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Department of  
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**CVG 3109**  
**SOIL MECHANICS - I**  
**MIDTERM EXAMINATION**

<u>Question</u>	<u>Max Marks</u>	<u>Marks Awarded</u>
1	20	
2	10	
3	40	
4	20	
<b>Total</b>	<b>100%</b>	

## Question 1 (20 Marks)

Calculate the effective stress for a soil element at depth 5 m in a uniform deposit of soil (Figure 1). Given that specific gravity of the soil,  $G_s = 2.7$ .

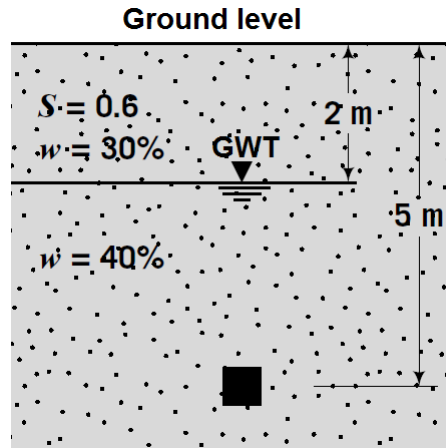


Figure 1

### Solution:

First we need to determine the unit weight of the soil both above and below the ground water table. Above the GWT:

$$Se = G_s w$$

$$e = \frac{G_s w}{S} = \frac{2.7 \times 0.3}{0.6} = 1.35$$

$$\gamma = \frac{G_s + Se}{1 + e} \gamma_w = \frac{2.7 + 0.6 \times 1.35}{1 + 1.35} \times 9.81 = 14.65 \text{ kN/m}^3$$

Below the GWT we assume that the degree of saturation is  $S=100\%$

$$e = \frac{G_s w}{S} = \frac{2.7 \times 0.4}{1.0} = 1.08$$

$$\gamma_{sat} = \frac{G_s + e}{1 + e} \gamma_w = \frac{2.7 + 1.08}{1 + 1.08} \times 9.81 = 17.83 \text{ kN/m}^3$$

The total stress at 5 m depth is:

$$\sigma = 2 \times \gamma + 5 \times \gamma_{sat} = 2 \times 14.65 + 5 \times 17.83 = 118.45 \text{ kN/m}^2$$

The PWP at 5 m depth is:

$$u = 3 \times \gamma_w = 3 \times 9.81 = 29.43 \text{ kN/m}^2$$

The effective stress at 5 m depth is:

$$\sigma' = \sigma - u = 118.45 - 29.43 = 89.02 \text{ kN/m}^2$$

## Question 2 (40 Marks)

For the weir embedded 3 m into a permeable soil stratum 24.0 m-thick (Figure 2),

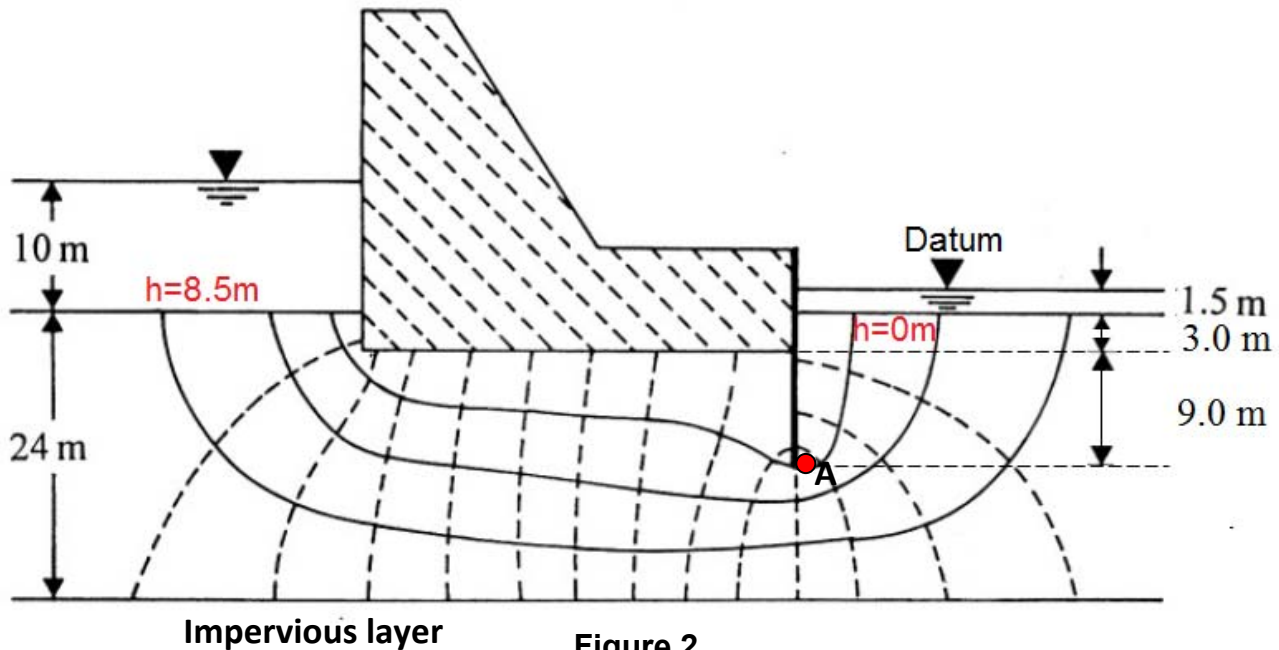
- Draw the flow net using Figure 2. (20 Marks)
- Calculate the total rate of seepage,  $q$  under the weir per unit length in  $\text{m}^3/\text{s}$ . Given that the coefficient of permeability of the soil,  $k = 1.0 \times 10^{-5} \text{ m/sec}$ . (5 Marks)
- Calculate the effective stress at Point A if  $\gamma_{\text{sat}} = 20 \text{ kN/m}^3$ . (15 Marks)

### Solution:

a) The flow net ( $N_f=4$ ,  $N_d=14$ ) is shown:

$$\text{Total Head Loss} = 10 - 1.5 = 8.5 \text{ m}$$

$$\Delta h = \frac{8.5}{14} = 0.607 \text{ m}$$



b) The total rate of seepage,  $q$  under the weir per unit length in  $\text{m}^3/\text{s}$  (unit width).

$$q = kh_w \left( \frac{N_f}{N_d} \right) = (1.0 \times 10^{-5})(8.5) \left( \frac{4}{14} \right) = 2.429 \times 10^{-5} \text{ m}^3 / \text{s} / \text{m}$$

c) To determine the effective stress at point A, we need to calculate the pore water pressure at A.

$$\text{total head @ A} = 0 + 4 \times \Delta h = 4 \times 0.607 = 2.43 \text{ m}$$

$$h_{w(A)} = \text{total head} - \text{elevation head} = 2.43 - (-13.5) = 15.93 \text{ m}$$

$$u_A = h_{w(A)} \times \gamma_w = 15.93 \times 9.81 = 156.27 \text{ kN} / \text{m}^2$$

Total stress at A:

$$\sigma_A = 1.5\gamma_w + 12\gamma_{sat} = 1.5 \times 9.81 + 12 \times 20 = 254.72 \text{ kN} / \text{m}^2$$

Effective stress at A:

$$\sigma'_A = \sigma_A - u_A = 254.72 - 156.27 = 98.45 \text{ kN} / \text{m}^2$$

### **Question 3 (25 Marks)**

At a vertical stress of 200 kPa, the void ratio of a saturated clay soil sample tested in an oedometer was 1.52 (point A). An increment of vertical stress of 150 kPa compressed the sample to a void ratio of 1.43 (point B). Assuming that the clay sample is normally consolidated,

- Determine the compression index,  $C_c$ , of the soil. **(5 Marks)**
- The sample was then unloaded to a vertical stress of 200 kPa, and the void ratio increased to 1.45 (point C). Determine the swelling (recompression) index,  $C_s$ . **(5 Marks)**
- What is the overconsolidation ratio (OCR) of the soil at point C? **(5 Marks)**
- If the soil specimen were reloaded to a vertical stress of 500 kPa, what void ratio would be attained (point D)? **(5 Marks)**
- Draw a sketch of the soil response on a plot of vertical effective stress (log scale) versus void ratio and show the locations of points A, B, C, and D. Use the graph paper provided (Figure 3). **(5 Marks)**

### **Solution:**

- Determine the compression index,  $C_c$ , of the soil.

The compression index,  $C_c$ , of the soil is the slope of AB (see the Figure in part e).

$$C_c = \frac{-(1.43 - 1.52)}{\log(350/200)} = 0.37$$

- Determine the swelling (recompression) index,  $C_s$  (or  $C_r$ ) is the slope of BC (see the Figure in part e).

$$C_r = \frac{-(1.43 - 1.45)}{\log(350/200)} = 0.08$$

- What is the overconsolidation ratio (OCR) of the soil at point C?

Past maximum vertical effective stress:  $\sigma'_{zc} = 350$  kPa

Current vertical effective stress:  $\sigma'_z = 200$  kPa

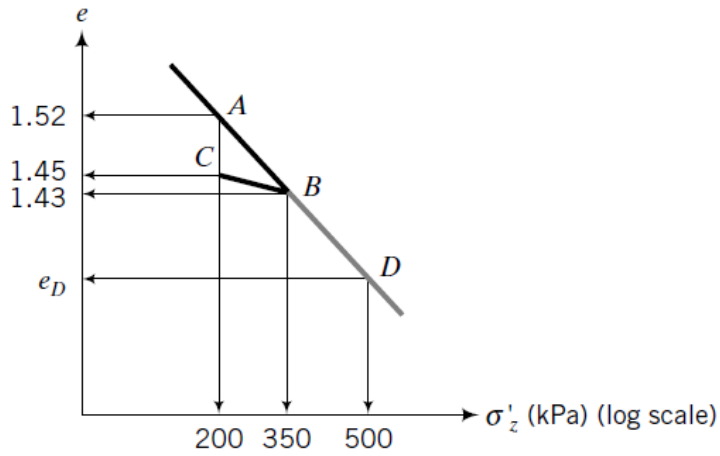
$$\text{OCR} = \frac{\sigma'_{zc}}{\sigma'_z} = \frac{350}{200} = 1.75$$

- If the soil specimen were reloaded to a vertical stress of 500 kPa, what void ratio would be attained (point D)?

The void ratio at 500 kPa is the void ratio at point D on the virgin compression line (see the Figure in part e).

$$e_D = e_B - C_c \log\left(\frac{500}{350}\right) = 1.43 - 0.37 \log 1.43 = 1.37$$

e) Draw a sketch of the soil response on a plot of vertical effective stress (log scale) versus void ratio and show the locations of points A, B, C, and D.



### Question 4 (15 Marks)

A 3 m high embankment is to be constructed as shown in Figure 4. If the unit weight of fill used in the embankment is  $19.0 \text{ kN/m}^3$ , calculate the vertical stress increase due to the embankment loading at points  $P_1$ ,  $P_2$ , and  $P_3$ . Use the chart on the last page of this exam to determine the influence value,  $I$ .

### Solution:

The embankment is divided into blocks as shown in Figure 4. The details of each block for making use of the influence factor chart are summarized in the table below.

$$q = \gamma H = 19 \times 3 = 57 \text{ kN/m}^2, z = 3 \text{ m}$$

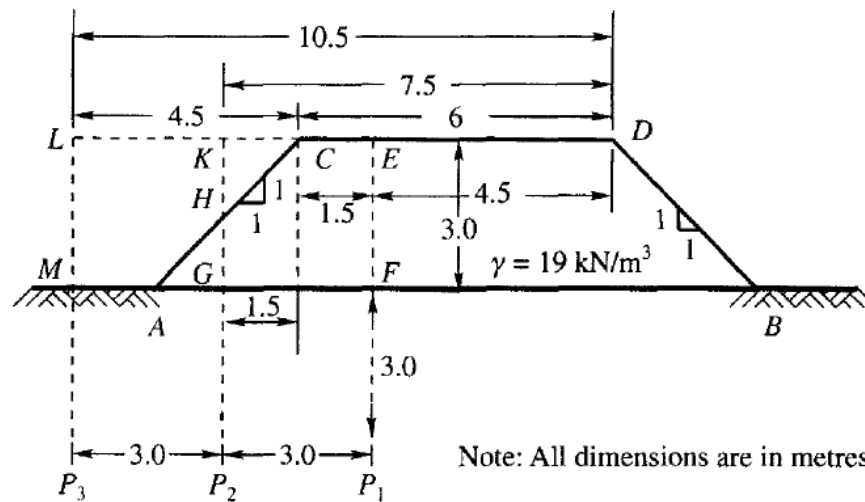


Figure 4

Point	Block	$B_1$ (m)	$B_2$ (m)	$B_1/z$	$B_2/z$	$I_2$
$P_1$	ACEF	1.5	3	0.5	1	0.39
	EDBF	4.5	3	1.5	1	0.477
$P_2$	AGH	0	1.5	0	0.5	0.15
	GKDB	7.5	3	2.5	1.0	0.493
	HKC	0	1.5	0	0.5	0.15
$P_3$	MLDB	10.5	3.0	3.5	1.0	0.498
	MACL	1.5	3.0	0.5	1.0	0.39

Vertical stress  $\sigma_z$

At point  $P_1$ ,  $\sigma_z = (0.39 + 0.477) \times 57 = 49.4 \text{ kN/m}^2$

At point  $P_2$ ,  $\sigma_z = 0.15 \times (57/2) + 0.493 \times 57 - 0.15 \times (57/2) = 28.1 \text{ kN/m}^2$

At point  $P_3$ ,  $\sigma_z = (0.498 - 0.39) 57 = 6.2 \text{ kN/m}^2$