Step 10: check for deflectⁿ [slendernous ratio < 20]

Step 11: Computation of development length

NOTE

If the applied moment is larger than the limitting moment 2 alternatives will be available.

1. To increase the depth of section
2. To provide compression reinforcement

In many cases the max value of depth of the section may be limitted or restricted from architectural considerations. In such cases the only alternative will be to provide compression reinforcement, giving rise to doubly reinforcement section.

A doubly reinforced section is therefore provided in the following circumstances

1. when there are architectural restrictions such as headroom requirements, appearances etc on the depth
2. Restriction in depth at the location of beam at plinth level along with the provision of ventilated between the ground level and the bottom of the plinth beam
3. It is required to ↑se the stiffness of the beam
4. It is found that the compression steel ↑ses the rotation capacity & ductility structures with high ductility responds better to seismic forces
5. In a continuous beam floor system where the beam acts as a T beam in the mid span and act as a rectangular beam at the support.

Q: Design a reinforced concrete beam supported on 2 walls 500mm thick spaced at a clear distance of 6m. The beam carries a super imposed load of 30 kN/m. The size of the beam is restricted to 300mm x 500mm. Use M20 concrete and Fe415

Soln:

M_{20} $f_{ck} = 20\ N/mm^2$

Fe415 $f_y = 415\ N/mm^2$

$b = 300mm$

$D = 500mm$

$L.L = 30kN/m$

width of support = 300mm
clear span = 6m.

Step 1 :- BEAM DIMENSION

Assume cover = 30mm
(Table 16)

ϕ of bar = 20mm

$d = 500 - 30 - 20/2$

$= 460$ mm

$l_{eff} \Rightarrow c/c = \frac{500}{2} + 6000 + \frac{500}{2}$

$= 6500$ mm

clear span + d = 6000 + 460

= 6460 mm

$\therefore l_{eff} = 6460$ mm

Step 2 :- BM and LOAD

L.L = 30 kN/m

$DL = \boxed{b \times D \times 25}$

$= 0.300 \times 0.500 \times 25$

$= 3.75$ kN

TL = L.L + D.L = 30 + 3.75

= 33.75 kN

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

$= \frac{33.75 \times 6.46^2}{8}$

$M = 176.055$

$M_u = 176.055 \times 1.5$

$= 264.082$ kNm

$M_u = 264.082 \times 10^6$ Nmm

Step 3 : SINGLY ...

cl. G.1.1.c

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

$= 0.36 \times 0.48 \left[1 - 0.42 \times 0.48\right] 300 \times 460^2 \times 20$

$= 175158485$

$= 175.158$ kNm

$M_u > M_{u\,limit}$

$\therefore$ Doubly reinforced section.

Step 4 :

$M_{u\,limit} = 0.36 \frac{x_u}{d}\left[1 - 0.42\frac{x_u}{d}\right] bd^2 f_{ck}$

$\cancel{264.082 \times 10^6}$ $175.158 \times 10^6 = 0.36 \frac{x_u}{d}\left[1 - 0.42\frac{x_u}{d}\right] 300 \times 460^2 \times 20$

$\cancel{0.577}$ $0.383 = \frac{x_u}{d} - 0.42 \frac{x_u}{d}^2$

$\cancel{x = 0.982, 1.398}$

$x = 0.479, 1.9$

$\frac{x_u}{d} = \cancel{0.982}\ 0.479$

$\frac{x_{umax}}{d} = 0.48$

$\frac{x_u}{d} < \frac{x_{umax}}{d}$

under reinforced

Step 5 : COMPUTATION OF REINFORCEMENT

$M_{u\,limit} = 0.87 f_y A_{st_1} d \left[1 - \frac{A_{st_1} f_y}{b d f_{ck}}\right]$

$A_{st_1} \rightarrow A_{sc} \rightarrow A_{st_2}$

$175.15 \times 10^6 = 0.87 \times 415 \times A_{st_1} \times 460 \left[1 - \frac{A_{st_1} \times 415}{300 \times 460 \times 20}\right]$

$1054.593 = A_{st_1} - 1.503 \times 10^{-4} A_{st_1}^2$

$x = 1314.16, 5339.19$

$A_{st_1} = 1314.16$

Annexure G.1.2 of IS 456: 2000

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

Assume

Same

$(264.08 - 175.15) = f_{sc} A_{sc} (460 - 38)$

{Assume ϕ of compression reinforcement = 16mm

$d' = 30 + 16/2 = 38$}

$f_{sc} \rightarrow$ stress corresponding to ε_{sc}

Strain, $\varepsilon_{sc} = 0.0035 \frac{(x_{umax} - d')}{x_{umax}}$

$= 0.0035 \frac{(0.48d - d')}{0.48 d}$

$= 0.0035 \frac{(0.48 \times 460 - 38)}{0.48 \times 460}$

$= 2.897 \times 10^{-3}$

14.10.19
MONDAY

~~Asc~~ = ~~8~~

— design curve

--- characteristic curve

4 Fe 415 ⇒ $0.87 f_y$ from curve

stress 355

From fig. 3 of SP 16

$f_{sc} = 355$

Cl. G.1.2 of IS 456:2000

$88.93 \times 10^6 = 355 \times A_{sc}\ 422$

$A_{sc} = \cancel{5.936 \times 10^{-4}}$

$= 593.618\ mm^2$

Cl. G.1.2 of IS 456:2000

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

$= \frac{593.618 \ (\cancel{5.936 \times 10^{-4}}) \times 355}{0.87 \times 415}$

$A_{st_2} = 583.67\ mm^2$

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

$= 1314.16 + 583.67$

$= 1897.83\ mm^2$

check for tension reinforcement

From cl. 26.5.1.1 of IS 456:2000

$\frac{A_{st_{min}}}{bd} = \frac{0.85}{f_y}$

$A_{st_{min}} = \frac{0.85}{415} \times 300 \times 460$

$= 282.65$

$A_{st_{max}} = 0.04 bD$

$= 0.04 \times 300 \times 500$

$= 6000$

$A_{st_{min}} < A_{st} < A_{st_{max}}$

CHECK FOR COMPRESSION REINFORCEMENT (A_{sc})

Cl. 26.5.1.2

~~not less~~

$A_{sc_{max}} = 0.04\,bD$

$= 6000$

$A_{sc_{min}} \Rightarrow$ ~~it should~~ shall not be less than 0.2% of bD (Cross Section area)

not in IS code

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

$= 0.002 \times 300 \times 500$

$= 300$

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

No. of bars in tension

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

tension ϕ 20

Compre ϕ16

$$= \frac{1897.83}{\frac{\pi}{4} \times 20^2}$$

$= 6.04 \approx 7$ bar

No. of bars in compression

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

$$= \frac{593.618}{\frac{\pi}{4} \times 16^2} = 2.95$$

$= 3$ bars

Assume ϕ 25 for no. of bars in tension

(Since no. of bars are more)

$$\frac{1897.83}{\frac{\pi}{4} \times 25^2} = 3.86$$

4 ~~bars~~ bars

So provide 4 bars of 25mm ϕ on the tension side and 3bars of 16mm ϕ at compression side.

Step 6: CHECK FOR SHEAR

(Cl. 40.1. of IS 456: 2000)

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

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

$$= \frac{33.15 \times 6.46}{2} \times 1.5$$

$= 163.518$ kN

$$\tau_v = \frac{163.518 \times 10^3}{300 \times 460}$$

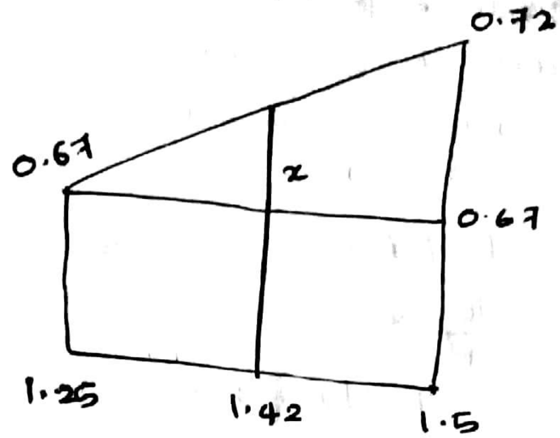
$= 1.184$

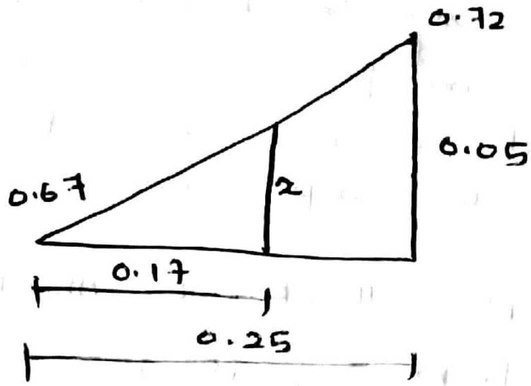
$\tau_c \Rightarrow \frac{100\,A_s}{bd}$ $A_s \Rightarrow$ area steel in tension

$$\frac{100 \times 4 \times \pi/4 \times 25^2}{300 \times 460}$$

$= 1.42$

From table 19 of IS 456: 2000





$$\frac{0.05}{x} = \frac{0.25}{0.17}$$

$x = 0.034$

$\tau_c = 0.67 + x = 0.67 + 0.034$

$= 0.704 \ N/mm^2$

Table ~~23~~ 20 $\quad \tau_{cmax} = 2.8$

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

Since $\tau_c < \tau_v$ design shear reinforcement in the form of vertical stirrup is to be provided

from cl. 40.4. a of IS 456 : 2000

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

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

$= 163.518 \times 10^3 -$

$0.704 \times 300 \times 460$

$= \underline{\underline{66\,366 \ N}}$

Assume 2 legged stirrups of 8mm ϕ

$$66\,366 = \frac{0.87 \times 415 \times 2 \times \frac{\pi}{4} \times 8^2 \times 460}{S_v}$$

$S_v = 251.58$

Check for spacing of shear reinforcement
(cl. 26.5.1.5 of IS 456:2000)

(i) 251.58 mm ✓ ⇒ round back $= 250mm$

(ii) $0.75d = 0.75 \times 460 = 345mm$

(iii) 300mm

So provide 2 legged stirrups of 8mm ϕ @ 250mm c/c

<u>Step 7</u> : CHECK FOR DEFLECTION

Slendernous ratio

$$\frac{l}{d} = \frac{6460}{460} = 14.04$$

less than 20

∴ Safe

<u>Step 8</u> : CHECK FOR DEVELOPMENT LENGTH

(cl. 26.2.1)

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

$$\overline{4 \times 1.2}$$

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

= ~~1161~~

= 1880.46 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 $c + \frac{\phi}{2}$

Material M20 concrete

Fe 415 steel.

d' = 50

STEP 1 COMPUTATION OF BEAM DIMENSION

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

$l_{eff} = 5m$

$D = 500mm$

~~$\frac{l}{d} \geq 12$~~ ~~$d \leq \frac{5000}{12}$~~

or

$D - \text{eff cover} = d$

$d + \phi/2 + c$

50

$d = 500 - 50 = 450$

$d' = 50$

$b = 250$

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

$f_y = 415\ N/m^2$

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

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

$= 125$

$M_u = 125 \times 1.5$

$= 187.5$

STEP 3 SINGLY / DOUBLY

cl. G.1.1.c

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

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

$= 139688064$

$= 139.688$ kNm

$M_u > M_{u_{limit}}$

∴ Doubly reinforced.

SKIP STEP 4

STEP 5 : COMPUTATION OF REINFORCEMENT

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

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

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

$x = 1070.6,\ 4364.08$

$A_{st_1} = 1070.6$

16/10/17