American University of Beirut - Faculty of Engineering and Architecture

CIVE 530 – Foundation Engineering (Spring 2012)

Assignment No. 2

Bearing Capacity and Elastic & Consolidation Settlements

Assigned: Thursday April 12, 2012

Due: Wednesday April 18, 2012

Problem 1 - A civil engineer plans to construct a structure founded on a rectangular flexible footing (3.0m X10.0m) on a Site situated in Beirut. Based on a relatively old geotechnical investigation performed 15 years ago, the subsurface conditions would consist of man-made fill 2m thick (γ_{sat}=17KN/m^3; γ_{wet}=16.5KN/m^3) followed by a sandy deposit (γ_{sat}=18KN/m^3; γ_{wet}=17.5KN/m^3). The Sand is medium dense and has a friction angle of 35 degrees with an average SPT N_{field} of 28 and N_{70} of 25. No ground water measurements were done during the old investigation but water table is thought to be deep below the foundation level.

a) Recommend a suitable foundation level.
b) Draw a sketch showing the various problem components.
c) Recommend an adequate method for the computation of the soil bearing capacity under the foundation.
d) Calculate the safe bearing capacity.
e) Calculate the allowable bearing capacity based on the SPT results.
f) Another investigation was recommended by the geotechnical engineer to confirm the soil conditions and ground water table level. The new investigation indicated that water table is very shallow as it is reported to be at 1m below natural ground level. Re-calculate the safe bearing capacity. What is the safe load?
g) The load is inclined at 75 degrees from the horizontal. Calculate the safe bearing capacity in this case.
h) Consider that the load is eccentrically applied (two-way eccentricity) on the foundation with e =0.25m. Re-calculate the safe bearing capacity and safe load. What if e=0.6m?
i) With reference to Question e) above and based on the new geotechnical investigation, compute the average immediate settlement using the equations developed from the Elastic Theory and using the safe bearing capacity value. Use a typical Poisson's ratio value for the sand layer.
j) Recommend an allowable bearing capacity value if the allowable average total settlement is 3.5cm.

k) A clay layer was encountered during the new investigation drilling works at a depth of 15m below the natural ground level. Is it necessary to consider this layer while computing the bearing capacity/settlement of the foundation? Assume that when stress is less than 10% of that applied at the foundation level then its effect can be ignored. Perform your calculations under the center of the foundation only.

Problem 2:

A three storey structure having a square footprint of 225 m^2 is constructed on a clayey deposit. The structure is planned to be supported by square isolated footings having a width of 2m and spaced at 5m center to center. A typical borehole indicates that the soil consists of 2m fill layer at the top (γ=17KN/m^3) followed by a very stiff clay layer 2m thick (γ_{sat}=18.5KN/m^3) underlain by a normally consolidated soft clay layer of 4.5m thickness (γ_{sat}=17KN/m^3) followed by a rock layer extending down to the bottom of borehole. The foundations are laid on top of the stiff clay layer. Water table is located at the top of the stiff clay layer. undisturbed samples were taken from the middle of each clay layer and consolidation tests done on undisturbed samples indicated the following:

- Stiff Clay: C_c=0.15; C_s = 0.02; P_c = 120 kPa; e_0=0.9
- Soft Clay: C_c=0.38; C_s = 0.06; e_0=1.0

a) Draw a sketch representing the various problem components.
b) The isolated foundations are subjected to a stress of 140 kPa. Calculate the consolidation settlement. Consider the very stiff clay as one layer and divide soft clay layer into two equal sub-layers. Calculate settlement under one typical foundation.
c) What would be the maximum additional stress applied on a central foundation from two neighboring foundations (situated at the left and right sides of the central foundation). Is it necessary to consider the additional stresses from neighboring foundations in the settlement calculations?
d) A concern is the differential settlement between isolated adjacent footings. It was decided to change the design to have the structure founded on a raft foundation subjected to a stress of 45 kPa. Compute the consolidation settlement and comment on the results.

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E value correlations for Sands and Silts

TABLE 5-6

Equations for stress-strain modulus E_s by several test methods

E_s in kPa for SPT and units of q_c for CPT: divide kPa by 50 to obtain ksf. The N values should be estimated as N_{55} and not N_{70}. Refer also to Tables 2-7 and 2-8.

Soil	SPT	CPT
Sand (normally consolidated)	$E_s = 500(N + 15)$ $= 7000\sqrt{N}$ $= 6000N$ — — —	$E_s = (2 \text{ to } 4)q_u$ $= 8000\sqrt{q_c}$ — — — $E_s = 1.2(3D_r^2 + 2)q_c$
	‡$E_s = (15\,000 \text{ to } 22\,000) \cdot \ln N$	*$E_s = (1 + D_r^2)q_c$
Sand (saturated)	$E_s = 250(N + 15)$	$E_s = Fq_c$ $e = 1.0 \quad F = 3.5$ $e = 0.6 \quad F = 7.0$
Sands, all (norm. consol.)	¶$E_s = (2600 \text{ to } 2900)N$	
Sand (overconsolidated)	†$E_s = 40\,000 + 1050N$	$E_s = (6 \text{ to } 30)q_c$
	$E_{s(\text{OCR})} \approx E_{s,\text{nc}}\sqrt{\text{OCR}}$	
Gravelly sand	$E_s = 1200(N + 6)$ $= 600(N + 6) \quad N \le 15$ $= 600(N + 6) + 2000 \quad N > 15$	
Clayey sand	$E_s = 320(N + 15)$	$E_s = (3 \text{ to } 6)q_c$
Silts, sandy silt, or clayey silt	$E_s = 300(N + 6)$	$E_s = (1 \text{ to } 2)q_c$
	If $q_c < 2500$ kPa use $\quad$ §$E'_s = 2.5q_c$ $2500 < q_c < 5000$ use $\quad E'_s = 4q_c + 5000$ where E'_s = constrained modulus $= \dfrac{E_s(1-\mu)}{(1+\mu)(1-2\mu)} = \dfrac{1}{m_v}$	