Mid-Semester Examination Solution, March-2017
Reinforced Concrete Design (CVL4121)

Semester: 6^{th} **Branch:** Civil Engineering
Full mark: 100 **Time:** 2 Hours

Question 1

A slab is simply supported on two beams and the beams simply supported on two walls as shown in Figure 1. The wall are 250mm thick have a clear distance of 7m between them. Beams have a center to center distance of 3m. The slab has to carry a dead load of $1.5\frac{kN}{m^2}$ and a live load of $4.5\frac{kN}{m^2}$. Design tensile and shear reinforcement for slab and beams each respectively according to IS456:2000. **20 + 10 + 20 + 10**

Slab Design

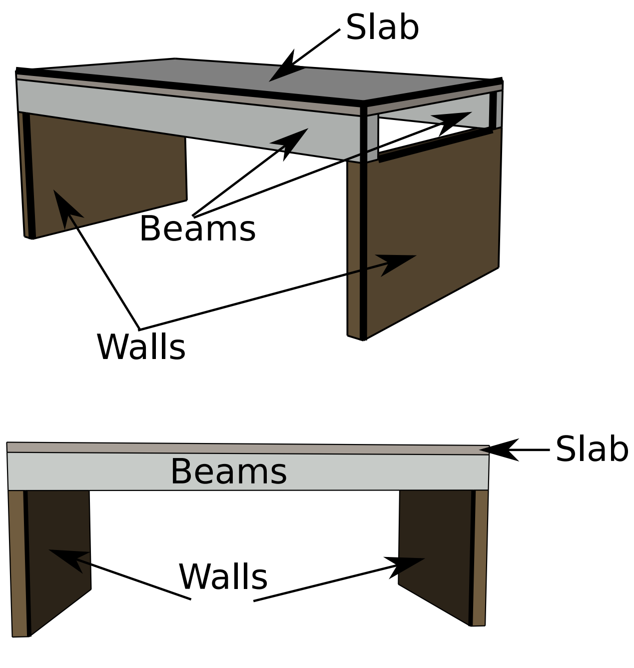

Figure 1:

1. The exposure condition given is moderate. From IS:456 (table-5) the minimum grade of concrete for reinforced concrete at moderate condition is M25 and clear cover is $20mm$.

2. From clause 22.2 of IS:456,

$$l \text{ (effective span)} = \text{minimum} \begin{cases} \text{clear span} + d \\ \text{center-to-center distance} \end{cases}$$

which gives $l = 3m$.

3. Maximum effective depth from span to depth ratio as given in clause 23.2.1, for simply supported slab is 20 which after multiplication to $k_t = 1.25$ is 25. From that $\frac{l}{d} = 20$, we found $d = 162.5mm$ and take value $160mm$ (rounded off).

4. Nominal/clear cover from Table-16 (exposure condition) will be taken to be $20mm$.

5. Initial guess for reinforcements assumed to be $20mm$. Gives total depth to be 160+20+20/2 = $190mm$.

6. Design loads

   - self load $= 0.19 \times 25\frac{kN}{m^3} = 4.75\frac{kN}{m^2}$.
   - dead load $= 1.5\frac{kN}{m^2}$
   - live load $= 4.5\frac{kN}{m^2}$

   total load $= 10.75\frac{kN}{m^2}$
   design load $= 1.5 \times 10.75\frac{kN}{m^2} = 16.125\frac{kN}{m^2}$
   Design moment $= \frac{w \times l^2}{8} = 21.3kN - m$ per meter width of slab.

7. Limiting effective depth $(d_{lim}) = M_u/0.1389f_{ck}b = 78.3mm$. Check if $d_{lim} < d_{provided}$.

8. $(A_{st})_{reqd}$ from $\frac{M_u}{bd^2} = 0.87f_y\frac{p_t}{100}[1 - \frac{p_tf_y}{100f_{ck}}]$. Find required spacing according to assumed main bars and provide according to 26.5.2.1.

9. Provide distribution bars according to clause 26.5.2.1.

10. Provide spacing based on clause 26.3.3.

11. Check maximum diameter of bars in both directions from 26.5.2.2.

12. Check if section is not over-reinforced i.e. $(A_{st})_{bal} > (A_{st})_{provided}$ (You can find$(A_{st})_{bal}$ from $C_{bal} = T_{bal}$).

13. Check if the clear distances between bars and concrete surfaces is according to clause 26.3.2.

14. Reconfirm the allowable moment capacity of designed section to be more than design moment.

15. Check for deflection control from Figure 4 and 5 from code.

16. Refer Clause 40 for complete reference on shear reinforcement of slab for limit state of collapse and provide shear reinforcement accordingly.

17. Draw and detail your section according to above points and clause D-1.6 (Annex-D) for shear and negative moment safety.

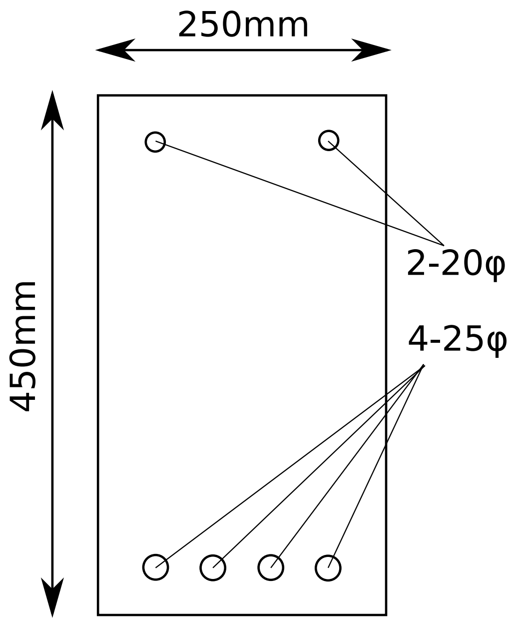

Figure 2:

Beam Design

1. The exposure condition given is moderate. From IS:456 (table-5) the minimum grade of concrete for reinforced concrete at moderate condition is M25 and clear cover is $20mm$.

2. From clause 22.2 of IS:456,

$$l \text{ (effective span)} = \text{minimum} \begin{cases} \text{clear span} + d \\ \text{center-to-center distance} \end{cases}$$

   which gives $l = 7.25m$.

3. Maximum effective depth from span to depth ratio as given in clause 23.2.1, for simply supported slab is 20. From that $\frac{l}{d} = 15$, we found $d = 483.33mm$ and take value $450mm$ (rounded off).

4. Nominal/clear cover from Table-16 (exposure condition) will be taken to be $20mm$.

5. Initial guess for reinforcements assumed to be $20mm$. Gives total depth to be 450+20+20/2 = $480mm$. Let us assume $D = 500mm$. Change $d = 500 - 20 - 20/2 = 470mm$.

6. Assume width of the section to be half of total depth as $250mm$.

7. Design loads

   - slab load $= \frac{3.25}{2} \times 10.75\frac{kN}{m^2} = 17.47\frac{kN}{m}$. $3.25m$ is slab span and divided by two as the load will be distributed on both beams equally.
   - self load $= 0.25 \times 0.5 \times 25\frac{kN}{m^3} = 3.125\frac{kN}{m}$.

   total load $= 20.6\frac{kN}{m}$
   design load $= 1.5 \times 20.6\frac{kN}{m} = 31\frac{kN}{m}$
   Design moment $= \frac{w \times l^2}{8} = 203kN - m$.

8. Find limiting effective depth (d_{lim}) of concrete based on $M_u = kf_{ck}bd^2$. find k according to grade of steel. Check d to be well above d_{lim}.

9. Find $(A_{st})_{reqd}$ from $\frac{M_u}{bd^2} = 0.87f_y\frac{p_t}{100}[1 - \frac{p_tf_y}{100f_{ck}}]$. Provide A_{st} a little more than required. Choose reinforcing and stirrup steel bars from $\phi5, \phi6, \phi7, \phi8, \phi10, \phi12, \phi16, \phi18, \phi20, \phi22, \phi25, \phi28, \phi32, \phi36, \phi40, \phi45, \phi50$.

10. Check if it is in minimum and maximum reinforcement limit from clause 26.5.1.1.

11. Check if section is not over-reinforced i.e. $(A_{st})_{bal} > (A_{st})_{provided}$ (You can find$(A_{st})_{bal}$ from $C_{bal} = T_{bal}$).

12. Check if the clear distances between bars and concrete surfaces is according to clause 26.3.2.

13. Reconfirm the allowable moment capacity of designed section to be more than design moment.

14. Check for deflection control from Figure 4 and 5 from code.

15. Calculate τ_v according to Figure 2 from code.
Note - You can also over-design by taking shear at supports.

16. Check if this case requires design of shear reinforcement or minimum shear reinforcement or inadequate section.

17. Based on above point, use clause 40.3 or 40.4.

18. Provide spacing of stirrups according to clause 26.5.1.5.

19. Recheck for above shear reinforcement to be above minimum limit as given in 26.5.1.6.

20. Draw and detail your design for shear and tensile reinforcement.

Question 2

The beam as shown in Figure 2 has an effective span of 8m. Find the strain in compression and tension steel. Determine the moment of resistance and maximum UDL that can be carried by the beam. Assume Fe415 steel, M20 concrete and 25mm clear cover. Refer to data given in Table 1 and 2. **25 + 15**

1. Given : b = 250mm, d = 450-25-25/2 = 412.5mm, A_{st} = 4-ϕ25 = 1962.5mm^2, f_y = 415MPa, f_{ck} = 20MPa, d' = 35mm, A_{sc} = 2-ϕ20 = 628mm^2, $x_{u,max}$ = 0.4791d for Fe 415; which is 0.479 412.5 = 197.6mm

2. Assuming $f_{sc} = f_{st} = 0.87 f_{ck}$, and considering force equilibrium
   $x_u = \frac{f_{st}A_{st}-(f_{sc}-0.447f_{ck})A_{sc}}{0.362f_{ck}b} = \frac{0.87\times415\times1962.5-(0.87\times415-0.447\times20)\times628}{0.362\times20\times250}$
   $= 269.30mm > x_{u,max} = 197.6mm$. Evidently, the section is over-reinforced.

3. Iterations will be needed to find actual x_u.

   (a) Assuming $x_{u,1} = \frac{x_u+x_{u,max}}{2}$.

   (b) Calculate $\epsilon_{sc} = 0.0035(1 - d\prime/x_u)$ and $\epsilon_{st} = 0.0035(d/x_u - 1)$.

   (c) Calculate f_{sc} and f_{st} from Table 2.

   (d) Calculate $x_{u,2} = \frac{f_{st}A_{st}-(f_{sc}-0.447f_{ck})A_{sc}}{0.362f_{ck}b}$.

   (e) Check for convergence i.e. if $x_{u,1} = x_{u,2}$.

   (f) If not converged recalculate $x_{u,3} = \frac{x_{u,1}+x_{u,2}}{2}$ and redo from step 2.

4. From calculated $x_{u,final}$ calculate strains as given in above steps.

5. Calculate $M_u = C_c(d - 0.416x_u) + C_s(d - d\prime)$.

6. Calculate Maximum UDL from $\frac{M_u}{1.5} = \frac{wl^2}{8}$.

Grade of steel	d'/d			
	0.05	**0.10**	**0.15**	**0.20**
Fe 250	**217.5**	**217.5**	**217.5**	**217.5**
Fe 415	**355.1**	**351.9**	**342.4**	**329.2**
Fe 500	**423.9**	**411.3**	**395.1**	**370.3**

Table 1: **f_{sc} for Fe415 at $x_u = x_{lim}$**

Strain	Stress(MPa)
0	**0**
0.00144	**288.7**
0.00163	**306.7**
0.00192	**324.8**
0.00241	**342.8**
0.00276	**351.8**
$\geq$0.00380	**360.9**

Table 2: **Stress-Strain data Fe415**

$p_t = \frac{100A_{st}}{bd}$	$f_{st}(MPa)$		
	145	**190**	**245**
0.3	-	**1.89**	**1.47**
0.4	-	**1.68**	**1.34**
0.5	**1.95**	**1.53**	**1.23**
0.6	**1.79**	**1.43**	**1.17**
0.8	**1.57**	**1.29**	**1.06**
1.0	**1.42**	**1.20**	**0.99**
1.2	**1.33**	**1.12**	**0.95**
1.4	**1.26**	**1.08**	**0.92**
1.6	**1.21**	**1.03**	**0.88**
1.8	**1.17**	**0.99**	**0.85**
2.0	**1.12**	**0.97**	**0.83**

Table 3: **Data for k_t or k_1**