THE OPEN UNIVERSITY OF SRI LANKA
DIPLOMA IN TECHNOLOGY (CIVIL) – LEVEL 04
Final Examination 2007/2008

CEX4230 – SOIL MECHANICS AND INTRODUCTION TO ROCK MECHANICS

102

Time allowed: Three Hours.

Date: Friday, 28th April, 2008 Time: 0930-1230

PART A:
Answer all questions. All questions carry equal marks. Attach Part A of this paper to your answer script. You are advised to spend approximately One (1) hour for Part A. (36 points)

Identify the true responses by placing a cross e.g. ☒, in the cage provided; if the response is incorrect, then leave the cage empty.

1. The equation $y = \frac{x}{1+w}$ relates two parameters x and y, where parameter w is the Water Content.
   a) Parameters x and y should have the same units of measurement. ☐
   b) Parameter w should always be less than 1 ☐
   c) Parameter x is obtained using the Sand Cone Test ☐

2. Relative Density D_r is expressed as: $D_r = \left(\frac{e_{max} - e}{e_{max} - e_{min}}\right) x100\%$.
   a) D_r should always represent a value between 0 and 1 ☐
   b) Parameter e_{min} represents the loosest possible packing ☐
   c) Parameter e is defined as the ratio: V_w to V_s ☐

3. The Hydrometer Test determines per cent finer versus particle size.
   a) This test is performed on clays, silts and sands ☐
   b) The Hydrometer reading represents the density of soil-solution at a given time; this density reduces with time ☐
   c) Parameter H_r, the factor that represents the depth to the centre of volume of the hydrometer, is used to determine the particle size ☐

4. The Unified Soil Classification System (USCS) uses Sieve Analysis Test to classify coarse-grained Soils.
   a) A coarse-grains soils has particle sizes greater than 0.002mm ☐
   b) Soils with group symbols GW and SP has per cent fines less than 5. ☐
   c) Soils with group symbols GC and SM is determined based on Sieve Analysis Test only. ☐

5. Atterberg Consistency Limit Tests are used to classify fine-grained soils.
   a) Atterberg Consistency Limit Tests are performed on soil fraction passing 0.2mm standard sieve ☐
   b) Liquid Limit for a given soil changes with its natural moisture content ☐
   c) High-plastic soils are identified based on both Liquid Limit and Plasticity Index ☐

6. The Unified Soil Classification System (USCS) uses Liquid Limit and Plastic Limit to classify fine-grained soils.
   a) A `CL' soil lies above the A-line of the Plasticity Chart ☐
   b) A `MH' soil has a Liquid Limit less than 50 ☐
   c) Plasticity Index define the range of water content between upper limit of viscous flow and the lower limit of `plastic' behaviour ☐

7. The Coefficient of Curvature and Coefficient of Uniformity is used to determine whether a particular coarse-grained soil is well-graded or uniformly graded.

   a) The two parameters D_{10} and D_{60} quantify Coefficient of Curvature ☐
   b) D_{10} is expressed as a percentage ☐
   c) During Sieve Analysis Test it is ensured that all grains pass through the selected sieves ☐

8. Soil is considered to be a non-homogeneous and an anisotropic granular material.

   a) Non-homogeneity arises due to varying particle sizes and shapes, from point to point ☐
   b) Mild-steel is a homogeneous but an anisotropic material ☐
   c) Soil anisotropy is caused when soil strata are formed ☐

9. Terzarghi's Principle of Effective Stress states that $\sigma = \sigma' + u$.

   a) Term u at a given point, depends on the direction selected (e.g. vertical versus horizontal) ☐
   b) σ represents the average inter-granular stress (i.e. between soil particles) ☐
   c) The relation between σ in vertical and horizontal directions is expressed as: $\sigma_h = K_0\sigma_v$. ☐

10. Granular materials maintain an angle of repose when heaped. The angle of repose is higher for a soil:

    a) With spherical grains than a soil with angular grains ☐
    b) With a smoother surface texture than a soil with a rough surface texture ☐
    c) With a uniform gradation than a well-graded soil ☐

11. Coefficient of Permeability (Hydraulic Conductivity) quantifies the ability of water to flow through soil. For a given soil:

    a) Permeability is more for a soil with a higher Void Ratio ☐
    b) Permeability increases with an increase in viscosity ☐
    c) Hydraulic Gradient that causes flow is less for a high permeable soil ☐

12. The Standard Proctor Compaction Test is performed to:

    a) Determine how well a particular soil compacts when varying amounts of moisture is added during compaction ☐
    b) Determine the dry density of a field-compacted soil layer ☐
    c) Determine the amount of water required for optimum compaction for a given effort ☐

13. During field compaction:

    a) Moisture is sprayed to bring soil consistency closer to the maximum moisture content it could hold ☐
    b) Trials are performed to determine the optimum height of a layer spread and the optimal number of roll passes ☐
    c) Compacted layers are sampled to determine the relative density, D_r ☐

14. The Unconfined Compression Test

    a) Is a laboratory test that determines undrained shear strength parameters c_u and ϕ_u ☐
    b) The shear strength parameters can be used to perform an effective stress analysis ☐
    c) The sample fails in shear; the plane of failure makes a 30^0 angle with the horizontal plane ☐

15. The bearing capacity of a shallow foundation determines its capacity to withstand the bearing stress resulting from the building load.

    a) The maximum safe bearing capacity, q_s is obtained by dividing the Ultimate Bearing Capacity by a suitable safety factor. ☐
    b) The Ultimate Bearing Capacity can be established through in-situ tests ☐
    c) For sandy soils, the Allowable Bearing Capacity, q_a is the same as q_s ☐

16. The 1-Dimensional Consolidation Test (i.e. the Oedometer Test) is used to estimate in-situ Primary Consolidation Settlement.

a) Parameter c_v estimates the consolidation settlement ☐
b) e_0 is the void ratio at zero vertical stress ☐
c) Primary Consolidation settlement is proportional to the corresponding change in void ratio ☐

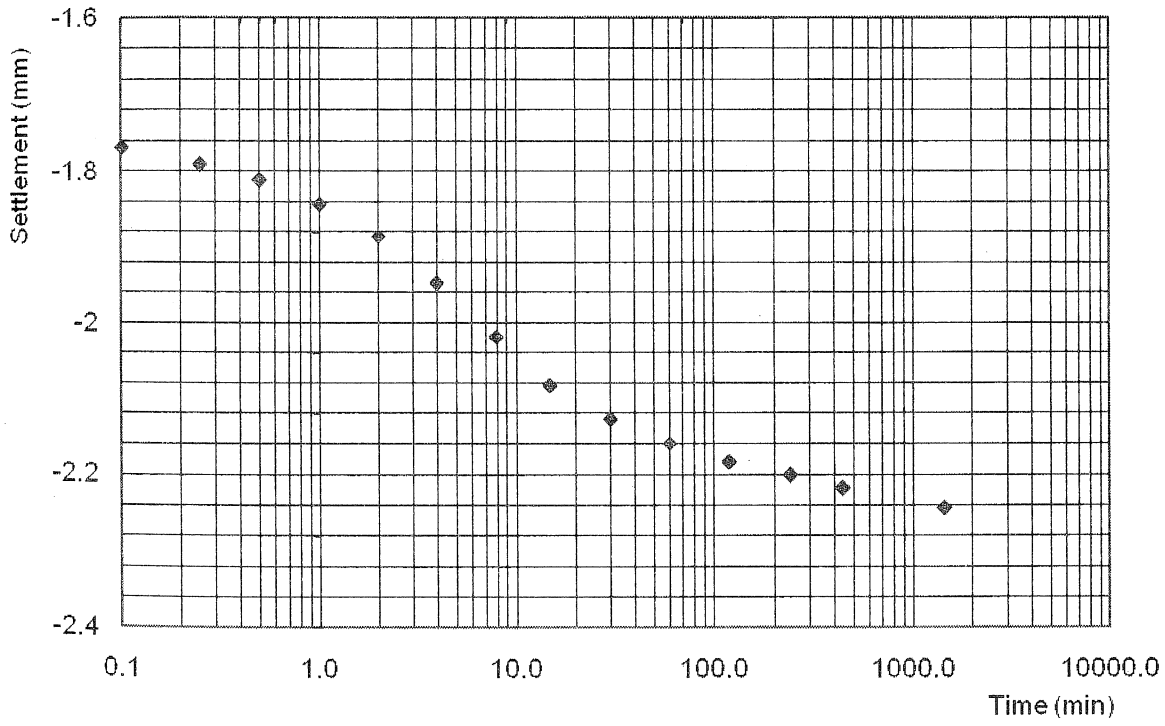
17. Visual Soil Classification of fine-grained soils are done based on the tests: Dry Strength, Dilatancy Reaction, Toughness of soil thread at Plastic Limit and Plasticity.

a) A high Dry Strength and a high Dilatancy reaction characterise CH soils ☐
b) CL soils show a medium Dilatancy reaction ☐
c) The Toughness of a soil thread at Plastic Limit represents it's capacity to hold water within the soil ☐

18. Factors of Safety with respect to cohesion and friction are expressed as $F_c = c/c_d$ and $F_\varphi = \tan\varphi / \tan\varphi_d$.

a) $\phi > \phi_d$ ☐
b) ϕ_d is established through laboratory or in-situ tests ☐
c) The above two equations are used to assess stability of an infinite slope ☐

Question 4: Figure Q4



PART B:

Answer four questions. All questions carry equal marks. You are advised to spend approximately 28 minutes per question, for Part B. (16x4 = 64 points)

1. Soil matrix is made of three distinct phases.
   a) Describe these three distinct phases (2 points)
   b) Define the two parameters void ratio and porosity using parameters that quantifies the three phases (2 points)
   c) Using definitions stated in 1(b), derive the relationship between void ratio and porosity. (4 points)
   d) Given $G_s = 2.65$, e = 0.65, w = 18% compute:
      i) Porosity (2 points)
      ii) Degree of saturation (2 points)
      iii) Water content w% corresponding to 100% saturation (2 points)
      iv) Dry Density in kg/m^3 (2 points)

2. Figure Q2 shows an element of clay located at a depth 8m from the surface.
   a) State the Principle of Effective Stress. (2 points)
   b) Compute σ_{yy}, σ'_{yy} and u at depths 0m, -2m, -4m and -8m. (3 points)
   c) Assuming that $\sigma'_{xx} = 0.5\sigma'_{yy}$, compute the total horizontal stress and effective horizontal stress at depth -8m. (3 points)
   d) For the soil element described in 2(c) above:
      i) Sketch the Mohr's circles of stress corresponding to total and effective stresses. You may consider that shear stress τ_{xy} is negligible. (2 points)
      ii) State the principal values. (1 point)
      iii) Name the two axes. (2 points)
      iv) Compute the stresses (σ'_n, τ) acting on the same element in the direction which makes 30^0 from the horizontal plane. (3 points)

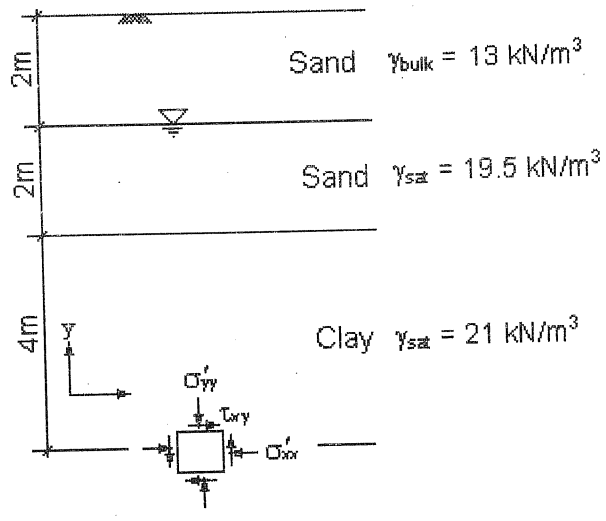


Figure Q2

3. When answering the sub-questions, you are expected to provide logical and sound reasons in support of your responses.
   a) You may have observed that a 3mm thread of a high plastic soil needs to be rolled and re-rolled sever times before it cracks when bent. Explain why this is so. (4 point
   b) During the Unconfined Compression test you may have observed that the failure plane makes an ang of 45^0 with the horizontal. Sketch the Mohr's Circle of Stress and the failure envelope; explain this observation. (4 point
   c) A uniform fine sand when poured on to a smooth flat surface tend to heap. When water is poured on a smooth flat surface it does not heap or lump, but trickles away. Explain why. (4 point
   d) Silts show a rapid dilatancy reaction compared to fine sands. Explain why. (4 point

4. Figure Q4 shows a data plot for a Normally Consolidated Kaolin Soil, which is subjected to a 1kg load.

a) Compute the normal stress in kPa, corresponding to a 1-kg load in the consolidometer. The average ring diameter = 50.2mm. Lever arm ratio 1:10 (2 points)

b) Plot a smooth curve joining the data points. (2 points)

c) Compute the settlement associated with Primary Consolidation (4 points)

d) Sketch the Settlement vs. Time plot typical to this set of data. (2 points)

e) Comment on the observed rate of settlement observed in Q4(d) above. (2 points)

f) Give a possible explanation for the observed behaviour described in Q4(d) above. (4 points)

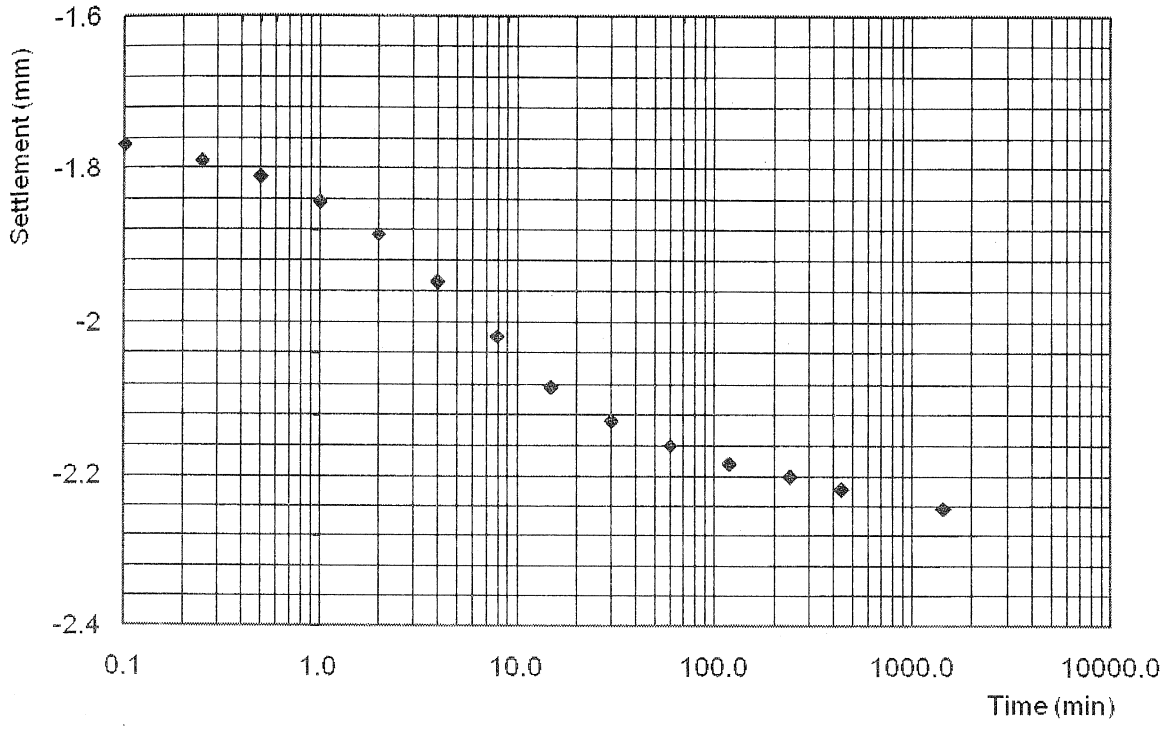


Figure Q4

5. Figure Q5 shows a soil mass retained by a sheet pile wall. The soil mass is also subjected to a surcharge load of 30 kPa acting along the length of the sheet pile wall.

a) Compute σ'_v and σ'_h for soil element A, which is at an Active State of Plastic Equilibrium. (4 points)

b) Sketch the Mohr's Circle of stress for the stress state described in 5(a) above. (2 points)

c) Show the Mohr-Coulomb failure envelope on the same plot; show principal values. (2 points)

d) Determine the normal stress and shear stress on the plane which is inclined at a 45^0 angle from the horizontal plane. (2 points)

e) Determine the Bending Moment and Shear Force per meter run, acting on the sheet pile wall, at point B, which is 4.5 meters from the top of the sheet pile. (6 points)

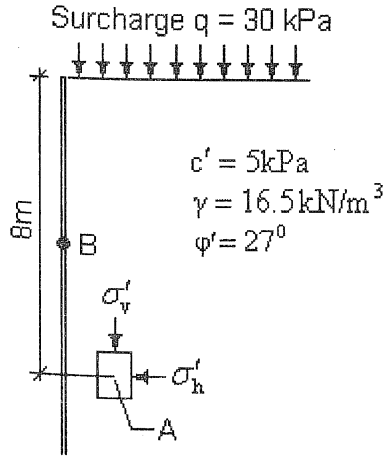


Figure Q5

6. The following assumptions were made by Taylor when deriving a theoretical solution to assess the stability of a finite slope

I. The slope is plane and is of finite length; the top and bottom surfaces are plane and horizontal.
II. No shearing stresses act on the plane of the section; therefore the problem is two-dimensional.
III. The soil is homogeneous, un-fissured and isotropic to a depth well below the critical slip surface.
IV. No seepage forces are present within the soil.
V. No water table exists within the soil under stress.
VI. The surface of slip is a circular arc.
VII. No tension cracks are present in the soil.
VIII. The c_d and ϕ_d developed by the soil for equilibrium are the same throughout the arc at any given instant.
IX. At failure, the shear strains at all points of the critical surface must be large enough to mobilise all available shear strength.

a) Draw a sketch that demonstrates Assumption No. I, given above. (3 points)

b) Draw a sketch that demonstrates Assumption No. II, given above. (3 points)

c) Assumption No. VII states that no tension cracks are considered in this analysis. Explain the influence that a tension crack may have when Taylor's stability analysis is used to assess stability. (3 points)

d) Compare parameters c and c_d, and ϕ and ϕ_d. (3 points)

e) Figure Q6(e) represents the typical stress-strain behaviour observed for a soil. Explain Assumption No. IX based on observed stress-strain behaviour of soils. (4 points)

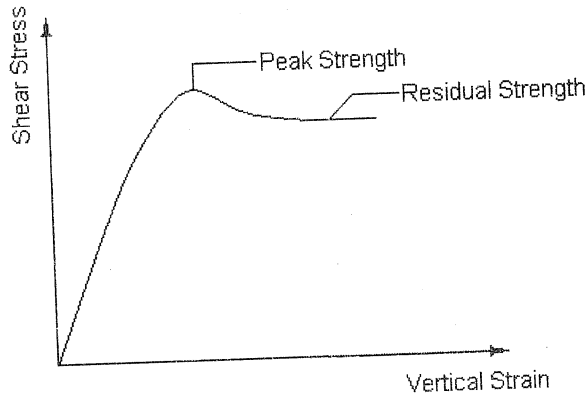


Figure Q6(e)

7.

a) Lateritic soils are produced during in-situ weathering of parent rock. `Kabook' is a common lateritic formation in the wet-zone of Sri Lanka.
i) Sketch the cross-section of a newly exposed roadside cut; use different shades to identify various strata. (3 points)
ii) Describe the characteristics of engineering significance for strata identified in Q7(a)(i) above. (4 points)

b) During geotechnical investigations, bore-holes extend to a few meters into bedrock.
i) List two instances where bore-holes are extended to a few meters in to bedrock (2 points)
ii) Discuss how rock quality is assessed (4 points)

c) Explain how rock core samples are obtained during geotechnical investigations (3 points)