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1a. The design of structure must be safe

ii. The structure must be economical

iii. The deformation of the structure must not impair with its integrity

1b. Limit state design considers the disadvantages of load factor design and any other failure that can cause the structure to be structually unfit 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 are only a fraction of the elastic limit of the material.

Staircase Design

Slope Factor $= \frac{\sqrt{R^2+T^2}}{T} = \frac{\sqrt{150^2 + 275^2}}{275} = 1.14$

Load Analysis

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

Finishes $= 1.2\ kN/m^2$

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 $= ((A \times B) \times S_F) + C$
$= (4.8 \times 1.14) + 3.3$
$= 8.77\ kN/m$

$D.L.F = 1.4\,G_k + 1.6\,Q_k$
$= 1.4(8.77) + 1.6(1.5) = 14.68\ kN/m^2$

Span $= T_{total} + 0.5(12 + 16) = (275 \times 12) + 0.5(225 + 225)$

$d = h - cover - \frac{1}{2}\phi$
$= 150 - 25 - 6 = 119\ mm$

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

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

$I_a = 0.5 + \sqrt{0.25 - K/0.9} = 0.5 + \sqrt{0.25 - \frac{0.052}{0.9}} = 0.938$

$Z = I_a d = 0.938 \times 119 = 111.622\ mm$

$A_s = \frac{M}{0.95 f_y z} = \frac{18.24 \times 10^6}{0.95 \times 410 \times 111.622} = 419.53$

$A_{sprov} = 452\ mm$

Provide Y12 @ 250 c/c

Deflection check

$f_s = \frac{2}{3} \times \frac{1}{\beta} \times A_{req}/A_{prov} \times f_{yv}$

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

$M.F = 0.56 + \frac{477 - 154.69}{120\left(0.9 + \frac{18.24 \times 10^6}{1000 \times 119^2}\right)}$

$= 1.18$

$d_{req} = \frac{Span}{mf \times edv} = \frac{3525}{1.78 \times 26} = 76.17mm$

since $d_{req} < d$, Deflection is OK

2a. $P_1 = P_2 = P_3 = \frac{4300}{4000} = 1.075 < 2 = 2$ way slab

$P_2 : P_8 = P_9 = \frac{4500}{4000} = 1.25 < 2 = 2$ way slab

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

$P_{10} = P_{11} = P_{12} = \frac{4000}{1500} = 2.66 > 2 = 1$ way slab

2b) Designing of P_2

$\frac{l_y}{l_x} = \frac{4500}{4000} = 1.075 \simeq 1.1$

Short span coefficient $= \frac{-}{0.054}$

Long span coefficient $= \frac{0.058}{0.044}$

Specifications of slab thickness = 175mm

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

$f_y = 410 N/mm^2$

DL = 1.4 Gk + 1.6 Qk

Gk : weight of slab = 0.175 × 24
Partition = 1.0
Finishes = 1.2
6.4 kN/m²

For Factory
DL = (1.4 × 6.4) + (1.6 × 5)
= 16.96 ≃ 17 kN/m²

Short span coefficient = 0.044
0.033

Long span coefficient = 0.037
0.028

Short span mid = P
$m = \beta_x \cdot wl_x^2$ = 0.044 × 17 × 4²
= 11.968

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

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

$l_a = 0.5 + \sqrt{0.25 - k/0.9}$ = 0.97 > 0.95 = 0.95

Z = 0.95 × 144 = 136.8

$A_s = \frac{M}{0.95 f_y z} = \frac{11.968 \times 10^6}{0.95 \times 410 \times 136.8}$ = 224.61

Provide y^{12} @ 377mm

Continuous

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

$d = 144$

$k = \frac{M}{bd^2 f_{cu}} = \frac{8.976 \times 10^6}{0.95 \times 144^2 \times 25} \Rightarrow 0.0173$

$l_a = 0.5 + \sqrt{0.25 - K/0.9} = 0.5 + \sqrt{0.25 - \frac{0.0173}{0.9}}$
$= 0.83$

$z = l_a \times d = 0.83 \times 144 = 119.52$

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

provide y12 @ 377mm

Long Span
Mid , $d = d(\text{shortspan}) - \text{steel thickness} = 144 - 12$
$= 132mm$

$M = \beta \times w l_x^2 = 0.037 \times 17 \times 4^2 = 10.064$

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

$l_a = 0.5 + \sqrt{0.25 - K/0.9} = 0.97 > 0.95 = 0.95$

$z = l_a \times d = 0.95 \times 132 = 125.4$

$A_s = \frac{M}{0.95 f_y z} = \frac{10.064 \times 10^6}{0.95 \times 125.4 \times 410} = 206.04$
provide y12 at 817mm

Long Span - continuous

$d = 132\,mm$

$M = B_{sx} w l^2 x = 0.028 \times 17 \times 4^2 = 7.616$

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

$$P_a = 0.5 + \sqrt{0.25 - k/0.9} = 0.98 > 0.95 = 0.95$$

$Z = I_a d = 125.4$

$$A_s = \frac{M}{0.95 f_{yk}} = \frac{7.616 \times 10^6}{0.95 \times 410 \times 125.4} = 155.93$$

provide y12 @ 377 mm

Deflection Check

$$f_s = \frac{2}{3} \times f_{yu} \times B \times \frac{A_{req}}{A_s\ provided}$$

$$f_s = \frac{2}{3} \times 250 \times 1 \times \frac{224.61}{377} = 99.3$$

$$M.F = 0.55 + \frac{422 - 99.3}{120\left(0.9 + \frac{11.968 \times 10^6}{1000 \times 144^2}\right)}$$

$= 2.68 > 2$

$$d_{req} = \frac{4 \times 1000}{2 \times 26} = 76.92 \quad OK$$