P2

THE OPEN UNIVERSITY OF SRI LANKA
DIPLOMA IN TECHNOLOGY (CIVIL) – LEVEL 04
Final Examination 2006/2007

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

16

Time allowed: Three Hours.

Date: Tuesday, 20th March, 2007 | 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. (40 points)

You are expected to provide clear and concise answers. State your answer within the space provided.

1. Engineering soils are made of three distinct phases. They are a) ____________ b) ____________ c) ________________ phases.

   Soil Mechanics is the Engineering discipline that deals with properties, behaviour and performance of soils. List two engineering properties displayed by clay soils.

   d) ____

   e) ____

2. When an element of soil becomes saturated, its Degree of Saturation changes from a value less than 1.0 to 1.0. State whether the following statements are true.
   a) During this change soil fabric remains unchanged. True ☐
   b) The water content increases. True ☐
   c) The void ratio increases. True ☐
   d) The dry density increases. True ☐

3. A soil element that is located at a depth of 10m. The overburden soil has a Saturated Unit Weight of $20kN/m^3$ and a Bulk Unit Weight of $17.5kN/m^3$. Water table is 3m below ground surface. Determine the average vertical effective stress.

4. Relative Density D_r is defined as $D_r = \left(\frac{e_{max} - e}{e_{max} - e_{min}}\right) x100\%$. Explain how you would determine e_{min} for a given sandy soil sample.

____

____

____

____

5. Hydrometer test determines particle size and the size distribution of a fine-grained soil. The following equation expresses the particle diameter in millimetres: $D = 0.0055341\sqrt{\frac{\eta H}{(\rho_s - \rho_f)t}}$. Define the terms:

a) η ____________________

b) H ____________________

c) ρ_s ____________________

d) ρ_f ____________________

6. Figure SQ6 show the particle size distribution of soils A and B. Assign a suitable group symbol for each soil.

a) Soil A: ________ b) Soil B: ________

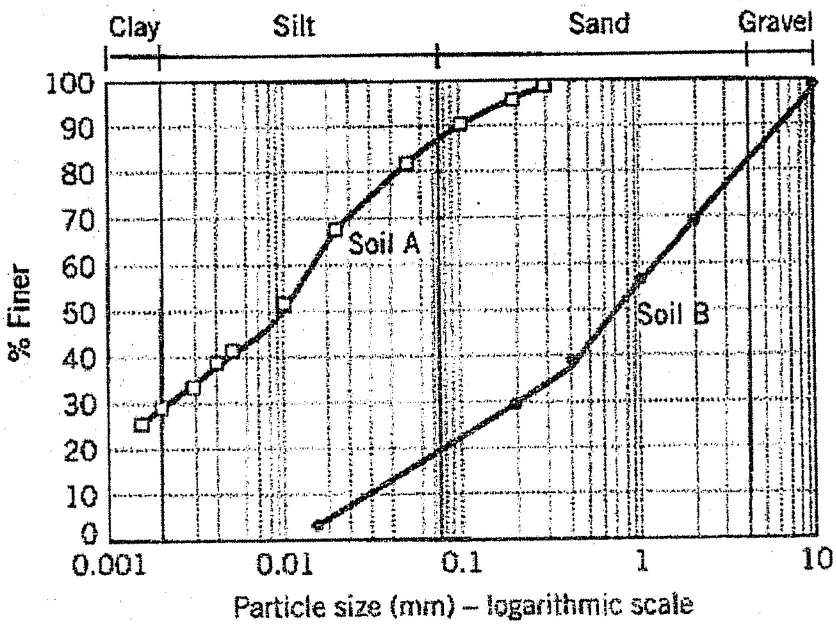


Figure SQ6

7. Describe the engineering properties displayed by following soil types.

a) SW ____

b) MH ____

8. Casagrande's Plasticity Chart identifies a soil type as CL-ML. Explain how you would identify a CL-ML material based on the usual classification tests.

9. Explain why total head drops between the inlet and outlet points when a fluid flows through a porous media.

10. A wet sand sample has a volume of 4.6×10^{-4} m^3 and weighs 7.8N. The oven dried weight is found to be 7.4N. Calculate void ratio and water content. $G_s = 2.72$

11. State whether the following statements are true.
    a) The zero air void curve represents the variation of dry density and water content when S=100%. True ☐
    b) To plot this curve, one needs to estimate the specific gravity of solids. True ☐
    c) Zero air void curve intersects the compaction curve at a higher water content. True ☐
    d) Zero air void curve is used to determine S at Optimum Moisture Content. True ☐

12. State whether the following statements are true.
    a) In a granular material, effective stress reflects forces acting at particle contact points. True ☐
    b) Presences of pore water pressures increase the effective stress. True ☐
    c) Pore water pressures are hydrostatic. True ☐
    d) When estimating the effective stress at a depth below water table, the Bulk Unit Weight is used. True ☐

13. State whether the following statements are true.
    a) Shear strength parameter C_u reflects soil strength, which is determined with respect to effective stress. True ☐
    b) The Consolidated Drained Triaxial loading test gives us shear strength parameters c′ and ϕ'. True ☐
    c) The Unconsolidated Undrained Test gives us $\phi_u = 0$. True ☐
    d) The Consolidated Undrained Triaxial loading test gives us c_u, c and ϕ. True ☐

14. State whether the following statements are true.
    a) During normal consolidation, the soil element is subjected to stresses which it has not experienced before, during its geologic history. True ☐
    b) An over-consolidated soil undergoes greater settlement than a normally consolidated soil. True ☐
    c) The coefficient of consolidation does not change with stress. True ☐
    d) During primary consolidation the settlement rate increases with time. True ☐

15. State whether the following statements are true.
    a) Raft foundations give reduced soil bearing pressures compared to pad-foundations, when subjected to the same structural loads. True ☐
    b) Foundations are placed below surface level in order to protect them. True ☐
    c) The presence of water table at founding level does not affect its Ultimate Bearing Capacity. True ☐
    d) Differential settlement is caused due to uneven settlement of footings. True ☐

16. State whether the following statements are true.
    a) During visual classification of coarse-grained soils, the sample is separated manually, in to fines, fine-sand, medium-sand, coarse-sand and gravel. True ☐
    b) The Plasticity Test represents consistency at it's Liquid Limit. True ☐
    c) High-plastic soils show a higher Toughness at its Plastic Limit. True ☐
    d) A rapid dilatency reaction indicates the presence of sand in the soil mix. True ☐

17. State whether the following statements are true.

a) The Coefficient of Passive Earth Pressure when expressed in terms of effective stress is $\tan^2(45 - \phi/2)$ True ☐

b) The Coefficient of Earth Pressure at rest is the ratio of total horizontal stress to total vertical stress. True ☐

c) During Active Rankine State of plastic equilibrium, the entire soil mass is believed to be in a plastic state. True ☐

d) Soil cohesion reduces active earth pressures. True ☐

18. State whether the following statements are true.

a) Slope instabilities take place along a weakened surface. True ☐

b) Rainfall triggers land slides since it adds weight to soil mass. True ☐

c) Tension cracks form in sandy soils. True ☐

d) $F_\phi = \left[\dfrac{\tan\phi}{\tan\phi_d}\right]$; ϕ_d refers to the soil angle of internal friction. True ☐

PART B

Answer four questions. All questions carry equal marks.

1. The relationship between Dry Density, ρ_d and Water Content, w is expressed as: $\rho_d = \dfrac{G_s\rho_w}{1+\dfrac{wG_s}{S}}$.

   a) <u>Draw</u> a diagram representing the three phases; indicate the gravimetric and volumetric parameters. (2 points)

   b) Using first principles <u>prove</u> this relationship. (6 points)

   c) Figure Q1 shows results of eight compaction curves compacted according to Standard Proctor Compaction Test, their grain fractions and plasticity data (Johnson and Sallberg, 1960). <u>State</u> four important conclusions you could make based on these results; also <u>explain</u> the observed behaviour. (8 points)

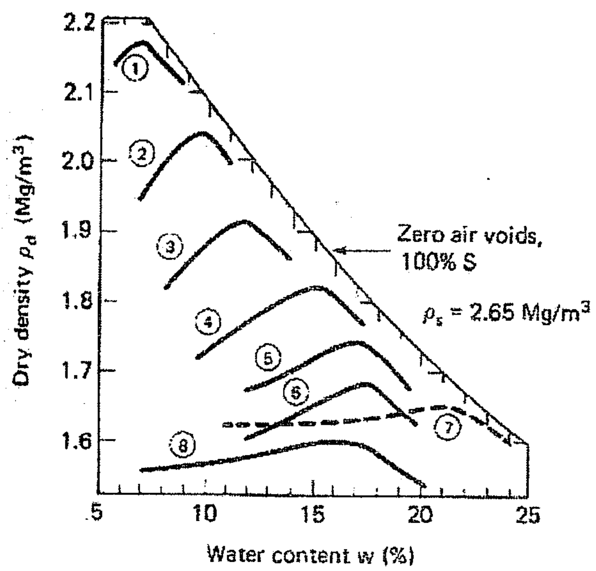


Figure Q1

Soil texture and plasticity data

No.	Description	Sand	Silt	Clay	LL	PI
1	Well-graded loamy sand	88	10	2	16	N.P.
2	Well-graded sandy loam	72	15	13	16	N.P.
3	Med-graded sandy loam	73	9	18	22	4
4	Lean sandy silty clay	32	33	35	28	9
5	Lean silty clay	5	64	31	36	15
6	Loessial silt	5	85	10	26	2
7	Heavy clay	6	22	72	67	40
8	Poorly graded sand	94	– 6 –		N.P.	–

2. Figure Q2 shows a Constant Head Permeability Test apparatus. The inlet side is subjected to an additional pressure of 10kPa.

   a) Considering that the datum passes through point B, <u>determine</u> the Elevation Head, Pressure Head and Total Head at points A and B. (5 points)

Point	Elevation Head	Pressure Head	Total Head
A			
B			

   b) <u>Determine</u> the Hydraulic Gradient across the soil sample. (1 points)

   c) <u>Determine</u> k_{20} for a measured flow rate of 7 litres per minute. The average diameter of the soil sample is 50mm. The flow rate is measured at 30^{0}C. η_{20} = 1.002 mPa.s; η_{30} = 0.798 mPa.s; $\rho_{30}/\rho_{20} \approx 1.0$. (4 points)

   d) The Intrinsic Permeability $\overline{K}$ of a soil is expressed as $k = \dfrac{\overline{K}\rho g}{\eta}$, where ρ, η are the density and viscosity of the fluid. k is its Coefficient of Permeability.

   i) <u>Determine</u> the units of $\overline{K}$. (4 points)

   ii) <u>Explain</u> the importance of $\overline{K}$ as a parameter. (2 points)

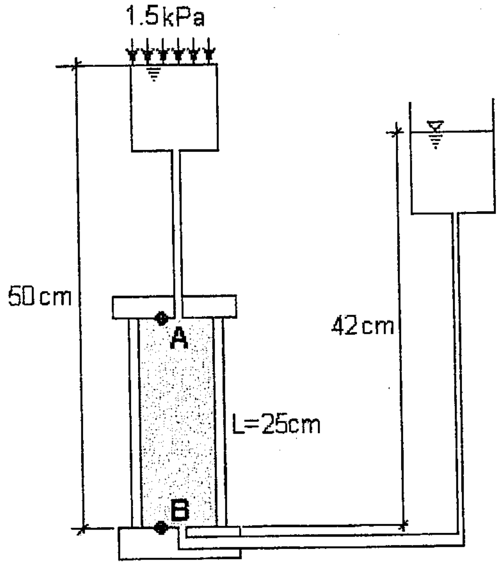


Figure Q2

3. Figure Q3 shows a typical e-log(p) curve obtained during the 1-D Consolidation Test. The laboratory curve is used to construct the `ideal' e-log(p) curve (OABC) that represents in-situ consolidation settlements.

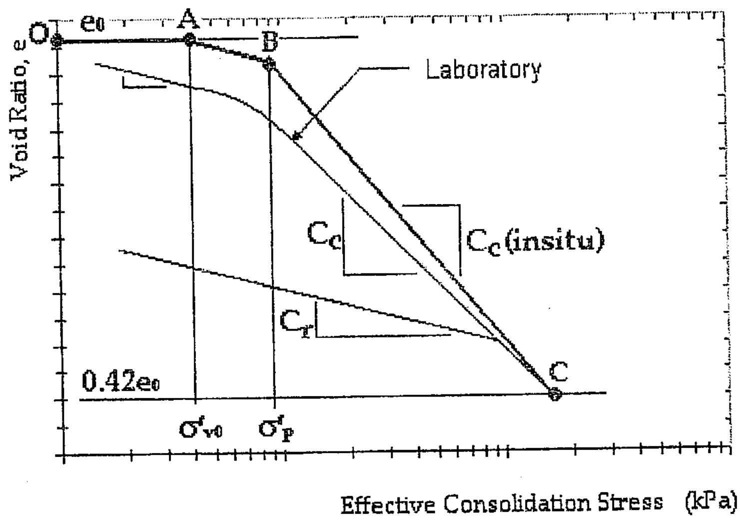


Figure Q3

a) Define the terms e_0, σ'_{v0} and σ'_p. (3 points)

b) Explain how each of these parameters are obtained. (6 points)

c) Explain the nature of settlement represented by line segment AB (4 points)

d) Explain how the line segment AB is determined. (3 points)

4. A pad footing 1m square is to be located at a depth D_f = 1m. The footing supports a 300mm square column; its height is 150mm. The soil parameters are γ = 17.2kN/m^3, ϕ = 26^0, and c = 28kN/m^2. The required bearing stress to carry the structural load is 68kPa.

a) Determine the factor of safety against ultimate bearing capacity failure condition. (6 points)

b) Determine q_{all} based on a settlement of 25mm. (6 points)

c) Determine the stress acting along the centre line, at a depth of 1m below the founding level. (4 points)

5.

a) Explain criteria that govern the natural slope angle of a granular soil. (3 points)

b) The factor of safety of a circular slip circle is expressed as $F_s = \dfrac{c + \sigma' \tan\phi}{c_d + \sigma' \tan\phi_d}$. Discuss it's validity. (5 points)

c) The slope shown in Figure Q5 needs to be checked for stability. AC represents a trial failure plane. For the wedge ABC. The soil properties are γ = 17.2kN/m^2, ϕ = 12^0, and c = 28kN/m^2. Determine the factor of safety against sliding. (8 points)

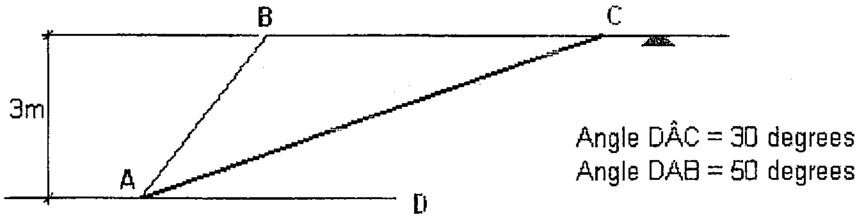


Figure Q5

6. Shear Strength of soils is expressed in terms of Mohr-Coulomb failure criterion.

a) State the equation that expresses Mohr-Coulomb failure criterion; define its terms. (3 points)

b) Give one example where the above equation is used. Explain how you ensure safety against shear failure. (3 points)

c) Field and laboratory strength tests are used to determine shear strength parameters. These parameters are used to establish Mohr-Coulomb failure criterion for a given soil, subject to given test conditions. Express the Mohr-Coulomb failure criterion as interpreted by:

i) Unconfined Compression Test. (2 points)

ii) Consolidated Drained Triaxial Loading Test. (2 points)

d) A Consolidated-Undrained triaxial loading test was performed on an undisturbed dense sand. The following values were observed.

Cell Pressure	= 200kPa
Principal stress difference at failure	= 300kPa
Pore Water Pressure at failure	= 100kPa.

Determine parameters c′, ϕ', c and ϕ. (6 points)

7.

a) Weathering is the process by which rock is disintegrated to form soils. Explain how chemical and physical weathering occur (4 points)

b) Discuss three rock failure modes commonly seen in engineering applications. (4 points)

c) Physical and mechanical properties of dry Gneissic rock is as follows:

Specific Gravity	2.7
Porosity	1%
Unconfined Compressive Strength (UCS)	50–200MPa
Modulus of Elasticity	45GPa
Tensile Strength	10MPa
Friction Angle ϕ	30^0.

Compare these properties with properties of engineering soils. (4 points)

d) Explain the Point Load Test (PLT); discuss how PLT results are related to rock strength (4 points)

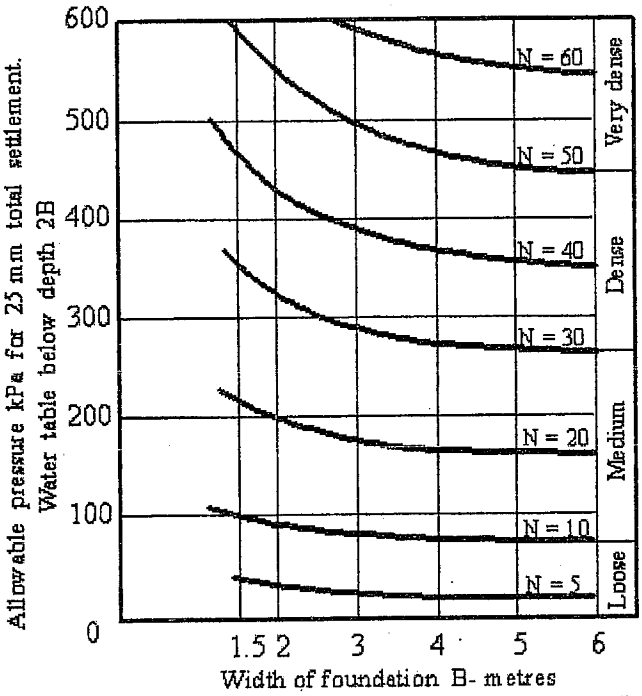
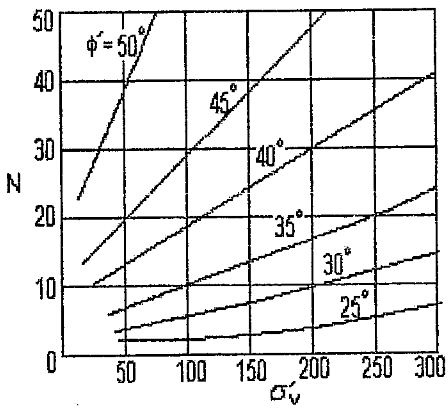
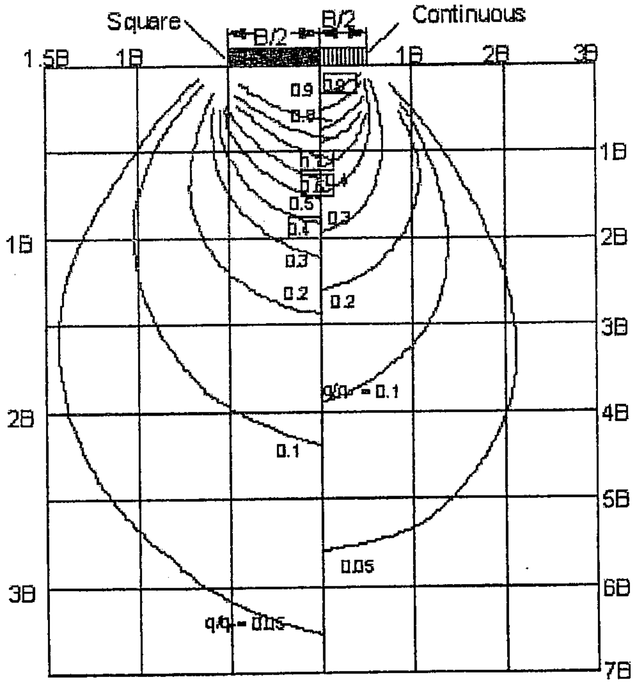
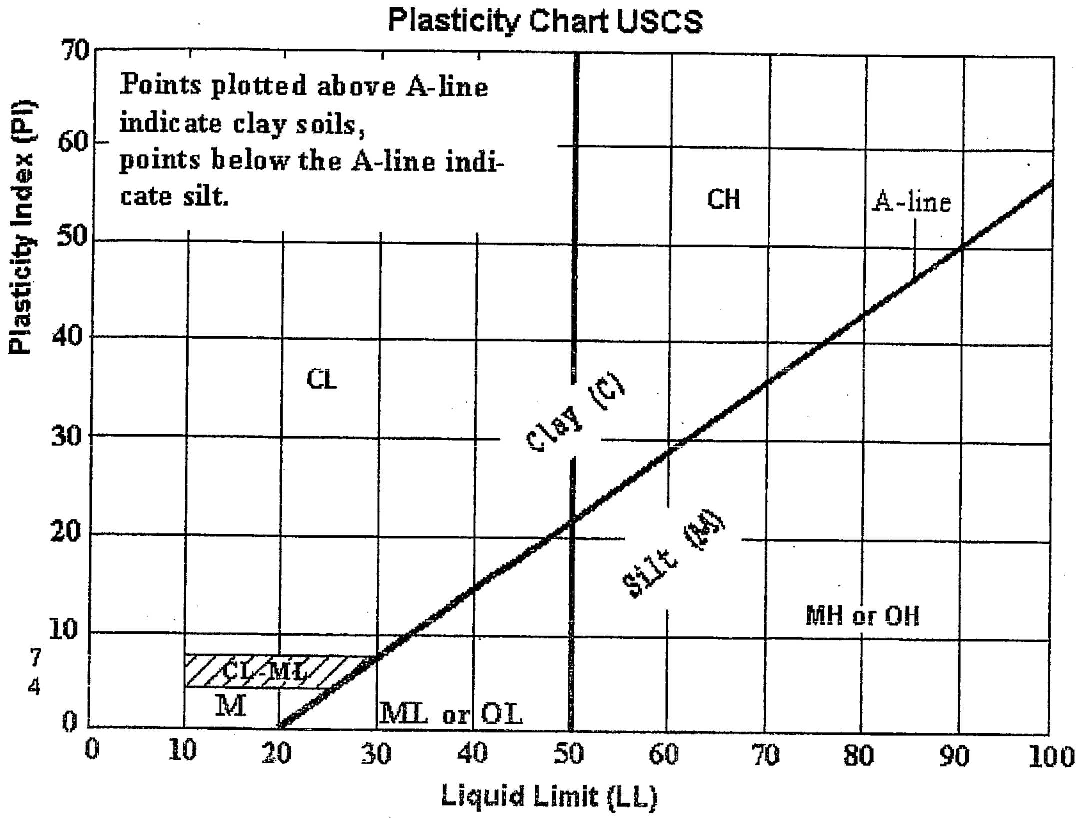
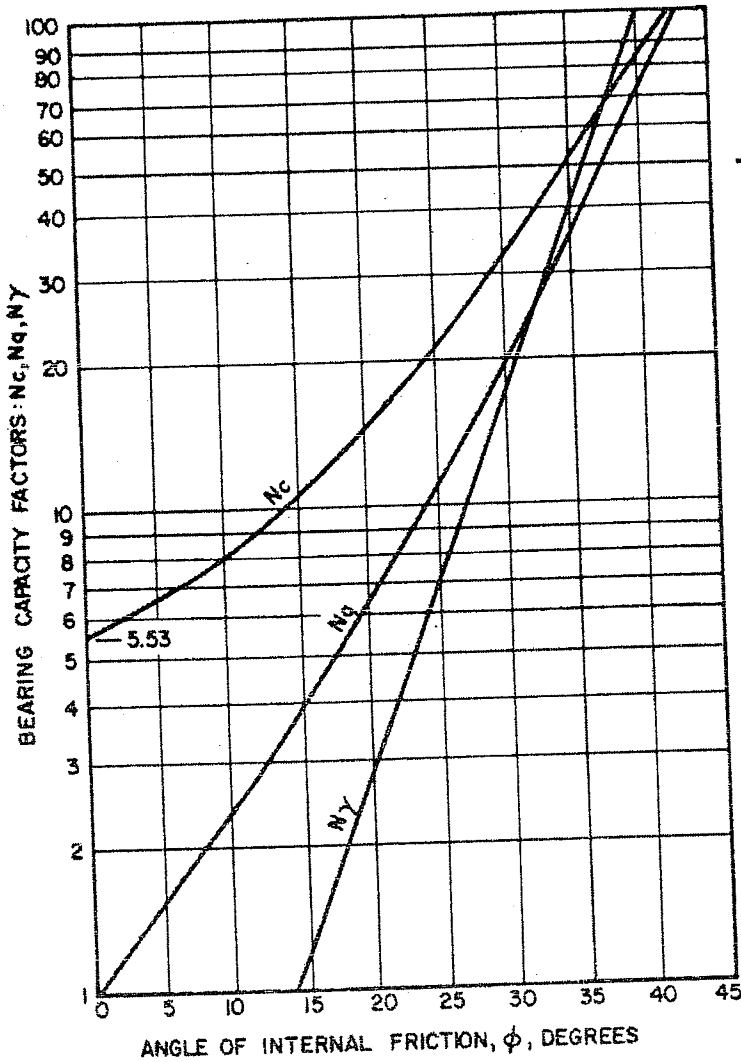


Chart for estimating allowable bearing pressure for foundations in sand on basis of results of standard penetration test (Terzaghi & Peck)






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)
0
10
20
30
40
50
60
70
80
90
100
7
4



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

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

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:

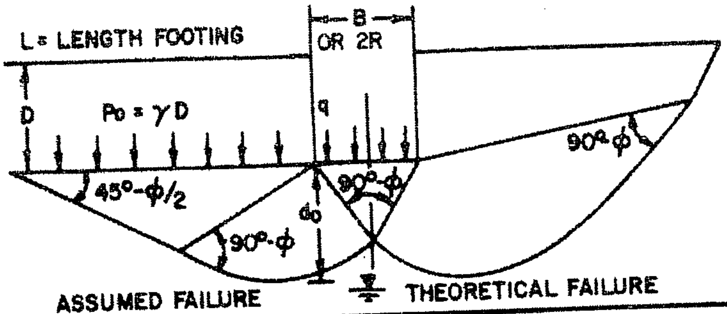
$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

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

CIRCULAR FOOTING:

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



ASSUMED CONDITIONS:

1. D ≤ B
2. SOIL IS UNIFORM TO DEPTH d_0 > B.
3. WATER LEVEL LOWER THAN d_0 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