first row of rivets or welds
Angle, channels, Z-sections and stems of tee sections	Nominal width
Flange of beam and tee sections	Half the nominal width

(3) Where a plate is connected to other parts of a built up member along lines generally parallel to the longitudinal axis of the member, the width between any two adjacent lines of connections or supports shall not exceed the following :

(*a*) For plates in uniform compression : $\frac{1440\,T_1}{\sqrt{f_y}}$, subject to a maximum of 90 T_1

However, where the width exceeds : $\frac{560\,T_1}{\sqrt{f_y}}$, subject to a maximum of 35τ_1, for welded plates which are not stress relieved, or

$\frac{800\,\tau_1}{\sqrt{f_y}}$, subject to a maximum of 50 τ_1, for other plates,the excess width shall be assumed to be located centrally and its sectional area shall be neglected when calculating the effective geometrical properties of the section.

(*b*) For plates in uniform tension—100 T_1. However where the width exceeds 60 t (web thickness), the excess width shall be assumed to be located centrally and its sectional area shall be neglected when calculating the geometrical properties of the section.

In this rule, τ_1 shall be taken to be the thickness of the plate, irrespective of whether the plate is a flange or a web of the member.

(4) The provisions contained in (2) and (3) shall not be applicable to box girders (where width/depth is greater than 0·2). In such cases strength is not usually governed by lateral buckling. However, in such cases check should be exercised for local buckling and yield stress of material.

(5) For only the diaphragm of the box girder, all the provisions pertaining to size, thickness, spacing etc. as given in (2) and (3) for plate girders shall be applicable.

1·16. Holes

(1) *Diameter* : In calculating the area to be deducted for rivets, bolts or pins, the diameter of the hole shall be taken.

(2) In making deduction for rivets less than or equal to 25 mm in diameter, the diameter of the hole shall be assumed to be 1·5 mm in excess of the nominal diameter of the rivet unless specified otherwise. If the diameter of the rivet is greater than 25 mm, the diameter of the hole shall be assumed to be 2·0 mm in excess of the nominal diameter of the rivet unless specified otherwise.

(3) In making deduction for bolts, the diameter of the hole shall be assumed to be 1·5 mm in excess of the nominal diameter of the bolt, unless otherwise specified.

(4) For counter sunk rivets or bolts the appropriate addition shall be made to the diameter of the hole.

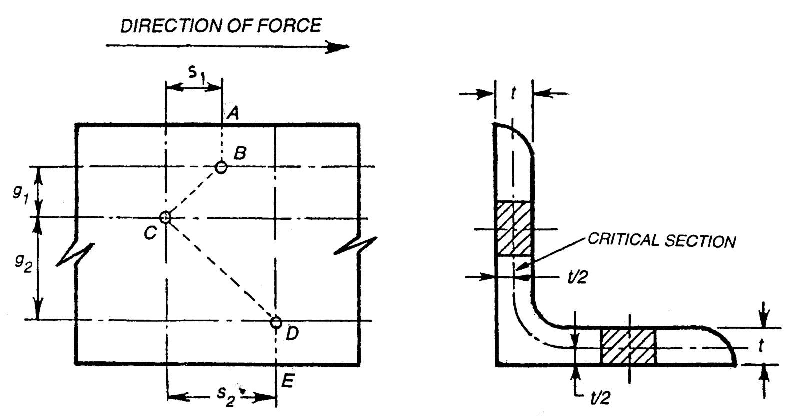
(5) *Deduction for Holes* : Except as required in (6) the areas to be deducted shall be the sum of the sectional area of the maximum number of holes in any cross section at right angles to the direction of stress in the member for :

(*a*) all axially loaded tension members,

(*b*) plate girders with *d/t* ratio exceeding the limits specified in chapter (8).

where, t = thickness of web, and

d = depth of the girder to be taken as the clear distance between flange angles or where there are no flange angles the clear distance between flanges ignoring fillets.



(*a*) Plates (*b*) Angles

Fig. 1·1. Staggered pitch, *s*, and gauge, *g*.

$$\text{DEDUCTION} = (\text{Sum of sectional areas of holes B, C and D}) - \left[\frac{s_1^2 t}{4g_1} + \frac{s_2^2 t}{4g_2}\right]$$

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 members 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.

(6) Where bolt or rivet holes are staggered, the area to be deducted shall be the sum of the sectional areas of all holes in a chain of lines extending progressively across the member, less $\frac{s^2 t}{4g}$ for each line extending between holes at other than right angles to the direction of stress, where, s, g and t are respectively the staggered pitch, gauge, and thickness associated with the line under consideration [*see* Fig. 1·1 (*a*)]. The chain of lines shall be chosen to produce the maximum such deduction. For non-planer sections, such as angles with holes in both legs, the gauge, g, shall be the distance along the centre of the thickness of the section between hole centres [*see* Fig. 1·1 (*b*)].

1·17. Maximum Slenderness Ratio

(1) The maximum slenderness ratio $\lambda \left(= \frac{l}{r} \right)$ of a beam, strut or tension member given in Table 1·8 shall not be exceeded. In this '*l*' is the effective length of the member (*see* Art. 10·2) and '*r*' is appropriate radius of gyration based on the effective section as defined in 1·18.

Table 1·8. Maximum slenderness ratios

Sl. No.		*Maximum Slenderness Ratio* λ
(1)	(2)	*(3)*
(*i*)	A member carrying compressive loads resulting frcm dead loads and imposed loads	180
(*ii*)	A tension member in which a reversal of direct stress due to loads other than wind or seismic forces occurs	180
(*iii*)	A member subjected to compression forces resulting from wind/earthquake forces provided the deformation of such member does not adversely affect the stress in any part of the structure	250
(*iv*)	Compression flange of a beam	300
(*v*)	A member normally acting as a tie in a roof truss or a bracing system but subject to possible reverse of stress resulting from the action of wind or earthquake forces	350
(*vi*)	Tension members (other than pretensioned members)	400

1·18. Corrosion Protection—Minimum Thickness of Metal

(1) *General*—Except where the provisions of subsequent clauses in this section require thicker elements of members, the minimum thickness of metal for any structural element shall be, as specified under (2) to (4).

(2) *Steelwork Directly Exposed to Weather*—Where the steel is directly exposed to weather and is fully accessible for cleaning and repainting, the thickness shall be not less than 6 mm and where the steel is directly exposed to weather and is not accessible for cleaning and repainting, the thickness shall be not less than 8 mm. These provisions do not apply to the webs of Indian Standard rolled steel joists and channels or to packings.

(3) *Steelwork not Directly Exposed to Weather*—The thickness of steel in main members

not directly exposed to weather shall be not less than 6 mm. The thickness of steel in secondary members not directly exposed to weather shall be not less than 4·5 mm.

(4) *Rolled Steel Beams and Channels*—The controlling thickness as specified under (2) and (3) for rolled beams and channels shall be taken as the mean thickness of flange, regardless of the web thickness.

(5) The requirements of thicknesses specified under (2) to (4) do not apply to special light structural work or to sealed box section or to steel work in which special provision against corrosion, such as use of special paints has been made or to steelwork exposed to highly corrosive industrial fumes or vapour or saline atmosphere. In such cases the minimum thickness of structural and secondary members shall be mutually settled between the customer and the designer.

1·19. Increase in Stresses

(1) *General*—Except as specified in (2) to (4), all parts of the structure shall be so proportioned that the working stresses shall not exceed the specified values.

(2) *Increase in Permissible Stresses in Members Proportioned for Occasional Loadings*

(3) *Wind or earthquake loads* :

(*a*) *Structural steel and steel castings*—When the effect of wind or earthquake load is taken into account, the permissible stresses specified may be exceeded by 33$\frac{1}{3}$ percent.

(*b*) *Rivets, bolts and tension rods*—When the effect of the wind or earthquake load is taken into account, the permissible stresses specified may be exceeded by 25 percent.

(4) *Erection loads* :

(*a*) *Secondary effects—without wind or earthquake loads*—For constructions where secondary effects are considered without wind or earthquake loads, the permissible stresses on the member or its connections as specified may be exceeded by 25 percent.

(*b*) *Secondary effects combined with wind or earthquake loads*—When secondary effects are considered together with wind or earthquake loads, the increase in the permissible stresses shall be as specified in (2).

(5) In no case shall a member or its connections have less carrying capacity than that needed if the wind or earthquake loads or secondary effects due to erection loads are neglected.

(6) *Increase in Permissible Stresses for Design of Gantry Girders and Their Supporting Structures*—While considering the simultaneous effects of vertical and horizontal surge loads of cranes for the combination given in Art. 1·9 (4) and 1·9 (5) the permissible stresses may be increased by 10 percent.

(7) Where the wind load is the main load acting on the structure, no increase in the permissible stresses is allowed.

1·20. Fluctuation of Stresses

(1) Members subjected to fluctuations of stresses are liable to suffer from fatigue caused by loads much lower than those which would be necessary to cause failure under a single application. The fatigue cracks occur primarily due to stress concentrations introduced by constructional details. Discontinuities such as bolt or rivet holes, welds and other local or general changes in geometrical form cause such stress concentrations from which fatigue cracks may initiate. These cracks may subsequently propagate through the connected or fabricated members.

All details shall, therefore, be designed to avoid, as far as possible, stress concentrations likely to result in excessive reduction of the fatigue strength of members or connections. Care shall be taken to avoid sudden change of shape of a member or part of a member, especially in regions of tensile stress or local secondary bending.

Except where specifically stated to the contrary, the permissible fatigue stresses for any particular detail are the same for all steels.

(2) When subjected to fluctuations of stresses the permissible stresses shall be the basic stress stipulated in IS : 1024-1979 for different f_{min}/f_{max} and for different number of stress cycles and classes of constructional details.

The following provisions shall also be considered while determining the permissible stress in members subjected to fluctuations of stress :

(*a*) While computing the value of f_{min}/f_{max} the effect of wind or earthquake temperature and secondary stresses shall be ignored.

(*b*) For plain steel in the as-rolled condition with no gas cut edges the constructional detail shall be considered as Class A of IS : 1024-1979.

(*c*) For members of steel with yield stress 280 MPa and over, and fabricated or connected with bolts or rivets the construction details shall be considered as Class C of IS : 1024-1979.

For members of steels with yield stress below 280 MPa, fabricated or connected with bolts or rivets the construction details shall be considered as Class D of IS : 1024-1979.

(*d*) The value of f_{max} shall not exceed the permissible tensile or compressive fatigue stress as determined from IS : 1024-1979. Where co-existent bending and shear stresses are present, f_{max} shall be taken as the principal stress at the point under consideration.

1·21. Resistance to Horizontal Forces

(1) In designing the steel framework of building, provisions shall be made by adequate moment connections or by a system of bracing to effectively transmit to the foundations all the horizontal forces, making due allowance for the stiffening effect of the walls and floors, where applicable.

(2) When the walls, or walls and floors and/or roof are capable of effectively transmitting all of the horizontal forces directly to the foundations, the structural framework may be designed without considering the effect of wind.

(3) Wind and earthquake forces are reversible and therefore call for rigidity in both longitudinal and transverse directions. To provide for torsional effects of wind and earthquake forces bracings in plan should be provided and integrally connected with the longitudinal and transverse bracings to impart adequate torsional resistance to the structure.

(4) In shed type buildings, adequate provisions shall be made for wind bracings to transfer the wind or earthquake loads from their points of action to the appropriate supporting members. Where the connections to the interior columns are so designed that the wind or earthquake loads are not transferred to the interior columns, the exterior columns shall be designed to resist the total wind or earthquake loads. Where the connections to the interior columns are so designed that the wind or earthquake effects are transferred to the interior columns also, both exterior and interior columns shall be designed on the assumption that the wind or earthquake load is divided among them in proportion to their relative stiffnesses. Columns also should be tested for proper anchorage to the trusses and other members to withstand the uplifting effect caused by excessive wind or earthquake pressure from below the roof.

(5) Earthquake forces are proportional to the mass of structural component and the imposed load. Therefore earthquake forces should be applied at the centre of gravity of all such components of loads and their transfer to the foundation should be ensured (*see* IS : 1893-1975).

(6) In buildings where high-speed travelling cranes are supported by the structure or where a building or structure is otherwise subjected to vibration or sway, triangulated bracing or especially rigid portal systems shall be provided to reduce the vibration or sway to a minimum.

(7) *Foundations*—The foundations of a building or other stucture shall be so designed as to ensure such rigidity and strength as have been allowed for in the design of the superstructure, including resistance to all forces.

(8) *Overhang of Walls*—Where a 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 solid floor slab in such a way as to prevent the beam deforming torsionally.

(9) *Notional Horizontal Loads*—To analyze a frame subjected to gravity loads, considering the sway stability of the frame, notional horizontal forces should be applied. The notional horizontal forces account for practical imperfections and should be taken at each level as being equal to 0·5 percent of factored dead load plus vertical imposed loads applied at that level. The notional load should not be applied along with other lateral loads such as wind and earthquake loads in the analysis.

The notional loads should be applied on the whole structure, in both orthogonal directions, in one direction at a time, at roof and all floor levels or their equivalent. The loads should be considered as acting simultaneously with factored gravity loads.

The notional loads should not be

(*a*) applied when considering overturning or overall stability;

(*b*) combined with other horizontal loads;

(*c*) combined with temperature effects; and

(*d*) taken to contribute net shear on the foundation.

The sway effect using notional loads under gantry load need not be considered if the ratio of height to lateral width of the building is less than unity.

1·22. Stability

(1) 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 and anchorage, shall be not less than the sum of 1·2 times the maximum overturning moment due to dead load and 1·4 times the maximum overturning moment due to imposed loads and wind or earthquake loads.

(2) In cases where dead load provides the restoring moment, only 0·9 times the dead load shall be considered. Restoring moment due to imposed loads shall be ignored.

(3) To ensure stability at all times, account shall be taken of probable variations in dead load during construction, rapair or other termporary measures. The effect on the load from the deflected or deformed shape of the structure or of individual elements of the lateral load resisting systems, may be considered as required.

Note 1. In complying with the requirements of 1, it is necessary to ascertain that the resulting pressures and shear forces to be communicated by the foundations to the supporting soil would not cause failure.

Note 2. All individual members of the structure which have been designed for their dead and imposed loads, wind or earthquake loads to the permissible stresses stipulated in this code shall be deemed to be adequately covered for this margin of stability.

1·23. Limiting Deflection

(1) *Limiting Vertical Deflection*

The deflection of a member shall be calculated without considering the impact factor or dynamic effect of the loads causing deflection.

The deflection of member shall not be such as to impair the strength or efficiency of the structure and lead to damage to finishings. Generally, the maximum deflection should not exceed the values given in Chapter 6, Table 6·8.

(2) *Limiting lateral Deflection*

At the caps of columns in single storey buildings, the lateral deflection due to lateral forces should not ordinarily exceed that given in Table 6·8. This limit may be exceeded in cases where greater deflection would not impair the strength and efficiency of the structure or lead to damage to finishing.

The horizontal deflection at column cap level of columns supporting crane runway girders in the building shall not exceed limits as may be specified in Table 6·8.

1·24. Expansion Joints

(1) In view of the large number of factors involved in deciding the location, spacing and nature of expansion joints, provisions of expansion joints should be left to the discretion of the designer.

(2) Structures in which marked changes in plan dimensions take place abruptly, they shall be provided with expansion joints at the section where such changes occur. Expansion joints shall be so provided that the necessary movement occurs with a minimum resistance at the joint. The structure adjacent to the joint should preferably be supported on separate columns but not necessarily on separate foundation.

(3) The details as to the length of a struture where expansion joints have to be provided may be determined after taking into consideration various factors such as temperature, exposure to weather and structural design, etc. For the purpose of general guidance the following provisions have been recommended :

(*a*) If one set of column longitudinal bracing is provided at the centre of the building or building section, the length of the building section may be restricted to 180 metres in case of covered buildings and 120 metres in case of open gantries (*see* Fig. 1·2).

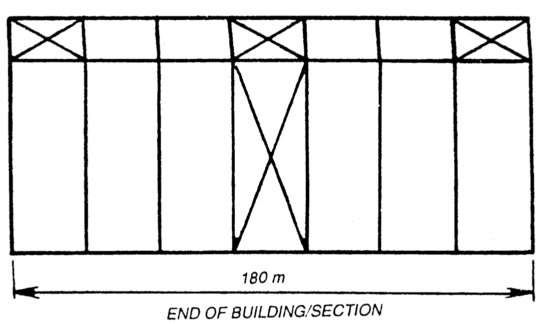


Fig. 1·2. Maximum length of building with one set of column bracing.

(*b*) If one set of column longitudinal bracing are provided near centre of the building/section, the maximum centre line distance between the two sets of bracing may be restricted to 48 metres for covered buildings (and 30 metres for open gantries) and the maximum distance between centre of the bracing to the nearest expansion joint/end of building or section may be restricted to 90 metres (60 metres in case of open gantries). The maximum length of the building section thus may be restricted to 228 metres for covered buildings and 150 metres for open gantries [(*see* Fig. 1·3)].

(*c*) The maximum width of the covered building section should preferably be restricted to 150 metres beyond which suitable provisions for the expansion joints may be made.

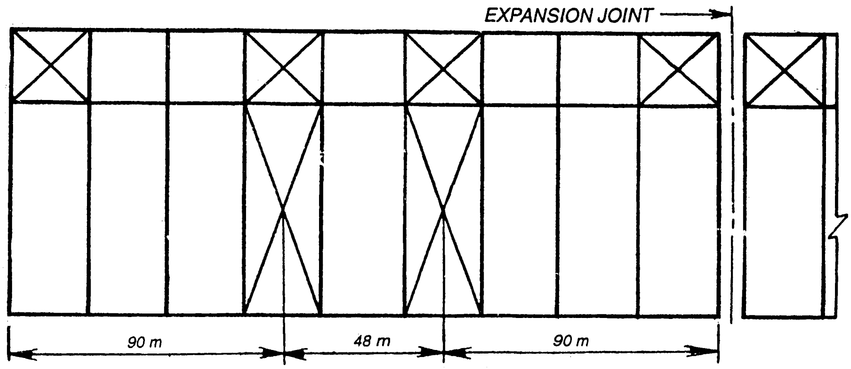


Fig. 1·3. Maximum length of buildings/section with two sets of column bracings.

Objective Type Questions

1·1. For floors in dwelling houses, tenements, hospital ward's, bed rooms and private sitting rooms in hostels and dormitories, the live load per square metre is taken as

(*a*) $2 kN/m^2$ (*b*) $3 kN/m^2$ (*c*) $4 kN/m^2$ (*d*) $5 kN/m^2$

(*e*) $7{\cdot}5 kN m^2$.

1·2. For floors of banking halls, office entrance halls and reading rooms, the live load per square metre is taken as

(*a*) $2 kN/m^2$ (*b*) $3 kN/m^2$ (*c*) $4 kN/m^2$ (*d*) $5 kN/m^2$

(*e*) $7{\cdot}5 kN/m^2$.

1·3. For shop floors and used for the display and sale of merchandise, floors of work-rooms, floors of class-rooms in schools, floors of assembly with fixed seating, restaurants and circulation space in machinery halls, power stations, where not occupied by plant or equivalent, the live load per square metre is taken as

(*a*) $2 kN/m/^2$ (*b*) $3 kN/m^2$ (*c*) $4 kN/m^2$ (*d*) $5 kN/m^2$

(*e*) $7{\cdot}5 kN/m^2$.

1·4. For floors of warehouses, factories and other buildings or part of buildings of similar category for light weight loads, office floors for storage and filing purposes, floors of places of assembly without fixed seating, public rooms in hotels, dance halls, waiting halls etc. the live load per square metre is taken as

(*a*) $2 kN/m/^2$ (*b*) $3 kN/m^2$ (*c*) $4 kN/m^2$ (*d*) $5 kN/m^2$

(*e*) $7{\cdot}5 kN/m^2$.

1·5. For floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for medium weight loads, live load per square metre is taken as

(*a*) $2 kN/m/^2$ (*b*) $3 kN/m^2$ (*c*) $4 kN/m^2$ (*d*) $5 kN/m^2$

(*e*) $7{\cdot}5 kN/m^2$.

1·6. For floors of warehouses, workshops, factories and other buildings or parts of buildings of similar category for heavy weight loads, floors of book stores and libraries, roofs and pavement light over basements projecting under the public footpath, live load per square metre is taken as

(*a*) $5 kN/m^2$ (*b*) $7{\cdot}5 kN/m^2$ (*c*) $10 kN/m^2$.

1·7. Impact factor for frames supporting lifts and cranes is taken as

(*a*) 100 per cent of live load (*b*) 50 per cent of live load

(*c*) 40 per cent of live load (*d*) 25 per cent of live load

(*e*) 20 per cent of live load (*f*) 10 per cent of live load.

1·8. Impact factor for foundations, footings and piers supporting lifts and hoisting apparatus is taken as

(*a*) 100 per cent of live load (*b*) 50 per cent of live load
(*c*) 40 per cent of live load (*d*) 25 per cent of live load
(*e*) 20 per cent of live load (*f*) 10 per cent of live load.

1·9. Impact factor for light machinery or shaft or motor unit is taken as

(*a*) 100 per cent of live load (*b*) 50 per cent of live load
(*c*) 40 per cent of live load (*d*) 25 per cent of live load
(*e*) 20 per cent of live load (*f*) 10 per cent of live load.

1·10. Impact factor for reciprocating machinery or power unit is taken as

(*a*) 100 per cent of live load (*b*) 50 per cent of live load
(*c*) 40 per cent of live load (*d*) 25 per cent of live load
(*e*) 20 per cent of live load (*f*) 10 per cent of live load.

1·11. Impact factor for vertical loads of electric overhead travelling cranes is taken as

(*a*) 100 per cent of live load (*b*) 50 per cent of live load
(*c*) 40 per cent of live load (*d*) 25 per cent of live load
(*e*) 20 per cent of live load (*f*) 10 per cent of live load.

1·12. Impact factor for vertical loads of hand operated cranes is taken as

(*a*) 100 per cent of live load (*b*) 50 per cent of live load
(*c*) 40 per cent of live load (*d*) 25 per cent of live load
(*e*) 20 per cent of live load (*f*) 10 per cent of live load.

1·13. Wind pressure '*p*' if 'ρ' in density of air at sea level and *V* is the velocity of wind, is taken as

(*a*) $0{\cdot}002\ \rho V^2$ (*b*) $0{\cdot}0025\ \rho V^2$ (*c*) $0{\cdot}003\ \rho V^2$.

1·14. Where the steel is directly exposed to weather and is fully accessible for cleaning and repairing, the thickness shall not be less than

(*a*) 8 mm (*b*) 6 mm (*c*) 4·5 mm.

1·15. Where the steel is directly exposed to weather and is not accessible for cleaning and repainting the thickness shall not be less than

(*a*) 8 mm (*b*) 6 mm (*c*) 4·5 mm.

1·16. Where the steel is not directly exposed to weather, the thickness for primary members shall not be less than

(*a*) 8 mm (*b*) 6 mm (*c*) 4·5 mm.

1·17. Where the steel is not directly exposed to weather, the thickness for secondary members shall not be less than

(*a*) 8 mm (*b*) 6 mm (*c*) 4·5 mm.

1·18. The coefficient of expansion for steel may be taken as

(*a*) $1{\cdot}0 \times 10^{-5}$ °C (*b*) $1{\cdot}2 \times 10^{-5}$ °C (*c*) $1{\cdot}5 \times 10^{-5}$ °C.

Answers

1·1. (*a*)	**1·2.** (*b*)	**1·3.** (*c*)	**1·4.** (*d*)	**1·5.** (*e*)	**1·6.** (*c*)
1·7. (*a*)	**1·8.** (*c*)	**1·9.** (*e*)	**1·10.** (*b*)	**1·11.** (*d*)	**1·12.** (*f*)
1·13. (*c*)	**1·14.** (*b*)	**1·15.** (*a*)	**1·16.** (*b*)	**1·17.** (*c*)	**1·18.** (*b*).