[ENG18]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATION 2023/2024

SOIL MECHANICS AND HYDRAULICS

MODULE NO: CIE4020

Date: Wednesday 15th May 2024 **Time: 14:00 – 16:00**

INSTRUCTIONS TO CANDIDATES: **OPEN-BOOK EXAM**

This exam paper contains two sections: section 'A' and section 'B'

Section A contains TWO questions: you should answer BOTH questions. Each of these questions is worth 25 marks.

Section B contains TWO questions: you should answer BOTH questions. Each of these questions is worth 25 marks.

Marks for parts of questions are shown in brackets.

This assessment carries 100 marks.

All working must be shown.

Useful Formulae Sheet on Page 8 to 11.

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Section A – Soil Mechanics (Answer Both Questions in this Section)

Question 1

(a) **Figure Q1** below shows a soil profile consists of three layers with properties shown in **Table Q1a**. Calculate the following:

(i) The equivalent coefficient of permeability along the x-direction (**3 marks**)

(ii) The equivalent coefficient of permeability along the z-direction (**3 marks**)

(iii) The ratio of coefficients in two direction. (**2 marks**)

Layer	Thickness (m)	k_x (m/s)	k_z (m/s)
1	3.0	$2.0\text{x}10^{-6}$	$1.0\text{x}10^{-6}$
2	4.0	$5.0\text{x}10^{-8}$	$2.5\text{x}10^{-8}$
3	3.0	$3.0\text{x}10^{-5}$	$1.5\text{x}10^{-5}$

Table Q1a

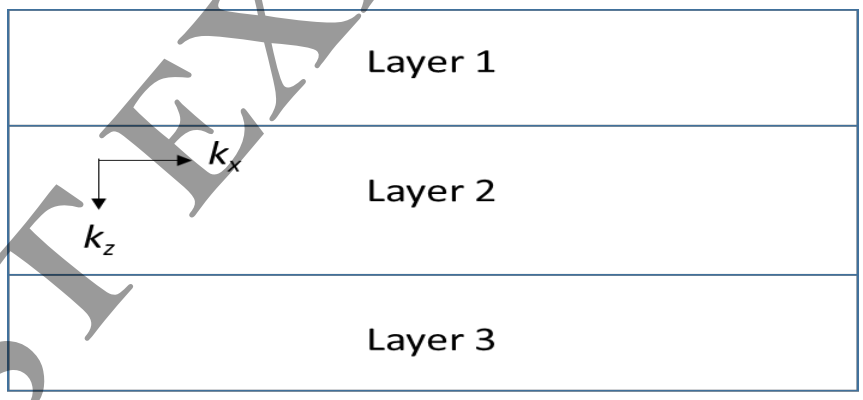

Figure Q1

Question 1 continues over the page….

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Question 1 continued…

(b) The results of a standard compaction test for a soil having a value of ($\mathbf{Gs = 2.5}$) are shown in **Table Q1b** below.

Water Content (%)	6.2	8.1	9.81	11.5	12.3	13.2
Bulk Unit Weight (kN/m^3)	16.9	18.7	19.5	20.5	20.4	20.1

Table Q1b

(i) Plot the compaction curve and obtain the maximum dry unit weight (γ_d in kN/m^3) and the optimum water content.

(**5 marks**)

(ii) On the same axes, draw the γ_d vs w curves for 0%, 5% and 10% air content and determine the air content for the maximum dry unit weight.

(**5 marks**)

(iii) Determine the corresponding void ratio and degree of saturation reached for the maximum dry unit weight.

(**7 marks**)

Total 25 marks

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Question 2

(a) Sketch a "soil model" diagram clearly showing the solids, water and air components annotated with conventional symbols to allow development of 'soil property' equations.

(5 marks)

(b) An undisturbed sample of clayey soil is found to have a wet weight of 285 N, a dry weight of 250 N, and a total volume of $14x10^3$ cm^3, if the specific gravity of soil solids is 2.70. Determine:

(i) The water content **(2 marks)**

(ii) Void ratio **(2 marks)**

(iii) Porosity **(2 marks)**

(iv) Degree of saturation **(2 marks)**

(v) The air content **(2 marks)**

(c) Use the percentages of minerals given in **Table Q2** below to determine the missing values and the name of the soil texture using the soil texture triangle shown in **Figure Q2** (on Page 5).

	Percentage (%)			
No	**Gravel**	**Sand**	**Silt**	**Clay**
1	**0**	**55**		**15**
2	**15**	**25**	**30**	
3	**0**		**45**	**20**
4	**10**	**50**	**10**	
5	**0**		**75**	**10**

Table Q2

(**10 marks**)

Total 25 marks

Question 2 continues over the page….

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Question 2 continued…

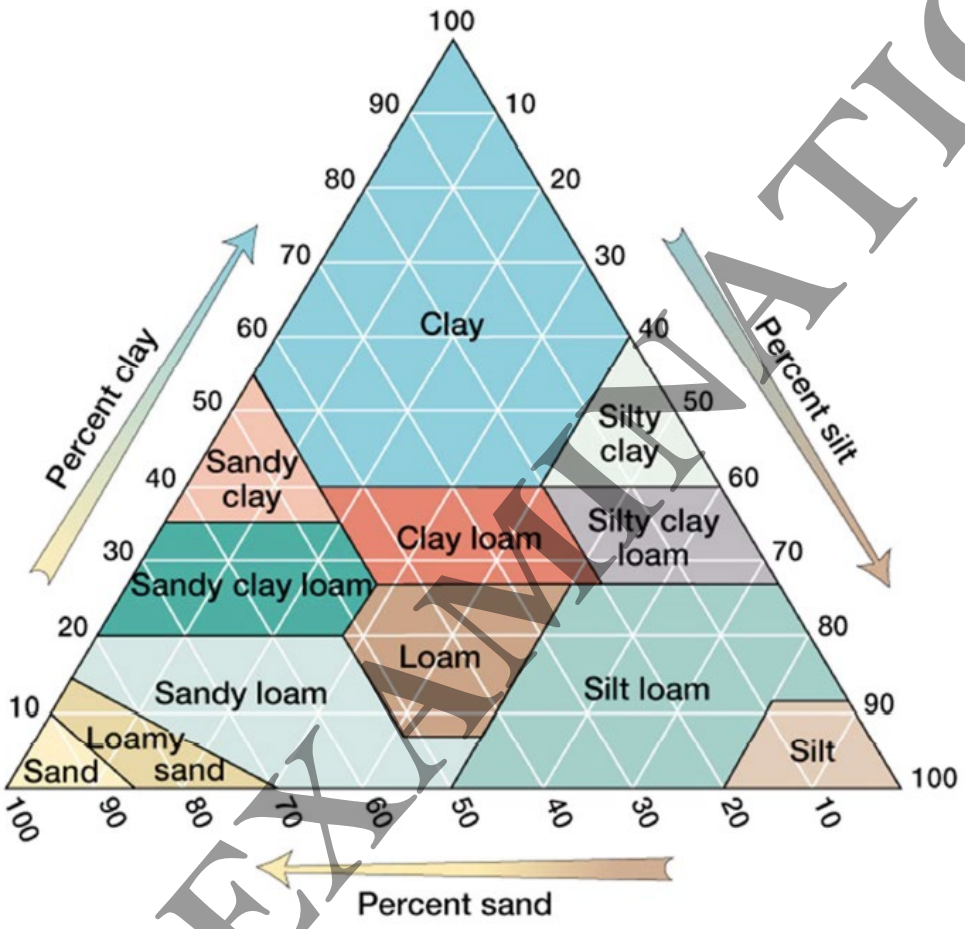

Figure Q2: **Soil Texture Triangle**

END OF SECTION A

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Section B – Hydraulics (Answer Both Questions in this Section)

Question 3

(a) What criteria govern the following types of flow?

a. Uniform flow.
b. Non-uniform (varied) flow.
c. Steady flow.

(**6 marks**)

(b) Two parallel pipes carrying freshwater and seawater are connected to each other by a double U-tube differential manometer, as shown in (**Figure Q3b)**,

(i) Determine the pressure difference between the two pipelines.

(**9 marks**)

(ii) What would be the pressure difference between the two pipes if the oil in the manometer is replaced by air and all other heights remain the same?

(**4 marks**)

Take the density of seawater at that location as 1035 kg/m^3, the fresh water as 1000 kg/m^3, the mercury as 13600 kg/m^3 the air as 1.1213 kg/m^3 and the specific gravity of the oil as 0.72. Assume all fluids are incompressible. The heights in the double tube are measured as follows: $h_w = 0.7$ *m,* $h_{Hg} = 0.3$ *m,* $h_{oil} = 0.9$ *m and* $h_{sea} = 0.5$ *m.*

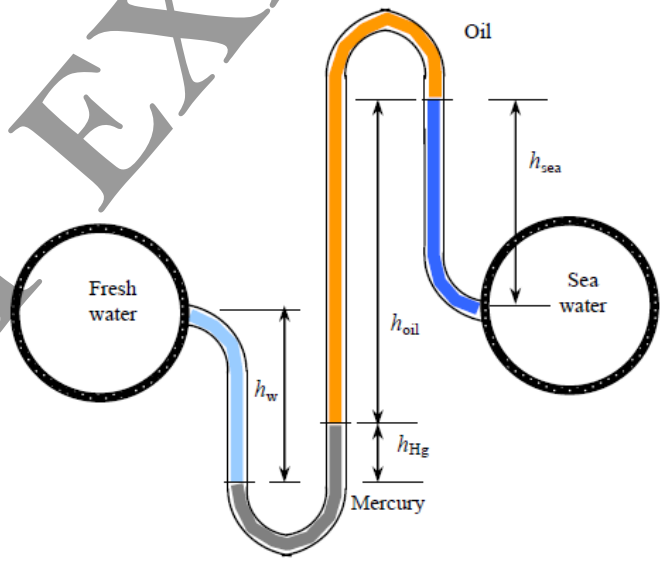

Figure Q3b

Question 3 continues over the page….

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Question 3 continued…

(c) A rectangular channel 2m wide carries water with a discharge of 10 m^3/s. A rectangular weir **(Figure Q3c)** is to be installed across the canal to raise the water level 4m above the channel floor. Calculate the required height of the weir (P) if the weir is suppressed. Assume ($C_d = 0.6$)

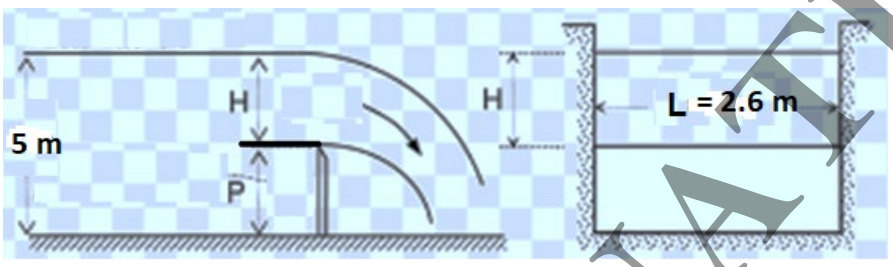

Figure Q3c

(**6 marks**)

Total 25 marks

Question 4

(a) The compound channel section **(Figure Q4a)** has a roughness coefficient (n) equals 0.025, slope = 0.0005. Find (1) the discharge and (2) the flow velocity. Assume that **the velocity is not uniform across the whole compound section** of the channel. Consider the following dimensions:
Top width (B) = 8m
Bottom width (b) = 2m
Depth of water (D) = 2.5m
h = 0.5 m

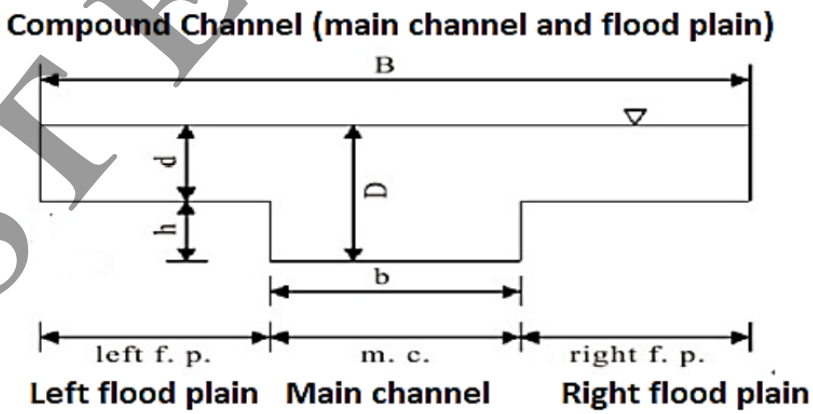

Figure Q4a

(**12 marks**)

Question 4 continues over the page….

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Question 4 continued…

(b) Water flowing from a large reservoir to atmosphere **(Figure Q4b)** through a 200mm diameter pipe 500m long. The entry from the reservoir to the pipe is a sharp-edged entrance and the outlet is 15m below the surface level in the reservoir. Taking friction factor (f) = 0.05 in the Darcy-Weisbach formula, calculate the discharge passing through the pipe.

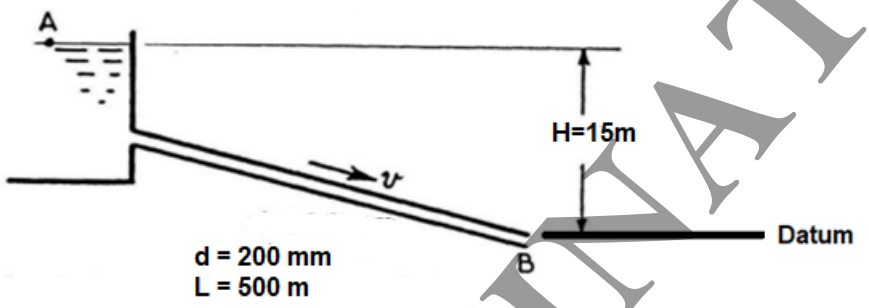

Figure Q4b

(**13 marks**)

Total 25 marks

END OF SECTION B

END OF QUESTIONS

Useful Formula Sheets follow over the page

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Useful Formulae Sheet

TERMINOLOGY, SYMBOLS AND UNITS

Term	Symbol	Units
Volume		m^3
Mass		kg
Gravity	g	9.81 m/sec^2
Weight		kN = (kg x 9.81)/1000
Total volume	V	m^3
Volume of air	V_A	m^3
Volume of water	V_W	m^3
Volume of voids	V_V	m^3
Volume of Solids	V_S	m^3
Mass of water	M_W	kg
Mass of solids	M_S	kg
Total mass	M	kN
Specific gravity	G_s	None
Density of water	ρ_w	1000kg/m^3
Unit weight of water	γ_w	9.81 kN/m^3
Void ratio	e	None
Degree of saturation	S_r	None
Moisture content	w	None
Porosity	n	None
Soil Bulk density	ρ_b	kg/m^3
Dry density	ρ_d	kg/m^3
Saturated density	ρ_{sat}	kg/m^3
Soil Bulk unit weight	γ_b	kN/m^3
Dry unit weight	γ_d	kN/m^3
Saturated unit weight	γ_{sat}	kN/m^3
Coefficient of Permeability	k	m/s
Soil Layer Thickness	H	m

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DEFINITIONS

Term	Expression
Density of water, ρ_w Unit weight of water, γ_w	
Specific gravity, G_s	$\frac{\text{density of solids}}{\text{density of water}} \quad \frac{\rho_s}{\rho_w}$
Water content, w	$\frac{\text{mass of water}}{\text{mass of solids}} \quad \frac{M_w}{M_s}$
Void ratio, e	$\frac{\text{volume of voids}}{\text{volume of solids}} \quad \frac{V_v}{V_s}$
Degree of saturation, S_r	$\frac{\text{volume of water}}{\text{volume of voids}} \quad \frac{V_w}{V_v}$
Porosity, n	$\frac{\text{volume of voids}}{\text{total volume}} \quad \frac{V_v}{V}$
Bulk density, ρ_b	$\frac{\text{total mass}}{\text{total volume}} \quad \frac{M}{V}$
Dry density, ρ_d	$\frac{\text{mass of solids}}{\text{total volume}} \quad \frac{M_s}{V}$
Saturated density, ρ_{sat}	$\frac{\text{total saturated mass}}{\text{total volume}} \quad \frac{M}{V}$
Bulk unit weight, γ_b	$\frac{\text{total weight}}{\text{total volume}} \quad \frac{W}{V}$
Dry unit weight, γ_d	$\frac{\text{weight of solids}}{\text{total volume}} \quad \frac{W_s}{V}$
Saturated unit weight, γ_{sat}	$\frac{\text{total saturated weight}}{\text{total volume}} \quad \frac{W}{V}$
Air voids, A_v	$\frac{\text{volume of air}}{\text{total volume}} \quad \frac{V_a}{V}$

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BASIC PROPERTIES Formulae:

Void space relationship from soil model $w\,G_s = S_r\,e$

Bulk Density

$$\rho_b = \frac{(G_s + S_r\,e)\rho_W}{1+e} \qquad \rho_b = \frac{\rho_W\,G_s(1+w)}{1+e}$$

Dry Density

$$\rho_d = \frac{\rho_W\,G_s}{1+e} \qquad \rho_d = \frac{\rho_b}{1+w} \qquad \rho_d = \frac{\rho_{sat}}{1+w_{sat}}$$

Theoretical Dry Density

$$\rho_d = \frac{\rho_W\,G_s\,(1-A_v)}{1+w\,G_s}$$

Porosity

$$n = \frac{e}{1+e}$$

Air voids

$$A_v = n\,(1 - S_r)$$

Soil Coefficient of Uniformity

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

Soil Coefficient of Curvature

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

$$Constant\ head\ permeability, k = \frac{V_w L}{Aht}$$

$$Falling\ head\ permeabilit, k = \frac{2.303\ a\ L}{At}\log\frac{h_1}{h_2}$$

$$Stratified\ Soil\ Layers, \quad k_H = \frac{1}{H}(k_{H1}xH_1 + k_{H2}xH_2 + \ \ldots\ldots\ldots\ldots + k_{Hn}xH_n)$$

$$Stratified\ Soil\ Layers, \quad k_v = \frac{H}{(\frac{H_1}{k_1} + \frac{H_2}{k_2} + \frac{H_3}{k_3} + \ \ldots\ldots\ + \frac{H_n}{k_n})}$$

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