W.S.M.

1). **Working stress method**

→ Based on elastic Theory.

Stress = load / Area

→ Stresses are considered for normal working load condition.

→ Stresses are limited to a fraction of stress at which material fails when tested.

→ $F.O.S = \frac{\text{Yield stress}}{\text{Working stress}}$

L.S.M. 2) **Load factor method or Ultimate load method**

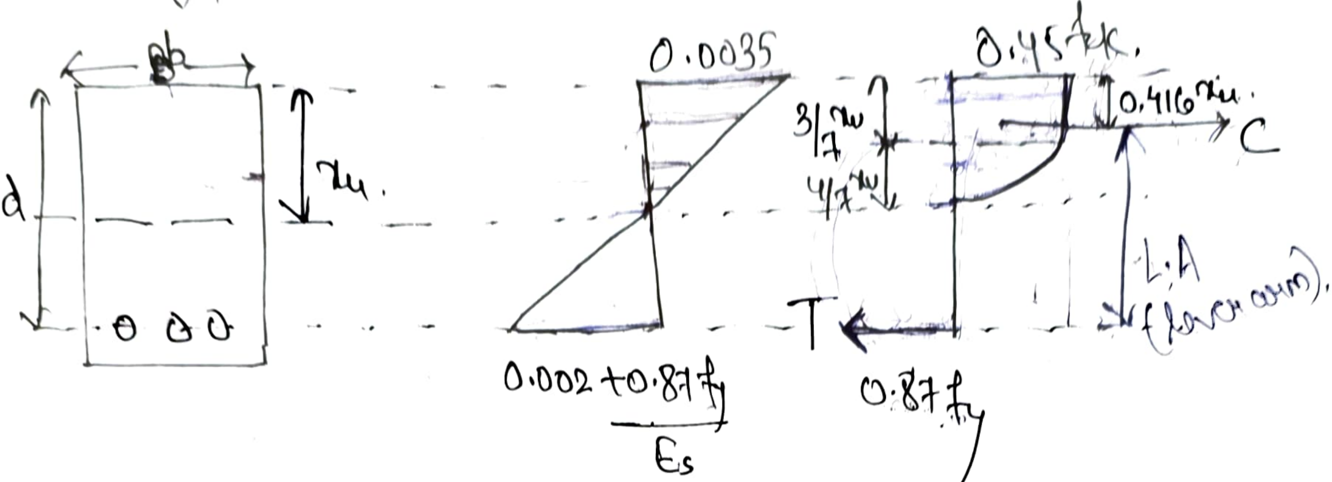
→ Ultimate load is known multiple of Maximum working load.

→ $\text{Load factor} = \frac{\text{Collapse load}}{\text{working load}}$

→ Due to large reserve strength in plastic region, the resulting member is very Slender or thin, thus give rise to deformation & crack.

→ Does not consider Serviceability requirements

Singly R/f Beam



Comp force = $0.36 f_{ck} \cdot x_u \cdot b$.

Tensile force = $0.87 f_y \cdot A_{st}$.

$$\frac{x_{u,max}}{d} = \frac{700}{1100 + 0.87 f_y}$$

For diff grade of steel –

f_y	250	415	500
$\frac{x_{u,max}}{d}$	0.53	0.48	0.46.

ie $x_{u,max}$ 0.53d 0.48d 0.46d.

Singly R/F rectangular Beams -

For equilibrium of forces -
Comp force = Tensile force.

ie $0.36 f_{ck} . x_u . b = 0.87 f_y . A_{st}$.

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

or $$\frac{x_u}{d} = 2.417 \; p_t \; f_y / f_{ck}$$

where $p_t = \frac{A_{st}}{b.d}$ (% reinforcement)

Three cases may arise -

Case i x_u/d less than limiting value.

if $x_u < x_{u,lim}$, then section is under reinforced

∴ Moment of Resistance = T. Lever arm
$= T(d - 0.42 x_u)$

$$M.R = 0.87 f_y . A_{st} (d - 0.42 x_u)$$

~~or M.R =~~ ie stress in steel reaches to its yield value before conc reaches its ultimate strain.
The type of failure here is ductile.

Case ii If. $x_u = x_{u,lim}$.

This case corresponds to Balanced section, in which the Steel reaches its yield stress at the same instant when Conc reaches its ultimate strain.

∴ Moment of Resistance is given by-

$$M.R_{lim} = 0.36\, f_{ck}\, (x_{u,lim})\, b.\, (d - 0.42\, x_{u,lim})$$

$$M.R_{lim} = 0.87\, f_y . A_{st}\, (d - 0.42\, x_{u,lim})$$

Case iii If $x_u > x_{u,lim}$

This case corresponds to over reinforced section. Maxm strain in conc reaches before yielding of steel. Hence Conc fails first and failure is sudden. This type of failure should be avoided.

Hence an over r/f section is not allowed.

$$M.R = 0.36 . f_{ck} . b . x_{u,lim}\, (d - 0.42\, x_u)$$

Design of Singly R/f Beam.

1) When size of beam is not known –

To determine – b, d and Ast.

(* Always a limiting section should be designed.)

Step 1 – Determine limiting depth of N.A

$$\frac{x_{u,lim}}{d} = \frac{700}{1100 + 0.87 f_y}$$ (or from Grade of steel)

Step 2 – Select d/b ratio between 1.5 to 3.

Step 3 Find 'd' from –

$$M_{u_{lim}} = 0.36 f_{ck}\, x_{u,lim} \cdot b \cdot (d - 0.42\, x_{u,lim}).$$

OR

$$M_{u,lim} = 0.36 f_{ck} \cdot \frac{x_{u,lim}}{d} \left(1 - 0.42 \frac{x_{u,lim}}{d}\right) b \cdot d^2$$

Step-4. Knowing value of 'b' & 'd', determine Area of reinforcement from –

$$M_{u,lim} = 0.87 \cdot f_y \cdot A_{st} (d - 0.42 x_{u,lim}).$$

Analysis of T- Beam

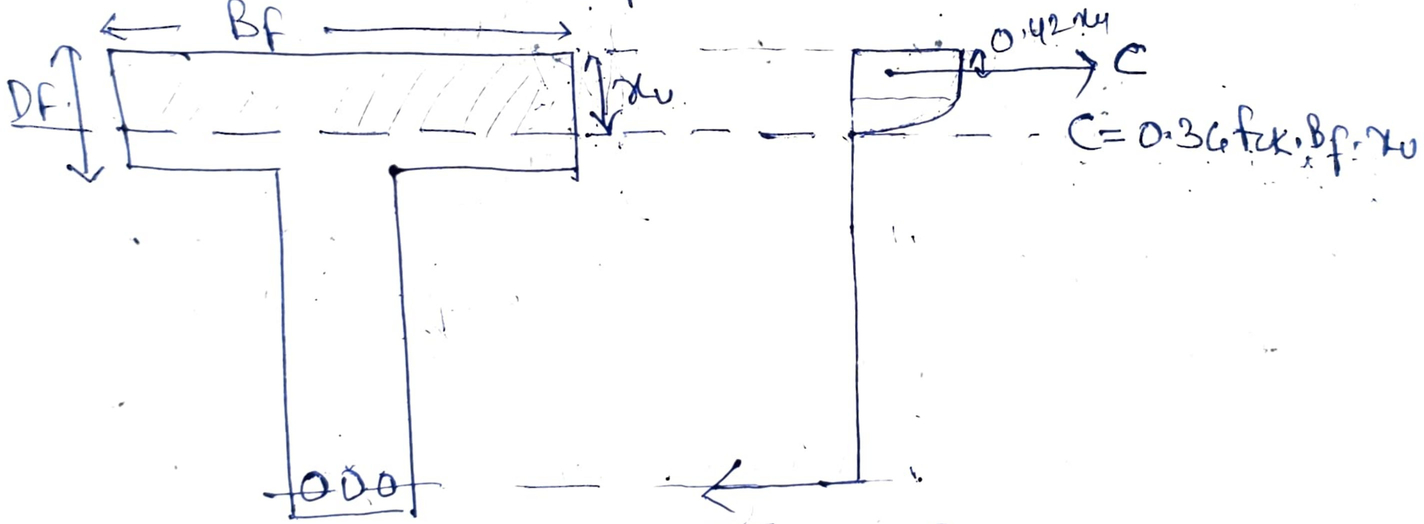
1) Limiting Depth of Neutral Axis -

$x_{u,lim} = 0.53d \rightarrow Fe-250$
$= 0.48d \rightarrow Fe\text{-}415$
$= 0.46d \rightarrow Fe\ 500$

2) Actual Depth of N.A and Moment of Resistance -

Case (i) When N.A lie in Flange Area -

ie $x_u < D_f$



In this case the section will behave as rectangular section with width = Bf.

∴ 1) Total Comp Force, $C = 0.36 \cdot f_{ck} \cdot B_f \cdot x_u$.

2) Total Tensile Force, $T = 0.87 \cdot f_y \cdot A_{st}$

3) Lever arm $= (d - 0.42 x_u)$.

4) $x_u = \dfrac{0.87 f_y \cdot A_{st}}{0.36 \cdot f_{ck} \cdot B_f}$, $M.R = 0.36 f_{ck} \cdot B_f \cdot x_u (d - 0.42 x_u)$

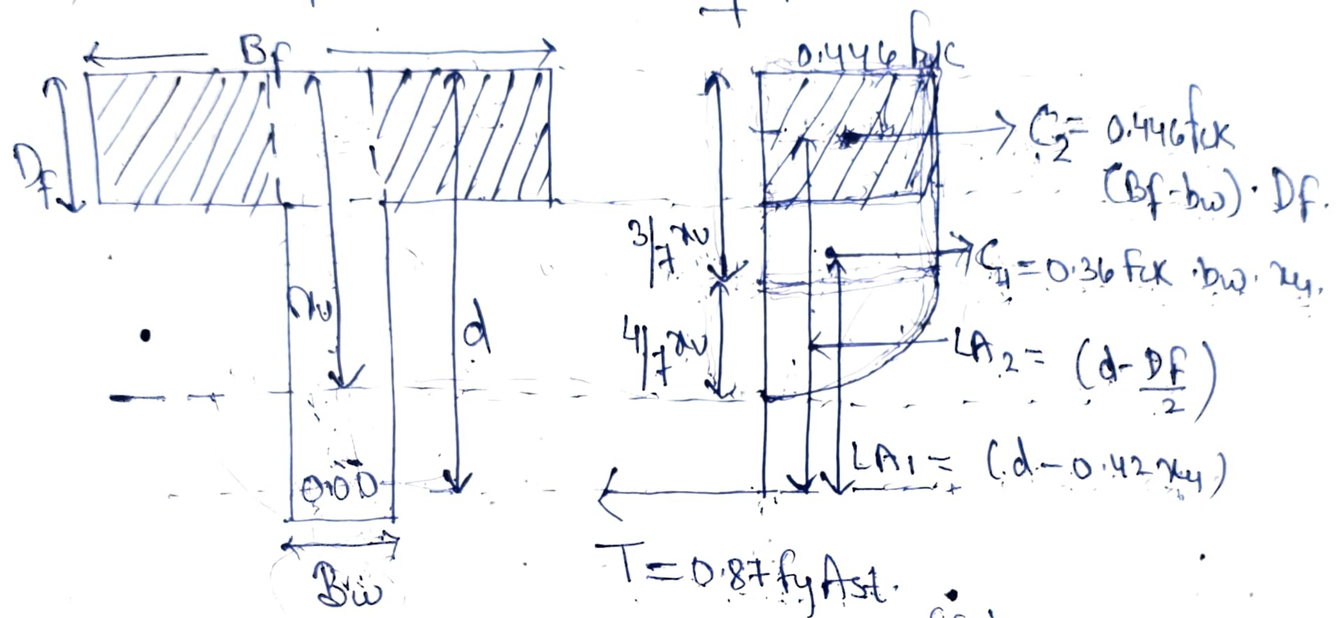
or $= 0.87 f_y A_{st} (d - 0.42 x_u)$

(Case ii) When N.A lies in web Area

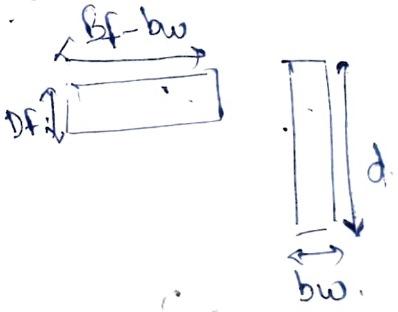
ie $x_u > D_f$.

Now two sub case arises –

a) $x_u > D_f$ but $d_f < \frac{3}{7} x_u$.



1) Total comp force



(i) for web portion –

$C_1 = 0.36\, f_{ck} \cdot b_w \cdot x_u$

$LA_1 = (d - 0.42 x_u)$

$T_1 = 0.87\, f_y\, A_{st1}$

ii) for flange portion –

$C_2 = 0.446\, f_{ck}\, (B_f - b_w)\, D_f$.

$LA_2 =$ ~~0.87~~ $\left(d - \frac{D_f}{2}\right)$

$T_2 = 0.87\, f_y\, A_{st2}$.