STEPS INVOLVED IN THE DEIGN PROCESS

General design requirements:

The general design requirements are outlined in Section 3 of IS 800:2007. (P-15)

- The objective of design as Achievement of an acceptable probability that structures will perform satisfactorily for the intended purpose during the design life.
- With an appropriate degree of safety, they should sustain all the loads and deformations, during construction and use and have adequate resistance to certain expected accidental loads and fire.
- Structure should be stable and have alternate load paths to prevent unbalanced overall collapse under accidental loading.

Methods of Design

- Clause 3.1.2 from IS800-2007 Structure and its elements shall normally, be designed by the limit state method. Account should be taken of accepted theories, experimental information and experience and the need to design for durability.
- This clause admits that calculations alone may not produce Safe, serviceable and durable structures.
- Suitable materials, quality control, adequate detailing and good supervision are equally important.
- As per Cl. 3.1.2.2 of IS 800:2007, where the limit states method cannot be conveniently adopted; the working stress design (Section 11 of IS 800:2007) may be used.
- Clause 3.1.3 of IS 800:2007 specifies structural design, including design for durability, construction and use should be considered as a whole.
- The realization of design objectives requires compliance with clearly defined standards for materials, fabrication, erection and in-service maintenance.
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The following methods may be employed for the design of the steel frame work:

1. Simple design
2. Semi-rigid design
3. Fully rigid design and
4. Plastic design

1. Simple Design

This method is based on elastic theory and applies to structure in which the end connections between members are such that they will not develop restraint moments adversely affecting the members and the structures as a whole and in consequence the structure may be assumed to be pin jointed.

2. Semi-rigid design

This 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. In the case of triangulated frames, it permits rotation 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, it is ensured that the assumed partial fixity is available and 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 IS : 800-1984.

3. Fully rigid design

This method assumes that the end connections are fully rigid and are capable of transmitting moments and shears. It is also assumed that the angle between the members at the joint does not change, when it is subjected to loading. This method gives 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 virtually unchanged original angles between such members and the members they connect. The design should be based on accurate methods of elastic analysis and calculated stresses shall not exceed permissible stress.

4. **Plastic design**

The method of plastic analysis and design is recently (1935) developed and all the problems related to this are not yet decided. In this method, the structural usefulness of the material is limited up to ultimate load. This method has its main application in the analysis and design of statically indeterminate framed structures. This method provides striking economy as regards the weight of the steel. This method provides the margin of safety in terms of load factor which one is not less than provided in elastic design. A load factor of 1.85 is adopted for dead load plus live load and 1.40 is adopted for dead load, live load and wind or earthquake forces. The deflection under working load should not exceed the limits prescribed in IS : 800-1984.

LIMIT STATE DESIGN

The current revision of the code of practice, IS 800:2000, recommends limit state method for design of structures using hot rolled sections. This method is outlined in section 5(page 26) of IS 800:2007.

- In the limit state design method, the structure shall be designed to withstand safely all loads likely to act on it throughout its life.
- It shall not suffer total collapse under accidental loads such as from explosions or impact or due to consequences of human error to an extent beyond the local damages.
- The objective of the design is to achieve a structure that will remain fit for use during its life with acceptable target reliability. In other words, the probability of a limit state being reached during its life time should be very low.

- The acceptable limit for the safety and serviceability requirements before failure occurs is called a limit state.
- In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.
- Steel structures are to be designed and constructed to satisfy the design requirements with regard to stability, strength, serviceability, brittle fracture, fatigue, fire, and durability such that they meet the following:

1. Remain fit with adequate reliability and be able to sustain all actions (loads) and other influences experienced during construction and use.
2. Have adequate durability under normal maintenance
3. Do not suffer overall damage or collapse disproportionately under accidental events like explosions, vehicle impact or due to consequences of human error to an extent beyond local damage.

LIMIT STATE DESIGN PHILOSOPHY

For achieving the design objectives, the design shall be based on characteristic values for material strengths and applied loads (actions), which take into account the probability of variations in the material strengths and in the loads to be supported. The characteristic values shall be based on statistical data, if available. Where such data is not available, these shall be based on experience. The design values are derived from the characteristic values through the use of partial safety factors, both for material strengths and for loads. In the absence of special considerations, these factors shall have the values given in this section according to the material, the type of load and the limit state being considered.

The reliability of design is ensured by satisfying the requirement

Design action ≤ Design strength

The limit states are classified as

a) Limit state of strength

b) Limit state of serviceability.

The limit states of strength:

The limit states of strength are those associated with failures (or imminent failure), under the action of probable and most unfavorable combination of loads on the structure using the appropriate partial safety factors.

The limit state of strength includes:

a. Loss of equilibrium of the structure as a whole or any of its parts or components.
b. 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 or components
d. Fracture due to fatigue
e. Brittle fracture.

The limit state of serviceability:

The limit state of serviceability include

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) e) Fire.

Working stress method	Ultimate load method	Limit state method
• It is based on *elastic theory* (i.e. attainment of the initial yielding forms design criteria for the members in this approach) • Safety is considered in terms of *Factor of Safety* which is applied to the material strength	• It is based on *plastic theory* (i.e. steel possess a reserve strength beyond its yield stress due to strain hardening upto ultimate stress which is utilized in this approach) • Safety is considered in terms of *Load factor* which is applied to the external load	• It is developed after Ultimate load method & is based on *plastic theory.* • Safety is considered in terms of *partial safety factor* which is applied to both material strength & external load.

TYPE OF LOADS ON STRUCTURES AND LOAD COMBINATIONS

LOADS AND FORCES :(Clause 3.2 of IS 800:2007)

For the purpose of designing any element, member or a structure, the following loads (actions) and their effects shall be taken into account, where applicable, with partial safety factors and combinations

- Dead loads
- Imposed loads (live load, crane load, snow load, dust load, wave load, earth
  pressures, etc.)
- Wind loads; (d) Earthquake loads
- Erection loads
- Accidental loads such as those due to blast, impact of vehicles, etc.
- Secondary effects due to contraction or expansion resulting from temperature changes, differential settlements of the structure as a whole or of its components, eccentric connections, rigidity of joints differing from design assumptions.

LOADS ON STRUCTURES:

- Dead Load: [I.S. 875 Part-I]-Code of practice for Design loads (dead load)

  Dead loads are the permanent loads acting on the structure including the self-weight of the section.

- Live Load: [I.S. 875 Part-II] -Code of practice for Design loads (imposed load)

  It is an imposed load in structure due to people, furniture, movable objects etc. Based on utility of the structure the values are given in [I.S 875 Part-II]

  Example:
  For Residential Buildings – 2 KN/m^2
  For Commercial Buildings – 3 KN/m^2

- Wind Load [I.S 875 Part-III] -Code of practice for Design loads (wind load)
- Snow Load [I.S 875 Part-IV] -Code of practice for Design loads (snow load)
- Seismic Load (or) Earth quake Load [I.S 1893-2002]
- Accidental Loads
- Errection Loads
- Temperature effects

LOAD COMBINATIONS:

[I.S 875 Part-V] -Code of practice for Design loads (Special Loads and Combinations)

Load combinations for design purposes shall be those that produce maximum forces and effects and consequently maximum stresses and deformations. The following combination of loads with appropriate partial safety factors as given in Table 4 of IS 800:2007 may be considered.

a) Dead load + imposed load
b) Dead load + imposed load + wind or earthquake load
c) Dead load + wind or earthquake load
d) Dead load+ erection load.

The effect of wind load and earthquake loads shall not be considered to act simultaneously. The load combinations are outlined in detail in Clause. 3.5 of IS 800:2007.

CHARACTERISTICS OF LOAD:

It is designed as the action of the load which are not expected more than five percentage probability during the life of the structure.

1. Partial safety factor for loads for limit state ‘γf’ is given in table 4 [I.S 800-2007]

2. Partial safety factor for material is given in table 5 [I.S 800-2007]

Table 4 Partial Safety Factors for Loads, γ_f, for Limit States

(*Clauses* 3.5.1 *and* 5.3.3)

Combination	Limit State of Strength					Limit State of Serviceability			
	DL	LL[1]		WL/EL	AL	DL	LL[1]		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 (0.9)[2]	—	—	1.5	—	1.0	—	—	1.0
DL+ER	1.2 (0.9)[2]	1.2	—	—	—	—	—	—	—
DL+LL+AL	1.0	0.35	0.35	—	1.0	—	—	—	—

Table 5 Partial Safety Factor for Materials, γ_m

(*Clause* 5.4.1)

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