AIR-1 Notes

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Steel Structure

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DESIGN OF STEEL STRUCTURES

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Design of Steel Structures

[12-13 Ques in PTE
15-25% in Subjective]

1) Introduction
2) General Design consideration
3) Connection → Bolted / → welded
4) Tension Member
5) Compression Member
6) Beam Design
7) Gantry Girder
8) Plate Girder
9) Industrial building.

Code : I.S 800 - 2007
IS 808 → Structural steel components.

1. Introduction

→ IS codes

(a) IS 800 : 2007 - General construction in steel. (with amendment no. 1, January 2012)

(b) IS 808 : 1989 - Dimensions for steel sections (Steel Table)

→ Steel

→ It is an alloy of iron having carbon content between 0.1 to 1.1%.

→ Based on Carbon content, 3 types of steel are:

(a) Low Carbon steel (0.1 to 0.25% Carbon)
(b) Medium Carbon steel (0.2 to 0.60% Carbon)
(c) High Carbon steel (0.6 to 1.1% Carbon)

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→ Deoxidizers such as silicon or aluminium is used to control Dissolved Oxygen during the manufacturing process.

→ Lower %age of oxygen content is good for durability of steel and on the basis of oxygen content, we classify steel as

(a) ~~Field~~ Killed Steel [< 30 ppm Oxygen]

(b) Semi-Killed Steel [30 to 150 ppm Oxygen]

(c) Rimmed steel [> 150 ppm oxygen]

→ Structural steel are generally killed or semi-killed. Carbon %age in structural steel is generally < 0.25% [Low carbon steel]

→ Mild Steel has a carbon content of nearly 0.1%

→ IS 800 : 2007 can be used for structural Mild steel or high tension structural steel

⇒ Various grades of Steel

Grade		Ultimate Stress (MPa)	Yield Stress (MPa)
E 250 (Fe 410)	A	410	250
	B	410	250
	C	410	250
E 300 (Fe 440)		440	300
E 350 (Fe 490)		490	350
E 410 (Fe 540)		540	410

E 250 (Fe 410) A → grade of steel

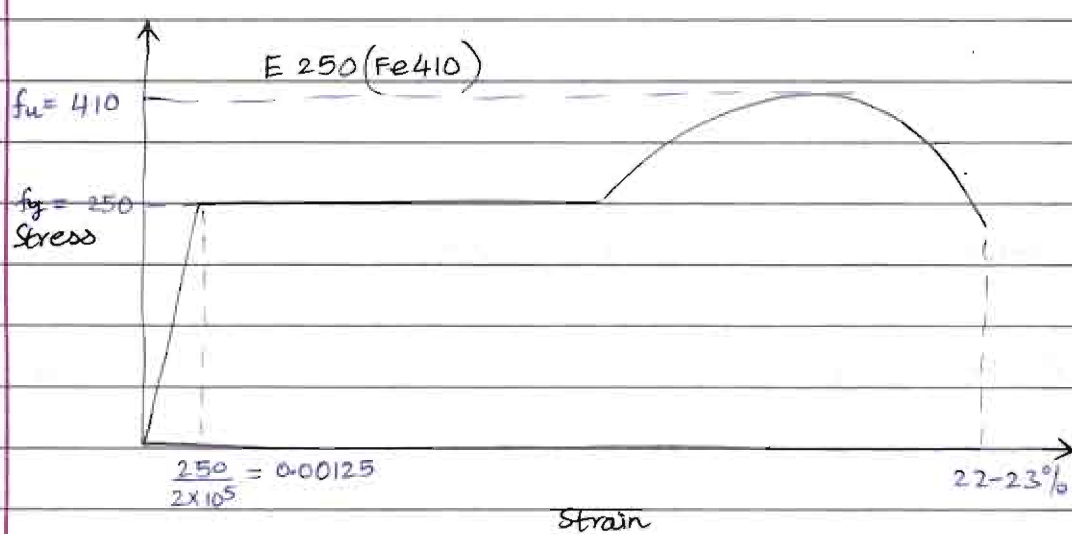
- E 250 → Characteristic Yield Stress
- Fe 410 → Characteristic Ultimate Stress

Fe 410 W → denotes higher weldability

NOTE:

1) Structural steel is specified according to characteristic ultimate tensile stress i.e. f_u. It is the ultimate stress below which not more than 5% of the materials are expected to fall.

2) R/F bars in RCC are specified according to yield stress.



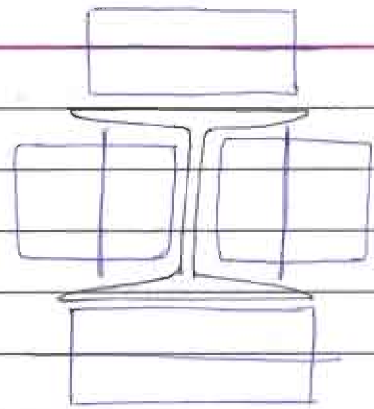
3) Thinner the section, higher is the strength due to higher amount of rolling, cold working, uniform rate of cooling.

Ex-

Residual Stress ⇑ →

	t < 20 mm	20 < t < 40 mm	t > 40 mm
E 250 (Fe 410)	f_y = 250 MPa	f_y = 240 MPa	f_y = 230 MPa

→ No. of Rollings ⇓ Grain distribution poor



4) Brittle fracture due to higher tensile stress, lower temperature, thicker material, rapid change of stresses etc

5) Stainless steel is a low Carbon steel with around 10.5% chromium by weight.

⇒ Grade A is used for non-critical Application i.e. when members are not prone to brittle fracture.

⇒ Grade B is used for critical applications when temperature does not fall below 0°c and when parts are prone to brittle fracture or fluctuations of stresses as in case of bridges.

⇒ Grade C has a guaranteed low temperature upto -40°c and it shall be used for impact loading and higher chances of brittle fracture.

⇒ Physical properties of steel (for all grades)

(a) Density - 7850 kg/m^3

(b) Modulus of Elasticity - 2×10^5 MPa

(c) Poisson's Ratio - 0.3 (Elastic Range)
0.5 (Plastic Range)

(d) Shear Modulus - $G = \frac{E}{2(1+\nu)} = 0.769 \times 10^5$ MPa.

(e) Specific Gravity - 7.85

(f) Coefficient of thermal expansion - $12 \times 10^{-6} / °c$

⇒ Advantages of Steel as a Structural material

1) High strength per unit weight
2) High ductility and toughness.
3) Uniformity i.e. very less quality control issues.
4) Environment friendly and high recyclability (≃ 100%)
5) Easy connections and faster construction.
6) Easy repair and modifications.
7) Longer life if properly maintained.

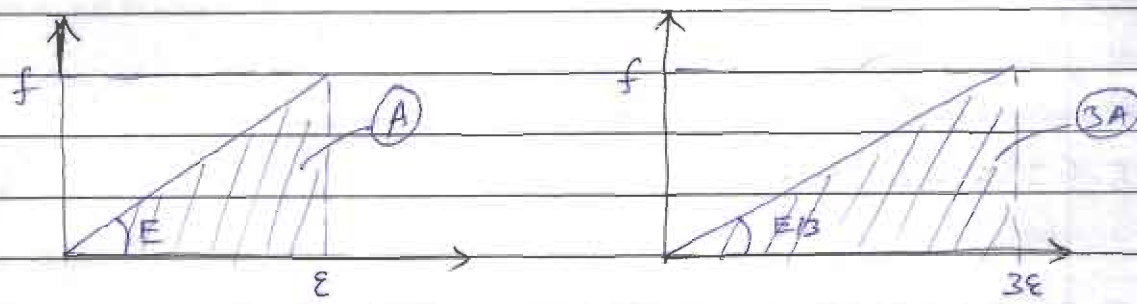
⇒ Disadvantage of steel as a structural material

1) Higher maintenance due to corrosion
2) Fire-proofing cost
3) Prone to buckling due to longer and slender member
4) Fatigue.

⇒ Aluminium

→ Higher strength to unit weight ratio as compared to steel.
→ However, due to lower modulus (≃ 1/3 of steel) bigger sections are required to avoid buckling.
→ greater resistance to corrosion and hence less maintenance.
→ Density is approx. 1/3 of steel [2700 to 2800 kg/m^3]
→ Coefficient of thermal expansion is nearly twice that of steel [23×10^{-6}]
→ less ductile than mild steel.
→ Does not have a well defined yield point and hence yield is assumed as 0.2% proof stress.
→ As it's modulus is 1/3 of steel, It can absorb 3 times the energy at same stress level as ~~a steel~~ compared to a steel member of same dimension

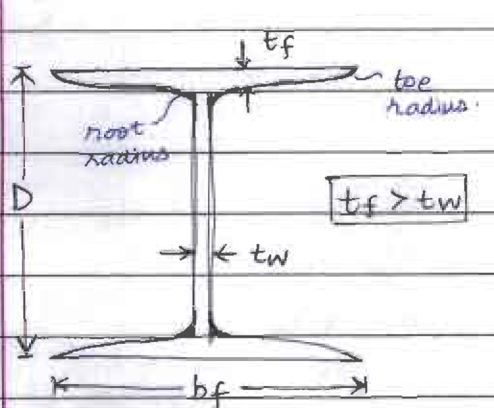
provided the stress does not exceed the proportionality limit. Hence it is also used for impact loading provided higher deflection is allowed.



Steel   Aluminium.

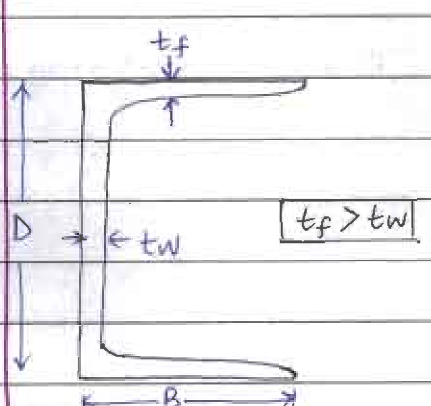
→ Design concept is same as steel structure. (IS814)

⇒ Standard structural steel sections



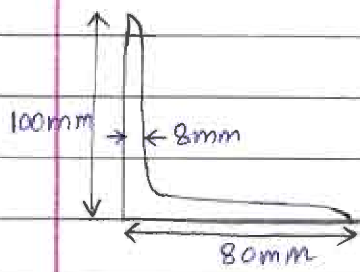
ISJB → Indian Standard Junior Beam
ISLB → " " Light Beam
ISMB → " " Medium Beam
ISHB → " " Heavy Beam
ISSC → " " Column Section
↳ Type of I-section

Ex- ISMB 300
D = 300 mm, B or b_f = 140 mm, t_f = 13.1 mm, t_w = 7.7 mm



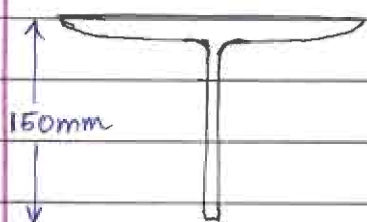
ISJC → Junior channel
ISLC → Light channel
ISMC → Medium channel.

Ex- ISMC 100
D = 100 mm, B = 50 mm, t_f = 7.7 mm, t_w = 5 mm



ISA → Indian Standard equal/unequal angle.

Ex- ISA 100X80X8



ISNT → Indian Standard Normal T-section
ISMT → " " Medium T-section

Ex- ISNT 150@ 223.7 N/m

⇒ ISRO → Round Bars (ISRO 10) i.e. 10 mm dia.

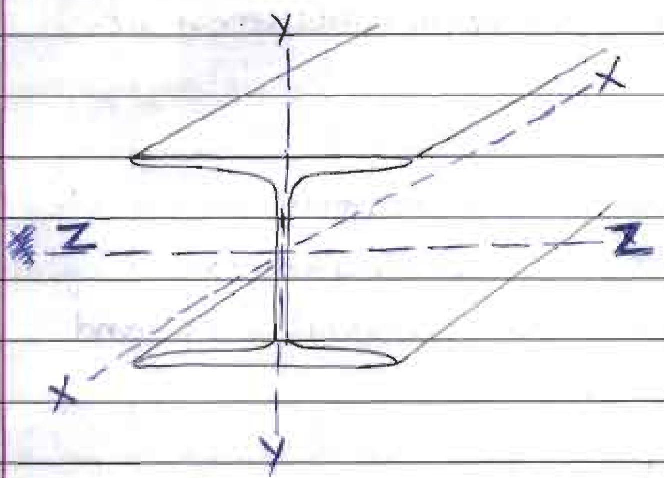
⇒ ISSQ → Square Bars (ISSQ 10 i.e. 10mm side)

⇒ ISPL → Plate (ISPL 2000 X 1000 X 8 → Length x width x thickness)

⇒ ISFL → Flat Section (30 ISF 10 → 30 mm width and 10mm thickness)

→ These sections can be used either alone (Rolled sections) or in combinations (Built up sections).

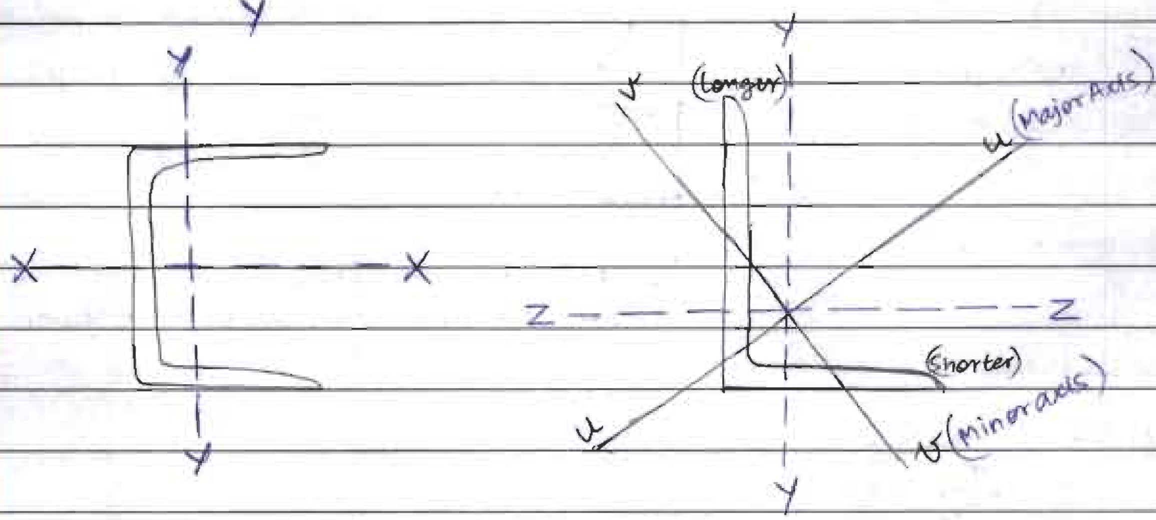
⇒ Convention for member axes



Along the member - X-X

Parallel to flange - Z-Z (Major axis)

Perpendicular to flange - Y-Y (Minor axis)



→ Parallel to smaller leg - ZZ } for angle sections.

→ ⊥ar to smaller leg - YY

→ In earlier version of IS 800 : 1984, major axis was denoted as X-X

2) General Design Consideration

→ Structure shall fulfill safety, serviceability, economy, aesthetic and environmental criteria.

→ 3 design methods :

(a) Elastic or Working stress method

(b) Plastic / Ultimate Load method

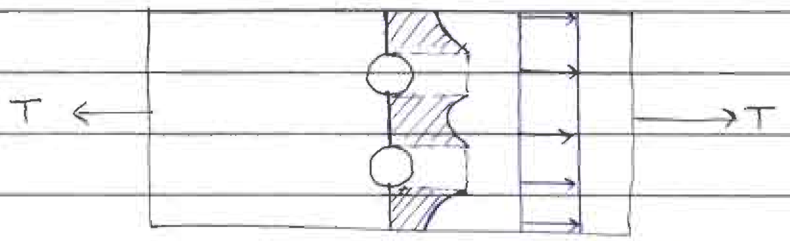
(c) Limit State Method

⇒ WSM (Working Stress Method)

→ It assumes linear elastic response & Safety is ensured by ensuring working stress will be less than permissible stress i.e.

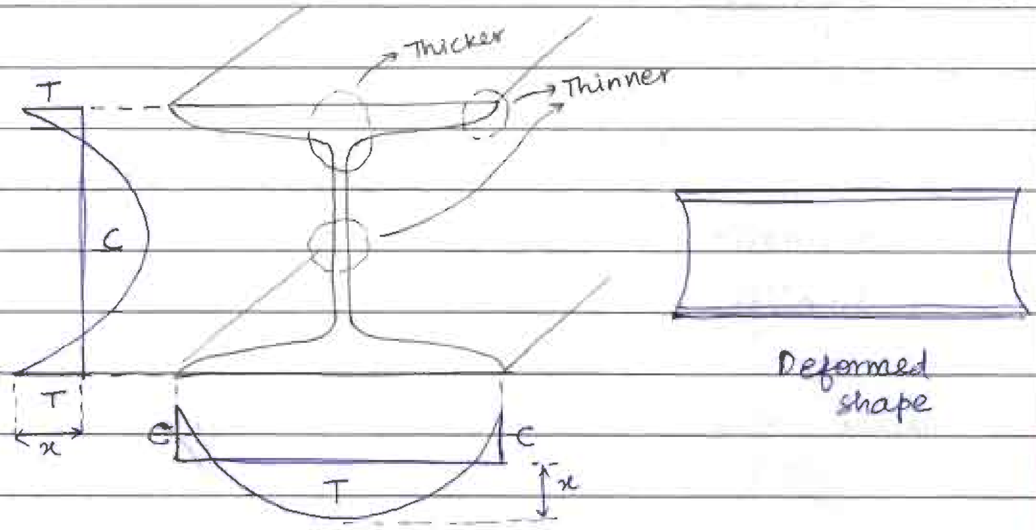
$$\frac{\text{Strength of material}}{\text{FOS}}$$

→ However, assumptions of stress being less than permissible stress is not realistic because of stress concentration, long term effect of creep and shrinkage, residual stress and other secondary stresses.



↳ stress concentration due to reduced area of X-section.

NOTE:



Residual stress along the length

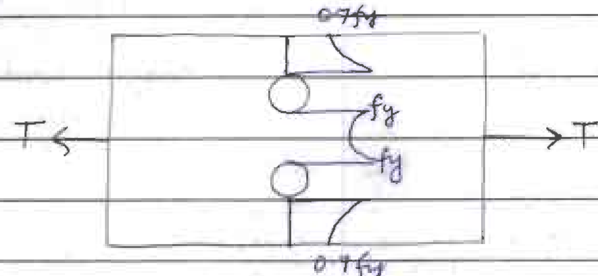
→ Unequal rate of cooling due to different thickness and exposed area and uneven compression by roller will lead to generation of residual stress. The part of section which cools first will have compression because it will resist the shortening of slower cooling part.

→ Also the slower cooling part will have tension.

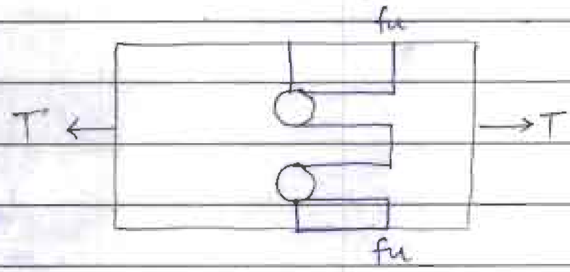
⇒ Does not utilise the reserved strength derived from ductility and redistribution of stress and hence FOS does not give a realistic figure or exact margin of safety.

→ FOS does not have a scientific basis and is based on experience.

→ It fails to discriminate b/w different types of loads that are simultaneously acting but having varying degrees of uncertainty.



When working load is acting, ~~momen~~ redistribution of stresses is not available.



At ultimate load, redistribution is significant.

Hence the material ~~to~~ strength is highly underutilized in WSM

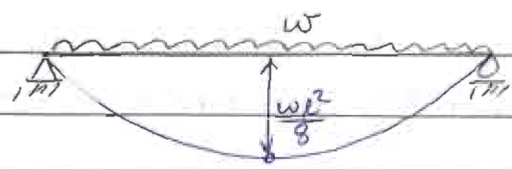
⇒ ULM (Ultimate Load Method)

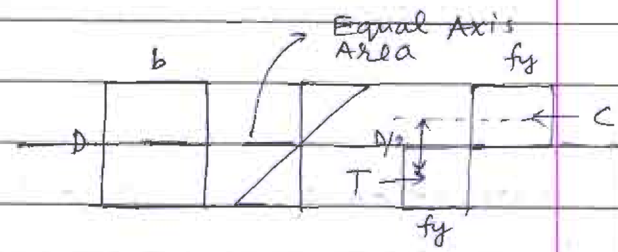
→ Design is done as in the case of plastic analysis in which working load multiplied by load factor is ensured to be less than the collapse load or ultimate load.

→ However, this method does not ensure serviceability criteria like deflection, vibration etc. Also, structure subjected to impact and fatigue loading shall not be designed with plastic theory as it uses full material strength beyond elastic limit.

→ Also safety factor for material is not considered and hence it gives smaller section than WSM.

NOTE: Plastic Analysis





Only one mechanism required for failure

$$\frac{wl^2}{8} = M_p = f_y \frac{bD}{2} \cdot \frac{D}{2}$$

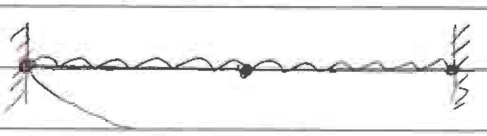
$$M_p = f_y \underbrace{\frac{bD^2}{4}}_{Z_p}$$

Z_p → Plastic section modulus.

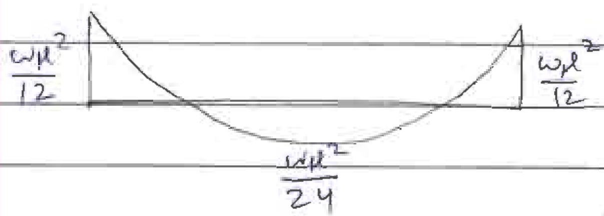
$$Z_p = 1.5\ Z_e$$

↳ elastic section modulus $= \frac{bd^2}{6}$

In case of SS steel beam ⇒ $\boxed{w_{max} = \frac{8M_p}{l^2}}$



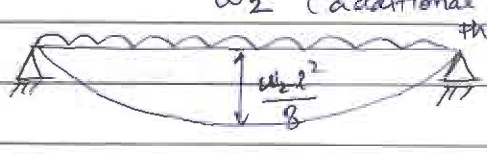
3 hinges required for failure



$\frac{wl^2}{12} = M_p$ → 2 plastic hinge at rigid joints occur.

converted to simply supported

w_2 (additional load that can be applied)



$\frac{w_2 l^2}{8} = \frac{M_p}{2}$ → because $\frac{M_p}{2}$ has been utilized before

So, total load that can be applied $= w_1 + w_2$

$$= \frac{12M_p}{l^2} + \frac{8M_p}{2l^2}$$

$$= \frac{16M_p}{l^2}$$

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⇒ LSM (Limit State Method)

→ To avoid all deficiencies of WSM and ULM, LSM was proposed.

→ Partial safety factors are used for both loads and material strength based on acceptable probability of failure derived using reliability analysis. (Level I)

→ Partial safety factors take into account possible overloads and under strength.

Design action (considering partial safety factor for loads) ≤ Design strength (considering partial safety factor for materials)

→ Factored Load / Design Load (F_d) = (Characteristic Load) × γ_f

γ_f → Partial safety factor for loads depending on load combination and limit state being considered.

→ Design strength (f_d) = $\dfrac{\text{Characteristic Strength}}{\gamma_m}$

γ_m → Partial safety factor for material strength.

→ Characteristic Load is the load which has 95% probability of not being exceeded during the life of the structure.

→ Characteristic strength is the strength below which not more than 5% of the test samples are expected to fall.

⇒ γ_f accounts for (Partial safety factor for loads)

① Possibility of load exceeding characteristic load.

② Possibility of inaccurate assessment of load.

③ Uncertainty in assessment of effect of load. (failure mechanism)

(4) Uncertainty in the assessment of limit state being considered.

⇒ γ_m accounts for (partial safety factor for material strength)

① Possibility of strength falling below characteristic strength.
② Reduction in member size due to faulty construction.
③ Reduction in strength due to fabrication and tolerances.
④ Uncertainty in theoretical assumptions.
⑤ Uncertainty in the calculation of strength of member.

→ Limit states are the states beyond which the structure becomes unfit for use.

→ The limit states are classified as:

① Limit State of strength / Ultimate Limit strength.
② Limit State of serviceability.

⇒ Limit state considered by IS code

① Limit State of Strength

(a) Strength including yielding, buckling and transformation into a mechanism (plastic hinge formation)
(b) Stability against overturning and sway
(c) failure due to excessive deformation or rupture
(d) fracture due to fatigue.
(e) Brittle fracture.

② Limit State of serviceability

(a) Deformation and deflection (can cause damage to non structural components and finishes but not to structural component)