$$= \frac{\quad}{4 \times 1.2}$$

$$= \frac{25 \times 0.87 \times 415}{4 \times 1.2}$$

$$= 1880.46 \text{ mm}$$

Q: Design a RC beam of rectangular section using the following data

effective span = 5m

width of beam = 250mm

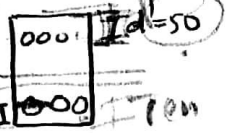
Overall depth D = 500mm

Service load including DL and LL = 40 kN ⇒ w

Effective cover = 50mm

Material M20 Concrete

Fe 415 Steel.



STEP 1 COMPUTATION OF BEAM DIMENSION

effective cover = clear cover + $\phi/2$

$l_{eff} = 5$ m

D = 500 mm

$\frac{l}{d} = 12$ $\quad d = \frac{5000}{12}$

or

D − eff cover = d

$d = 500 - 50 = 450$

$d' = 50$

$b = 250$

$f_{ck} = 20$ N/mm²

$f_y = 415$ N/m²

$$BM = \frac{wl^2}{8}$$

$$= \frac{40 \times 5^2}{8}$$

$$= 125$$

$$M_u = 125 \times 1.5$$

$$= 187.5$$

STEP 3 SINGLY / DOUBLY

cl. G1.1.1.c

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

$$= 0.36 \times 0.48 \left[1 - 0.42 \times 0.48\right] \times 250 \times 450^2 \times 20$$

$$= 139688064$$

$$= 139.688 \text{ kNm}$$

$c + \frac{\phi}{2}$

$Mu > Mu_{limit}$

∴ Doubly reinforced.

SKIP STEP 4

STEP 5 : COMPUTATION OF REINFORCEMENT

$$Mu_{limit} = 0.87 f_y A_{st_1} d\left[1 - \frac{A_{st_1} f_y}{bd f_{ck}}\right]$$

$$139.688 \times 10^6 = 0.87 \times 415 A_{st_1} \times 450 \left[1 - \frac{A_{st_1} 415}{250 \times 450 \times 20}\right]$$

$$859.76 = A_{st_1} - A_{st_1}^2 \times 1.84 \times 10^{-4}$$

$x = 1070.6, 4364.08$

$A_{st_1} = 1070.6$

WEDN Annexure G.1.2 of 456:2000

$M_u - M_{u_{limit}} = f_{sc} A_{sc} (d - d')$

Strain,

$$\varepsilon_{sc} = 0.0035 \left[\frac{x_{umax} - d'}{x_{umax}} \right]$$

$$= 0.0035 \left[\frac{0.48d - d'}{0.48d} \right]$$

$$= 0.0035 \left[\frac{0.48 \times 450 - 50}{0.48 \times 450} \right]$$

$$= 2.68 \times 10^{-3}$$

from fig. 3 of SP16

$f_{sc} = 350 \ N/mm^2$

Annex G.1.2 of 456:2000

$M_u - M_{ulimit} = f_{sc} A_{sc} (d - d')$

$(87.5 - 139.688) 10^6 = f_{sc} A_{sc} (450 - 50)$

$47.812 \times 10^6 = f_{sc} A_{sc} \times 400$

$$A_{sc} = \frac{47.812 \times 10^6}{350 \times 400}$$

$$= 341.51 \ mm^2$$

cl. G.1.2 of IS 456:2000

$$A_{st_2} = \frac{A_{sc} f_{sc}}{0.87 f_y}$$

$$= \frac{341.51 \times 350}{0.87 \times 415}$$

$A_{st_2} = 331.058 \ mm^2$

$A_{st} = A_{st_1} + A_{st_2}$

$= 1070.6 + 331.058$

$= 1401.65 \ mm^2$

Check for tension reinforcement

from cl. 26.5.1.1 of IS 456:2000

$$\frac{A_{stmin}}{bd} = \frac{0.85}{f_y}$$

$$A_{stmin} = \frac{0.85 \times 250 \times 450}{415}$$

$= 230.42$

$A_{stmax} = 0.04 \ bD$

$= 0.04 \times 250 \times 500$

$= 5000$

$A_{stmin} < A_{st} < A_{stmax}$

CHECK FOR COMPRESSION REINFORCEMENT

cl. 25.5.1.2

$A_{scmax} = 0.04 \ bD$

$= 5000$

A_{scmin} = shall not be less than 0.2% of bD

$A_{sc_{min}} = \frac{0.02\ bD}{100}$

$= \frac{0.02 \times 250 \times 500}{100}$

$= 250$

$A_{sc_{min}} < A_{sc} < A_{sc_{max}}$

No. of bars in tension

$$\frac{A_{st}}{\text{Area of 1bar}}$$

$= \frac{1401.65}{\pi/4 \times 25^2} = 2.8$

$\approx$ ~~5 Nos~~ 3 bars

No. of bars in compression

$= \frac{A_{sc}}{\text{Area of 1bar.}}$

$= \frac{341.51}{\frac{\pi}{4} \times 16^2} = 1.6$

$= 2$ bars

So provide 3 bars of 25mm ϕ on tension side and 2 bars of 16 mm ~~of~~ on compression side.

STEP 6 : CHECK FOR SHEAR

(Cl. 40.1 of IS 456 : 200)

$\tau_v = \frac{V_u}{bd}$

$V_u = \frac{wl}{2} \times 1.5$

$= \frac{40 \times 5}{2} \times 1.5$

$= 150$ kN

$\tau_v = \frac{150 \times 10^3}{250 \times 450}$

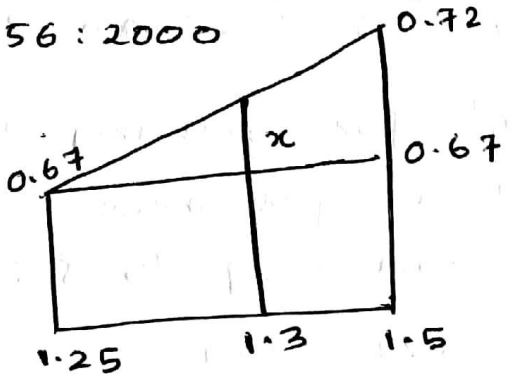
$= 1.33$

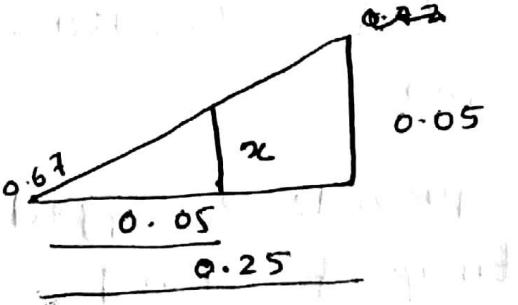
$\tau_c \Rightarrow \frac{100\ A_s}{bd}$ → tension

$= \frac{100 \times 3 \times \pi/4 \times 25^2}{250 \times 450}$

$= 1.3$

From table 19 of IS 456 : 2000





$\frac{0.05}{x} = \frac{0.25}{0.05}$ $x = 0.01$

$\tau_c = 0.67 + x$

$= 0.68 \ N/mm^2$

$\tau_{cmax} = 2.8 \ N/mm^2$

$\tau_v > \tau_c > \tau_{cmax}$

Provide design shear reinforcement in the form of vertical stirrups

$$V_{us} = \frac{0.87 \ f_y \ A_{sv} \ d}{s_v}$$

$V_{us} = V_u - \tau_c b d$

$= 150 \times 10^3 - 0.68 \times 250 \times 450$

$= 73500 \ N$

2 legged - $\phi 8mm$

$$73500 = \frac{0.87 \times 415 \times 2 \times \frac{\pi}{4} 8^2 \times 450}{s_v}$$

$s_v = 222.22 \ mm = 220$

Check for spacing of shear reinforcement

Cl 26.5.1.5 of IS 456 : 2000

(i) $222.22 = 220$

(ii) $0.75d = 0.75 \times 450 = 337.5$

(iii) 300

So provide 2 legged stirrup of 8mm ϕ @ 220 c/c

STEP 7 CHECK FOR DEFLECTION

$$\frac{l}{d} = \frac{5000}{450} = 11.11 < 20$$

$\therefore$ safe

STEP 8 CHECK FOR DEVELOPMENT LENGTH

Cl. 26.2.1

$$L_d = \frac{\phi \sigma_s}{4 \tau_{bd}}$$

$$= \frac{25 \times 0.87 \times 415}{4 \times 1.2}$$

$$= 1880.46 \text{ mm}$$

23.10.19