Problem 1 (10%)

Name and describe the laboratory tests which you would perform to classify a soil sample according to the Unified Soil Classification System (USCS). Make sure to describe the soil properties that can be determined based on those laboratory tests.

Problem 2 (20%)

(i) (5%) A direct shear test is performed on a cohesionless soil. Determine the shear strength parameter(s) if the shear stresses at failure corresponding to the normal stresses of 50 kPa, 100 kPa and 200 kPa are 28 kPa, 57 kPa, and 112 kPa, respectively.

(ii) (5%) If consolidated drained (CD) triaxial test is perform on the same soil sample in (i), do you expect the shear strength parameter(s) to be the same, smaller than or larger than what you have determined in (i)? Explain your answer.

(iii) (2%) Which soil has a larger friction angle, (a) well-graded sand or (b) poorly-graded sand?

(iv) (2%) Which soil has a larger friction angle, (a) round sand or (b) angular sand?

(v) (2%) Which soil has a larger friction angle, (a) sand with relative density of 80% or (b) sand with relative density of 50%?

(vi) (4%) An unconfined compression test is performed on a saturated clay sample. The sample fails at a pressure of 50 kPa. Determine the undrained shear strength of the soil.

Problem 3 (20%)

Answer the following questions related to shallow foundation design.

(i) (9%) Suppose that there are 3 construction sites (A, B, and C). They are primarily composed of sand (site A), normally consolidated clay (site B) and heavily consolidated clay with OCR>5 (site C), respectively. If a square footing is to be built on each site, determine whether the short-term or long-term ultimate bearing capacity would control the footing design for each site. Also, explain your answer.

(ii) (6%) A square footing of 3 m × 3 m in plan is situated on a sandy stratum with an embedded depth of 1 m. The groundwater table is located at a depth of 0.5 m. The effective friction angle of sand is 32°. The unit weights of sand above and below the groundwater table are 18 kN/m^3 and 20 kN/m^3, respectively. Apply Meyerhof's bearing capacity equation to evaluate the ultimate bearing capacity of the footing.

Note: bearing capacity factors: $N_c = (N_q - 1)\cot\phi$, $N_q = \tan^2(45 + \frac{\phi}{2})e^{\pi\tan\phi}$, $N_\gamma = (N_q - 1)\tan 1.4\phi$

(iii) (5%) What are the three modes of bearing capacity failure? Is Meyerhof's bearing capacity equation applicable for all three modes of failure? Explain your answer.

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Meyerhof's shape and depth factors

Shape factors
For $\phi = 0$
$F_{cs} = 1 + 0.2(B/L)$
$F_{qs} = F_{\gamma s} = 1$
For $\phi \geq 10^{\circ}$
$F_{cs} = 1 + 0.2(B/L)\tan^2(45 + \phi/2)$
$F_{qs} = F_{\gamma s} = 1 + 0.1(B/L)\tan^2(45 + \phi/2)$
Depth factors
For $\phi = 0$
$F_{cd} = 1 + 0.2(D_f/B)$
$F_{qd} = F_{\gamma d} = 1$
For $\phi \geq 10^{\circ}$
$F_{cd} = 1 + 0.2(D_f/B)\tan(45 + \phi/2)$
$F_{qd} = F_{\gamma d} = 1 + 0.1(D_f/B)\tan(45 + \phi/2)$ D_f: embedded depth of footing

Problem 4 (25%)

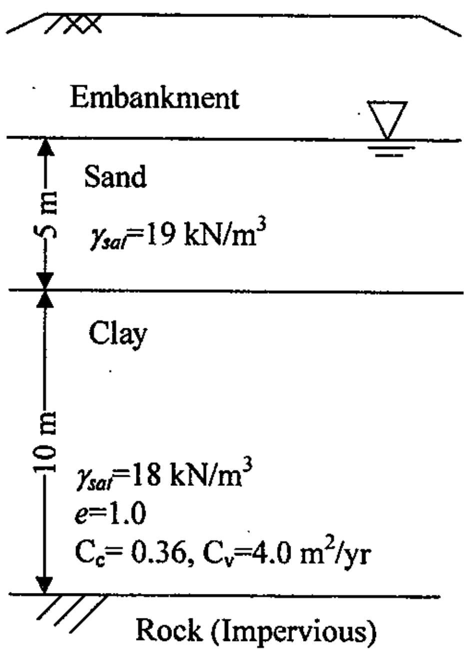
The figure below shows the ground profile of a site, on which a large scale of embankment is constructed. Given that the height of the embankment is 4 m and the unit weight of the embankment soil is 20 kN/m^3, please answer the following questions:

(i) (5%) Estimate the primary consolidation settlement of the ground due to the construction of the embankment.

(ii) (10%) Predict the consolidation settlement-time relationship for the embankment.

(iii) (10%) To reach 95% consolidation in 18 months by precompression, estimate the required surcharge.

$U = 0 - 60\%,\ T_v = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$; $U > 60\%,\ T_v = 1.781 - 0.933\log(100 - U\%)$



Problem 5 (25%)

Answer the following questions about the active pressure of a 5-m-high retaining wall with a sandy backfill.

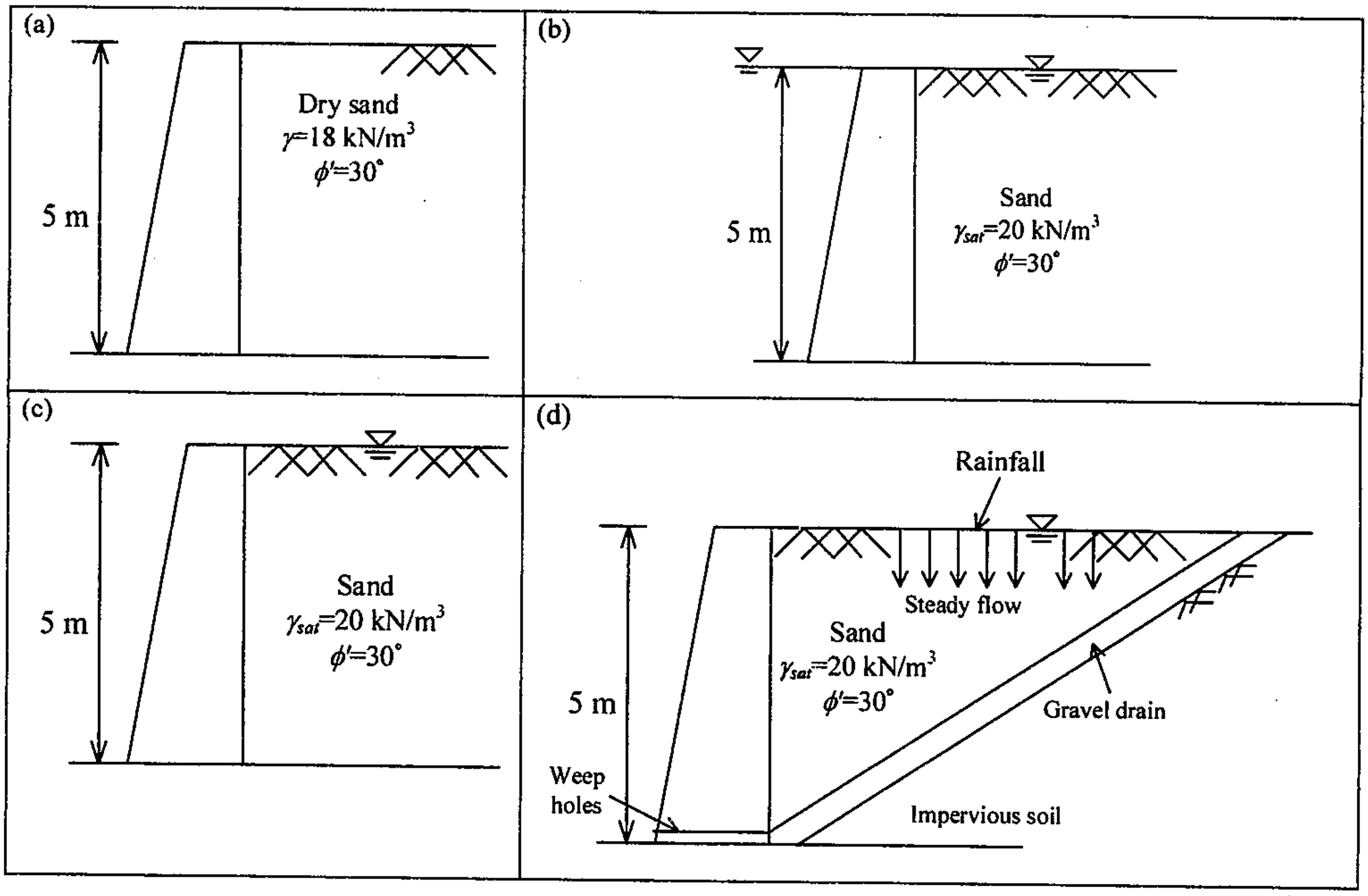
(i) Assume that the interface between the wall and backfill is frictionless, analyze the distributions of lateral active earth pressure (including water pressure) with depth, and the total lateral active thrusts and their application locations for the following four conditions.

(a) (5%) The backfill is dry.

(b) (5%) The wall is fully submerged in water.

(c) (5%) Groundwater level in the backfill is at the ground surface.

(d) (5%) A gravel drain is installed at the bottom of the backfill, and the backfill is subjected to downwall seepage due to continuous rain (Note: the pressure head at the gravel grain is zero).



(ii) (5%) Compare the magnitudes of the lateral active thrusts of the above four cases and give comments on your results.

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