B10 Soil Mechanics Applications

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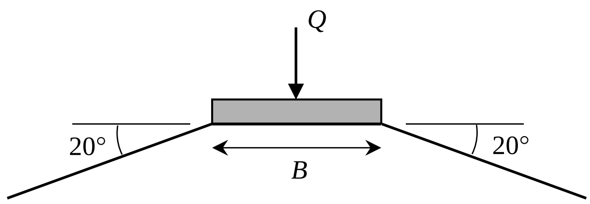
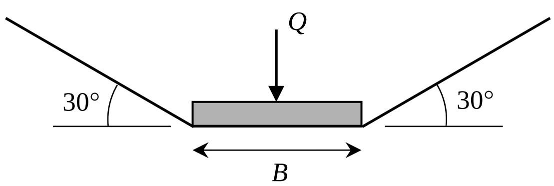
EXAMPLES SHEET 1

1. Using a lower bound approach, calculate the undrained bearing capacity Q of each of the strip footings shown below. The undrained shear strength of the soil is s_u, and the sloping surfaces adjacent to the footing are stress-free. Neglect the self-weight of the soil.

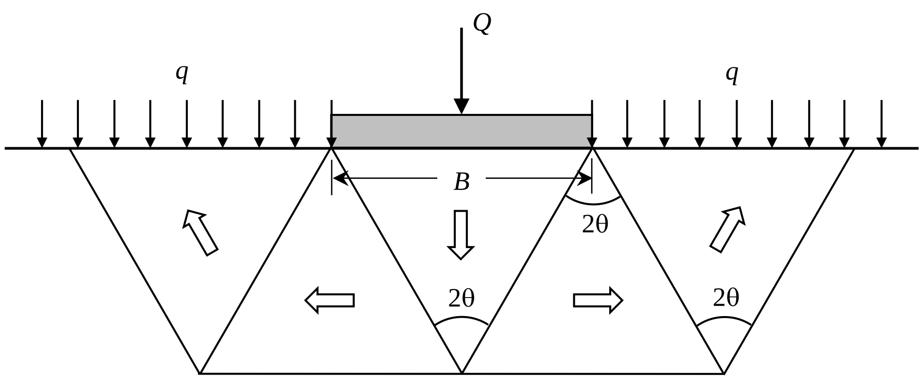




2. The collapse mechanism shown below can be used to carry out an upper bound calculation of the undrained bearing capacity of the foundation. The soil is a clay with undrained shear strength s_u and unit weight γ, and the surfaces adjacent to the foundation are subjected to a uniform surcharge pressure q.

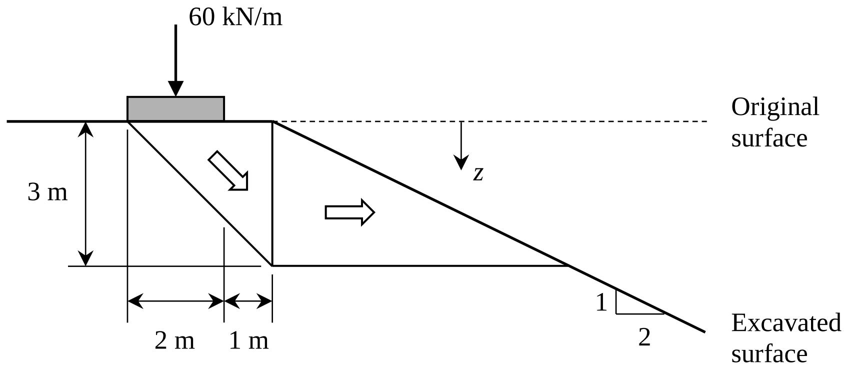
(a) Draw the velocity diagram for this mechanism and hence calculate the angle θ that is critical (i.e. gives the lowest bearing capacity Q).

(b) From your expression for Q, deduce the values of the dimensionless bearing capacity factors N_c, N_q and N_γ obtained from this mechanism. How do they compare with the exact values for $\phi_u = 0$?

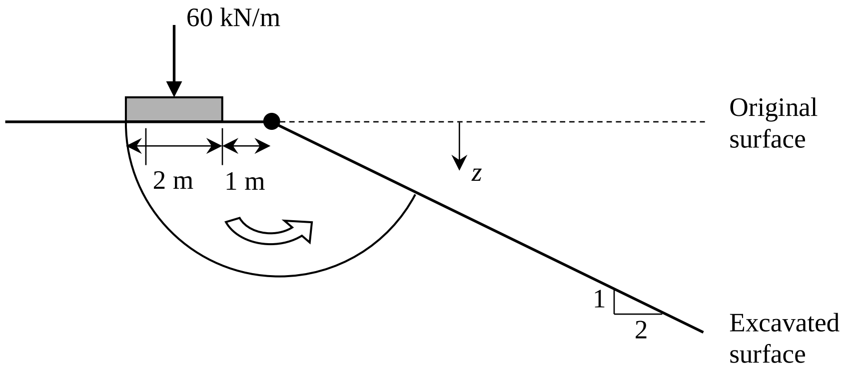


3. An excavation with sloping sides is to be made in a soft clay deposit where the undrained shear strength increases linearly with depth as $s_u = s_{u0} + kz$, where $s_{u0} = 10$ kPa, $k = 2$ kPa/m and z is the depth in metres below the level of the (original) soil surface. The unit weight of the clay is 20 kN/m^3 and the sides of the excavation are to be cut at a gradient of 1 in 2. The contractor doing the excavation wishes to drive fully laden dump trucks along a haul road adjacent to the slope. Each of these trucks can be idealized as a strip footing of width 2 m carrying a line load of 60 kN/m, as shown below. Safety fencing will ensure that there is always a minimum clear distance of 1 m between a truck and the start of the slope. Some preliminary upper bound analyses are to be performed using the collapse mechanisms suggested below. What is the factor of safety in each case? Do the results warrant a more thorough investigation?

Two blocks:



Slip circle (R = 3 m):



4. A strip footing of width 2 m is constructed at a depth of 1.2 m in sandy silt. The bulk unit weight of the soil is 19 kN/m^3 above the water table, and 21 kN/m^3 below. Using Terzaghi's original equation with Brinch Hansen's approximate formula for N_γ (see lecture notes) predict the bearing capacity using:

(a) an undrained analysis with s_u = 105 kPa and ϕ_u = 0, assuming the water table is level with the base of the footing.

(b) a drained analysis with c' = 0 and ϕ' = 28°, assuming the water table is

(i) a long way below the footing;

(ii) level with the base of the footing;

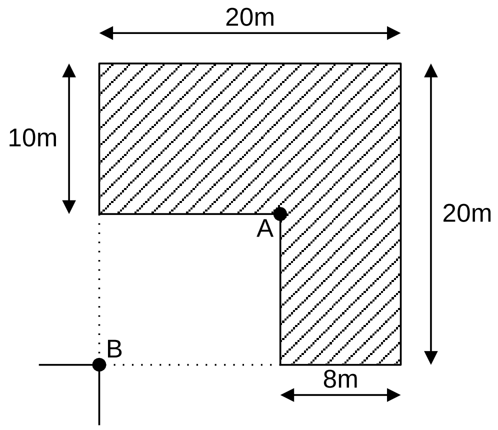
(iii) at the soil surface (this one is tricky!).

Take γ_w = 9.8 kN/m^3.

5. Consider a stress discontinuity in drained soil with strength parameters c' = 0, ϕ' > 0. Derive equation (10) in the lecture notes from first principles. Hint: read the section of the lecture notes leading up to the equation.

6. A square foundation, 1.5 m × 1.5 m in plan and 0.5 m deep, is to be used as the base for a column carrying a load of 30 kN. The foundation is on dense sand which is expected to compress by only a very small amount. From 2 m to 3.5 m below the ground surface, however, there is a layer of soft clay with an estimated m_v value of 1.6×10^{-3} m^2/kN. Using a load-spread angle of 1:3, estimate the consolidation settlement due to the presence of the clay layer. (Divide the clay into three layers for the purposes of the calculation, and remember that the foundation is a square, not a strip, so the load is spread in a 3D manner).

7. A uniform load of 25 kPa is to be applied to a foundation on sand with the plan shown below. Use Fadum's chart to find the increase in vertical stress at a depth 10 m below point A, and at a depth 10 m below point B on an adjacent building.



8. A proposed oil tank will, when full, apply a uniform surface pressure load of 200 kPa over a circle of diameter 20 m. The soil beneath the tank consists of 5 m of sand (γ_{dry} = 16 kN/m^3, γ_{sat} = 19 kN/m^3) overlying a deep deposit of soft clay (γ = 19 kN/m^3). The water table is located at a depth of 3 m below the ground surface. On the same axes, plot the *in situ* variation of vertical effective stress with depth, and the change in vertical total stress (directly beneath the centre of the tank) that will occur once the tank is filled. Find the depth at which the expected increment in σ_v is equal to 10% of the *in situ* σ'_v (this is generally regarded as the depth to which samples should be recovered for oedometer testing). Take γ_w = 9.8 kN/m^3.

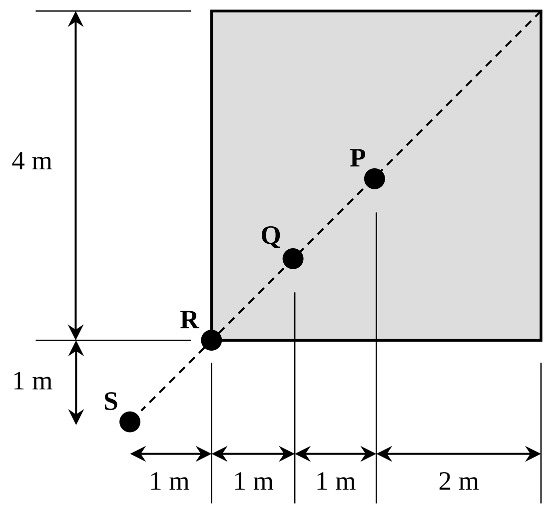
9. A uniform pressure load of 40 kPa is applied over a 4 m × 4 m square area on the surface of a deep clay layer with shear modulus G = 2 MPa.

(a) What value of Poisson's ratio ν is appropriate for the calculation of immediate settlements in this case? Justify your answer.

(b) Referring to the diagram below, calculate the immediate settlement at points P, Q, R and S using Giroud's influence factors, and plot these results versus distance from the centre of the loaded area.

(c) Estimate the settlement at point S by replacing the uniform loading by an equivalent point load at P. How does this compare with the solution found in (b)?

(d) What other type of settlement would need to be considered in design?



Answers (taking γ_w = 9.8 kN/m^3)

1. $4.44Bs_u$, $6.19Bs_u$
2. (a) 35.3° (b) $N_c = 5.66$, $N_q = 1$, $N_\gamma = 0$
3. Q = 123.0, 131.4 kN/m (FoS 2.05, 2.19)
4. (a) 1125 kN/m (b) (i) 1087 kN/m (ii) 916.3 kN/m (iii) 664.3 kN/m
6. 8.2 mm
7. 12.6, 1.2 kPa
8. 29.8 m
9. (a) 0.5 (b) 22.4, 20.1, 11.2, 6.3 mm (c) 6.0 mm