Internal Assessment Test 2 Solution – December 2022

Sub:	Design Of RC Structural Elements	SubCode:	18CV53	Branch:	Civil

1	A RCC beam 250mm wide and 450 mm deep is reinforced with 3 numbers of 20mm dia bars of grade Fe415, on the tension side with an effective cover of 50mm. If the shear reinforcement of 2 legged 8mm dia stirrups at a spacing of 160mm c/c is provided at a section, determine the design ultimate shear strength of the section. Assume M20 concrete.

Q7) $b = 250\ mm$

$d = 450 - 50 = 400\ mm$

$A_{st} = 3 \times \frac{\pi}{4} \times 20^2 = 942.47\ mm^2$

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

$S_v = 160\ mm$

$f_{ck} = 20\ MPa$

$f_y = 415\ MPa$

i) Percentage of steel in tension

$$P_t = \frac{A_{st}}{bd} \times 100 = \frac{942.47}{250 \times 400} = 0.94$$

ii) From table 19 (Shear strength of concrete)

0.75	0.56
0.94	?
1.00	0.62

$\tau_c = 0.606\ N/mm^2$

iii) Shear resisted by concrete

$V_c = \tau_c bd = 0.606 \times 250 \times 400 = 60.6\ kN$

iv) Shear resisted by vertical stirrups

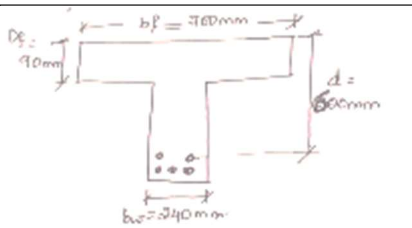
$$V_{us} = \frac{0.87 \times 415 \times 100.5 \times 400}{160} = 90.7\ kN$$

v) Total shear strength

$V_u = V_c + V_{us}$

$= 60.6 + 90.7 = 151.3\ kN$

2	A T – beam having a width of flange 700 mm and depth of flange 90mm. Effective depth of beam is 600mm, width of web is 240mm reinforced with 5 bars of 25mm dia on tension side. Find moment of resistance of the section. Use M15 grade concrete and Fe415 grade steel.



$A_{st} = 5 \times \frac{\pi}{4} \times (25^2) = 2454.375 mm^2$

Solⁿ:– Assuming that N.A lies within the flange.

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

$x_u = \frac{0.87 \times 2454.375 \times 415}{0.36 \times 15 \times 700 \times 600} \times 600$

$= 234.43mm$

$x_u > d_f$ ∴ N.A lies outside the flange.

∴ Our assumption is wrong.

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} y_f (b_f - b_w) = 0.87 A_{st} \cdot f_y$.

$y_f = (0.15 x_u + 0.65 D_f) \nless D_f$.

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} (0.15 x_u + 0.65 D_f)(b_f - b_w) = 0.87 A_{st} \cdot f_y$.

$\boxed{x_u = 400mm}$

$y_f = 0.15 \times 400 + 0.65 \times 90 = 118.5 > D_f$. Hence not OK.

Taking $y_f = D_f$.

$0.36 f_{ck} b_w x_u + 0.45 f_{ck} \cdot D_f (b_f - b_w) = 0.87 A_{st} \cdot f_y$.

∴ $x_u = 468.134mm$

Compare x_u & x_{umax}

$x_u > x_{umax}$, Hence the section is over reinforced

taking $x_u = x_{umax}$.

$D_f/d \leq 0.2$.

$90/600 = 0.15 \leq 0.2$

∴ $M_u = 0.36 \frac{x_{umax}}{d} \left(1 - 0.42 \frac{x_{umax}}{d}\right) f_{ck} \cdot b_w \cdot d^2 + 0.45 f_{ck} (b_f - b_w) D_f (d - D_f/2)$

Mu =

3 A rectangular RCC beam is of 250mm x 500mm overall size with an effective cover of 50mm on both the tension and compression sides. It is reinforced with 4 bars of 20mm bars on compression sides. Calculate the steel on tension side with 20mm bars and find the total moment of resistance of the section. Use M25 concrete and Fe415 steel.

$A_{sc} = 1256\ mm^2$, $b = 250\ mm$, $D = 550\ mm$.
$d' = 50\ mm$, $f_{ck} = 25\ N/mm^2$, $f_y = 415\ N/mm^2$.

Ans: To make the beam section fully effective, should be balanced section.

$$x_u = x_{ulim} = 0.48\,d = 0.48 \times 500 = 240\ mm.$$

$$\epsilon_{sc} = 0.0035\left(1 - \frac{d'}{x_u}\right) = 2.7708 \times 10^{-3}.$$

Table A $\quad f_{sc} = 351.9\ N/mm^2$

$$0.36 f_{ck}\, x_u b + f_{sc} A_{sc} = 0.87 f_y A_{st}$$

$$\therefore A_{st} = 2720\ mm^2$$

$\therefore$ 20mm ϕ bars. $\quad$ No. of bars $= \dfrac{2720}{\pi/4 \times 20^2} = \underline{\underline{8.65}}$

To keep section under reinforced, select only 8 bars.

$$A_{st} = \pi/4 \times 8 \times 20^2 = 2513\ mm^2$$

Exact x_u is found by trial & error method.

Trial 1 $\quad$ let $x_u = 236\ mm$.

$\epsilon_{sc} = 2.7584 \times 10^{-3}$

$f_{sc} = 351.7\ N/mm^2$

$C_u = T_u$.

$$0.36 \times 25 \times 250 x_u + 351.7 \times 1256 = 0.87 \times 415 \times 2513.$$

$\therefore x_u = 206.9\ mm$ is not close to assumed x_u.

Trial 2 $\quad$ let $x_u = 220\ mm$.

$\epsilon_{sc} = 2.7045 \times 10^{-3}$

$f_{sc} = 351.7\ N/mm^2$

$\therefore C_u = T_u$.

$x_u = 207.15\ mm$ is not close to assume x_u

Trial 3 $\quad x_u = 210\ mm$.

$\epsilon_{sc} = 2.667 \times 10^{-3}$

$f_{sc} = 349.23\ N/mm^2$

$C_u = T_u$.

$$0.36 f_{ck} x_u b + f_{sc} A_{sc} = 0.87 f_y A_{st}$$

$$x_u = 208.30.$$

Let take $x_u = 209\ mm$.

$f_{sc} = 349.23\ N/mm^2$

$$M_u = 391.23 \times 10^6 = 391.23\ kN\text{-}m.$$

4	An isolated simply supported T beam has a flange width of 2400mm and flange thickness of 120mm. The effective span of beam is 3.6m. The effective depth of beam is 580mm and its width 300mm. It is reinforced with 8 – 20mm diameter Fe415 bars. Determine the moment of resistance of the section. Use M20 concrete.

Data :- $b = 2400\,mm$ $D_f = 120mm$

$b_w = 300mm$ $d = 580mm$

$A_{st} = 8 \times \frac{\pi}{4}(22^2)$ $f_{ck} = 20N/mm^2$

$= 3041\,mm^2$ $f_y = 415N/mm^2$

$l = 3.6m = 3600mm$

Effective width of flange (b_f)

$$b_f = \frac{l_o}{\frac{l_o}{b} + 4} + b_w$$

$l_o = l = 3600mm$

$$b_f = \frac{3600}{\frac{3600}{2400} + 4} + 300 = 954.54mm < \text{actual width } (b = 2400mm)$$

Depth of neutral axis (x_u)

Assuming neutral axis lies in the flange.

$$x_u = \frac{0.87 f_y A_{st}}{0.36 f_{ck} \cdot b_f} = \frac{0.87 \times 415 \times 3041}{0.36 \times 20 \times 954.54}$$

$= 159.75mm > D_f$

Hence, our assumption was wrong.

The value of x_u is slightly more than D_f. Therefore, it may be the case :-

$$D_f > \frac{3}{7} x_u \quad \text{or} \quad \frac{D_f}{x_u} > 0.43$$

The depth of neutral axis can be found by using

$$0.36 f_{ck} \cdot b_w x_u + 0.45 f_{ck} Y_f (b_f - b_w) = 0.87 f_y \cdot A_{st}$$

	$0.36 \times 20 \times 300 x_u + 0.45 \times 20 \times y_f (954.54 - 300) = 0.87 \times 415 \times 3041$ $2160 x_u + 5890.94 y_f = 1097953$ $y_f = 0.15 x_u + 0.65 D_f$ $= 0.15 x_u + 0.65 \times 120$ $= 0.15 x_u + 78$ $\therefore 2160 x_u + 5890.94 (0.15 x_u + 78) = 1097953$ $3043.64 x_u = 638459.68$ $x_u = 209.76 mm$ $\frac{3}{7} x_u = \frac{3}{7} \times 209.76 = 90.2 mm < D_f$ Hence our assumption was correct. $x_{umax} = 0.48d$ $= 278.4 mm$ $x_{umax} > x_u$. Hence, the section is under reinforced. $y_f = 0.15 \times 209.76 + 0.65 \times 120$ $= 109.46 mm < D_f$ Hence OK. Moment of resistance of the section (M_u). $M_u = 0.36 \frac{x_u}{d} (1 - 0.42 \frac{x_u}{d}) f_{ck} b_w d^2 + (0.45 f_{ck} (b_f - b_w) y_f (d - \frac{y_f}{2})$ $= 0.36 \times \frac{209.76}{580} (1 - \frac{0.42 \times 209.76}{580}) \times 20 \times 300 \times 580^2 +$ $0.45 \times 20 (954.54 - 300) \times 109.46 (580 - \frac{109.46}{2})$ $= 562500695 N\text{-}mm$ $= 562.5 kN\text{-}m$
5	Calculate the moment of resistance of a RC beam of rectangular section 250mm wide and 500mm deep, if it is reinforced with 6 – 20mm bars on tension side and 2 number of bars on compression side. Assume steel of grade Fe250 and concrete of grade M20. Effective cover provided is 40mm on both sides.

	Sol^n

$b = 250mm$, $D = 500mm$, $d' = 40mm$, $d = 500 - 40 = 460mm$

$f_{ck} = 20N/mm^2$ $f_y = 250 N/mm^2$

$A_{st} = 6 \times \frac{\pi}{4} \times 20^2 = 1885 mm^2$, $A_{sc} = 2 \times \frac{\pi}{4} \times 20^2 = 628mm^2$

Assuming compression as well as tensile steel yielded.

$f_{sc} = f_{st} = 0.87 f_y$.

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

$0.36 \times 20 \times x_u \times 250 + 0.87 \times 250 \times 628 = 0.87 \times 250 \times 1885$

$\therefore x_u = 151.89 mm$

$x_{u lim} = 0.53d = 0.53 \times 460 = 243.8mm$.

$x_u < x_{u lim}$ or $x_{u max}$. $\therefore$ Tensile steel has yielded.

Strain in compression steel.

$$\epsilon_{sc} = 0.0035\left(1 - \frac{d'}{x_u}\right) = 0.0035 \times \left(1 - \frac{40}{151.89}\right)$$
$$= 2.578 \times 10^{-3}$$

Minimum strain at which yielding starts in compression steel.

$$\epsilon_y = 0.87 \frac{f_y}{E_s} + 0.002 = 1.0875 \times 10^{-3}$$

$\therefore \epsilon_{sc} > \epsilon_y$

$\therefore$ Assumption that stress in compression steel is $0.87 f_y$ is correct. $\therefore x_u = \underline{151.89 mm}$

$$M_u = 0.36 f_{ck} x_u b (d - 0.42 x_u) + f_{sc} A_{sc} (d - d')$$
$$= 165.69 kN\text{-}m$$