



IIT ROORKEE



NPTEL ONLINE
CERTIFICATION COURSE

EARTHQUAKE RESISTANT DESIGN OF FOUNDATIONS

Lecture 37: Raft Foundations – Numerical Examples

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ERD of Foundations - Modules

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Miscellaneous

Module - 6: Chapters

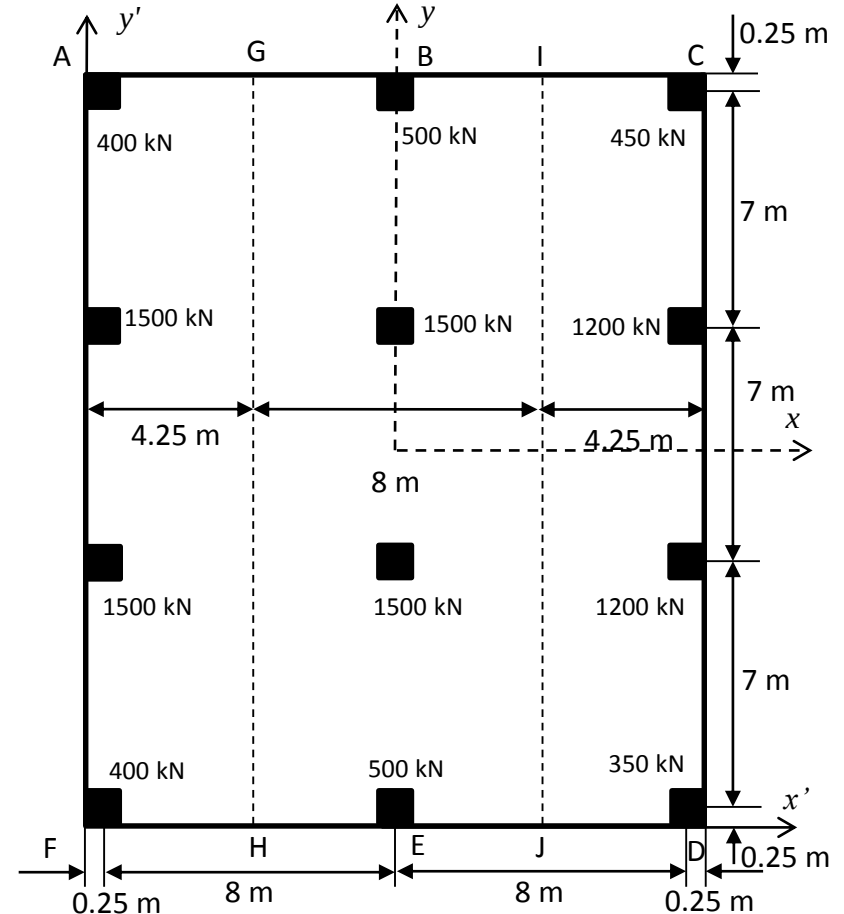
1. Raft Foundation – Numerical Examples
2. Shallow Foundations on Slopes

Chapter 1: Raft Foundation - Numerical Examples

- **For Soil Pressure**
- **For Design of Raft Foundation**

Raft Foundations

Example 1: The plan of mat foundation is shown in Fig. Calculate the soil pressure at points A, B, C, D, E and F. (all column section are planned to be 0.5 m X 0.5 m.)



Example: 1 (Continued...)

Solution:

The soil pressure at different point can be calculated using the Eqn.

$$q = \frac{Q}{A} \pm \frac{M_y x}{I_y} \pm \frac{M_x y}{I_x}$$

$$A = \text{Area of raft} = 16.5 \times 21.5 = 354.75 \text{ m}^2$$

$$I_x = \frac{1}{12} BL^3 = \frac{1}{12} 16.5 \times 21.5^3 = 13665 \text{ m}^4$$

$$I_y = \frac{1}{12} LB^3 = \frac{1}{12} 21.5 \times 16.5^3 = 8050 \text{ m}^4$$

Example: 1 (Continued...)

Total column load on the raft, Q

$$Q = 350 + 2 \times 400 + 450 + 2 \times 500 + 2 \times 1200 + 4 \times 1500 = 11,000 \text{ kN}$$

$$M_y = Qe_x; \quad e_x = x' - \frac{B}{2}$$

$$x' = \frac{Q_1 x'_1 + Q_2 x'_2 + Q_3 x'_3 + Q_4 x'_4 + \dots}{Q}$$

$$x' = \frac{1}{11,000} \left[\begin{array}{l} 8.25 \times (500 + 1500 + 1500 + 500) \\ + 16.25 \times (350 + 1200 + 1200 + 450) \\ + 0.25 \times (400 + 1500 + 1500 + 400) \end{array} \right]$$

$$x' = 7.814 \text{ m}$$

$$e_x = x' - \frac{B}{2} = 7.814 - \frac{16.5}{2} = -0.435 \sim -0.44 \text{ m}$$

Example: 1 (Continued...)

Hence, the resultant line of action is located to the left of the center of the mat. So $M_y = Qe_x = 11000 \times (-0.44) = -4840 \text{ kNm}$. Similarly,

$$M_x = Qe_y; \quad e_y = y' - \frac{L}{2}$$

$$y' = \frac{Q_1 y'_1 + Q_2 y'_2 + Q_3 y'_3 + Q_4 y'_4 + \dots}{Q}$$

$$y' = \frac{1}{11,000} \left[0.25 \times (400 + 500 + 350) + 7.25 \times \left(\frac{1500 + 1500 + 1200}{1500 + 350} \right) + 21.25 \times (400 + 500 + 450) \right]$$

$$y' = 10.85 \text{ m}$$

$$e_y = y' - \frac{L}{2} = 10.85 - \frac{21.5}{2} = 0.1 \text{ m}$$

Example: 1 (Continued...)

$$M_x = Qe_y = 11,000 \times 0.1 = 1100 \text{ kNm.}$$

The location of the line of action of the resultant column load is shown in the next slide

$$q = \frac{Q}{A} \pm \frac{M_y x}{I_y} \pm \frac{M_x y}{I_x}$$
$$q = \frac{11,000}{345.75} \pm \frac{-4840x}{8050} \pm \frac{1100y}{13,665}$$
$$q = 31.0 \mp 0.6x \pm 0.08y \text{ (kN/m}^2\text{)}$$

Example: 1 (Continued...)

Therefore, the soil pressure at

$$\text{A: } q = 31.0 + 0.6 \times 8.25 + 0.08 \times 10.75 \\ = 36.81 \text{ (kN/m}^2\text{)}$$

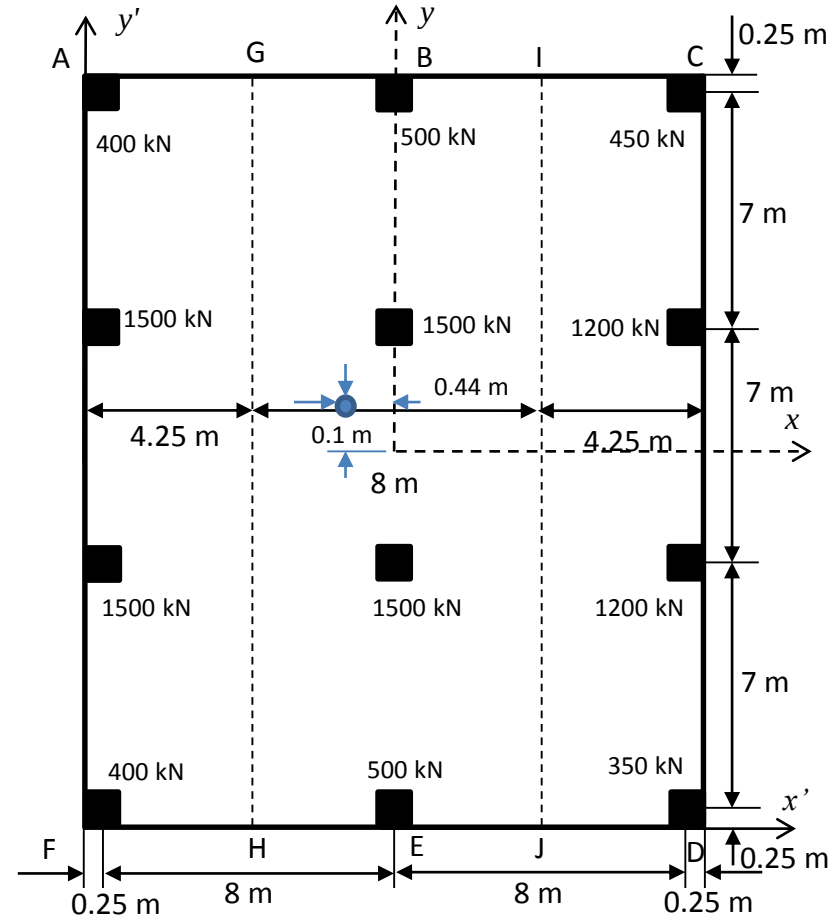
$$\text{B: } q = 31.0 + 0.6 \times 0 + 0.08 \times 10.75 \\ = 31.86 \text{ (kN/m}^2\text{)}$$

$$\text{C: } q = 31.0 - 0.6 \times 8.25 + 0.08 \times 10.75 \\ = 26.91 \text{ (kN/m}^2\text{)}$$

$$\text{D: } q = 31.0 - 0.6 \times 8.25 - 0.08 \times 10.75 \\ = 25.19 \text{ (kN/m}^2\text{)}$$

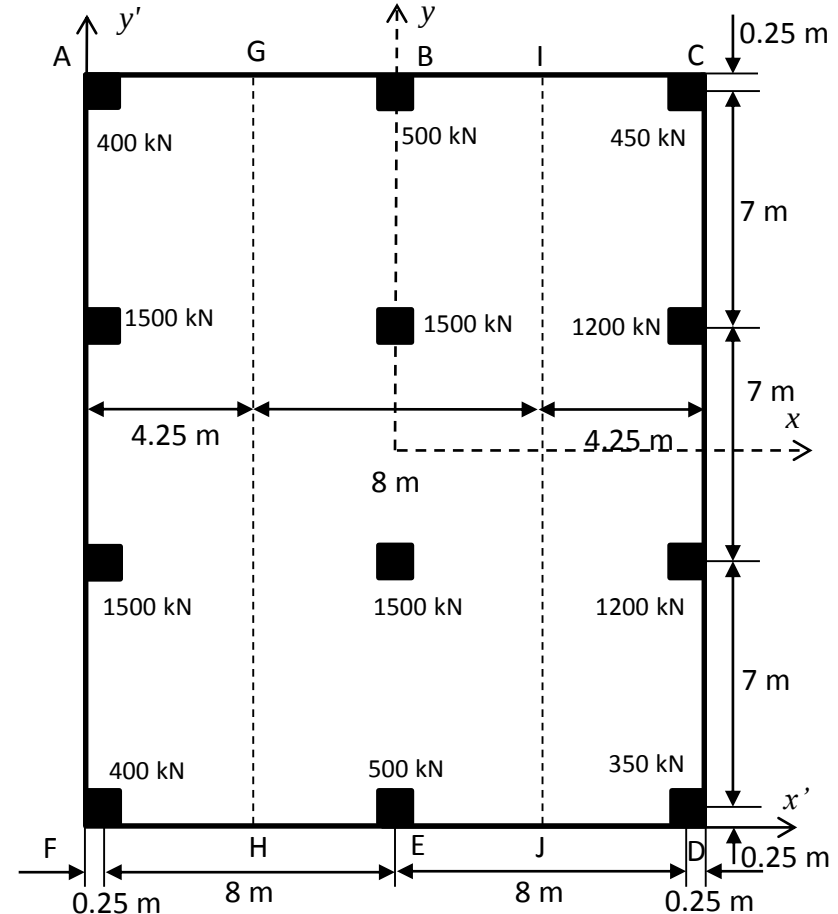
$$\text{E: } q = 31.0 + 0.6 \times 0 - 0.08 \times 10.75 \\ = 30.14 \text{ (kN/m}^2\text{)}$$

$$\text{F: } q = 31.0 + 0.6 \times 8.25 - 0.08 \times 10.75 \\ = 35.09 \text{ (kN/m}^2\text{)}$$



Raft Foundations

Example 2: Divide the mat foundation shown in fig. Into three strips, such as $AGHF$ ($B_1 = 4.25$ m) $GJIH$ ($B_1 = 8$ m) and $ICDJ$ ($B_1 = 4.25$ m) use the result of example 1 and determine the shear force and bending moment diagrams the y direction. Also find the thickness of raft. Given, $f'_c = 20.7$ MN/m², $f_y = 413.7$ MN/m², and the load factor is 1.7



Example: 2 (Continued...)

Determination of shear and moment diagram for strips :

Strip AGHF:

$$\text{Average soil pressure} = q_{av} = q_{(at A)} + q_{(at F)} = \frac{36.81 + 35.09}{2} = 35.95 \text{ kN/m}^2$$

$$\text{Total soil reaction} = q_{av} B_1 L = (35.95 \times 4.25 \times 21.50) = 3285 \text{ kN}$$

The sum of the column loads on the strip will not equal $q_{av} B_1 L$, because the shear between adjacent strips has not been taken into account. For this reason, the soil reaction and the column loads need to be adjusted, or

$$\begin{aligned} \text{Average Load} &= \frac{\text{Load due to soil reaction} + \text{column Loads}}{2} \\ &= \frac{3285 + 3800}{2} = 3542.5 \text{ kN} \end{aligned}$$

Example: 2 (Continued...)

So ,modified average soil pressure,

$$q_{av(modified)} = q_{av} \left(\frac{3542.5}{3285} \right) = (35.95) \left(\frac{3542.5}{3285} \right) = 38.768 \text{ kN/m}^2$$

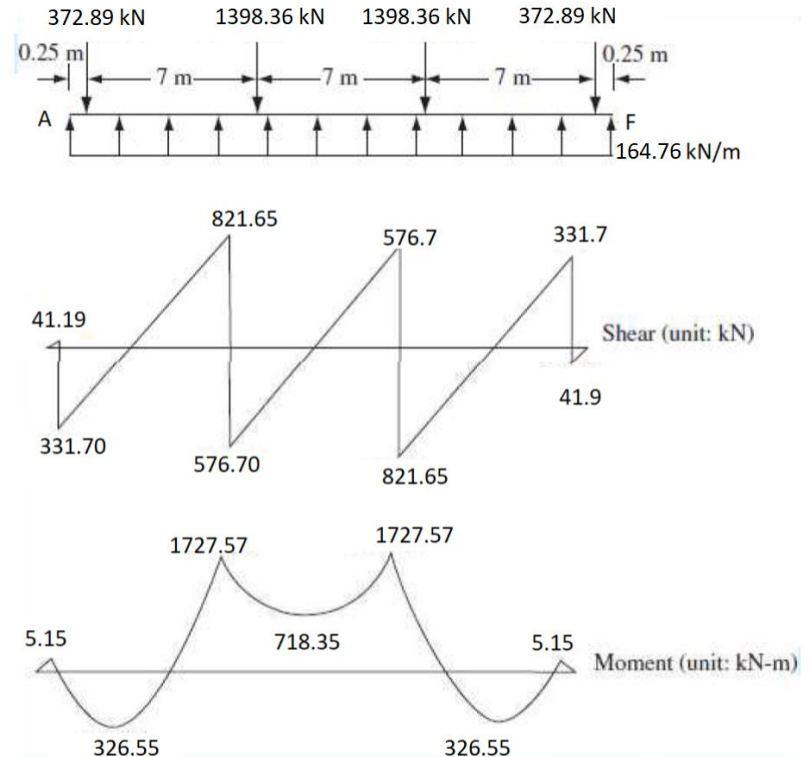
The column loads can be modified in similar manner by multiplying factor

$$F = \frac{3542.5}{3800} = 0.9322$$

Fig. in next slide shows the loading on the strip and corresponding shear and moment diagram. Note that the column loads shown in this figure have been multiplied by $F = 0.9322$. Also the load per unit length of the beam is equal to $B_1 q_{av(modified)} = (4.25)(38.768) = 164.76 \text{ kN/m}$.

Example: 2 (Continued...)

Load, shear and
moment diagram
for strip *AGHF*



Example: 2 (Continued...)

Strip GIJH : In a similar manner,

$$q_{av} = \frac{q(\text{at } B) + q(\text{at } E)}{2} = \frac{31.86 + 30.14}{2} = 31.0 \text{ kN/m}^2$$

$$\text{Total soil reaction} = (31 \times 8 \times 21.5) = 5332 \text{ kN}$$

$$\text{Total column load} = 4000 \text{ kN}$$

$$\text{Average Load} = \frac{5332 + 4000}{2} = 4666 \text{ kN}$$

$$q_{av(\text{modified})} = (31.0) \left(\frac{4666}{5332} \right) = 27.12 \text{ kN/m}^2$$

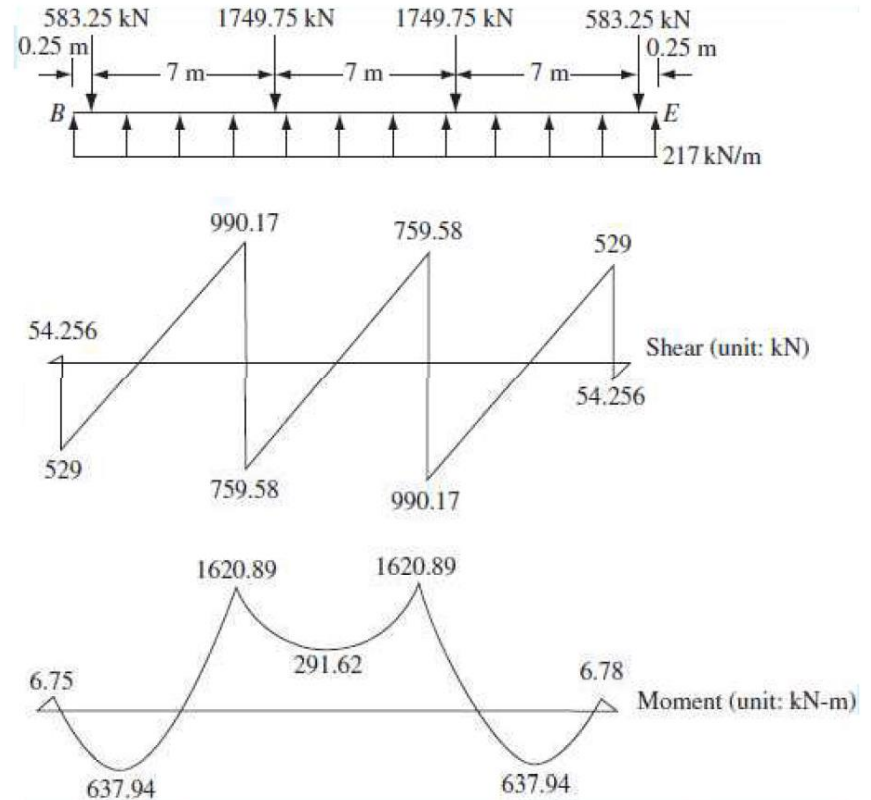
$$\text{load per unit length of the beam is equal to } B_1 q_{av(\text{modified})} = (8)(27.12) = 216.96 \text{ kN/m.}$$

$$F = 4666 / 4000 = 1.1665$$

The load, shear, moment diagram are shown in next slide.

Example: 2 (Continued...)

Load, shear and
moment diagram
for strip *GIHJ*



Example: 2 (Continued...)

Strip ICDJ : In a similar manner,

$$q_{av} = \frac{q(\text{at } C) + q(\text{at } D)}{2} = \frac{26.91 + 25.19}{2} = 26.05 \text{ kN/m}^2$$

$$\text{Total soil reaction} = (26.05 \times 4.25 \times 21.5) = 2380 \text{ kN}$$

$$\text{Total column load} = 3200 \text{ kN}$$

$$\text{Average Load} = \frac{2380 + 3200}{2} = 2790 \text{ kN}$$

$$q_{av(\text{modified})} = (26.05) \left(\frac{2790}{2380} \right) = 30.53 \text{ kN/m}^2$$

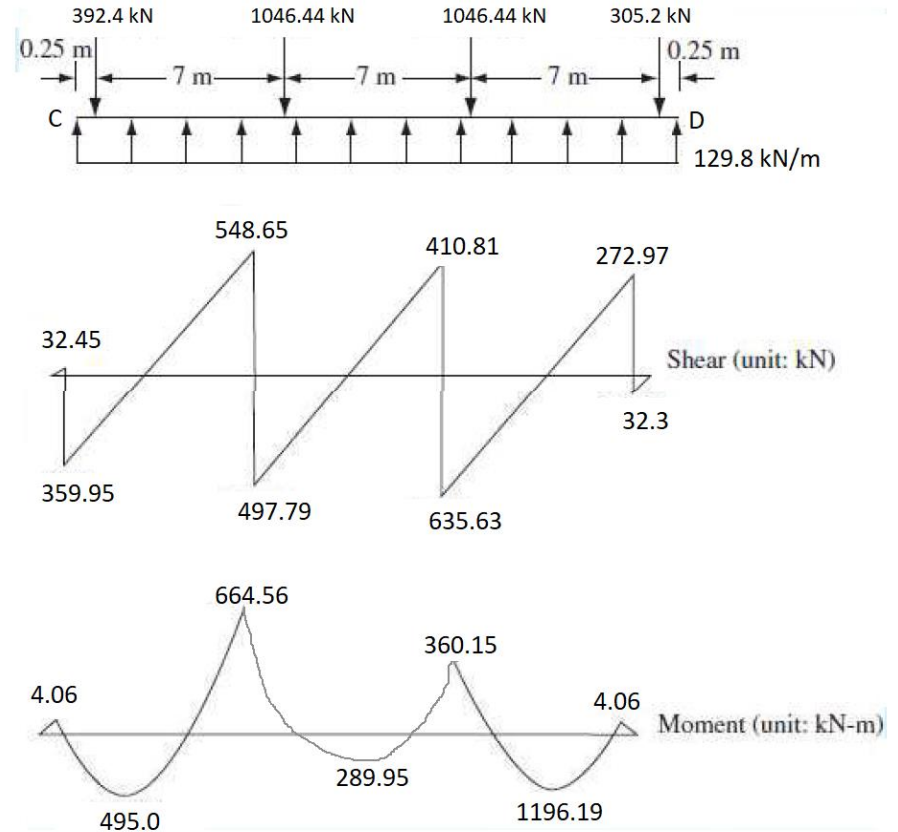
$$\text{load per unit length of the beam is equal to } B_1 q_{av(\text{modified})} = (4.25)(30.53) = 129.75 \text{ kN/m.}$$

$$F = 2790 / 3200 = 0.872$$

The load, shear, moment diagram are shown in next slide.

Example: 2 (Continued...)

Load, shear and
moment diagram
for strip *ICDJ*



Example: 2 (Continued...)

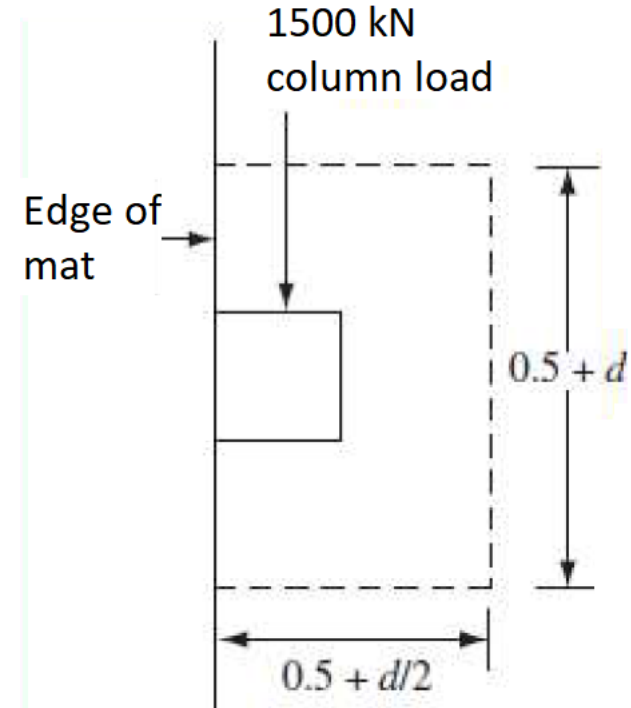
Determination of thickness of the mat

For this problem, the critical section for the diagonal tension shear will be at the column carrying 1500 kN of load at the edge of the mat. So

$$\begin{aligned} b_o &= \left(0.5 + \frac{d}{2}\right) + \left(0.5 + \frac{d}{2}\right) + (0.5 + d) \\ &= 1.5 + 2d \end{aligned}$$

Determine the effective depth d of the mat by checking for diagonal tension shear near various column. According to ACI code 318-95 for the critical section:

$$U = (b_o d) \left[(\phi)(0.34)\sqrt{f'_c} \right]$$



Example: 2 (Continued...)

ϕ = reduction factor = 0.85

f'_c = Compressive strength of concrete at 28 days (MN/m²)

U = factored column load (MN) or (column load * load factor)

$$U = 1.7 \times 1500 = 2550 \text{ kN} = 2.55 \text{ MN}$$

$$2.55 = (1.5 + 2d)(d)[(0.85)(0.34)\sqrt{20.7}]$$

$$\text{or } d = 0.68 \text{ m}$$

Example: 2 (Continued...)

Assuming a minimum cover of 76 mm over the steel reinforcement and also assuming that the steel bars to be used are 25 mm in diameter, the total thickness of the slab is

$$h = 0.68 + 0.076 + 0.025 = 0.781 \text{ m} \approx 0.8 \text{ m}$$

The thickness of this mat will satisfy the wide beam shear condition across the three strip under consideration.

Thank You

