SLOPE STABILITY - TUTORIAL 1
PLANAR MOVEMENTS
STABILITY CHARTS & METHOD OF SLICES

Q1. A vertical cut 3.5m deep is excavated in saturated intact clay. The clay is isotropic and has an undrained strength (S_u) of 28kN/m^2 and a saturated unit weight (γ) of 19kN/m^3.

(a) Assuming that a vertical, air filled tension crack forms behind the slope crest to a depth of 1.5m, determine the factor of safety of the cut slope under short-term (end-of-construction conditions). Use a planar failure surface and apply the Limit Equilibrium method.

(b) What new value of this factor of safety will result if the lower part of the cut is submerged by fresh water to a depth of 1m? The tension crack remains free of water.

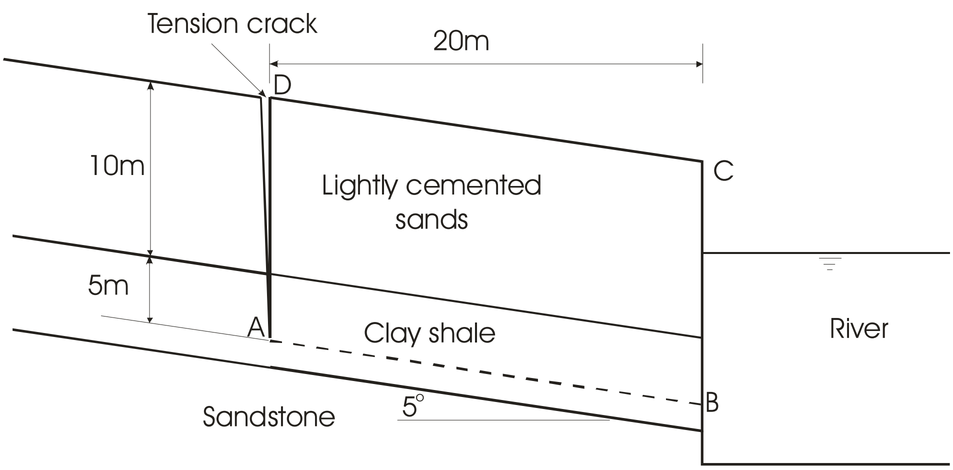
Answers Q1: (a) FoS=1.18, (b) FoS=1.24

Q2. A deep river channel has been cut through a sequence of weak sediments, as shown in Fig. 1. Following a prolonged wet period, failure of the mass ABCD occurred by slip along the plane AB in the clay shale when the water level in the river was 10m above B. Well before the ultimate failure took place, a vertical tension crack AD had formed and become completely filled with water. The bulk unit weights of the lightly cemented sands and the clay shale are 18 kN/m^3 and 20 kN/m^3 respectively.

(a) Treating the problem two-dimensionally, estimate the effective angle of friction mobilised in the clay shale at failure, assuming $c' = 0$.

(b) Assuming failure occurred just as the tension crack became full of water, calculate the undrained shear strength of the clay shale.

(c) If the clay shale has strength parameters $c' = 10$ kPa, $\phi' = 16°$, determine the Factor of Safety when the water level in the tension crack is 5 m below ground level and the river level is 9 m above B, and has been at that level for some time.



Answers Q2: (a) $\phi' = 20°$; (b) S_u = 54.7 kPa; (c) F of S = 2.15.

Q3. A site consists of a soft saturated clay, with an average undrained strength S_u of 36 kPa, over-lying rock at a depth of 12.2 m. It is proposed to excavate a cutting through this clay to a depth of 9.1 m. Find the side slope which will give a factor of safety of 1.4 if a nominal 10% reduction in S_u is made to allow for tension cracks. The unit weight of the clay is 19.1 kN/m^3.

(a).Immediately after making a cutting with a depth of 6.1 m and side slopes of 2½ (horizontal):1 (vertical), a failure took place. The ground consists of 10.7 m of soft saturated clay, underlain by hard shale. Assuming that the unit weight of the soft clay is 18.0 kN/m^3, calculate the average undrained shear strength from a back analysis of the failure.

(b).For the continuation of this cutting, at the same depth through similar ground, what side slope should be worked to if a factor of safety of 1.25 is required?

(c).For the continuation of the cutting designed under (b) above, determine the factor of safety if both during and subsequent to excavation the cutting is kept flooded with fresh water:

(i) just to its top (*i.e.* to original ground level), and

(ii) to a level 4m above original ground level.

Q4. A natural slope has a vertical height of 18m and a uniform inclination of 2 (horizontal) to 1 (vertical). It is composed of uniform clayey till which extends down to a level rock surface located 4.5m beneath the toe of the slope. The properties of the till in and below the slope are as follows: unit weight γ = 19.56 kN/m^3, c′ = 8.8 kPa, and ϕ' = 30°.

a) If the most critical potential circular slip surface is a base failure, tangential to the surface of the rock, and the average pore pressure ratio, $\bar{r}_u$, for this surface is 0.39, determine the factor of safety of the slope using the stability coefficients given below for $c'/\gamma H = 0.025$, $\phi' = 30°$ and depth factor D = 1.25:

Slope	m	n
2:1	1.956	1.915
3:1	2.431	2.342
4:1	2.953	2.806

b) If it is decided to increase the factor of safety of the slope to a value of 1.40, determine:

(i) the value to which $\bar{r}_u$ must be reduced by drainage measures if the slope profile is left unchanged, and

(ii) the inclination to which the slope must be trimmed back, assuming that $\bar{r}_u$ is left unchanged.

Q5. A 3:1 soil slope, 26.7 m high, rests on a horizontal rock surface level with the toe. The slope has a homogeneous pore pressure ratio of 0.35 and fails under long term conditions by circular slipping. If the bulk unit weight of the soil is 22 kN/m^3 and the value of ϕ' mobilised at failure is 25°, determine, using the stability coefficients given below, the value of c′ mobilised at failure.

$c'/\gamma H$	m	n
0	1.399	1.554
0.025	1.875	1.696
0.05	2.193	1.757

Answers:
(Q3) ≈19.5°; (a) ≈17.4 kPa (if tension cracks are neglected); (b) ≈12.2°; (c) ≈2.74 in both cases.
(Q4) F = 1.21; $\bar{r}_u$ = 0.29; 21.6°; (Q5) c′ = 5 kPa.

Q6. Show by using the two equations of force equilibrium, that when the "Conventional Method" is applied to a non circular slip surface the following equation for the factor of safety is obtained:

$$F = \frac{\sum_{i=1}^{n}\left(c_i' L_i + \left(W_i \cos\alpha_i - U_i\right)\tan\varphi_i'\right)}{\sum_{i=1}^{n} W_i \sin\alpha_i}$$

Where for a typical slice "i", (see Figure Q6) L_i is the length of the base of the slice, α_i is the inclination of the base to the horizontal, W_i is the weight of the slice, U_i is the resultant force from the pore water pressures acting on the base of the slice (note: this force acts normal to the base of the slice) and c′ and φ′ are drained strength parameters appropriate to the soil through which the base of the slice passes. n is the number of slices.

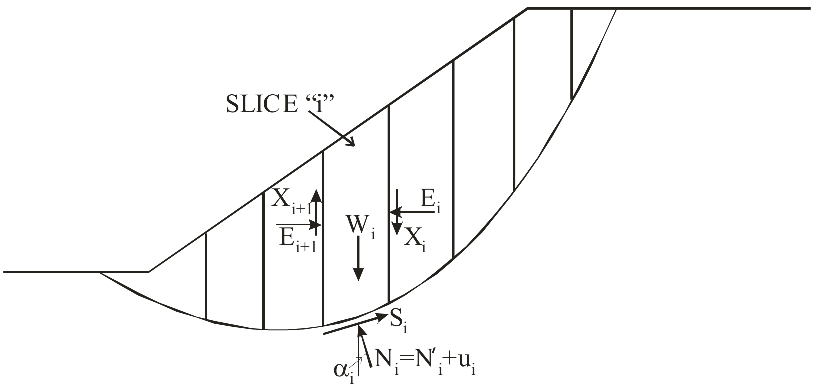


Figure Q6

Q7. The slope in Figure Q7 is on the point of failure. Using the failure surface and slice geometry shown in the Figure apply the "Conventional Method" of slices to determine the angle of shearing resistance φ' of the soil. Assume that the soil is uniform with a bulk unit weight γ_{sat}=20kN/m^3 and a cohesion c'=0. The piezometric surface is shown in Figure Q7. The soil may be assumed to be saturated both above and below this line.

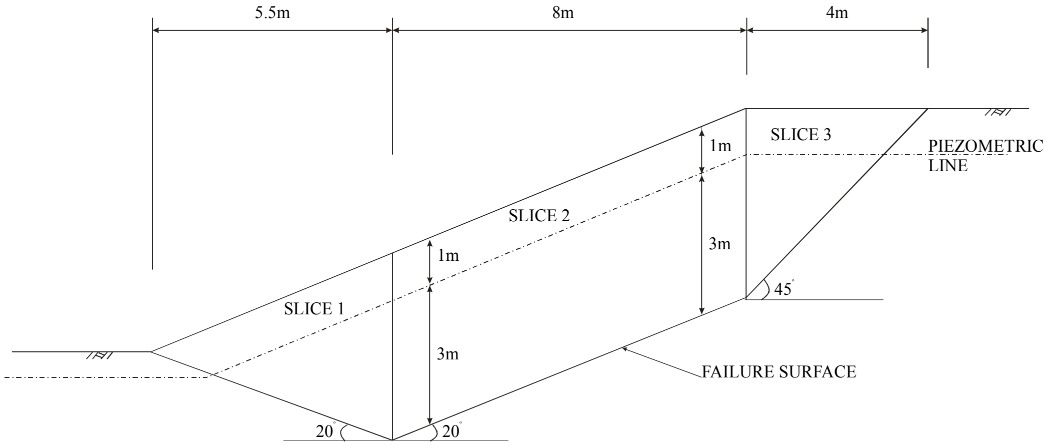


Figure Q7