Limit States –

Limit states are the states beyond which the structure no longer satisfied the specified performance requirements.

The various limit states to be considered in design may be grouped into the following 2 major categories.

a) Limit state of strength.

b) Limit state of serviceability.

a) Limit state of strength –

The limit states, prescribed to avoid collapse of structure which may endanger the safety of life & property, are grouped under this category.

The limit state of strength includes.

→ Loss of equilibrium of whole or part of the structure.

→ Loss of stability of structure as a whole or part of it.

→ failure by excessive deformation.

→ fracture due to fatigue.

→ Brittle fracture.

b) Limit state of serviceability –

→ Deformations & Deflections adversely affecting the appearance or effective use of structure or causing improper functioning of equipment or services or causing damage to finishings.

→ Vibrations in structures or any part of its Component limiting its functional effectiveness.

→ Corrosion.

→ fire.

Design strength –

In using the strength value of a material for design, the following uncertainties should be accounted.

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 & tolerances, &

d) Uncertainty in the calculation of strength of materia

Hence IS 800-2007, Recommends Reduction in the strength of materials by a P.S.F [Partial Safety factor γ_m] which is defined as.

$$\gamma_m = f_u / f_d \quad \text{i.e} \quad f_d = \frac{f_u}{\gamma_m}.$$

Where →

f_u – Ultimate strength

f_d → Design strength.

→ γ_m → P.S.F
Table → 5
P.No → [30]

Deflection Limits –

Deflection limits are specified from the consideration that excess deformations do not cause damage finishing. Deflections are to be checked to adverse but realistic combination of service loads & their arrangement.

Elastic analysis may be used to find deflection. Design load for this purpose is the same as characteristic load (i.e. partial safety factor $\gamma_f = 1.0$). Except when apart from DL, LL, CL & some more imposed loads are considered.

The deflection limits specified by IS 800:2007 are as [Table 6 in IS 800-2007] → P.No → [51]

Other Serviceability Limits –

Apart from deflection requirement, the design should also satisfy the following serviceability limits -

a) Vibration limit.

b) Durability consideration

c) Fire resistance.

Vibration Limit –

Though most of the structures are designed for strength & then checked for deflection limits, some of the structures need check for vibration limits. The structures the floors of which support machineries, the flexible structures [with height to effective width ratio exceeding 5:1) etc. should be investigated for vibration under Dynamic loads. [11]

In such cases there are possibilities of resonance, fatigue failures.

IS 800-2007 gives a set of guidelines to take care of Vibration limits in its Annex 'C'.

Durability Considerations — P.NO → [32]

The following factors affect the durability of a steel structure.

a) Environment.
b) Degree of exposure.
c) Shape of the member & the structural detail.
d) Protective measures.
e) Ease of maintenance.

Fire Resistance P.NO → [32] IS 800-2007.

A steel structure should have sufficient fire Resistance level (FRL) specified in terms of minutes depending upon the purpose for which the structure is used & the time taken to evacuate in case of fire. For detailed specifications a designer may refer section 16 of IS 800-2007 along with IS 1641, IS 1642, IS 1643 & any other specialised literature on fire Resistance.

Stability Checks

After designing a structure for strength & stability, it should be checked for instability due to Overturning, uplift or sliding under factored loads.

In Checking for instability disturbing forces should be taken as design loads & stabilising forces may be taken as design loads (factored loads) with lesser factor of safety (0.9) as specified in [Table 4 - IS 800-2007].

Local Buckling -

Most structural members, either hot or cold rolled are composed of flat plate elements. For Example I-sections, channels or angle sections can be regarded as combination of individual plate elements connected together to form the shape. Therefore while considering the stability of a structural shape subjected to a compressive strain, the stability of its component plate elements must also be considered.

Local buckling adversely affects the load carrying capacity of columns & beams due to reduced stiffness & strength of the locally buckled plate elements of the section.

The structural member may be affected in 2 ways.

1) The buckling may lead to the overall failure making the plate element ineffective.

2) The buckling may produce a redistribution of stresses & thus influence the carrying capacity & behaviour of the member.

Types of Buckling –

The individual elements of a column i.e. flange or web may buckle locally forming wrinkles. This type of buckling causing column failure is called local buckling. It can be prevented by providing suitable width - thickness ratios of the elements. [P. No. - 18 IS 800 - 2007]

However, when an axially loaded compression member becomes unstable overall (that is, not locally unstable). it can buckle in one of the following 3 ways.

1) Flexural Buckling.
2) Torsional Buckling.
3) Flexural - Torsional Buckling.