Limit State Design

* Limit state method is method of design in which both collapse and serviceability criteria are considered.
* Limit state method consist of two limit states →

(a) Limit state of collapse ⇒ It is a criteria of design in limit state method due to which structure collapse. i.e Flexure, shear, Development length, torsion

(b) Limit state of Servicibility ⇒ It is a criteria in limit state method for which designing does not considered instead of this these criteria only used to check the service condition or servicibility of the member i.e cracking, Deflection, vibration, shrinkage, creep.

Qus Which of the following criteria are serviceability criteria

(a) Cracking (b) Flexure (c) Vibration (d) Shear

i) a and b

ii) b and c

iii) a and c ✓

iv) All of the above depending upon the loading condition.

* Limit state method is always at higher stress level than working stress method.

Qus. For Fe 250 grade of steel, 250 stands for

(a) Upper yield limit

(b) Strength of a steel bar

(c) Characteristic strength of a steel bar ✓

(d) All of these

NOTE ⇒ Characteristic strength of any material is the mean strength of more than one sample.

Characteristic strength of a material ⇒ [f_{ck}]

The strength of a member below which not more than 5% test results are expected to fall, that strength is called characteristic strength of the member.

Ques.) While determining the characteristic strength, how much test result are expected to safe or not fall

(a) 5% (b) 75% (c) 85% (d) 95% ✓

Partial Safety Factor ⇒

(a) Factor of Safety

It is the ratio of yield stress or ultimate stress to working stress.

$$F.O.S = \frac{\text{yield stress}}{\text{Working stress}}$$ → For steel

$$F.O.S = \frac{\text{ultimate stress}}{\text{working stress}}$$ → For concrete

$= F \geq 1$

= Dimensionless quantity.

⇒

Partial safety Factor (γ)	Factor of Safety (F)
→ For Limit state method	→ For working state method
$\gamma_{st} = 1.15$	$F_{st} = 1.78 - 1.82$
$\gamma_c = 1.5$	$F_c = 3$
working stress in steel ⇒ $\frac{\text{yield stress}}{\gamma_{st}} = \frac{f_y}{1.15}$ $= .87 f_y$	working stress in steel $= \frac{f_y}{F_{st}} = \frac{f_y}{1.8}$ $= .55 f_y$
working stress in concrete $= \frac{\text{yield stress}}{\gamma_c} = \frac{f_{ck}}{1.5}$ $= .67 f_{ck}$	working stress in concrete $= \frac{f_{ck}}{3}$ $= .33 f_{ck}$

NOTE ⇒

The above statement conclude that Limit state design is an higher stress level than working stress design.

Ans. The Partial safety factor for concrete is more than steel bcz,

(a) Steel is a isotopic and homogeneous material.
(b) The coefficient of thermal expansion of steel is more than concrete.

(c) Concrete is a brittle material steel is a ductile material.
(d) The quality control of concrete is not as good as steel.

Assumption in Limit State Design ⇒

(1) Plane section remains plane before bending and after bending.
(a) This assumption is valid for Both Limit state and working state method.
(b) This assumption is only valid for strain.
(c) This assumption state that the strain variation is always linear.

2) The tensile strength of concrete is ignored.
(a) This assumption insure the safety of a concrete under tension.
b) Flexure ~~th~~ tensile strength of concrete or Modulus of rupture. [f_{cr}]

$$f_{cr} = .7\sqrt{f_{ck}}$$

⇒ Modulus of rupture is the tensile stress in bending tension at which cracking will takes place in tension zone or it represents the onset of cracking.

NOTE:—

The tensile strength of concrete is <u>10–15%</u> of compressive strength of concrete.

$$\% \text{ strength} = \frac{.7\sqrt{f_{ck}}}{f_{ck}} \times 100$$

(3) The maximum strain in concrete at outermost compression Fiber is taken as <u>.0035</u>.

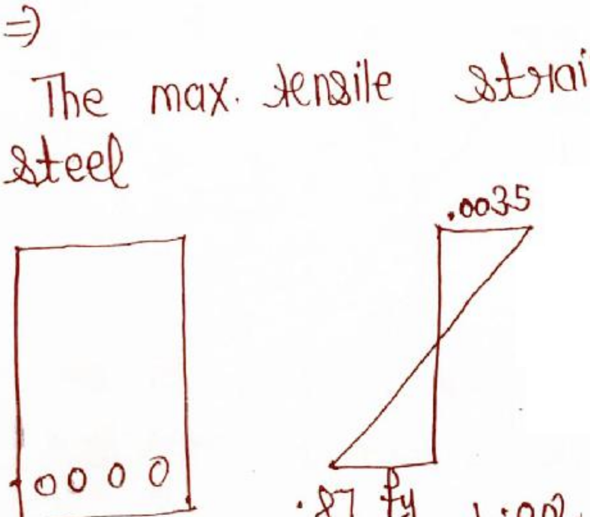
(4) The Partial Safety factor for steel is taken as 1.15.

(5) The design stress for concrete is taken as .67 fck. and Partial safety factor applied on it.

(6) The maximum tensile strain for concrete and steel at failure must be greater than $0.87\frac{f_y}{E_{st}} + .002$.

NOTE ⇒

The max. tensile strain is only depends upon grade of steel



Imp.
Tensile strain, For

Fe 250 Et > .0031

Fe 415 Et > .0038

Fe 500 Et > .0041

$E_{st} = 2 \times 10^5 \, N/mm^2$

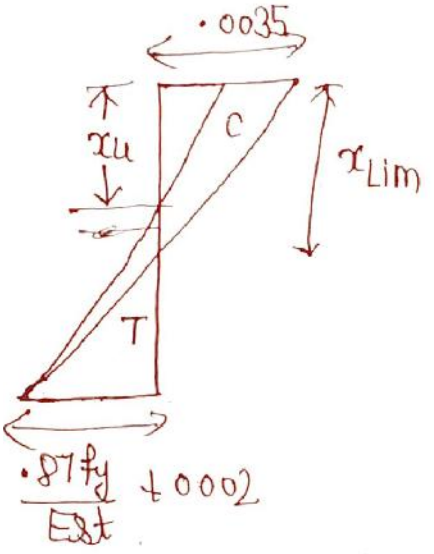
Under Reinforced, Over Reinforced and Balanced section ⇒

a) Under Reinforced section ⇒

A section is said to be under Reinforced if permissible stress reaches in steel before concrete.

⇒ In this section, the member ~~fails~~ gives warning before failure and failure will occur due to shear stress.

⇒ This section is considered as the most safer section among all section.



$$\boxed{x_u < x_{Lim}}$$

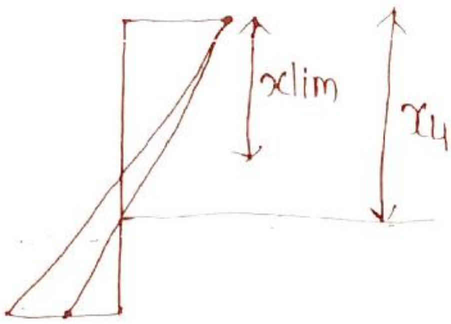
b) Over Reinforced section ⇒

A section is said to be over Reinforced if the permissible stress reaches in concrete before steel.

⇒ This section is subjected to brittle failure a member fails suddenly.

⇒ This section is considered as weakest section among all section.

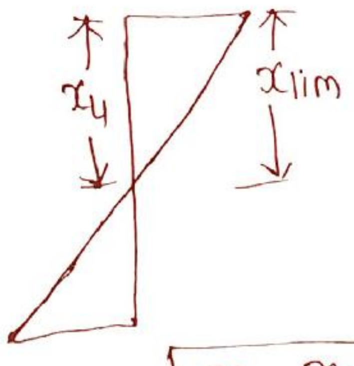
⇒ The member fails due to normal stress.



$$x_u > x_{lim}$$

(c) Balance Section ⇒

A section is said to be balance if the permissible value of stress reaches in steel and concrete simultaneously.



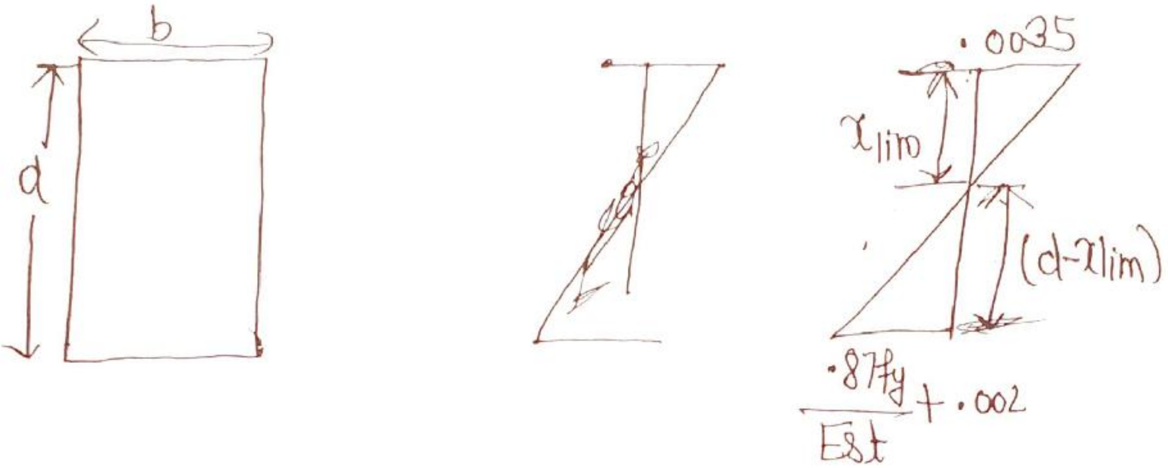
$$x_u = x_{lim}$$

NOTE ⇒ All R.C.C structure are designed as a balance section

Limiting Neutral Axis Depth ⇒ (Singly R/F Beam)

It is the distance from top fibre to the centroid of the beam when strain reaches its maximum value both top and bottom.

⇒ A beam is said to be singly R/F when it carries only tensile reinforcement.



From similar Δ,

$$\frac{\frac{.87 f_y}{E_{st}} + 0.002}{.0035} = \frac{d - x_{lim}}{x_{lim}}$$

$$= \frac{\frac{.87 f_y}{E_{st}} + .002}{.0035} = \frac{d}{x_{lim}} - 1$$

$$\frac{d}{x_{lim}} = \frac{\frac{.87 f_y}{E_{st}} + .002 + .0035}{.0035}$$

$$\frac{x_{lim}}{d} = \frac{.0035}{\frac{.87 f_y}{E_{st}} + .0055}$$ → Limiting Neutral Axis depth factor

If $E = 2\times10^5$

$$\frac{x_{lim}}{d} = \frac{.0035}{\frac{.87 f_y}{2\times10^5} + .0055}$$

$$x_{lim} = \frac{700d}{.87 f_y + 1100}$$ **

For Fe 250, $x_{lim} = 0.53d$

Fe 415, $x_{lim} = 0.48d$

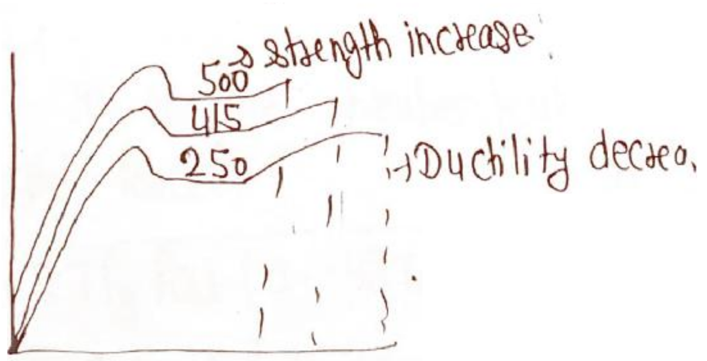
Fe 500, $x_{lim} = 0.46d$

* For JE, IES

NOTE ⇒ Imp.

The limiting neutral axis depth factor is depends upon the characteristic strength of steel.

As the carbon content increases strength increases



As carbon content Increase, limiting N.A depth decrease and member tends to brittle failure.