National Exams **May 2016**

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. Candidates must choose three (3) more questions out of the five (5) options in Question 6. 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 no plasticity. Soil B has a liquid limit of 70% and a plastic limit of 25%.

15 marks

Table Q1

		Percent Finer	
Metric Sieve Size	**US Sieve Size**	**Soil A**	**Soil B**
75 mm	3 in	100	100
50 mm	2 in	100	100
25 mm	1 in	95	100
19 mm	0.75 in	90	100
9.5 mm	0.375 in	75	100
4.76 mm	No. 4	70	100
2.38 mm	No. 8	55	100
0.84 mm	No. 20	35	97
420 μm	No. 40	25	92
150 μm	No. 100	15	82
75 μm	No. 200	7	75

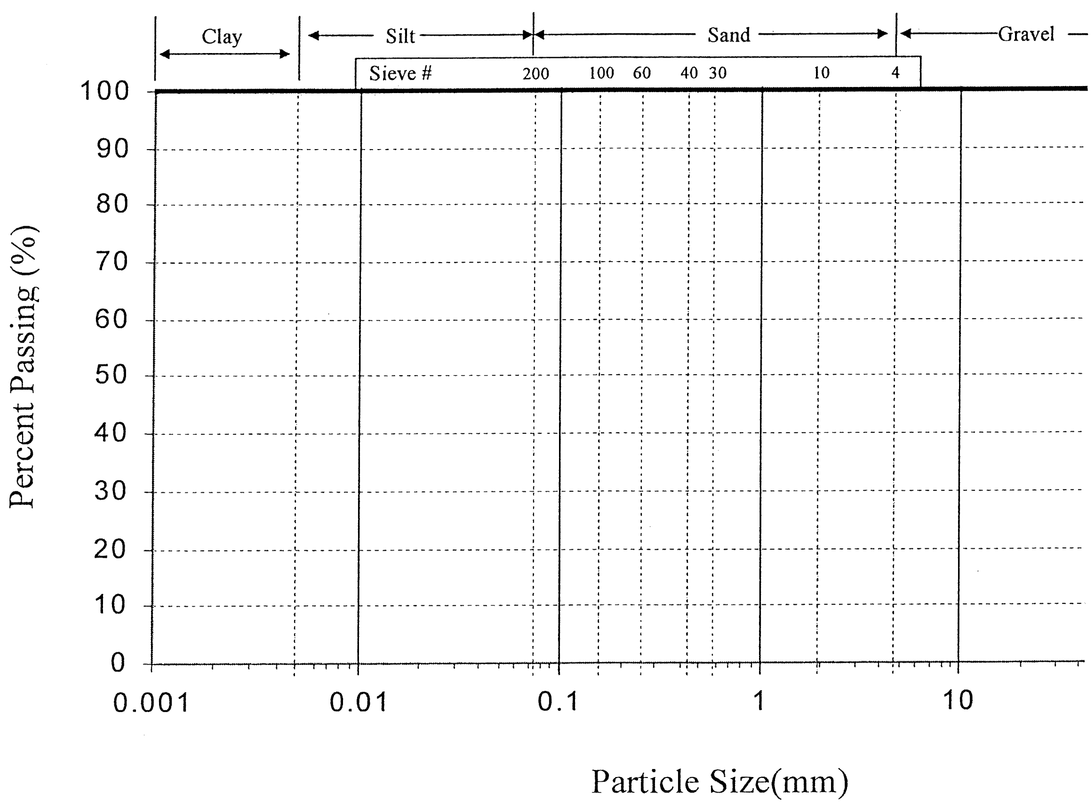


Figure Q1

Question 2. Soil Physical Properties

15 marks

1. For a given soil, e =0.70, w = 15%, and G_s =2.70. If any assumptions are required, state them clearly.

   Calculate:
   a) The porosity
   b) Moist unit weight
   c) Dry unit weight
   d) degree of saturation
   e) the mass of water to be added to 10 m^3 of soil for full saturation

2. An embankment for a highway is to be constructed from a soil compacted to a dry unit weight of 16.5 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 14 kN/m^3 and its natural water content is 4.5%. 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 and drained (CD) triaxial compression tests (tests A and B) were conducted on dense dry sand at the same void ratio. Test A had a cell pressure of 150 kPa, while in test B the cell pressure was 600 kPa (u=0kPa). These stresses were held constant throughout the test. At failure, they had maximum principal stress differences of 600 and 2550 kPa, respectively. You are asked to:
   a) Plot the Mohr circles for both tests at initial conditions and at failure.
   b) Determine shear strength of this soil.
   c) Determine the shear stress on the failure plane at failure for both tests?
   d) Determine the orientation of the failure plane in each specimen (use equations or graphical solution).
   e) Determine the orientation of the major principal plane at failure.
   f) Determine the orientation of the plane of maximum shear stress at failure
   g) If these soil samples were tested in direct simple shear, would the soil exhibit compression or dilation?

Question 4. Consolidation

20 marks

1. A foundation is to be constructed at a site where the soil profile is as shown in Figure Q-4. A sample of overconsolidated clay was obtained from the midheight of the clay layer. The initial in-situ void ratio e_0 of the overconsolidated clay layer is 0.72. The compression index $C_c = 0.28$, recompression index $C_r = 0.054$, the coefficient of consolidation $c_v = 2.68\text{x}10^{-4}$ cm^2/s and preconsolidation stress, σ'_p = 180 kPa. The net consolidation pressure at the mid-height of the clay layer under the center of the foundation ($\Delta\sigma$) was calculated to be 65.4 kN/m². You are asked to:

a. Plot the total and effective stress profiles before construction.
b. Calculate the primary consolidation settlement for the clay layer.
c. How many years will it take for 50% of the total expected primary consolidation settlement to take place?
d. Calculate the final total and effective stresses at mid-height of the overconsolidated clay layer.
e. Compute the amount of primary consolidation settlement that will occur in 1 year.
f. It is suspected that there might be a layer of sand at the bottom of the overconsolidated clay layer. What would be the answers to questions 3 and 5 in this case?

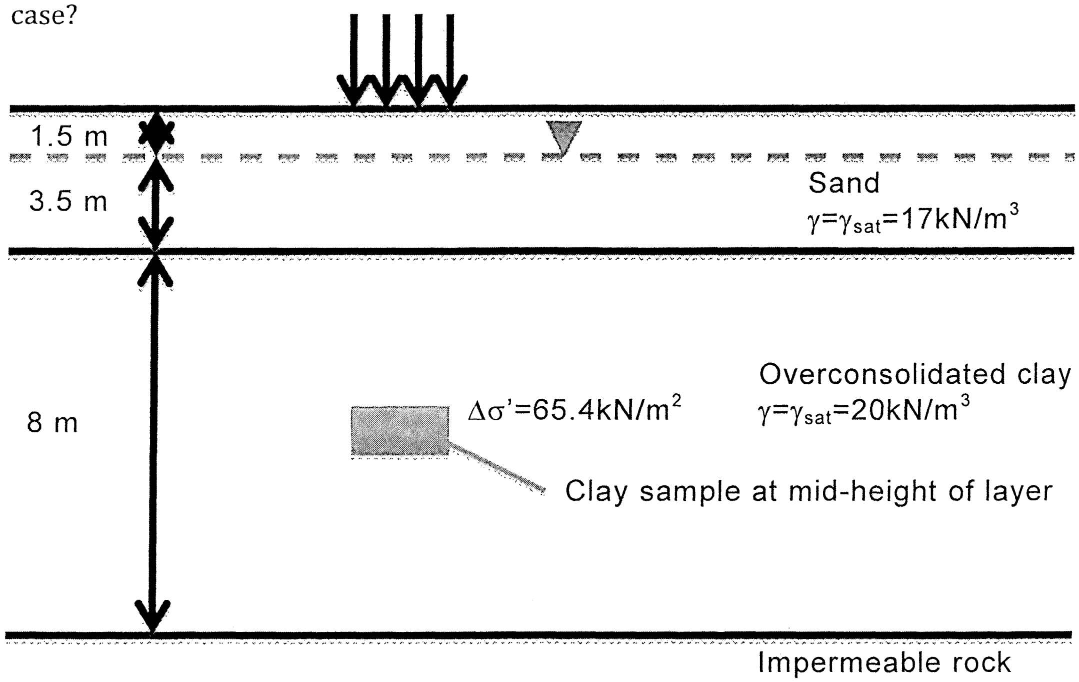


Figure Q-4

Question 5. Seepage

15 marks

Two configurations are shown in the Figures below for a concrete dam constructed on a saturated homogeneous clay layer. The conductivity of the clay layer is 4×10^{-6} m/s. For BOTH configurations you are asked to:

1. Label the boundary conditions at A and B.
2. Calculate total head, elevation head and pressure head for points 1 and 2.
3. Plot the distribution of pore pressure head along the bottom of the dam.
4. Calculate the flow under the dam.
5. Without any calculation, show which of the two dams is subject to the highest uplift forces?

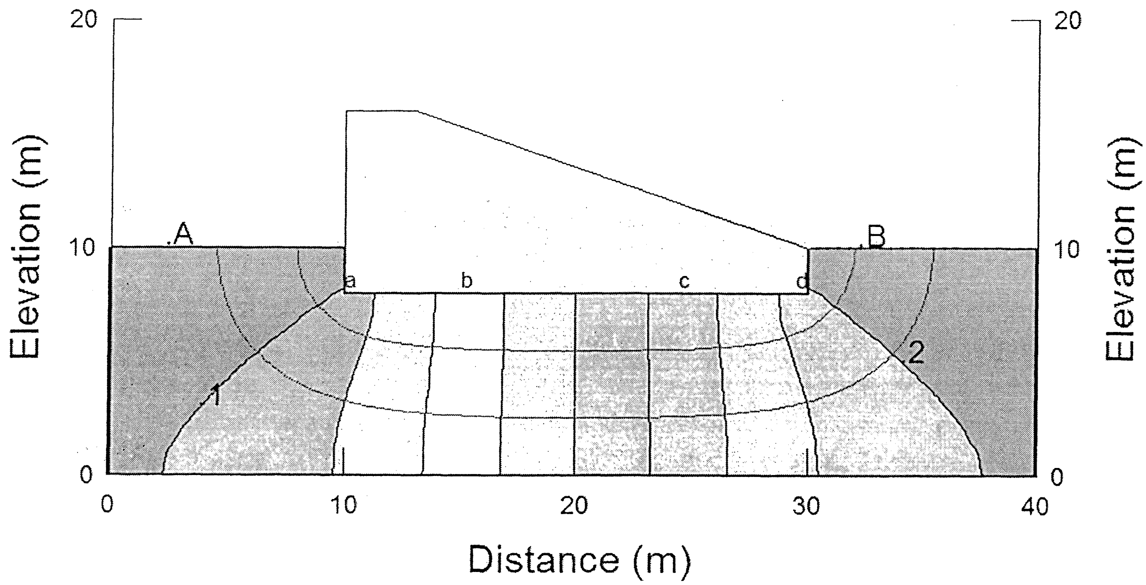


Figure Q5-1. Configuration A

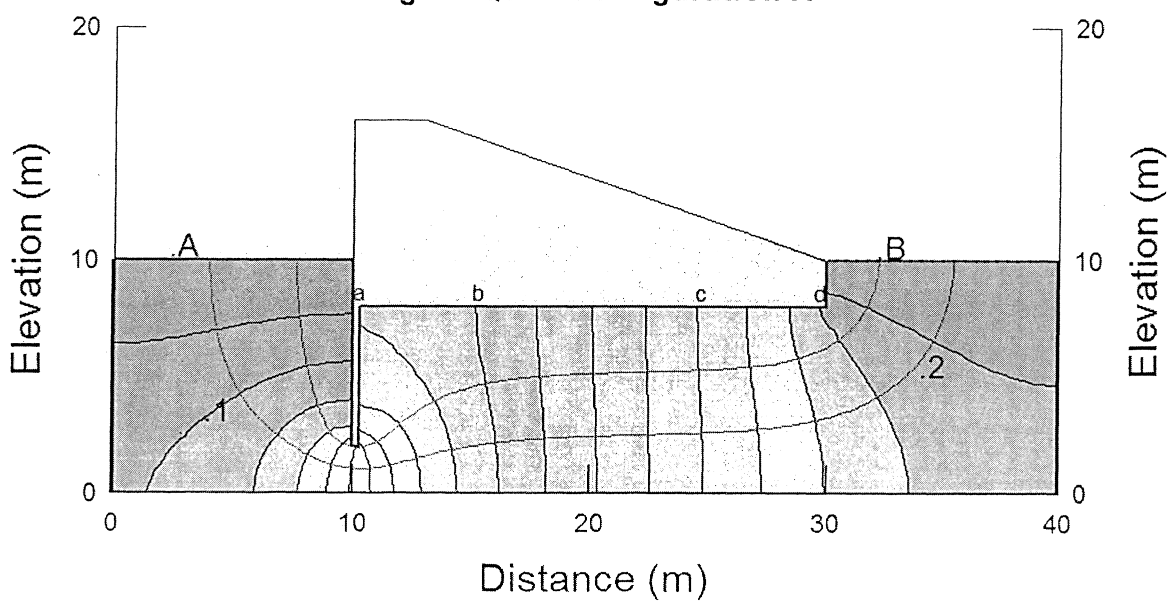


Figure Q5-2. Configuration B

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)

$I_P = 0.73(w_L - 20)$

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

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

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

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

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

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

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

$$v = ki$$

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

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

$$q = vA = kiA$$

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

$$\mathrm{k} = \frac{\mathrm{aL}}{\mathrm{A}\Delta \mathrm{t}} \ln \frac{\mathrm{h}_1}{\mathrm{h}_2} = 2.3 \frac{\mathrm{aL}}{\mathrm{A}(\mathrm{t}_2 - \mathrm{t}_1)} \log \frac{\mathrm{h}_1}{\mathrm{h}_2}$$

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/s^2

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

→ 1 kPa = 1 kN/m^2

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

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

$$\sigma' = \sigma - u$$

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

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

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

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

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

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

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

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

$\alpha_{ff} = 45^\circ + \phi/2$

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

$n = e/(1+e)$

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

$a = c'\cos\phi'$

United Soil Classification System

Coarse grained soils (more than half of material is larger than 75 µm)

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		
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 $I_P>7$	

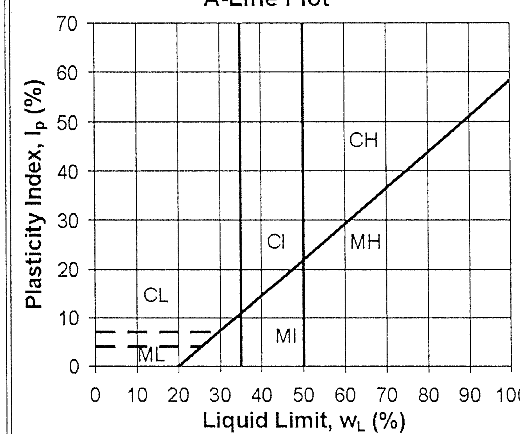
Fine grained soils (more than half of material is smaller than 75 µm)

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
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	

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

A-Line Plot



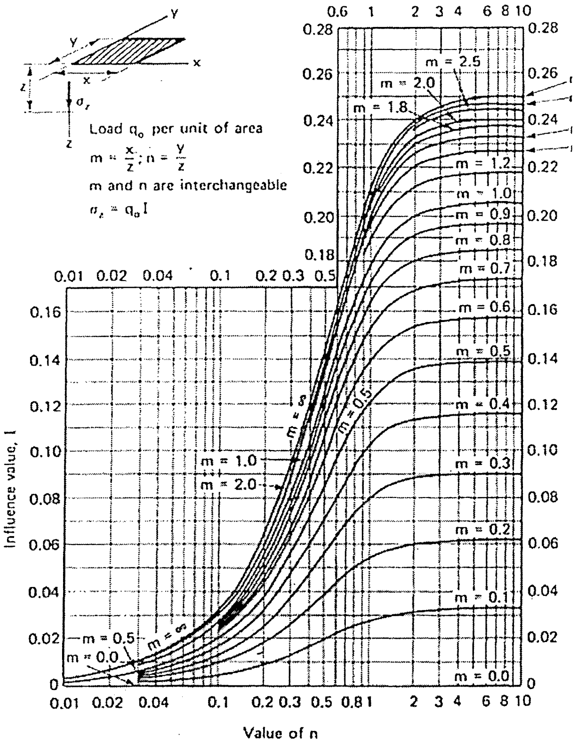


Fig. 8.21 Influence value for vertical stress under corner of a uniformly loaded rectangular area (after U.S. Navy, 1971).

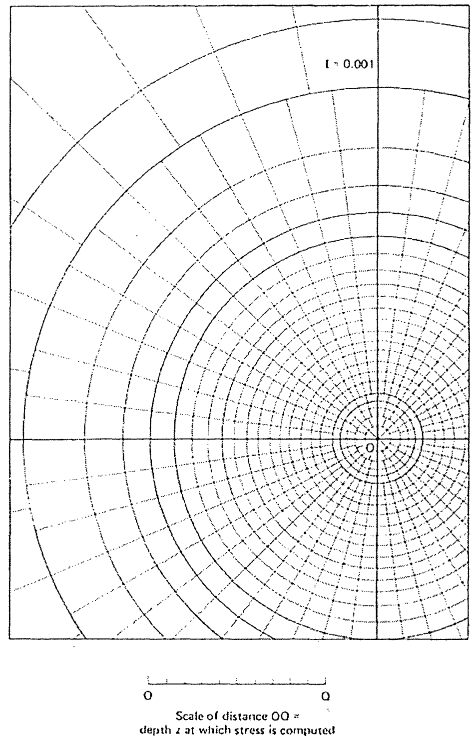


Fig. 8.25 Influence chart for vertical stress on horizontal planes (after Newmark, 1942).

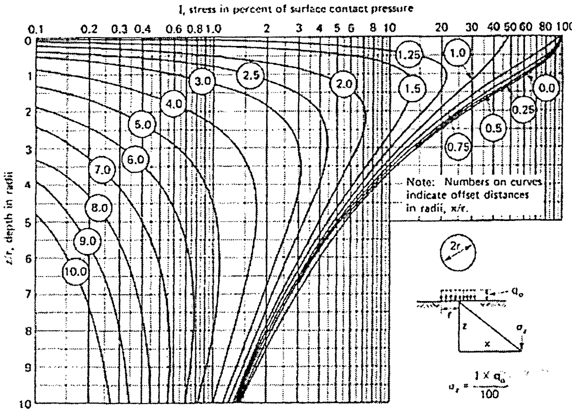
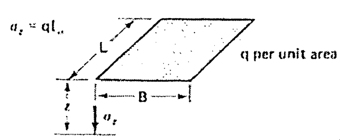


Fig. 8.22 Influence values, expressed in percentage of surface contact pressure, q_o, for vertical stress under uniformly loaded circular area (after Foster and Ahlvin, 1954, as cited by U.S. Navy, 1971).

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



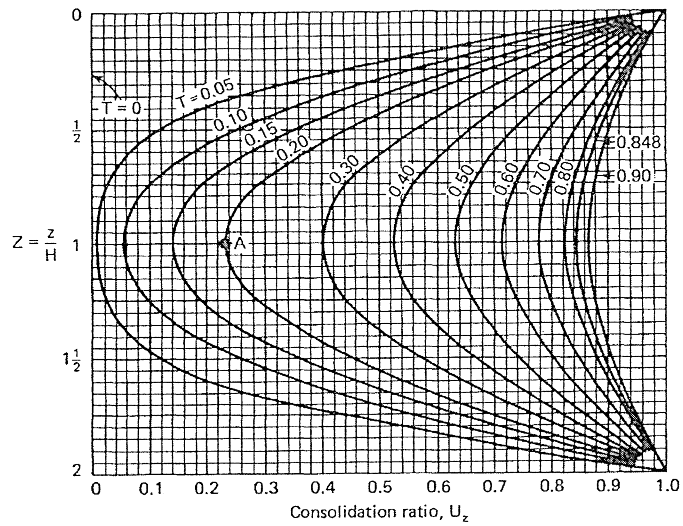
Boussinesq Case

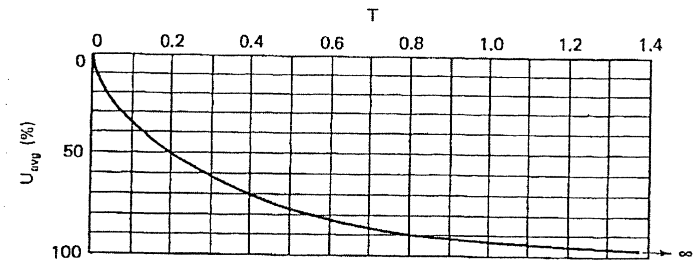
B/z	L/z: 0.1	0.2	0.4	0.6	0.8	1.0	2.0	∞
0.1	0.005	0.009	0.017	0.022	0.026	0.028	0.031	0.032
0.2	0.009	0.018	0.033	0.043	0.050	0.055	0.061	0.062
0.4	0.017	0.033	0.060	0.080	0.093	0.101	0.113	0.115
0.6	0.022	0.043	0.080	0.107	0.125	0.136	0.153	0.156
0.8	0.026	0.050	0.093	0.125	0.146	0.160	0.181	0.185
1.0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

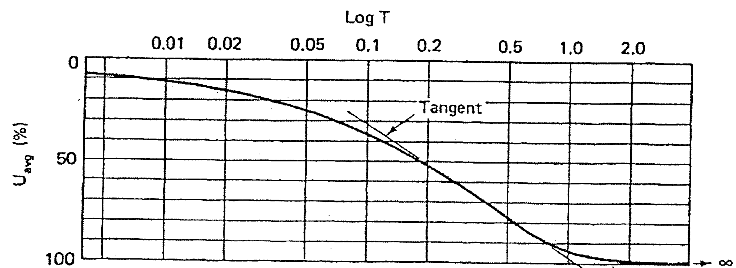
B/z	L/z: 0.1	0.2	0.4	0.6	0.8	1.0	2.0	∞
0.1	0.003	0.006	0.011	0.014	0.017	0.018	0.021	0.022
0.2	0.006	0.012	0.021	0.028	0.033	0.036	0.041	0.044
0.4	0.011	0.021	0.039	0.052	0.060	0.066	0.077	0.082
0.6	0.014	0.028	0.052	0.069	0.081	0.089	0.104	0.112
0.8	0.017	0.033	0.060	0.081	0.095	0.105	0.125	0.135
1.0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

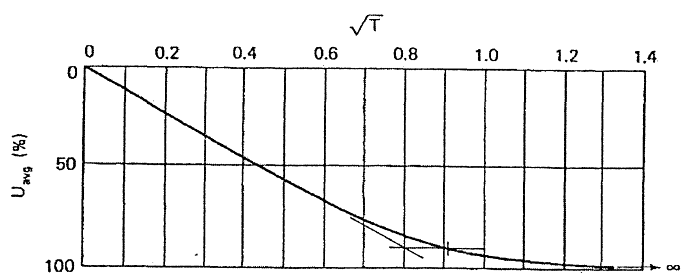




(a)



(b)



(c)

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