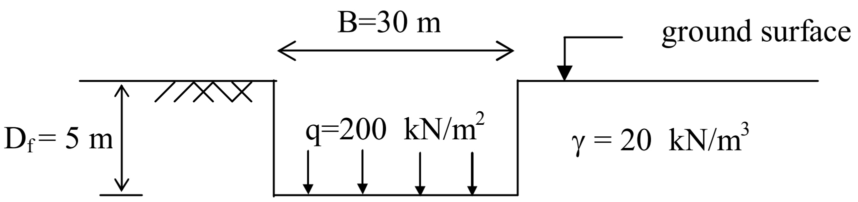
CE 366 – SITE INVESTIGATION (Problems & Solutions)

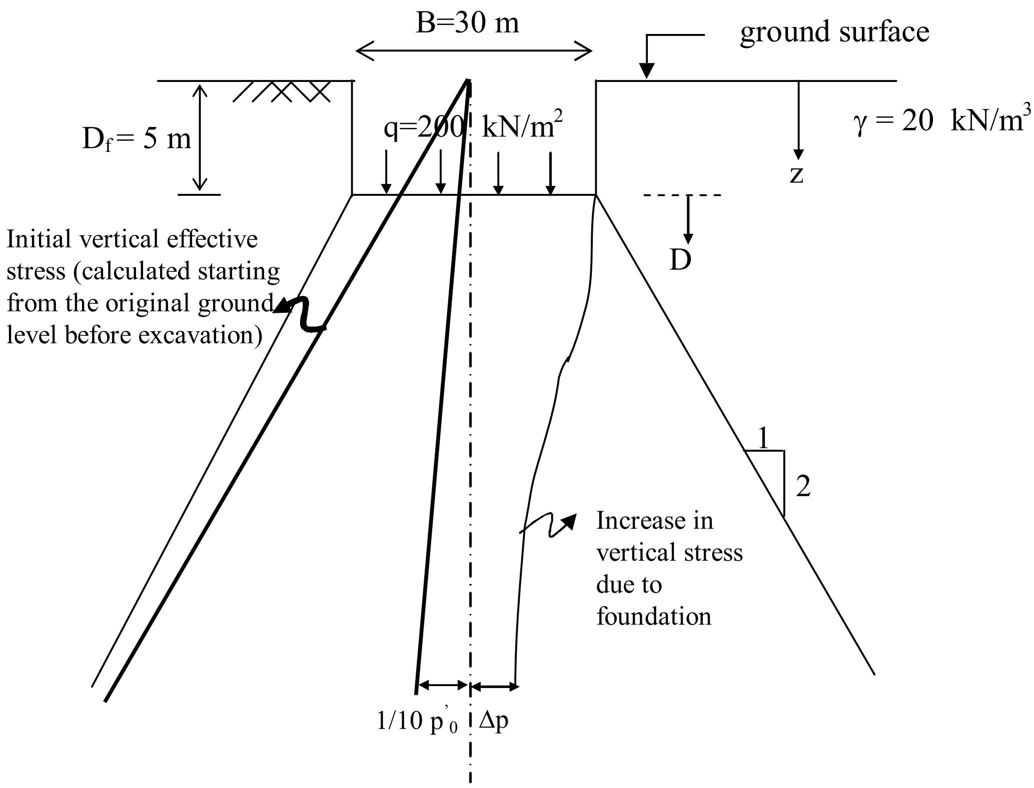
P1. DEPTH OF EXPLORATION

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 $\Rightarrow \therefore \frac{1}{10} p_0^{'} = \Delta p$

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

$$\frac{1}{10}p_0{}' = \frac{1}{10}(20(D+5))$$

$$\frac{200\text{x}30\text{x}50}{(30+\text{D})(50+\text{D})} = \frac{1}{10}\text{x}20(\text{D}+5)$$

$$2\text{D}^3 + 170\text{D}^2 + 3800\text{D} = 285000$$

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

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

P2. CONE PENETRATION TEST (CPT)

Question:

Table 1. CPT Data

Depth (m)	q_c (MPa)	q_s (kPa)
0.5	1.86	22.02
1.5	1.16	28.72
2.5	2.28	24.89
3.5	0.29	12.44
4.5	0.38	15.32
5.5	0.40	14.74
6.5	6.90	28.72
7.5	9.20	26.81
8.5	8.45	43.09
9.5	9.50	34.60

- Indicate the soil classification by depth.
- Plot the cone penetration test data given in Table 1 including friction ratio F_R.
- Estimate undrained shear strength at depth 5.5 m assuming the cone factor N_k=18.
- Estimate angle of shearing resistance of the soil (ϕ') at depth 7.5 m using the graph given in Figure 1.

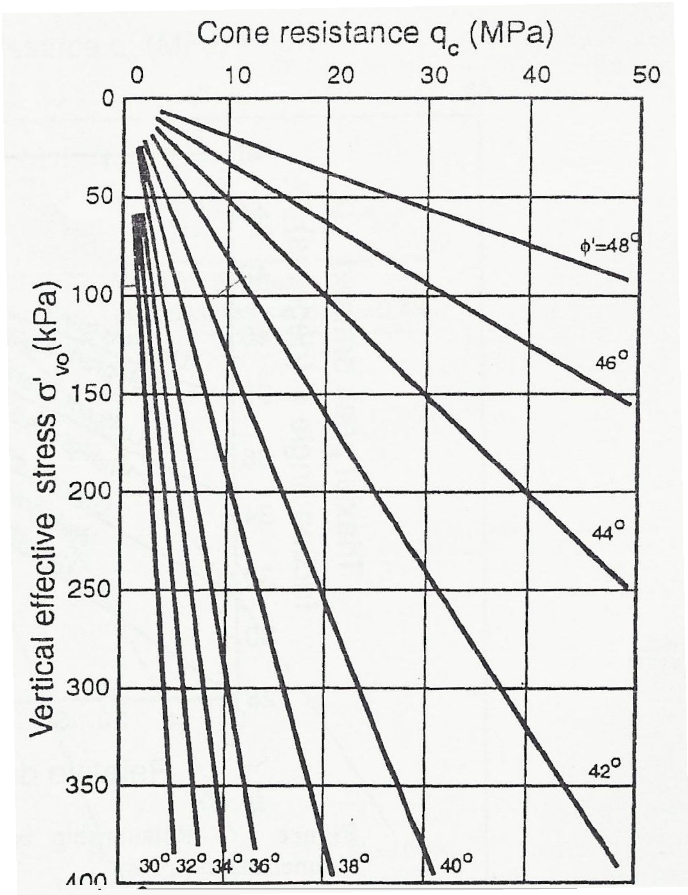


Figure 1. Correlation between cone data and angle of internal friction (Robertson and Campanella, 1983)

Assume an average γ=16.5 kN/m^3 to GWT at depth 3 m, and γ_{sat}=19.8 kN/m^3 for below GWT.

Solution:

Depth (m)	**q_c (MPa/kPa)**	**q_s (kPa)**	**F_R (%)** *[1]	**Soil Classification***[2]
0.5	1.86 / 1860	22.02	1.19	Silt Mixtures – clayey silt to silty clay
1.5	1.16 / 1160	28.72	2.48	Clay – silty clay to clay
2.5	2.28 / 2280	24.89	1.09	Sand Mixtures – silty sand to sandy silt
3.5	0.29 / 290	12.44	4.29	Clay – silty clay to clay
4.5	0.38 / 380	15.32	4.03	Clay – silty clay to clay
5.5	0.40 / 400	14.74	3.69	Clay – silty clay to clay
6.5	6.90 / 6900	28.72	0.42	Sands – clean sand to silty sand
7.5	9.20 / 9200	26.81	0.29	Sands – clean sand to silty sand
8.5	8.45 / 8450	43.09	0.51	Sands – clean sand to silty sand
9.5	9.50 / 9500	34.60	0.36	Sands – clean sand to silty sand

*[1]: Note that; F_R (%) $= \frac{q_s}{q_c} x100$

*[2]: Soil classification is obtained by using Figure 2.19 in lecture notes.

- Plot of the Cone Penetration Test data (CPT) is shown in Figure 2.

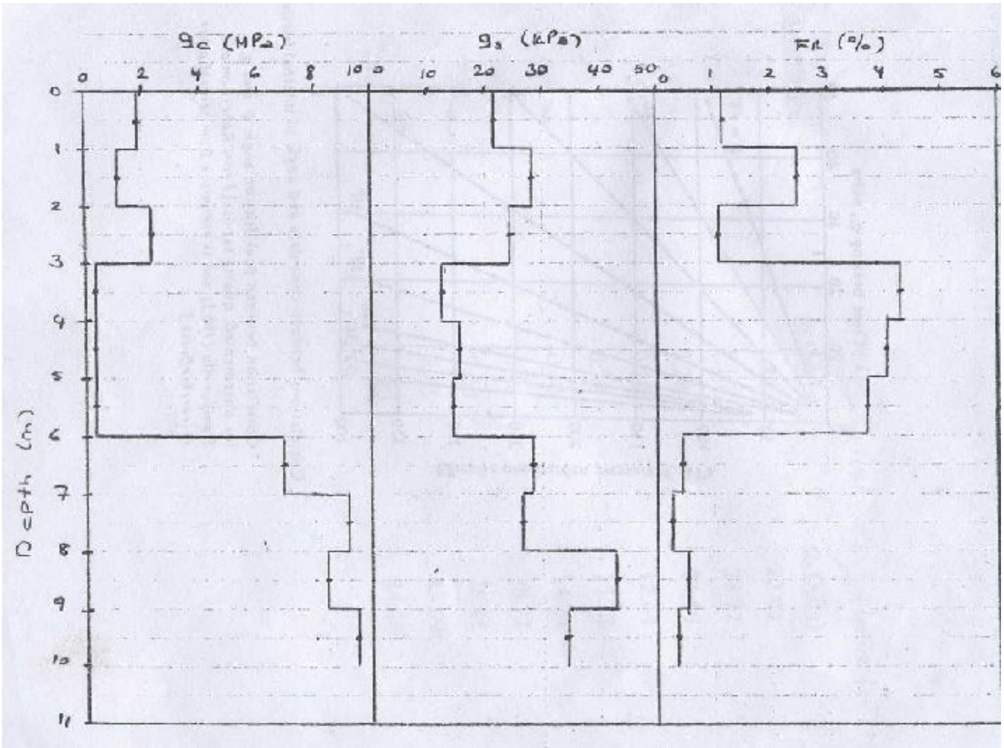


Figure 2. Plot of CPT data

- Estimate undrained shear strength at depth 5.5 m assuming the cone factor N_k=18.

$$c_u = \frac{q_c - p_o}{N_k}$$

where; p_o is total overburden pressure at the level of cone tip

Since γ_d=16.5 kN/m^3 and γ_{sat}=19.8 kN/m^3 then,

$$p_o = 3x16.5 + 2.5x19.8 = 99 \text{ kPa}$$

$$c_u = \frac{400-99}{18} = 16.7\ kPa \text{ (@ z = 5.5 m)}$$

- Estimate ϕ' at depth 7.5 m from Figure 1 where p'_o= effective overburden pressure;

$(p'_o @ z = 7.5\ m) = [3 \times 16.5] + [4.5 \times (19.8-9.8)] = 94.5\ kPa$

$(q_c @ z = 7.5\ m) = 9.2\ MPa$

$\Big\} \quad \boldsymbol{\phi = 41°}$

P3. STANDARD PENETRATION TEST (SPT)

Question:

Referring to Table 2 given below estimate the SPT-N_1 value you would use for a footing which is 2 x 2 m in dimensions and located at 2 m depth. Assume the unit weight of both sands is 18.1 kN/m^3 and 19.7 kN/m^3 above and below ground water table, respectively. GWT is at 6 m depth. Assume that the given N values are corrected for energy efficiency and field procedures.

Table 2. SPT Data

Depth (m)	N_{field}	Soil Type
1	6	Coarse Sand
2	9	Coarse Sand
3	10	Coarse Sand
4	8	Coarse Sand
5	7	Coarse Sand
6	9	Coarse Sand
7	22	Silty fine sand
8	28	Silty fine sand
9	31	Silty fine sand

Solution:

Depth (m)	**N**	**Soil Type**	**Silty Sand Correction, N' *1**	**p'$_0$ (kPa) *2**	**C_N *3**	**N_1 *4**
1	6	Coarse Sand	6 (no correction)	18.1	2.00	12
2	9	Coarse Sand	9 (no correction)	36.2	1.63	15
3	10	Coarse Sand	10 (no correction)	54.3	1.33	13
4	8	Coarse Sand	8 (no correction)	72.4	1.15	9
5	7	Coarse Sand	7 (no correction)	90.5	1.03	7
6	9	Coarse Sand	9 (no correction)	108.6	0.94	8
7	22	Silty fine sand	18.5≈19	118.3	0.90	17
8	28	Silty fine sand	21.5≈22	128.0	0.86	19
9	31	Silty fine sand	23	137.7	0.83	19

***1: <u>Silty sand correction</u>**: SPT-N values should be corrected for the increased resistance due to negative excess pore water pressure.

Applied when all three conditions are satisfied simultaneously:
(i) When the test is carried out in very fine sand or silty sand
(ii) When the test is carried out below ground water table
(iii) When N is greater than 15 (N > 15)

$$N' = 15 + \tfrac{1}{2}(N-15)$$

Where;
N': Silty sand corrected SPT-N value

Note that N' values should always be reported as rounded to the nearest integer.

*2: **Overburden correction (C_N):**

$$N_1 = N \times C_N$$

Where;

C_N: values are determined using equation 2.3 in Lecture Notes (page 31)

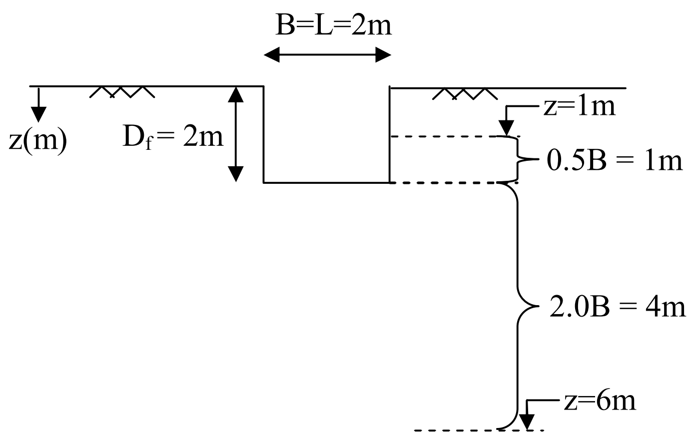
$$C_N = 9.78 \cdot \sqrt{\frac{1}{\sigma'_v (kN/m^2)}} \leq 2.00$$

N: is equal to N' if silty sand correction is applicable.

Note that N_1 values should always be reported as rounded to the nearest integer.

In order to estimate SPT-N_1 value to be used in calculations for a foundation, the SPT-N_1 values in depth interval of 0.5B above and 2B below the foundation level should be considered (where B = foundation width).

0.5B above   0.5 x 2 = 1 m above foundation level
2B below   2 x 2 = 4 m below foundation level
} Depth interval is in between z = 1 m and z = 6 m.



Within this depth interval the weighted average of SPT-N_1 can be used solely for the analysis of given footing.

$$N_{1,av} = \frac{(12+15+13+9+7+8)}{6} = 11$$

P4. PLATE LOAD TEST (FIELD LOAD TEST)

a. Footing on Clay (load test on clay)

Question:

The results of a plate load test in stiff clay are shown in the Figure 3. The size of the test plate is 0.305 m x 0.305 m. Determine the size of a square column footing that should carry a load of 2500 kN. (FS = 2.0; maximum permissible settlement is 40 mm)

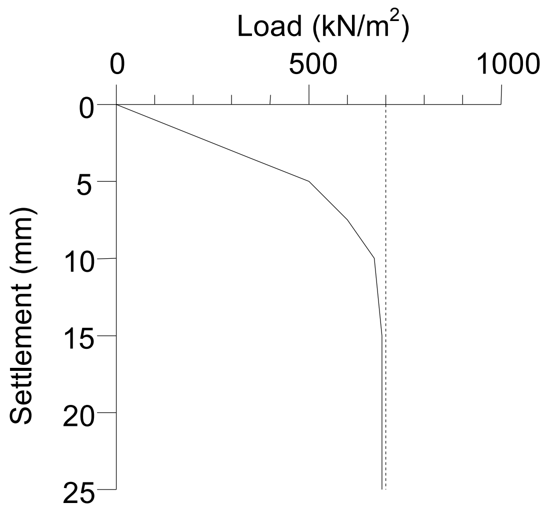
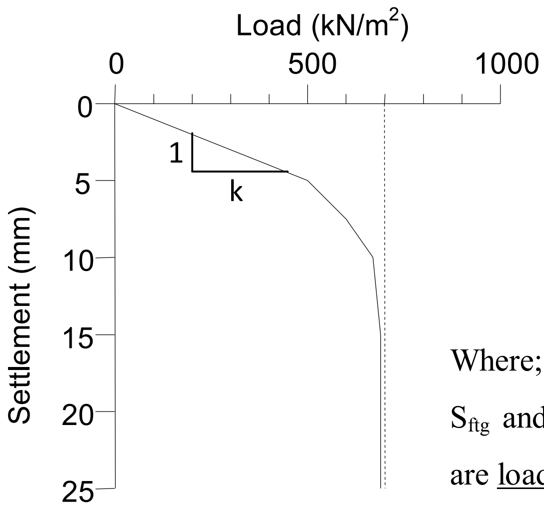


Figure 3. Plate load test in stiff clay

Solution:



Cohesive Soil

$$(q_{ult})_{ftg} = (q_{ult})_{test}$$

$$S_{ftg} = S_{test} \times \frac{B}{b}$$

Where;

S_{ftg} and S_{test} : settlements of footing and test plate which are loaded with the same pressure, respectively.

B (or B_F such as in Lecture Notes): width of footing

b (or B_P such as in Lecture Notes): width of test plate

$$(q_{ult})_{test} = 700 \text{ kN/m}^2 = (q_{ult})_{ftg}$$

$$q_{all} = \frac{700}{FS = 2.0} = 350\text{kPa} \Rightarrow \frac{2500}{BxB} = 350 \Rightarrow B = 2.7\text{m}$$

$$S_{ftg} = \underbrace{\frac{350x5}{500}}_{S_{test} \text{ under } 350 \text{ kPa loading}} x \frac{2.7}{0.305} = 31\text{mm} < 40\text{mm}$$

Settlement calculation, however, is not very reliable; because it can not represent consolidation settlement. Generally, <u>bearing capacity criteria governs</u>, not the settlement, in the design of foundations resting <u>on clays</u>.

Coefficient of subgrade reaction: $k = \frac{q}{S}$ (kN / m^3) (k is the slope of q vs S graph, for more information about "k" see Lecture Notes p.112-113 or Ordemir p. 28)

$$k_{test} = \frac{500}{0.005} = 100000\ kN/m^3 = 100MN/m^3$$

b. Load test on sand

Question:

The results of a plate load test in a sandy soil are shown in the Figure 4. Size of the test plate: 0.305 m x 0.305 m. Determine the size of square footing that should carry a load of 2500 kN with a maximum permissible settlement of 40 mm.

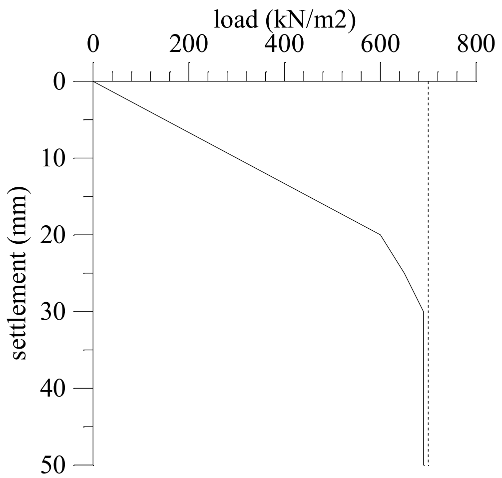
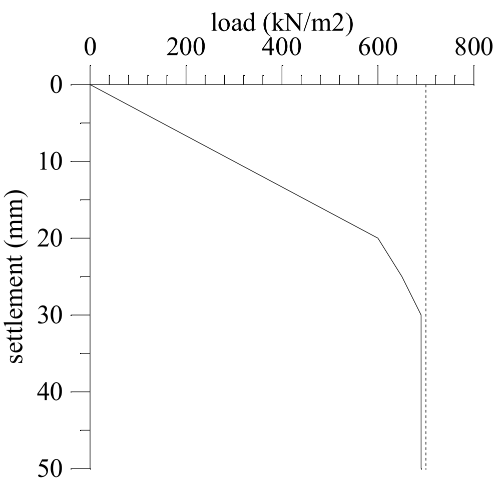


Figure 4. Plate load test in sandy soil

Solution:



Cohesionless Soils

$(q_{ult})_{ftg} = (q_{ult})_{test} \times \frac{B}{b}$

$S_{ftg} = S_{test}\left[\frac{B(b+0.3)}{b(B+0.3)}\right]^2$ (For typical plate dimension, b=0.3 m, this becomes equation 2.13 page 52 in Lecture Notes)

B and b are in meters!

Q (kN)	Assumed B (m)	$q=Q/B^2$ (kPa)	S_{test} (mm)	S_{ftg} (mm)
2500	4	156	5.2 (20/600x156)	17.7<40
	3	278	9.3	30.2<40
	2.5	400	13.3	41.7>40
	2.6	370	12.3	38.9
	2.55	384	12.8	40.4

Square column footing of 2.55 x 2.55 m dimensions will be appropriate.

-OR-

$$S_{ftg} = 40 = \underbrace{\frac{2500}{B^2} x \frac{20}{600}}_{S_{test}} \times \left[\frac{B(0.305 + 0.3)}{0.305(B + 0.3} \right]^2 \Rightarrow B = 2.56m$$

Thus,

$$q_{ftg} = q_{test} x \frac{B}{b} = 700 x \frac{2.55}{0.305} = 5852 kN/m^2$$

$$F.S. = \frac{5852}{384.5} = 15.2 \quad (settlement\ governs\ design)$$

Thus, factor of safety against bearing capacity (*F.S.*) is,

Thus, coefficient of subgrade reaction (*k*) is,

$$k = \frac{600}{0.020} = 30MN/m^3$$