National Exams December 2018

18-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 eight (8) 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

10 Marks

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 27%. Soil B has a liquid limit of 40% and a plastic limit of 30%.

Table Q1-1

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	95	100
9.5 mm	0.375 in	80	100
4.76 mm	No. 4	72	91
2.38 mm	No. 8	50	80
0.84 mm	No. 20	40	72
420 μm	No. 40	35	70
150 μm	No. 100	12	59
75 μm	No. 200	8	55

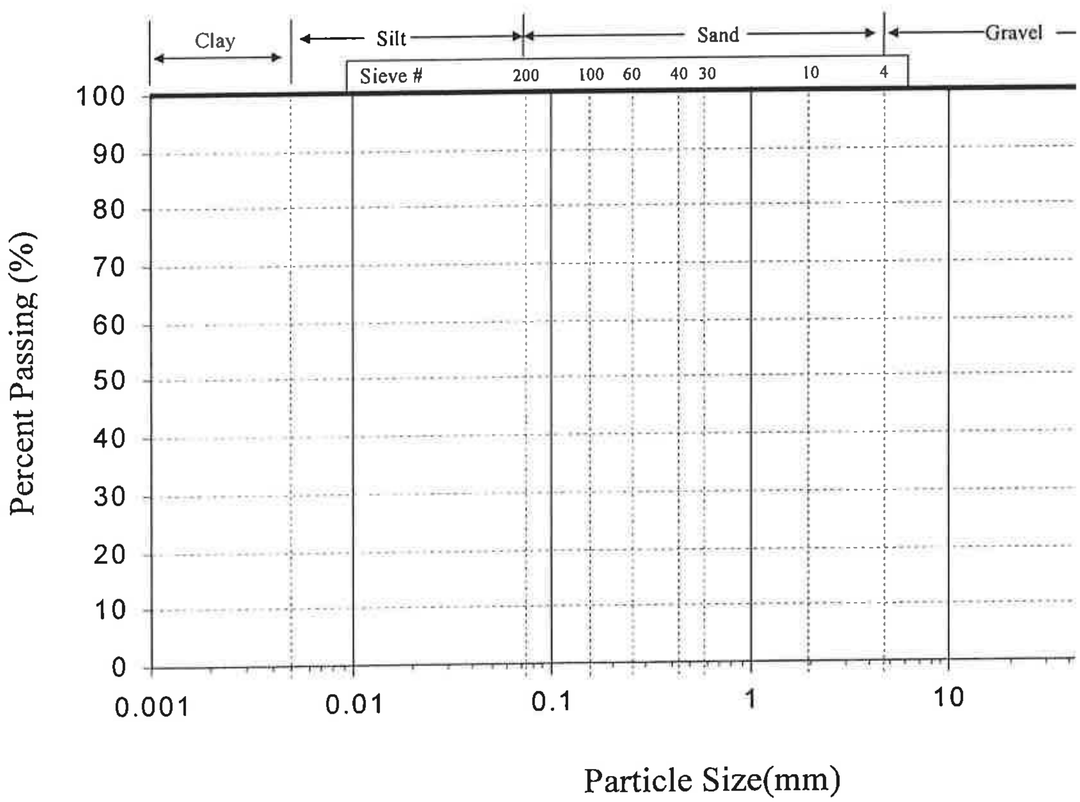


Figure Q1-1

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 curves
      ii) Optimum water content and maximum dry unit weight for the standard and modified proctor curves
      iii) Line of optimums
   c) For the test at 12% water content, determine:
      i) Void ratio
      ii) Degree of saturation
      iii) Total unit weight
      iv) Volumetric water content
      v) Porosity
      vi) Dry density

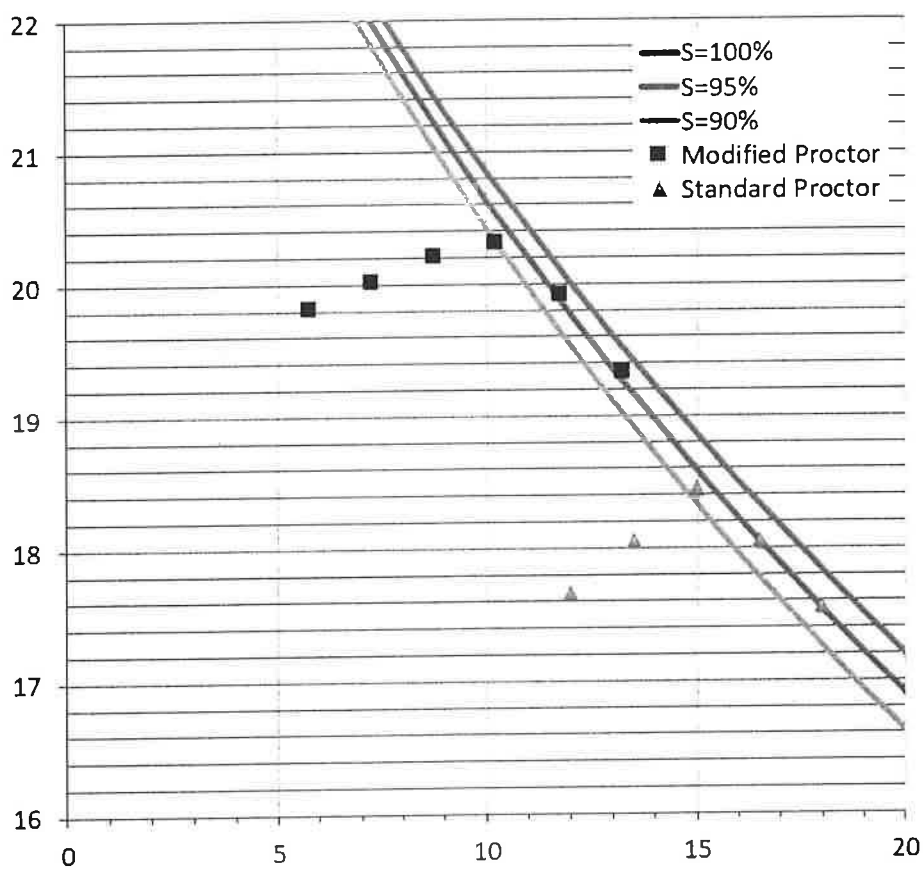


Figure Q2-1.

Question 3. Shear Strength

20 Marks

1. Test A is a conventional consolidated-drained (CD) triaxial. The cell pressure is 100 kPa, and the additional axial effective stress at failure is 250 kPa. No back pressure is applied during saturation or consolidation.

   You are asked to:

   a) Plot the Mohr circles for both the initial and failure stress conditions.

   b) Plot the Mohr-Coulomb failure envelope.

   c) Determine the strength parameters, c' and □', for the sand.

   d) Determine the normal stress and shear stress on the failure plane at failure.

   e) Determine the angle of the failure plane in the specimen.

   f) Determine the maximum shear stress at failure and the angle of the plane on which acts. Calculate the available shear strength on this plane

2. Test B is a direct shear test. The normal stress of 60 kPa is held constant during the test. The initial horizontal stress is 30 kPa. At failure, the normal stress is still 60 kPa and the shear stress is 40 kPa.

   You are asked to determine:

   a) Principal stresses at failure.

   b) Orientation of the failure plane.

   c) Orientation of the major principal plane at failure.

   d) Maximum shear stress at failure and the angle of the plane on which acts. Calculate the available shear strength on this plane and the factor of safety on this plane. Compare this values to your answer in 1.(f) above.

   e) Of the two test results which ones do you trust the most. Describe the test steps in detail.

Question 4. Consolidation

20 Marks

1. A foundation is to be constructed at a site with the soil profile shown in **Figure Q4-1**. A sample of overconsolidated clay was obtained from the midheight of the clay layer. The oedometer test results are shown in **Figure Q4-2**. The additional stress at the midheight of the clay layer under the center of the foundation ($\Delta\sigma$) was calculated to be **$\Delta\sigma$=150 kPa**. You are asked to:

   a. Plot the total and effective stress profiles before construction from 0-8.5m.
   b. Calculate the final total and effective stresses at midheight of the overconsolidated clay layer.
   c. Determine the preconsolidation pressure of the soil.
   d. Calculate the primary consolidation settlement for the clay layer.

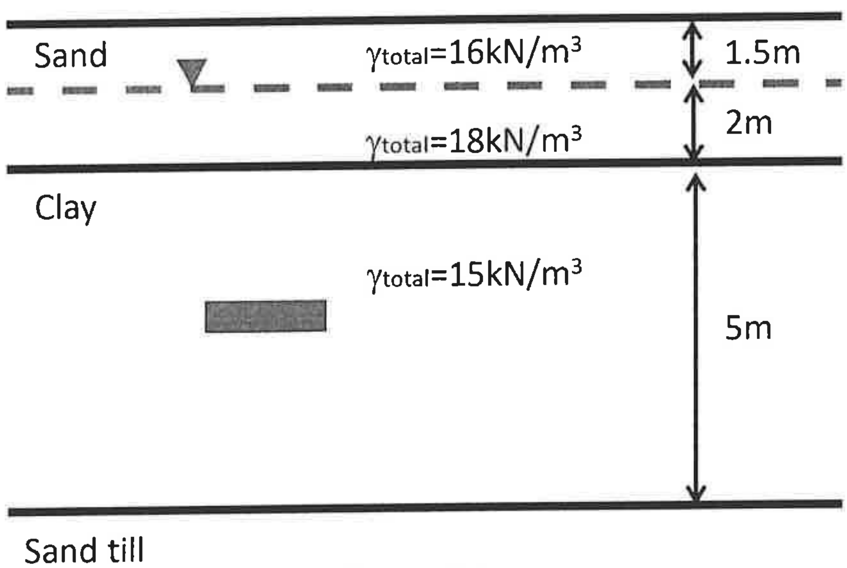


Figure Q4-1

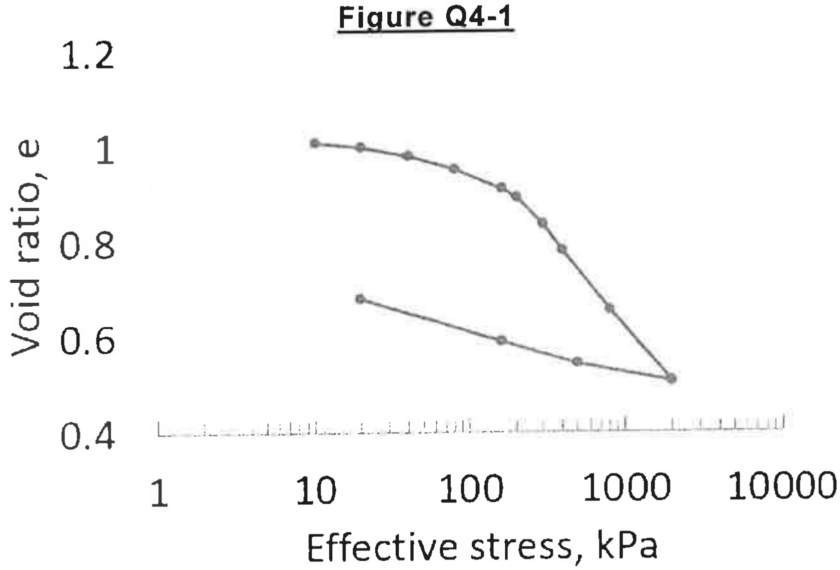


Figure Q4-2

Question 5. Seepage

20 Marks

1. Refer to the dam and the flow net shown in **Figure Q5-1**:
   $L = 30$ m, $H = 20$ m, $h_t = 10$ m, $D = 1$ m, $\gamma_{sat} = 21.3$ kN/m^3,
   $\gamma_w = 9.81$ kN/m^3 and points a, b, c, d and e are 7.5 m apart,

   You are asked to find:

   a. Write the Bernouli equation.

   b. Total head, elevation head, and porewater pressure head at points A, B, C, and D, assuming that their depths below the ground surface are $z_A = 10$ m, $z_B = 15$ m, $z_C = 6$m and $z_D = 9$ m.

   c. The rate of seepage volume under the dam per unit length if $k = 3 \times 10^{-3}$cm/s.

   d. Draw the pore water pressure diagram along the base of the dam between **1** and **5** based on pore water pressure values at **1, 2, 3, 4** and **5**. Calculate the total uplift force per unit length between **1** and **5**.

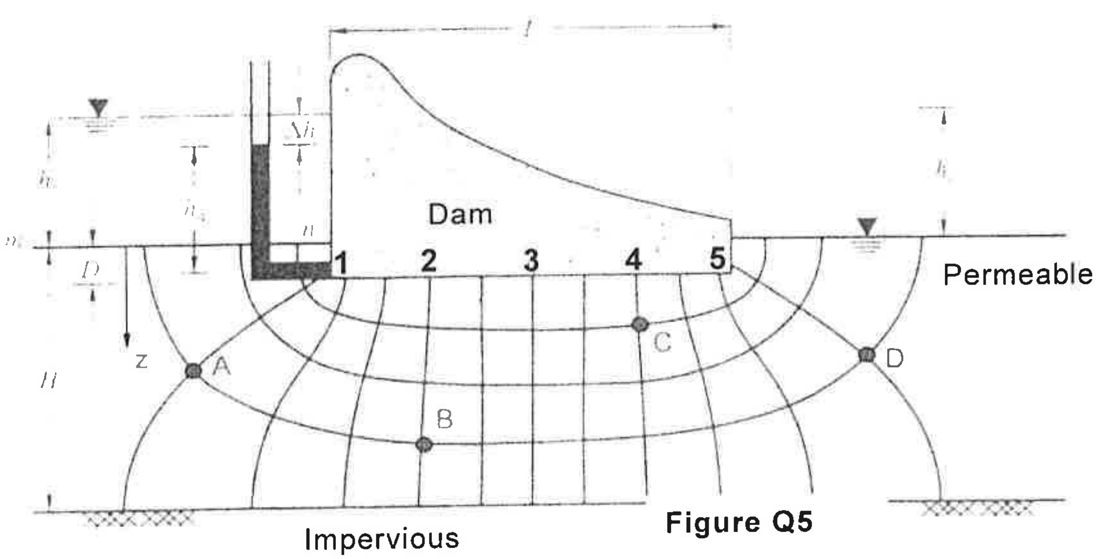


Figure Q5-1.

Question 6. Optional Questions

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

5 Marks each

1) Write 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.

6) Soil behaviour is affected by water content. Describe the change in strength and stiffness of a clay soil based on its water content and relate it to consistency (Atterberg) limits.

7) A falling head test was performed on a soil. The soil specimen was 5 cm diameter and 10 cm tall. The head in the 5 mm diameter burette fell from 1.25 m to 1.15 m in 35 minutes.
   a) Calculate the conductivity of the soil in centimeters per second.
   b) What type of soil was being tested?

8) A soil has gravimetric water content of 15%, void ratio of 0.54 and specific gravity of 2.6. Calculate the soil's dry density, volumetric water content and degree of saturation.

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 =QL/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/s²

Pressure → Pascal (Pa) → 1 Pa = 1N/m²

→ 1 kPa = 1 kN/m²

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

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

$\sigma' = \sigma - u$

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

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

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

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

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

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

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

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

$\alpha_{ff} = 45° + \phi/2$

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

n=e/(1+e)

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

$a = c'\cos\phi'$

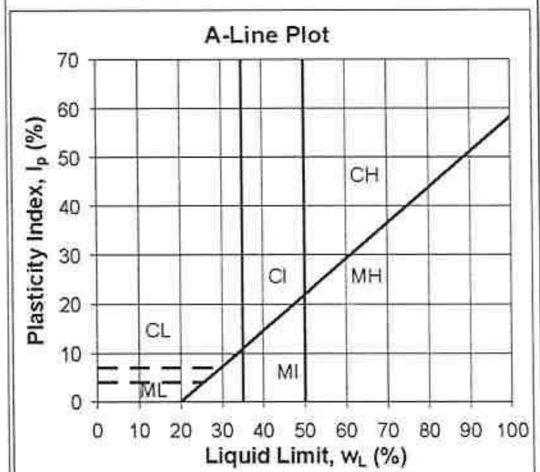
United Soil Classification System

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 FOR UNDISTURBED SOILS ADD INFORMATION ON STRATIFICATION, DEGREE OF COMPACTNESS, CEMENTATION, MOISTURE CONDITIONS & DRAINAGE CHARACTERISTICS	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: $C_U = \frac{D_{60}}{D_{10}}$ $C_C = \frac{(D_{30})^2}{D_{10}D_{60}}$ LESS THAN 5%; GW, GP, SW, SP MORE THAN 12% GM, GC, SM, SC 5% TO 12% BORDERLINE CASES REQ. USE OF DUAL SYMBOLS	$C_U > 4;\ 1 < C_C < 3$	
			Predominantly one size of a range of sizes with some intermediate sizes missing	GP	POORLY GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES			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			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			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			$C_U > 6;\ 1 < C_C < 3$	
			Predominantly one size of a range of sizes with some intermediate sizes missing	SP	POORLY GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES			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 $I_P>7$	

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

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 FOR UNDISTURBED SOILS AND INFORMATION ON STRUCTURE, STRATIFICATION, CONSISTENCY IN UNDISTURBED & REMOULDED STATES, MOISTURE & DRAINAGE CONDITIONS
			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	
			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	



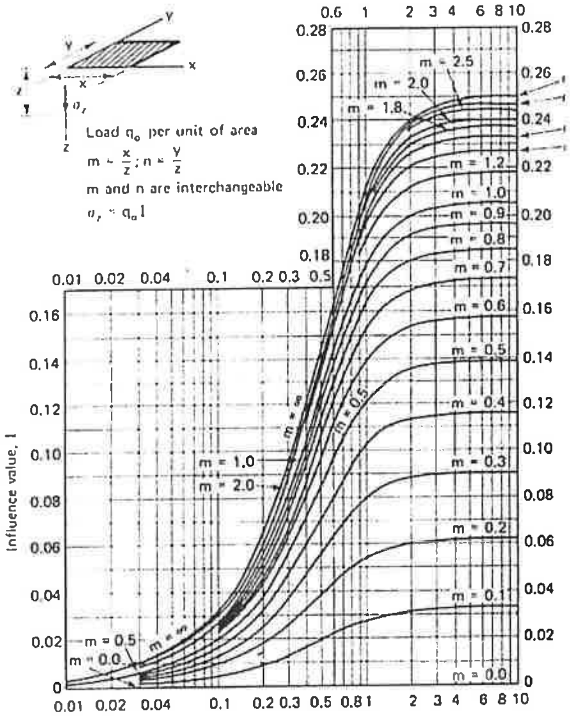


Fig. 8.21 Influence value for vertical stress under corner of a uniformly loaded rectangular area (after U.S. Navy, 1971).

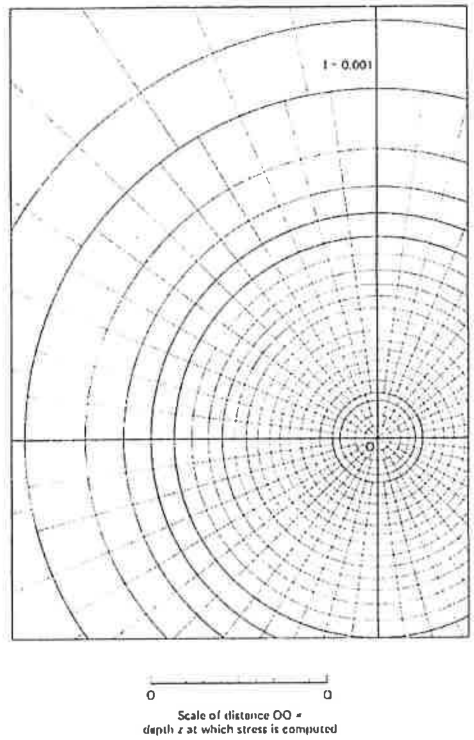


Fig. 8.25 Influence chart for vertical stress on horizontal planes (after Newmark, 1942).

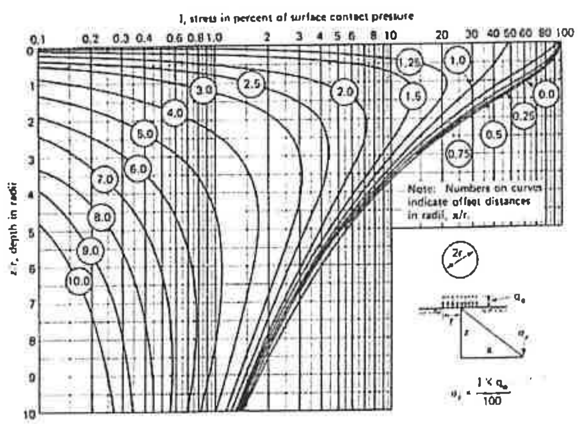
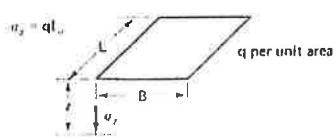


Fig. 8.32 Influence values, expressed in percentage of surface contact pressure, q_o, for vertical stress under uniformly loaded circular area (after Foster and Ahlvin, 1954, as cited by U.S. Navy, 1971).

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



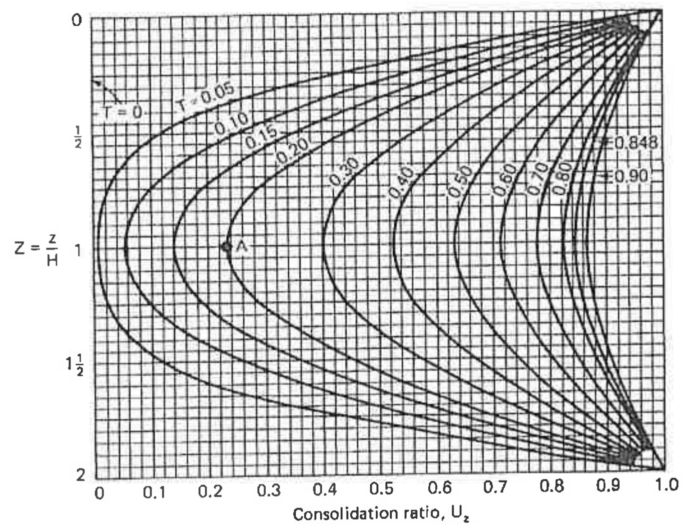
Boussinesq Case

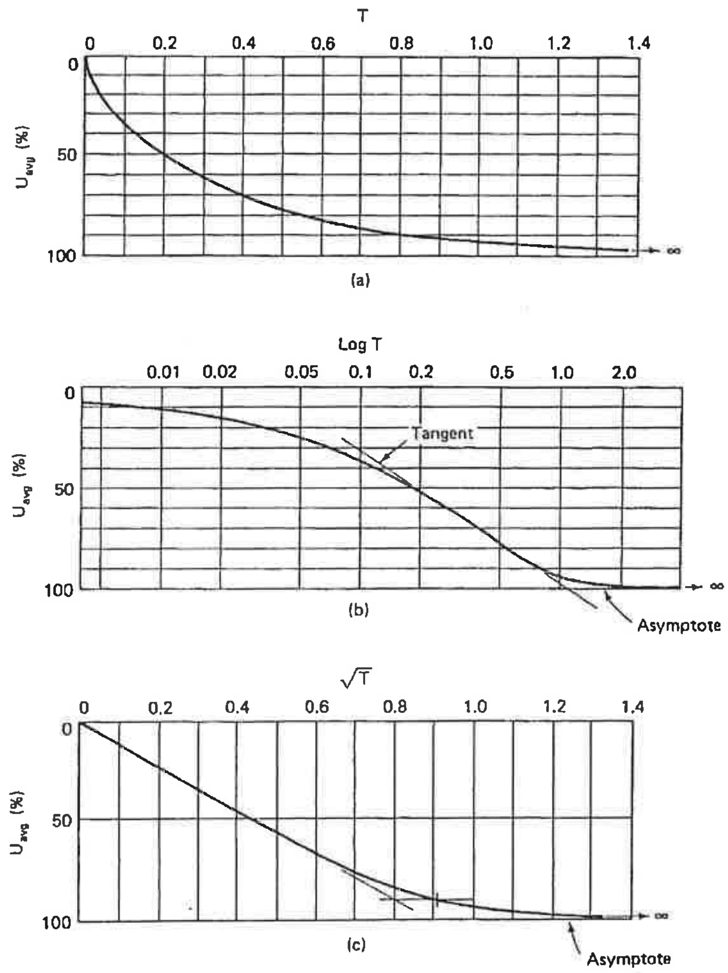
B/z \ L/z	0.1	0.2	0.4	0.6	0.8	1.0	2.0	∞
0.1	0.005	0.009	0.017	0.022	0.026	0.028	0.031	0.032
0.2	0.009	0.018	0.033	0.043	0.050	0.055	0.061	0.062
0.4	0.017	0.033	0.060	0.080	0.093	0.101	0.113	0.115
0.6	0.022	0.043	0.080	0.107	0.125	0.136	0.153	0.156
0.8	0.026	0.050	0.093	0.125	0.146	0.160	0.181	0.185
1.0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