National Exams December 2017

04-Geol-A6, Soil Mechanics

3 hours duration

NOTES:

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit with the answer paper, a clear statement of any assumptions made.

2. This is a CLOSED BOOK EXAM. Candidates may use one of two calculators, the Casio or Sharp-approved model. A compass and ruler are also required.

3. SIX (6) questions constitute a complete exam paper. YOU MUST ANSWER QUESTIONS 1 TO 5. For Question 6, candidates must choose three (3) more questions out of the five (5) options. Where stated in the examination, please hand in any additional pages with your exam booklet.

4. The marks assigned to the subdivisions of each question are shown for information. The total number of marks for the exam is 100.

Question 1. Classification

1. Plot the grain-size curves and classify soils A and B according to the Unified Soil Classification System. Soil A has a liquid limit of 30% and plastic limit of 17.5%. Soil B has a liquid limit of 70% and a plastic limit of 25%.

10 Marks

Table Q1

Metric Sieve Size	US Sieve Size	Percent Finer	
		Soil A	Soil B
75 mm	3 in	100	100
50 mm	2 in	100	100
25 mm	1 in	100	100
19 mm	0.75 in	100	100
9.5 mm	0.375 in	100	100
4.76 mm	No. 4	100	100
2.38 mm	No. 8	97	100
0.84 mm	No. 20	77	97
420 μm	No. 40	20	92
150 μm	No. 100	15	82
75 μm	No. 200	6	75

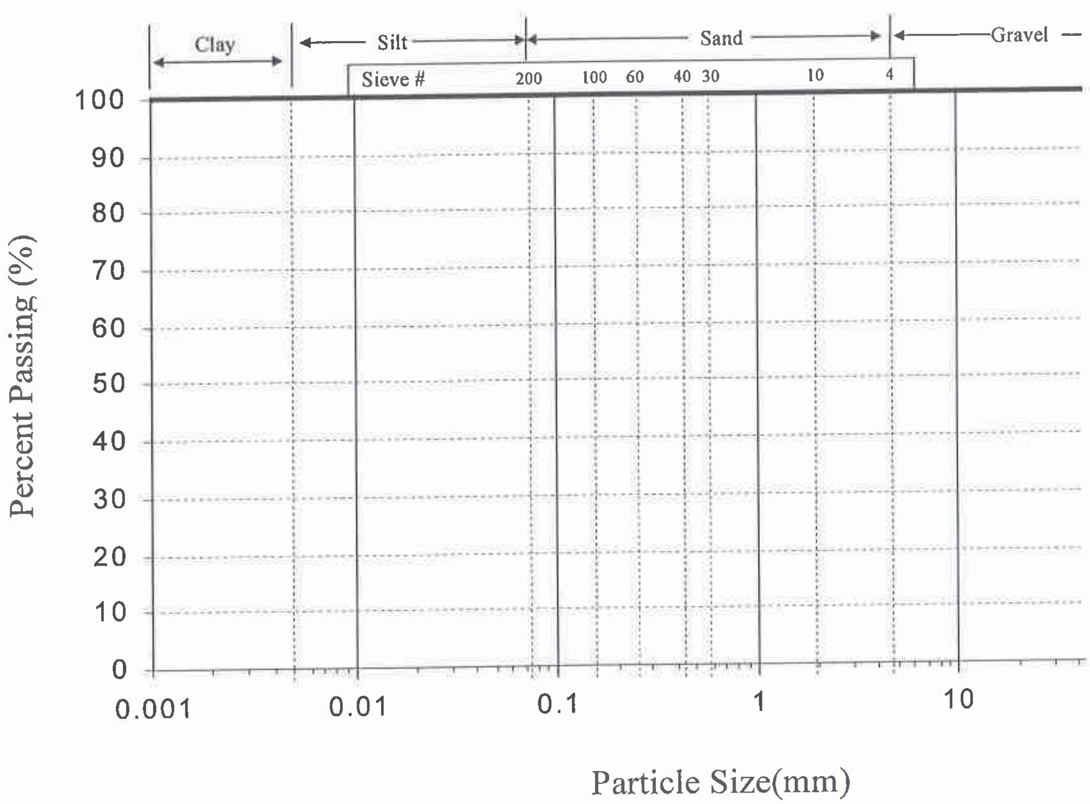


Figure Q1

Question 2. Soil Physical Properties

15 Marks

1. A standard compaction curve for a soil is plotted below in **Figure Q2-1**.
   a) Label the axes and units on the graph.
   b) Using the graph interpret the:
      i) Compaction curve
      ii) Optimum water content and maximum dry unit weight for the standard proctor curve
   c) For the test at 7% water content, determine:
      i) Void ratio
      ii) Degree of saturation
      iii) Total unit weight

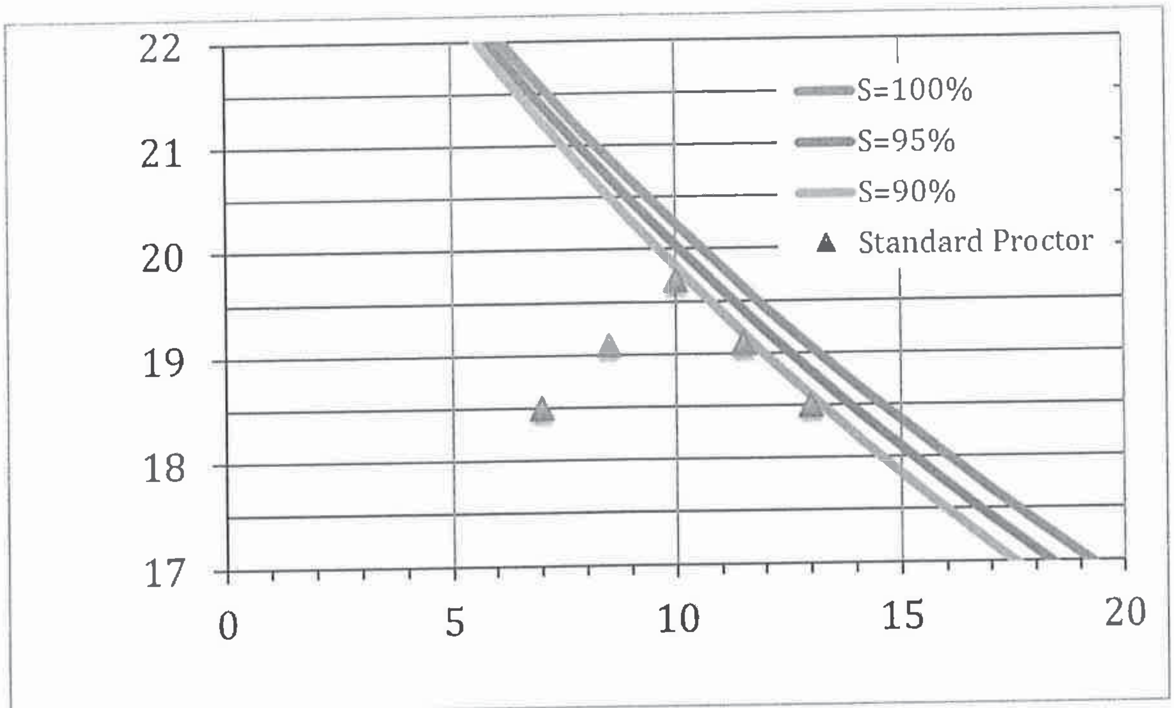


Figure Q2-1.

2. An embankment for a highway is to be constructed from a soil compacted to a dry unit weight of 17.5 kN/m^3 at water content of 19%. The clay has to be trucked to the site from a borrow pit. The bulk unit weight of the soil in the borrow pit is 15 kN/m^3 and its natural water content is 5.5%. Calculate:

   a) The volume of clay from the borrow pit required for 1 m^3 of embankment. Assume G_s =2.7.
   b) The amount of water required per cubic meter of embankment, assuming no loss of water during transportation.

Question 3. Shear Strength

20 Marks

1. Two consolidated drained (CD) triaxial tests are performed on an over-consolidated clay. The results are listed in Table Q5. You are asked to:

   a) Sketch the (σ_1-σ_3) vs axial strain and volume strain versus axial strain plots. Label the key values.

   b) Determine the shear strength of the soil.

   c) For Test 2, calculate the shear and normal stresses acting on the failure plane at failure.

   d) For Test 2, determine the angle of the failure plane from the horizontal.

   e) A third consolidated drained test is performed at cell pressure of 75 kPa. Calculate the (σ_1-σ_3) at failure for the third test.

   f) What test would you perform to evaluate soil strength for:

      i) First time quick loading of a foundation on clay.

      ii) Long-term, steady-state slope stability.

Table Q3-1

Test	Cell pressure, (σ_3) (kPa)	(σ_1-σ_3) at failure (kPa)
1	20	80
2	135	300
3	75	???????

Question 4. Consolidation

20 Marks

1. A layer of clay was found below a sand deposit as shown in Figure Q4-1. The water table is located at 2.25m depth. The construction of a very wide soil embankment will apply a stress of 80 kPa at the surface.

   a. Calculate and plot the effective stress at the top, middle and bottom of each layer, before and after the construction of the embankment.

   b. Calculate

      i. Total consolidation settlement of the clay layer.

      ii. How long 50% consolidation will take.

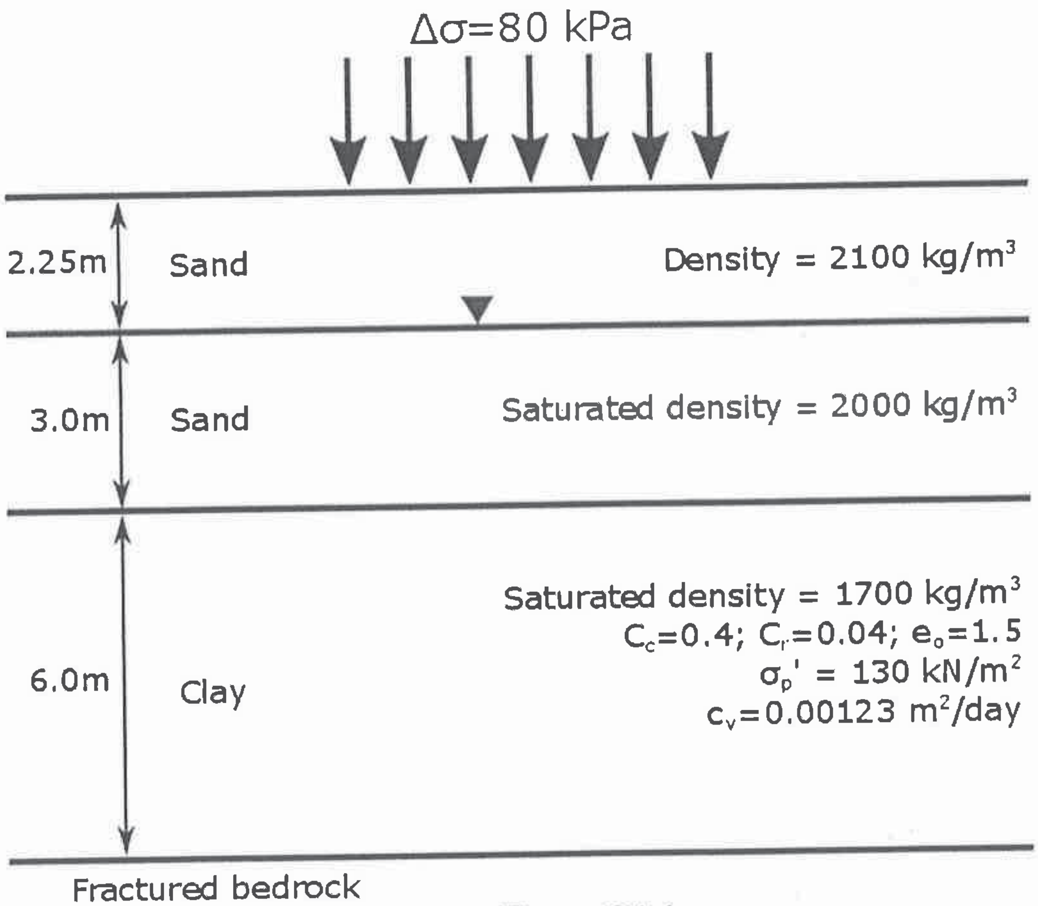


Figure Q4-1

Question 5. Seepage

20 marks

1. Flow analysis for a sheet pile wall was performed using a finite element program as shown below in **Figure Q5-1**.

   a. Label the axes on the Figure.
   b. Label the Datum on the Figure.
   c. What are the boundary conditions at points A, B, C, and D.
   d. Some lines are numbered 1, 2, and 3.
      i. Name the lines and describe what they represent.
      ii. Give the values for each of lines numbered 1, 2, and 3.
   e. Indicate the direction of flow on the figure.
   f. Write and describe the Bernoulli equation.
   g. What are the three components of head at Point X and Point Y?

   h. Vertical effective stress. The saturated unit weight of the ground is γ_{sat}=18kN/m^3. At points X and Y, calculate
      i. Vertical total stress
      ii. Pore pressure
      iii. Effective vertical stress

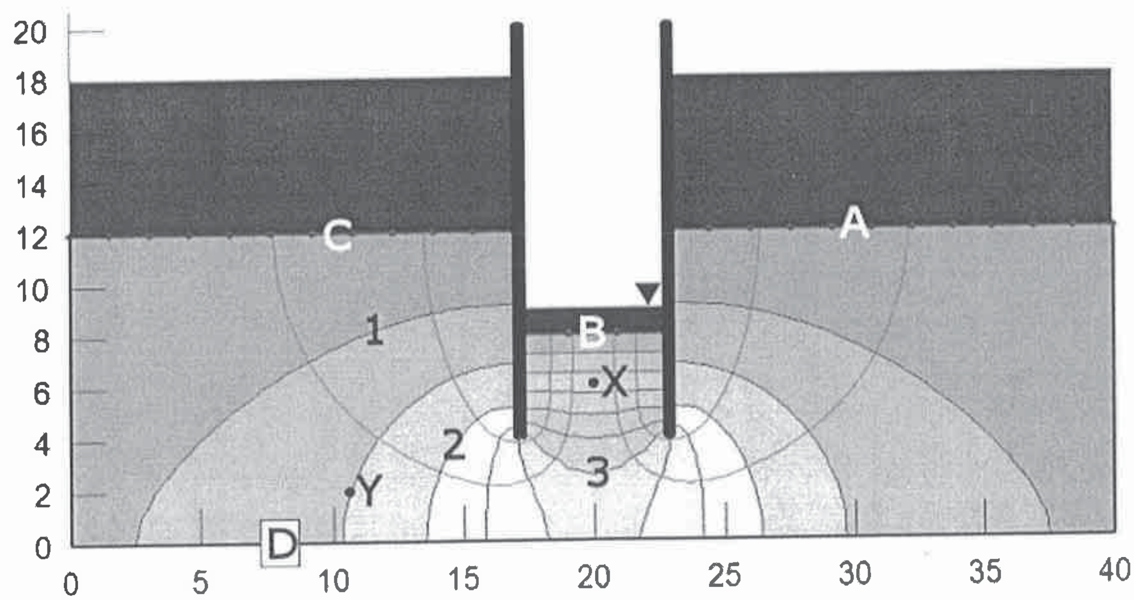


Figure Q5-1.

Question 6. Optional Questions

Answer **three** of the **following five questions**. **Only** the **first three** answers will be marked.

5 Marks each

1) List the equation for Darcy's Law and describe its components. Use a diagram to help explain your answer.

2) Draw the conceptual model for effective stress between two grains of sand and provide a brief derivation for the effective stress equation. Use a diagram to help explain your answer.

3) Describe capillary rise in a capillary tube and relate it to water retention curves for unsaturated soils. Use a diagram to help explain your answer.

4) You are an earthwork construction control inspector checking the field compaction of a layer of soil. When you conducted the sand cone test, the volume of soil excavated was 1165 cm^3. It weighed 2600 g wet and 1645 g dry.
   a) What is the field compacted dry density?
   b) What is the field water content?

5) Define the term groundwater table and plot the components of total head for the case of a 5 m thick sand layer with the groundwater table 1.5 m below the surface. Use a diagram to help explain your answer.

USEFUL INFORMATION

$$C_u = \frac{D_{60}}{D_{10}}$$

$$C_c = \frac{(D_{30})^2}{D_{10}D_{60}}$$

$$N_{corrected} = 100\% \frac{N - N_{fines}}{100 - N_{fines}}$$

PI = 0.73(LL-20)

$I_P = 0.73(w_L - 20)$

$$I_D = \frac{e_{max} - e}{e_{max} - e_{min}}$$

$$I_L = \frac{w - w_P}{w_L - w_P}$$

$$Activity = \frac{w_L - w_P}{\%clay}$$

$$\rho_d = \frac{\rho_t}{(1+w)}$$

$\rho' = \rho_{sat} - \rho_w$

$$h_t = h_e + h_p = z + \frac{u}{\gamma_w}$$

$$i = \frac{\Delta h}{L}$$

$v = ki$

$$k = \frac{\gamma_w}{\eta}\overline{K}$$

$$v_s = \frac{v}{n}$$

$q = vA = kiA$

$$q = k\Delta h \frac{N_f}{N_d}$$

$$k = \frac{aL}{A\Delta t}\ln\frac{h_1}{h_2} = 2.3\frac{aL}{A(t_2 - t_1)}\log\frac{h_1}{h_2}$$

$k = \dot{Q}L/hA$

$$k_N = \frac{H}{\left(\frac{H_1}{k_1} + \frac{H_2}{k_2} + \frac{H_3}{k_3}\right)}$$

$$k_p = \frac{k_1H_1 + k_2H_2 + k_3H_3}{H}$$

$$p = \frac{\sigma_1 + \sigma_3}{2}$$

$$q = \frac{\sigma_1 - \sigma_3}{2}$$

Force → Newton (N) → 1 N = 1 kg m/s^2

Pressure → Pascal (Pa) → 1 Pa = 1N/m^2

→ 1 kPa = 1 kN/m^2

$$\Delta u = B[\Delta\sigma_3 + A(\Delta\sigma_1 - \Delta\sigma_3)]$$

$\tau_{rupt} = c' + \sigma' \tan\phi'$

$\sigma' = \sigma - u$

$\psi' = \arctan(\sin\phi')$ $a = c'\cos\phi'$

$$T = \frac{c_v t}{H_{dr}^2} \qquad c_v = \frac{k}{m_v \gamma_w}$$

$$\Delta H = C_r\left(\frac{H_o}{1+e_o}\right)\log\frac{\sigma'_p}{\sigma'_{vo}} + C_c\left(\frac{H_o}{1+e_o}\right)\log\frac{\sigma'_{vf}}{\sigma'_p}$$

$$T = \frac{\pi}{4}\left(\frac{U}{100}\right)^2 \qquad U < 60\%$$

$$T = 1.781 - 0.933\log(100 - U) \qquad U > 60\%$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$\sigma_{ff} = (\sigma_{1f}+\sigma_{3f})/2-((\sigma_{1f}-\sigma_{3f})\sin\phi)/2$

$\tau_{ff} = \sigma_{ff}\tan\phi$

$\alpha_{ff} = 45° + \phi/2$

$N\phi = \sigma_{1f}/\sigma_{3f}$

$n = e/(1+e)$

$\psi' = \arctan(\sin\phi')$

$a = c'\cos\phi'$

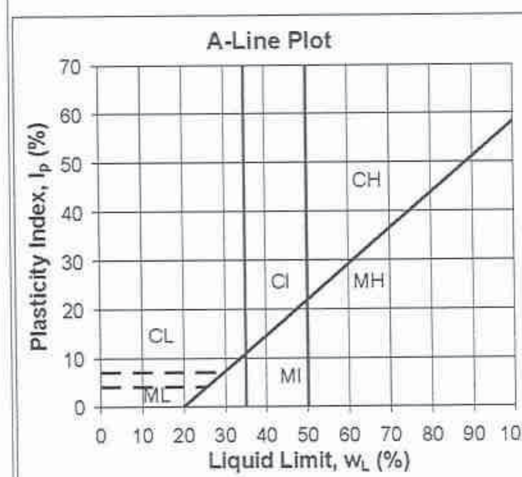
United Soil Classification System

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 75 mm and basing fractions on estimated mass)				Grp Sym	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS	LABORATORY CLASSIFICATION CRITERIA		
COARSE GRAINED SOILS (MORE THAN HALF OF MATERIAL IS LARGER THAN 75 µm)	GRAVELS (MORE THAN HALF OF COARSE FRACTION IS LARGER THAN 4.75 mm)	CLEAN GRAVELS (little or no fines)	Wide range in grain size & substantial amounts of all intermediate particle sizes	GW	WELL GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES	GIVE TYPE; NAME, IF NECESSARY; INDICATE APPROX % OF SAND & GRAVEL; MAX. SIZE; ANGULARITY, SURFACE CONDITION & HARDNESS OF GRAINS; LOCAL OR GEOLOGIC NAME & OTHER PERTINENT DESCRIPTIVE INFORMATION; & SYMBOL IN PARENTHESES	DETERMINE PERDENTAGES OF GRAVEL & SAND FROM GRAIN SIZE CURVE. DEPENDING ON PERCENTAGE OF FINES (FRACTION SMALLER THAN 75 µm) COARSE GRAINED SOILS ARE CLASSIFIED AS FOLLOWS:	$C_U > 4;\ 1 < C_C < 3$	
			Predominantly one size of a range of sizes with some intermediate sizes missing	GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES		$C_U = \frac{D_{60}}{D_{10}}$	NOT MEETING ALL GRADATION REQUIREMENTS FOR GW	
		GRAVEL WITH FINES (appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	GM	SILTY GRAVELS, POORLY GRADED GRAVEL-SAND-SILT MIXTURES		$C_C = \frac{(D_{30})^2}{D_{10}D_{60}}$	ATTERBERG LIMITS BELOW A-LINE, OR $I_P<4$	ABOVE A-LINE WITH I_P BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
			Plastic fines (for identification procedures see CL below)	GC	CLAYEY GRAVELS, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES		LESS THAN 5%; GW, GP, SW, SP	ATTERBERG LIMITS ABOVE A-LINE WITH $I_P>7$	
	SANDS (MORE THAN HALF OF COARSE FRACTION IS SMALLER THAN 4.75 mm)	CLEAN SANDS (little or no fines)	Wide range in grain size & substantial amounts of all intermediate particle sizes	SW	WELL GRADED SANDS, LITTLE OR NO FINES	FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITIONS & DRAINAGE CHARACTERISTICS	MORE THAN 12% GM, GC, SM, SC	$C_U > 6;\ 1 < C_C < 3$	
			Predominantly one size of a range of sizes with some intermediate sizes missing	SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES		5% TO 12% BORDERLINE CASES REQ. USE OF DUAL SYMBOLS	NOT MEETING ALL GRADATION REQUIREMENTS FOR SW	
		SANDS WITH FINES (appreciable amount of fines)	Non-plastic fines (for identification procedures see ML below)	SM	SILTY SANDS, POORLY GRADED SAND-SILT MIXTURES			ATTERBERG LIMITS BELOW A-LINE, OR $I_P<4$	ABOVE A-LINE WITH I_P BETWEEN 4 AND 7 ARE BORDERLINE CASES REQUIRING USE OF DUAL SYMBOLS
			Plastic fines (for identification procedures see CL below)	SC	CLAYEY SANDS, POORLY GRADED SAND-CLAY MIXTURES			ATTERBERG LIMITS ABOVE A-LINE WITH $I_P>7$	

IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN 425 µm

			DRY STRENGTH (CRUSHING CHARACTERISTICS)	DILATENCY (REACTION TO SHAKING)	TOUGHNESS (CONSISTENCY NEAR PLASTIC LIMIT)	Grp Sym	TYPICAL NAMES	INFORMATION REQUIRED FOR DESCRIBING SOILS
FINE GRAINED SOILS (MORE THAN HALF OF MATERIAL IS SMALLER THAN 75 µm)	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 35%	NONE	QUICK	NONE	ML	INORGANIC SILTS & SANDY SILTS OF SLIGHTLY PLASTICITY, ROCK FLOUR	GIVE TYPE; NAME, IF NECESSARY, INDICATE DEGREE & CHARACTER OF PLASTICITY, AMOUNT & MAXIMUM SIZE OF COARSE GRAINS, COLOUR IN WET CONDITION, ODOUR, IF ANY, LOCAL OR GEOLOGIC NAME & OTHER PERTINANT INFORMATION & SYMBOL IN PARENTHESES
			MEDIUIM TO HIGH	NONE TO VERY SLOW	MEDIUM	CL	SILTY CLAYS (INORGANIC), GRAVELLY CLAYS, SANDY CLAYS, LEAN CLAYS	
			SLIGHT TO MEDIUM	SLOW	SLIGHT	OL	ORGANIC SILY OF LOW PLASTICITY, ORGANIC SANDY SILTS	
		LIQUID LIMIT BETWEEN 35% AND 50%	NONE TO SLIGHT	SLOW TO QUICK	SLIGHT	MI	INORGANIC COMPRESSIBLE FINE SANDY SILT WITH CLAY OF MEDIUM PLASTICITY, CLAYEY SILTS	
			HIGH	NONE	MEDIUM TO HIGH	CI	SILTY CLAYS (INORGANIC) OF MEDIUM PLASTICITY	FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTENCY IN UNDISTURBED & REMOULDED STATES, MOISTURE & DRAINAGE CONDITIONS
			SLIGHT TO MEDIUM	VERY SLOW	SLIGHT	OI	ORGANIC SILTY CLAYS OF MEDIUM PLASTICITY	
		LIQUID LIMIT GREATER THAN 50%	SLIGHT TO MEDIUM	SLOW TO NONE	MEDIUM	MH	INORGANIC SILTS, HIGHLY COMPRESSIBLE MICACEOUS OR DIATOMACEOUS FINE SANDY SILTS, ELASTIC SILTS	
			HIGH TO VERY HIGH	NONE	HIGH	CH	CLAYS (INORGANIC) OF HIGH PLASTICITY, FAT CLAYS	
			MEDIUM TO HIGH	NONE TO VERY SLOW	SLIGHT TO MEDIUM	OH	ORGANIC CLAYS OF HIGH PLASTICITY	
HIGHLY ORGANIC SOILS			IDENTIFIED BY COLOUR, ODOUR, SPONGY FEEL & FREQUENTLY BY FIBROUS TEXTURE			PL	PEAT & OTHER HIGHLY ORGANIC SOILS	

USE GRAIN SIZE CURVE IN IDENTIFYING THE FRACTIONS AS GIVEN UNDER FIELD IDENTIFICATION



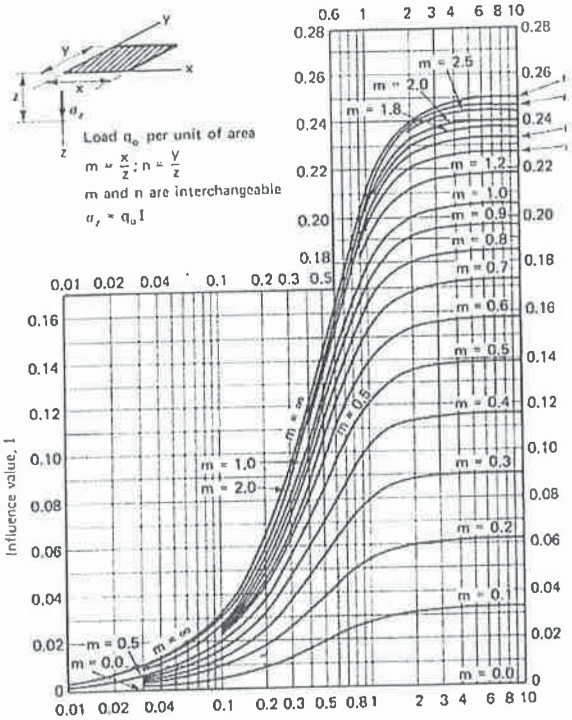


Fig. 8.21 Influence value for vertical stress under corner of a uniformly loaded rectangular area (after U.S. Navy, 1971).

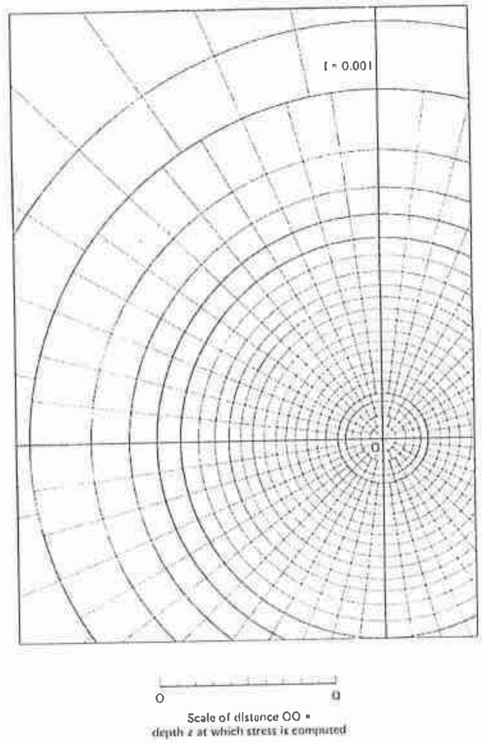


Fig. 8.25 Influence chart for vertical stress on horizontal planes (after Newmark, 1942).

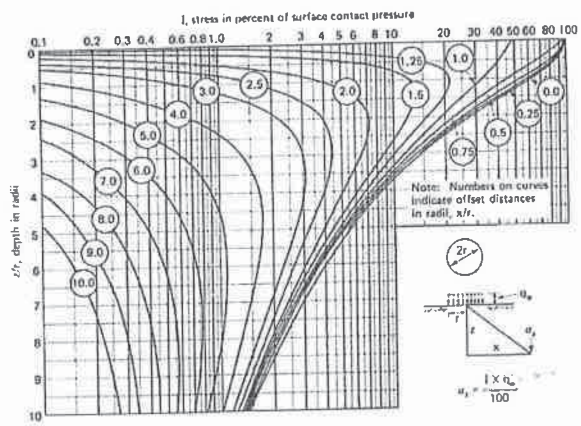
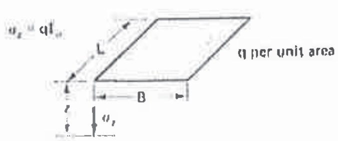


Fig. 6.22 Influence values, expressed in percentage of surface contact pressure, q_o, for vertical stress under uniformly loaded circular area (after Foster and Ahlvin, 1954, as cited by U.S. Navy, 1971).

TABLE 8-6 Influence Values for Vertical Stress Under Corner of a Uniformly Loaded Rectangular Area*



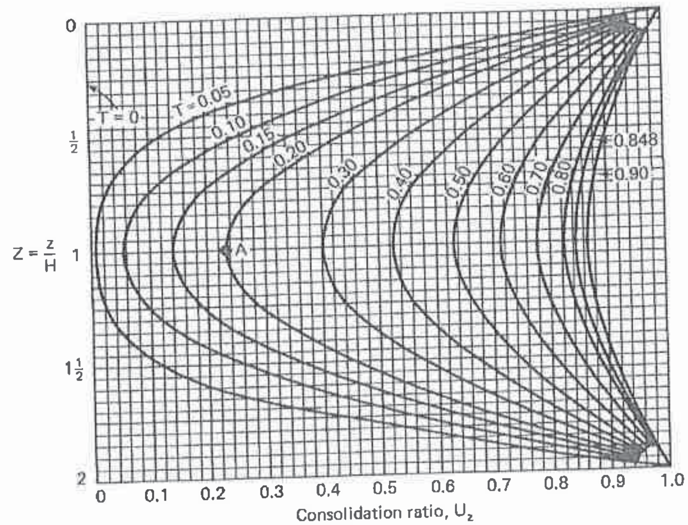
Boussinesq Case

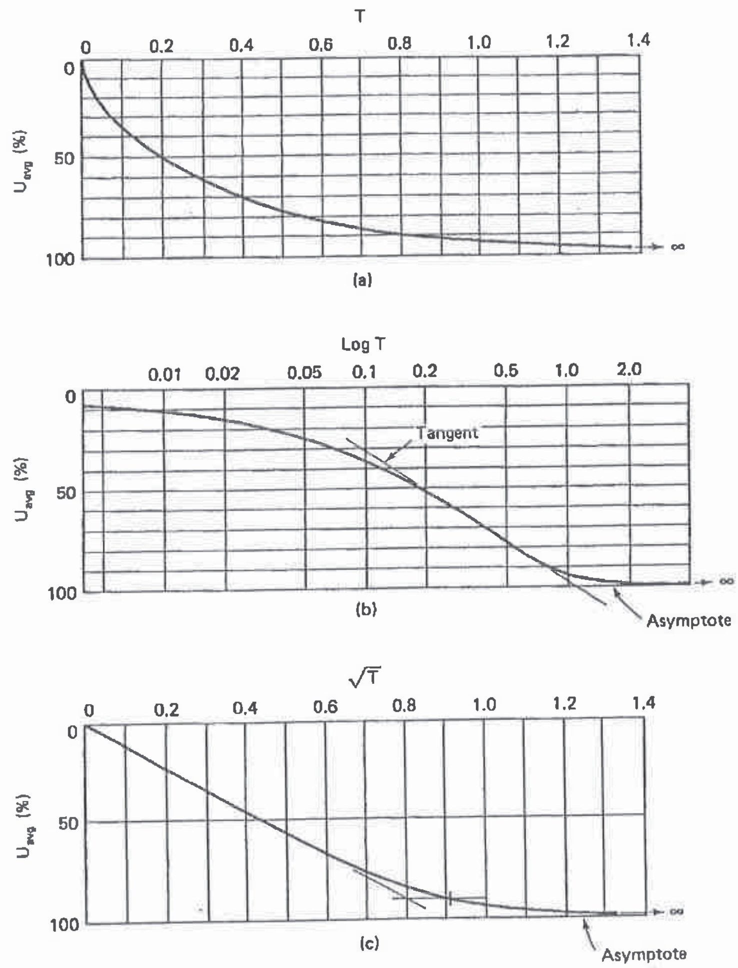
B/z	L/z = 0.1	0.2	0.4	0.6	0.8	1.0	2.0	∞
0.1	0.005	0.009	0.017	0.022	0.026	0.028	0.031	0.032
0.2	0.009	0.018	0.033	0.043	0.050	0.055	0.061	0.062
0.4	0.017	0.033	0.060	0.080	0.093	0.101	0.113	0.115
0.6	0.022	0.043	0.080	0.107	0.125	0.136	0.153	0.156
0.8	0.026	0.050	0.093	0.125	0.146	0.160	0.181	0.185
1.0	0.028	0.055	0.101	0.136	0.160	0.175	0.200	0.205
2.0	0.031	0.061	0.113	0.153	0.181	0.200	0.232	0.240
∞	0.032	0.062	0.115	0.156	0.185	0.205	0.240	0.250

Westergaard Case

B/z	L/z = 0.1	0.2	0.4	0.6	0.8	1.0	2.0	∞
0.1	0.003	0.006	0.011	0.014	0.017	0.018	0.021	0.022
0.2	0.006	0.012	0.021	0.028	0.033	0.036	0.041	0.044
0.4	0.011	0.021	0.039	0.052	0.060	0.066	0.077	0.082
0.6	0.014	0.028	0.052	0.069	0.081	0.089	0.104	0.112
0.8	0.017	0.033	0.060	0.081	0.095	0.105	0.125	0.135
1.0	0.018	0.036	0.066	0.089	0.105	0.116	0.140	0.152
2.0	0.021	0.041	0.077	0.104	0.125	0.140	0.174	0.196
∞	0.022	0.044	0.082	0.112	0.135	0.152	0.196	0.250

*After Duncan and Buchignani (1976).





U%	10	20	30	40	50	60	70	80	90	100
T	.008	.031	.071	.126	.197	.287	.403	.567	.848	1.125