National Exams May 2015

04-Geol-06, 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 has a liquid limit of 32% and a plastic limit of 25%. Soil B has a liquid limit of 52% and a plastic limit of 32%.

15 marks

Table Q1

Metric Sieve Size	US Sieve Size	Percent Finer Soil A	Percent Finer Soil B
75 mm	3 in	100	100
50 mm	2 in	99	100
25 mm	1 in	98	100
19 mm	0.75 in	96	100
9.5 mm	0.375 in	-	100
4.76 mm	No. 4	77	100
2.38 mm	No. 8	-	96
0.84 mm	No. 20	55	94
420 μm	No. 40	-	73
150 μm	No. 100	30	-
75 μm	No. 200	18	55

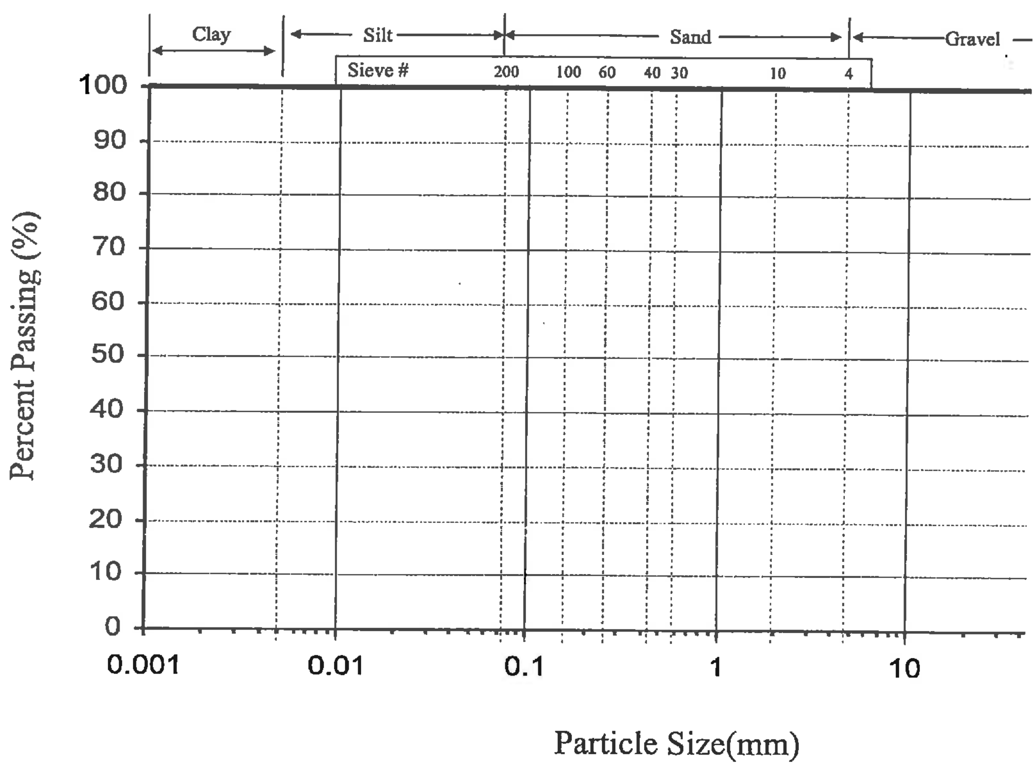


Figure Q1

Question 2. Soil Physical Properties

15 marks

1. For a given soil, e =0.75, w = 22%, and Gs =2.66. 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. A sample of soil plus container weighs 397.6 g when the initial water content is 6.3%. The container weighs 258.7 g. How much water needs to be added to the original specimen if the water content is to be increased by 3.4%?

3. An embankment for a highway is to be constructed from a soil compacted to a dry unit weight of 18 kN/m^3 at water content of 7%. 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 17 kN/m^3 and its natural water content is 5%. Calculate:

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

Question 3. Shear Strength / Slope Stability

20 marks

1. A volume of sand (ϕ' = 30°) is in a state of failure. Within that volume, a plane which makes a 30° angle with respect to the horizontal, has a normal stress of 50 kPa and a shear stress of 10 kPa. There are two Mohr circles that satisfy these conditions. Using the graph paper on the next page:

   a) For the smaller of the two possible circles, find the principal stresses and their orientation with respect to the horizontal.

   b) What are the normal and shear stresses on the failure planes, for that failure mode?

2. Describe the general approach common to all limit equilibrium methods of slope stability analysis.

Question 4. Consolidation

20 marks

1. Consider the following stratigraphy:

0 to 5m	Sand Total unit weight, γ_t = 21 kN/m^3
5 to 8m	Saturated grey clay Overconsolidation ratio (OCR) = 1.5 γ_t = 19 kN/m^3 e_0 = 0.993 c_v = 0.81 m^2/yr C_c = 0.15 C_r = 0.02
Below 8m	Impervious rock

The water table is at the sand-clay interface

a. Calculate the average stress increase within the clay, below the center of a 5m x 5m uniform load of 500 kN/m^2 at the ground surface.

b. A different load at the surface is expected to induce an average stress increase of 150 kPa in the clay. Calculate the settlement of the clay, 2 years after the application of the load.

Question 5. Seepage

15 marks

Refer to the dam and the flow net shown in Figure Q5: L = 20 m, H = 10 m, h_t = 10 m, D = 1 m, γ_{sat} = 20 kN/m^3, γ_w = 10 kN/m^3 and points 1, 2, 3, 4, and 5 are 5 m apart, find:

1. The quantity of seepage loss under the dam when k = 6 x10^{-3}cm/s
2. Total head, elevation head, and pore water pressure head at points A, B, C, and D, assuming that z_A =10 m, z_B = 15 m, z_C =6m and z_D = 9 m
3. Draw the pore water pressure diagram between points 1 and 5 based on pore water pressure values at points 1, 2, 3, 4, and 5 located at the base of the Dam. Calculate the total uplift force between 1 and 5.

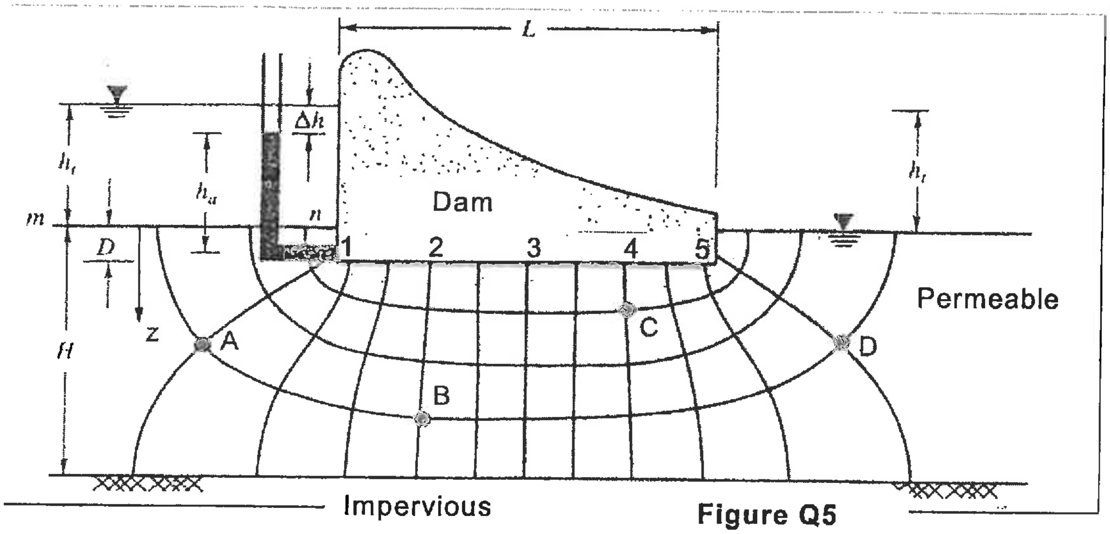


Figure Q5

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 2230 g wet and 1852 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 10 m thick sand layer with the groundwater table 2 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 =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

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

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

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

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

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

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

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

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

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

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

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

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

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

n=e/(1+e)

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

$a = c'\cos\phi'$

United Soil Classification System

FIELD IDENTIFICATION PROCEDURES (Excluding particles larger than 75 mm and basing fractions on estimated mass)

Major division	Division	Group	Field identification	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	$C_U > 4; 1 < C_C < 3$	
			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	

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:

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

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

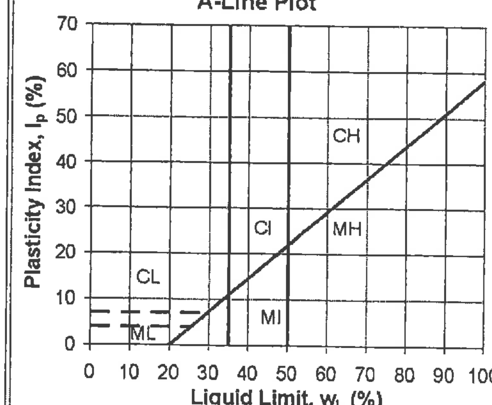
LESS THAN 5%; GW, GP, SW, SP
MORE THAN 12% GM, GC, SM, SC
5% TO 12% BORDERLINE CASES REQ. USE OF DUAL SYMBOLS

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

IDENTIFICATION PROCEDURES ON FRACTION SMALLER THAN 425 µm

Major division	Group	Liquid limit	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
			MEDIUM 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	

A-Line Plot



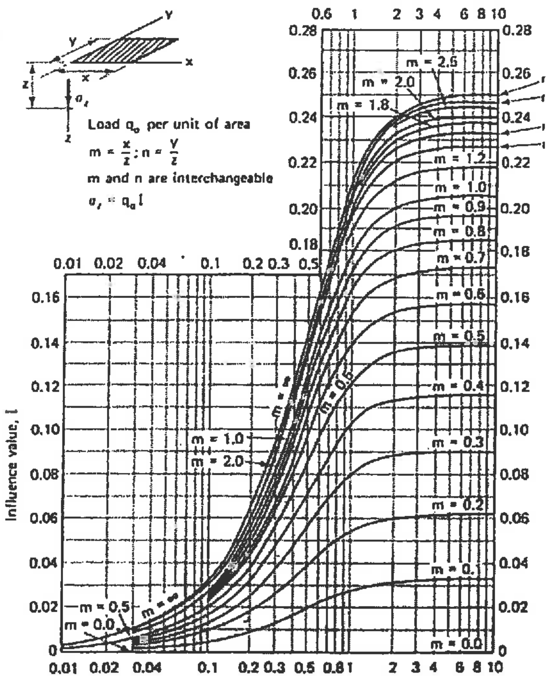


Fig. 8.21 Influence value for vertical stress under corner of a uniformly loaded rectangular area (after U.S. Navy, 1971).

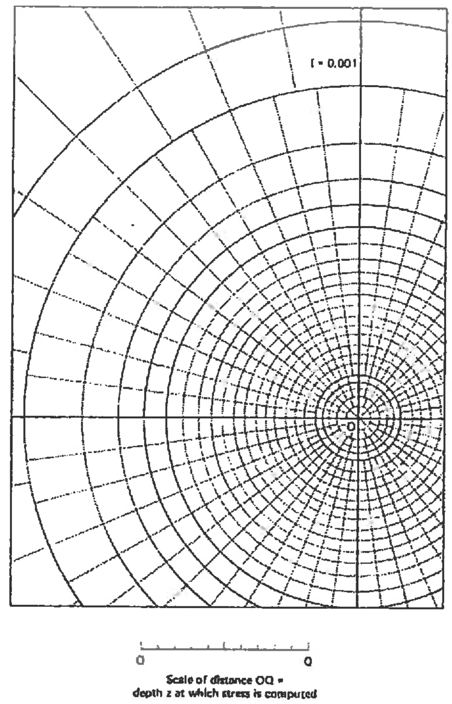


Fig. 8.25 Influence chart for vertical stress on horizontal planes (after Newmark, 1942).

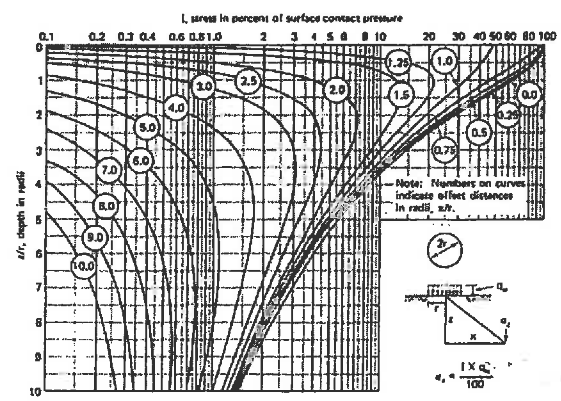
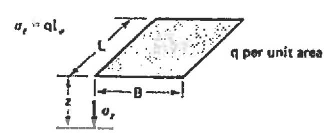


Fig. 8.22 Influence values, expressed in percentage of surface contact pressure, q_o, for vertical stress under uniformly loaded circular area (after Foster and Ahlvin, 1954, as cited by U.S. Navy, 1971).

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



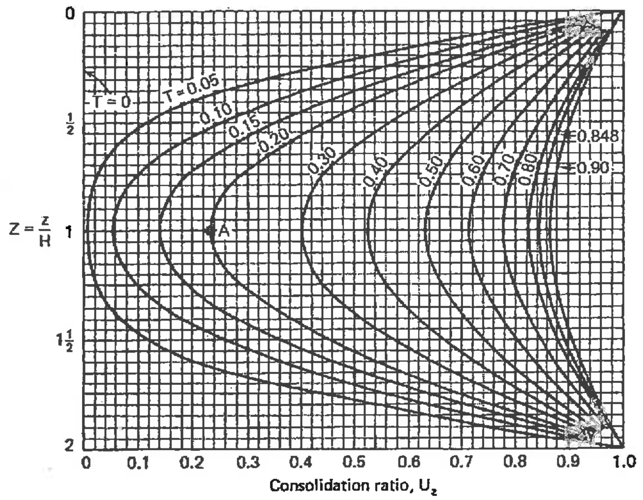
Boussinesq Case

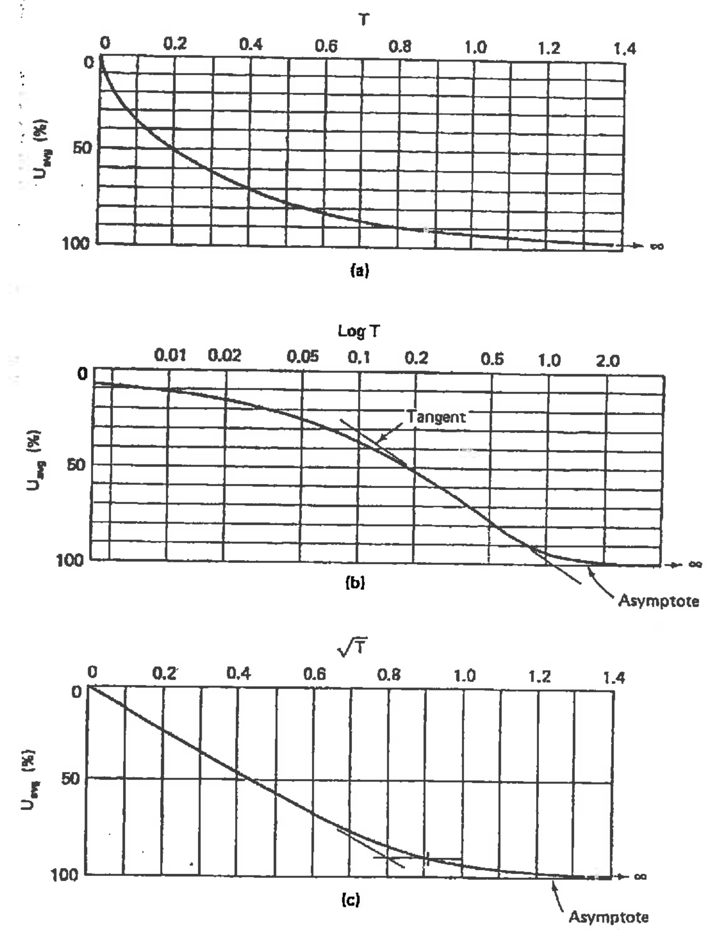
B/z	L/z 0.1	0.2	0.4	0.6	0.8	1.0	2.0	∞
0.1	0.005	0.009	0.017	0.022	0.026	0.028	0.031	0.032
0.2	0.009	0.018	0.033	0.043	0.050	0.055	0.061	0.062
0.4	0.017	0.033	0.060	0.080	0.093	0.101	0.113	0.115
0.6	0.022	0.043	0.080	0.107	0.125	0.136	0.153	0.156
0.8	0.026	0.050	0.093	0.125	0.146	0.160	0.181	0.185
1.0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





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