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Torsion

1. Shear & Torsion

equivalent shear 'Ve' is calculated

$$V_e = V_u + 1.6\frac{T_u}{b}$$

P.N. 75

where V_e = equ shear, V_u = Factored shear
T_u = Torsional moment, b = width of beam

Equivalent nominal shear stress to be given by

$$\tau_{ve} = \frac{V_e}{bd}$$

The value of τ_{ve} shall not exceed τ_{cmax}.

2. R/F in members subjected to torsion -

If the equivalent nominal shear stress τ_{ve} does not exceed τ_c, then min. shear R/F shall be provided.
If τ_{ve} exceeds τ_c, then R/F is required.

(a) Longitudinal Reinforcement - The longitudinal R/F shall be designed to resist an equivalent Bending moment M_{e1} given by

$$M_{e1} = M_u + M_t$$

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where M_{t} = factored bending moment

$$M_t = T_u\left(\frac{1 + D/b}{1.7}\right)$$ T_u = torsional moment

P.N. 75

If the value of $M_t > M_u$, then R/f is provided in compression zone also. corresponding to the moment M_{e2}.

$$M_{e2} = M_t - M_u$$

(b) Transverse Reinforcement - 2 legged closed hoops enclosing the corner longitudinal bars shall have an area of cross section A_{sv} given by

$$A_{sv} = \frac{T_u s_v}{b_1 d_1 (0.87 f_y)} + \frac{V_u s_v}{2.5 d_1 (0.87 f_y)}$$

however the total R/f shall not be less than $\frac{(\tau_{ve} - \tau_c) b \cdot s_v}{0.87 f_y}$

S_v = Spacing of stirrups

b_1 = c/c distance b/w corner bars in the direction of width

d_1 = c/c distance b/w corner bars in the direction of depth.

Q. Determine the R/f required for a rectangular beam section
width of section – 300mm , factored BM = 80kN m
Depth of – 500mm factored torsional Moment = 40kNm
factored shear force = 70kN , use M15 & Fe415

1. Equivalent Shear

Total depth D = 500mm

Assume 20 mm dia bars, 25mm clear cover & 10mm stirrups.

$$d = 500 - \frac{20}{2} - 25 - 10 = 455\,mm$$

$$V_e = V_u + \frac{1.6\,T_u}{b} = 70 + \frac{1.6 \times 40}{0.3} = 283.33\,kN$$

$$\tau_{ve} = \frac{283.33 \times 10^3}{300 \times 455} = 2.07\,N/mm^2$$

τ_{cmax} for M15 = $2.5\,N/mm^2$ [Table 20]

$\tau_{cmax} > \tau_{ve}$ hence ok

2. Longitudinal R/f

$$M_{e1} = M_u + M_t$$

$$M_t = T_u\left[\frac{1 + D/b}{1.7}\right] = 40\left[\frac{1 + 0.5/0.3}{1.7}\right]$$
$$= 62.745\,kNm$$

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$Me_1 = 80 + 62.745 = 142.745\ kNm$

The moment of Resistance of balanced section is given by.

$$Mulim = 0.36\, f_{ck} \frac{x_{umax}}{d} \left[1 - 0.42 \frac{x_{umax}}{d}\right] bd^2$$

here $\frac{x_{umax}}{d} = 0.48$ for Fe415

or = $Mulim = 0.138\, f_{ck} bd^2$

$\Rightarrow 0.138 \times 15 \times (300)(455)^2 = 128.5 \times 10^6$ Nmm

~~Space~~ ~~[illegible]~~ ~~the~~ ~~section~~ ~~[illegible]~~

~~[illegible]~~

To calculate Area of steel

$$A_{st} = \frac{0.5 f_{ck}}{f_y} \left[1 - \sqrt{1 - \frac{4.6\, Me_1}{f_{ck} \cdot bd^2}}\right] bd$$ ★★

$$\Rightarrow \frac{0.5 \times 15}{415} \left[1 - \sqrt{1 - \frac{4.6 \times 142.745 \times 10^6}{15 \times 300 \times 455^2}}\right] \times 300 \times 455$$

$\Rightarrow 1126\ mm^2$

provide 4–20 mm ϕ having total $A_{st} = 4 \times 314 = 1256\ mm^2$
provide 2–12 mm ϕ ~~[illegible]~~ hanger bars.

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3. Transverse R/f

$$\frac{100 \cdot A_{st}}{bd} = \frac{100 \times 1256}{300 \times 455} = 0.92\%$$

for M15

$$\tau_c = 0.54 + \frac{0.60 - 0.54}{0.25} \times 0.17 = 0.58 \text{ N/mm}^2$$

since $\tau_{ve} > \tau_c$ hence shear design reqd.

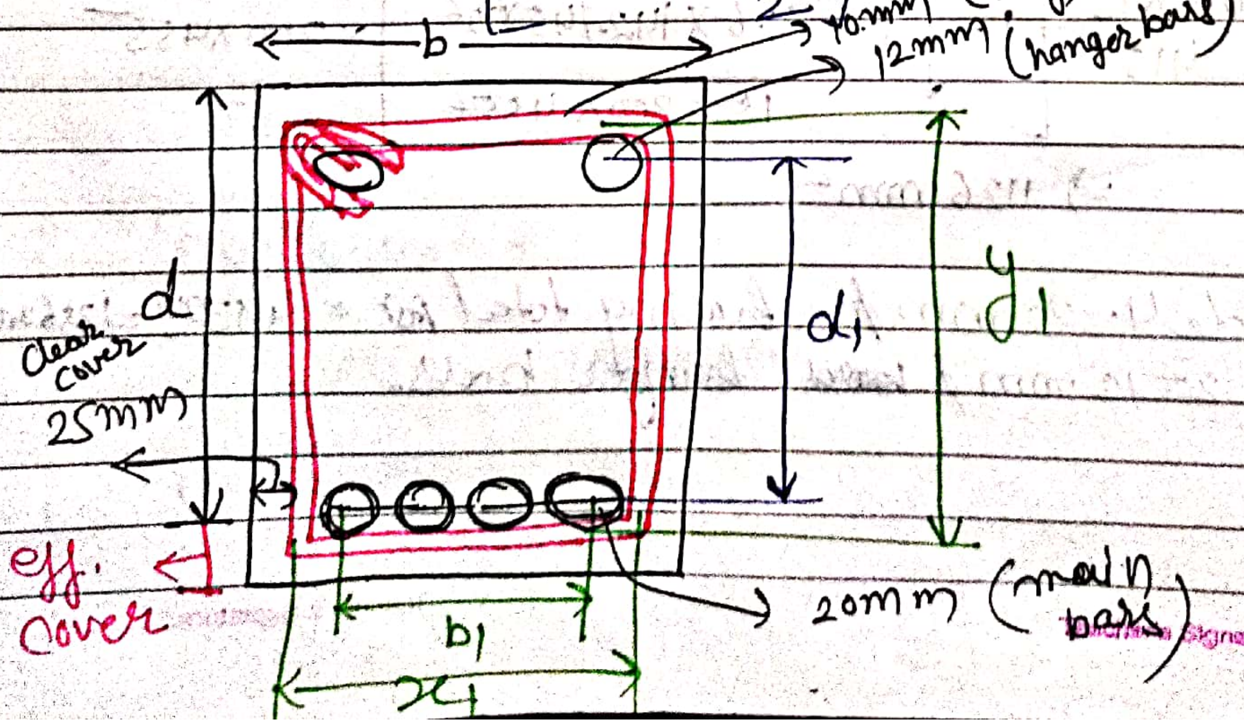
The area of 2 legg stirrup should satisfy

$$A_{sv} = \frac{T_u \cdot S_v}{b_1 d_1 \, 0.87 f_y} + \frac{V_u \cdot S_v}{2.5 d_1 (0.87 f_y)}$$

Assuming dia of stirrups as 10mm

$$d_1 = 500 - \left(25 + 10 + \frac{20}{2}\right) - 25 + 10 + \frac{12}{2} = 414\text{mm}$$

$$b_1 = 300 - 2\left[25 + 10 + \frac{20}{2}\right] = 210\text{mm}.$$



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$$\frac{A_{sv}}{S_v} = \frac{40\times10^6}{210\times414\times361} + \frac{70\times10^3}{2.5\times414\times361}$$

$$\frac{A_{sv}}{S_v} = 1.457 \text{ mm}$$

Also area of all the legs of stirrups should satisfy

$$A_{sv} = \frac{(\tau_{ve} - \tau_c)\, b.S_v}{0.87 f_y}$$

$$\Rightarrow \frac{A_{sv}}{S_v} = \frac{(2.07 - 0.58)\times 300}{361} = 1.24 \text{ mm}$$

Choosing the greater one of the 2 we have

$$\frac{A_{sv}}{S_v} = 1.457$$

hence $S_v = \frac{A_{sv}}{1.45} = \frac{2\times\frac{\pi}{4}\times10^2}{1.45} = 108 \text{ mm}$

hence provide stirrups @ 100mm c/c.

As per codal requirement spacing should not exceed x_1, $(x_1+y_1)/4$ & 300 mm.

where x_1 = short dimension of stirrups $= 300 - 2(25+5) = 240$ mm

y_1 = longer dimension of stirrup $= 500 - 2(25+5) = 440$ mm

$$\frac{x_1+y_1}{4} = \frac{240+440}{4} = 170 \text{ mm}$$

hence 10 mm ϕ 2 legged @ 100 mm c/c.

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