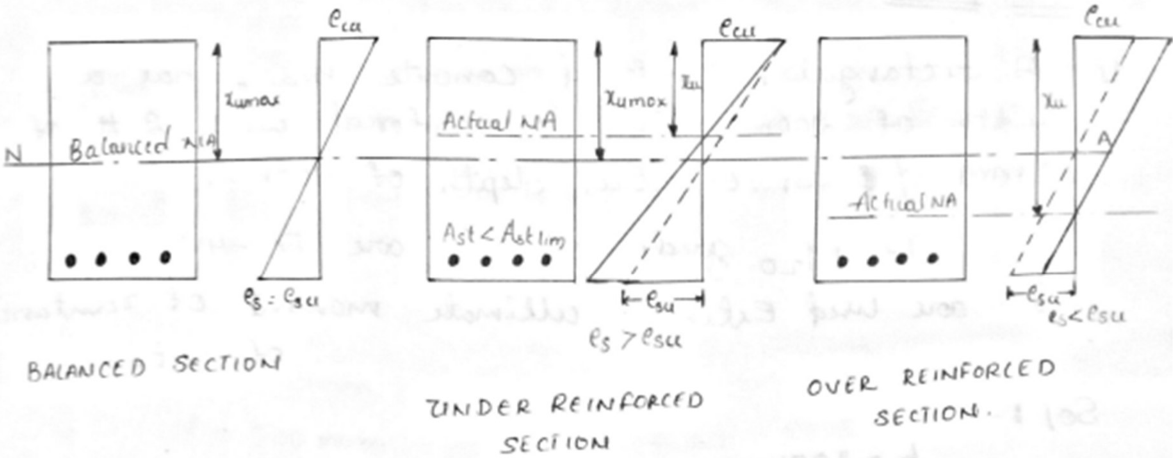
1	Explain balanced section, over reinforced section and under reinforced section with neat sketch. List the situations when they are adopted.



Balanced Section: The strain in steel and strain in concrete reach their maximum value simultaneously. the $e_c = e_{cu}$ & $e_s = e_{su}$. The % of steel in this section is known as critical (or) limiting steel percentage (P_t lim). The depth of neutral axis $x_u = x_{umax}$.

Under Reinforced Section: is one in which P_t is less than critical (or) limiting percentage. Due to this the actual NA is above the balanced NA & $x_u < x_{umax}$. Hence stress in steel required reaches first than concrete.

Beam fails by excess yielding of steel.

Before beam fails it gives sufficient warning.

Over Reinforced Section: In this type of beam c/s the % of steel is greater than what is required for balanced section. Hence stress in concrete reaches first than steel ∴ Beam fails by crushing of concrete in compression zone. Hence this type of failure is sudden & it won't give warning before it fail.

∴ IS 456:- is not permitting over reinforced design.

	Case 1: x_u/d "equal" to limiting value, $\frac{x_{umax}}{d}$: "BALANCED SECTION" Case 2: $\frac{x_u}{d}$ "less" than limiting value $\frac{x_{umax}}{d}$: "UNDER - REINFORCED SECTION Case 3: $\frac{x_u}{d}$ "More" than limiting value $\frac{x_{umax}}{d}$: "OVER REINFORCED SECTION"
2	Explain working stress method and limit state method of design. List the different loads to be considered in the design of a reinforced concrete element.
	• Working stress Method (WSM) The conceptual basis of WSM is simple. The method basically assumes that the structural material behaves in a linear elastic manner, and the adequate safety can be ensured by suitably restricting the stresses in the material induced by the expected "working load" (Service load) on structure. As specified permissible (allowable) stresses are kept well below the material strength (i.e in the initial phase of stress strain curve), the assumption of linear elastic behaviour is considered justifiable. The ratio of strength of material to the permissible stress is often referred to as the factor of safety. The stresses under the applied loads are analysed by applying the methods of 'strength of material', such as simple bending theory. In order to apply such methods to a composite material like reinforced concrete, strain compatibility (due to bond) is assumed, whereby the strain in reinforcing steel is assumed to be equal to the adjoining concrete to which it is bonded. Further more, as the stresses in concrete and steel are assumed to be linearly related to there respective strains, it follows that the stress in steel is linearly related to adjoing concrete by a constant factor (Modular ratio), The stresses under working load within the permissible stresses are not found realistic by the assumptions made. This may be because of the following reasons. ① Perm effect of creep and shrinkage ② The effect of stress concentration

(5) And other secondary ... effects.

All such effects results in significant local increase in re-distribution of calculated stresses.

WSM does not provide realistic measure of actual factor of safety.

The design usually results in large sections of structural members, compare to ULM & LSM, thereby resulting in better serviceability performance (less deflection, less crack width,) under the usual working load.

LIMIT STATE METHOD [LSM]"

An ideal method is the one which takes into account not only the ultimate strength of the structure but also the serviceability and durability requirements. The newly emerging limit state method of design is oriented towards the simultaneous satisfaction of all requirments.

A structure is designed for safety against collapse (for ultimate strength to resist ultimate load) and checked for its serviceability @ working load. The LSM includes considuation of a structure @ both the working and ultimate load level with a view to satisfy the requirments of safety and serviceability.

"The acceptable limit of safety and serviceability requirments, before failure occurs is called Limit State"

A limit state is a state of impending failure, beyond which a structure ceases to perform its intended function satisfactorily, in terms of either safety or serviceability. i,e either by collapses or become unserviceable.

For ensuring above objectives, the design should be based on characteristic values of material strength and applied loads, which takes into account the variations in material strengths and in the loads to be supported. The characteristic values should be based on statistical

	data if available where such data are not available, they should be based on experience. The design values are derived from the characteristic value through the use of partial safety factor, one for material strength and one for load. Loads acting on Structural Members. Structural elements are designed to resist the following types of load. 1. Dead Load: or: Self weight: These are the loads which are due its own weight on the area of the structural element. It is calculated by the density x area In the structural elements or in a structure we have concrete element and RCC element. Hence the specified density of it will be taken that is Density of plain cement concrete : Density of Reinforced cement concrete : 2. Live Load: * These are loads that change w.r.t time. * imposed loads includes the load due to people occupy the floor or due to material stored on floor. * IS code 875 part 2. Table 2 gives details of materials and loads. 3. Wind Load: These loads are considered when designing multistorey buildings.
3	A singly reinforced concrete beam 250 x 450 mm deep upto the centre of reinforcement is reinforced with 3 – 16 mm dia at an effective cover 50mm, effective span 6m, M20 concrete and Fe415 steel. Determine the central point load that can be supported in addition to the self weight.

Solution :-

Given :-
$b = 250 mm$
$d = 450 mm.$
$A_{st} = 3 \times \pi/4 \times 16^2 = 603.186 mm^2$
$d' = 50 mm.$
$l = 6 m.$
$f_{ck} = 20 MPa$
$f_y = 415 MPa.$

$$\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} b d}$$

$$= \frac{0.87 \times 415 \times 603.186}{0.36 \times 20 \times 250 \times 450} = 0.27$$

For Fe415 $\rightarrow \frac{x_{umax}}{d} = 0.48$

$\frac{x_u}{d} < \frac{x_{umax}}{d} \rightarrow$ Hence Under reinforced.

$$M_u = 0.87 f_y A_{st} d \left(1 - 0.42 \frac{x_u}{d}\right).$$

$$= 0.87 \times 415 \times 603.186 \times 450 (1 - 0.42 \times 0.27)$$

$$= \underline{86.89 \text{ kN-m}}$$

Selfweight $= \omega_{DL} = 0.25 \times 0.5 \times 25$
$= 3.125$ kN/m.

$$M_u = M_{DL} + M_{LL}$$

$$\frac{86.89}{1.5} = \frac{\omega_{DL} l^2}{8} + \frac{\omega_{LL} l}{4}$$

$$\frac{86.89}{1.5} = \frac{3.125 \times 6^2}{8} + \frac{\omega_{LL} \times 6}{4} \Rightarrow \therefore \boxed{\omega_{LL} = 29.24 kN}$$

4 Find the moment of resistance of a T beam having a web width of 240 mm effective depth of 400 mm; flange width of 740mm and flange thickness equal to 100mm. The beam is reinforced with 5 – 16mm diameter, Fe415 bars. Use M20 concrete

Data :-

$b_w = 240mm$

$d = 400mm$.

$b_f = 740mm$.

$D_f = 100mm$.

$A_{st} = 5 \times \pi/4 (16^2) = 1005.3mm^2$

$f_{ck} = 20 N/mm^2$

$f_y = 415 N/mm^2$

Solution :-

Assuming the neutral axis to fall in the flange.

$$\frac{x_u}{d} = \frac{0.87 f_y A_{st}}{0.36 f_{ck} \cdot b_f \cdot d} = \frac{0.87 \times 415 \times 1005.3}{0.36 \times 20 \times 740 \times 400}$$

$= 68.13mm$.

$$\frac{x_{umax}}{d} = 0.48$$

$\frac{x_u}{d} < \frac{x_{umax}}{d}$, hence, the section is under-reinforced.

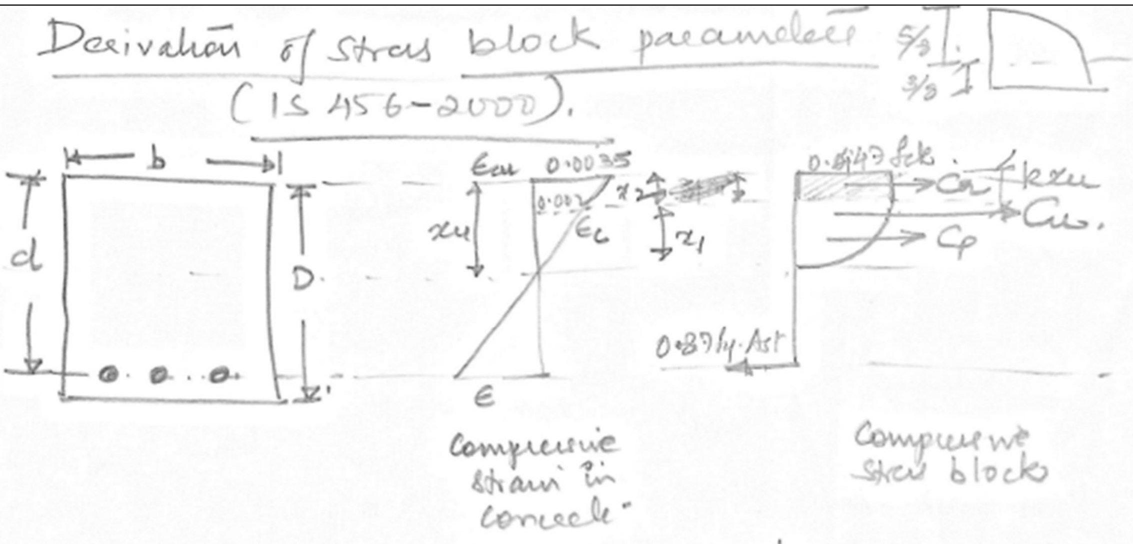
$$M_u = 0.87 f_y A_{st} (d - 0.42 x_u) = 0.87 f_y A_{st} d \left(1 - 0.42 \frac{x_u}{d}\right)$$

$$= 0.87 \times 415 \times 1005.3 \times (1 - 0.42 \times 68.13) \times 400$$

$= 134.95 \ kN\text{-}m$.

5 What is a stress block? Derive from fundamentals the expression for area of stress block $0.36 f_{ck} x_u$ and depth of centre of compressive force from the extreme fibre in compression $0.42 x_u$.

Derivation of stress block parameters
(IS 456-2000).



Concrete Stress block

Compressive stress block of as per IS456 -
$\square^{lar}$ - parabolic.

The $\square^{lar}$ portion corresponds to design yield stress of concrete upto 0.2% strain.

Depth of this $\square^{lar}$ portion is fixed..?

from $|||^{lar}$ Δ^{le} properties of strain diagram.

$$\frac{0.0035}{x_u} = \frac{0.002}{x_1}$$

$$\therefore x_1 = \frac{0.002}{0.0035} x_u = \frac{2}{3.5} x_u = \frac{4}{7} x_u$$

x_1 is the depth of parabolic portion.

$\therefore$ depth of $\square^{lar}$ portion :-

$$x_2 = x_u - \frac{4}{7} x_u = \frac{3}{7} x_u.$$

Now, let
C_R = Total compression of □^le portion.
$= 0.447 f_{ck} \times (\frac{3}{7} \times x_u) \times b$
$= 0.192 f_{ck} x_u b$ @ $\frac{1}{2} \times \frac{3}{7} x_u$ from top

IIly C_P = Total compression of parabolic portion.
$= \frac{2}{3} \times 0.447 f_{ck} \times \frac{4}{7} x_u b = 0.17 f_{ck} x_u b$.
@ $5/8 \times 4/7 x_u$. from NA

Total ultimate compressive force in Concrete
$\therefore C_u = C_R + C_P = (0.192 + 0.17) f_{ck} x_u b$
$= 0.362 f_{ck} x_u b$

87 fig 4A

Position of C_u from top fibre

Since C_u is resultant of C_R & C_P.
Using Varignon's principle of moments about
~~028 Pavan Kumar~~ top fibre.

$$C_u \times k x_u = C_R \times \frac{3}{14} x_u + C_P \left(x_u - \frac{20}{56} x_u\right)$$

Now
$C_u = 0.362 f_{ck} x_u b$
$C_R = 0.192 f_{ck} x_u b$
$C_P = 0.17 f_{ck} x_u b$.

$\therefore 0.362 \times k = 0.192 \times \frac{3}{14} + 0.17\left(1 - \frac{20}{56}\right)$

$0.362\,k = 0.041143 + 0.109286.$

$\therefore k = \frac{0.150429}{0.362} = 0.416 \approx 0.42$

$\therefore$ Cu is @ 0.42 x_u from top