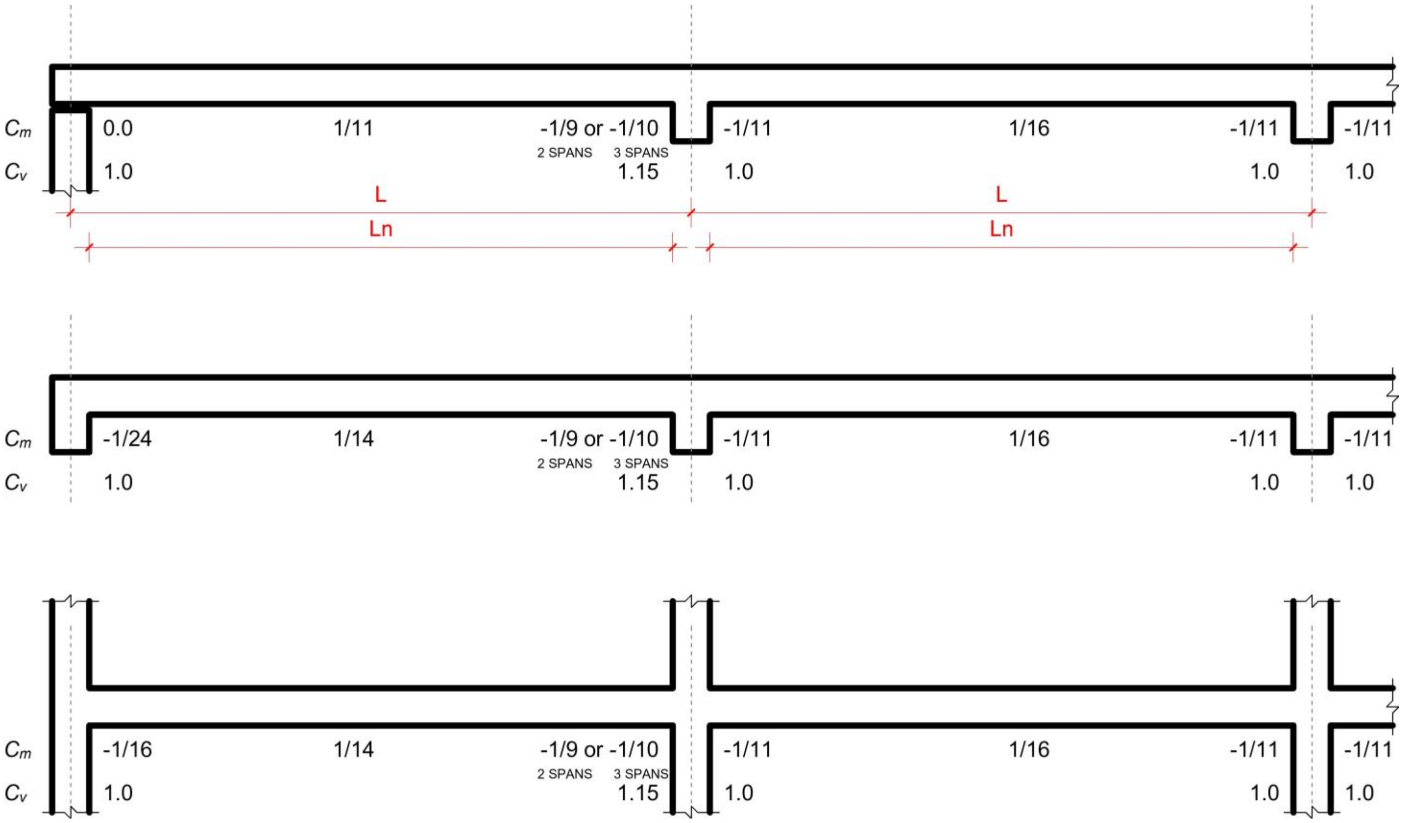
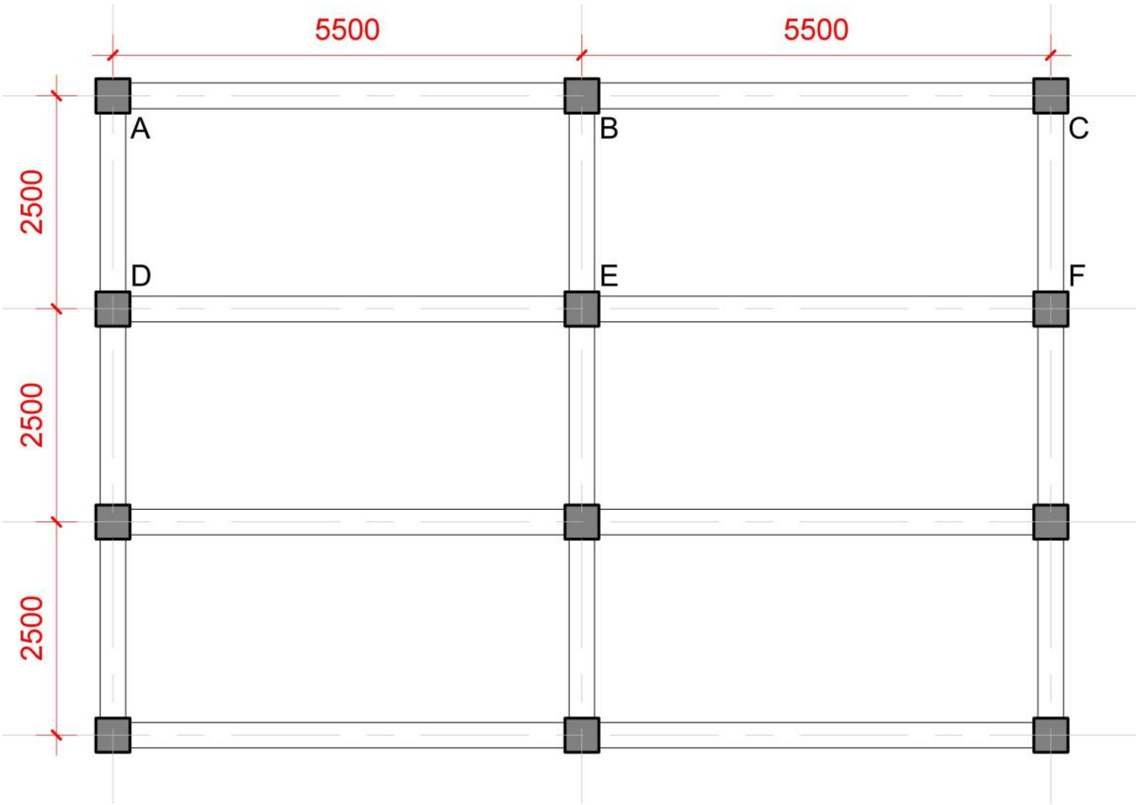
Design of Continuous Beams:



$M_u = C_m(w_u l_n^2)$ $\rightarrow$ *Approximate moments for continuous beams , SBC − 18,6.5.2*

$V_u = C_v\left(w_u l_n /2\right)$ $\rightarrow$ *Approximate shears for continuous beams , SBC − 18, 6.5.4*



All beams are 300×400 mm supported by 400×400 mm columns. Slab thickness is 100 mm.

DL = 4.8 kN/m² including slab weigh, LL = 2.9 kN/m². Design the continuous beam DEF for flexure. Use f'_c = 25 MPa, f_y = 420 MPa, d_s=10 mm, and d_b 12mm.

1- Find ultimate load on beam:

$$w_{DL} = DL \times TA\ thickness + Beam\ self\ weight = 4.8 \times 2.5 + (0.4 - 0.1) \times 0.3 \times 24 = 14.16\ kN/m$$

$$w_{LL} = LL \times TA\ thickness = 2.9 \times 2.5 = 7.25\ kN/m$$

$$w_u = 1.4DL + 1.7LL = 1.4 \times 14.16 + 1.7 \times 7.25 = 32.15\ kN/m$$

2- Find ultimate moment and ultimate shear:

	Span DE Exterior			Span EF Exterior		
l (m)		5.5			5.5	
l_n *(m)*		5.1			5.1	
w_u *(kN/m)*		32.15			32.15	
C_m	– 1/16	1/14	– 1/9	– 1/9	1/14	– 1/16
$w_u\, l_n^2$*(kN.m)*	836.22	836.22	836.22	836.22	836.22	836.22
M_u *(kN.m)*	– 52.26	**59.73**	**– 92.91**	**– 92.91**	**59.73**	– 52.26
C_v	1		1.15	1.15		1
$w_u\, l_n/2$*(kN)*	164		164	164		164
V_u *(kN)*	164		188.6	188.6		164

3- Design the beam for flexure:

Take – ve moment = 93 kN.m, + ve moment = 60 kN.m.

4- Design for maximum – ve moment as rectangular beam:

$$d = h - 65 = 400 - 65 = 335\ mm$$

$$R_n = \frac{M_u}{\emptyset b d^2} = \frac{93 \times 10^6}{0.9 \times 300 \times 335^2} = 3.069$$

$$\rho = \frac{0.85 f_c'}{f_y}\left(1 - \sqrt{1 - \frac{4R_n}{1.7 f_c'}}\right) = \frac{0.85 \times 25}{420}\left(1 - \sqrt{1 - \frac{4 \times 3.069}{1.7 \times 25}}\right) = 0.006508346325$$

$$A_s = \rho b_w d = 0.006508346325 \times 300 \times 335 = 654.09\ mm^2$$

$$A_{s,min} = Max\left(\frac{\sqrt{f_c'}}{4 f_y} b_w d, \frac{1.4}{f_y} b_w d\right) = Max\left(\frac{\sqrt{25}}{4 \times 420} \times 300 \times 335, \frac{1.4}{420} \times 300 \times 335\right)$$

$$A_{s,min} = 335\ mm^2$$

$A_s \geq A_{s\ min}$ ➔ ✓

Use 6Ø12 $A_{s\ provided} = 6 \times \pi\ 12^2/4 = 678.6\ mm^2$, 4Ø12 over web and 2Ø12 over flange

Actual $d = h - cover - ds - db/2 = 400 - 40 - 10 - 6 = 344\ mm$ > assume $d = 335\ mm$ ➔ no checks required.

5- Design for maximum + ve moment as T beam:

5a- Calculate effective flange width b_e:

$$b_e = min\begin{cases} b_w + 16h_f = 300 \times 16 \times 100 = 1900\ mm \\ b_w + s_w = 300 + 2100 = 2400\ mm \\ b_w + \frac{l_n}{4} = 300 + \frac{5100}{4} = 1575\ mm \end{cases}$$

$$b_e = 1575\ mm$$

5b- Find, ρ and $A_{s\ min}$: and A_s

Assume steel is yielding and Ø = 0.9.

$$d = h - 65 = 400 - 65 = 335\ mm$$

$$R_n = \frac{M_u}{\emptyset b_e d^2} = \frac{60 \times 10^6}{0.9 \times 1575 \times 335} = 0.377171239$$

$$\rho = \frac{0.85 f_c'}{f_y}\left(1 - \sqrt{1 - \frac{4R_n}{1.7 f_c'}}\right) = \frac{0.85 \times 25}{420}\left(1 - \sqrt{1 - \frac{4 \times 0.377171239}{1.7 \times 25}}\right) = 0.000753973515$$

$$A_s = \rho b_e d = 0.000753973515 \times 1575 \times 335 = 397.82\ mm^2$$

$$A_{s,min} = Max\left(\frac{\sqrt{f_c'}}{4f_y}b_w d, \frac{1.4}{f_y}b_w d\right) = Max\left(\frac{\sqrt{25}}{4 \times 420} \times 300 \times 335, \frac{1.4}{420} \times 300 \times 335\right)$$

$$A_{s,min} = 335\ mm^2$$

Use 4Ø12 $A_{s\ provided} = 4 \times \pi\ 12^2/4 = 452.16\ mm^2$

$A_s \geq A_{s\ min}$ ➔ ✓

Actual $d = h - cover - ds - db/2 = 400 - 40 - 10 - 6 = 344\ mm$ > assume $d = 335\ mm$ ➔ no moment check required.

5c- Find Neutral axis depth (c) from top fibers assuming steel is yielding and $a \leq h_f$:

$$a = \frac{A_s f_y}{0.85 f_c' b_e} = \frac{452.16 \times 420}{0.85 \times 25 \times 1575} = 5.67\ mm$$

5.67 < 100 ➔ assumption satisfied.

6- Design the beam for shear:

6a- Find factored shear force at end and middle of the span, V_e *and* V_m *and* $V_u/Ø$ at distance d from support.

$$w_{uL} = 1.7LL = 1.7 \times 7.25 = 12.325\ kN/m$$

$$ØV_{e-1} = 164\ kN$$

$$V_{e-1} = \frac{164}{0.75} = 218.67\ kN$$

$$ØV_{e-2} = 188.6\ kN$$

$$V_{e-2} = \frac{188.6}{0.75} = 251.47\ kN$$

$$use\ V_e = V_{e-2} = 251.47\ kN$$

$$ØV_m = w_{uL}\frac{l_n}{8} = 12.325 \times \frac{5.1}{8} = 7.86\ kN$$

$$V_m = \frac{7.86}{0.75} = 10.5\ kN$$

$$\left(\frac{V_u}{Ø}\right)_d = V_e - \frac{2d}{l_n}(V_e - V_m) = 251.47 - \frac{2 \times 344}{5100}(251.47 - 10.5) = 218.963\ kN = 218963\ N$$

6b- Check beam dimensions adequacy and if stirrups are required.

$$V_c = \left(\frac{\sqrt{f_c'}}{6}\right)b_w d = \left(\frac{\sqrt{25}}{6}\right)300 \times 344 = 86000\ N = 86\ kN$$

$$5ØV_c = 5 \times 0.75 \times 86 = 322.5\ kN > V_u = 218.963\ \ kN$$

$V_u < 5ØV_c$ ➔ section dimensions are satisfactory.

$$0.5\emptyset V_c = 0.5 \times 0.75 \times 86 = 32.25\ kN < V_u = 218.963\ \ kN$$

$V_u > 0.5\emptyset V_c$ ➔ stirrups are required, calculate A_v

$$A_v = 2 \times \pi \frac{{d_s}^2}{4} = 2 \times \pi \frac{10^2}{4} = 157.08\ mm^2$$

6c- Find maximum spacings, S^1_{max}, S^2_{max} and S^3_{max}

$$3\emptyset V_c = 3 \times 0.75 \times 86 = 193.5\ kN < V_u = 218.963\ \ kN$$

$$3\emptyset V_c < V_u \rightarrow s^1_{max} = Min\left(\frac{d}{4}, 300mm\right) = 86\ mm$$

$$s^2_{max} = Min\left(\frac{16}{\sqrt{f'_c}}, 3\right)\frac{A_v f_{yt}}{b_w} = Min\left(\frac{16}{\sqrt{25}}, 3\right)\frac{157.08 \times 420}{300} = 659\ mm$$

$$s^3_{max} = \frac{A_v f_{yt} d}{\frac{V_u}{\emptyset} - V_c} = \frac{157.08 \times 420 \times 344}{\frac{218.963}{0.75} - 86} = 110.2\ mm$$

$$s = Min(s^1_{max}, s^2_{max}, s^3_{max}) = 86\ mm$$

Use s = 75 mm at critical section.

6d- Find spacing at other sections.

First spacing s_1 = 75 mm ➔ Second spacing s_2 = 250mm.

@ First spacing:

$$s_1 = 75\ mm\ @\ V_u = 218.963\ kN$$

@ Second spacing:

$$V_n = V_c + V_s = V_c + \frac{A_v f_{yt} d}{s} = 86000 + \frac{157.08\ \times 420 \times 344}{250} = 176779\ N = 176.779\ kN$$

$$x = \frac{\left(V_e - \frac{V_u}{\emptyset}\right)}{V_e - V_m} \times \frac{l_n}{2} = \frac{(251.47 - 176.779)}{251.47 - 10.5} \times \frac{5.1}{2} = 0.8\ m$$

@ No stirrups required:

$$\frac{V_u}{\emptyset} = V_n = 0.5\emptyset V_c = 0.5 \times 86000 = 43000\ N = 43.0\ kN$$

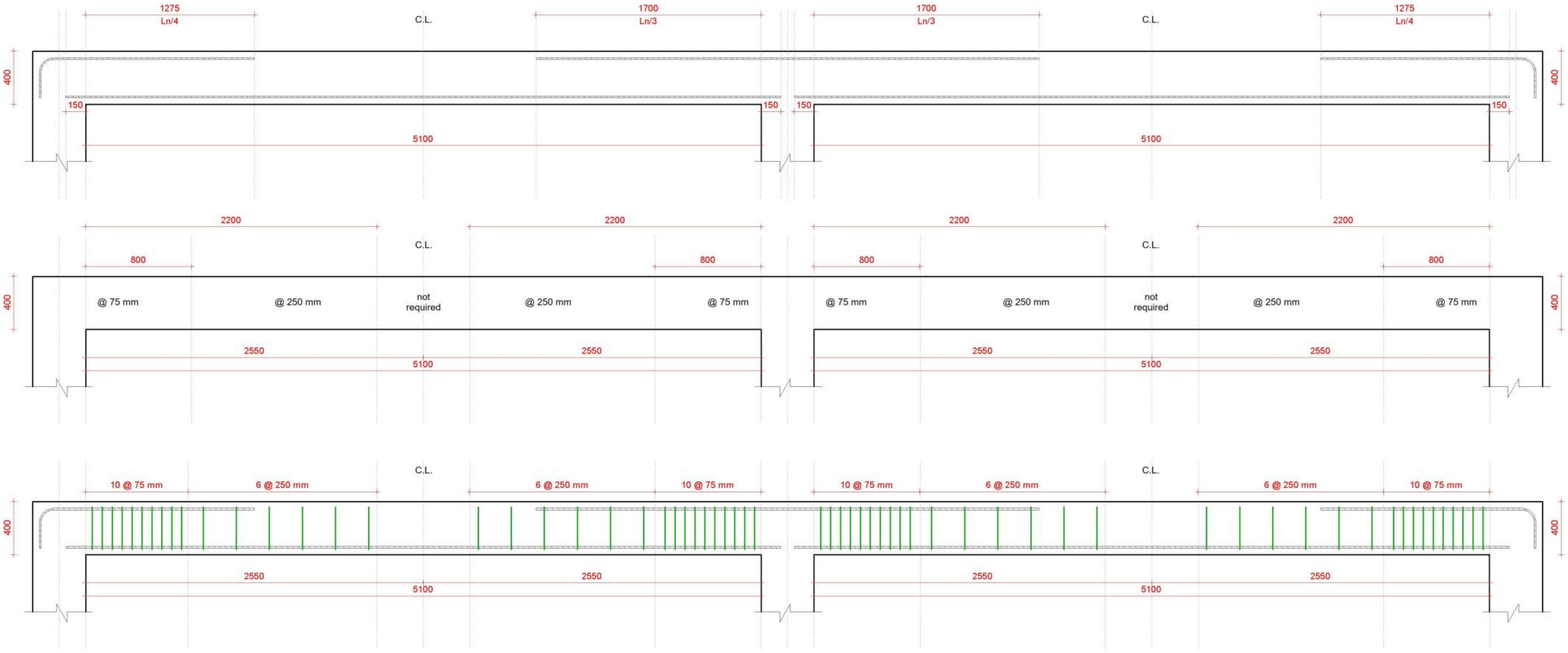
$$x = \frac{\left(V_e - \frac{V_u}{\emptyset}\right)}{V_e - V_m} \times \frac{l_n}{2} = \frac{(251.47 - 43.0\ )}{251.47 - 72.53} \times \frac{5.1}{2} = 2.2\ m$$

6e- find number of stirrups.

$$Number\ of\ stirrups = \frac{Distance\ in\ which\ stirrups\ of\ the\ same\ spacing\ has\ to\ be\ provided}{spacing\ between\ the\ stirrups}$$

$$(Number\ of\ stirrups)_{s=75} = \frac{800 - 50}{75} = 10.0\ use\ 10@75\ mm$$

$$(Number\ of\ stirrups)_{s=250} = \frac{2200 - (50 + 10 \times 75)}{250} = 5.6\ use\ 6@250\ mm$$


1275
Ln/4
C.L.
1700
Ln/3
1700
Ln/3
C.L.
1275
Ln/4
400
150
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@ 75 mm
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not required
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2550
2550
5100
10 @ 75 mm
6 @ 250 mm
6 @ 250 mm
10 @ 75 mm
10 @ 75 mm
6 @ 250 mm
6 @ 250 mm
10 @ 75 mm

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