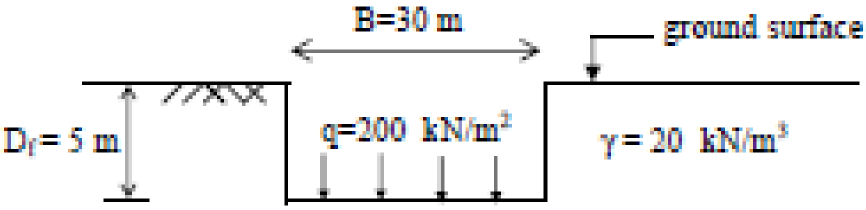
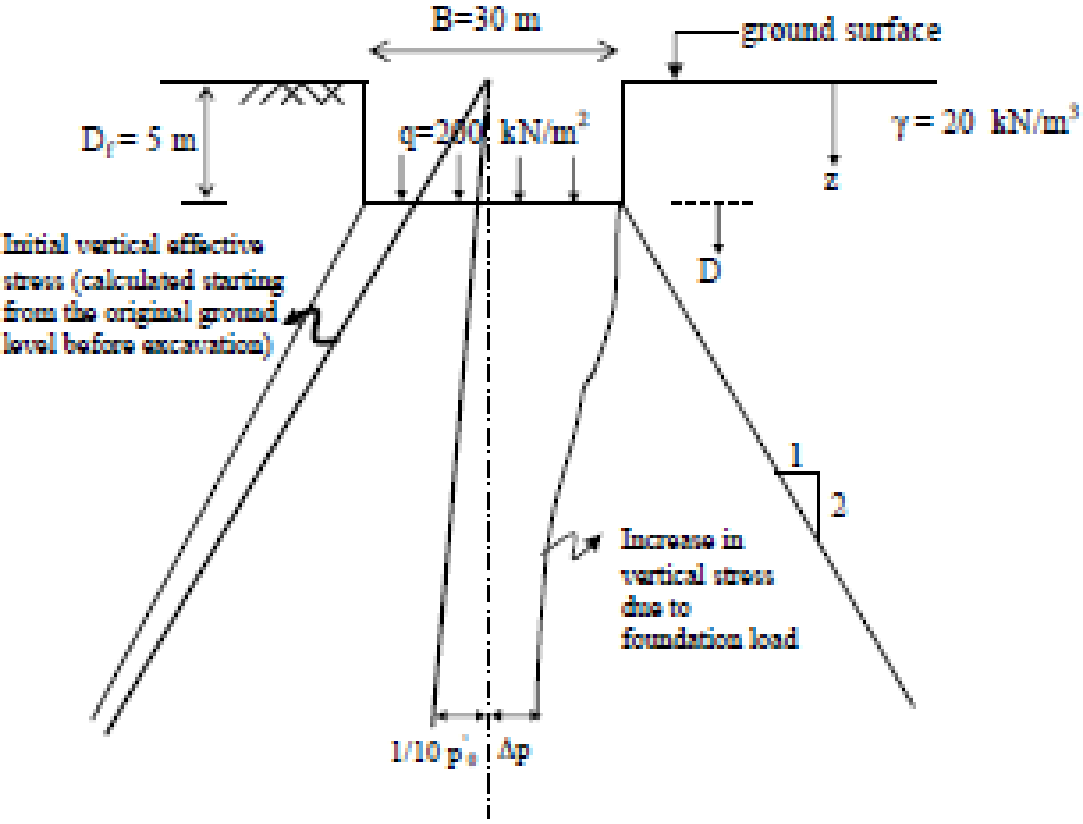
P1. DEPTH OF EXPLORATION

Question:

Find the depth of exploration from ground level for the 30x50 m, 15 storey building.



Solution:



Depth of exploration should reach such a depth where vertical stress increase due to weight of the structure would approximately be equal to the 10% of the initial effective overburden pressure:

De Beer's rule $\Rightarrow \therefore \frac{1}{10} p_o' = \Delta p$

$$\Delta p = \frac{200x30x50(kN)}{(30+D)(50+D)}$$

$$\frac{1}{10}p_o' = \frac{1}{10}(20(D+5))$$

$$\frac{200x30x50}{(30+D)(50+D)} = \frac{1}{10}x20(D+5)$$

$$2D^3 + 170D^2 + 3800D = 285000$$

$$D=28 \text{ m}$$

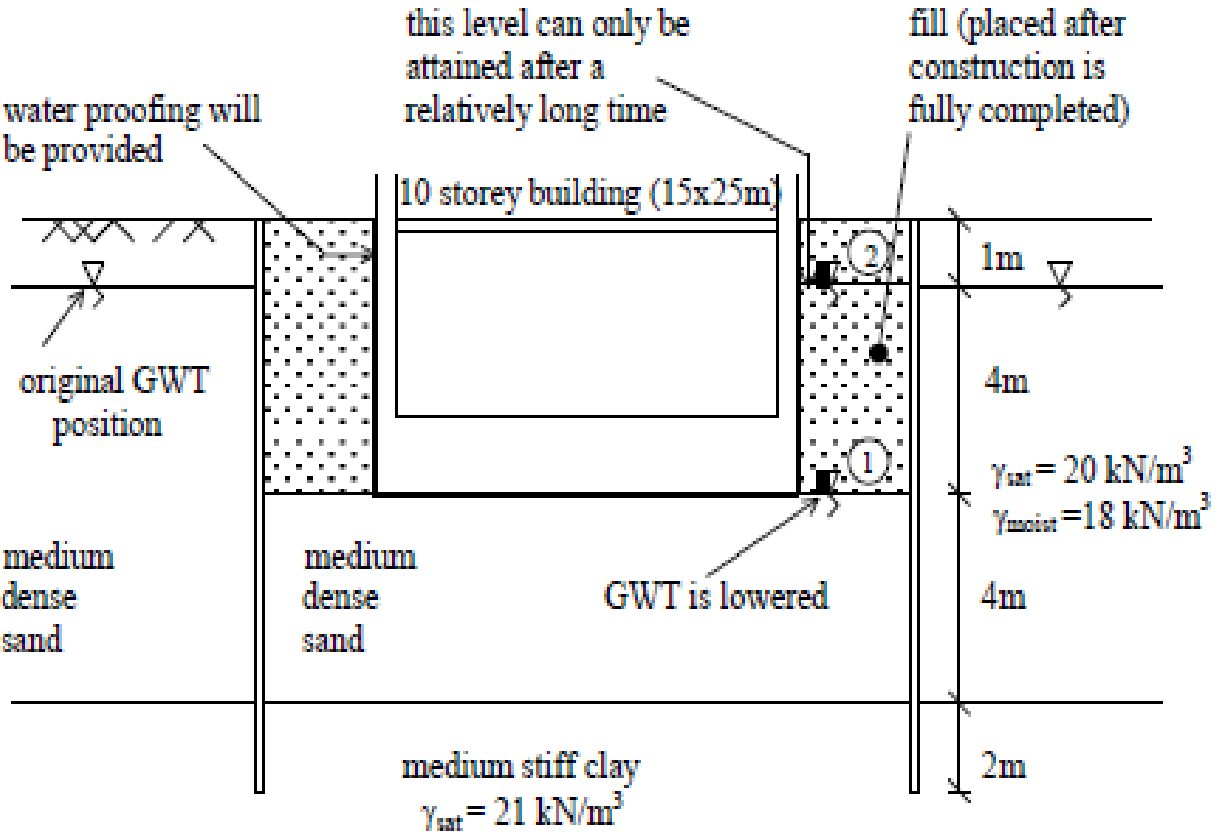
Thus, depth of exploration, z =28+5=33 m from ground level

BEARING CAPACITY (Problems & Solutions)

P1

Question:

An excavation will be made for a ten storey 15x25 m building. Temporary support of earth pressure and water pressure will be made by deep secant cantilever pile wall. The gross pressure due to dead and live loads of the structure and weight of the raft is 130 kPa (assume that it is uniform).

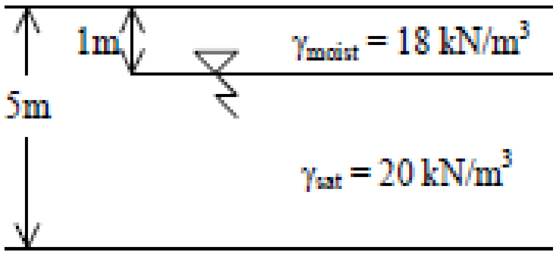


a) What is net foundation pressure at the end of construction but before the void space between the pile wall and the building has been filled, and *there is no water inside the foundation pit yet* (water level at the base level) (GWT position 1).

b) What is net foundation pressure long after the completion of the building, i.e. water level is inside the pile wall and the backfill between the building and the pile wall is placed (GWT position 2). What is the factor of safety against uplift?

Solution:

a) $q_{net} = \begin{bmatrix} \text{final effective stress} \\ \text{at foundation level} \end{bmatrix} - \begin{bmatrix} \text{initial effective stress} \\ \text{at foundation level} \end{bmatrix}$



$\rightarrow \sigma_o'$ $\quad$ $\underline{\sigma_o' = 18x1 + 4x(20\text{-}9.8) = 58.8 \text{ kPa}}$

(gross pressure – uplift pressure) = final effective stress at foundation level, σ_f'

gross pressure =130 kPa (given)

uplift pressure = 0 kPa (Since GWT is at foundation level (1), it has no effect on structure load)

σ_f' =130 –0 = 130 kPa

q_{net} =130 – 58.8

= **71.2 kPa**

b) σ_f' = 130 – 4x9.8 = 90.8 kPa

(4x9.8 → uplift pressure)

σ_o' = 58.8 kPa (same as above)

q_{net} = 90.8 – 58.8

= **32.0 kPa**

<u>OR</u>

q_{net}=q_{gross}-γ_{sat}D =130-(18x1+4x20)

=**32.0 kPa**

<u>Factor of safety against uplift is:</u>

$(FS)_{uplift}$ = weight of structure / uplift

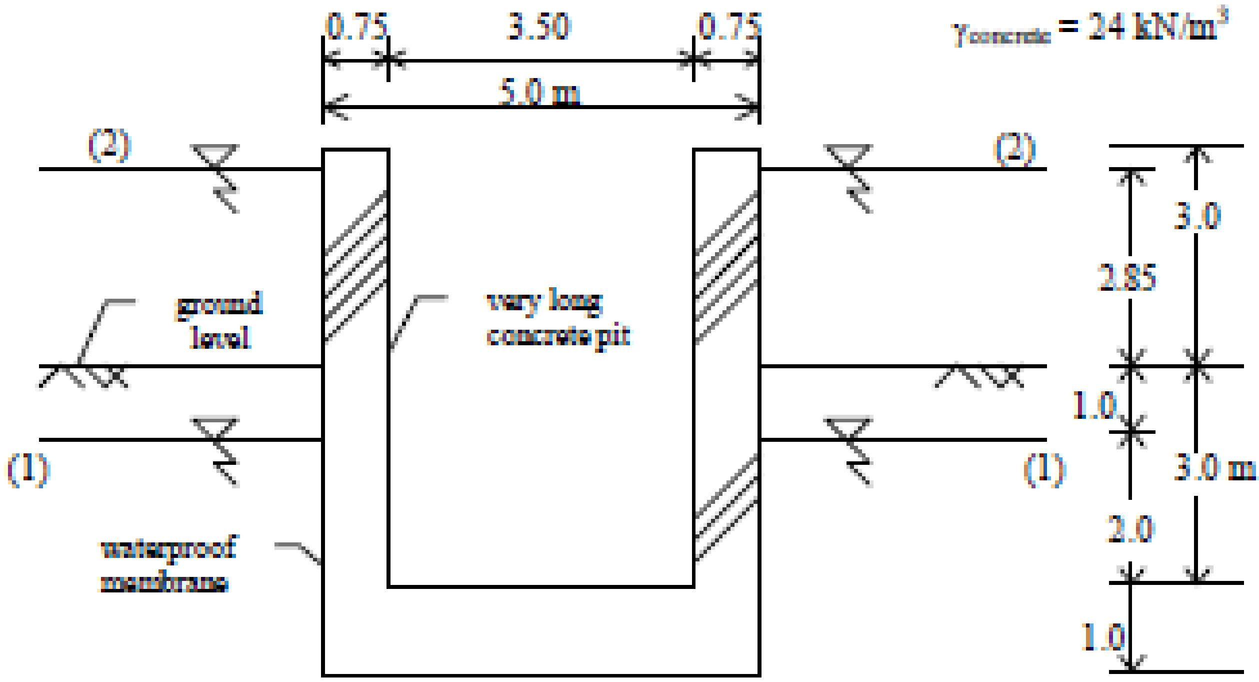
= (130x15x25) / (4x9.8x15x25)

= 3.3

P2

Question:

Calculate the FS against uplift and calculate effective stress at the base level for water level at (1) and (2) for the canal structure given below. Note that the canal is very long into the page.



Solution:

- **water table at (1)**

  Factor of Safety against uplift = $\underbrace{(2\text{x}6\text{x}0.75 + 5\text{x}1)\text{x}24}_{\Sigma\text{weight of pit}}\ /\ \underbrace{(3\text{x}5)\text{x}9.8}_{\text{uplift}}$

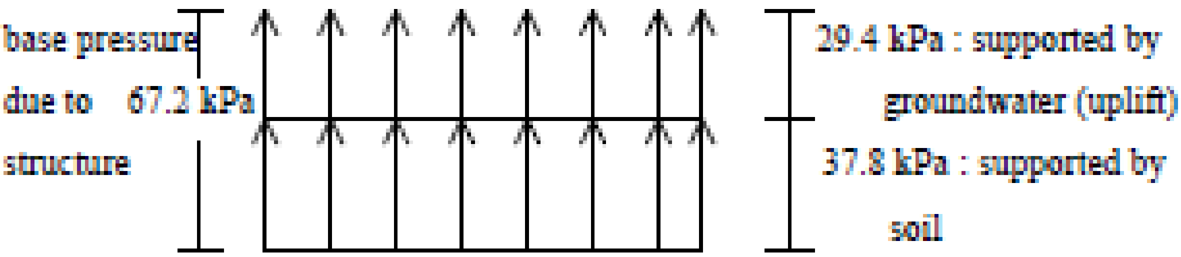
  = 336 / 147

  = 2.28

  Base pressure = 336 / 5 = 67.2 kN/m^2 due to weight of structure.(per meter of canal)

  147 / 5 = 29.4 kN/m^2 is supported by groundwater

  67.2 – 29.4 = 37.8 kN/m^2 is supported by soil (effective stress at the base)



- <u>water table at (2)</u>

FS = 336 / (6.85x5x9.8)

= 1.0 < 1.5 NOT OKEY

➡ base pressure = 67.2 kPa is supported by ground water uplift = weight of structure

<u>Soil does not carry any load, structure tends to float</u>

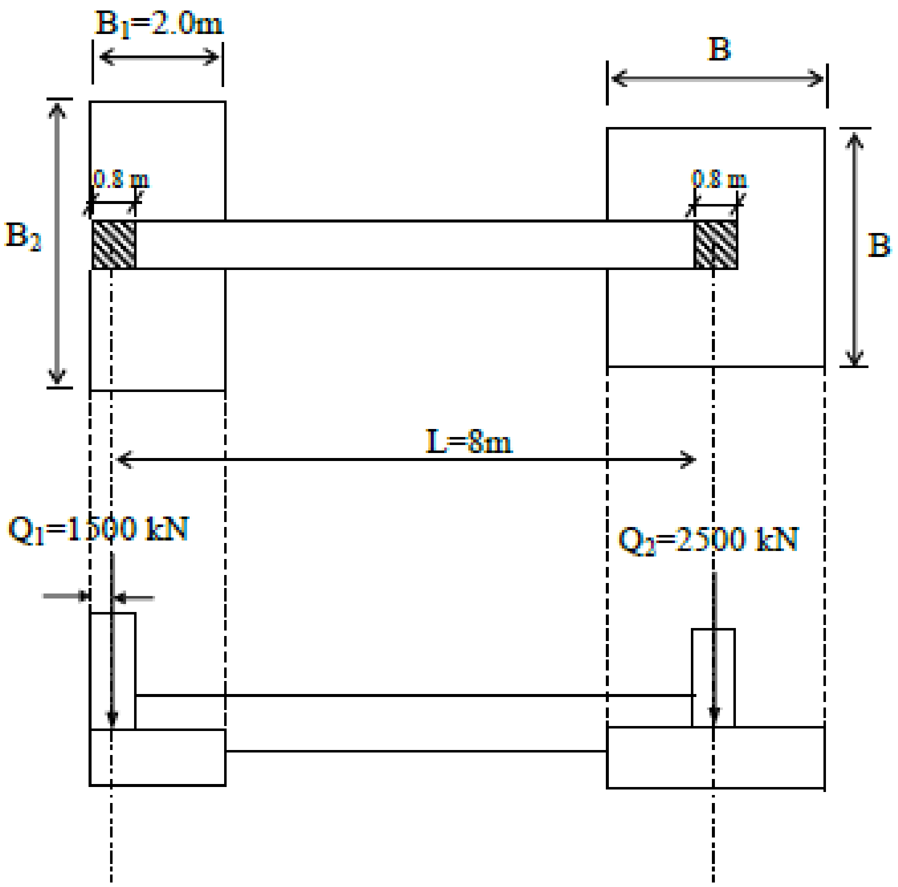
SHALLOW FOUNDATIONS

P.1) CANTILEVER FOOTING

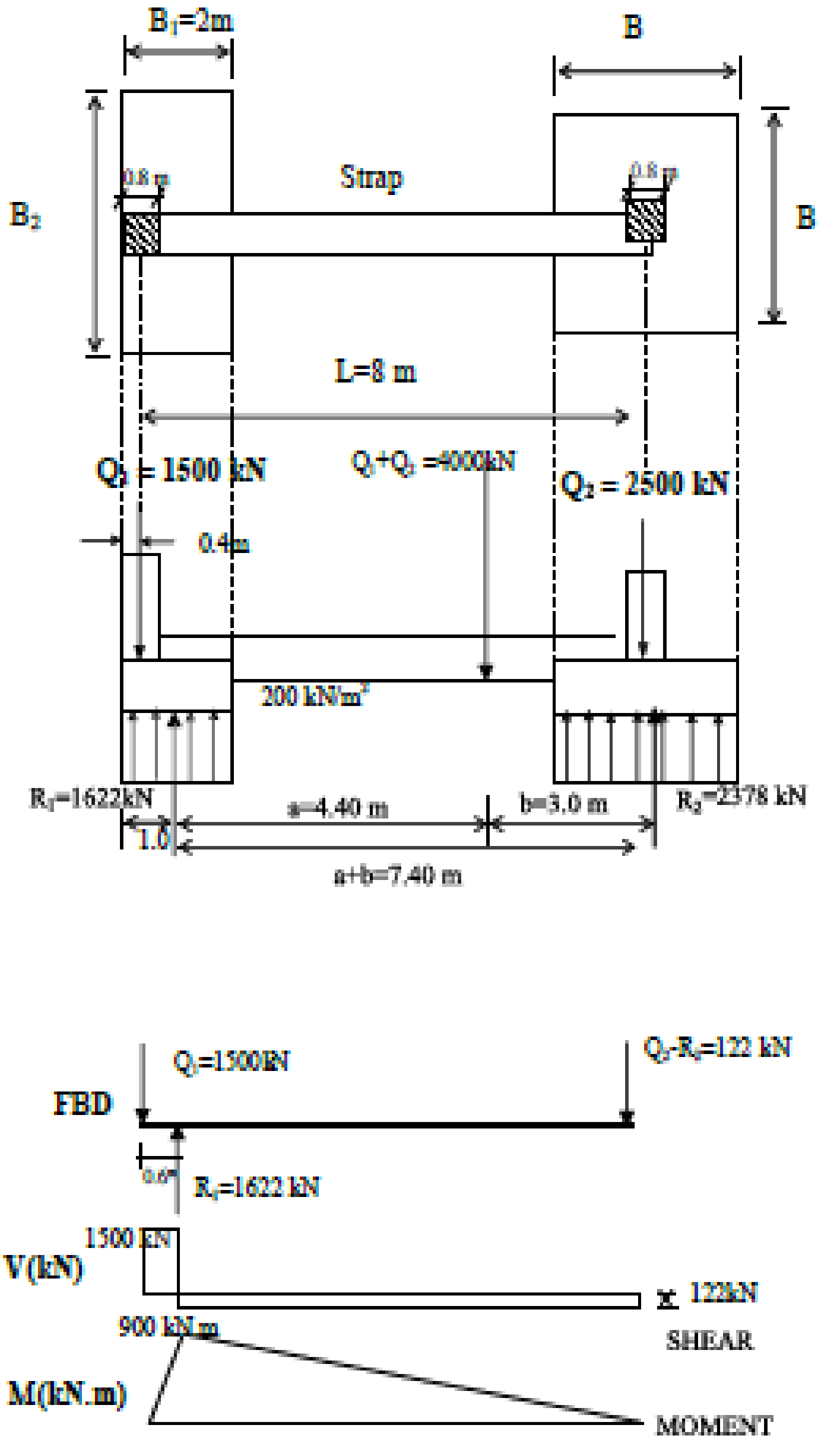
Question:

Given: $Q_1 = 1500$ kN, $Q_2 = 2500$ kN, $q_{all} = 200$ kN/m^2

Ignore the weight of footings and find dimensions B and B_2 of a cantilever footing for a uniform soil pressure distribution. Draw shear and bending moment distributions.



Solution:



Locate $\Sigma Q = Q_1 + Q_2$

$b = 1500 \times 8 / 4000 = 3$

For B_1=2m

$a = 8.0 + 0.4 - 1.0 - 3.0$

$\rightarrow a = 4.40$m

$R_1 = (4000 \times 3) / 7.4 = 1622$kN

$R_2 = 4000 - 1622 = 2378$ kN

Determine B_2,

$q_{all} = Q / (2 \times B_2)$

$200 = 1620 / (2 \times B_2) \rightarrow B_2 = 4$ m

OR

Without considering resultant $(Q_1 + Q_2)$

Moment w.r.t Q_2 or (R_2);

$Q_1 x8 - R_1 x7.4 = 0 \rightarrow R_1 = 1622$ kN

From force equilibrium;

$\Sigma F_{vertical} = 0$

$1500 + 25000 - 1622 - R_2 = 0$

$\rightarrow R_2 = 2378$ kN

Determine B_2,

$q_{all} = Q / (2 \times B_2)$

$200 = 1622 / (2 \times B_2) \rightarrow B_2 \approx 4$ m

Similary,

$200 = 2378 / B^2 \rightarrow B \approx 3.45$ m

RETAINING WALL PROBLEMS

P1. CANTILEVER RETAINING WALL

Question

For the retaining wall and the profile shown below, calculate:

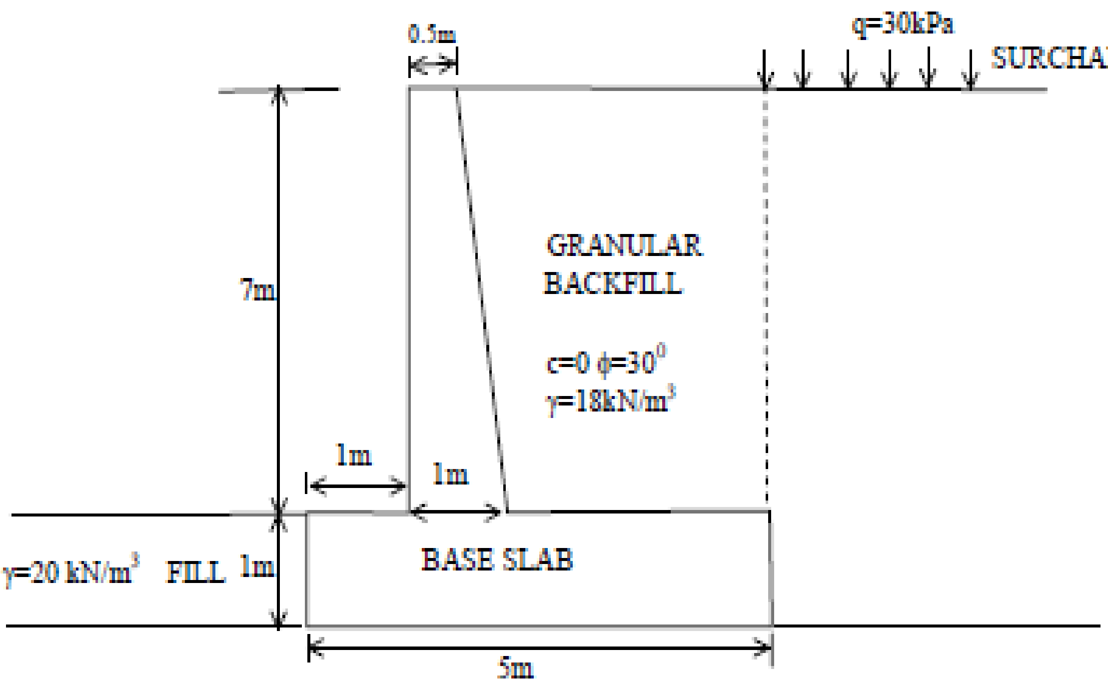
a. The safety factor against overturning,

b. The safety factor against sliding (minimum required F.S. =1.5),

Do not consider the passive resistance of the fill in front of the wall.

c. If the overturning safety is not satisfactory, extend the base to the right and satisfy the overturning stability requirement.

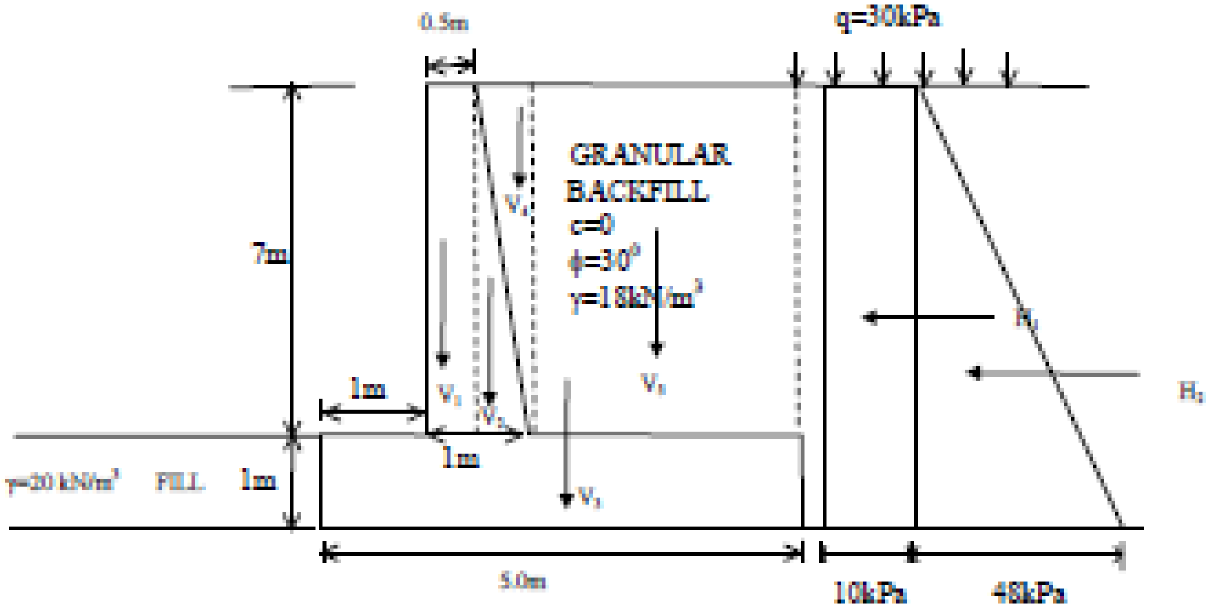
If the sliding is not satisfactory, design a shear key (location, thickness, depth) under the base slab to satisfy the sliding stability. Take advantage of passive resistance of the foundation soil. Calculate the vertical stress starting from the top level of the base but consider the passive resistance starting from the bottom level of the base slab (i.e. in the sand). Use a factor of safety of 2.0 with respect to passive resistance.



MEDIUM DENSE SILTY SAND

$c=0$, $\phi=32^0$, $\gamma=20kN/m^3$, $\tan\delta=0.5$(base friction) , $\gamma_{conc}=24kN/m^3$

Solution:



$K_a = \tan^2(45-\phi/2)$

For granular backfill⇒ $K_a = \tan^2(45-30/2) = 0.333$

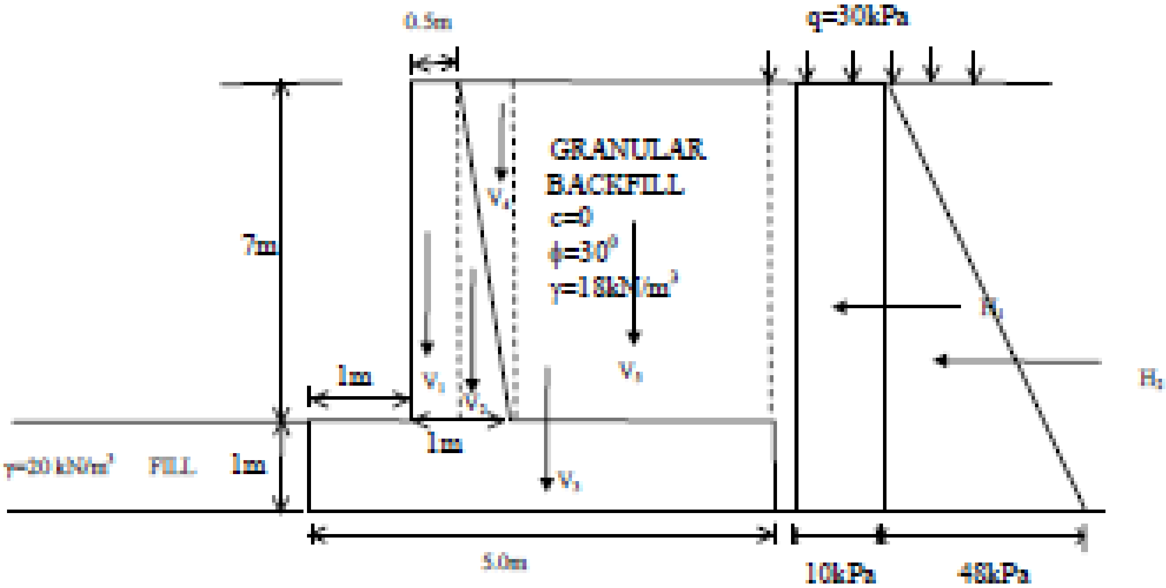
Active pressure, $p_a = (q+\gamma z)K_a - 2c\sqrt{K_a}$

$z=0 \Rightarrow\ p_a = 30x0.333 = 10\ kN/m^2$

$z=8 \Rightarrow\ \sigma_a = (30+18x8)0.333 = 58\ kN/m^2$

Force(kN/m)	Arm about toe(m)	Moment(kN.m/m)
$V_1=0.5x7x24=84$	1.25	105
$V_2=0.5x7x1/2x24=42$	1.67	70
$V_3=1x5x24=120$	2.5	300
$V_4=0.5x7x1/2x18=31.5$	1.83	57.75
$V_5=3x7x18=378$	3.5	1323
$\Sigma V=655.5$		$\Sigma M_r=1855.75$
$H_1=10x8=80$	4	320
$H_2=(58-10)x8x1/2=192$	8/3	512
$\Sigma H=272.0$		$\Sigma M_{ov}=832$

Solution:



$K_a = \tan^2(45-\phi/2)$

For granular backfill⇒ $K_a = \tan^2(45-30/2) = 0.333$

Active pressure, $p_a = (q+\gamma z)K_a - 2c\sqrt{Ka}$

$z=0 \Rightarrow p_a = 30x0.333 = 10$ kN/m^2

$z=8 \Rightarrow \sigma_a = (30+18x8)0.333 = 58$ kN/m^2

Force(kN/m)	Arm about toe(m)	Moment(kN.m/m)
V_1=0.5x7x24=84	1.25	105
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V_4=0.5x7x1/2x18=31.5	1.83	57.75
V_5=3x7x18=378	3.5	1323
ΣV=655.5		ΣM_r=1855.75
H_1=10x8=80	4	320
H_2=(58-10)x8x1/2=192	8/3	512
ΣH=272.0		ΣM_{ov}=832

Then, $65D+32.5D^2=160.5$ $\Rightarrow$ <u>D=1.43m</u>

<u>If passive resistance (with a F.S. of 2.0) is subtracted from the driving horizontal forces, (i.e. used in the denominator)</u>

Use F.S.=2.0 w.r.t. passive resistance $\Rightarrow$ $P_p=1/2(65D+1/2x65D^2)$

$$(F.S.)_{sliding}=\frac{\sum V.\tan\delta}{H-Pp}=1.50$$

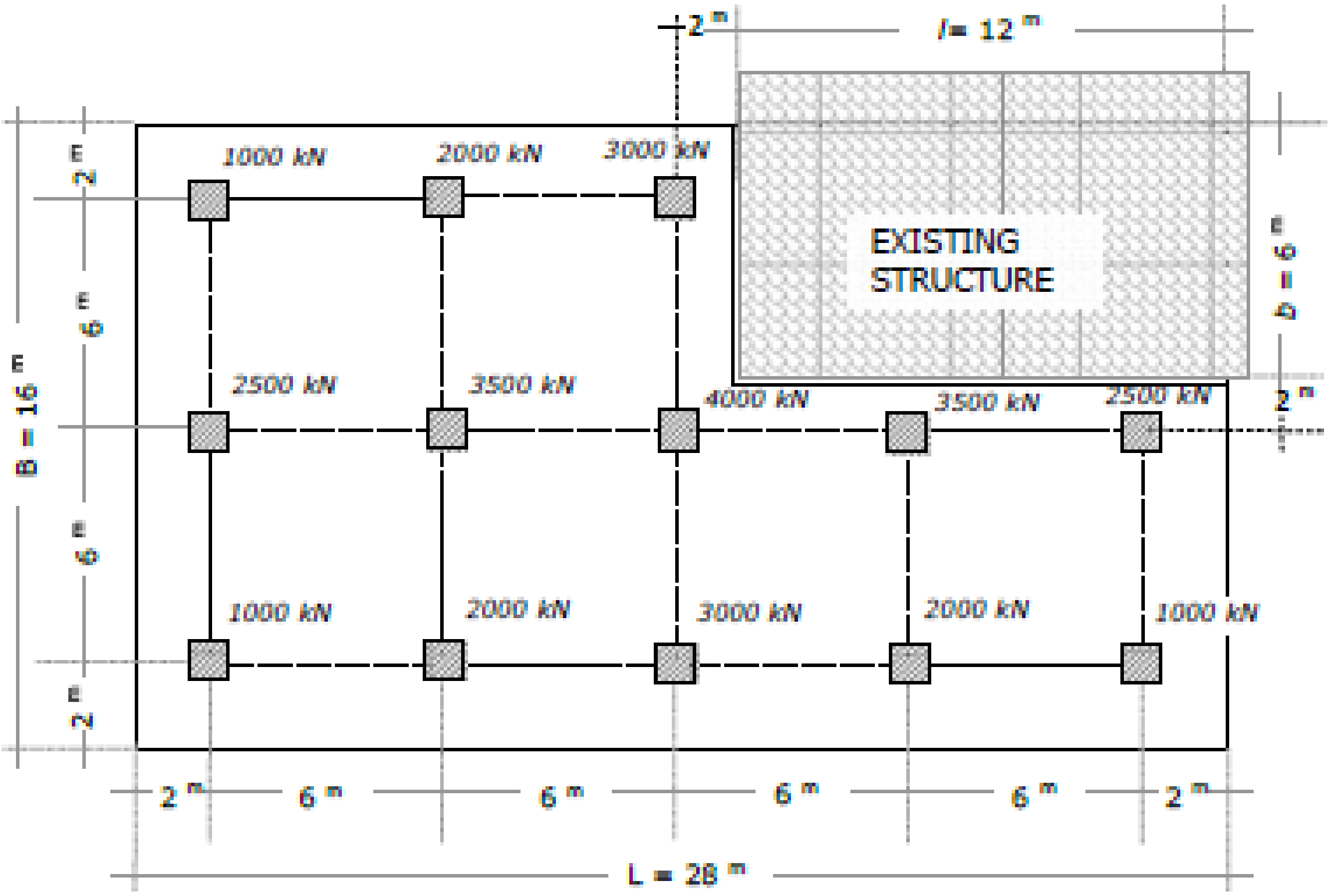
Then, <u>D=1.07m</u>

Take **D=1.43m** as it is on safe side.

P.3) MAT FOUNDATION

Question:

A mat foundation rests on a sand deposit whose allowable bearing value is 150 kN/m^2. Column loads are given in the figure. The thickness of the mat is 2.0 m ($\gamma_{concrete}$ = 24 kN/m^3). Calculate base pressures assuming that the lines passing through the centroid of the mat and parallel to the sides are principal axes. Find the base pressure distribution beneath the base and check whether the mat foundation given is safe?



Solution:

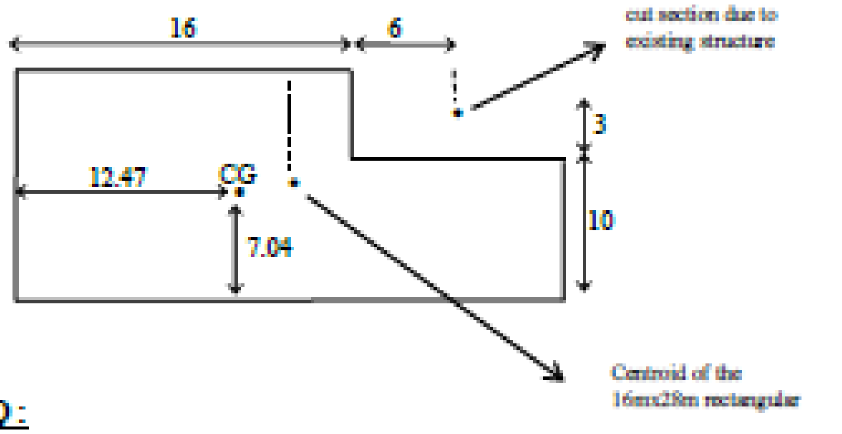
Area of foundation = 28 x 16 – 12 x 6 = 376 m^2

Total vertical load = Σ V = Column loads + Weight of mat=31000+(376) x 24 x 2 = 49048 kN

* **Center of gravity (CG) of mat:**

$$\frac{28 \times 16 \times 14 - 6 \times 12 \times (16+6)}{376} = 12.47 \quad \text{m from left}$$

$$\frac{28 \times 16 \times 8 - 6 \times 12 \times (3+10)}{376} = 7.04 \quad \text{m from bottom}$$



* **Location of ΣQ :**

→ Take moment about the left side:

= (1 / 49048) . [2 x (1000+2500+1000) + 8 x (2000+3500+2000) + 14 x (3000 +

+ 4000 + 3000) + 20 x (3500+2000) + 26 x (2500+1000) + 376 x 2 x 24 x 12.47]

= 12.95 m from left

→ Take moment about bottom side :

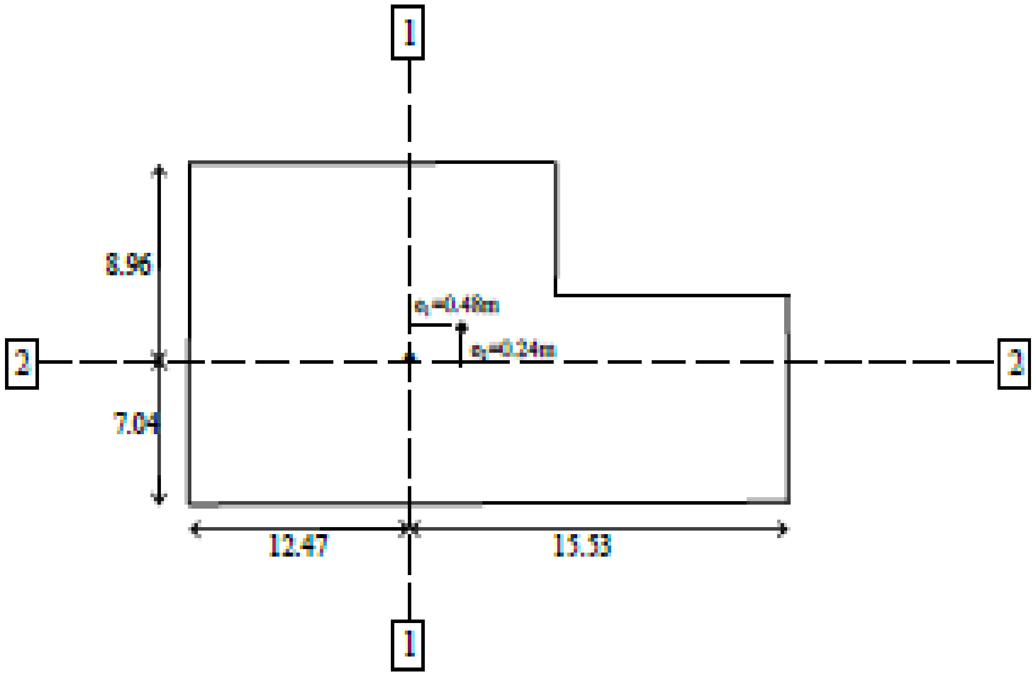
= (1 / 49048) . [2 x (1000+2000+3000+2000+1000) + 8 x (2500 + 3500 + 4000 +

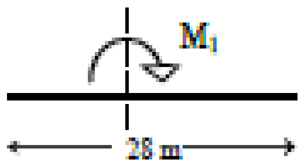
+ 3500 + 2500) + 14 x (1000+2000+3000) + 376 x 2 x 24 x 7.04]

= 7.28 m from bottom

Eccentricity :

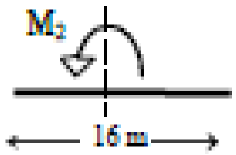
$e_1 = 12.95 - 12.47 = 0.48$ m
$e_2 = 7.28 - 7.04 = 0.24$ m





M_1 about 1-1 axis:

$M_1 = \Sigma Q \cdot e_1 = 49048 \cdot (0.48) = 23543$ kN.m



M_2 about 2-2 axis:

$M_2 = \Sigma Q \cdot e_2 = 49048 \cdot (0.24) = 11772$ kN.m

$$I_{1-1} = \left[\frac{B \cdot L^3}{12} + B \cdot L \cdot (D_1)^2\right] - \left[\frac{b \cdot l^3}{12} + b \cdot l \cdot (d_1)^2\right] =$$

$$= \left[\frac{16 \times 28^3}{12} + 16 \times 28 \times (14 - 12.47)^2\right] - \left[\frac{6 \times 12^3}{12} + 6 \times 12 \times (22 - 12.47)^2\right] = 22915 \quad m^4$$

$$I_{2-2} = \left[\frac{L \cdot B^3}{12} + B \cdot L \cdot (D_2)^2\right] - \left[\frac{l \cdot b^3}{12} + b \cdot l \cdot (d_2)^2\right] =$$

$$= \left[\frac{28 \times 16^3}{12} + 16 \times 28 \times (8 - 7.04)^2\right] - \left[\frac{12 \times 6^3}{12} + 12 \times 6 \times (13 - 7.04)^2\right] = 7197 \quad m^4$$

Note: In soil mechanics compression is taken as positive (+)

$$q = \frac{\Sigma Q}{Area} \pm \frac{M_1 \cdot y_1}{I_{1-1}} \pm \frac{M_2 \cdot y_2}{I_{2-2}}$$

$$q = \frac{49048}{376} \pm \frac{23543 \cdot y_1}{22915} \pm \frac{11772 \cdot y_2}{7197} = 130.4 \pm 1.03 y_1 \pm 1.64 y_2$$

$q_A = 130.4 \pm 1.03 y_1 \pm 1.64 y_2 = 130.4 + 1.03 \cdot (3.53) + 1.64 \cdot (2.96) = 138.9$ kN/m²

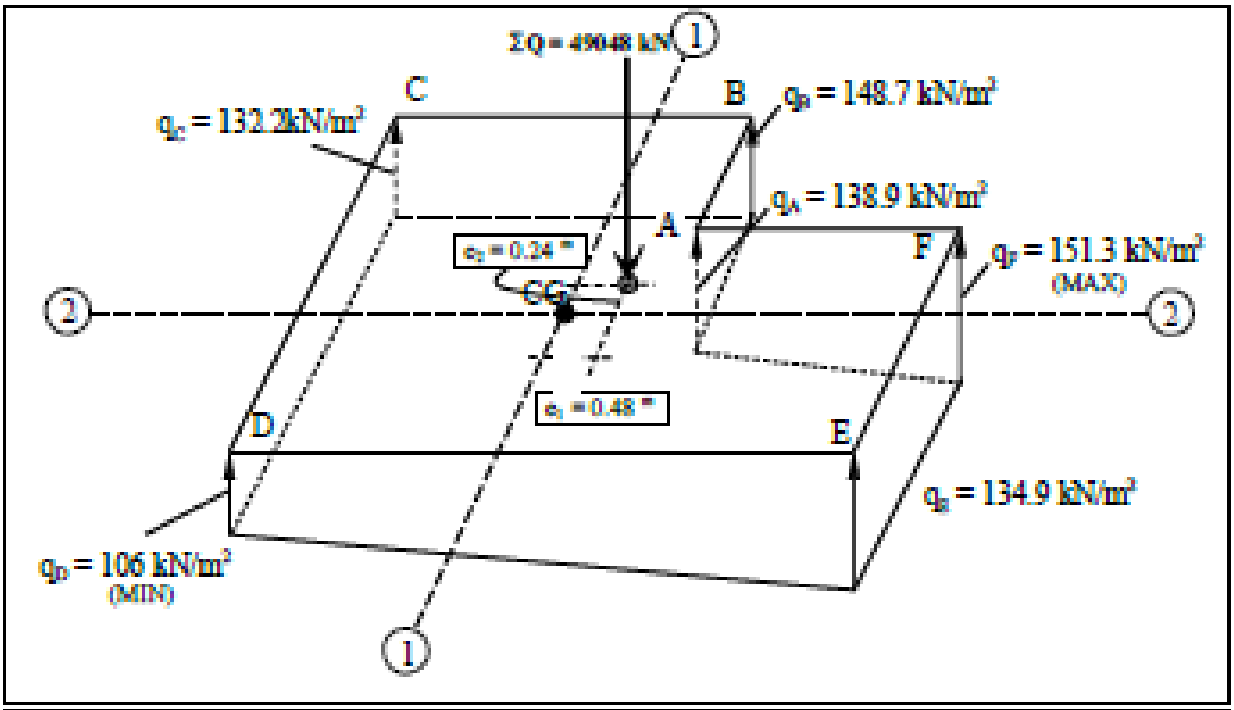
$q_B = 130.4 + 1.03 \cdot (3.53) + 1.64 \cdot (8.96) = 148.7$ kN/m²

$q_C = 130.4 - 1.03 \cdot (12.47) + 1.64 \cdot (8.96) = 132.2$ kN/m²

$q_D = 130.4 - 1.03 \cdot (12.47) - 1.64 \cdot (7.04) = 106$ kN/m²

$q_E = 134.9$ kN/m²

$q_F = 151.3$ kN/m²



Since at all critical points stress values are almost ≈< q_{all} = 150 kN/m² given mat foundation is safe.