

CE 366 Foundation Engineering – I

2011-2012 Spring Semester

Homework 1

Due on: 05.04.2012

**Question 1 (20%)**

The figure below shows the plan dimensions of an existing factory building founded on the surface of a thick deposit of homogeneous clay. The foundation pressure from the building is  $30 \text{ kN/m}^2$ . Also shown is the line of an existing tunnel through the clay, the crown of the tunnel being at an average depth of 12 m below ground level.

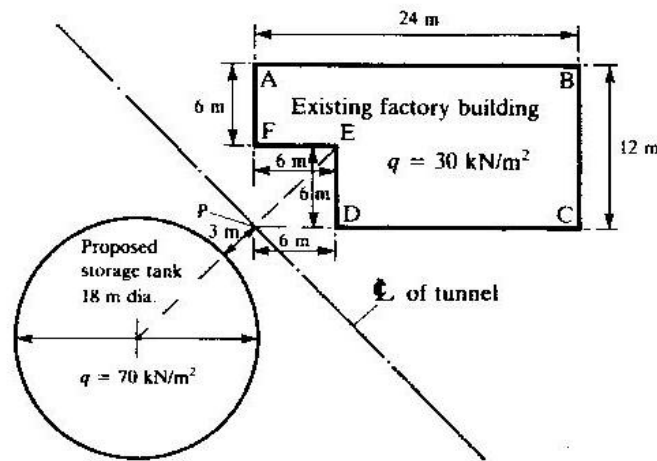


Figure 1.

It is proposed to construct a storage tank in the position shown, having an 18 m diameter flexible foundation which will transmit a pressure of  $70 \text{ kN/m}^2$  to the surface of the clay. If this proposed construction is carried out, estimate:

- The total vertical stress in the soil 12 m below point P and
- The immediate surface settlement which will occur at P and the edge and center of the circular foundation.

The properties of the clay are  $\rho_s = 1.90 \text{ Mg/m}^3$ ,  $E = 5500 \text{ kN/m}^2$  and  $\nu = 0.5$ .

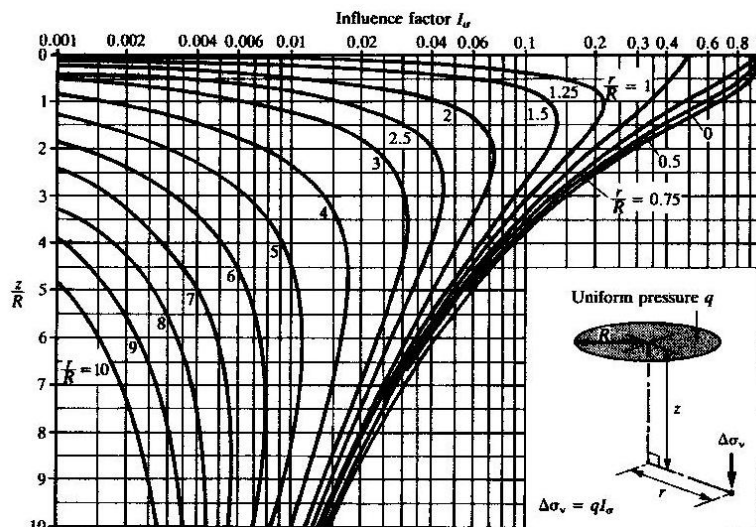
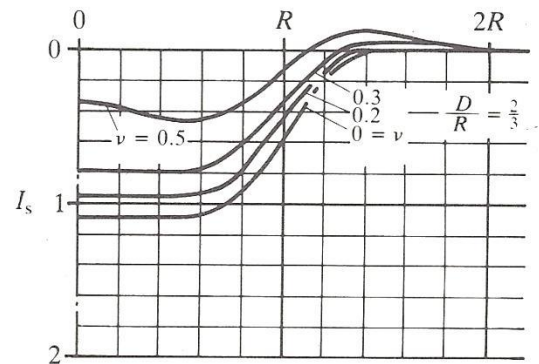
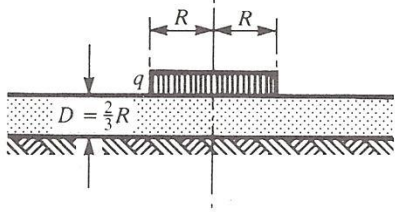
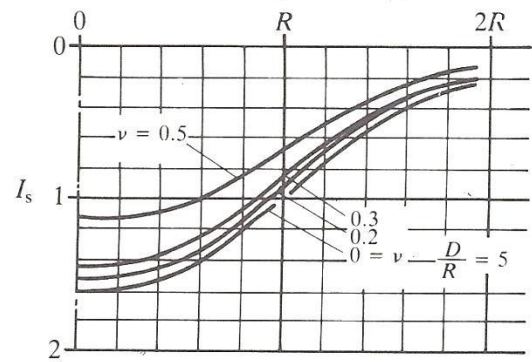
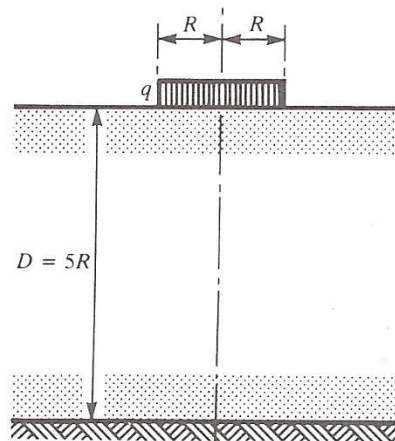
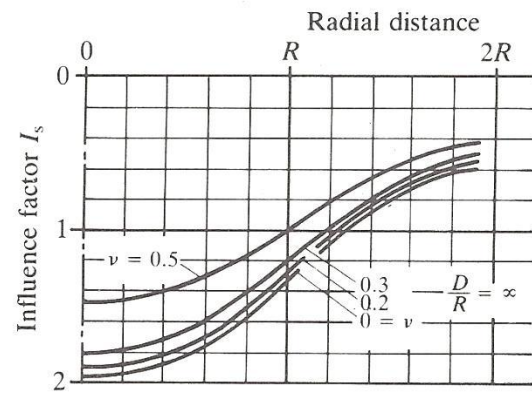
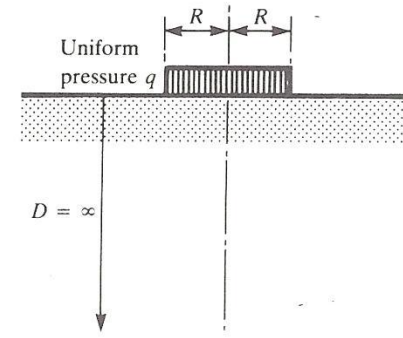


Figure 2. Values of influence factor  $I_0$  for calculating increase in total vertical stress  $\Delta\sigma_v$  under a uniformly loaded circular area (After Foster and Ahlvin, 1954)



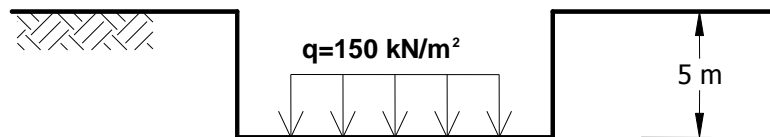
Immediate surface settlement:

$$S_i = \frac{qR}{E} I_s$$

Figure 3. Values of influence factor  $I_s$  for calculating the immediate surface settlement  $S_i$  under a uniformly loaded flexible circular area (After Terzaghi, 1943)

**Question 2.a (10%)**

Estimate the net foundation pressure after the application of a gross foundation pressure of 150 kPa at a foundation depth of 5 meters. Unit weight of the soil can be taken as  $18 \text{ kN/m}^3$ .



**Question 2.b (10%)**

At 6 m depth, a silty sand layer was encountered and a Standard Penetration Test (SPT) was performed. For the first, second and third 15 cm increments, the blowcounts were reported as 7,8,8 blows, respectively. Safety hammer of an energy ratio of 55 % was used during the test. The borehole diameter was measured as 110 mm and the SPT sampler used was a standard sampler with constant inside diameter (no room for liners). The length of the rod from the bottom of the safety hammer to the sampler at 6 m depth was measured as 8.2 m. Estimate the overburden and procedure corrected SPT blowcounts ( $N_{1,60}$ ) for 30 cm penetration of the sampler (water table depth is at 2 m and the unit weights of soil above and below water tables can be assumed as  $18$  and  $19 \text{ kN/m}^3$ , respectively)

### **Question 3 (20%)**

A building will be constructed on a clay deposit. The building will rest on a mat foundation at 2m depth and has 10m\*10m dimensions in plan. The clay deposit is 12m deep and overlies a rock layer. The groundwater level is at 2m depth. The coefficient of volume compressibility of clay layer is  $0.85 \cdot 10^{-4} \text{ m}^2/\text{kN}$ . An approximate average influence factor for vertical displacement (immediate settlement)  $I_s$  under foundation area can be taken as 1.20. Poisson's ratio of clay ( $\nu$ ) is 0.5. Skempton-Bjerrum correction factor  $\mu$  can be taken as 0.65. The undrained modulus of clay is  $60 \text{ MN/m}^2$ . Take  $\gamma_w = 10 \text{ kN/m}^3$ . If  $q_{\text{all,net}} = 104 \text{ kN/m}^2$ , calculate the settlement under the center of the building.

HINT:

$$s_i = \frac{qB}{E} (1 - \nu^2) I_s$$

$$s_{\text{oed}} = m_v \cdot \Delta\sigma^l \cdot H; \text{ for overconsolidated clays } s_c = \mu \cdot s_{\text{oed}}$$

$$\Delta\sigma^l = 4 \cdot q_n \cdot I_\sigma \text{ and } I_\sigma = 0.175 \text{ (corner)}$$

### **Question 4 (20%)**

Footing of a wall is 3 m wide and is constructed at a depth of 2 m. Relevant data for the cone penetration resistance of the underlying soil is provided in the figure below. Calculate the line load (P) in units of kN/m that the footing can support for an allowable settlement of 5 cm, using Schmertmann's strain distribution method.

$$I_z = 0.2 \text{ at } z = 0$$

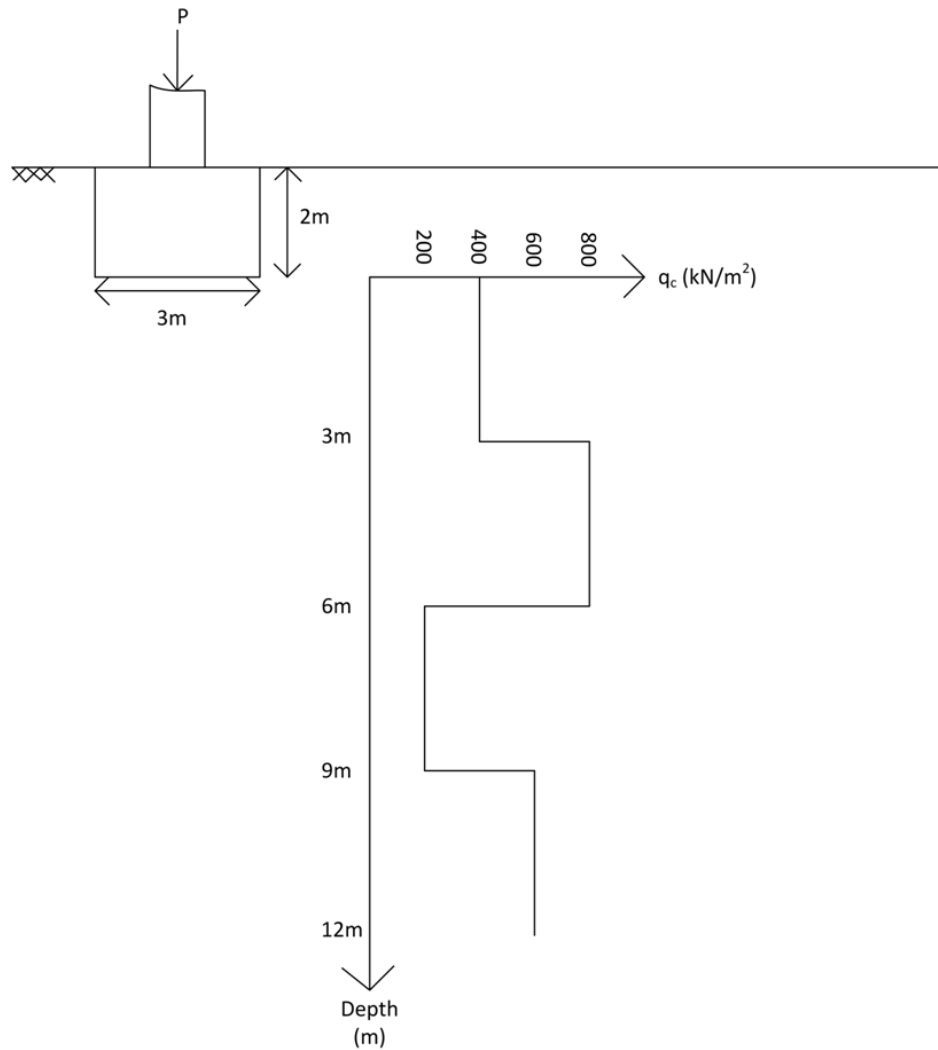
$$\text{Assume: } E_s = 2q_c$$

$$I_z = 0.5 \text{ at } z = B$$

$$c_1 = 0.9 \text{ (depth factor)}$$

$$I_z = 0.0 \text{ at } z = 4B$$

$$c_2 = 1.4 \text{ (creep factor)}$$



### Question 5 (20%)

- a) A rectangular footing having  $1.8 \times 2.6$  m plan dimensions rests on normally consolidated clay, foundation depth being 2.0 m below ground surface. Water table is at 2 m depth. The clay has the following short term (undrained) and long term (drained) shear strength parameters:

*Undrained*,  $c_u = 50 \text{ kPa}$   $\phi_u = 0^\circ$  , *Drained*,  $c' = 5 \text{ kPa}$  ,  $\phi' = 25^\circ$   
*Dry unit weight* =  $19 \text{ kN/m}^3$  , *Saturated unit weight* =  $20 \text{ kN/m}^3$

Calculate (i) **short-term** and (ii) **long-term**, net safe bearing capacity using  $F.S.=3.0$ . (Assume that the water level does not change in short term and in long term cases.) Considering that the net safe bearing capacity is the allowable pressure we can apply on to the soil, comment in one sentence, which value we should use in our design.

*Hint:*

for long term:

$$q_f = 0.5 S_\gamma \gamma B N_\gamma + S_c c N_c + S_q \gamma D N_q$$

$$S_c = 1 + 0.2(B/L), S_q = 1, S_\gamma = 1 - 0.2(B/L)$$

for short term:

$$q_f = c_u (N_c)_{\text{Skempton}} + \gamma D$$

$$q_{nf} = q_f - \gamma D$$

$$(q_n)_{\text{safe}} = q_{nf} / \text{F.S.}$$

$$(N_c)_{\text{rectangle}} = (N_c)_{\text{square}} \times 0.84 + 0.16 \frac{B}{L}$$

b) Answer the questions below. (Note that students are required to understand the reasoning behind the answers.)

b1) If the same foundation as in part (a), would be constructed on a soil with drained friction angle of 35 degrees, instead of 25 degrees (cohesion is the same  $c' = 5$  kPa), keeping all other parameters constant, the ultimate bearing capacity,  $q_f$ , would be .....

*lower / higher / would not change.*

b2) Keeping all other parameters constant as in part (a), the larger the B, the larger will be its drained ultimate bearing capacity. .... *True or False*

b3) When a foundation is constructed on a clay, short term ultimate bearing capacity will be more than the long term ultimate bearing capacity. .... *True or False*

b4) Ultimate bearing capacity of a foundation constructed on a clay soil, will be governed by the undrained shear strength,  $c_u$  of the clay, not the friction angle. .... *True or False*

b5)  $N_c$  values in the two ultimate bearing capacity,  $q_f$ , equations given above have the same values ..... *True or False*

b6) If the net ultimate bearing capacity ( $q_{nf}$ ) is less than the net foundation pressure ( $q_{\text{net}}$ ) the building is going to apply, then the building will have a bearing capacity failure. ....

*True or False*

b7) Consider the bearing capacity of a cylindrical shaped reinforced concrete pile in clay. We can consider the pile similar to a circular foundation with large  $D_f/B$  ratio (depth of foundation  $\gg$  width of foundation). The ultimate bearing capacity of a pile in clay can be calculated by  $N_c \times c_u$ . What is  $N_c$  number we should use in this case.  $N_c = \dots$