STRUCTURAL DESIGN [RCD] - CVE 308

Assignment 1 - Solutions

Purpose of Structural Design

1a) I. To design for Safety and durability.

II. The design must be economical.

III. The deformation of the structure should not occur under expected loads considering structural integrity.

1b) Difference between limit state design (plastic design) and working stress design (elastic design)

- Limit state design considers the disadvantages of load factor design and any other failure that could cause the structure to be unfit, as the name suggests, the stress in the material is allowed to go beyond the yield limit and enter the plastic zone to reach ultimate strength, While, Elastic design is a method of analysis which the design of a structural member is based on a linear stress - strain relationship, assuming that the working stress is only a fraction of the elastic limit of the material. It is calculated such that the stress in the material is restrained to it's yield point for the design strength.

1c) Staircase Design

Slope factor $= \frac{\sqrt{R^2 + T^2}}{T} = \frac{\sqrt{150^2 + 275^2}}{275}$

$= 1.14$

Load Analysis

A. Waist $= R \times 24 kN/m^2$

$= 0.15 \times 24 = 3.6 kN/m^2$

B. Finishes $= 1.2 kN/m^2$

C. Steps $= T \times \frac{1}{2} \times 24 kN/m^2$

$= 0.275 \times 0.5 \times 24 = 3.3 kN/m^2$

D. $G_k = ((A+B) \times SF) + C$

$= (4.8 \times 1.14) + 3.3$

$= 8.772 kN/m$

D.L, $F = 1.4 G_k + 1.6 Q_k$

$= 1.4(8.772) + 1.6(1.5)$

$= 14.68 kN/m^2$

Span $= T_{total} + 0.5(l_a + l_b)$

$= (275 \times 12) + 0.5(225 + 225)$

$= 3.525 m$

$d = h - cover - \frac{1}{2}\phi = 150 - 25 - \frac{1}{2}(12) = 119 mm$

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$$M = \frac{Fl^2}{10} = \frac{14.68 \times 3.525^2}{10} = 18.24\ kNm$$

$$K = \frac{M}{bd^2 f_{cu}} = \frac{18.24 \times 10^6}{1000 \times 119^2 \times 25} = 0.052$$

$$l_a = 0.5 + \sqrt{0.25 - K/0.9}$$
$$= 0.5 + \sqrt{0.25 - \frac{0.052}{0.9}} = 0.928 \quad (\leq 0.95)$$

$$Z = l_a d = 0.928 \times 119 = 111.6\ mm$$

$$A_s = \frac{M}{0.95 f_y Z} = \frac{18.24 \times 10^6}{0.95 \times 410 \times 111.6}$$
$$= 419.53\ mm^2$$

(Provide Y12 @ 250 c/c [$A_{s\,prov} = 452\ mm^2$])

→ Deflection Check

$$f_s = \frac{2}{3} \times \frac{1}{\beta} \times \frac{A_{req}}{A_{prov}} \times f_y$$

$$f_s = \frac{2}{3} \times 1 \times \frac{419.53}{452} \times 250$$
$$= 154.69\ N/mm^2$$

$$M.F = 0.55 + \frac{477 - f_s}{120\left(0.9 + \frac{M}{bd^2}\right)} \quad [\leq 2]$$

$$\therefore \text{mif} = 0.55 + \frac{477 - 154.69}{120\left(0.9 + \frac{18.24 \times 10^6}{1000 \times 119^2}\right)}$$

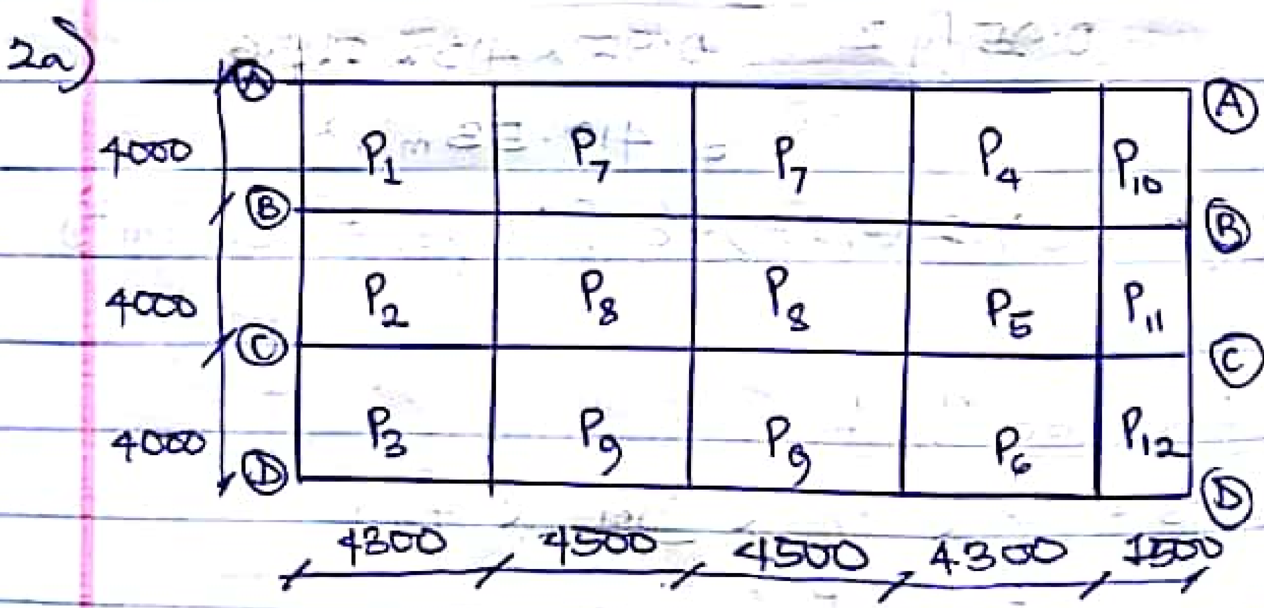
$$= 1.78$$

$$d_{req} = \frac{\text{Span}}{\text{mif} \times \text{effective depth ratio}}$$

$$= \frac{3.525 \times 1000}{1.78 \times 26} = 76.17\,mm$$

Since $d_{req} < d_{prov}$,
Deflection is Ok

2a)



l_y/l_x

$$P_1 = P_2 = P_3 = \frac{4300}{4000} = 1.075 < 2$$

$\therefore \rightarrow$ 2-way slab

$$P_7 = P_8 = P_9 = \frac{4500}{4000} = 1.125 < 2$$

$\therefore \rightarrow$ 2-way slab

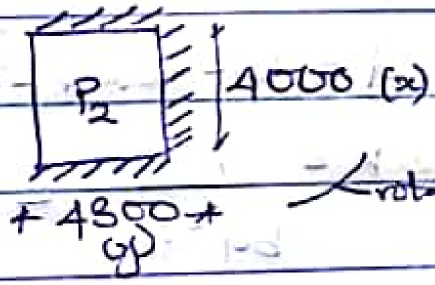
$P_4 = P_5 = P_6 = \frac{4300}{4000} = 1.075 < 2$

$\therefore \rightarrow$ 2-way slab

$P_{10} = P_{11} = P_{12} = \frac{4000}{1500} = 2.66 > 2$

$\therefore \rightarrow$ 1-way slab

2b) Designing Panel 2



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$\frac{l_y}{l_x} = \frac{4300}{4000} \simeq 1.1$

Shortspan coefficient = 0.044, 0.033

Long span coefficient = 0.037, 0.028

Assumed; Slab thickness = 175 mm

$F_{cu} = 25 N/mm^2$

$F_y = 410 N/mm^2$

G_k = Wt. of Slab = $0.175 \times 24 = 4.2 KN/m^2$

Partition = $1.0 KN/m^2$

Finishes = $1.2 KN/m^2$

$6.4 KN/m^2$

Design Load (D.L) = $1.4 G_k + 1.6 Q_k$

$= (1.4 \times 6.4) + (1.6 \times 5)$

$= 16.96 \simeq 17 KN/m$

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Short Span

- Mid Span

$M = \beta_x w l_x^2 = 0.044 \times 17 \times 4^2$

$= 11.968$ KNm

$d = h - \text{cover} - \frac{1}{2}\phi = 144$

$K = \frac{M}{bd^2 F_{cu}} = \frac{11.968 \times 10^6}{1000 \times 144^2 \times 25} = 0.023$

$I_a = 0.5 + \sqrt{0.25 - K/0.9}$

$= 0.5 + \sqrt{0.25 - \frac{0.023}{0.9}} = 0.97 \quad (\leq 0.95)$

$Z_1 = I_a d = 0.95 \times 144 = 136.8$ mm

$A_s = \frac{M}{0.95 F_y Z_1} = \frac{11.968 \times 10^6}{0.95 \times 410 \times 136.8} = 224.61 mm^2$

Provide Y12 @ 300 c/c ($A_s = 377 mm^2$)

- Continuous edge

$M = \beta_x w l_x^2 = 0.033 \times 17 \times 4^2 = 8.976$ KNm

$d = 144$

$$k = \frac{M}{bd^2 f_{cu}} = \frac{8.976 \times 10^6}{1000 \times 144^2 \times 25} = 0.0173$$

$$I_a = 0.5 + \sqrt{0.25 - k/0.9} = 0.5 + \sqrt{0.25 - \frac{0.173}{0.9}}$$
$$= 0.83$$

$$Z_1 = I_a d = 0.83 \times 144$$
$$= 119.52 \text{ mm}$$

$$A_s = \frac{M}{0.95 f_y z} = \frac{8.976 \times 10^6}{0.95 \times 410 \times 119.52} = 192.81 \text{ mm}$$

Long Span

- Mid Span

$$d = 144 - 12 = 132 \text{ mm}$$

$$M = \beta_x w l_x^2 = 0.037 \times 17 \times 4^2 = 10.064 \text{ kNm}$$

$$k = \frac{M}{bd^2 f_{cu}} = \frac{10.064 \times 10^6}{1000 \times 132^2 \times 25} = 0.0231$$

$$I_a = 0.5 + \sqrt{0.25 - k/0.9} = 0.97 \quad (\leq 0.95)$$

$$Z_1 = I_a d = 0.95 \times 132 = 125.4$$

$$A_s = \frac{M}{0.95 f_y z_1} = \frac{10.064 \times 10^6}{0.95 \times 410 \times 125.4} = 206.04 \text{ mm}^2$$

Provide Y12 @ 300 c/c [377 mm²]

- Continuous edge

$M = 0.028 \times 17 \times 4^2 = 7.616$ kNm

$K = \frac{M}{bd^2 f_{cu}} = \frac{7.616 \times 10^6}{1000 \times 132^2 \times 25} = 0.017$

$d = 132$ mm

$I_a = 0.5 + \sqrt{0.25 - \frac{0.017}{0.9}} = 0.98 \quad (\leq 0.95)$

$Z_1 = I_a d = 0.95 \times 132 = 125.4$

$A_s = \frac{M}{0.95 f_y Z_1} = \frac{7.616 \times 10^6}{0.95 \times 410 \times 125.4}$

$= 155.93 \text{ mm}^2$

Provide Y12 @ 300 c/c [377 mm²]

Deflection Check

$f_s = \frac{2}{3} \times f_y \times \frac{1}{\beta} \times \frac{A_{req}}{A_{prov}}$

$= \frac{2}{3} \times 250 \times 1 \times \frac{224.61}{377} = 99.3 \text{ N/mm}^2$

$mf = 0.55 + \frac{477 - f_s}{100\left(0.9 + \frac{M}{bd^2}\right)} \quad (\leq 2)$

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$$\therefore mif = 0.55 + \frac{477 - 99.3}{120\left(0.9 + \frac{11.968 \times 10^{6}}{1000 \times 144^{2}}\right)}$$

$$= 2.68 > 2$$

$$\therefore d_{req} = \frac{Span}{mif \times eff.\ depth\ ratio}$$

$$= \frac{4000}{2 \times 26} = 76.92$$

$d_{req} < d$ $\therefore$ deflection is ok.