00134

THE OPENUNIVERSITY OF SRI LANKA
DIPLOMA IN TECHNOLOGY (CIVIL) – LEVEL 04
Final Examination 2013/2014
CEX4230 – SOIL MECHANICS AND INTRODUCTION TO ROCK MECHANICS

Time allowed: Three Hours. Index No. _________

Date: Friday, 29th August, 2014 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. Circle the correct response.

(3x12 = 36 points)

1. Bulk unit weight γ is expressed as $\gamma = \left[\frac{G_s + Se}{1+e}\right]\gamma_w$. A natural soil specimen has a water content of 60%; the specific gravity of solids is 2.45. The saturated unit weight in kN/m^3 is equal to:

   a. 15.6 b. 16.4 c. 17.7 d. 18.1 e. 18.8 a b c d e

2. Which of the following statements are true?

   A. During Liquid Limit test, if the standard grove closes by 13mm at 15 blows, the soil is considered to be in a plastic state.

   B. A soil with a liquidity index of 0.5 is considered to be in a plastic state.

   C. At water contents below shrinkage limit a soil does not reduce its total volume.

   D. A clay soil with a natural water content less than the Plastic Limit indicates that it has a stiff consistency.

   a. A, B and C only b. B, C and D only. c. A, B and D only. d. A, C and D only.
   e. A, B, C and D. a b c d e

3. A soil has 14% of soil fraction passing 0.063mm sieve size. The soil type could be:

   a. GW b. GP c. SM d. MC e. CH a b c d e

4. Which of the following statements are true?

   A. A rapid dilatancy reaction is observed in pure silt, when compared with pure fine-sand.

   B. A high-plasticity clay has a high dry strength.

   C. The toughness of a 3mm diameter soil thread near plastic limit is quantified based on the pressure required to roll the thread.

   D. A soil with high plasticity can hold more water molecules within its soil matrix.

   a. A, B and C only b. B, C and D only. c. A, B and D only. d. A, C and D only.
   e. A, B, C and D. a b c d e

5. Which of the following statements are true, regarding the Hydrometer Test?

   A. Hydrometer reading reflects the density of fluid and its suspended particles.

   B. Error due to adding a dispersing agent is corrected by reading the hydrometer when it is dipped in the control jar.

   C. Settlement time depends on the specific gravity of solids.

   D. The diameter of particles in suspension decreases with increasing time.

   a. A, B and C only b. B, C and D only. c. A, B and D only. d. A, C and D only.
   e. A, B, C and D. a b c d e

6. Which of the following statements are true, regarding Constant Head Permeability Test?

A. The hydraulic gradient across any two points along the soil specimen is considered constant.

B. The average velocity through soil increases with increasing viscosity.

C. Coefficient of permeability represents both soil matrix and the permeating fluid.

D. For 'sandy soils' Coefficient of Permeability k_{20} is proportional to e^2.

a. A and B only. b. B and C only. c. C and D only. d. A and C only.
e. A and D only. a b c d e

7. Which of the following statements are true, regarding Falling Head Permeability Test?

A. During the test, a constant total head at outlet is maintained.

B. The said test suited for fine-grained soils, which are less permeable.

C. During the test, hydraulic gradient across the soil specimen remains constant.

D. The measured Coefficient of Permeability could be of the order of 10^{-6} cm/s.

a. A, B and C only b. B, C and D only. c. A, B and D only. d. A, C and D only.
e. A, B, C and D. a b c d e

8. Which of the following statements are true, regarding the Standard Proctor Compaction Test?

A. Compaction below optimum moisture content causes air volume in specimen to increase, with increasing moisture.

B. Compaction beyond optimum moisture content causes mass of solids in specimen to decrease, with increasing moisture.

C. Compaction beyond optimum moisture content causes mass of water in specimen to increase, with increasing moisture.

D. A well-graded sand shows greater compaction when compared with a poorly-graded sand.

a. A, B and C only b. B, C and D only. c. A, B and D only. d. A, C and D only.
e. A, B, C and D. a b c d e

9. Terzarghi's one-dimensional consolidation theory expresses Coefficient of Permeability as $k_v = c_v m_v \gamma_w$. Which of the following statements are true?

A. Parameter m_v represents the variation of settlement vs. time, for a particular load increment.

B. Parameter m_v is measured in kPa^{-1}.

C. The said consolidation theory assumes that k_v decreases during the consolidation process.

D. The said consolidation theory considers that the soil is fully saturated.

a. A and B only. b. B and C only. c. C and D only. d. B and D only.
e. A and D only. a b c d e

10. Which one of the following statements is <u>incorrect</u>?

a. Ultimate Bearing Capacity is the maximum capacity that causes soil beneath a shallow footing to undergo shear failure.

b. Maximum safe bearing capacity provides adequate safety against settlement.

c. Allowable bearing capacity is reduced when water table rises to the footing level.

d. Ultimate Bearing Capacity is estimated using Terzharghi's Bearing Capacity Equation.

e. When performing an undrained analysis, for a shallow footing, on a saturated clay soil, bearing capacity factors are determined considering $\phi = 0$. a b c d e

11. Which of the following statements are true?

A. When a pat of moist silt is squeezed on your palm, moisture appears on the surface.

B. Moist sand can be moulded to any shape since particles are held together by surface tension.

C. High plasticity clays have the tendency to swell, when saturated.

D. When dry sand is poured on a flat surface, it's angle of repose is equal to its angle of internal friction.

a. A, B and C only b. B, C and D only. c. A, B and D only. d. A, C and D only.
e. A, B, C and D. a b c d e

12. Which of the following statements are true, with regard to a submerged infinite sandy slope?

A. The factor of safety is determined based on a total stress analysis.

B. To ensure stability, the slope angle should not exceed the angle of internal friction of the soil.

C. The analysis assumes that the potential failure plane is parallel to the slope.

D. When the slope is stable, the mobilized friction along the plane is proportional to the mass of solids above this plane.

a. A and B only. b. B and C only. c. C and D only. d. A and C only.
e. A and D only. a b c d e

PART B:

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

1. The bulk unit weight, γ of a soil can be expressed as $\rho = [(1-n)G_s + Sn]\rho_w$.

A. Define all terms used in this equation using volume and mass parameters representing the 3-phase soil model. (5 points)

B. Prove that the Right Hand Side of the above equation represents the bulk density of soil. (4 points)

C. Using the above equation derive an expression for saturated density, as a function of water content, specific gravity of solids and density of water. (4 points)

D. A sandy soil has w = 15% and G_s = 2.66. Compute the submerged unit weight in kN/m^3. (3 points)

2. Figure B2 shows a constant head permeameter.

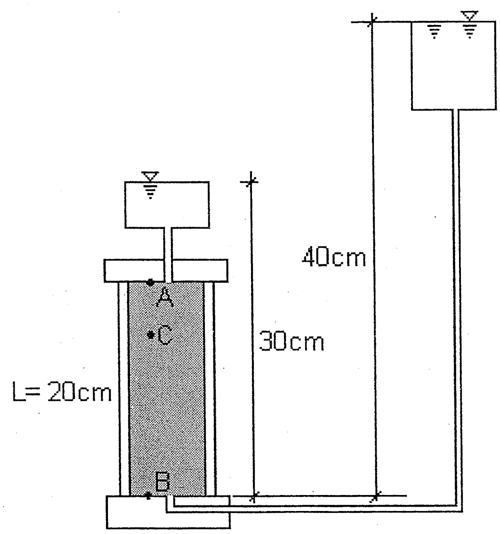

Figure B2

A. Considering that the datum passes through point B, complete the table given below. (4 points)

Point	Elevation Head	Pressure Head	Total Head
A			
B			

B. Point C is 15cm above Point B. Compute the hydraulic gradient between points B and C. (3 points)

C. Determine k_{20} for a measured flow rate of 8 ml per minute. The average diameter of the soil sample is 50mm. The above flow rate is measured at 30^0C. η_{20} = 1.002 mPa.s; η_{30} = 0.798 mPa.s; $\rho_{30}/\rho_{20} \approx 1.0$. (3 points)

D. During Constant Head Permeability Test, you may have observed that sand boiling starts at point B. When deriving a theoretical expression for Critical Hydraulic Gradient, i_c, we need to consider the total pressure at Point B, which is equal to the pressure caused by inlet water head. This pressure is also equal to the pressure due to outlet water head plus the pressure at B due to the weight of soil skeleton.

   i. Derive an expression for i_c based on above reasoning. (4 points)

   ii. Show why i_c is considered to be equal to 1. (2 points)

3. Figure B3 shows the results of a combined sieve-hydrometer test. The Liquid Limit and the Plastic Limit is found to be 40 and 31, respectively.

   A. Compute the percentage of silt, and clay, with respect to the total soil mass. (2 points)

   B. State whether this soil is a fine-grained soil or a coarse-grained soil. State your reasons. (2 points)

   C. Determine the group symbol based on Unified Soil Classification System. State your reasons. (4 points)

   D. State its soil description, considering the different soil groups and sub-groups that are present in the soil mix. (4 points)

   E. Discuss its response to Dry Strength Test, Dialatancy Test, Toughness of thread near Plastic Limit and Plasticity. State your reasons. (4 points)

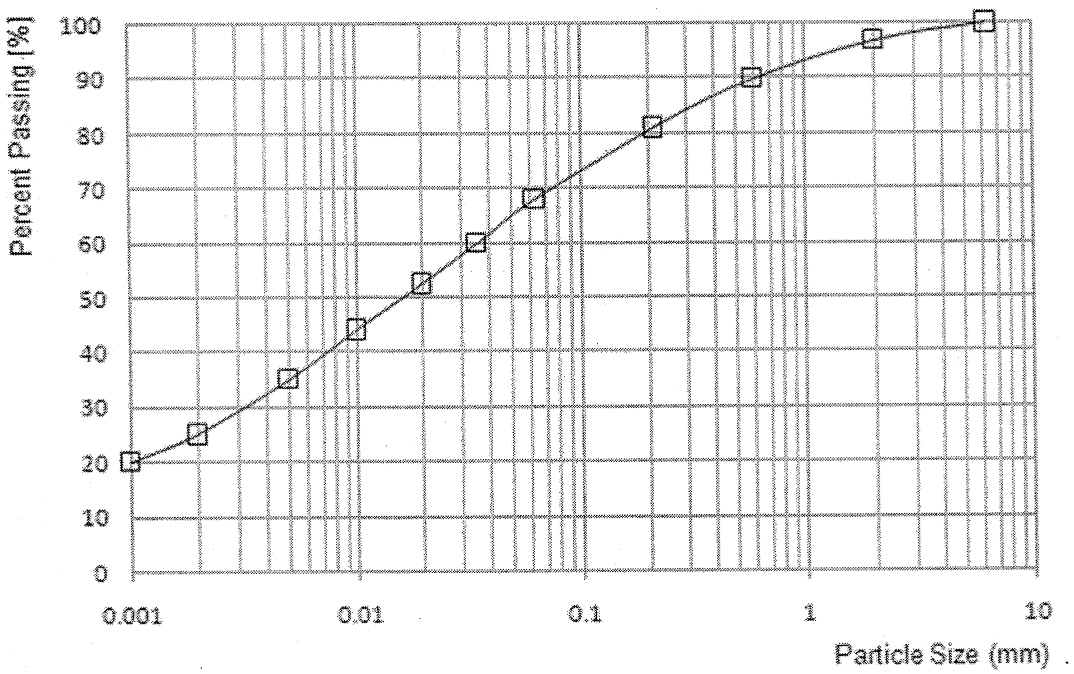

Figure B3

4.

   A. The contact pressure of 70kPa is applied on a shallow square footing (refer Figure B4a).

      i. Compute the vertical stress increment acting along the centreline of the footing, at the top of the organic clay layer. (1 points)

      ii. Compute the depth of organic clay layer at which 5% of footing pressure occurs along the centreline of the footing. (2 points)

B. Figure B4b shows the laboratory compression curve and its idealised form (i.e. curve OABC) used when performing settlement calculations. Following observations were made during a consolidation test:

Initial specimen height (cm)	=	2.02
Diameter of specimen (cm)	=	5.06
Mass of solids + water at beginning of test (g)	=	60.720
Total settlement from beginning to end of test (mm)	=	2.068
Mass of solids + water at end of test (g)	=	57.142
Mass of solids measured at the end of test (g)	=	45.080

i. Compute initial void ratio considering assuming that the specimen used is not saturated. (3 points)

ii. Compute the initial degree of saturation. (1 point)

C. Compute the effective vertical consolidation stress at the centre of the layer thickness computed in 4Aii above. (3 points)

D. Compute the settlement due to bearing stress assuming that $C_c = 0.53$; $C_r = 0.03$ and $\sigma'_p = 90$kPa. State all assumptions you've made during this computation. (6 points)

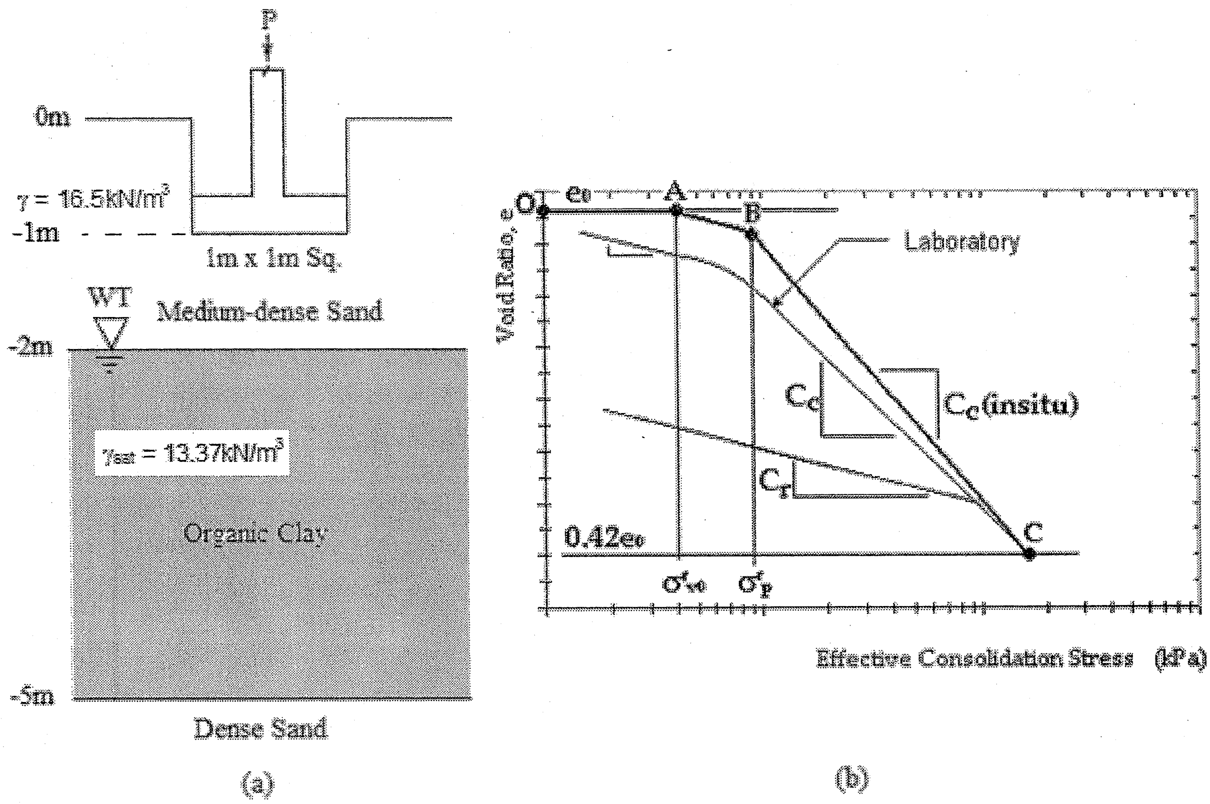

Figure B4

5.

A. Define Standard Penetration Test N. (2 points)

B. Discuss the relationship between SPT N and angle of internal friction, ϕ'. (2 points)

C. Figure B5 shows a square shallow footing located in a medium-dense sand, 1m below ground level. Groundwater level is considered to be below the zone of influence.

i. Assuming a factor of safety of 3.0, compute the maximum safe super-structure load (in kN) the column could carry. (4 points)

ii. Compute the safe super-structure load (in kN) the column could carry if the total settlement of footing is limited to 25mm. (4 points)

iii. Compute the factor of safety, if the water table is at footing level, and the soil bears the same super-structure load computed in 5C(i) above. (4 points)

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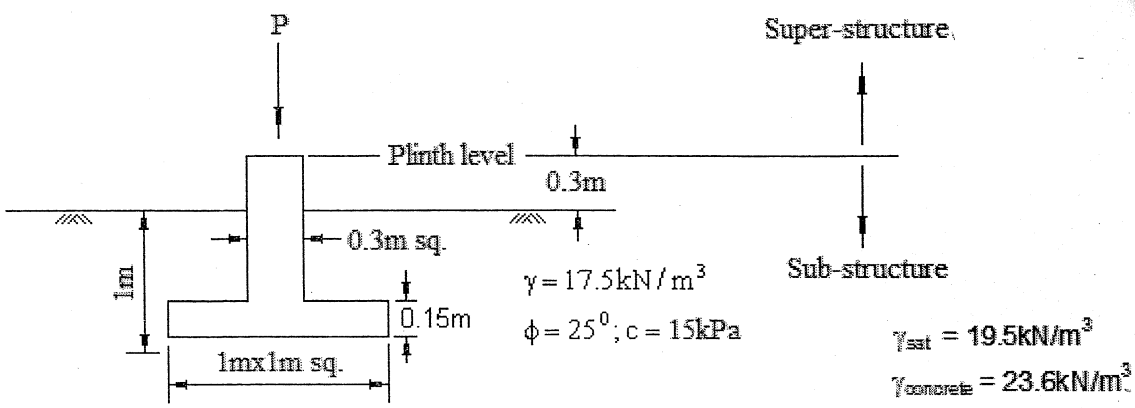

Figure B5

6.

A. The Unconfined Compression (UC) Test is used to determine the Undrained Cohesion, c_u, of a saturated in-situ clay soil specimen.

   i. Explain why undrained cohesion increases when in-situ moisture content of a saturated specimen is decreased (3 points)

   ii. Sketch Mohr's Circles of stress corresponding to failure situations. Name the two axes. (3 points)

   iii. Explain why failure plane gives $\phi_u = 0$. (3 points)

B. Figure B6(b) shows a saturated slope in a normally consolidated clay formation. The Undrained Cohesion of the soil is estimated at 35kPa. The saturated unit weight is estimated at 19 kN/m^3.

   i. Discuss how shear strength is mobilized against sliding along AEB. (3 points)

   ii. Compute the factor of safety against sliding. (4 points)

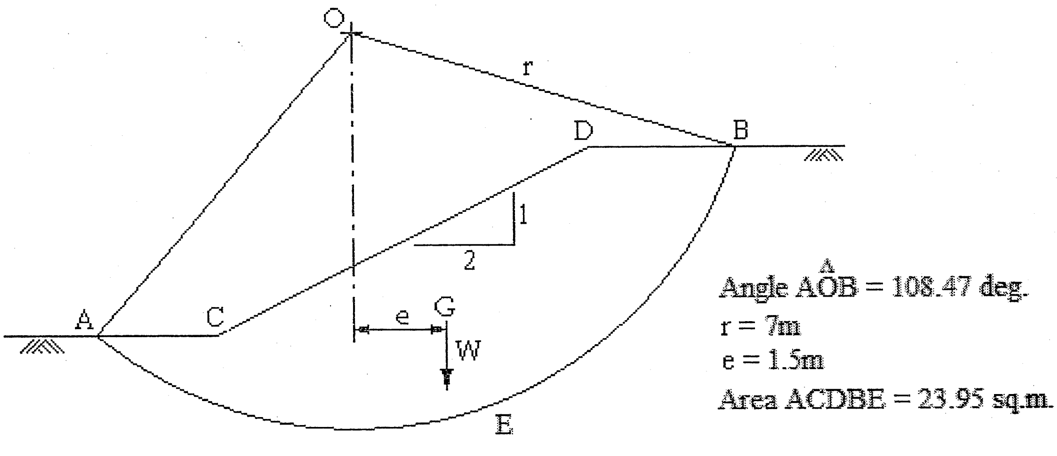

Figure B6(b)

Flow Chart For USCS

Modified to reflect BS Classification

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

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	$C_U \geqslant 4$ and $1 \leqslant C_C \leqslant 3$	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	$C_U \geqslant 4$ and $1 \leqslant C_C \leqslant 3$	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)	$\frac{(LL)_{oven\ dried}}{(LL)_{not\ dried}} < 0.75$	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)	$\frac{(LL)_{oven\ dried}}{(LL)_{not\ dried}} < 0.75$	OH

(PT - heavy odor, primarily organic)

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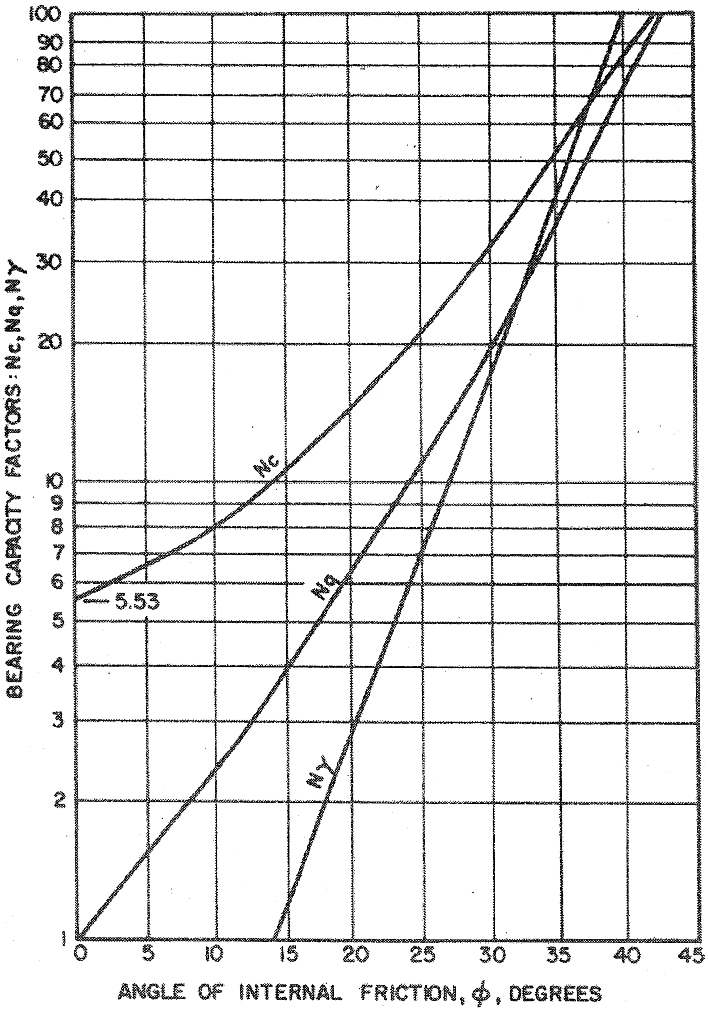


ULTIMATE BEARING CAPACITY = q_{ult}

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

$q' = cN_c + \gamma DN_q$

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

$q_{ult} = cN_c + \gamma DN_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c\ (1 + .3 \frac{B}{L}) + \gamma DN_q + 0.4 \gamma BN_\gamma$

CIRCULAR FOOTING: R = B/2

$q_{ult} = 1.3\, cN_c + \gamma DN_q + 0.6 \gamma RN_\gamma$

FOR COHESIONLESS FOUNDATION SOILS (c = 0)

CONTINUOUS FOOTING:

$q_{ult} = \gamma DN_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma DN_q + 0.4 \gamma BN_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma DN_q + 0.6 \gamma RN_\gamma$

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

CONTINUOUS FOOTING:

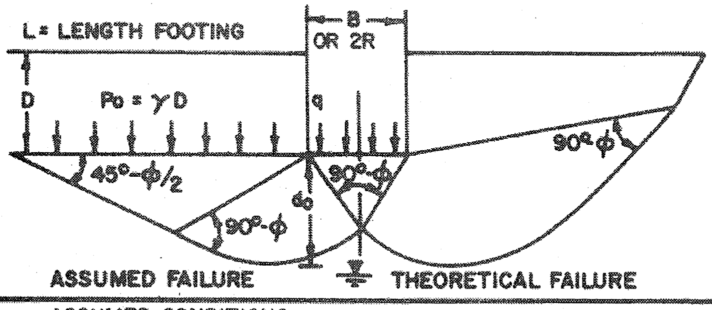
$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

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

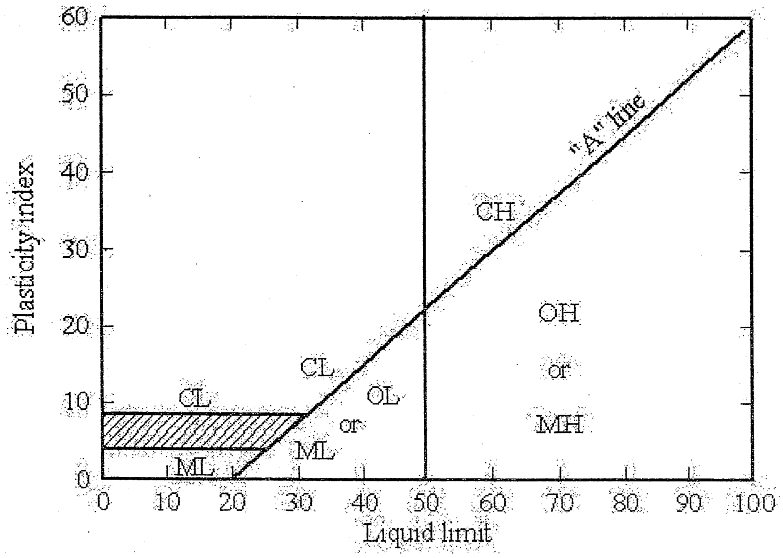
CIRCULAR FOOTING:

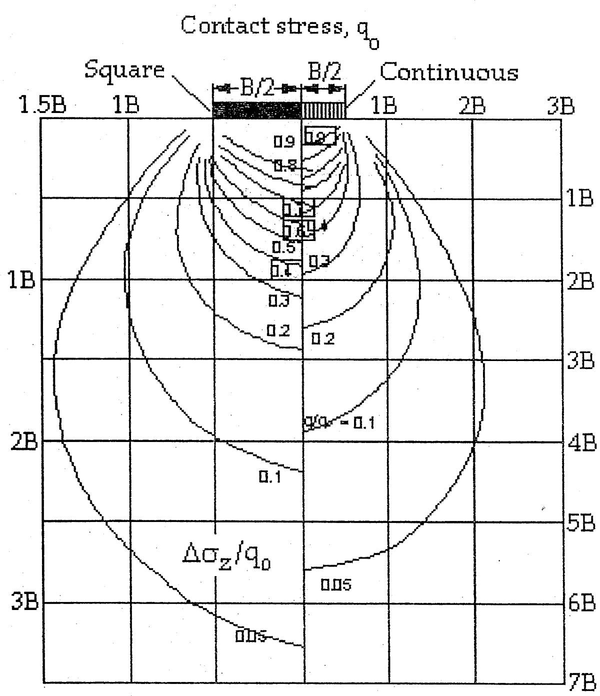
$q_{ult} = 1.3\, cN_c + \gamma D$

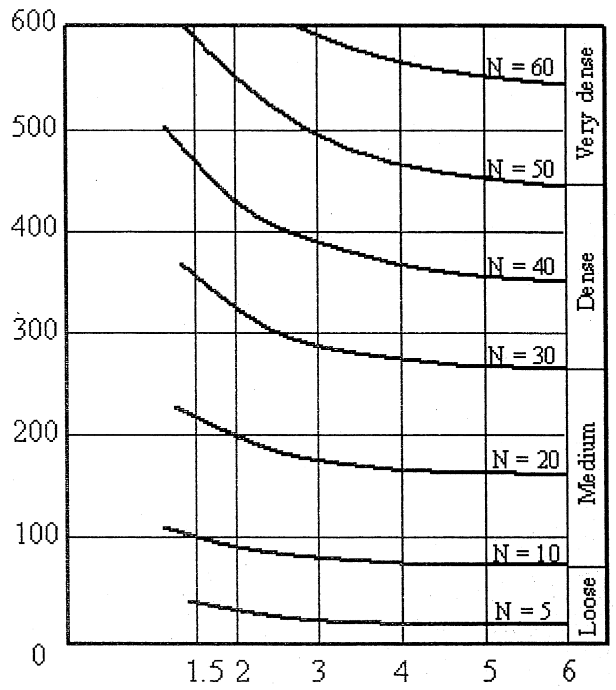


ASSUMED CONDITIONS:

1. $D \leq B$
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


Plasticity index
Liquid limit
"A" line
CH
CL
OL
or
ML
OH
or
MH
CL
ML
0
10
20
30
40
50
60
0
10
20
30
40
50
60
70
80
90
100


Contact stress, q_0
Square
Continuous
B/2
B/2
1.5B
1B
1B
2B
3B
1B
2B
3B
4B
5B
6B
7B
1B
2B
3B
$\Delta\sigma_z/q_0$
0.9
0.8
0.5
0.4
0.3
0.2
0.2
0.1
0.1
0.05
0.05


600
500
400
300
200
100
0
1.5
2
3
4
5
6
N = 60
N = 50
N = 40
N = 30
N = 20
N = 10
N = 5
Very dense
Dense
Medium
Loose

15