Tutorial Problems 2: CVE362 Soil Mechanics

One dimensional compression, Consolidation and Settlement

1. A 0.5 m thick soil layer is normally consolidated with an average vertical effective stress of 56 kPa and void ratio of 1.12. A reduction of 20 kPa in the effective stress ultimately leads to a heave of 5.1 mm. Calculate the compression index. Is this Cc or Cr?
2. A soil layer 2 m thick has a compression index Cc = 0.5, and a re-compression index Cr = 0.08. At the centre of the soil layer the void ratio, e = 1.2 and the effective vertical stress, $\sigma'v$ = 50 kPa. Calculate the settlement of the layer if a building increases the effective vertical stress by 50 kPa, and the soil has an initial over-consolidation ratio, OCR = 2.
3. A normally consolidated sample in an oedometer has a void ratio e = 0.8 and an effective vertical stress of 50 kPa. If the compression index, Cc = 0.4 and the re-compression index, Cr = 0.1 calculate the final void ratio when the effective stress is increased to 200 kPa and then reduced back to 50 kPa.
4. Calculate the settlement of a 2 m thick clay layer when the vertical stress decreases uniformly by 35 kPa, the initial void ratio is 0.94, the initial vertical effective stress is 83 kPa, the initial over-consolidation ratio, OCR = 1.2, and the compression and recompression indexes are Cc = 0.4 and Cr = 0.08 respectively.
5. Calculate the settlement of a 2 m thick clay layer when the vertical stress decreases uniformly by 35 kPa, the initial void ratio is 0.94, the initial vertical effective stress is 83 kPa, the initial over-consolidation ratio, OCR = 1.2, and the compression and recompression indexes are C_c = 0.4 and C_r = 0.08 respectively.(Answer : -0.0196 m)
6. Due to groundwater lowering the effective vertical stress in a 2.5 m thick clay layer increases from 50 to 57 kPa. If the initial void ratio is 1.45, the initial over-consolidation ratio, OCR = 1.2, and the compression and recompression indexes are C_c = 0.35 and C_r = 0.05 respectively, calculate the settlement of the layer due to the groundwater lowering. (Answer : 2.9 m)
7. Determine the vertical stress increase at a depth of 8 m below point X on the ring beam foundation, with inside radius, r_1 = 8 m, and outer radius r_2 = 12 m, shown in Figure 1, when the ring beam foundation is subjected to a uniform pressure of 225 kPa. (Answer : approx 105 kPa)

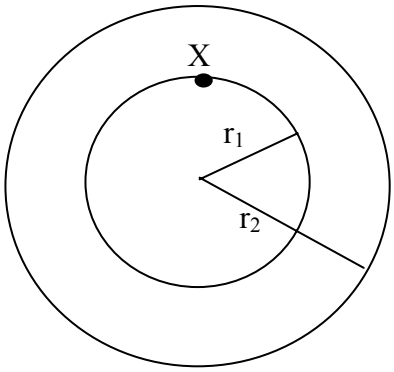

Figure 1

8. The flexible area shown in figure 2 is uniformly loaded. Given that q = 150 kN/m2 , determine the vertical stress increase at point A. (Answer: 62.284)

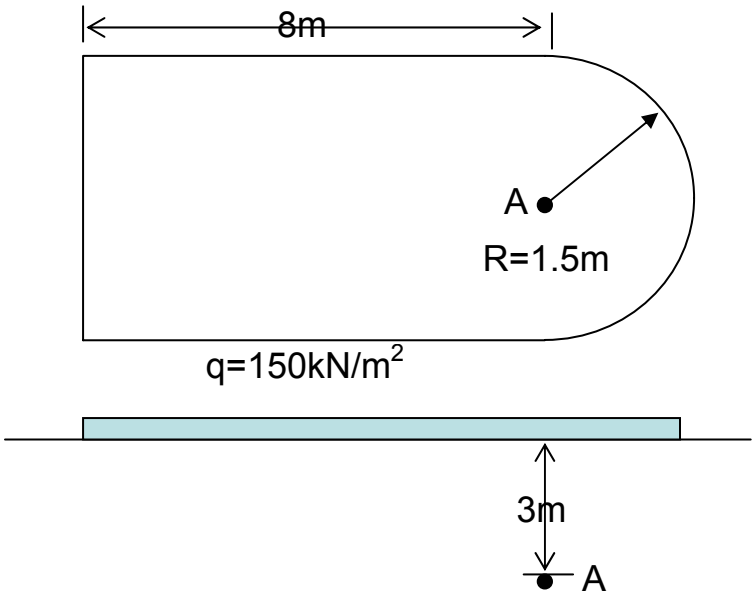

Figure 2

9. The plan of a foundation of uniform thickness for a building is shown in figure 3 . Determine the vertical stress increase at a depth of 4m below the centroid. The foundation applies a vertical stress of 200 kPa on the soil surface.

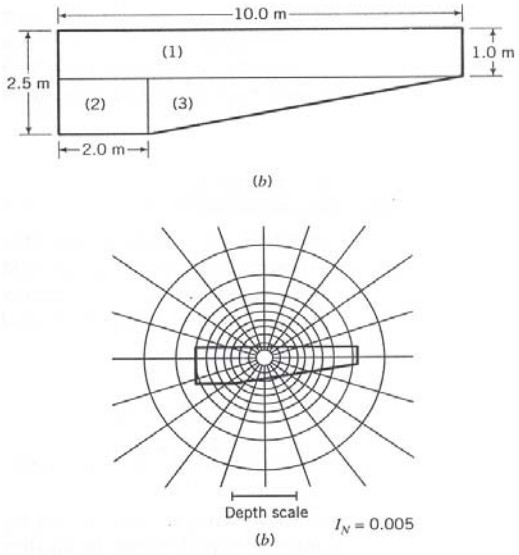

Figure 3

10 A clay specimen, 15 mm thick, has been tested in an oedometer apparatus with two-way drainage, and it is observed that 50% of the consolidation settlement occurs in 1 hour. A layer of the same clay is observed to settle 10mm in 10 years and after many years to settle by 35 mm. Determine the thickness of the clay layer if it drains only from its upper surface. (Answer :H = 3.89 m)

11. A cubical specimen of soil is subjected to increases in total principal stresses $\Delta\sigma_1$ = 50 kPa, $\Delta\sigma_2$ = 30 kPa, $\Delta\sigma_3$ = 10 kPa, without allowing drainage, and the following strains are measured ε_1 = 0.001, ε_2 = 0, ε_3 = - 0.001. The specimen is then allowed to drain, without any change in total stress, and an additional strain of 0.0006 is measured

in each direction, that is $\varepsilon_1 = \varepsilon_2 = \varepsilon_3 = 0.0006$. Determine the elastic parameters for the soil.
Hence, determine the immediate and final settlements of a rigid square foundation, of area 10 m^2, placed on a 7 m thick layer of this soil which overlies rock, when a load of 1500 kN is applied to the foundation.
Comment on the likely accuracy of settlements estimated using elastic solutions.
(Answer :$E' = 25$ Mpa, $\nu' = 0.25$, $s_{immediate} = 0.0077$ m, $s_{long\ term} = 0.0128$ m)

12. A 25 mm thick clay specimen is installed in an oedometer apparatus with one-way drainage. 1 day after the application of a stress increase of 50 kPa a settlement of 0.46 mm is observed. What settlement will be measured after 5 days if $c_v = 0.05$ mm^2/min.
(Answer :$s_{5days} = 0.968$ mm)

13. At a point in a deep deposit of saturated clay total stress changes of $\Delta\sigma_{zz} = 45$ kPa, $\Delta\sigma_{xx} = \Delta\sigma_{yy} = 15$ kPa result from loads applied to the soil surface. Assuming that the soil can be treated as a linear elastic material with properties $E' = 26{,}000$ kPa, $\nu' = 0.3$, determine the strain in the z-direction immediately after the load is applied.(Answer :$E_u = 30$ Mpa, $\varepsilon_{zz} = 0.001$)

14. Determine the radius of a rigid circular foundation if the final settlement is to be 2 mm when subjected to a load of 750 kN. The foundation is to be placed on the surface of a 7.5 m deep soil layer which overlies rock. The properties of the soil are $E' = 70{,}000$ kPa, $\nu' = 0.2$. (Answer :$a \approx 2.1$ m)

15. A 3m thick layer of clay is free to drain at the surface and overlays highly fissured permeable bedrock. Application of an extensive surface loading is expected to cause a long term settlement of 12 mm. If a settlement of 6 mm occurs in 7.5 years calculate the settlement after 1.5 years. (Answer : Settlement at 1.5 years = 2.64mm)

16. A 3 m thick soil layer has an average vertical effective stress $\sigma' = 80$ kPa, a void ratio $e = 0.9$, a pre-consolidation pressure $\sigma'_{pc} = 95$ kPa, a compression index $C_c = 0.3$, and a re-compression index $C_r = 0.1$. Determine the settlement of the layer if extensive surface loading causes a uniform vertical stress increase of 10 kPa.(Answer :s = 8.08mm)

Challenge problem

17. It is proposed to place a building on a site through which a small buried pipe containing sensitive cables passes. It is planned to support the building on a rectangular raft foundation that transmits a uniform pressure of 220 kPa to the soil beneath. A plan view of the building is shown in Figure 4a, which also shows the line of the pipe. The site consists of 2 m of sand overlaying a 5 m thick deposit of clay, which overlays rock. The site elevation is shown in Figure 4b. The pipe is buried in the middle of the clay layer. The water table is level with the surface of the clay. The sand is dry with unit weight $\gamma_{dry} = 15$ kN/m^3, and for the clay, $\gamma_{sat} = 18$ kN/m^3. For both soil types the specific gravity, $G_s = 2.6$. The over-consolidation ratio, OCR, is 3 throughout the clay layer. The sand may be assumed incompressible and for the clay $C_r = 0.1$, $C_c = 0.5$.

(i) Determine the settlement of the pipe at the points A, B, and C. Use a single layer in the analyses.

(ii) Will these settlements cause a problem for the buried pipe if the maximum permitted angular distortion of the pipe is 0.005.

(iii) Suggest 2 alternative foundation designs that could reduce any distress of the pipe, and briefly explain why.

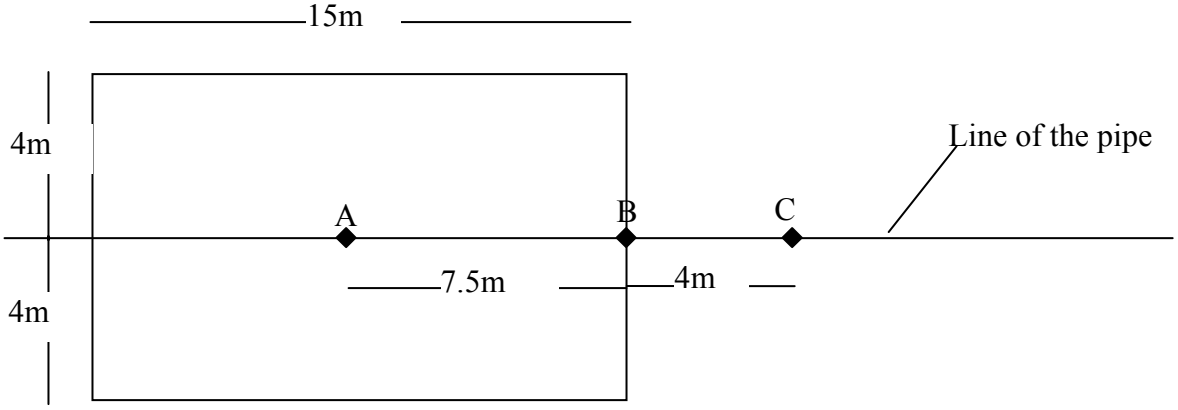

Figure 4a Plan of the raft foundation

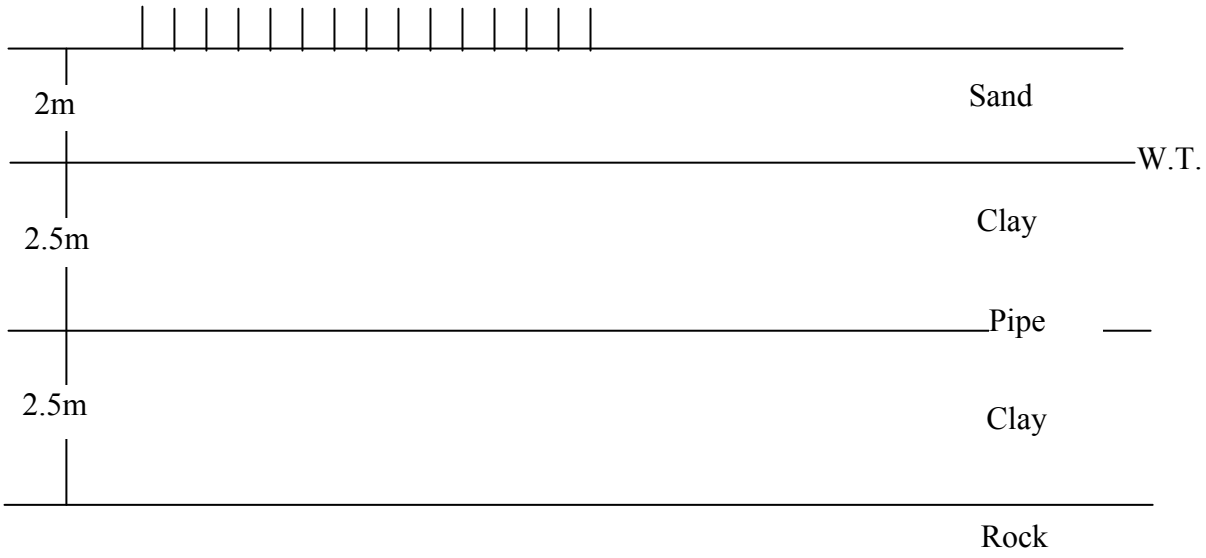

Figure 4b Elevation