UNAM
UNIVERSITY OF NAMIBIA

FACULTY	AGRICULTURE, ENGINEERING AND NATURAL SCIENCES		
SCHOOL	ENGINEERING AND THE BUILT ENVIRONMENT		
DEPARTMENT	CIVIL AND MINING ENGINEERING		
SUBJECT	SOIL MECHANICS		
SUBJECT CODE	TCVD3682		
DATE	NOVEMBER 2023		
DURATION	3 HOURS	**MARKS**	100

First Opportunity Examination

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This question paper consists of **5** pages excluding this front page.
Additionally, **4** answer sheets and **4** pages of equations, charts and tables are provided.

Instructions

1. Closed book examination.
2. Read the questions carefully.
3. The paper contains 5 questions. **Attempt any four (4) questions** for full marks.
4. Some relevant equations, tables and charts have been provided.
5. Answers should be brief and to-the-point and where necessary be supplemented with neat sketches.
6. Marks for each question are indicated.
7. Any missing or 'wrong' data may be assumed suitably giving proper justification.

Question 1 – Soil Classification & Compaction (25 marks)

a) The results of a sieve analysis of a soil specimen is given in Table Q1.

Table Q1: Results of sieve analysis

Sieve Number	Diameter (mm)	Mass of soil retained on each sieve (g)
4	4.75	0
10	2	40
20	0.85	60
40	0.425	80.
60	0.25	150
100	0.15	130
140	0.106	210
200	0.075	56
Pan		12

i. Plot the grain size distribution curve. [6]
ii. Determine D_{10}, D_{30}, and D_{60}. [3]
iii. Compute C_c and C_u [2]
iv. Determine the percentage of gravel, sand silt and clay according to USCS [2]
v. Classify the soil material using USCS classification system. [2]

b) An embankment requires 3000 m^3 of fill material with a dry unit weight of 18 kN/m^3 and water content, w = 14%. The burrow pit has the following characteristics bulk unit weight = 19 kN/m^3, water content, w =16% and specific gravity, G_s = 2.70. Determine how much material should be excavated from the burrow pit. [10]

Question 2 – **Effective Stress and Applied stresses** **(25 marks)**

a) Define effective stress and state its significance in soil mechanics. [3]

b) Compute the change in the effective over burden stress at point A due to lowering of the water table from -8 m to -12 m at a construction site shown Figure Q2a. [10]

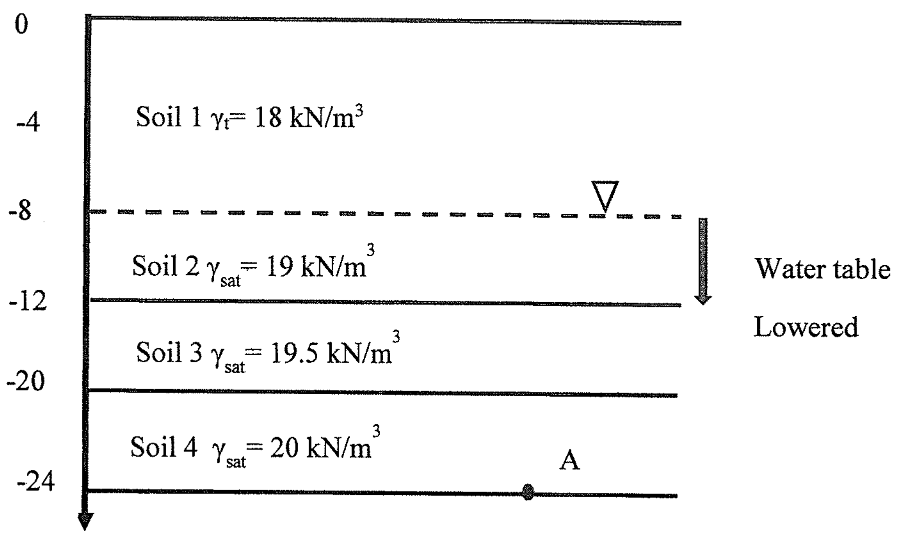


Figure Q2a

c) What is the consequence of lowering this water table? [2]

d) A foundation with dimensions shown in plan in Figure Q2b carries a uniform load of q = 80 kN/m^2. Compute the vertical stress increase under points A and B at a depth of z = 4 m. [10]

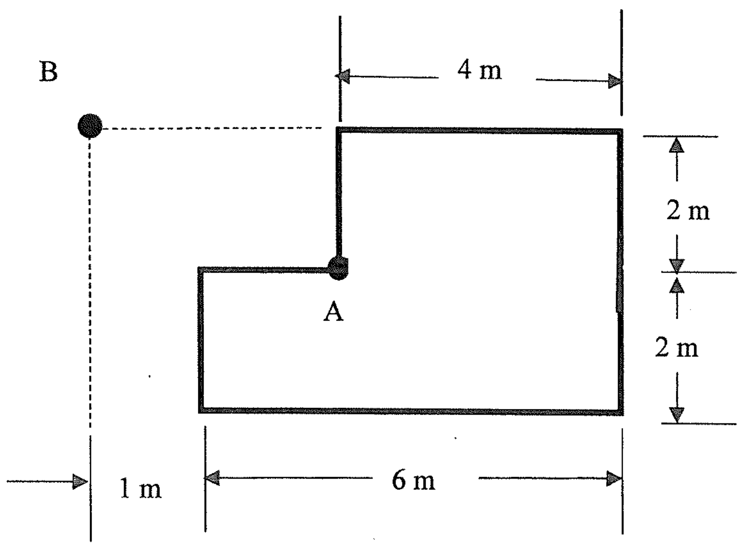


Figure Q2b

Question 3 – **Soil Hydraulics** **(25 marks)**

a) List two different methods of determining the permeability coefficient of a soil in the laboratory. State for which type of soil each of the methods is utilized. [4]

b) In a laboratory permeability test, the initial head of 1.0 m dropped to 0.35 m in 2 hours and the diameter of the standpipe was 5 mm. The soil specimen had dimensions of 200 mm long and 100 mm diameter. Calculate the coefficient or permeability of the soil. [6]

c) A soil stratum has a permeability of, k =5 x 10^{-9} m/s overlying an impermeable stratum at a depth of 18 m below the ground surface as shown in Figure Q3. A sheetpile is driven to a depth of 8 m below the soil surface. The water level on the upstream side of the wall is at a height of 9 m above the soil surface and 1.5 on the downstream side. The point P is located at a depth of 8 m below the soil surface and 4 m away from the sheet pile wall on the upstream side

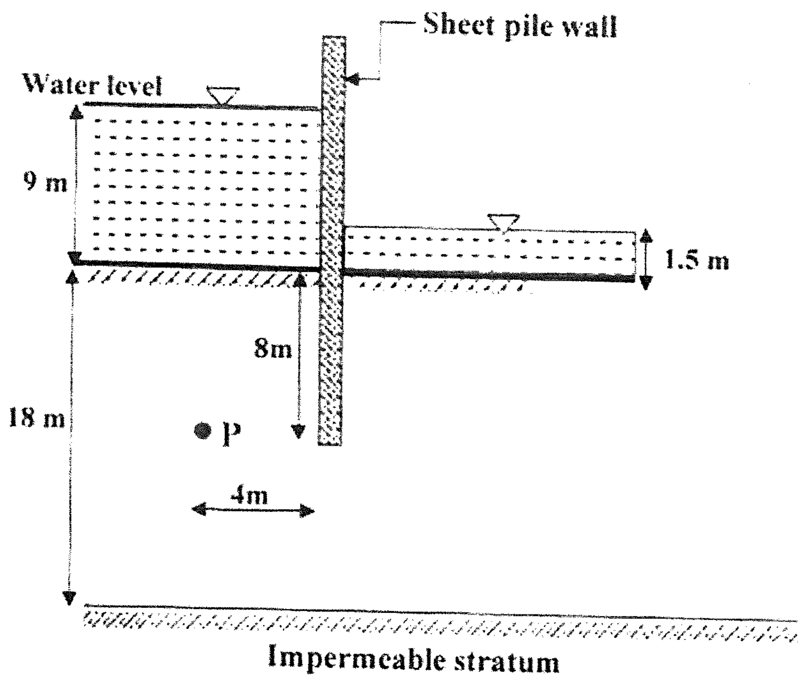


Figure Q3

i. Construct the flow net and determine the quantity of seepage, q, in m^3/day. [10]
ii. Determine the pore pressure at point P. [3]
iii. State two methods that can be used to increase the factor of safety against piping. [2]

Question 4 – **Consolidation & Settlement** **(25 marks)**

a) Define a normally consolidated clay and give some reasons for its occurrence. [5]

b) The results of a consolidation tests carried out on a clay specimen 20 mm thick with drainage taking place both at the top and bottom is given in Table Q 4.

Table Q 4: Results of consolidation test.

Time (min)	Vertical deformation dial reading (mm)
0	8.60
0.1	8.30
0.25	8.10
0.5	7.92
1	7.56
2	7.12
4	6.78
10	6.63
15	6.59
30	6.52
120	6.44
245	6.42
620	6.38
1420	6.34

Determine t_{90} and Cv by square root of time method (Taylor's method). [10]

c) A sand layer 12 m thick lies over a 10 m thick clay layer underlain by an impermeable rock. The water table is located which undergoes continuous dewatering for a period of 45 weeks. The unit weight of the dry sand is 17 kN/m^3 and the saturated unit weight of the sand and clay are 19 and 21 kN/m^3 respectively. The relationship between the void ratio and the effective stress as the dewatering occurs is given by $e = 0.9 - 0.3log\left(\frac{\sigma'}{100}\right)$ and C_v is given as 1.4

i. Make an appropriate sketch of the soil profile with all relevant parameters. [2]

ii. Determine the final settlement of the clay including the settlement after 4 years of dewatering. [8]

Question 5 – Shear strength of soil **(25 marks)**

a) Make a sketch indicating the directions of the failure plane, failure envelope and friction angle of a specimen that has undergone a triaxial compression. **[5]**

b) The results of a consolidated undrained tests (CU), with pore pressure measurements on a saturated clay specimen is given Table Q5

Table Q5- results of (CU) tests

All round pressure (kN/m^2)	Principal stress difference (kN/m^2)	Pore water pressure (kN/m^2)
150	192	80
300	341	154
450	504	222

Determine the effective stress parameters c' and ϕ' [10]

c) A drained triaxial compression test on a normally consolidated clay specimen was carried out with σ_3' =100 kPa. After the test, the failure plane of the specimen had an angle of 55° to the horizontal. Determine

i. The effect angle of internal friction. [5]

ii. The deviator stress σ_1' at failure. [5]

Equations, Charts and Tables

Term	Symbol	Unit	Basic Equation	Formulae
Moisture Content	w	%	$\frac{m_w}{m_s}$	$m = \frac{W_w}{W_s}$; $m = \frac{eS}{G_s}$
Air Content	A	%	$\frac{V_a}{V_t}$	$\frac{V_a}{V_t}$
Void Ratio	e		$\frac{V_v}{V_s}$	$e = \frac{n}{1-n} = \frac{w \cdot G_s}{S_r}$
Porosity	n		$\frac{V_v}{V_t}$	$n = \frac{e}{1+e} = \frac{w \cdot G_s}{S_r + w \cdot G_s}$
Degree of Saturation	S_r	%	$\frac{V_w}{V_v}$	$S_r = \frac{\rho \cdot w \cdot G_s}{\rho_w \cdot G_s(1+w) - \rho_{bulk}} \cdot 100$
Air Voids Content	A_v	%	$\frac{V_a}{V_t}$	$A_v = n(1 - S_r)$; $\gamma_d = (1 - \frac{A}{100})\left[\frac{G_s \gamma_w}{G_s m + 1}\right]$
Particle Density	ρ_s	Mg/m³	$\frac{m_s}{V_s}$	$\rho_s = G_s \cdot \rho_w$
Specific Gravity	G_s		$\frac{\rho_s}{\rho_w}$	$G_s = \frac{(1+e)\rho_{dry}}{\rho_w}$
Water Density	ρ_w	Mg/m³	$\frac{m_w}{V_w}$	$\rho_w = 1.0$ Mg/m³
Bulk Density	ρ_{bulk}	Mg/m³	$\frac{m_t}{V_t}$	$\rho_{bulk} = \frac{G_s(1+w)\rho_w}{1+e}$
Saturated Density	ρ_{sat}	Mg/m³	$\frac{m_s + m_w}{V_s + V_w}$	$\rho_{sat} = \frac{(G_s + e)\rho_w}{1+e}$
Dry Density	ρ_{dry}	Mg/m³	$\frac{m_s}{V_t}$	$\rho_d = \frac{\rho_w G_s}{1-e} = \frac{\rho_b}{1+w}$
Buoyant Density	ρ'	Mg/m³	$\rho' = \rho_{sat} - \rho_w$	$\rho' = \frac{(G_s - 1)\rho_w}{1+e}$
Unit Weight	γ	kN/m³	$\rho \cdot g$	$\gamma_w = 9.81$ kN/m³
Total Vertical Stress	σ	kN/m²	γz	γz
Effective Stress	σ'	kN/m²	$\gamma' z$	$\gamma' z$

A soil is said to be well graded if the coefficient of curvature C_c lies between 1 and 3, with C_u greater than 4 for gravels and greater than 6 for sands.

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

$$\sigma_z = \frac{P}{z^2}\frac{3}{2\pi}\left[\frac{1}{\left(\frac{r}{z}\right)^2 + 1}\right]^{5/2} \qquad s = \int_0^H \Delta\varepsilon_{zz}\,dz \qquad E_u = \frac{3E'}{2(1+\upsilon')} \qquad T_v = \frac{c_v t}{H^2}$$

$$Q = kA\frac{\Delta h}{\Delta l} \qquad k_H = \frac{k_1 d_1 + k_2 d_2}{d_1 + d_2} \qquad k_V = \frac{d_1 + d_2}{\frac{d_1}{k_1} + \frac{d_2}{k_2}}$$

$$k = 2.3\,\frac{aL\ \log(H_1/H_2)}{A(t_2 - t_1)} \qquad k = \frac{XL}{AHT} \qquad C_u = \frac{D_{60}}{D_{10}}\ ;\ C_c = \frac{D_{30}^2}{(D_{60} \times D_{10})}$$

$$\sigma_1' = N_\phi \sigma_3' + 2c'\sqrt{N_\phi} \qquad k_{eq} = \sqrt{k_H k_V} \qquad k = c_v m_v \gamma_w$$

$$x = \alpha\bar{x} \qquad z = \bar{z} \qquad \Delta S = m_v . H_0 . \Delta\sigma'$$

$$\alpha = \sqrt{\frac{k_H}{k_V}} \qquad \sigma_z = \frac{3P}{2\pi}\frac{z^3}{R^5} \qquad U = \sqrt{\frac{4T_v}{\pi}} \qquad \Delta\sigma_z = \frac{P}{(B+z)(L+z)}$$

$$\sigma_z = qI \qquad \sigma_z = \frac{P}{z^2}I \qquad i = \Delta h/\Delta L \qquad Q = kAi$$

Gravel	G	76.2 to 4.75
Sand	S	4.75 to 0.075
Silt	M	Fines < 0.075
Clay	C	

$$u_i = \gamma_w (h_i - z_i) \qquad u_2 = \gamma_w (h_2 - z_2)$$

$$\tau_f = \sigma' \tan\phi \qquad u_1 = \gamma_w (h_1 - z_1)$$

$$k = \left(\frac{\dot{Q}}{\pi}\right)\frac{\ln(r_2/r_1)}{h_2^2 - h_1^2} \qquad k = \left(\frac{\dot{Q}}{2\pi D}\right)\frac{\ln(r_2/r_1)}{(h_2 - h_1)} \qquad N_\phi = \frac{1+\sin\phi'}{1-\sin\phi'}$$

$$\sigma_v = \gamma z \ ; \qquad \sigma' = \sigma - u \qquad \sigma_z = \frac{P}{z^2}I$$

$$Q = kH\frac{N_f}{N_h}\ ; \qquad h = \frac{u_w}{\gamma_w} + z\ ; \qquad FS = \frac{i_{crit}}{i}\ ; \qquad i_{crit} = \frac{\gamma_{sat} - \gamma_w}{\gamma_w}$$

$$s = \frac{p\,a}{E_0} I_\rho \qquad s = \frac{p\,h}{\pi E} I_\rho \qquad c_v = \frac{k_v}{m_v \gamma_w} \qquad \frac{\Delta S}{H} = \frac{\Delta e}{1+e}$$

$$\varepsilon_v = -\frac{\Delta e}{1+e_0} \qquad \varepsilon_v = m_v . \Delta\sigma' \qquad \rho_d = \frac{\rho_w S}{w + \frac{S}{G_s}} \qquad \gamma_d = (1 - \frac{A}{100})\left[\frac{G_s \gamma_w}{G_s m + 1}\right]$$

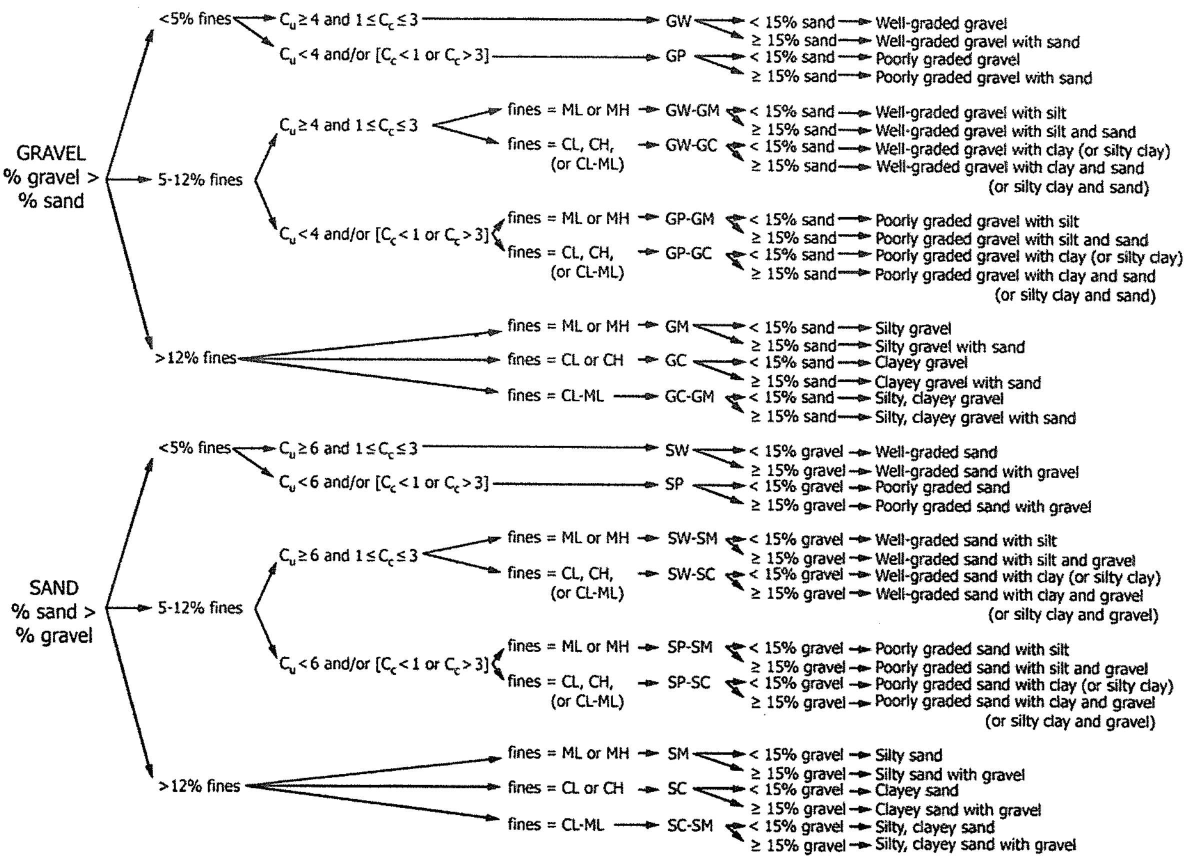
$$M_v = \frac{1}{1+e_I}\left(\frac{e_I - e_f}{\sigma'_f - \sigma'_I}\right); \qquad C_c = \frac{e_I - e_f}{\log_{10}(\sigma'_f / \sigma'_I)}; \qquad A = A_o\left(\frac{1 - \varepsilon_v}{1 - \varepsilon_a}\right) \quad ; \varepsilon_V = \frac{dV}{V_0} \quad ; \varepsilon_a = \frac{dh}{h_0}$$

$$\varepsilon_{zz} = \frac{\Delta S}{H} = \varepsilon_v = -\frac{\Delta e}{1+e} \qquad C = \frac{\Delta e}{\log_{10}(\sigma'_F / \sigma'_I)} \qquad Cc = 0.009\,(LL - 10)$$

$$S = \frac{C_c H}{1+e_0} \log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}\right) \qquad S = \frac{C_r H}{1+e_0} \log\left(\frac{\sigma'_{pc}}{\sigma'_o}\right) + \frac{C_c H}{1+e_0} \log\left(\frac{\sigma'_o + \Delta\sigma'}{\sigma'_o}\right)$$

$$m_v = \frac{\Delta V}{V_0} . \frac{1}{\Delta\sigma'} = \frac{\Delta S}{H_0} . \frac{1}{\Delta\sigma'} = \frac{\Delta e}{1+e_0} . \frac{1}{\Delta\sigma'} \qquad \Delta e = C_c \log(\sigma_f / \sigma_i)$$

Unit-weight relationship	Dry unit weight	Saturated unit weight
$\gamma = \frac{(1+w)G_s\gamma_w}{1+e}$	$\gamma_d = \frac{\gamma}{1+w}$	$\gamma_{sat} = \frac{(G_s + e)\gamma_w}{1+e}$
$\gamma = \frac{(G_s + Se)\gamma_w}{1+e}$	$\gamma_d = \frac{G_s\gamma_w}{1+e}$	$\gamma_{sat} = [(1-n)G_s + n]\gamma_w$
$\gamma = \frac{(1+w)G_s\gamma_w}{1 + \frac{wG_s}{S}}$	$\gamma_d = G_s\gamma_w(1-n)$	$\gamma_{sat} = \left(\frac{1+w}{1+wG_s}\right)G_s\gamma_w$
$\gamma = G_s\gamma_w(1-n)(1+w)$	$\gamma_d = \frac{G_s}{1 + \frac{wG_s}{S}}\gamma_w$	$\gamma_{sat} = \left(\frac{e}{w}\right)\left(\frac{1+w}{1+e}\right)\gamma_w$
	$\gamma_d = \frac{eS\gamma_w}{(1+e)w}$	$\gamma_{sat} = \gamma_d + n\gamma_w$
	$\gamma_d = \gamma_{sat} - n\gamma_w$	$\gamma_{sat} = \gamma_d + \left(\frac{e}{1+e}\right)\gamma_w$
	$\gamma_d = \gamma_{sat} - \left(\frac{e}{1+e}\right)\gamma_w$	


GRAVEL
% gravel > % sand
<5% fines
Cu ≥ 4 and 1 ≤ Cc ≤ 3
Cu < 4 and/or [Cc < 1 or Cc > 3]
GW
GP
< 15% sand → Well-graded gravel
≥ 15% sand → Well-graded gravel with sand
< 15% sand → Poorly graded gravel
≥ 15% sand → Poorly graded gravel with sand
5-12% fines
Cu ≥ 4 and 1 ≤ Cc ≤ 3
fines = ML or MH → GW-GM
fines = CL, CH, (or CL-ML) → GW-GC
< 15% sand → Well-graded gravel with silt
≥ 15% sand → Well-graded gravel with silt and sand
< 15% sand → Well-graded gravel with clay (or silty clay)
≥ 15% sand → Well-graded gravel with clay and sand (or silty clay and sand)
Cu < 4 and/or [Cc < 1 or Cc > 3]
fines = ML or MH → GP-GM
fines = CL, CH, (or CL-ML) → GP-GC
< 15% sand → Poorly graded gravel with silt
≥ 15% sand → Poorly graded gravel with silt and sand
< 15% sand → Poorly graded gravel with clay (or silty clay)
≥ 15% sand → Poorly graded gravel with clay and sand (or silty clay and sand)
>12% fines
fines = ML or MH → GM
fines = CL or CH → GC
fines = CL-ML → GC-GM
< 15% sand → Silty gravel
≥ 15% sand → Silty gravel with sand
< 15% sand → Clayey gravel
≥ 15% sand → Clayey gravel with sand
< 15% sand → Silty, clayey gravel
≥ 15% sand → Silty, clayey gravel with sand
SAND
% sand > % gravel
<5% fines
Cu ≥ 6 and 1 ≤ Cc ≤ 3
Cu < 6 and/or [Cc < 1 or Cc > 3]
SW
SP
< 15% gravel → Well-graded sand
≥ 15% gravel → Well-graded sand with gravel
< 15% gravel → Poorly graded sand
≥ 15% gravel → Poorly graded sand with gravel
5-12% fines
Cu ≥ 6 and 1 ≤ Cc ≤ 3
fines = ML or MH → SW-SM
fines = CL, CH, (or CL-ML) → SW-SC
< 15% gravel → Well-graded sand with silt
≥ 15% gravel → Well-graded sand with silt and gravel
< 15% gravel → Well-graded sand with clay (or silty clay)
≥ 15% gravel → Well-graded sand with clay and gravel (or silty clay and gravel)
Cu < 6 and/or [Cc < 1 or Cc > 3]
fines = ML or MH → SP-SM
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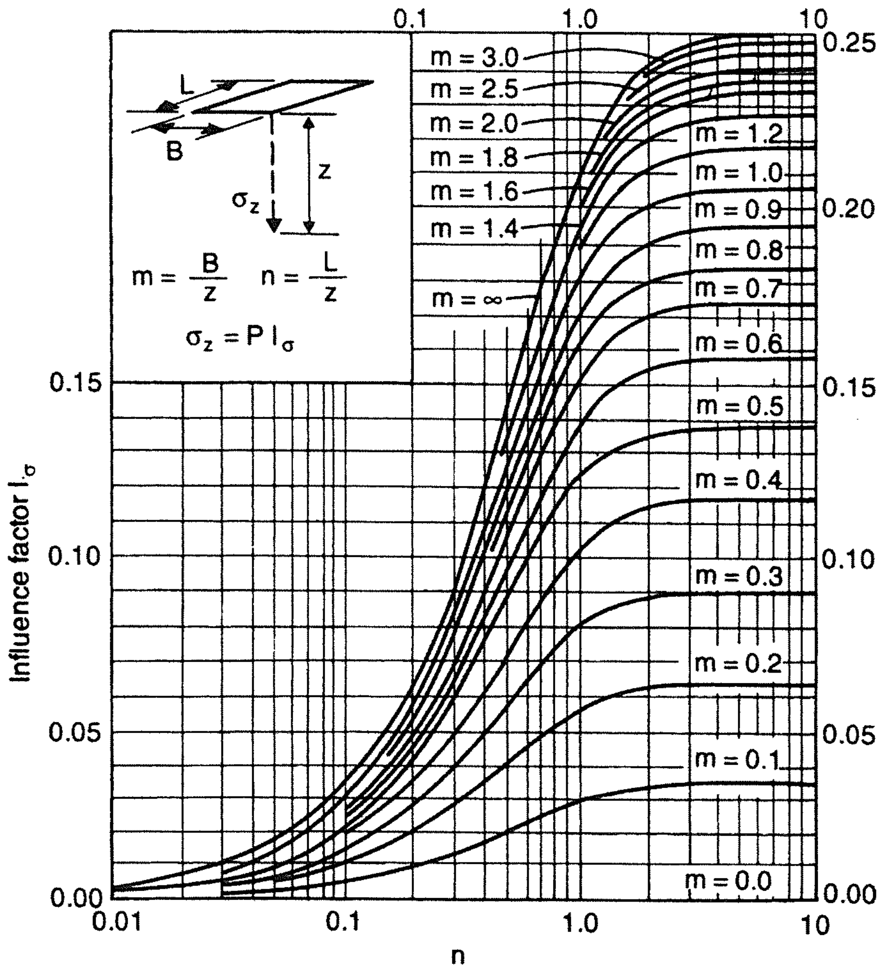
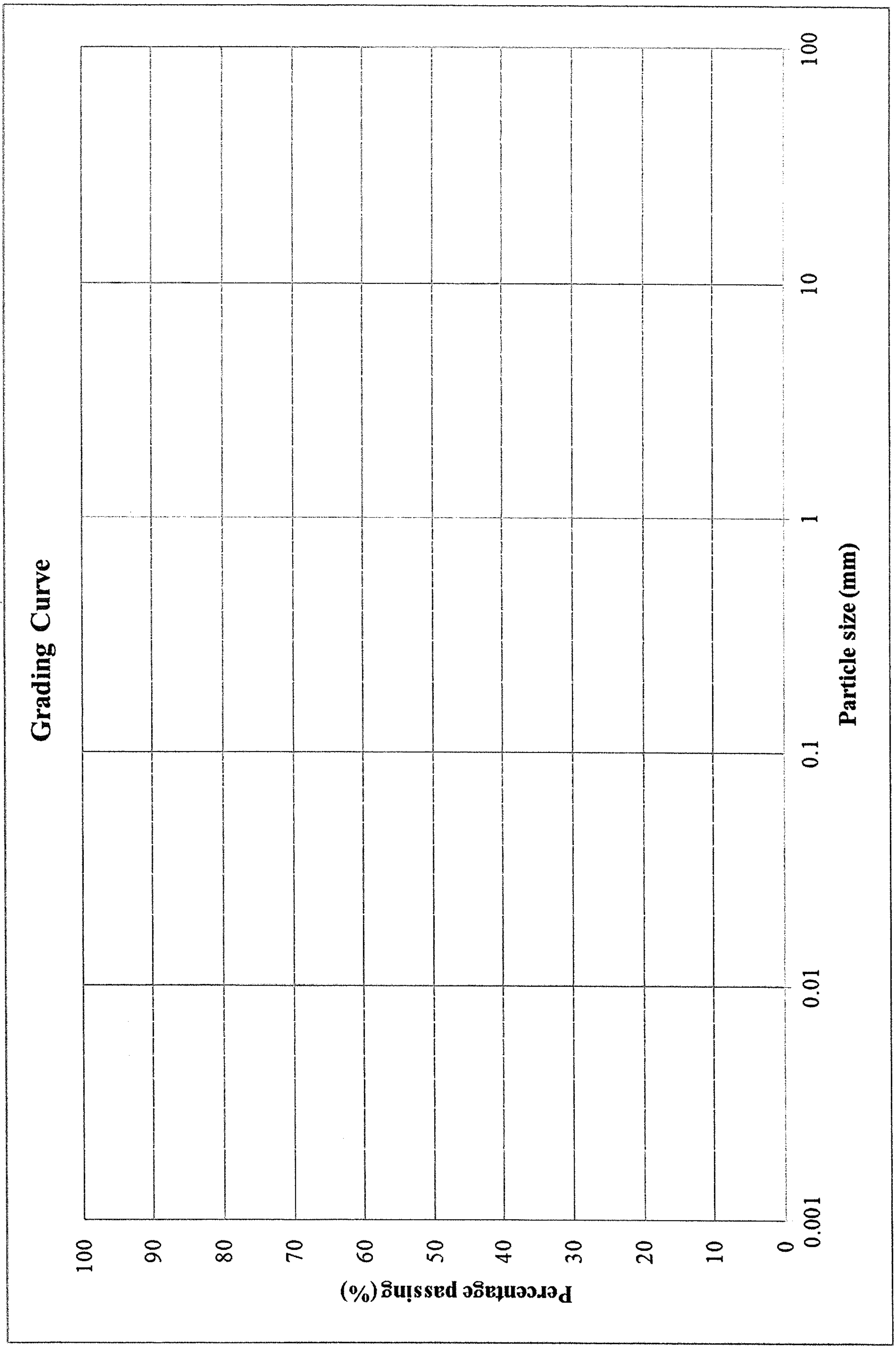
≥ 15% gravel → Poorly graded sand with clay and gravel (or silty clay and gravel)
>12% fines
fines = ML or MH → SM
fines = CL or CH → SC
fines = CL-ML → SC-SM
< 15% gravel → Silty sand
≥ 15% gravel → Silty sand with gravel
< 15% gravel → Clayey sand
≥ 15% gravel → Clayey sand with gravel
< 15% gravel → Silty, clayey sand
≥ 15% gravel → Silty, clayey sand with gravel


L
B
z
σz
m = B/z   n = L/z
σz = P Iσ
m = 3.0
m = 2.5
m = 2.0
m = 1.8
m = 1.6
m = 1.4
m = ∞
m = 1.2
m = 1.0
m = 0.9
m = 0.8
m = 0.7
m = 0.6
m = 0.5
m = 0.4
m = 0.3
m = 0.2
m = 0.1
m = 0.0
Influence factor Iσ
n
0.01
0.1
1.0
10
0.00
0.05
0.10
0.15
0.20
0.25

Student Name:______________________________ **Student Number:**_______________



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