THE OPEN UNIVERSITY OF SRI LANKA
DIPLOMA IN TECHNOLOGY (CIVIL) – LEVEL 04
Final Examination 2005/2006

CEX4230 – SOIL MECHANICS AND INTRODUCTION TO ROCK MECHANICS
CEU2202 – SOIL MECHANICS

Time allowed: Three Hours.

Date: Friday, 17th March, 2006 Time: 0900-1200

PART A:
Answer all questions. **Mark the correct response by colouring the appropriate square (refer sheet attached).** Attach this to your answer script. All questions carry equal marks. You are advised to spend around One (1) hour for Part A.

1. The sand cone apparatus is filled with dry uniform sand up to 5 litre mark; corresponding mass of sand is determined to be 7.62 kg. The specific gravity of sand is 2.65. The dry density and void ratio of the sand in the cone are:
   a) 1450 kg/m^3 and 0.74
   b) 1524 kg/m^3 and 1.4
   c) 1450 kg/m^3 and 1.4
   d) 1524 kg/m^3 and 0.74
   e) None of the above

2. Which of the following statements are true?
   i. The void ratio changes when a densely packed dry soil is saturated.
   ii. Porosity is always higher than void ratio.
   iii. In a saturated soil void ratio is directly proportional to water content.
   iv. Density and specific gravity has the same units.

   a) ii
   b) iii
   c) i and ii
   d) ii and iii
   e) i, ii and iii

3. Which of the following statements are true?
   i. Atterberg limit tests are performed on the fraction passing 0.425mm sieve.
   ii. Atterberg limit tests are performed on soils with fine sand, silt and clay sizes.
   iii. Soils with per cent fines > 12 are classified based on Liquid Limit and Plastic Limit tests, only.
   iv. The fine fraction is determined based on 0.425mm sieve.

   a) i and iii
   b) i, ii, and iii
   c) i, ii, iii and iv
   d) ii, iii and iv
   e) None of the above.

4. Which of the following statements are true?
   i. The hydrometer measures mass of soil particles in suspension at a particular time.
   ii. A rise in ambient temperature slows particle settlement.
   iii. Time taken for particle settlement is dependent of particle size.
   iv. Hydrometer floats more with time.
   v. A high-plasticity clay does not require adding a dispersion agent.

   a) i
   b) i and ii
   c) i and iii
   d) ii, iii, iv
   e) iii

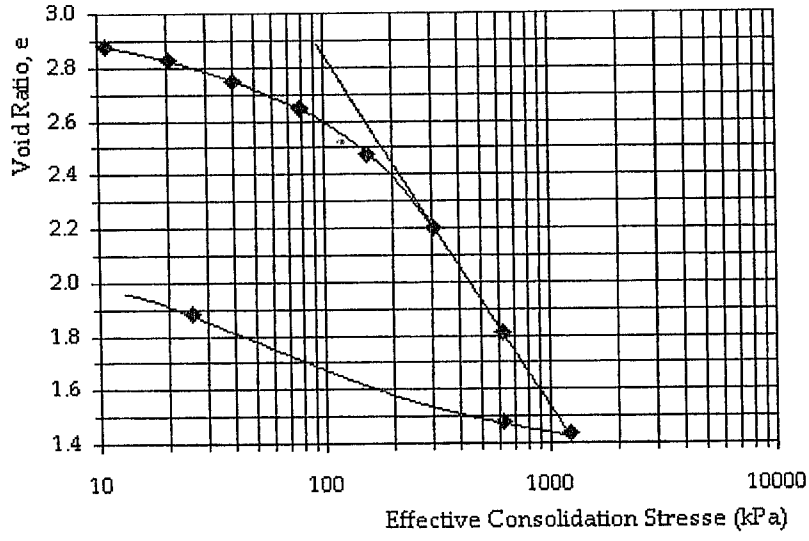
5. Which of the following statements are true?
   i. A non-plastic soil is used to form a thread, it can barely be rolled and the lump cannot be formed when drier than the Plastic Limit.
   ii. High plasticity soils show a low dry strength.
   iii. Silty soils show a rapid reaction to Dilatancy Test compared with clayey soils.
   iv. The above tests form visual classification test procedures for fine-grained soils.
   v. Toughness of plastic thread is the measure of `difficulty' in rolling the soil thread once it reaches the Plastic Limit, before it starts to crumble.

   a) i
   b) i, ii, iii
   c) iii, iv, v
   d) Non of the above
   e) All of the above

6. Which of the following statements are true?
   i. Zero air void curve relates ρ_d to w when S = 1.
   ii. Zero air void curve signifies that ρ_d is proportional to w
   iii. Zero air void curve can intersect the Proctor Compaction Curve at high water content.
   iv. Zero air void curve cannot intersect the Proctor Compaction Curve at high water content.

   a) i, ii
   b) i, ii, iii
   c) ii, iii
   d) ii, iv
   e) i, iv

Questions 7 – 10: Figure below shows a plot of $e - \log \sigma'_v$ obtained during a One-dimensional Consolidation Test. The sample had an initial height, H_0 = 20mm; e_0 = 2.93; total settlement, ΔH = 2.805mm.



7. The re-compression index is:
   a) 0.0003
   b) 0.085
   c) 0.21
   d) 0.45
   e) None of the above

8. The final void ratio is:
   a) 0.854
   b) 1.594
   c) 1.854
   d) 2.379
   e) None of the above

9. Which of the following statements is true?

   The dial gauge reading taken after 24 hours includes:
   a) Initial compression only.
   b) Primary consolidation only.
   c) Initial compression, primary consolidation and a small segment of secondary compression.
   d) Secondary compression only.
   e) Initial compression and primary consolidation only.

10. Which of the following statements are true?
   i. For a Normally Consolidated (NC) Clay, the ratio $\Delta e/\Delta\sigma'_v$ decreases with increasing effective vertical consolidation stress.
   ii. For a NC Clay, the ratio $\Delta e/\Delta\sigma'_v$ increases with increasing effective vertical consolidation stress.
   iii. For a NC Clay, the ratio $\Delta e/\Delta\sigma'_v$ does not change when effective vertical consolidation stress increases.
   iv. The information given in the above graph is sufficient to compute the Over Consolidation Ratio.

   a) i and iv
   b) ii and iv
   c) iii and iv
   d) i
   e) ii

11. Which of the following statements are true?
   i. Unconfined Compression Test is usually performed on a saturated soil sample.
   ii. UC test is a rapid test performed on low permeability soils.
   iii. UC test is a rapid test performed on high permeability soils.
   iv. c_u underestimates the true value when the test sample has lost its moisture prior to testing.
   v. c_u overestimates the true value when the test sample has lost its moisture prior to testing.

   a) i and iii
   b) ii and iii
   c) i, ii and v
   d) i and iv
   e) None of the above.

12. Which of the following statements are true?

   Coefficient of Permeability (Hydraulic Conductivity) of a soil:
   i. Is directly proportional to its void ratio.
   ii. Is measured in cm/s.
   iii. Increases with temperature.
   iv. Decreases with temperature.

   a) i, ii, iii
   b) i, ii, iv
   c) ii, iii
   d) All of the above
   e) None of the above

13. A constant head permeability test was carried out on a cylindrical sample of sand; 72mm diameter and 170mm high. 185 cm^3 of water was collected in 2.5 minutes under a head of 15cm. The hydraulic conductivity is computed as:
    a) 0.034 cm/s
    b) 0.038 cm/s
    c) 0.004 cm/s
    d) 0.01 cm/s
    e) None of the above.

Questions 14 – 15: Mohr-Coulomb failure criterion is expressed as $\tau_f = \sigma_n \tan\phi + c$

14. Which of the following statements are true?
    i. The expression $\tau_f = \sigma_n \tan\phi + c$ computes the shear stress on any plane taken about a point.
    ii. The variable terms are τ_f, ϕ and c.
    iii. ϕ is the angle of internal friction.
    a) i and iii
    b) i, ii, and iii
    c) i
    d) ii
    e) iii

15. Which of the following statements are true?
    i. The angle of internal friction ϕ is related to angle of repose.
    ii. The cohesion is measured in terms of kN/m^3.
    iii. The Unconfined Compression Test determines c under `undrained' condition.
    iv. For granular medium dense sands, ϕ ranges between 32^0 to 38^0.
    a) i and ii
    b) i and iii
    c) ii and iii
    d) i, iii and iv
    e) All of the above.

16. Which of the following statements are true?
    i. The Active Rankine State of plastic equilibrium refers to the condition where the soil mass is about to push the retaining wall outwards.
    ii. During active state the horizontal stress is around three times the vertical stress.
    iii. During active state a saturated soil will apply a water pressure equal to 1/3rd the hydro-static stress on the wall.
    iv. The apparent cohesion of the soil reduces the pressure on the wall.
    a) i and ii
    b) i and iii
    c) i and iv
    d) i, ii and iv
    e) ii and iv

17. Which of the following statements are true?
    i. The Standard Penetration Test (SPT) determines the Liquid Limit of fine grained soil.
    ii. SPT – N is the number of blows to penetrate a soil stratum by 300mm.
    iii. SPT is used to compute the allowable bearing capacity of a soil.
    iv. SPT gives undisturbed samples that can be used to determine the Compression Index.
    a) All of the above
    b) ii and iii
    c) ii, iii and iv
    d) iii and iv
    e) i, iii and iv

18. Which of the following statements are true?

i. Hydraulic Gradient represents an energy loss over a distance.
ii. Hydraulic Gradient is measured in terms of meters.
iii. For safe seepage to occur the Hydraulic Gradient should be maintained below 1.0
iv. Hydraulic Gradient changes significantly with temperature.

a) i and iii
b) i, ii, iii
c) All of the above
d) i, ii and iv
e) i, iii, iv

PART B

Answer four questions. All questions carry equal marks.

1. Figure Q1 shows a Constant Head Permeability Test apparatus.

a) Determine the Elevation Head, Pressure Head and Total Head at points A, C, B and D. (6 points)

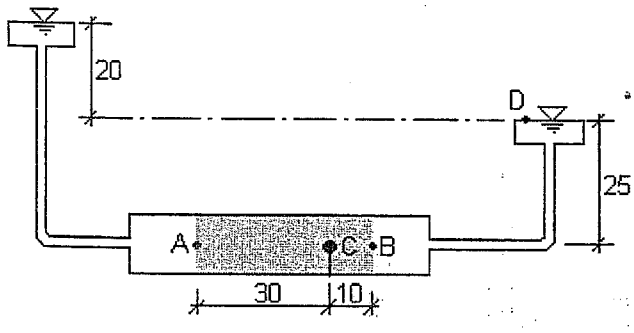
Point	Elevation Head	Pressure Head	Total Head
A			
C			
B			
D			

b) Explain why we neglect the Velocity Head. (1 points)

c) Determine the Hydraulic Gradient across the soil sample. (1 points)

d) The water flow across the sample is measured to be 50 litres per minute. The average diameter of the soil sample is determined to be 50mm. Measurements were made at room temperature of 30^0C. Determine k_{20}. η_{20} = 1.002 mPa.s; η_{30} = 0.798 mPa.s. (4 points)

e) Hazen (1911) related Hydraulic Conductivity to its effective grain size expressed as $k_{20} = CD_{10}^2$ cm/s. This is for clean sand with 5% passing 0.063mm sieve, for which D_{10} between 0.1 to 3.0mm; C takes values between 0.4 and 1.2. Estimate the hydraulic conductivity of a uniformly graded medium sand. State the assumptions made in your computation. (4 points)



All dimensions are in cm.

Figure Q1

2. You are to investigate sub-surface conditions to build a two story building at the location of Block 1 of Open University's Colombo Regional Centre. You may recall that this is the building where you had performed your Soil Mechanics laboratory practical class. The fill placed around 30 years ago is underlain by a soft peat, which may undergo settlement if its stresses are further increased. Previous investigations show that the bedrock is at a depth 10 – 12m from ground surface.

a) Discuss why it is important to perform a fresh investigation at the said location. (2 points)
b) Sketch the positions where you would locate your borings, assuming that no sensitive equipment will be installed in the proposed building. (2 points)
c) State the geotechnical concerns that you may wish to address during this investigation. (5 points)

d) State the recommended depth of investigation giving your reasons. (2 points)

e) List all information you may wish to collect during the investigation. (5 points)

3. A combined Sieve-Hydrometer Test performed on a soil sample is as follows:

Size (mm)	Per cent finer by weight
6.3	100
2	98
0.6	92
0.212	78
0.063	52
0.035	35
0.02	23
0.01	11
0.008	8

The Atterberg Consistency Limits were found to be w_L = 65 and w_P =35.

a) Determine the group symbol based on Unified Soil Classification System (5 points)

b) State its Soil Description. (3 points)

c) Explain how you would prepare a soil sample to test for Atterberg Consistency Limits (4 points)

d) State how this sample would respond to the Dilatency Test. Give reason(s) for your conclusion. (4 points)

4. Figure Q4 shows the settlement variation with time obtained for a load of 8kg, during a One Dimensional Consolidation Test. The initial height of the test specimen is determined to be 20mm.

a) Explain why readings are taken in a particular sequence, i.e. at minutes 0.25, 0.5, 1, 2, 4, 8, 15, 30; and hours 1, 2, 4, 8, 16 and 24. (2 points)

b) Determine the point where Primary Consolidation begins. (3 points)

c) The settlement reading for 4kg – load taken after 24 hours is -1.105. Determine initial compression. Explain what causes initial compression. (3 points)

d) Determine the coefficient of consolidation. State your answer in mm^2/s. (5 points)

e) Define the terms in the equation $k = c_v m_v \gamma_w$. (3 points)

f) Sketch to show how c_v should vary with vertical effective stress. Give reasons for your theoretical explanation. (3 points)

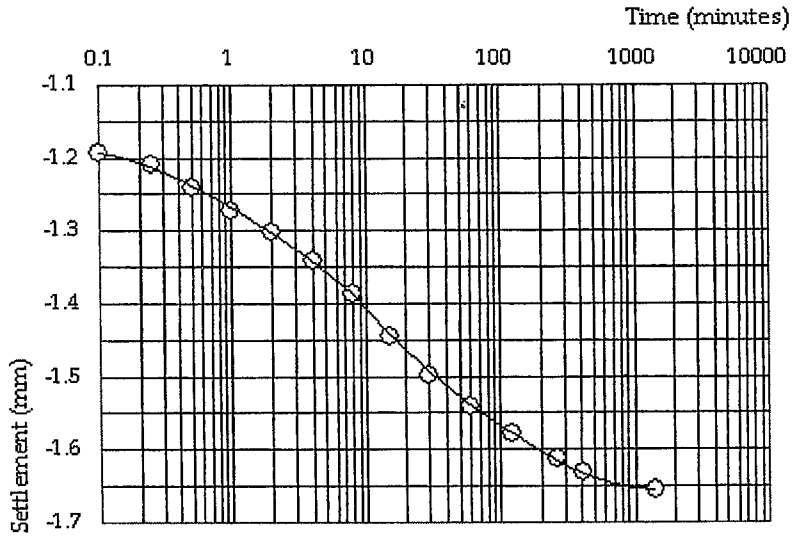


Figure Q4

5. Figure Q5(a) shows a plot of $e - \log\sigma'_v$ obtained during a One-dimensional Consolidation Test. The sample had an initial height, H_0 = 20mm; average diameter = 50mm; e_0 = 2.93; total settlement, ΔH = 2.805mm.

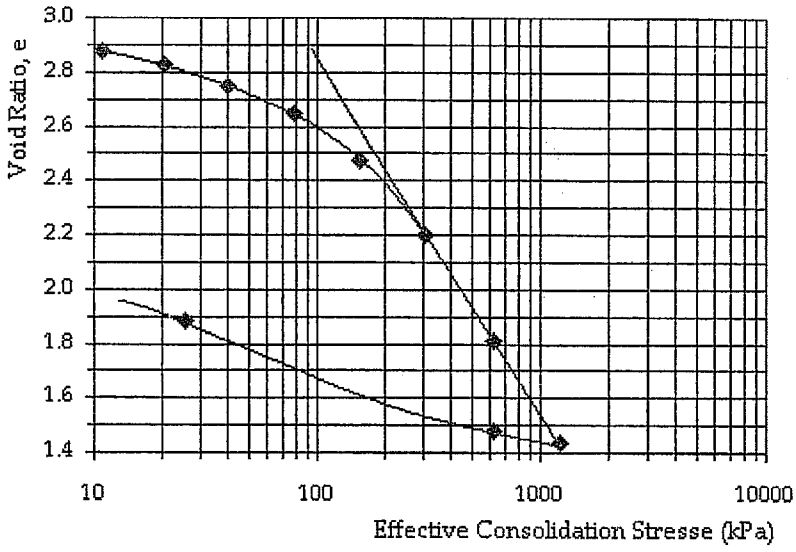


Figure Q5(a)

a) Determine the Compression Index for the above plot. (2 points)
b) Comment on its compressibility (2 points)
c) Determine the Pre-consolidation pressure. (3 points)

Figure Q5(b) shows the 16m thick clay layer subject to a 1.5m surcharge fill. The sample location corresponding to the above test results is at a depth of 8m (i.e. Sample A)

i) Determine the effective overburden stress. (3 points)
ii) State whether the soil is Normally Consolidated or Over Consolidated. (2 points)

d) Compute the expected total settlement of the clay layer. (3 points)

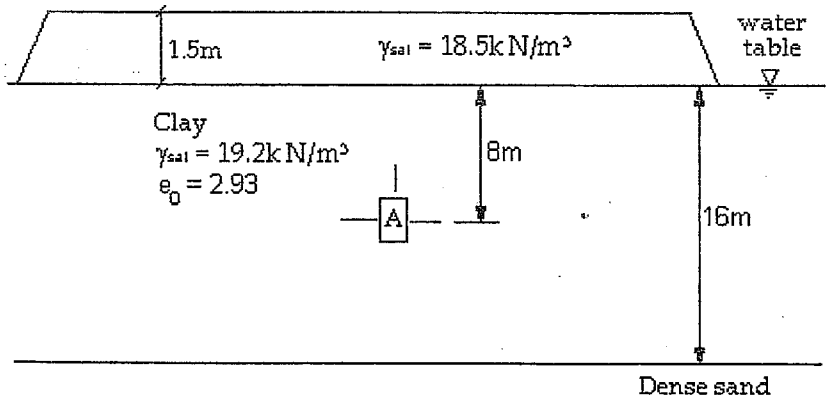


Figure Q5(b)

6. Figure Q6 shows a square footing resting on a medium dense sand, supporting a 200kN structural load.

a) Determine the Ultimate Bearing Capacity at the founding level (3 points)
b) Compute the factor of safety available to carry the structural load. (2 points)
c) Determine the allowable settlement based on a limiting settlement of 25mm. (2 points)
d) Determine the footing dimensions that satisfy both criteria, at the same depth. (3 points)
e) Discuss the types of structural damage associated with uniform settlement and differential settlement. (3 points)
f) Explain the advantages of placing a footing at a depth, than placing it at ground surface. (2 points)
g) State whether SPT-N when corrected to overburden increases bearing capacity. (1 point)

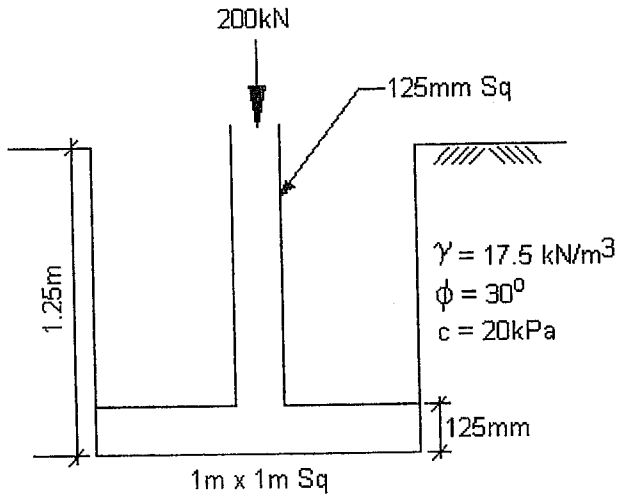
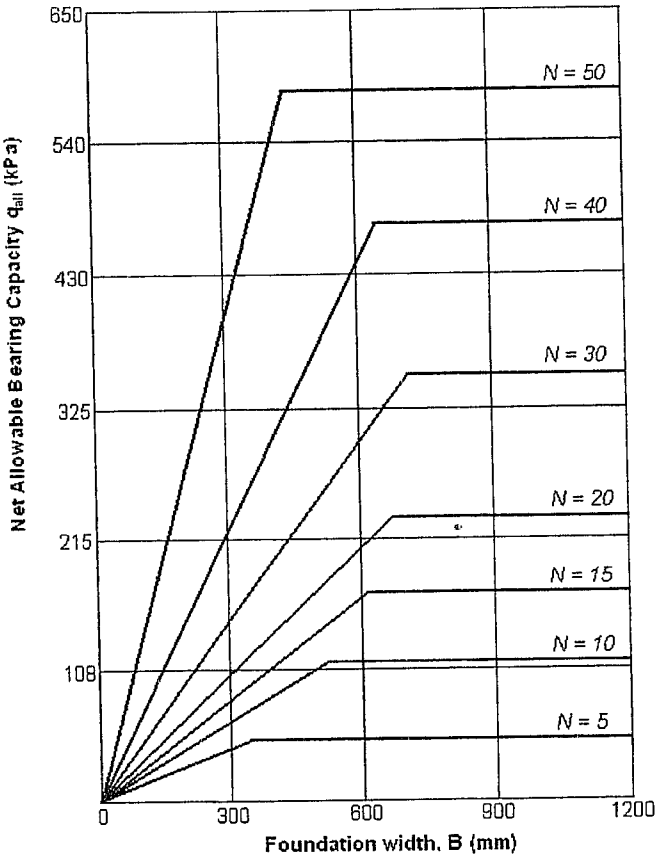
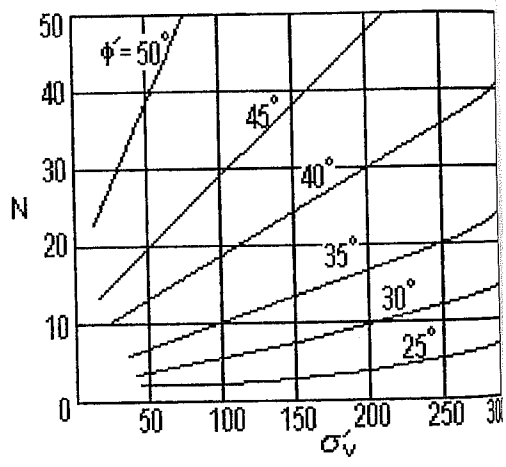
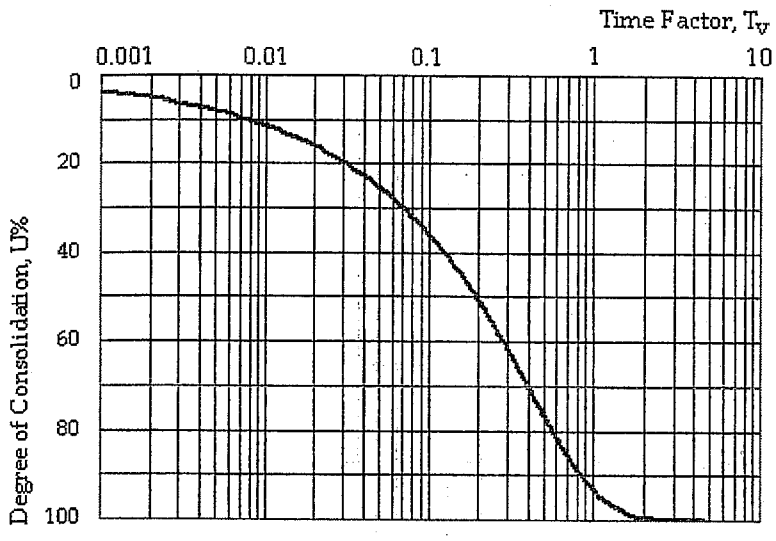
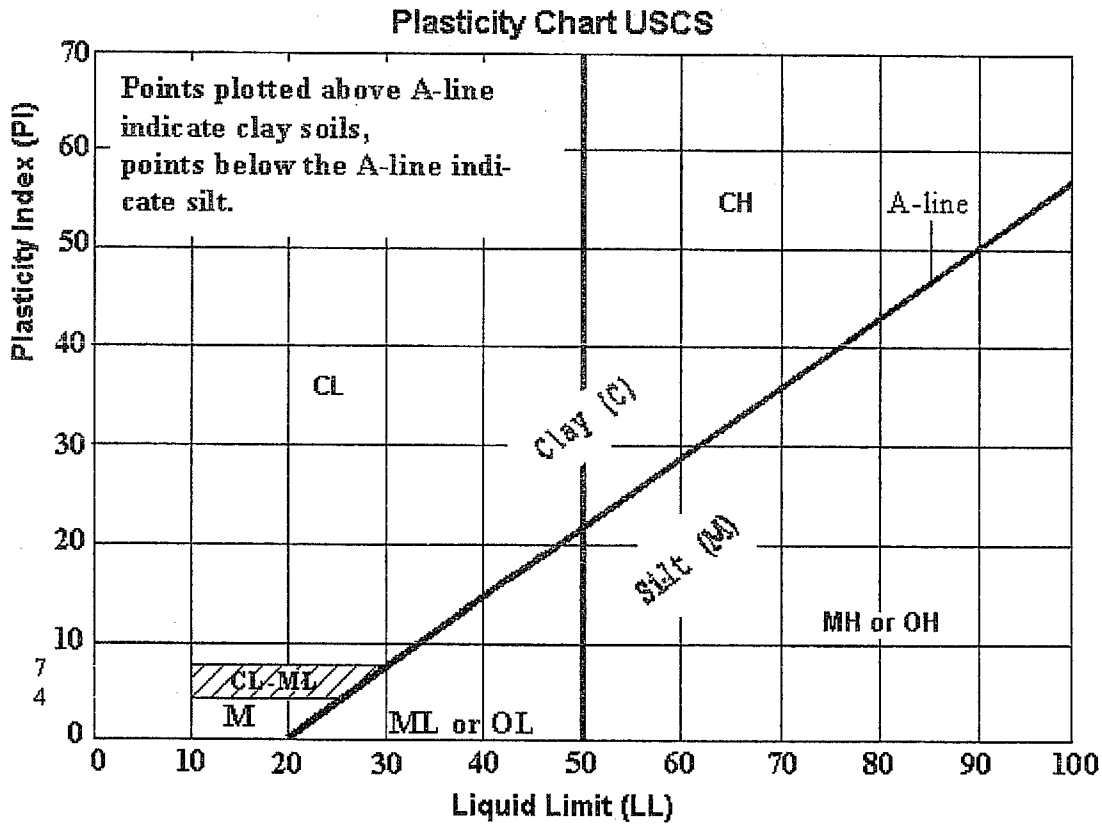

200kN
125mm Sq
1.25m
γ = 17.5 kN/m3
ϕ = 30°
c = 20kPa
125mm
1m x 1m Sq

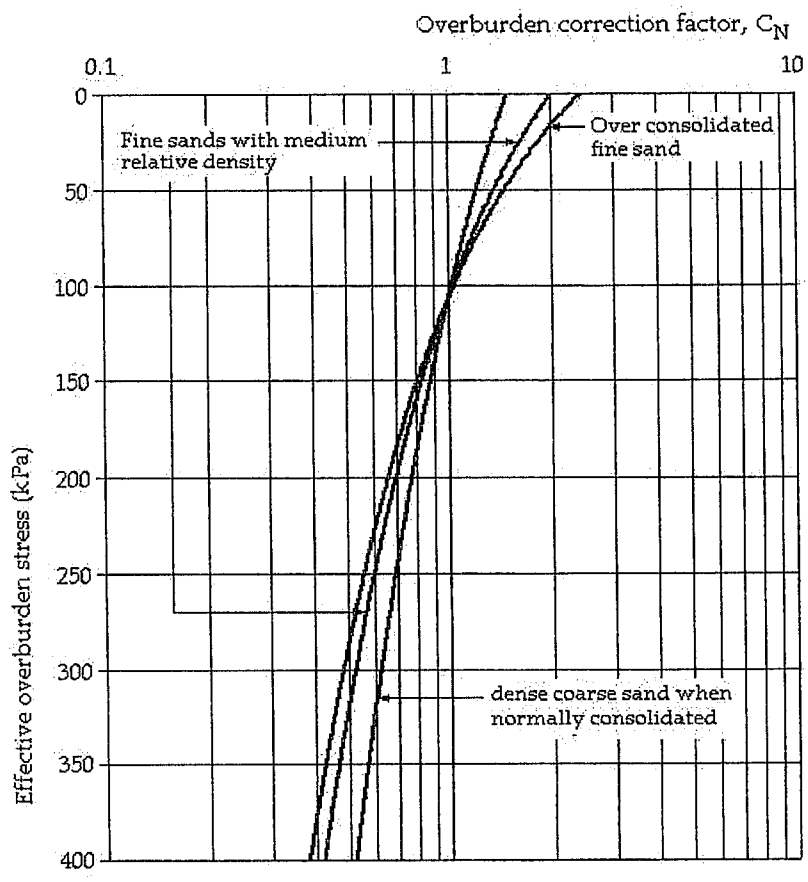
Figure Q6

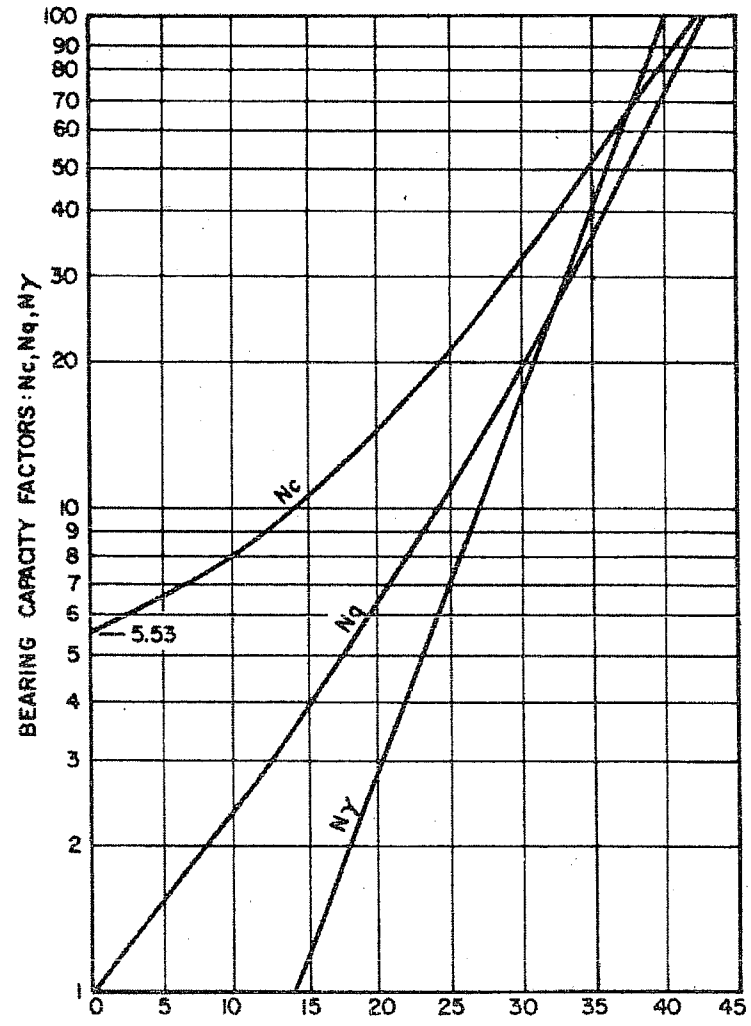

Net Allowable Bearing Capacity q_{all} (kPa)
650
540
430
325
215
108
N = 50
N = 40
N = 30
N = 20
N = 15
N = 10
N = 5
0
300
600
900
1200
Foundation width, B (mm)

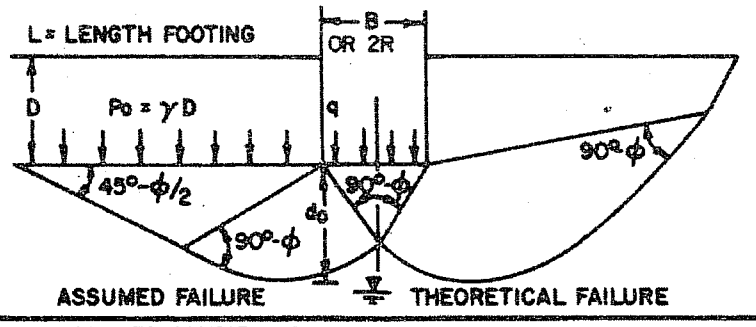

N
50
40
30
20
10
0
ϕ' = 50°
45°
40°
35°
30°
25°
50
100
150
200
250
σ'_v


Time Factor, T_v
0.001
0.01
0.1
1
10
0
20
40
60
80
100
Degree of Consolidation, U%


Plasticity Chart USCS
Points plotted above A-line indicate clay soils, points below the A-line indicate silt.
CH
A-line
CL
Clay (C)
Silt (M)
MH or OH
CL-ML
M
ML or OL
Plasticity Index (PI)
Liquid Limit (LL)
70
60
50
40
30
20
10
7
4
0
0
10
20
30
40
50
60
70
80
90
100


Overburden correction factor, C_N
0.1
1
10
0
50
100
150
200
250
300
350
400
Effective overburden stress (kPa)
Fine sands with medium relative density
Over consolidated fine sand
dense coarse sand when normally consolidated





ULTIMATE BEARING CAPACITY = q_{ult}

CONTINUOUS FOOTING; GENERAL CASE

$q_{ult} = q' + q''$

q' = PORTION OF BEARING CAPACITY ASSUMING WEIGHTLESS FOUNDATION SOIL

q'' = PORTION OF BEARING CAPACITY FROM WEIGHT OF FOUNDATION SOILS

$q' = cN_c + \gamma D N_q$

$q'' = \gamma \frac{B}{2} N\gamma$

$q_{ult} = cN_c + \gamma D N_q + \frac{\gamma B}{2} N\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c \left(1 + .3 \frac{B}{L}\right) + \gamma D N_q + 0.4 \gamma B N_\gamma$

CIRCULAR FOOTING: R = B/2

$q_{ult} = 1.3 cN_c + \gamma D N_q + 0.6 \gamma R N_\gamma$

FOR COHESIONLESS FOUNDATION SOILS (c = 0)

CONTINUOUS FOOTING:

$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.4 \gamma B N_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.6 \gamma R N_\gamma$

FOR COHESIVE FOUNDATION SOILS ($\phi = 0$)

CONTINUOUS FOOTING:

$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = cN_c \left(1 + .3 \frac{B}{L}\right) + \gamma D$

CIRCULAR FOOTING:

$q_{ult} = 1.3 cN_c + \gamma D$

ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_o > B$.
3. WATER LEVEL LOWER THAN d_o BELOW BASE OF FOOTING.
4. VERTICAL LOAD CONCENTRIC.
5. FRACTION AND ADHESION ON VERTICAL SIDES OF FOOTING ARE NEGLECTED.
6. FOUNDATION SOIL WITH PROPERTIES c, ϕ, γ

FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads

Modified to reflect BS Classification

Coarse-Grained Soils more than 50% retained on No. 200 sieve (0.063mm)	**Gravels** more than 50% of coarse fraction retained on No 10 sieve (size = 2mm)	**Clean Gravels** less than 5% fines	$C_U \geq 4$ and $1 \leq C_C \leq 3$	GW
			$C_U < 4$ and/or $1 < C_C < 3$	GP
		Between 5% and 12% fines	→	(GW-GM)
		Gravels with Fines more than 12% fines	below *A* line and hatched zone on plasticity chart	GM
			limits plot in hatched zone on plasticity chart	GM-GC
			above *A* line and hatched zone on plasticity chart	GC
	Sands 50% or more of coarse fraction passes No. 10 sieve (size = 2mm)	**Clean Sands** less than 5% fines	$C_U \geq 4$ and $1 \leq C_C \leq 3$	SW
			$C_U < 4$ and/or $1 < C_C < 3$	SP
		Between 5% and 12% fines	→	(SW-SM)
		Sands with Fines more than 12% fines	below *A* line and hatched zone on plasticity chart	SM
			limits plot in hatched zone on plasticity chart	SM-SC
			above *A* line and hatched zone on plasticity chart	SC
Fine-Grained Soils 50% or more passes the No. 200 sieve (0.063mm)	**Silt and Clays** liquid limit less than 50	**Inorganic** (examine color and odor)	PI > 7 and plots on or above *A* line	CL
			PI < 4 or plots below *A* line	ML
		Organic (examine color and odor)	$\frac{(LL)_{\text{oven dried}}}{(LL)_{\text{not dried}}} < 0.75$	OL
	liquid limit 50 or more	**Inorganic** (examine color and odor)	PI plots on or above *A* line	CH
			PI plots below *A* line	MH
		Organic (examine color and odor)	$\frac{(LL)_{\text{oven dried}}}{(LL)_{\text{not dried}}} < 0.75$	OH

GRADATION CURVE AND ATTERBERG LIMITS ON FRACTION PASSING A NO. 40 SEIVE (0.425mm)

(PT - heavy odor, primarily organic)

✂ ---------- Attach this sheet to your answer script

Index No. _____

PART A

	(a)	(b)	(c)	(d)	(e)		(a)	(b)	(c)	(d)	(e)
Q1	☐	☐	☐	☐	☐	Q10	☐	☐	☐	☐	☐
Q2	☐	☐	☐	☐	☐	Q11	☐	☐	☐	☐	☐
Q3	☐	☐	☐	☐	☐	Q12	☐	☐	☐	☐	☐
Q4	☐	☐	☐	☐	☐	Q13	☐	☐	☐	☐	☐
Q5	☐	☐	☐	☐	☐	Q14	☐	☐	☐	☐	☐
Q6	☐	☐	☐	☐	☐	Q15	☐	☐	☐	☐	☐
Q7	☐	☐	☐	☐	☐	Q16	☐	☐	☐	☐	☐
Q8	☐	☐	☐	☐	☐	Q17	☐	☐	☐	☐	☐
Q9	☐	☐	☐	☐	☐	Q18	☐	☐	☐	☐	☐