UPPSC-AE 2023

Uttar Pradesh
Public Service Commission

Combined State Engineering Services Examination

Assistant Engineer

Civil Engineering

Structural Steel Design

Well Illustrated **Theory** *with*
Solved Examples and **Practice Questions**

MADE EASY Publications

Structural Steel Design

Contents

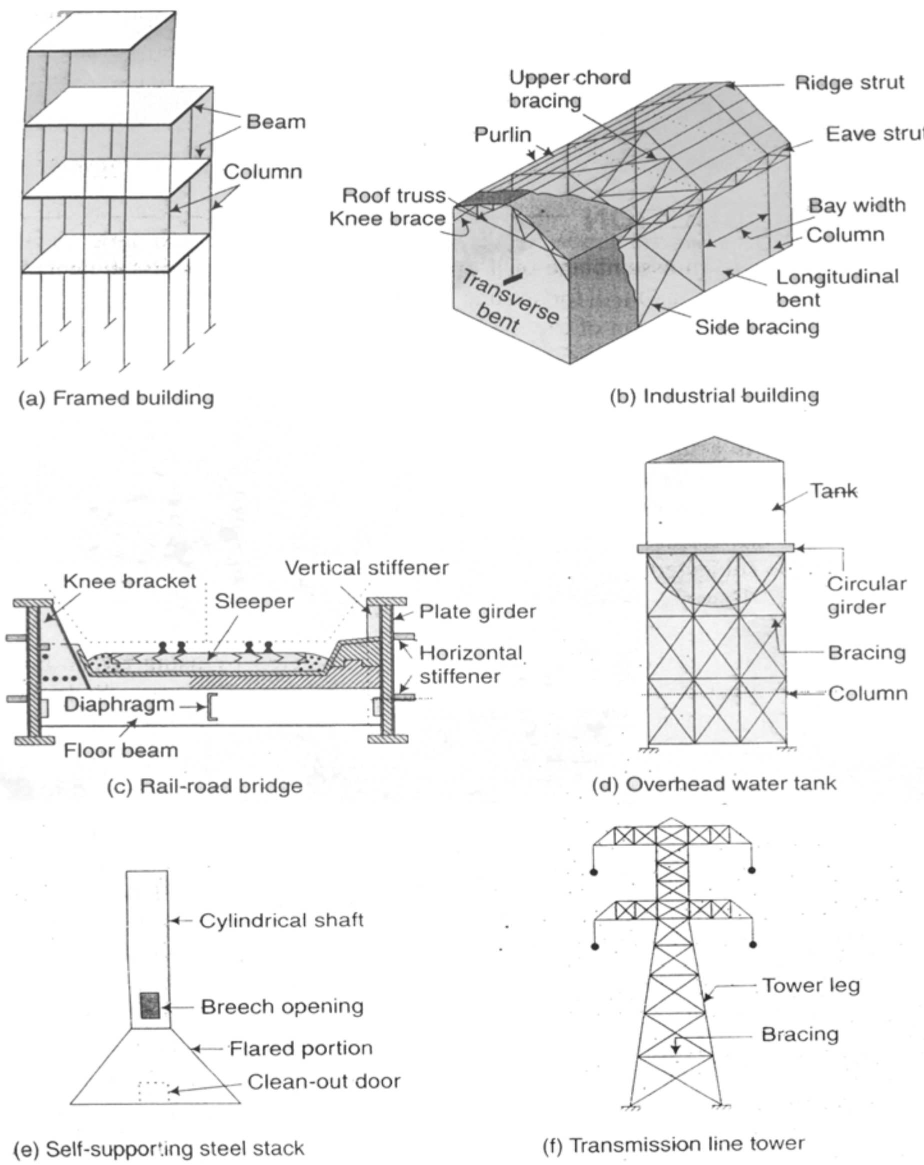
CHAPTER 1

General Design Consideration

1.1 Introduction

- A steel structure is an assemblage of a group of members (elements) expected to sustain their share of applied forces and to transfer them safely to the ground.
- Depending on the orientation of the member in the structure and its structural use, the member is subjected to forces, either axial, bending, or torsion, or a combination thereof.
- Axial load can be either tensile or compressive and accordingly the members are called tension members or compression members.
- An example of a tension member is a tie and that of a compression member is a strut.
- Primarily, all the steel structures are constructed with elements such as tension members– members subjected to tensile forces; compression members– members subjected to compressive forces; or flexural members– members subjected to bending.
- The elements of a steel structure, as discussed above, are rolled to a basic cross section in a mill, and worked to the desired size and form in a fabricating shop or site. These elements are connected by using rivets, bolts, pins or welds to form the structure and the connections so formed are called joints. Depending upon the fixity provided, the connections are classified as rigid– can transfer moments; flexible–can transfer axial loads (shears); or semi-rigid–that fall in between rigid and flexible.
- The design of steel structures involves the planning of the structure for specific purposes, proportioning of members to carry loads in the most economical manner and considerations for erection at site.
- First, the structure should serve the purpose for which it is intended and this is achieved by proper functional planning.
- Secondly, it should have adequate strength to withstand direct and induced forces to which it may be subjected during its lifespan.
- An inadequate assessment of forces and their effects on the structure may lead to excessive deformation and its failure.
- Therefore, the design of structures includes functional planning, acknowledgment of the various forces, strength of materials and the design method.
- Steel, as a building, material, has been used extensively in various types of structures. Some of the examples of civil engineering works in steel are highrise building skeletons, industrial buildings, transmission towers, railways bridges, overhead tanks, chimneys (stacks), bunkers and silos. Figure below illustrates some of the typical steel structures. Steel structures can be divided into two principal groups.

1. Steel structures, which are made largely of plates or sheets, such as tanks, bins, chimneys and steel roof covering of large buildings, and
2. Framed structures, which are characterized by assemblies of tension, compression and flexural members such as, truss-frame, rigid frames, girders and columns, etc.



Examples of steel structures

1.2 Steel as a Structural Material

Steel has many advantages as a structural material.

1. Steel members have high strength per unit weight. Therefore, a steel member of a small section which has little self-weight is able to resist heavy loads. The high strength of steel results in smaller sections to be used and fewer columns in buildings. The high strength-to-weight ratio is the most important property for the construction of long-span bridges, tall buildings and for buildings on soils with relatively low bearing capacities.

2. Steel, being a ductile material, does not fail suddenly, but gives visible, evidence of impending failure by large deflections. Also, the ductile nature of the structural steels enables them to yield locally at the points of high stress concentrations. The ductility of steel is responsible for relieving the overstressing in certain members by allowing redistribution of stresses due to yielding and thus, preventing premature failures.
3. Structural steels are tough, i.e., they have both strength and ductility. Thus, steel members subjected to large deformations during fabrication and erection will not fracture. Also, the steel may be bent, hammered, sheared or even the bolt holes may be punched without any visible damage.
4. Being light, steel members can be conveniently handled and transported. For this reason, prefabricated members can be frequently provided.
5. Properly maintained steel structures have a long life.
6. The properties of steel mostly do not change with time. This makes steel the most suitable material for a structure.
7. Additions and alterations can be made easily to steel structures.
8. They can be erected at a faster rate.
9. Steel has the highest scrap value amongst all building materials. Also, the steel can be reused after a structure is disassembled.
10. Steel is the ultimate recyclable material.

Despite of the innumerable advantages, steel has a few limitations as well, which of course are not of great concern if proper measures are adopted, and are as follows.

1. Steel structures, when placed in exposed conditions, are subjected to corrosion. Therefore, they require frequent painting and maintenance. The use of weathering steels, however, in suitable applications, may eliminate the requirement of frequent painting.
2. Steel structures need fireproof treatment, which increases cost. Furthermore, steel is an excellent heat conductor and, enough heat from a burning section or a room of a building to ignite materials with which they are in contact in the adjoining room. Although steel members are incombustible, their strength reduces drastically due to the temperatures reached during fire.
3. Fatigue of steel is one of the major drawbacks. Fatigue involves a reduction in the strength when steel is subjected to large number of stress reversals and even to a large number of variations of tensile stress.
4. At the places of stress concentration in the steel sections, under certain conditions, the steel may lose its ductility. Fatigue and very low temperatures aggravate the situation.

1.2.1 Structural Steel

Structural steel has been classified by the Bureau of Indian Standards based on its ultimate or yield strength. For example, Fe-410 steel has minimum tensile strength of 410 N/mm^2. The mechanical properties of steel largely depend on its chemical composition, rolling methods, rolling thickness, heat treatment and stress history. Some of the important mechanical properties of structural steels are given in table below.

Table: Mechanical properties of some typical structural steels

Type of Steel	Designation	UTS (MPa)	Yield Strength (MPa) Thickness (mm)			Min. Percentage Elongation (Gauge Length $= 5.65\sqrt{A_0}$	Charpy V-notch Impact Energy (min)
			<20	20 – 40	> 40		
Standard structural steel	Fe 410A	410	250	240	230	23	—
	Fe 410B	410	250	240	230	23	27
	Fe 410C	410	250	240	230	23	27
(IS 2062)							
			< 16	16-40	41-63		
Micro-alloyed	Fe 440B	440	300	290	280	22	30
Medium-/ high-strength steel	Fe 540B	540	410	390	380	20	25
	Fe 490B	490	350	330	320	22	25
(IS 8500)	Fe 590B /570B	590/570	450	430	420	30	20

NOTE

1. In Table, Fe stands for the steel followed with the number the characteristic ultimate tensile stress in megapascals. The letters A. B and C indicate the grade of steel.
2. Grade A Steel is intended to be used in structures subject to normal conditions.
3. Grade B Street is intended To-be treed in-structures subject to noncritical applications, where service temperature does not fall bellow 0°C. Usually, specified for structural parts prone to brittle fracture or subject to severe fluctuation of stresses.
4. Grade C Steel has guaranteed low temperature (up to –40°C) and impact properties.

Some of the other mechanical properties of structural steel are as follows.

1. Modulus of elasticity (E) 2×10^3 N/mm^2
2. Shear modulus (G) 0.769×10^5 N/mm^2
3. Poisson's ratio (μ)
   - (i) elastic range 0.3
   - (ii) plastic range 0.5
4. Coefficient of thermal expansion 12×10^{-6}/°C
5. Unit mass (ρ) 7.85×10^3 kg/m^3

1.2.2 Types of Structural Steel

IS 226 (Standard quality)
IS 2062 (Fusion welding quality)
IS 961 (High tensile steel)
IS 1977 (Ordinary quality)
IS 8500 (Medium and high strength qualities)

1.3 Rolled Steel Sections

The Bureau of Indian Standards (BIS) publishes **IS Handbook No.1** that tabulates weight per unit length, geometric dimensions and other dimensions for various types of steel sections.

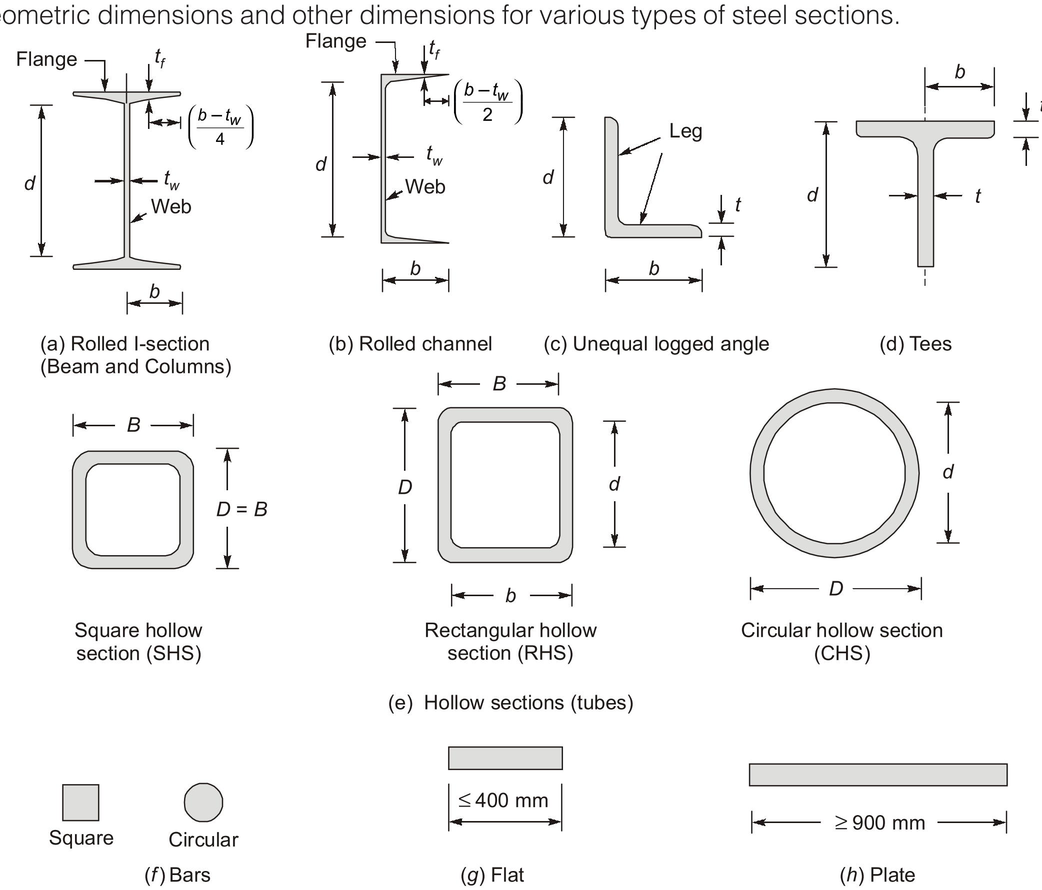


***Fig.** Rolled structural steel sectional shapes*

Commonly used sections are:

(a) Hot rolled steel I-section **Fig. (a)**
(b) Hot rolled steel channel section **Fig. (b)**
(c) Hot rolled steel angle section **Fig. (c)**
(d) Hot rolled steel tee (T) section **Fig. (d)**
(e) Hot rolled steel tube section **Fig. (e)**
(f) Hot rolled steel bars **Fig. (f)**
(g) Hot rolled steel flats **Fig. (g)**
(h) Hot rolled steel plates **Fig. (h)**
(i) Hot rolled steel sheets
(j) Hot rolled steel strips

1.3.1 Designation of Some Indian Standard Rolled Steel Sections

(a) ISJB : Indian Standard Junior Beam
(b) ISLB : Indian Standard Light Beam
(c) ISMB : Indian Standard Medium Beam
(d) ISHB : Indian Standard Heavy Beam (mostly used as column section)
(e) ISWB : Indian Standard Wide Flange Beam
(f) ISJC : Indian Standard Junior Channel
(g) ISLC : Indian Standard Light Channel
(h) ISMC : Indian Standard Medium Channel
(i) ISSC : Indian Standard Special Channel
(j) ISJT : Indian Standard Junior T Bar

(k)	ISNT	:	Indian Standard Normal T Bar
(l)	ISHT	:	Indian Standard Wide Flange T Bar
(m)	ISST	:	Indian Standard Long Legged T Bar
(n)	ISLT	:	Indian Standard Light T Bar
(o)	ISA	:	Indian Standard Angle (both equal and unequal legged)
(p)	ISBA	:	Indian Standard Bulb Angle
(q)	ISRB	:	Indian Standard Round Bar
(r)	ISSB	:	Indian Standard Square Bar
(s)	ISPL	:	Indian Standard Plate
(t)	ISF	:	Indian Standard Flat
(u)	ISSH	:	Indian Standard Sheet
(v)	ISST	:	Indian Standard Strip

REMEMBER: All standard I and channel sections have a slope of $16\frac{2}{3}\%$ on the inner face of the flange.

1.3.2 Sign Convention for Member Axes

x-x Longitudinal axis i.e. axis along the member

y-y Axis in the plane of the cross section which is:
- (a) normal to the flanges [Fig. (a)]
- (b) normal to the smaller leg in angle sections [Fig. (b)]

z-z Axis in the plane of the cross section which is:
- (a) parallel to the flanges [Fig. (a)]
- (b) parallel to the smaller leg in angle sections [Fig. (b)]

u-u Major axis in case it does not coincide with the *z-z* axis [Fig. (b)]

v-v Minor axis in case it does not coincide with the *y-y* axis [Fig. (b)]

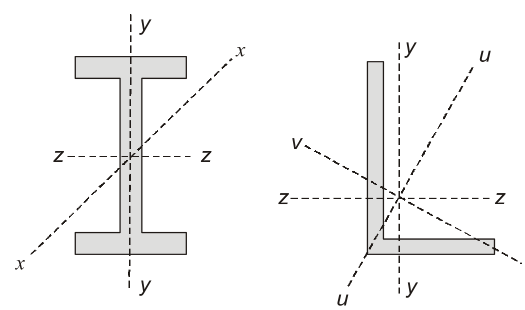


Fig. *Member axes notation*

1.4 Design Philosophies

- Design, of steel structures consists of design of steel members and their connections so that they will safely and economically resist and transfer the applied loads. This involves the knowledge of material properties, loads and factor of safety Economy usually means minimum steel-that is selection of the lightest possible cross section (weight/m length).
- As of today there are three design philosophies for the design of steel structures-elastic or working stress method, plastic or ultimate load method and limit state method.
- The basic difference between the three design philosophies is the manner in which safety is considered in the design and the confidence level enjoyed by the designer.
- In working stress method of design, the factors of safety used are purely based on engineering judgment.
- In the plastic method of design, load factor is used by which a set of loads acting on the structure must be multiplied to just cause structural or component failure (collapse); no safety factor is applied to the material.
- Limit State Design (LSD) approach makes use of partial safety factors applied to both loads and strength, calibrated using reliability methods; usually these are specified by the codes

- This permits the loading uncertainty to be accounted for in the load factors, and the uncertainty in yield stress and resistance modeling to be accounted for in the resistance and material partial factors.

1.4.1 Working Stress Design Method

- Working Stress Design (WSD), the traditional method of designing steel structures, is based on elastic theory.
- Attainment of the initial yielding forms the design criteria for the members in this approach. The working stress in the member should be less than the permissible stress
- The permissible stresses are some fraction of the yield stress of the material and may be defined as the ratio of the yield stress to the factor of safety. In other terms, when the yield point is well defined, the factor of safety is defined as the ratio of the yield stress to the maximum expected stress.
- Factor of safety may also be defined as the ratio of strength of the member to the expected force. The permissible stresses for fasteners are usually based on the ultimate strength of the connection using safety factor values of about 2 to 3 for various fasteners.

  Table: Permissible stresses in steel structural members

S. No.	Types of Stress	Notation	Permissible stress (MPa)	Factor of safety
1.	Axial tensile stress	σ_{at}	$0.6f_y$	1.67
2.	Maximum axial compressive stress	σ_{ac}	$0.6f_y$	1.67
3.	Bending tensile stress	σ_{bt}	$0.66f_y$	1.515
4.	Maximum bending compressive stress	σ_{bc}	$0.66f_y$	1.515
5.	Average shear stress	τ_{va}	$0.4f_y$	2.5
6.	Maximum shear stress	τ_{vm}	$0.45f_y$	2.22
7.	Bearing stress	σ_p	$0.75f_y$	1.33
8.	Stress of slab base	σ_{bs}	185	—

The concept of introducing a factor of safety is to make the structure safe. It accounts for the following:

1. The analysis methods are based on assumptions and do not give the exact stresses.
2. Structural members may temporarily be overloaded under certain circumstances.
3. Underestimation of the future live loads.
4. The stresses due to fabrication and erection are not considered in the design of ordinary structures.
5. The secondary stresses may be appreciable.
6. Stress concentrations.
7. Unpredictable natural calamities.

NOTE : The stresses used in practical design by this method are termed as working stresses or safe working stresses. These should never exceed the permissible stresses listed in Table above limitations of designing structures by WSD approach are as follows:

1. In WSD approach, the stress-strain behavior of the material is considered -to be linear and the structure is assumed to behave linearly in an elastic manner. Structures designed based on these assumptions possess considerable reserve of strength beyond elastic limit until they reach their ultimate strength, and lead to uneconomic design. This reserve strength is derived from ductility

(the ability of steel member to deform inelastically without major loss of strength) of steel and redundancy. One of the major drawbacks of designing steel structure by WSD approach is that the reserve strength beyond elastic limit is neither quantified nor utilized.

2. The failure mode of the structure cannot be visualized.
3. In the WSD approach, steel is assumed to be stressed well below its elastic limit under the working loads; which is achieved by factoring the yield stress, implying that the working stress must not exceed a specified permissible stress. The factors of safety used in working stress design were developed over time largely on the basis of experience and result in over design of the steel members.
4. Design parameters such as loads, material properties, strength, etc., are assumed to have unique values, though they are variable. The design parameters are predicted on experience or on field data. The design of structural elements therefore depends upon how closely the prediction is made. This uncertainty is non-deterministic and requires inclusion in the design methodology.
5. Many of the sources of loading vary with time. However, since all the sources of loads were considered to act simultaneously with their maximum value, while maintaining the same factor of safety, would lead to unconservative design.

1.4.2 Plastic Method of Design

- Steel possesses a reserve of strength beyond its yield, as is evident from stress-strain curve of mild steel, which engineers have tried to utilize in the plastic method of design
- In the plastic method, the design criterion is the ultimate strength and hence the behaviour of members beyond the yield stress in the inelastic or plastic range is considered.
- This method of design is based on failure conditions rather than working load conditions; failure implies collapse or extremely large deformations.
- The structure fails at a much higher load, called the collapse load, than the working load.
- The working loads are multiplied with specified factors, known as load factor, to obtain ultimate loads under which a structure collapses.
- Thereafter the maximum plastic moment is found.
- The plastic modulus of section Z_{pz} is found by dividing the maximum plastic moment with the yield stress. A section is selected which furnishes the required elastic modulus Z_e ($Z_e = Z_p/S$, where S is the shape factor).
- The cross sections of members are thus selected and designed on the basis of the collapse strength.
- The term plastic is used because, at failures, parts of the member will be subjected to very large strains—large enough to put the member into plastic range. When the entire cross section becomes plastic, infinite rotation takes place and a plastic hinge is formed. When sufficient plastic hinges are formed in the structural member at the maximum stressed locations a collapse mechanism is formed. Since the actual loads will be less than the collapse load by a factor of safety (load factor), the members designed will be safe.

1.4.3 Limit State Method of Design

- The limit state design (LSD) method was developed to take account of all conditions that can make the structure unfit for use, considering actual behaviour of materials and structures.
- This design method considers most critical limit states of strength and serviceability. In limit state design, basically statistical methods have been used for determination of loads and material

properties with a small probability of structure reaching the limit states of strength and serviceability.

- The objective of design is to achieve a structure that will not become unfit for use with acceptable target reliability.
- However, it is not yet possible to adopt a complete probability basis for design, and therefore, the method adopted ensures safety by using suitable factors, the partial safety factors.
- The design values, both for material strengths and for loads, are derived from the characteristic values through the use of partial safety factors.
- The working loads are factored using partial safety factors and the factored loads are used in the design load combinations.
- The nominal strength of the member also known as the ultimate capacity is determined and the design strength is computed by dividing; it by appropriate partial safety factor.
- This factor accounts for material (steel), poor workmanship and error in construction and fabrication. The ultimate stresses are used as design stresses. The member designed should satisfy the criterion.

$$\text{Design action} \leq \text{Design strength}$$

- The Section designed should also satisfy the serviceability requirements, such as limitations of deflection and vibration and should not collapse under accidental loads such as from explosions or impact or due to consequences of human error to an extent not originally expected to occur. Some of the advantages of LSD approach are as follows.
  1. This design method recognizes that the design parameters are variants and do not have unique values.
  2. The LSD approach attempts to rationally deal with variations in loads and member behaviour subjected to given loads.
  3. In this design approach partial safety factors are used to account for uncertainty in loads and material strength the members. It attempts to design structures which have consistent reliability, by using partial safety factors, without severely complicating the design process.
  4. In LSD, uncertainty is reflected in both loading and material strength rather than a single factor of safety (WSD) and load factor (PD).

The limit states of strength are those associated with failures (or imminent failure), under the action of probable and most unfavourable combination of loads on the structure using the appropriate partial safety factors, which may endanger the safety of life and property. The limit state of strength includes:

(a) Loss of equilibrium of the structure as a whole or any of its parts of components.
(b) Loss of stability of the structure (including the effect of sway where appropriate and overturning) or any of its parts including supports and foundations.
(c) Failure by excessive deformation, rupture of the structure or any of its parts of components.
(d) Fracture due to fatigue.
(e) Brittle fracture.

The limit state of serviceability includes:

(a) Deformation and deflections, which may adversely affect the appearance or effective use of the structure or may cause improper functioning of equipment or services or may cause damages to finishes and non-structural members
(b) Vibrations in the structure or any of its components causing discomfort to people, damages to the structure, its contents or which may limit its functional effectiveness. Special consideration

shall be given to systems susceptible to vibration, such as large open floor areas free of partitions to ensure that such vibrations are acceptable for the intended use and occupancy
(c) Repairable damage or crack due to fatigue
(d) Corrosion, durability
(e) Fire

1.5 Partial Safety Factors

1.5.1 Load Factors (γ_f)

It accounts for:

- Possibility of load exceeding characteristics load.
- Possibility of inaccurate assessment of load.
- Uncertainty in the assessment of the effects of the load.
- Uncertainty in the limit state being considered.

Table : Partial Safety Factors for Loads, γ_f for Limit States

Combination	Limit State of Strength					Limit State of Serviceability			
	DL	LL		WL/EL	AL	DL	LL		WL/EL
		Leading	Accompanying				Leading	Accompanying	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
DL + LL + CL	1.5	1.5	1.05	–	–	1.0	1.0	1.0	–
DL + LL + CL+	1.2	1.2	1.05	0.6	–	1.0	0.8	0.8	0.8
WL/EL	1.2	1.2	0.53	1.2					
DL + WL/EL	1.5	–	–	1.5	–	1.0	–	–	1.0
DL + ER	1.2	1.2	–	–	–	–	–	–	–
DL + LL + AL	1.0	0.35	0.35	–	1.0	–	–	–	–

Abbreviations:
DL = Dead load, LL = Imposed load (Live load), WL = Wind load, CL = Crane load (Vertical/Horizontal), AL = Accidental load, ER = Erection load, EL = Earthquake load.

1.5.2 For Materials 'or' Strength of Resistance Factors (γ_m)

It accounts for:

The Design Strength, S_d is obtained as given below from ultimate strength, S_u and partial safety factors for materials, γ_m given in Table 5.

$$S_d = S_u / \gamma_m$$

where partial safety factor for materials, γ_m account for:
(a) Possibility of unfavourable deviation of material strength from the characteristic value,
(b) Possibility of unfavourable variation of member sizes,

(c) Possibility of unfavourable reduction in member strength due to fabrication and tolerances, and
(d) Uncertainty in the calculation of strength of the members.

Table : Partial Safety Factor for Materials, γ_m

Sl. No.	Definition	Partial safety factor	
(i)	Resistance, governed by yielding, γ_{m0}	1.10	
(ii)	Resistance of member to buckling, γ_{m0}	1.10	
(iii)	Resistance, governed by ultimate stress, γ_{m1}	1.25	
(iv)	Resistance of connection:	Shop fabrications	Field fabrications
	(a) Bolts-friction type, γ_{mf}	1.25	1.25
	(b) Bolts-bearing type, γ_{mb}	1.25	1.25
	(c) Rivets, γ_{mr}	1.25	1.25
	(d) Welds, γ_{mw}	1.25	1.50

Example - 1.1 The loads on a floor beam of a commercial building are as follows:

Roof loads:
DL = 6 kN/m^2
LL = 4 kN/m^2
Roof finish =1.5 kN/m^2
Determine the design load for:
(a) Limit state of strength
(b) Limit state of serviceability

Solution: (a)
For limit state of strength
Load combination is 1.5(DL + LL)

$$DL = 6 + 1.5 = 7.5 \text{ kN/m}^2$$
$$LL = 4 \text{ kN/m}^2$$
$$\therefore \quad \text{Factored load} = 1.5(7.5 + 4) = 17.25 \text{ kN/m}^2$$

(b) For limit state of serviceability:
Load combination is 1 (DL + LL) = (7.5 + 4) = 11.5 kN/m^2

1.6 Loads

A structure should be designed to safely withstand all loads likely to act on it. For designing a structure, loads that are expected need to be known. The estimation of anticipated loads can be done on the basis of experience of designer and performance of the structure, which of course is a time taking process. To facilitate the designers, standard/codes publish load estimates. For the purpose of designing any element, member, or a structure, the following loads (action) and their effects should be taken into account, where applicable.

1. Dead loads; IS 875 (Part I)
2. Live load; IS 875 (Part II/IV)
3. Wind load; IS 875 (Part III)

4. Earthquake load; IS 1893
5. Erection loads
6. Accidental loads such as those due to blast; and
7. Secondary effects due to contraction or expansion resulting from temperature changes, differential settlement of the structure as a whole or of its components, eccentric connections, rigidity of joints differing from design specifications.

1.6.1 Wind Load (IS 875 Part III)

The wind pressure at any height of a structure depends upon the following:

(a) The velocity and density of the air.
(b) The height above G.L.
(c) The shape and aspect ratio of the building.
(d) Topography of the surrounding ground surface.
(e) The angle of wind attack.

Design Wind Speed (V_z)

$$V_z = V_b \cdot k_1 \cdot k_2 \cdot k_3$$

V_z = Design wind speed at a height of *zm* (m/s)

V_b = Basic wind speed as given in code for a short interval of 3 seconds and with a return period of 50 yrs

k_1 = Probability factor or risk coefficient

k_2 = Terrain, height and structure of loading factor

k_3 = Topography factor.

Design Wind Pressure (P_z)

$$P_z = 0.6 V_z^2$$

P_z = Design wind pressure at *zm* (in N/m^2)

Design Wind Load (F)

$$F = C_f \cdot A_e \cdot P_z$$

C_f = Force coefficient of the structure

A_e = Effective frontal area

Example - 1.2 A steel chimney 3.0 m in diameter is situated in a region where the intensity of wind pressure is 1200 N/m^2. Assuming the intensity of wind pressure to be uniform, estimate the shear due to wind load at a level 15 m below the top of the chimney.

Solution:

Design wind load = kP_1A_1

k = Shape factor = 0.7

P_1 = Intensity of wind pressure = 1200 N/m^2

A_1 = Projected area = 3.0 m × 15.0 m

$P = 0.7 \times 1200 \times (3 \times 15) = 37,800 \text{ N} = 37.8 \text{ kN}$

- The design wind pressure on a roof is determined by combination of external wind pressure and internal wind pressure:

External Wind Pressure

It depends on slope. The external wind pressure in terms of basic wind pressure ‘p’ on roofs when wind is normal to ridge.

Internal Wind Pressure

In depends on permeability of the structure. For different permeability of buildings, the internal air pressure in terms of basic wind pressure ‘p’ is given below:

Type of Building	Internal Pressure
1. Zero permeability, no openings (multistoried building with panel walls and no opening)	0
2. Normal permeability (upto 5% opening) (flow of air commonly afforded by structure through open windows and doors).	± 0.2P
3. Medium openings (5% – 20% openings)	± 0.5P
4. Large opening (area of opening > 20% of total area) (Hangers and sheds)	± 0.7P

Student's Assignment

Q.1 The structural steel (standard quality shall conform)
(a) IS 226 (b) IS 800
(c) IS 1977 (d) IS 2062 **(MPSC)**

Q.2 The percentage of carbon in standard structural steel is
(a) 0.23% (b) 0.6%
(c) 0.5% (d) 1.5% **(TNPSC)**

Q.3 The section which has more lateral buckling strength as compared to its counter part sections of same depth is
(a) ISWB (b) ISHB
(c) ISMB (d) ISJB **(OPSC)**

Q.4 Which of the following is not the limit state of serviceability?
(a) Deflection (b) Vibration
(c) Brittle fracture (d) Fire

Q.5 Which of the following is not a limit state of strength?
(a) Vibrations
(b) Fracture due to fatigue
(c) Stability against sway and overturning
(d) Rupture to structure **(TNPSC)**

Q.6 How are the most commonly produced and used structural elements in frames, floor beams etc. with high moment of inertia about x-axis, are designed?
(a) ISWB section (b) ISLB section
(c) ISMB section (d) ISHB section

Q.7 The structural advantage of using steel as a structural member is
(a) speed of erection or fabrication
(b) speed of dismantling
(c) good scrap value
(d) small weight to strength ratio

Q.8 For combination of dead load and live load for a floor beam, the partial safety factor for dead load and live load as per limit state of strength are respectively
(a) 1.0 and 1.0 (b) 1.5 and 1.2
(c) 1.0 and 1.5 (d) 1.5 and 1.5

Q.9 The partial safety factor for material governing by yield strength and ultimate tensile strength respectively are _______ and _____.
(a) 1.10 and 1.25 (b) 1.10 and 1.10
(c) 1.25 and 1.10 (d) 1.25 and 1.25

Q.10 The minimum thickness of main steel members as per IS 800: 1984, is directly exposed to weather, and not accessible for repainting is
(a) 5.0 mm (b) 6.0 mm
(c) 8.0 mm (d) 10.0 mm

Q.11 The internal pressure coefficient on walls for buildings with large permeability is taken as
(a) ± 0.2 (b) ± 0.5
(c) ± 0.7 (d) 0

Q.12 According to IS:875 Part 3, the design wind speed acting on industrial roof is estimated based on the basic wind speed by multiplying it by factors k_1, k_2 and k_3, k_1 is called
(a) Terrain height factor
(b) Structure size factor
(c) Topography factor
(d) Risk coefficient **(KPSC)**

Q.13 Upper yield point in the stress-strain curve in structural steel can be avoided by
(a) cold working (b) hot working
(c) quenching (d) galvanizing

Q.14 Steel of yield strength 400 MPa has been used in a structure. What is the value of the maximum allowable tensile strength?
(a) 240 MPa (b) 200 MPa
(c) 120 MPa (d) 96 MPa **(OPSC)**

Q.15 What is the allowable direct tensile stress in structural steel (approximately)?
(a) $0.45f_y$ (b) $0.6f_y$
(c) $0.66f_y$ (d) $0.80f_y$
where f_y is the yield stress or proof stress.

Q.16 The design wind speed is V_z. The design wind pressure will be given as
(a) $0.4\ V_z^2$ (b) $0.5\ V_z^2$
(c) $0.6\ V_z^2$ (d) $0.8\ V_z^2$

Q.17 A structure is to be constructed where basic wind speed is 47 m/s, risk coefficient = 1, terrain and size factor is 0.98, topographic factor = 1.0. The basic wind pressure would be about
(a) 46 N/m^2 (b) 1270 N/m^2
(c) 15.6 N/m^2 (d) 2120 N/m^2

Q.18 To account for secondary effects in the design due to geometric imperfections
(a) service loads
(b) working loads
(c) characteristics loads
(d) notional loads
are applied to the structure **(TNPSC)**

Q.19 The design wind speed depends upon
(i) risk coefficient
(ii) topography of the area
(iii) size of the structure
Of the above
(a) 1, 2 are correct (b) 2, 3 are correct
(c) 3, 1 are correct (d) 1, 2, 3 are correct

Q.20 The design wind speed is assumed to be constant from the mean ground level upto a height of
(a) 2 m (b) 5 m
(c) 10 m (d) 20 m **(MPSC)**

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1. (a)	**2.** (a)	**3.** (b)	**4.** (c)	**5.** (a)
6. (c)	**7.** (d)	**8.** (d)	**9.** (a)	**10.** (c)
11. (c)	**12.** (d)	**13.** (a)	**14.** (a)	**15.** (b)
16. (c)	**17.** (b)	**18.** (d)	**19.** (d)	**20.** (c)

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11. (c)

It includes both internal as well as external pressure.

12. (d)

As per IS code 875 clause 5.3

k_1 = Probability factor or Risk coefficient

k_2 = Terrain, height structure size

k_3 = Topography factor

13. (a)

Plastic deformation of metals below the re-crystallization temperature is known as cold working. In this process steel is loaded above elastic limit to have some plastic strain which in turn omits upper yield point later.

14. (a)

Maximum allowable tensile strength

$$= 0.6\ f_y$$
$$= 0.6 \times 400$$
$$= 240 \text{ MPa}$$

15. (b)

As per **IS : 800-1984**, the permissible stress in axial tension (σ_{at}) in MPa on the net effective area of the section shall not exceed

$$\sigma_{at} = 0.6 f_y$$

where f_y = minimum yield stress of steel in MPa.

The permissible stress in tension has been worked out after applying a factor of safety of 1.65.

17. (b)

$$V_z = k_1 \cdot k_2 \cdot k_3 \cdot V_b$$
$$= 1.0 \times 0.98 \times 1 \times 47$$
$$= 46.06$$

Basic wind pressure

$$P_z = 0.6\ V_z^2$$
$$= 0.6 \times (46.06)^2$$
$$= 1272.91 \text{ N/m}^2 \simeq 1270 \text{ N/m}^2$$

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