

Engineering Analysis Diagrams

Geometry

RC section design torsion - Section

Shape	rectangle
Width	400 mm
Height	600 mm
Effective depth	450 mm
Shear Rebar.notation	R12@150c/c

Design action

RC section design torsion - Design action

My	185 kNm
Fy	225 kN
Mx	55 kNm

Material

RC section design torsion - Material

Concrete.strength	28 MPa
Steel.strength	500 MPa

RC Section Design Torsion

For diagram, we assumed:

$$\text{cover, } c = 50 \text{ mm}$$

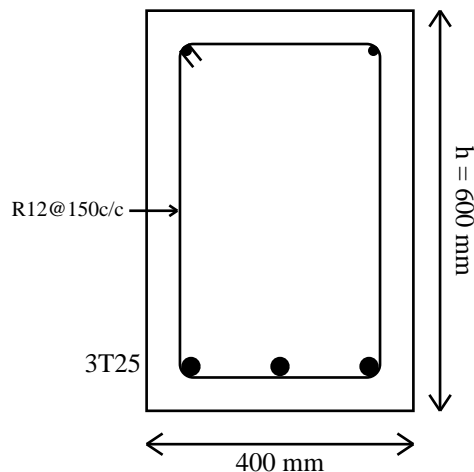


Fig. 1 RC Beam Section

Effective thickness of walls

$$\begin{aligned}
 t_{ef,i} &= \frac{b * h}{2 * (b + h)} \\
 &= \frac{400 \text{ mm} * 600 \text{ mm}}{2 * (400 \text{ mm} + 600 \text{ mm})} \\
 &= 120 \text{ mm}
 \end{aligned}$$

(Fig. 6.11)

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Area enclosed by line of wall $A_k = (b - t_{ef,i})(h - t_{ef,i})$
 $= (400 \text{ mm} - 120 \text{ mm})(600 \text{ mm} - 120 \text{ mm})$
 $= 134400 \text{ mm}^2$
 (Fig. 6.11)

Perimeter for line of wall $U_k = 2 * ((b - t_{ef,i}) + (h - t_{ef,i}))$
 $= 2 * ((400 \text{ mm} - 120 \text{ mm}) + (600 \text{ mm} - 120 \text{ mm}))$
 $= 1040 \text{ mm}$
 (Fig. 6.11)

Strength Reduction Factor of Concrete $v = 0.6 * (1 - f_{ck}/250)$
 $= 0.6 * (1 - 28 \text{ MPa}/250)$
 $= 0.53$
 (Eq. 6.6N)

Design shear stress $v_{t,Ed} = V_{Ed,max} / (b * d)$
 $= 225 \text{ kN} / (400 \text{ mm} * 450 \text{ mm})$
 $= 1.25 \text{ MPa}$

Torsion shear stress $t_{t,Ed} = \frac{T_{Ed,max}}{2 * A_k * t_{ef,i}}$
 $= \frac{55 \text{ kNm}}{2 * 134400 \text{ mm}^2 * 120 \text{ mm}}$
 $= 1.71 \text{ MPa}$
 (Eq. 6.26)

Concrete Strut Angle $\theta = 0.5 * \text{Asin}\left(\frac{2 * (v_{t,Ed} / 0.9 + t_{t,Ed})}{\alpha_{cw} * f_{cd} * v}\right)$
 $= 0.5 * \text{Asin}\left(\frac{2 * (1.25 \text{ MPa} / 0.9 + 1.71 \text{ MPa})}{1 * 28 \text{ MPa} * 0.53}\right)$
 $= 12.34^\circ < 21.8^\circ$, take $\theta = 21.8^\circ$
 (Cl. 6.2.3(2))

Maximum Torsional Resistance $T_{Rd,max} = 2 * v_1 * \alpha_{cw} * f_{cd} * A_k * t_{ef,i} * \sin(\theta) * \cos(\theta)$
 $= 2 * 0.53 * 1 * 28 \text{ MPa} * 134400 \text{ mm}^2 * 120 \text{ mm} * \sin(21.8) * \cos(21.8)$
 $= 165.05 \text{ kNm}$
 (Eq. 6.30)

$$\begin{aligned} \text{Maximum Shear Resistance } V_{Rd,max} &= \frac{\alpha_{cw} * b * 0.9 * d * v_1 * f_{cd}}{\cot(\theta) + \tan(\theta)} \\ &= \frac{1 * 400 \text{ mm} * 0.9 * 450 \text{ mm} * 0.53 * 28 \text{ MPa}}{\cot(21.8) + \tan(21.8)} \\ &= 828.95 \text{ kN} \end{aligned}$$

(Eq. 6.9)

$$\begin{aligned} \text{Combine Check for Concrete Section} &= \frac{T_{Ed,max}}{T_{Rd,max}} + \frac{V_{Ed,max}}{V_{Rd,max}} \\ &= \frac{55 \text{ kNm}}{165.05 \text{ kNm}} + \frac{225 \text{ kN}}{828.95 \text{ kN}} \\ &= 0.6 \leq 1, \text{ pass} \end{aligned}$$

(Eq. 6.29)

$$\begin{aligned} \text{Torsional Resistance Moment } T_{Rd,c} &= 2 * A_k * f_{ct,d} * t_{ef,i} \\ \text{without Reinforcement} &= 2 * 134400 \text{ mm}^2 * 28 \text{ MPa} * 120 \text{ mm} \\ &= 903.17 \text{ kNm} \end{aligned}$$

(Eq. 6.26)

$$\begin{aligned} \text{Concrete Factor } C_{Rd,c} &= \frac{0.18}{\gamma_c} \\ &= \frac{0.18}{1.5} \\ &= 0.12 \end{aligned}$$

(N.A. Cl.6.2.2(1))

$$\begin{aligned} \text{Reinforcement Ratio } \rho_1 &= \min\left(\frac{A_{sl}}{d * b}, 0.02\right) \\ &= \min\left(\frac{1472.62 \text{ mm}^2}{450 \text{ mm} * 400 \text{ mm}}, 0.02\right) \\ &= 0.008181 \end{aligned}$$

(Cl.6.2.2(1))

$$\begin{aligned} \text{Depth factor, k} &= 1 + (200/d)^{0.5} \\ &= 1 + (200 \text{ mm}/450 \text{ mm})^{0.5} \\ &= 1.67 \end{aligned}$$

(Cl. 6.2.2(1))

$$\begin{aligned} \text{Minimum Shear Stress } v_{min} &= 0.035 * k^{3/2} * (f_{ck})^{0.5} \\ &= 0.035 * 1.67^{3/2} * (28 \text{ MPa})^{0.5} \\ &= 0.4 \text{ MPa} \end{aligned}$$

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Design Shear Resistance $V_{Rd,c} = C_{Rd,c} * k * (100 * \rho_1 * f_{ck})^{1/3} * b * d$
 (Eq. 6.2a) $= 0.12 * 1.67 * (100 * 0.008181 * 28 \text{ MPa})^{1/3} * 400 \text{ mm} * 450 \text{ mm}$
 $= 102.45 \text{ kN}$

Combine Check for Concrete Section $= \frac{T_{Ed,max}}{T_{Rd,c}} + \frac{V_{Ed,max}}{V_{Rd,c}}$
 (Eq. 6.31) $= \frac{55 \text{ kNm}}{903.17 \text{ kNm}} + \frac{225 \text{ kN}}{102.45 \text{ kN}}$
 $= 2.26 > 1, \text{ Torsional Reinforcement Required!}$

Required Area of Additional Longitudinal Reinforcement for Torsion $A_{sl,req} = \frac{T_{Ed,max} * U_k * \cot(\theta)}{2 * A_k * f_{yd}}$
 (Eq. 6.28) $= \frac{55 \text{ kNm} * 1040 \text{ mm} * 2.5}{2 * 134400 \text{ mm}^2 * 434.78 \text{ MPa}}$
 $= 1223.59 \text{ mm}^2$

Suggested Longitudinal Side Rebars Arrangement

bars	area	util_ %
4T20	1256.64	97.4
12T12	1357.17	90.2
8T16	1608.5	76.1

Required Area for vertical reinforcement $\frac{A_{sw,req}}{s} = \frac{T_{Ed,max}}{2 * A_k * f_{yd} * \cot(\theta)}$
 $= \frac{55 \text{ kNm}}{2 * 134400 \text{ mm}^2 * 434.78 \text{ MPa} * 2.5}$
 $= 0.19 \text{ mm}^2/\text{m}$

Maximum Vertical Rebar Spacing $s_{w,max} = \min(\frac{U_k}{8}, b, d)$
 $= \min(\frac{U_k}{8}, 400 \text{ mm}, 450 \text{ mm})$
 $= 400 \text{ mm}$

Suggested Vertical Rebars Arrangement

Bar Dia.	n_legs	spacing	As_s(mm2/m)	notation
8	2	200	0.5027	R8@200 2 legs
12	2	200	1.131	R12@200 2 legs
16	2	200	2.0106	R16@200 2 legs

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20	2	200	3.1416	R20@200 2 legs
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