[ENG11]

UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

BENG (HONS) CIVIL ENGINEERING

SEMESTER TWO EXAMINATIONS 2021/2022

GROUND AND WATER STUDIES 1

MODULE NO: CIE4009

Date: Wednesday 18th May 2022 Time: 14:00 – 17:00

INSTRUCTIONS TO CANDIDATES:

There are TWO Sections; A and B.

You will be supplied with TWO Answer Booklets by the Invigilator. Answer Section A in ONE Answer Booklet, and Section B in the OTHER.

Section A: contains THREE questions: you should answer ANY TWO questions. Each of these questions is worth 20 marks.

Section B: contains FOUR questions: you should answer ANY THREE questions from these four questions. Each of these questions is worth 20 marks.

Marks for parts of questions are shown in brackets.

This assessment carries 100 marks.

All working must be shown.

A formula sheet is included.

Graph paper is provided.

Section A – Water (Answer TWO Questions from this Section)

Question 1

(a) Define the term fluid pressure and mention four ways to measure it.

(**5 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 Q1**,

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

(**10 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?

(**5 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 = *0.5m*, h_{Hg} = *0.1m*, h_{oil} = *0.75m and* h_{sea} = *0.2.5m.*

[Total 20 marks]

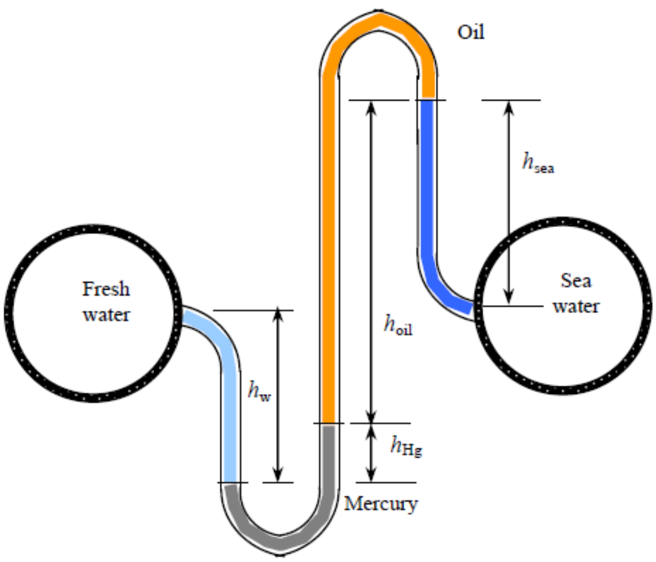

Figure Q1

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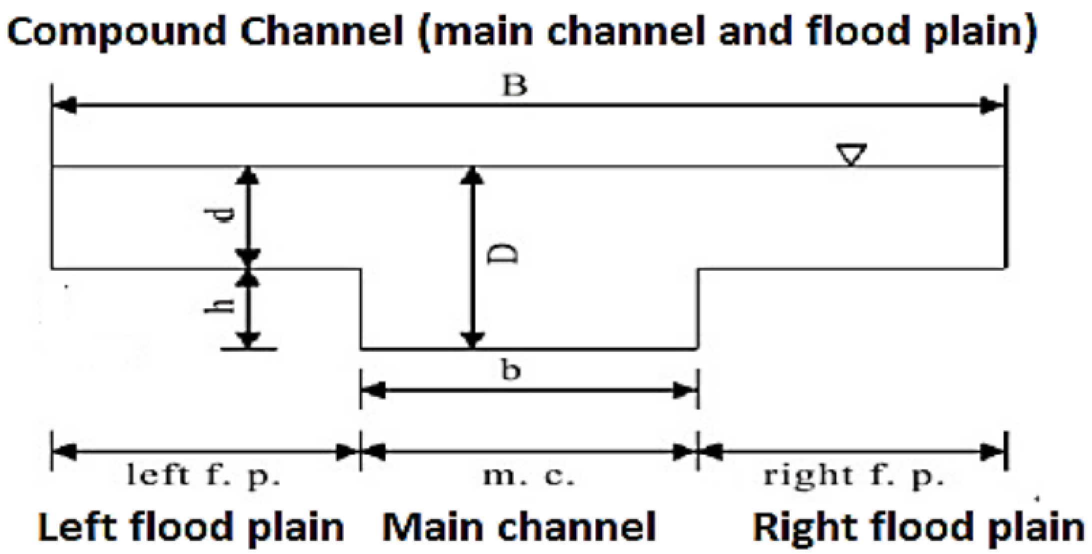
Question 2

(a) Water flows through an open channel of rectangular section, which is 4 m wide, bed slope is 0.0004, roughness coefficient (n) is 0.025 and discharge is 8 m^3/s. Determine the depth of water.

(**6 marks**)

(b) The compound channel section **(Figure 2b)** has a roughness coefficient (n) equals 0.023, 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) = 2.5m
Depth of water (D) = 2.5m
h = 0.5 m



(Figure 2b)

(**14 marks**)

Total 20 marks

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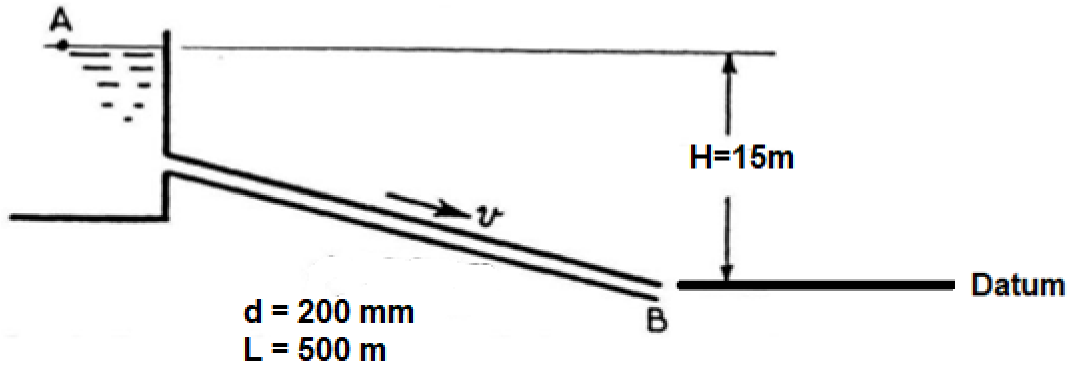
<u>Question 3</u>

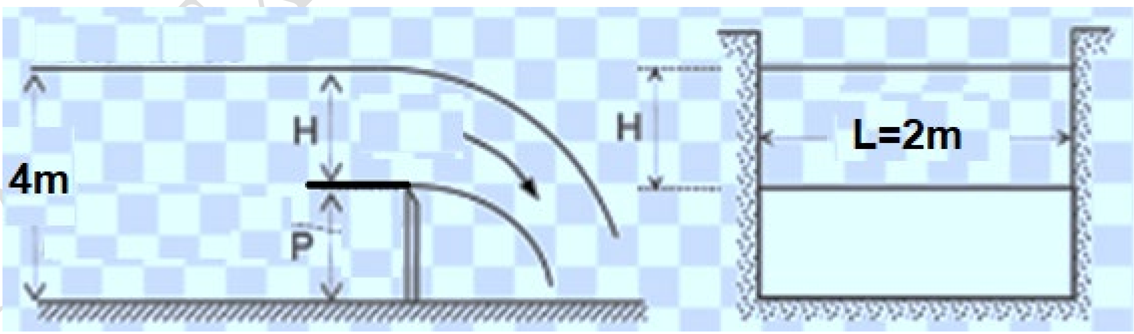
(a) Water flowing from a large reservoir to atmosphere **(Figure 3a)** through a 200mm diameter pipe 500m long. The entry from the reservoir to the pipe is a sharp-edged entrance and the outlet is 15m below the surface level in the reservoir. Taking friction factor (f) = 0.05 in the Darcy-Weisbach formula, calculate the discharge passing through the pipe.



(Figure 3 a)

(**12 marks**)

(b) A rectangular channel 2m wide carries water with a discharge of 10 m^3/s. A rectangular weir **(Figure 3 b)** 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 3b)

(**8 marks**)
Total 20 marks

END OF SECTION A

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Section B – Ground (Answer THREE Questions from this Section)

Question 4

(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) What would be the bulk unit weight and water content if the soil in (b) were fully saturated at the same void ratio as in its natural state?

(**5 marks**)

Total 20 marks

Section B continues over the page….

Section B continued….

Question 5

(a) Define the term soil compaction and explain three of its applications in civil engineering

(**5 marks**)

(b) The results of a standard compaction test for a soil having a value of ($G_s = 2.5$) are shown in the table 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

(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.

(**5 marks**)

Total 20 marks

Section B continues over the page….

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Section B continued….

Question 6

(a) Classify the following soils given the following data:

Gravel fraction (% retained on #4) = 30%
Sand fraction (passing #4, retained on #200) = 40%
Silt and clay fraction (passing #200) = 30%
LL = 30; PI = 12

(**7 marks**)

(b) Use the percentages of minerals given in **Table Q6** to determine the missing values and the name of the soil texture using the soil texture triangle given over leaf.

No	Percentage (%)			
	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 Q6

(**13 marks**)

Total 20 marks

Section B continued over the page….

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Section B continued….

Question 7

(a) Explain the term soil permeability, give three of its applications in civil engineering, and discuss the factors affecting a soil coefficient of permeability.
(**5 marks**)

(b) **Figure Q7** below shows a soil profile consists of three layers with properties shown in **Table Q7**. Calculate the following:

(i) The equivalent coefficient of permeability along the x-direction
(ii) The equivalent coefficient of permeability along the z-direction
(iii) The ratio of coefficients in two direction
(**15 marks**)

Total 20 marks

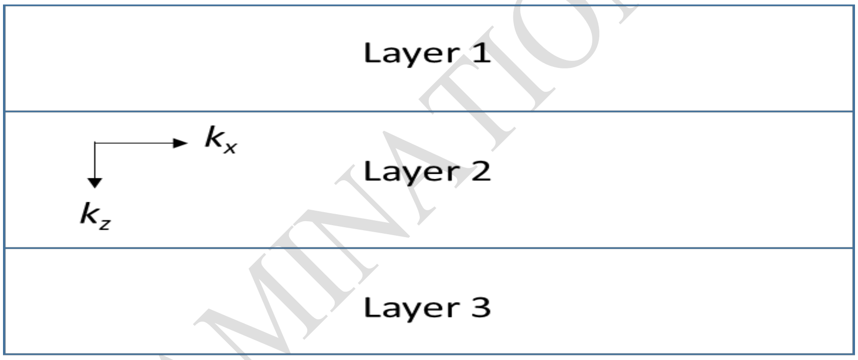

Figure Q7

Layer	Thickness (m)	kx (m/s)	kz (m/s)
1	2.5	2.0x10-6	1.0x10-6
2	5.0	5.0x10-8	2.5x10-8
3	2.5	3.0x10-5	1.5x10-5

TableQ7

END OF SECTION B

END OF QUESTIONS

Unified Soil Classification System, USDA Soil Traingle & Useful Formula over the page….

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UNIFIED SOIL CLASSIFICATION SYSTEM

UNIFIED SOIL CLASSIFICATION AND SYMBOL CHART

COARSE-GRAINED SOILS (more than 50% of material is larger than No. 200 sieve size.)		
GRAVELS More than 50% of coarse fraction larger than No. 4 sieve size — Clean Gravels (Less than 5% fines)	GW	Well-graded gravels, gravel-sand mixtures, little or no fines
	GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines
Gravels with fines (More than 12% fines)	GM	Silty gravels, gravel-sand-silt mixtures
	GC	Clayey gravels, gravel-sand-clay mixtures
SANDS 50% or more of coarse fraction smaller than No. 4 sieve size — Clean Sands (Less than 5% fines)	SW	Well-graded sands, gravelly sands, little or no fines
	SP	Poorly graded sands, gravelly sands, little or no fines
Sands with fines (More than 12% fines)	SM	Silty sands, sand-silt mixtures
	SC	Clayey sands, sand-clay mixtures
FINE-GRAINED SOILS (50% or more of material is smaller than No. 200 sieve size.)		
SILTS AND CLAYS Liquid limit less than 50%	ML	Inorganic silts and very fine sands, rock flour, silty of clayey fine sands or clayey silts with slight plasticity
	CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
	OL	Organic silts and organic silty clays of low plasticity
SILTS AND CLAYS Liquid limit 50% or greater	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts
	CH	Inorganic clays of high plasticity, fat clays
	OH	Organic clays of medium to high plasticity, organic silts
HIGHLY ORGANIC SOILS	PT	Peat and other highly organic soils

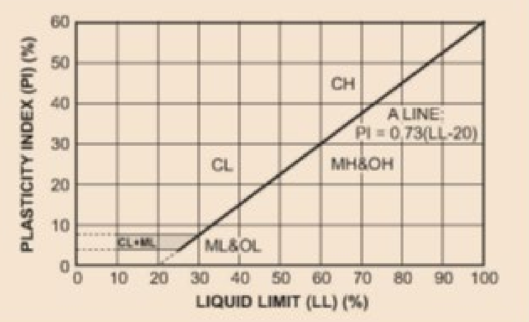
LABORATORY CLASSIFICATION CRITERIA

GW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
GP	Not meeting all gradation requirements for GW	
GM	Atterberg limits below "A" line or P.I. less than 4	Above "A" line with P.I. between 4 and 7 are borderline cases requiring use of dual symbols
GC	Atterberg limits above "A" line with P.I. greater than 7	
SW	$C_u = \frac{D_{60}}{D_{10}}$ greater than 4; $C_c = \frac{D_{30}}{D_{10} \times D_{60}}$ between 1 and 3	
SP	Not meeting all gradation requirements for GW	
SM	Atterberg limits below "A" line or P.I. less than 4	Limits plotting in shaded zone with P.I. between 4 and 7 are borderline cases requiring use of dual symbols.
SC	Atterberg limits above "A" line with P.I. greater than 7	

Determine percentages of sand and gravel from grain-size curve. Depending on percentage of fines (fraction smaller than No. 200 sieve size), coarse-grained soils are classified as follows:

Less than 5 percent .... GW, GP, SW, SP
More than 12 percent .... GM, GC, SM, SC
5 to 12 percent .... Borderline cases requiring dual symbols

PLASTICITY CHART



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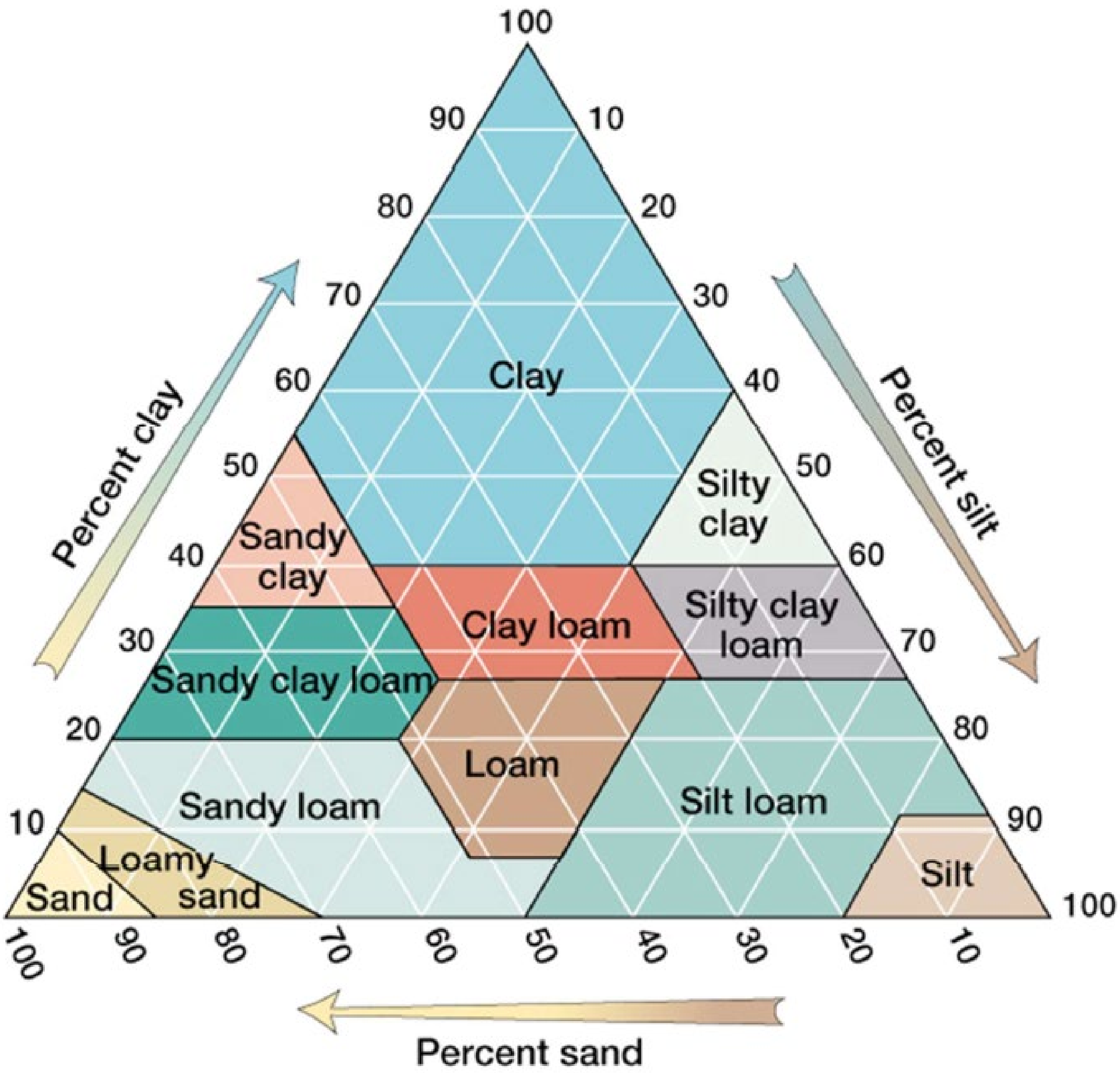
USDA Soil Triangle



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Useful Formulae
Soil Part

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

DEFINITIONS

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

BASIC PROPERTIES Formulae:

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

Bulk Density

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

$$\rho_b = \frac{\rho_W\;G_s(1 + w)}{1 + e}$$

Dry Density

$$\rho_d = \frac{\rho_W\;G_s}{1 + e}$$

$$\rho_d = \frac{\rho_b}{1 + w}$$

$$\rho_d = \frac{\rho_{sat}}{1 + w_{sat}}$$

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

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

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

$$k_H = \frac{1}{H}(k_{H1}xH_1 + k_{H2}xH_2 + \ \dots\dots\dots\dots + k_{Hn}xH_n)$$

$$k_v = \frac{H}{(\frac{H_1}{k_1} + \frac{H_2}{k_2} + \frac{H_3}{k_3} + \ \dots\dots\ + \frac{H_n}{k_n})}$$

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Hydraulics Part

Principles of Flow in Pipes

Reynold Number: $\boldsymbol{R_e = \frac{\rho V D}{\mu} = \frac{VD}{v}}$

Darcy-Weisbach Friction Head Loss: $\boldsymbol{h_f = \frac{fL}{D}\frac{V^2}{2g} = \left(\frac{8fl}{\pi^2 g D^5}\right) Q^2}$

Hagen-Poiseuille Friction Head Loss: $\boldsymbol{h_f = \frac{32\mu L V}{\rho g D^2}}$

Minor Head Loss: $\boldsymbol{h_l = K\frac{V^2}{2g}}$

Minor Head losses equation for sudden expansions: $\boldsymbol{\frac{(V_1 - V_2)^2}{2g}}$

Principles of Flow in Open Channels

Steady Uniform flow Equations:

Chezy velocity: $\boldsymbol{V = C\sqrt{RS_0}}$;

Manning velocity: $\boldsymbol{V = \frac{1}{n} R^{2/3} S_0^{1/2}}$

Flows over Weirs:

$\boldsymbol{Q = \frac{2}{3} C_d L \sqrt{2g} H^{3/2}}$ (*General flow over Weir*)

$\boldsymbol{Q = \frac{2}{3} C_d \sqrt{2g} L H^{3/2}}$ (*Suppressed Rectangular Weir*)

$\boldsymbol{Q = \frac{2}{3} C_d \sqrt{2g} (L - 0.2H) H^{3/2}}$ (*Unsuppressed Rectangular Weir*)

$\boldsymbol{Q = \frac{8}{15} C_d Tan\frac{\theta}{2} \sqrt{2g} H^{5/2}}$ (*Triangular (or V-notch) Weir*)

$\boldsymbol{Q = \frac{2}{3} C_d L \sqrt{2g} H^{3/2} + \frac{8}{15} C_d Tan\frac{\theta}{2} \sqrt{2g} H^{5/2}}$ (*Trapezoidal Weir*)

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