

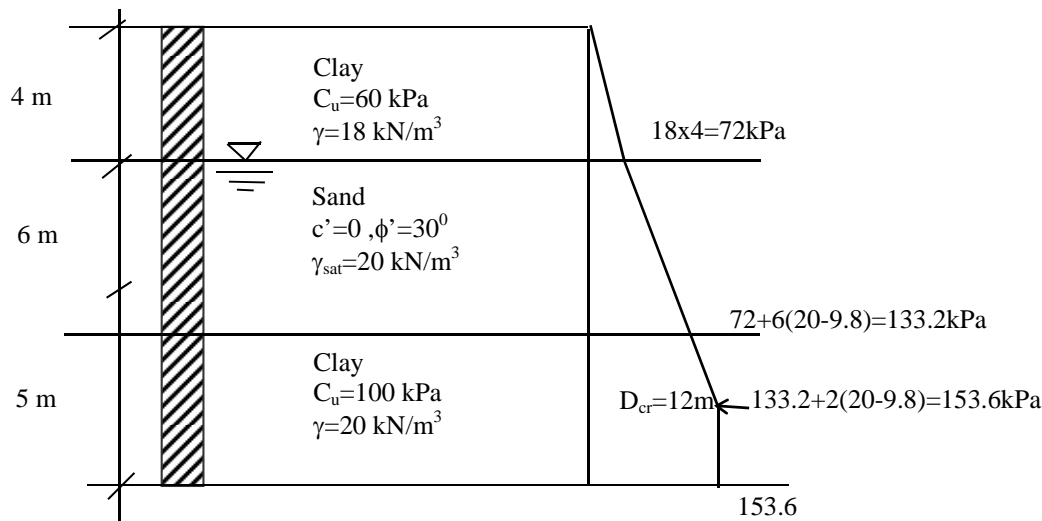
CE 366 – PILE FOUNDATIONS

Q1) ULTIMATE BEARING CAPACITY OF SINGLE PILES

Question

Determine the ultimate bearing capacity of the 800mm diameter concrete, bored pile given in the figure below. Assume $D_{cr} = 15 \times \text{diameter}$; and the pile-friction angle $= 0.75\phi'$

$$D_{cr} = 15 \times 0.8 = 12\text{m}$$



Solution

Ultimate capacity of pile:

$$Q_{ult} = Q_p + Q_s$$

- $Q_p = N_c \cdot c_u \cdot A_p = 9c_u A_p = 9 \times 100 \times [\pi \times (0.8)^2 / 4] = \underline{452 \text{ kN}}$

N_c : Fig 4.6, pp 73 of Lecture Notes

- $Q_s = Q_{s1} + Q_{s2} + Q_{s3}$

- where Q_{s1} ($0 < z < 4\text{m}$), Q_{s2} ($4 < z < 10\text{m}$), and Q_{s3} ($10 < z < 15\text{m}$),

$$Q_{s1} = \alpha \cdot c_u \cdot A_s = 0.8 \times 60 \times (\pi \times 0.8 \times 4) = \underline{483 \text{ kN}}$$

α : pp 215 of Lecture Notes

$$Q_{s2} = K_s \cdot \sigma'_{vo} \cdot \tan \delta \cdot A_s \quad ; \text{ where}$$

$$K_s = 0.5 \text{ (pp 215 of Lecture Notes)}, \delta = 0.75, \phi' = 22.5^\circ$$

$$A_s = p \cdot L = (\pi \times 0.8) \times 6 = 15.08 \text{ m}^2$$

$$Q_{s2} = 0.5 \times [(72 + 133.2) / 2] \times \tan(22.5) \times 15.08 = \underline{320 \text{ kN}}$$

$$Q_{s3} = \alpha \cdot c_u \cdot A_s = 0.58 \times 100 \times (\pi \times 0.8 \times 5) = \underline{729 \text{ kN}}$$

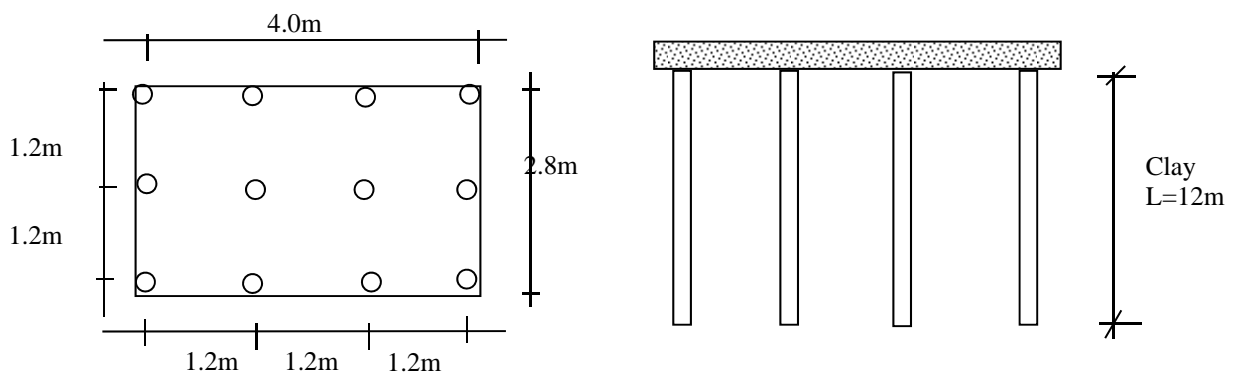
$$Q_{ult} = 452 + (483 + 320 + 729) = \underline{1984 \text{ kN}}$$

Q2) PILE GROUP CAPACITY

Question

Find the allowable bearing capacity of a single pile in the group of piles given below, by using: (Diameter : 0.4m, $C_u=50\text{kPa}$, $\gamma=18\text{kN/m}^3$, and use F.S.=2.5)

- Converse-Labarre Formula
- Terzaghi-Peck Method



Solution

a)

$$Q_{ult} = Q_p + Q_s$$

- $Q_p = 9c_u A_p = 9 \times 50 \times \pi \times (0.4)^2 / 4 = 56.5 \text{ kN}$
- $Q_s = \alpha \cdot c_u \cdot A_s = 0.84 \times 50 \times \pi \times 0.4 \times 12 = 633 \text{ kN}$

$$Q_{ult} = 56.5 + 633 = 689.5 \text{ kN}$$

$$Q_{all} = 689.5 / 2.5 \approx \mathbf{275.8 \text{ kN}}$$

Converse-Labarre(Group action reduction)

$$E = 1 - \theta \left[\frac{(n-1)m + (m-1)n}{90mn} \right]$$

$m = \# \text{ of rows} = 3$

$n = \# \text{ of piles in a row} = 4$

$$\theta = \arctan(D/s) = \arctan(0.4/1.2) = 18.4^\circ$$

$D = \text{diameter}$

$s = \text{spacing (center to center)}$

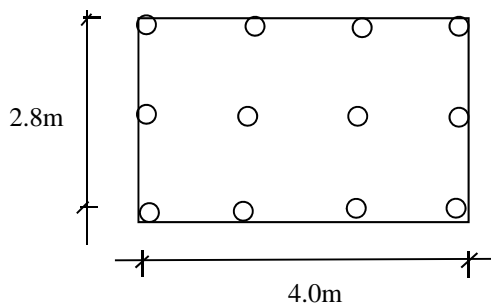
$$E = 1 - 18.4 \left[\frac{(4-1)3 + (3-1)4}{90 \times 3 \times 4} \right] = 0.71$$

$$(Q_{all})_{\text{single pile in the group}} = 275.8 \times 0.71 = \mathbf{195.8 \text{ kN}}$$

b)

Terzaghi Peck Group Reduction Method:

$$\begin{aligned} & \text{Skin fric.} \quad \text{Tip resist.} \\ (Q_g)_{ult} &= pD_f c_u + A(q_{ult})_{net} \quad ; \quad (q_{ult})_{net} = q_{nf} = c_u N_c \\ &= pD_f c_u + Aq_{ult} - AD_f \gamma \end{aligned}$$



$$p = 2(2.8 + 4.0) = 13.6 \text{ m}$$

$$A = 2.8 \times 4 = 11.2 \text{ m}^2$$

$$Q_g = 13.6 \times 12 \times 50 + 11.2(50 \times 8.6) = 12976 \text{ kN}$$

$$(Q_{ult})_{\text{for single pile}} = 12976 / 12 = 1081 \text{ kN}$$

$$(Q_{all})_{\text{for single pile}} = 1081 / 2.5 = 432.5 \text{ kN} > 275.8 \text{ kN}$$

$$> 195.8 \text{ kN}$$

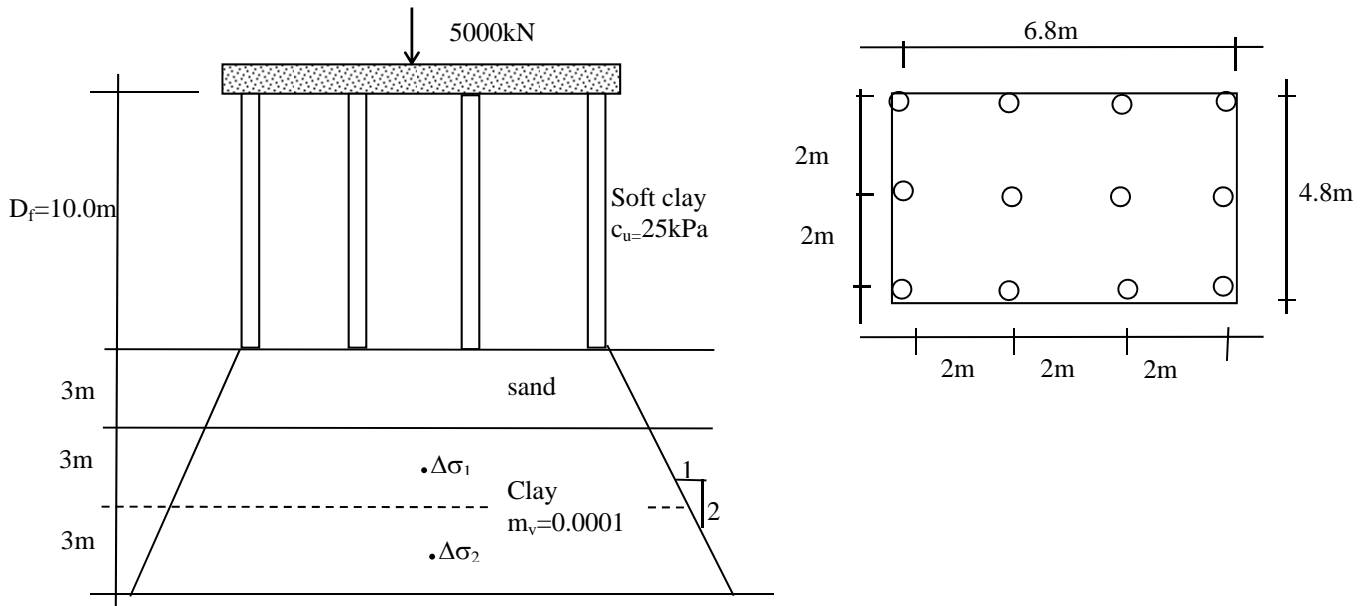
Bearing capacity is not controlled by Q_{group} ; therefore:

$$(q_{all})_{\text{single pile}} = \mathbf{195.8 \text{ kN}}$$

Q3) SETTLEMENT OF PILE GROUPS

Question

Calculate the consolidation settlement of the 12 pile group consisting of 10 m long end bearing piles. Piles are 80 cm in diameter and spaced at 2m center to center in either direction. Pile group carries a vertical load of 5000 kN including the weight of the pile cap. Use 2:1(V:H) pressure distribution and divide the layer into two equal layers.



Solution

Stress distribution begins at the bottom of the pile group in stiff clay media. In the case of soft clay the distribution should be started at depth of $2/3$ of L where L is the length of the pile.

$$s = H \times m_v \times \Delta\sigma$$

$$\Delta\sigma_1 = 5000 / ((6.8+4.5) \times (4.8+4.5)) = 47.6 \text{ kN/m}^2$$

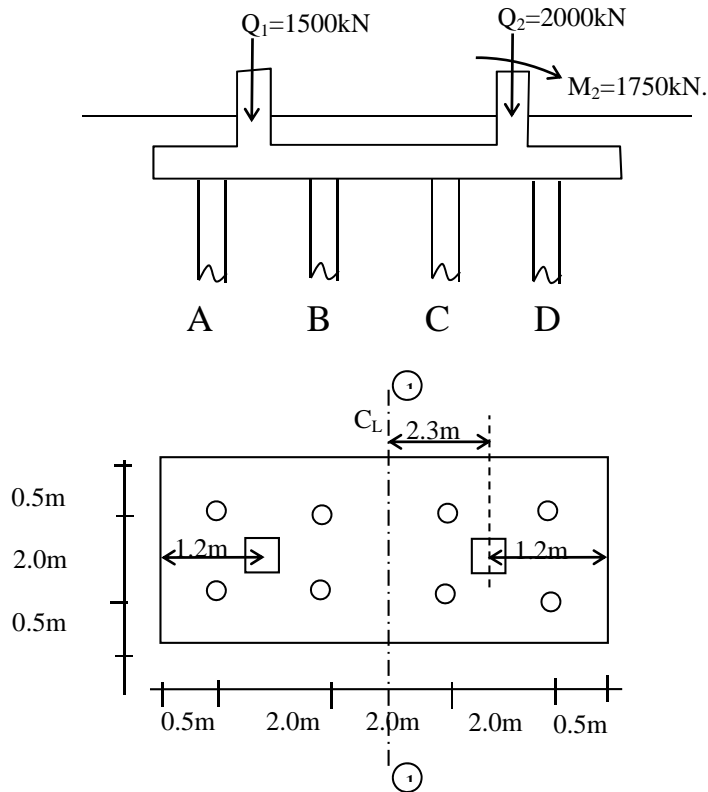
$$\Delta\sigma_2 = 5000 / ((6.8+7.5) \times (4.8+7.5)) = 28.4 \text{ kN/m}^2$$

$$s = 3 \times 0.0001 \times (47.6 + 28.4) = 0.0228 \text{ m} = \underline{\underline{2.28 \text{ cm}}}$$

Q4) LOAD ON PILES

Question

Find the maximum and minimum vertical load in the pile group given below



Solution

$$\Sigma Q = 3500 \text{ kN}$$

$$e = \frac{2000 \times 2.3 + 1750 - 1500 \times 2.3}{3500} = 0.83 \text{ m}$$

$$M = \Sigma Q_x e = 3500 \times 0.83 = 2900 \text{ kN.m}$$

$$I_{1-1} = 2 \times (2 \times 1^2 + 2 \times 3^2) = 40 \text{ pile-m}^4$$

└─ due to piles

$$Q_i = \Sigma Q / n \pm M x d_i / I$$

$$Q_D = 3500/8 + 2900 \times 3.0 / 40 = \underline{\underline{655 \text{ kN(max)}}$$

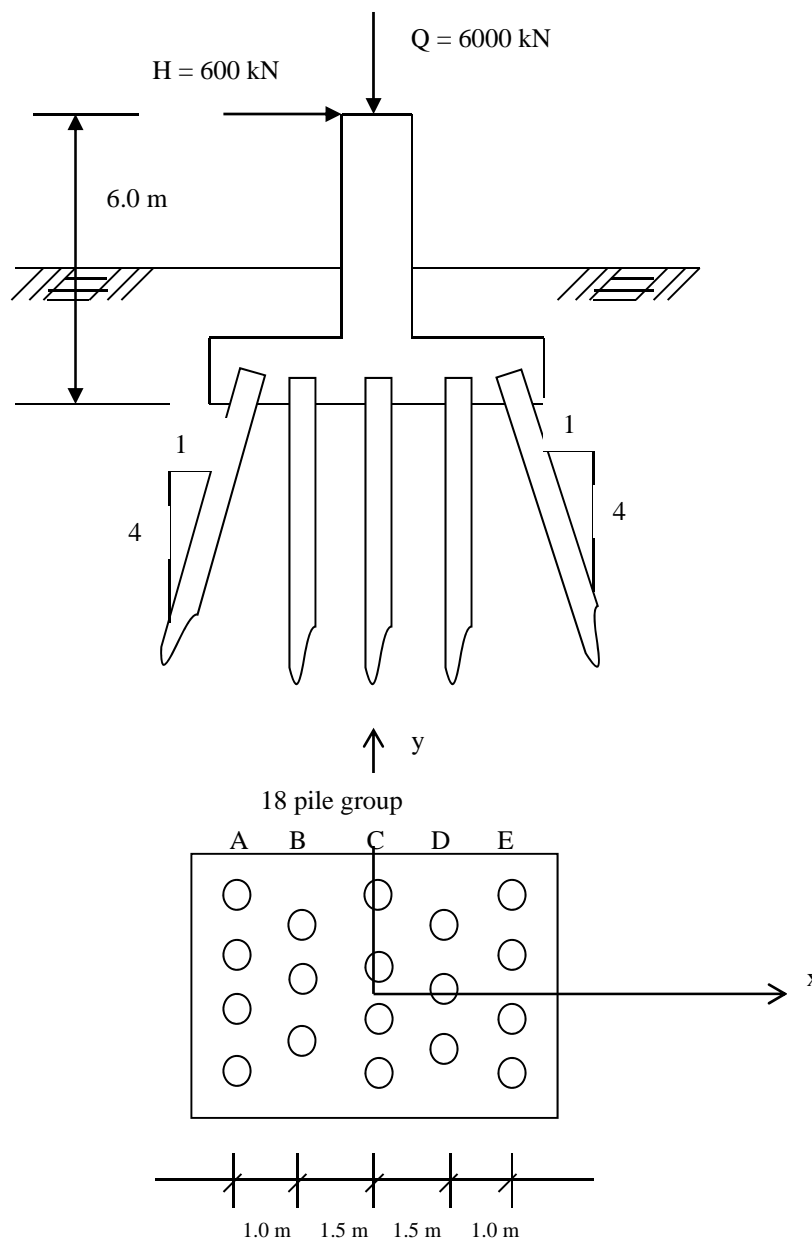
$$Q_A = 3500/8 - 2900 \times 3.0 / 40 = \underline{\underline{220 \text{ kN(min)}}$$

Q5) BATTER PILES

Question

One of the legs of a steel structure rests on a concrete pedestal footing which is supported by a group of 18 piles. Outside rows are formed from batter piles (1 to 4) as shown below. Each pile is permitted to resist an horizontal force of 25 kN.

- Calculate axial loads on all piles.
- Could the unbalanced horizontal force be overcome?
- If the allowable bearing value of single pile is equal to 600 kN, state whether or not this pile foundation is safe.



Solution

a)

- $M = 6 * 600 = 3600 \text{ kN} - \text{m}$
- $I = 2 * (3 * 1.5^2 + 4 * 2.5^2) = 63.5 \text{ pile} - \text{m}^2$

- Vertical Component of pile loads:

$$Q_i = \frac{Q}{n} \pm \frac{M}{I} * x_i$$

$$Q_A = \frac{6000}{18} - \frac{3600}{63.5} * 2.5 = 192 \text{ kN}$$

$$Q_B = \frac{6000}{18} - \frac{3600}{63.5} * 1.5 = 248 \text{ kN}$$

$$Q_C = \frac{6000}{18} = 333 \text{ kN}$$

$$Q_D = \frac{6000}{18} + \frac{3600}{63.5} * 1.5 = 418 \text{ kN}$$

$$Q_E = \frac{6000}{18} + \frac{3600}{63.5} * 2.5 = 475 \text{ kN}$$

- Axial loads:

$$\tan \alpha = \frac{1}{4} \rightarrow \cos \alpha = 0.970$$

$$P_A = \frac{Q_A}{\cos \alpha} = \frac{192}{0.970} = 198$$

$$P_B = Q_B = 248 \text{ kN}$$

$$P_C = Q_C = 333 \text{ kN}$$

$$P_D = Q_D = 418 \text{ kN}$$

$$P_E = \frac{Q_E}{\cos \alpha} = \frac{475}{0.970} = 490 \text{ kN}$$

b)

- Unbalanced horizontal force:

$$H_u = 600 + 4 * 192 * \frac{1}{4} - 4 * 475 * \frac{1}{4} = 317 \text{ kN}$$

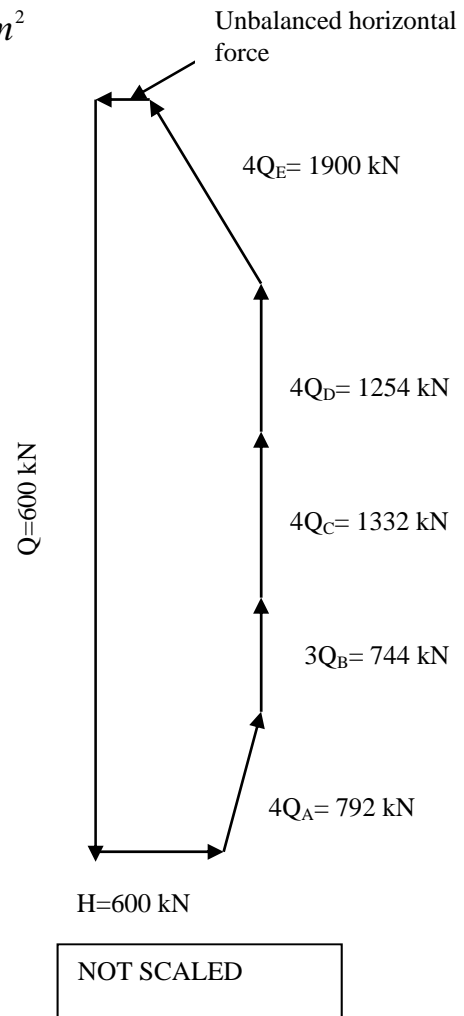
c)

- Available horizontal resistance:

$$H_r = 18 * 25 = 450 \text{ kN} . \text{ Since } H_u < H_r \therefore \text{ Unbalanced force is overcome.}$$

- Maximum axial load:

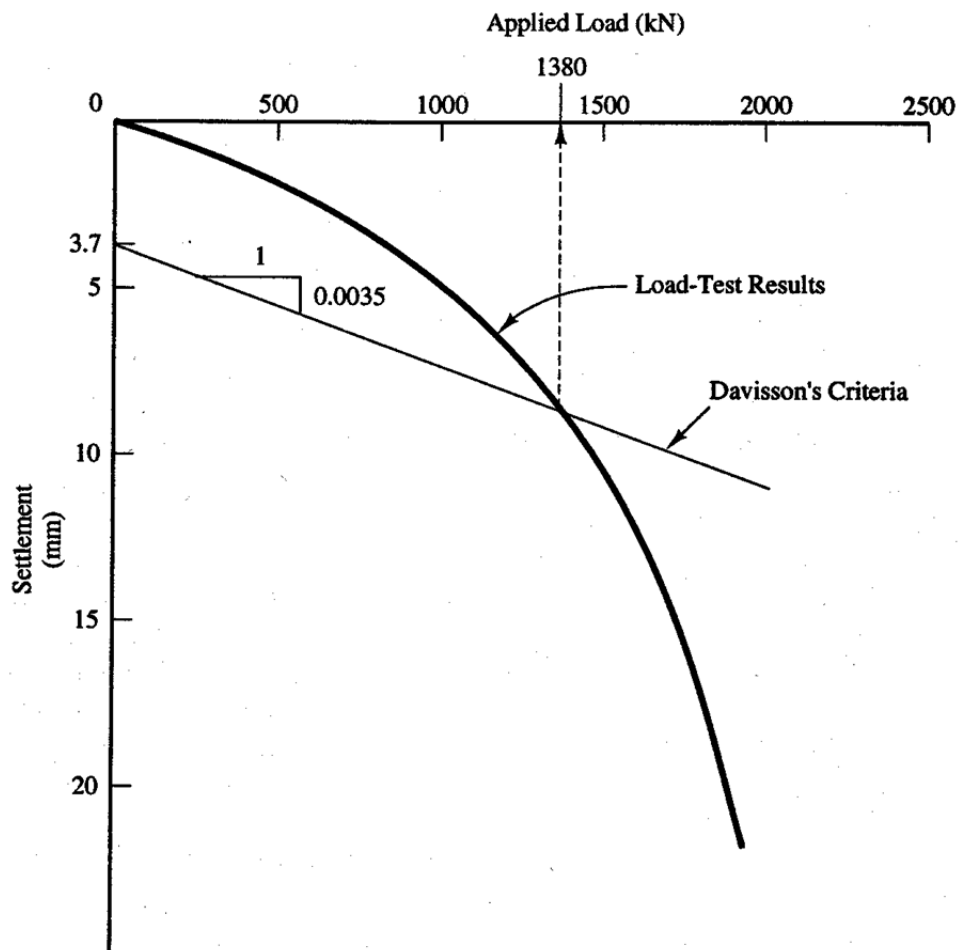
$$P_{\max} = 490 \text{ kN} < P_{\text{all}} = 600 \text{ kN} \text{ (Foundation is safe).}$$



Q6) INTERPRETATION OF PILE LOAD TEST

Question

The load-settlement data shown in the figure were obtained from a full-scale load test on a 400 mm square, 17 m long concrete pile (28-day compressive strength of concrete, $f_c' = 40$ MPa). Use Davisson's method to compute the ultimate downward load capacity.



Solution

Davisson's method defines the ultimate capacity as that which occurs at a settlement of $0.012B_r + 0.1B/B_r + PL/(AE)$. The last term in this formula is the elastic compression of a pile that has no skin friction.

B = Diameter of the pile B_r = Reference width = 300 mm
 P = Applied load L = Length of the pile

A= Cross-section area of the pile

E= Modulus of elasticity of the pile

200,000 MPa for steel

11,000 MPa for timber

$15,200\sigma_r (f_c'/\sigma_r)^{0.5}$ for concrete where reference stress, $\sigma_r = 0.1$ MPa

$$E = 15,200\sigma_r (f_c'/\sigma_r)^{0.5} = (15,200)(100 \text{ kPa})(40 \text{ MPa} / 0.10 \text{ MPa})^{0.5} \\ = 30.4 * 10^6 \text{ kPa}$$

$$\text{Settlement} = 0.012B_r + \frac{0.10B}{B_r} + \frac{PL}{AE} \\ = 0.012 * 300 + \frac{0.10(400)}{300} + \frac{P(17,000)}{400^2 (30.4 * 10^6) (1 * 10^{-6} \text{ m}^2 / \text{mm}^2)} \\ = 3.7 \text{ mm} + 0.0035P$$

Plotting this line on the load-displacement curve produces $P_{\text{ult}} = 1380 \text{ kN}$

Q7) PILE DRIVING ENERGY CORRECTION

Question

400 mm square concrete piles are to be driven to depth of 12.5. m. What should be the stroke of a 1.5 ton rammer, due to the Danish Formula, if the amount of penetration should be about 5 mm/blow for the safe working load of 2000 kN on the pile? ($E_{\text{conc}} = 30 * 10^6 \text{ kN/m}^2$)

Solution

$$A_{\text{pile}} = 0.4^2 = 0.16 \text{ m}^2$$

$$Q = \sqrt{\frac{W_r * H}{s + 0.5 * c_2}}, c_2 = \sqrt{\frac{2 * W_r * H * L}{A * E}}$$

$$c_2 = \sqrt{\frac{2 * (1.5 * 9.8) * H * 12.5}{0.16 * 30 * 10^6}} = \sqrt{\frac{H}{13100}}$$

$$Q = 2000 = \frac{14.7 * H}{0.005 + 0.5 * \sqrt{\frac{H}{13100}}} \Rightarrow$$

$$H = 1.4 \text{ m}$$

where

Wr: weight of rammer

H: stroke

L: Length of bored pile

s: average set

A: Area

E: Modulus of elasticity