Design of Simply Supported Beam:

Step by step procedure:

Step: ① Determination of required Depth:
Step: ② Check for required Depth.
Step: ③ Design for flexure
Step: ④ Curtailment of Steel.
Step: ⑤ Check for development length.
Step: ⑥ Check for Shear
Step: ⑦ Detailing of reinforcement.

Problem:

A RC rectangular beam of clear span 6M is supported on 300 mm wide masonary walls and carries UDL of intensity 30 KN/m. Design the beam and provide all necessary checks and also sketch the reinforcement details? use M20 mix & HYSD steel.

Sol: Given data * Clear span = 6M
* Support width = 300 mm
* Working UDL intensity = 30 KN/m
* f_{ck} = 20 mpa & f_y = 415 Mpa.

Assume width of the beam 'b' = 300 mm.

Self weight of beam per meter = 5 KN/m.

→ Step: ① Determination of Required Depth:

= $[d_{req}]$

* Effective span: [Cl: 22.2]

Effective span (L_{eff}) = Clear span + Wall width

= 6000 + 300 = 6300 mm.

Total UDL intensity $= W_D + W_L$

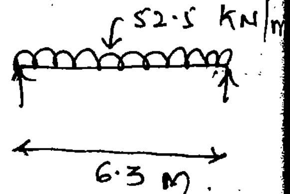
$= 5 + 30 = 35$ KN/m.

Factored UDL intensity $(W_U) = 1.5 \times W$

$= 1.5 \times 35 = 52.5$ kN/m.

Ultimate Bending moment $(M_U) = \dfrac{W_U \times l_{eff}^2}{8}$

$= \dfrac{52.5 \times 6.3^2}{8} = 260.46$ KN



We have, $M_U = 0.138 f_{ck} bd^2$

$$d_{req} = \sqrt{\frac{M_U}{0.138 f_{ck} b}}$$

$$\Rightarrow d_{req} = \sqrt{\frac{260.46 \times 10^6}{0.138 \times 20 \times 300}}$$

$\Rightarrow d_{req} = 560.86$ mm

$\therefore$ Adopt $d = 600$ mm. ; $D = d + d'$

$\Rightarrow D = 600 + 50 = 650$ mm.

Self weight of beam $= 0.3 \times 0.65 \times 25$

$= 4.875$ KN/m. < 5 KN

Hence OK

Step: ② Check for required Depth: [Cl: 23.2]

$$L/d \leq k_1 \times k_2 \times k_3 \times k_4 \times k_5$$

Where $L = 6000$ mm

$d = 600$ mm

$k_1 = 20$ [for simply supported beam]

$k_2 = 1$ [for span < 10 m]

$k_3 = k_4 = 1$ [Assume]

$k_5 = 1$ [for rectangular section]

$$\Rightarrow \frac{\cancel{6000}^{10}}{\cancel{600}} \leq 20 \times 1 \times 1 \times 1 \times 1$$

$$\Rightarrow 10 \leq 20 \quad \text{Hence ok.}$$

The beam is safe in deflection.

Step : (3) Design for flexure [Appendix G pg: No-96]
IS: 456-2000

$$M_u = 0.87 f_y A_{st} d \left[1 - \frac{f_y \times A_{st}}{f_{ck} b d}\right]$$

$$\Rightarrow 260.46 \times 10^6 = 0.87 \times 415 \times A_{st} \times 600 \times \left[1 - \frac{415 \times A_{st}}{20 \times 300 \times 600}\right]$$

$$\Rightarrow A_{st} = 1442.04 \text{ mm}^2$$

No. of bars required $= \frac{A_{st}}{A_\phi} = \frac{1442.04}{314} = 4.59 \simeq 5$ No. of bars

Assume 20 mm dia bars

Provide 5 no - 20 mm dia bars as positive moment reinforcement along the bottom edge of the beam at an effective cover of 50 mm.

A_{st} provided $= 5 \times 314 = 1570 \text{ mm}^2$ [$> 1442.04 \text{ mm}^2$]

Check for A_{st} : [cl : 26.5.1]

$$A_{st\,min} = \frac{0.85 \times b \times d}{f_y} = \frac{0.85 \times 300 \times 600}{415} = 368.67 \text{ mm}^2$$

$$A_{st\,max} = 0.04 \times b \times D = 0.04 \times 300 \times 650 = 7800 \text{ mm}^2$$

$$A_{st\,min} < A_{st} < A_{st\,max} \quad \text{Hence OK}$$

Step: ④ Curtailment of Steel / Reinforcement:

[Cl: 26.2.1]

* Required development length for 20 mm dia bar

$$\Rightarrow L_{d_{req}} = \frac{\phi \sigma_s}{4 \times \tau_{bd}}$$

$$\Rightarrow L_{d_{req}} = \frac{\phi \times 0.87 \times 415}{4 \times (1.2 \times 1.6)}$$

$$\Rightarrow L_{d_{req}} = 47\phi$$

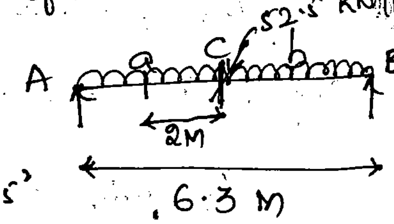
At Mid span

Development length required for positive moment reinforcement $= 47\phi + 12\phi$ or $= 47\phi + d$ } Which is greater

$\therefore$ Development length req $= 47 \times 20 + 600$

$= 1540$ mm

170.18 $\therefore$ provide the development length of 2 mm on either side of mid span of beam.



Moment at 1.15 M from support $M_u = V_A \times 1.15 - \frac{52.5 \times 1.15^2}{2}$

$V_A = \frac{wl}{2} = \frac{52.5 \times 6.3}{2}$ $\Rightarrow M_u = 155.46$ kN-m

$= 165.4$ KN

$$M_U = 0.87\, f_y\, A_{st} \times d \left[1 - \frac{f_y A_{st}}{f_{ck}\, bd}\right]$$

$$\Rightarrow 155.46 \times 10^6 = 0.87 \times 415 \times A_{st} \times 600 \times \left[1 - \frac{415 \times A_{st}}{20 \times 300 \times 600}\right]$$

$$\Rightarrow A_{st} = 789.47\ mm^2$$

No. of bars $= 789.47/314$

$= 2.51 \simeq 3$ no.

$\therefore$ 2 no - 20 mm dia bars are curtailed at distance of 2 m on either side of mid span and the remaining steel is continued into the support on same face.

Step : (5) Check for Development length :

Development length provided $= 6.3/2 - 2M$

$= 3.15 - 2 = 1.15\ M$

$= 1150\ mm$

$\nless 47\phi = \frac{47 \phi}{3} = 313.3\ mm$

At support $L_d \leq \frac{M}{B} + L_0$

Where $M = 0.87\, f_y\, A_{st} \times d \left[1 - \frac{f_y A_{st}}{f_{ck}\, bd}\right]$

Where $A_{st} = 3 \times 314$

$= 942\ mm^2$

$$\therefore M_U = 0.87 \times 415 \times 942 \times 600 \left[1 - \frac{415 \times 942}{20 \times 300 \times 600}\right]$$

$$\Rightarrow M_U = 181.9 \times 10^6\ kN\text{-}m$$

$V = \frac{wL}{2} = 165.4$ KN.

Initially assume $L_0 = 0$

$L_d \leq M/_{BV}$

$\Rightarrow 47\phi \leq \frac{181.9 \times 10^6}{165.4 \times 10^3}$

$\Rightarrow 47\phi \leq 1.09 \times 10^3$

$\Rightarrow \phi \leq \frac{1.09 \times 10^3}{47}$

$\Rightarrow \phi \leq 23.39$ mm.

[20 < 23.39] Hence ok

provide a 90° bend beyond the center of the support.

~~Anchorage~~ length $L_0 = 8\phi = 8 \times 20 = 160$ mm.

Step: (6) Check for shear: [Cl : 40]

Nominal shear stress $= \tau_v = V_u/_{bd} = \frac{165.4 \times 10^3}{300 \times 600}$

$\Rightarrow \tau_v = 0.91$ mpa.

Design shear stress $= \tau_c = 0.49$ mpa [from tab

$P_t = \frac{100 \, A_{st}}{bd} = \frac{100 \times 942}{300 \times 600}$

$\Rightarrow P_t = 0.52\%$.

Maximum shear capacity $\tau_{c\,max} = 2.8$ mpa.

* $\tau_v < \tau_{c\,max}$ — ok

* $\tau_v > \tau_c$

Assume 8 mm dia 2 legged vertical stirrupe

$$A_{sv} = 2 \times \frac{\pi}{4} \times 8^2 = 100.5 \text{ mm}^2$$

$$V_{us} = V_u - \tau_c bd$$

$$= 165.4 \times 10^3 - 0.49 \times 300 \times 600$$

$$V_{us} = 77.2 \text{ KN}$$

$$S_{v_1} = 0.87 f_y A_{sv} d / V_{us}$$

$$= \frac{0.87 \times 415 \times 100.5 \times 600}{77.2 \times 10^3}$$

$$\Rightarrow S_{v_1} = 282 \text{ mm}.$$

$$S_{v_2} = 0.75 d = 0.75 \times 600 = 450 \text{ mm}$$

$$S_{v_3} = 300 \text{ mm}$$

∴ provide 8 mm dia 2 legged vertical stirrupe at 250 mm center to center.

→ check for A_{sv} :

$$\frac{A_{sv}}{b s_v} \geq \frac{0.4}{0.87 f_y}$$

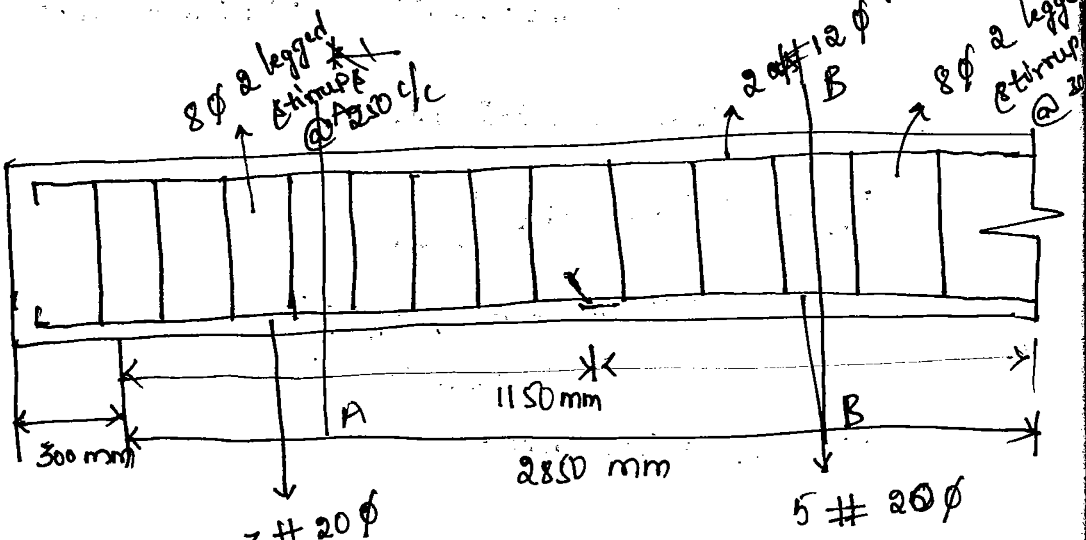
$$\Rightarrow A_{sv} \geq \frac{0.4 \times b \cdot s_v}{0.87 f_y}$$

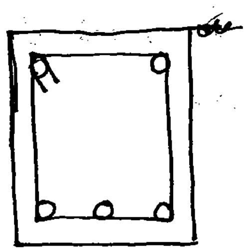
$$\Rightarrow A_{sv} \geq \frac{0.4 \times 300 \times 250}{0.87 \times 415}$$

$$\Rightarrow A_{sv} \geq 83 \text{ mm}^2 \quad [\because < 100.5 \text{ mm}^2]$$

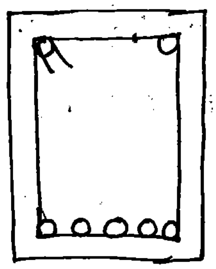
Hence ok

Step: (7) Detailing of reinforcement:





Section A-A



Section B-B