Plain & Reinforced Concrete-1

CE-314

DESIGN OF FORMWORK

DESIGN OF COLUMN FORMWORK

Design Of Sheathing

The sheathing is considered to be continuous over the yokes with one-way slab behavior in a vertical direction.

- Pressure on 1-m strip = P_{max} kN/m^2
- Load per unit length = $P_{max} \times 1$m
- w = P_{max} kN/m
- Let, S = spacing of the yokes

  = span for the sheathing

- BM per unit width for sheathing continuous over yokes,

$$M = \frac{w\,S^2}{10}$$

- For the same size of the yokes, the above bending moment may be made equal to bending capacity of the sheathing by adjusting the spacing of yokes.
- This means that wherever concrete pressure is expected to be more, the spacing of the yokes may be reduced.
- Resisting moment per unit width, $M_r = f \times \dfrac{b\,d^2}{6}$

- Here $b = 1$, $d = t$ = thickness of sheathing and f is the allowable bending stress in timber (7 MPa for wood and 9 MPa for structural hardwood plywood).

$$M_r = f \times \frac{t^2}{6} \qquad \frac{w\,S^2}{10} = f \times \frac{t^2}{6}$$

$$S_1 = t\sqrt{\frac{10f}{6w}} \qquad or \qquad t_1 = S\sqrt{\frac{6w}{10f}}$$

- Where, S_1 is the spacing of the yokes and t_1 is the thickness required for strength.
- Allowable deflection, $\Delta_{max} = S/270$
- E for wood = 8400 MPa
- I per unit width = $t^3 / 12$.

- Actual deflection for continuous sheathing

$$(\Delta_a) = \frac{3}{384}\frac{w\,S^4}{EI} \qquad \frac{3}{384}\frac{w\,S^4}{EI} = \frac{S}{270}$$

$$S_2 = \frac{6.9\,t}{w^{1/3}} \qquad and \qquad t_2 = \frac{S\,w^{1/3}}{6.9}$$

- Where, S_2 is the spacing of the yokes and t_2 is the thickness required for stiffness.
- Finally S is smaller of S_1 for strength and S_2 for deflections.

Example 15.2: For a column, given the rate of fill R = 4 m/h, d = 450 mm, temperature = 10 °C and slump = 75 mm, determine the required spacing of yokes at a depth of 5m from top of the column.

Solution:

- R = 3 m/h
- d = 450 mm
- Temperature = 10 °C
- Slump = 75 mm
- t = 32 mm
- H = 5 m

Table 15.1. Values of *k*-Factor for Determination of Concrete Pressures.

Mean Slump (mm)	**Concrete Temperatures °C**					
	5	10	15	20	25	30
25	1.45	1.10	0.80	0.60	0.45	0.35
50	1.90	1.45	1.10	0.80	0.60	0.45
75	2.35	1.80	1.35	1.00	0.75	0.55
100	2.75	2.10	1.60	1.15	0.90	0.65

- From Table 15.1, k = 1.80

$$1.\quad P_{\max} = \left(\frac{\gamma_c H}{100} + 10 \right) = \frac{2400 \times 5}{100} + 10 = 130.0 \quad kM/m^2$$

$$2.\quad P_{\max} = \left(3R + \frac{d}{10} + 25 \right) \quad kN/m^2$$

Maximum value of d = 500 mm

$$= 3 \times 3 + \frac{450}{10} + 25 = 79.0 \quad kN/m^2$$

$$3.\quad P_{\max} = \left(\frac{\gamma_c Rk}{100} + 15 \right) = \frac{2400 \times 3 \times 1.80}{100} + 15 = 145.0 \quad kN/m^2$$

$\therefore\ P_{max}$ = 79 kN/m^2

w = 79 × 10^3 / 10^6 × 1 mm

= 0.079 N/mm, f = 7 MPa

$$S_1 = t\sqrt{\frac{10f}{6w}} = 32 \times \sqrt{\frac{10 \times 7}{6 \times 0.079}} \cong 389 \quad mm$$

$$S_2 = \frac{6.9\,t}{w^{1/3}} = \frac{6.9 \times 32}{(0.079)^{1/3}} = 515 \quad mm$$

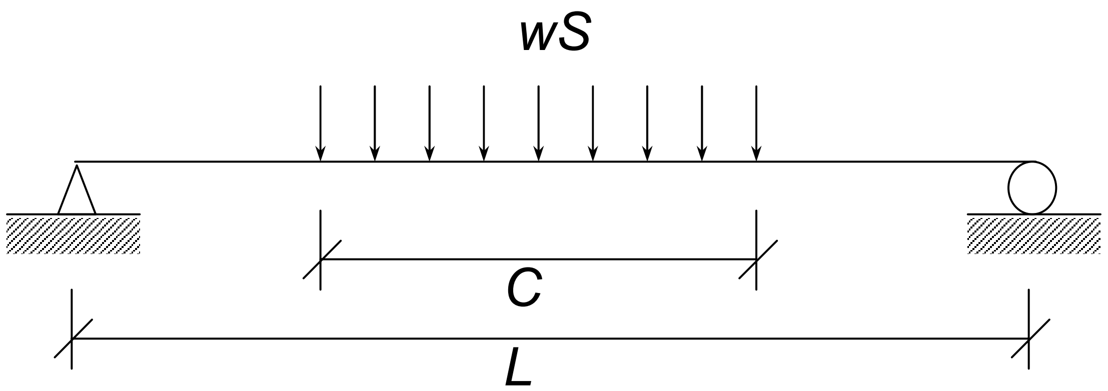
Hence, use a yoke spacing of 375 mm.

Size Of Yokes

The concrete load on the yoke will only be acting within the central portion equal to the column size, as shown in Fig. 15.16

Let, L = horizontal span of yoke between centers of bolts on both sides.

C = width of concrete or column size.



$$M_{\max} = \frac{wSC}{2}\left(\frac{L}{2}\right) - \frac{wS(C/2)^2}{2} \qquad = \frac{wSC}{8}\left(2L - C\right)$$

$$S_x = \frac{M_{\max}}{f}$$

$$\therefore \qquad \frac{bd^2}{6} = \frac{wSC}{8}\left(2L - C\right)$$

$$bd^2 = \frac{3wSC}{4f}\left(2L - C\right) \qquad (I)$$

$$\Delta_{max} = L / 270 \qquad \Delta_{max} = \frac{5M_c L^2}{48EI}$$

$$\frac{5L^2}{48EI} \frac{wSC}{8}(2L - C) = L/270$$

$$270 \times \frac{5}{48 \times 8400 \times bd^3/12} \frac{wSCL}{8}(2L - C) = 1$$

$$bd^3 = \frac{1}{199.1} wSCL(2L - C) \qquad (II)$$

Eq. II / Eq.I: $d_{min} = \frac{1}{199.1} \frac{4fL}{3} \cong fL/150 = L/21$

Design Of Yoke Bolts

Force in yoke-bolt

= half load on the yoke = $wSC / 2$

Effective area through threads of the bolt $\times f_t$

= $wSC / 2$

$$0.75 \times \pi/4\, d^2 \times 125 = wSC / 2$$

$$\therefore \quad d = \sqrt{\frac{wSC}{147}}$$

Example 15.3: For the column formwork of Example 15.2, design the yoke when the bolts are at 790 mm c/c along the yoke and column size parallel to the yoke is 450 mm.

Solution:

- w = 0.079 N/mm^2
- f = 7 MPa
- L = 790 mm
- C = 450 mm
- S = 375 mm
- d_{min} = L / 21 = 790 / 21 = 38 mm

$$bd^2 = \frac{3wSC}{4f}(2L - C)$$

$$= \frac{3 \times 0.079 \times 375 \times 450}{4 \times 7}(2 \times 790 - 450) = 1.614 \times 10^3$$

For b = 100 mm, d = 127 mm

For b = 75 mm, d = 147 mm

For b = d, b = d = 117 mm

- Use 120 × 120 mm or 100 × 130 yokes.
- Diameter of bolt $= \sqrt{\frac{wSC}{147}} = \sqrt{\frac{0.079 \times 375 \times 450}{147}} = 9.5mm$

Use 10 mm diameter bolts.

DESIGN OF SLAB FORMWORK

Design Of Decking / Slab Bottom

- The span length of decking is equal to the center-to-center spacing of the battens (*S*).
- Unit width of decking is considered for design (*b* = 1mm).
- Live load including provision for use of machinery and vibrations is considered equal to 370 kgs/m^2.
- The thickness of the reinforced concrete slab to be poured is denoted by *T*.
- For slab formwork, the thickness of sheathing is approximately equal to one-third of the depth of the reinforced concrete slab.
- The self weight of the decking is usually very small compared with other loads and it may be considered included in the work live load.

Dead load of fresh concrete = $\dfrac{2400 \times T}{1000} = 2.4\,T \quad kgs/m^2$

$$w = \frac{(2.4T + 370) \times 10}{10^6} \times 1\,\text{mm} \qquad \text{N/mm}$$

$$\frac{w\,S^2}{10} = \frac{(2.4T + 370) \times S^2}{10^6} \qquad N - mm$$

$$\therefore \qquad \frac{(2.4T + 370) \times S^2}{10^6} = f\,\frac{t^2}{6}$$

$$S_1 = 408\,t\sqrt{\frac{f}{2.4T + 370}} \quad or \quad t_1 = S\,\frac{\sqrt{(2.4T + 370)/f}}{408}$$

For deflection control:

$$\frac{3}{384} \times \frac{(2.4T + 370)}{10^5} \times \frac{S^4}{8400 \times t^3 / 12} = S / 270$$

$$S_2 = \frac{321t}{(2.4T + 370)^{1/3}} \quad or \quad t_2 = S \frac{(2.4T + 370)^{1/3}}{321}$$

Example 15.4: Calculate the spacing of battens for a 32 mm thick wooden decking to be used as floor form. The thickness of concrete slab to be poured is 150 mm.

Solution:

t = 32 mm, f = 7 MPa, T = 150 mm

$$S_1 = 408t\sqrt{\frac{f}{2.4T + 370}}$$

$$= 408 \times 32\sqrt{\frac{7}{2.4 \times 150 + 370}} = 1278\ mm$$

$$S_2 = \frac{321t}{(2.4T + 370)^{1/3}}$$

$$= \frac{321 \times 32}{(2.4 \times 150 + 370)^{1/3}} = 1140\ mm$$

$\therefore S = 1140$ mm

Example 15.5: Calculate the thickness of wooden decking required to support a 125 mm slab when the battens are provided at 1 m spacing.

Solution:

S = 1000 mm, f = 7 MPa, T = 125 mm

$$t_1 = S\,\frac{\sqrt{(2.4T + 370)/f}}{408} = 1000 \times \frac{\sqrt{(2.4 \times 125 + 370)/7}}{408} = 24mm$$

$$t_2 = S\,\frac{(2.4T + 370)^{1/3}}{321} = 100 \times \frac{(2.4 \times 125 + 370)^{1/3}}{321} = 28mm$$

$\therefore$ Use 30 mm thick wooden planks.

Design Of Battens

- If the span length of battens is larger than 1.5 m, the live load is considered equal to 200 kgs/m^2.
- *L* = span of battens = c/c spacing of joists
- *S* = spacing of the battens
- UDL on battens, *w* = $\dfrac{(2.4T + 200) \times 10}{10^6} \times S \quad N/mm$

$$M = \frac{wL^2}{8} = \frac{(2.4T + 200) \times S}{10^5} \times \frac{L^2}{8} \quad N - mm$$

$$\therefore \quad \frac{(2.4T + 200) \times S}{10^5} \times \frac{L^2}{8} = f\,\frac{bd^2}{6} \quad \text{where } f = 7\text{ MPa}$$

$$bd^2 = (2.4T + 200) \times \frac{SL^2}{933{,}000} \quad (I)$$

For deflection control:

$$\frac{5}{384} \times \frac{(2.4T + 200)}{10^5} \times \frac{S\,L^4}{8400 \times bd^3 / 12} = L / 270$$

$$bd^3 = (2.4T + 200) \times \frac{S\,L^3}{19.9 \times 10^6} \quad (II)$$

Eq. II / Eq. I $\Rightarrow$ $d_{min} = L / 21$

Example 15.4: Design battens of a slab formwork having span length of 1.8 m and spacing of 0.6 m. The slab thickness to be poured is 150 mm.

Solution:

- L = 1800 mm, S = 600 mm, T = 150 mm

$$bd^2 = (2.4T + 200) \times \frac{SL^2}{933,000}$$

$$= (2.4 \times 150 + 200) \times \frac{600 \times 1800^2}{933,000} = 1167 \times 10^3 \ mm^3$$

- d_{min} = L / 21 = 1800 / 21 = 86 mm

For d = 100 mm, b = 117 mm

For d = 150 mm, b = 52 mm

For d = 140 mm, b = 60 mm

∴ Use 60 × 140 mm battens.

Design Of Beam Side Forms

The side forms span horizontally between the cleats under lateral pressure of concrete. Their design is usually not critical and the thickness equal to slab decking may be used.

Design Of Beam Bottoms

This sheathing spans between the head-trees supported by the vertical props. The beam bottom is supported at interval of 1 to 1.2 meters according to the depth of the beam. As the span length is less than 1.5 m, the live load is considered equal to 370 kgs/m^2.

Let L = c/c spacing between the head-trees

t = thickness of the sheathing

and h = depth of beam including the slab

As for the slab decking, following is obtained:

$$L_1 = 408\,t\sqrt{\frac{f}{2.4h+370}} \quad or \quad t_1 = L\,\frac{\sqrt{(2.4h+370)/f}}{408}$$

$$L_2 = \frac{321t}{(2.4h+370)^{1/3}} \quad or \quad t_2 = L\,\frac{(2.4h+370)^{1/3}}{321}$$

Example 15.7: For a 600 mm overall depth of beam and 50 mm thickness of wooden planks used as beam bottom, calculate the required spacing of the props.

Solution:

- t = 50 mm, f = 7 MPa, h = 600 mm

$$L_1 = 408t\sqrt{\frac{f}{2.4h+370}} = 408 \times 50\sqrt{\frac{7}{2.4 \times 600 + 370}} = 1269mm$$

$$L_2 = \frac{321t}{(2.4h+370)^{1/3}} = \frac{321 \times 50}{(2.4 \times 600 + 370)^{1/3}} = 1317mm$$

$\therefore$ Spacing of props equal to the span length of beam bottom = 1260 mm.

Design Of Props

Load on props

- Posts over 2.5 m in height are braced both ways at centers.
- *S* = spacing of beams / battens, mm
- *L* = spacing of props, mm
- *T* = thickness of slab, mm
- *h* = total depth of beam, mm
- *b* = width of beam, mm

Load on props $= (2.4T + 200) \times \frac{SL}{10^6} + 2.4(h - T) \times \frac{bL}{10^6} \quad kgs$

Safe load on wooden shores

The maximum safe load on wooden shores is given by:

$$P = 0.8 \times \left(1 - \frac{L_e}{80B}\right) \times A \quad kgs$$

Where

L_e = effective height, mm

B = least dimension of shore, mm

A = area of cross-section of shore

Example 15.8: Calculate load and find the required diameter of a wooden prop supporting head-tree of a beam bottom with the following data:

- Thickness of slab, T = 125 mm
- Spacing of props along the beam, L = 1300 mm
- C/C spacing of props perpendicular to the beam, S = 2000 mm
- Beam depth, h = 500 mm
- Beam width, b = 300 mm
- Prop height, L_e = 3.5 m

Load on props, P = $(2.4T + 200)\times\frac{SL}{10^6} + 2.4(h - T)\times\frac{bL}{10^6}$ kgs

$$= (2.4\times125 + 200)\frac{2000\times1300}{10^6} + 2.4(500 - 125)\frac{300\times1300}{10^6}$$

= 1651 kgs

$$P = 0.8\times\left(1 - \frac{L_e}{80B}\right)\times A \quad kgs \qquad = 0.8\times\pi/4\ d^2 - 0.8\times\left(\frac{L_e}{80B}\right)$$

$d^2 - 28d - 2625 = 0$

$$d = \frac{28\pm106.23}{2} = 68mm$$

∴ Use 75 mm diameter circular prop.

Example 15.9: Calculate the maximum safe load which a 100 mm square wooden prop 3m long can support.

Solution:

L_e = 3000 mm, b = 100 mm, A = 10,000 mm^2

$$P = 0.8 \times \left(1 - \frac{L_e}{80B}\right) \times A \quad kgs$$

$$= 0.8 \times \left(1 - \frac{3000}{80 \times 100}\right) \times 10{,}000 = 5{,}000 \quad kgs$$

Design Of Joists / Ledgers

The batten loads may be considered as point loads acting on the ledgers and the bending moment is calculated accordingly. The remaining design procedure is same as that for the battens.

End of Topic