

## CVG 3106: SOIL MECHANICS II

### FINAL EXAMINATION

**On April 25 @ 800 King Edward (STE) in A0150 from 19:00 to 22:00**

Professor: Sai Vanapalli

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Family Name: \_\_\_\_\_

Other Names: \_\_\_\_\_

Student Number: \_\_\_\_\_

Signature \_\_\_\_\_

- (i) Students should show their Student ID card in the exam hall when they are asked. **THIS IS MANDATORY**
- (ii) Complete **Section A** first and then ask for **Section B**. Section A is a **CLOSED BOOK EXAM**.
- (iii) Section B is an **OPEN BOOK** exam. Textbooks on Soil Mechanics and Foundation Engineering allowed: Recommended Book: Principles of Foundation Engineering by Braja M. Das. You are permitted to bring other textbooks too.
- (iv) Class Notes is also permitted for SECTION B. Solutions to Assignments are also permitted (they should be in the form of manuscripts only. **LAPTOPS ARE NOT ALLOWED**).
- (v) If you do not understand a question, clearly state an assumption and proceed.
- (vi) Non programmable calculators are permitted
- (vii) Questions have the values shown next to the question.
- (viii) Marks will be taken out for missing units and labels.
- (ix) **IMPORTANT: PLEASE SUPPLEMENT YOUR ANSWERS WITH SKETCHES WHEREVER NECESSARY**

At the end of the exam, when time is up:

- Stop working and turn your exam upside down.
- Do not move or speak until ALL exams have been picked up by an Invigilator or the Professor.

<u>Question</u>	<u>Max Marks</u>	<u>Marks Awarded</u>
1. Objective ( <b>SECTION A</b> )	15	
2. Subjective ( <b>SECTION A</b> )	15	
3. (Retaining Wall)	25	
4. (Foundation Design)	15	
5. (Earth Pressures)	10	
6. (Question on Chap 1 or from any other Chapter)	10	
7. (Question on Chap 2 or any other question)	10	
<b>Total</b>	<b>100%</b>	

**SECTION A (30 Marks)****Question 1(a)****(1 × 10 = 10 marks)**

Circle the correct answer.

1	The passive earth pressure coefficient, $K_p$ increases as the retaining wall moves into the soil.	T	F
2	The factor of safety used in the design of earth dams is conventionally higher for short term stability conditions in comparison to long term stability conditions.	T	F
3	Slopes in clayey soils slowly gain strength with time; however, excavations loose strength with time.	T	F
4	Pressuremeter can be used to reliably determine the pore-water pressure in soils.	T	F
5	Skempton's bearing capacity can be applied for estimating the bearing capacity of saturated clays under undrained loading conditions.	T	F
6	The friction angle, $\phi'$ determined for identical saturated clayey specimens from both consolidated drained (CD) tests and consolidated undrained tests with pore-water pressure measurements ( $C\bar{U}$ ) is the same.	T	F
7	The lateral earth pressure value determined using the Coulomb's theory is reliable in comparison to the Rankine's theory.	T	F
8	The bearing capacity of a sandy soil is governed by the $\phi_u = 0$ concept.	T	F
9	When <i>SPT</i> value, $N$ is lower than 5 the bearing capacity of the soil can be expected to be very low and settlement to be large.	T	F
10	The field bearing capacity of a soil can be most reliably determined using Meyerhof's general bearing capacity theory.	T	F

## Multiple choice questions

### Question 1(b)

(5 marks)

1. The short term stability of an embankment constructed with clay can be determined using the shear strength parameters derived from:
  - a. Conducting consolidated drained (CD) direct shear tests on identical specimens
  - b. Conducting consolidated drained (CD) triaxial shear tests on identical specimens
  - c. Conducting consolidated undrained (CU) triaxial shear tests with pore-pressure measurements during the shearing stage on identical specimens
  - d. This is crazy! I am not going to answer this question.
  - e. None of above tests
  
2. The shear strength equation proposed by Terzaghi extending the Mohr-Coulomb failure criterion,  $\tau = c' + (\sigma - u_w) \tan \phi'$  is valid for:
  - a. Normally consolidated clays only
  - b. Over consolidated clays only
  - c. Both for normally and over consolidated clays
  
3. Several parameters are listed below for increasing the load carrying capacity of a coarse-grained soil; which one of the following is more effective than the others.
  - a. increase the thickness of the foundation
  - b. decrease the depth of the foundation
  - c. increase the depth of the foundation
  - d. increase the width of the foundation
  - e. by raising the ground water table to the natural ground level
  
4. When the total weight of the soil excavated for the foundation equals the total weight of the structure for construction, the foundation is called:
  - a. Mat or raft foundation
  - b. Shallow foundation
  - c. Floating foundation
  - d. Dancing foundation
  
5. The swelling index,  $C_s$  should be determined to estimate the
  - a. Consolidation settlement of normally consolidated clays
  - b. Consolidation settlement of overconsolidated clays
  - c. Preconsolidation pressure (i.e. past maximum effective overburden pressure)
  - d. Compression index
  - e. Degree of consolidation of a clay layer at some time  $t$  after the load is applied

**Short Questions**

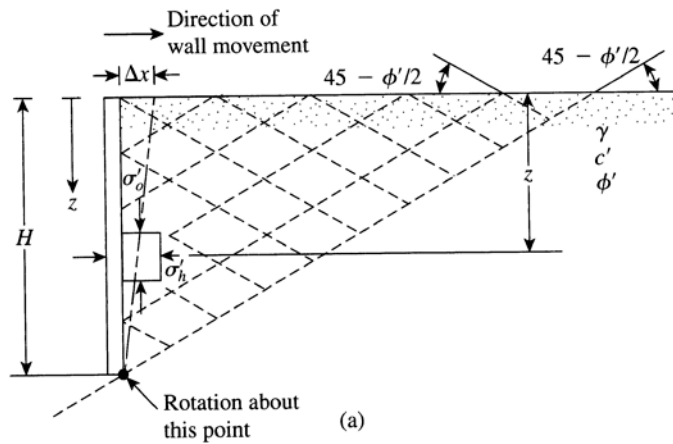
**Question 2(a)**

**(5 marks)**

Figure 1 below shows failure mechanism associated with the wall movement of a retaining wall due to earth pressure. Explain this failure using the Mohr circles and Mohr-Coulomb failure envelope.

Hint: This equation below is useful in answering the above question.

$$\sigma'_1 = \sigma'_3 \tan^2 \left( 45^\circ + \frac{\phi'}{2} \right) + 2c' \tan \left( 45^\circ + \frac{\phi'}{2} \right)$$



**Figure 1**

**Question 2(b)**

**(5 marks)**

Stability analysis of a slope that you have undertaken for a proposed LRT project in Ottawa with Champlain sea clay soil has shown that the **factor of safety** is low. The slope is close to a residential area where flattening (of side slopes) is not possible because of space restrictions. Your boss however has asked you to provide a couple of alternatives to improve the safety of this slope. What are the various suggestions that you propose to improve the slope stability. Supplement your answer with sketches if necessary.

**Hint:** Please note that resigning this job is not an alternative solution ☺.

**Question 2(c)**

**(5 marks)**

A retaining wall of 6 m height is proposed to be constructed in a city where favourable backfill material is not available. The only soil that is available for use as backfill material is expansive clay with a high plasticity index. What are the likely problems associated with using this clay as a backfill material instead of sand. What precautions and design measures you suggest for designing this retaining wall.

**Hint:** Supplement your answer with sketches and provide details.

SECTION B

**Question 3**

(25 marks)

The cross section of a cantilever retaining wall is shown in Figure 2. Calculate the factors of safety with respect to overturning and sliding.

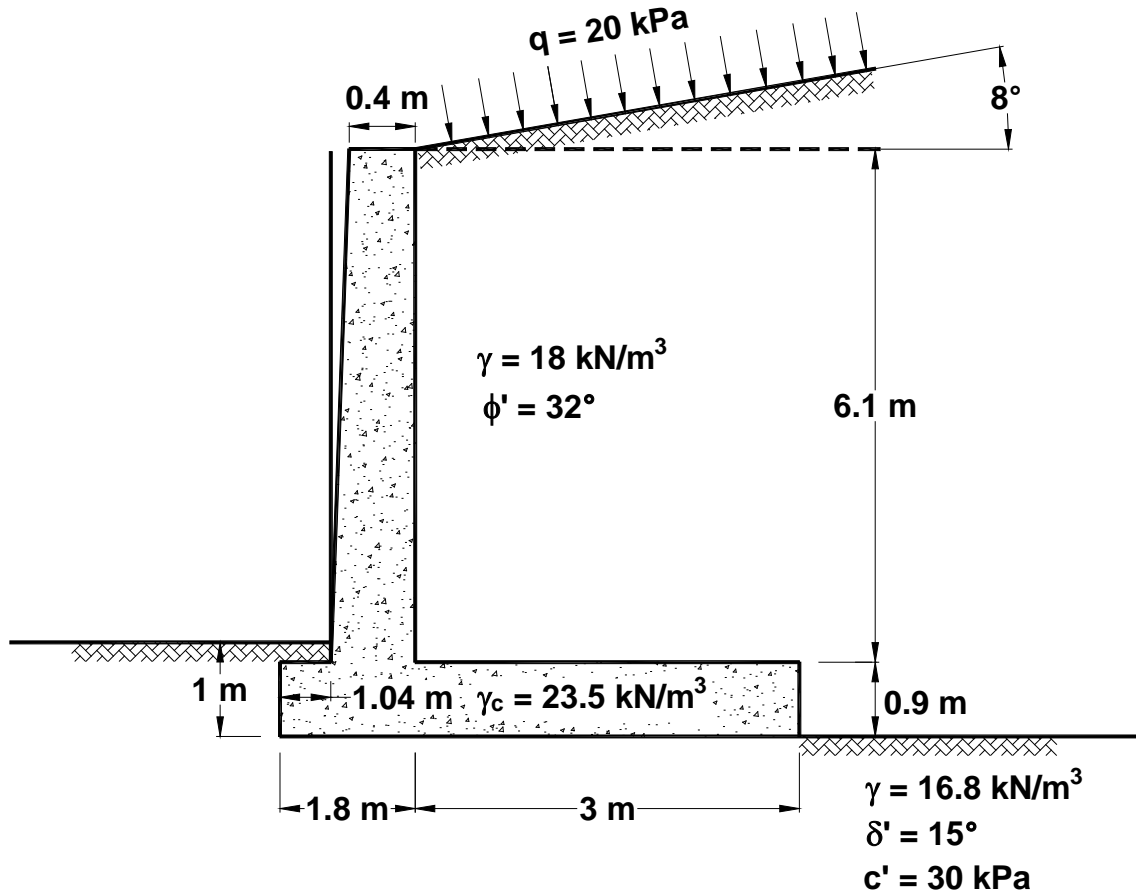


Figure 2





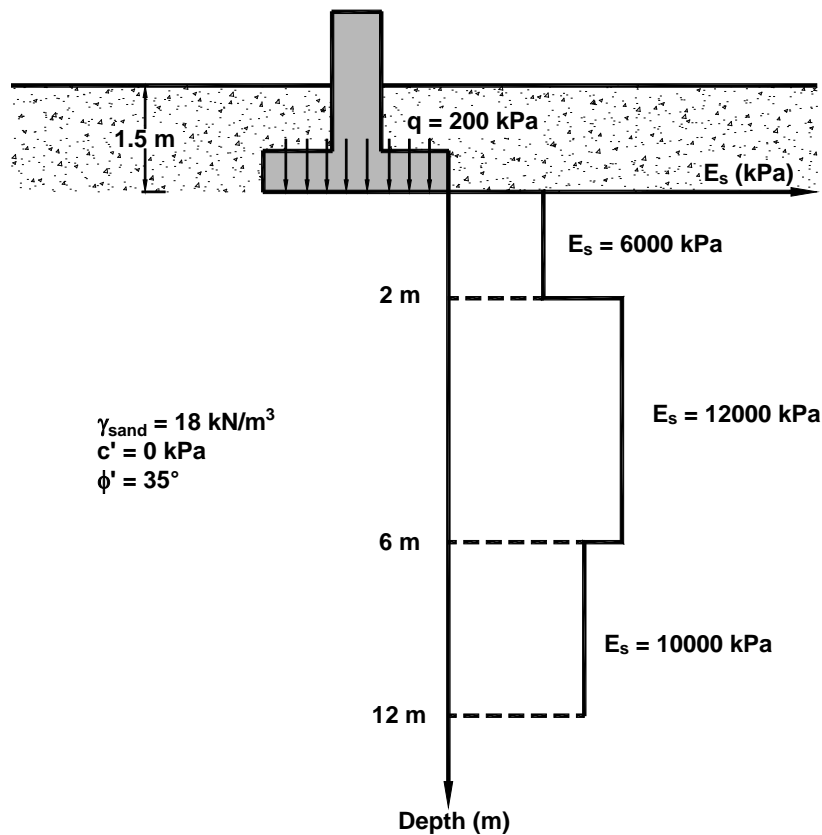


**Question 4**

**(15 marks)**

Determine the maximum allowable bearing capacity of a square foundation ( $B \times B = 1 \text{ m} \times 1 \text{ m}$ ) that is constructed in a coarse-grained soil. The factor of safety should be greater than 3 and the permissible settlement is 25 mm. The variation of  $E_s$  (i.e. elastic modulus) with depth obtained from CPT test is shown in 4. Use Terzaghi bearing capacity equation and Schmertmann strain influence factor method to calculate bearing capacity and settlement, respectively. The average unit weight of the sand and internal friction angle is  $20 \text{ kN/m}^3$  and  $36^\circ$ , respectively.

Also, estimate how much the bearing capacity would reduce if the ground water table reaches to the natural ground surface. Also, comment on the expected changes in the settlement behavior.



**Figure 2**

$\phi'$	$N_c$	$N_q$	$N_\gamma^a$	$\phi'$	$N_c$	$N_q$	$N_\gamma^a$
0	5.70	1.00	0.00	26	27.09	14.21	9.84
1	6.00	1.10	0.01	27	29.24	15.90	11.60
2	6.30	1.22	0.04	28	31.61	17.81	13.70
3	6.62	1.35	0.06	29	34.24	19.98	16.18
4	6.97	1.49	0.10	30	37.16	22.46	19.13
5	7.34	1.64	0.14	31	40.41	25.28	22.65
6	7.73	1.81	0.20	32	44.04	28.52	26.87
7	8.15	2.00	0.27	33	48.09	32.23	31.94
8	8.60	2.21	0.35	34	52.64	36.50	38.04
9	9.09	2.44	0.44	35	57.75	41.44	45.41
10	9.61	2.69	0.56	36	63.53	47.16	54.36
11	10.16	2.98	0.69	37	70.01	53.80	65.27
12	10.76	3.29	0.85	38	77.50	61.55	78.61
13	11.41	3.63	1.04	39	85.97	70.61	95.03
14	12.11	4.02	1.26	40	95.66	81.27	115.31
15	12.86	4.45	1.52	41	106.81	93.85	140.51
16	13.68	4.92	1.82	42	119.67	108.75	171.99
17	14.60	5.45	2.18	43	134.58	126.50	211.56
18	15.12	6.04	2.59	44	151.95	147.74	261.60
19	16.56	6.70	3.07	45	172.28	173.28	325.34
20	17.69	7.44	3.64	46	196.22	204.19	407.11
21	18.92	8.26	4.31	47	224.55	241.80	512.84
22	20.27	9.19	5.09	48	258.28	287.85	650.67
23	21.75	10.23	6.00	49	298.71	344.63	831.99
24	23.36	11.40	7.08	50	347.50	415.14	1072.80
25	25.13	12.72	8.34				



**Question 5****(10 marks)**

A 5-m high vertical wall supports a cohesive backfill with horizontal surface. The properties of the backfill are as follows (i) Upper 3 m depth:  $\gamma_{sat} = 17 \text{ kN/m}^3$ ,  $c' = 10 \text{ kPa}$  and  $\phi' = 20^\circ$ ; (ii) Lower 2 m depth:  $\gamma_{sat} = 19 \text{ kN/m}^3$ ,  $c' = 20 \text{ kPa}$ , and  $\phi' = 20^\circ$ . The free water level stands behind the wall at a depth of 4 m from the natural ground surface. Draw the earth pressure distribution diagram.



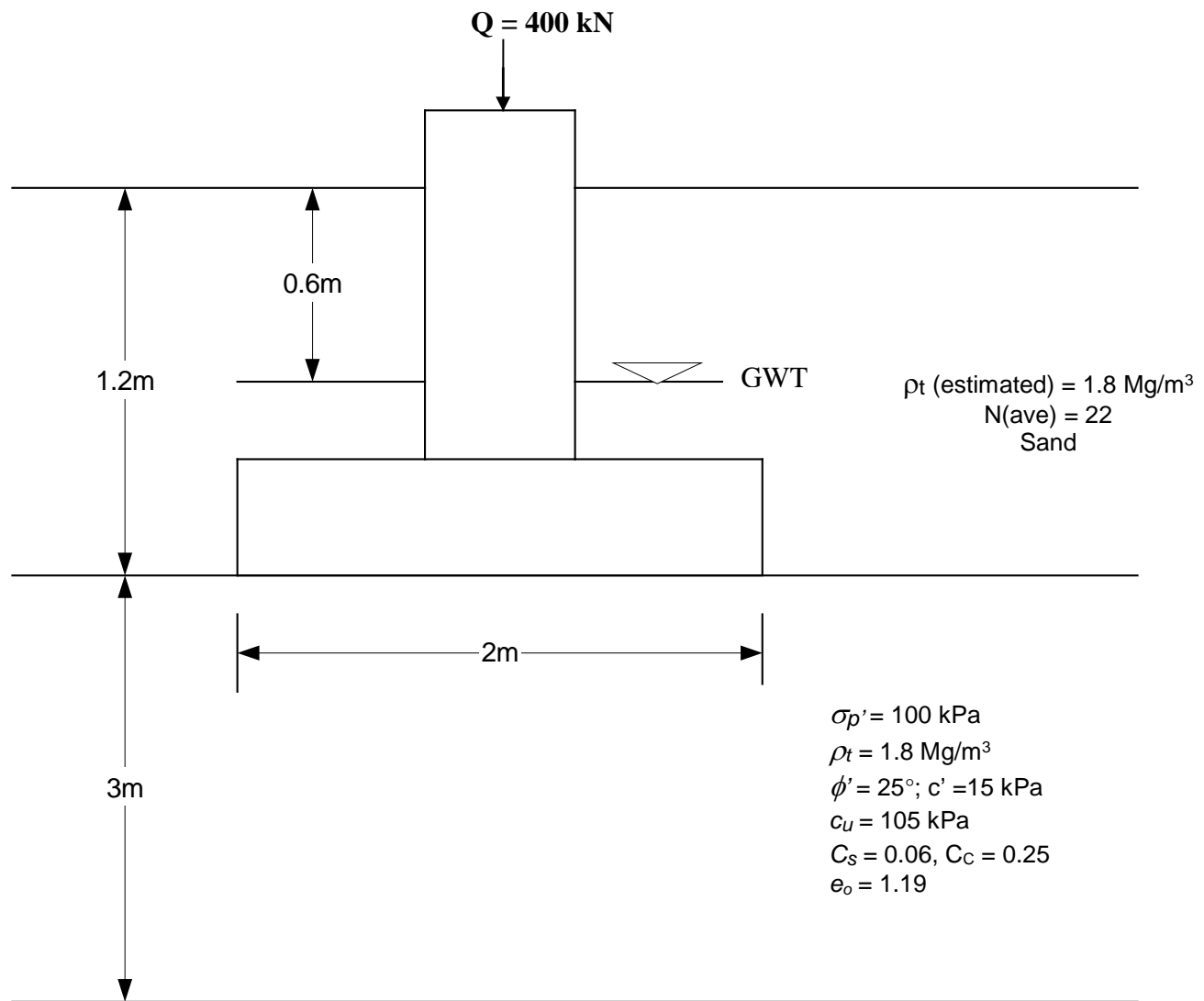
**Question 6****(10 marks)**

A square footing shown in **Figure Q.5** is designed for carrying a load of 400 kN.

The soil properties are given below:

Swelling index,  $C_s = 0.06$ , Compression index,  $C_c = 0.25$ , Average initial void ratio  $e_o = 1.19$

Using the 2:1 approximation for stress increase with depth, compute the consolidation settlement in the clay caused by the footing. Consider the footing width = 2m and clay layer thickness = 3m.

**Figure 3**





**Question 7****(10 marks)**

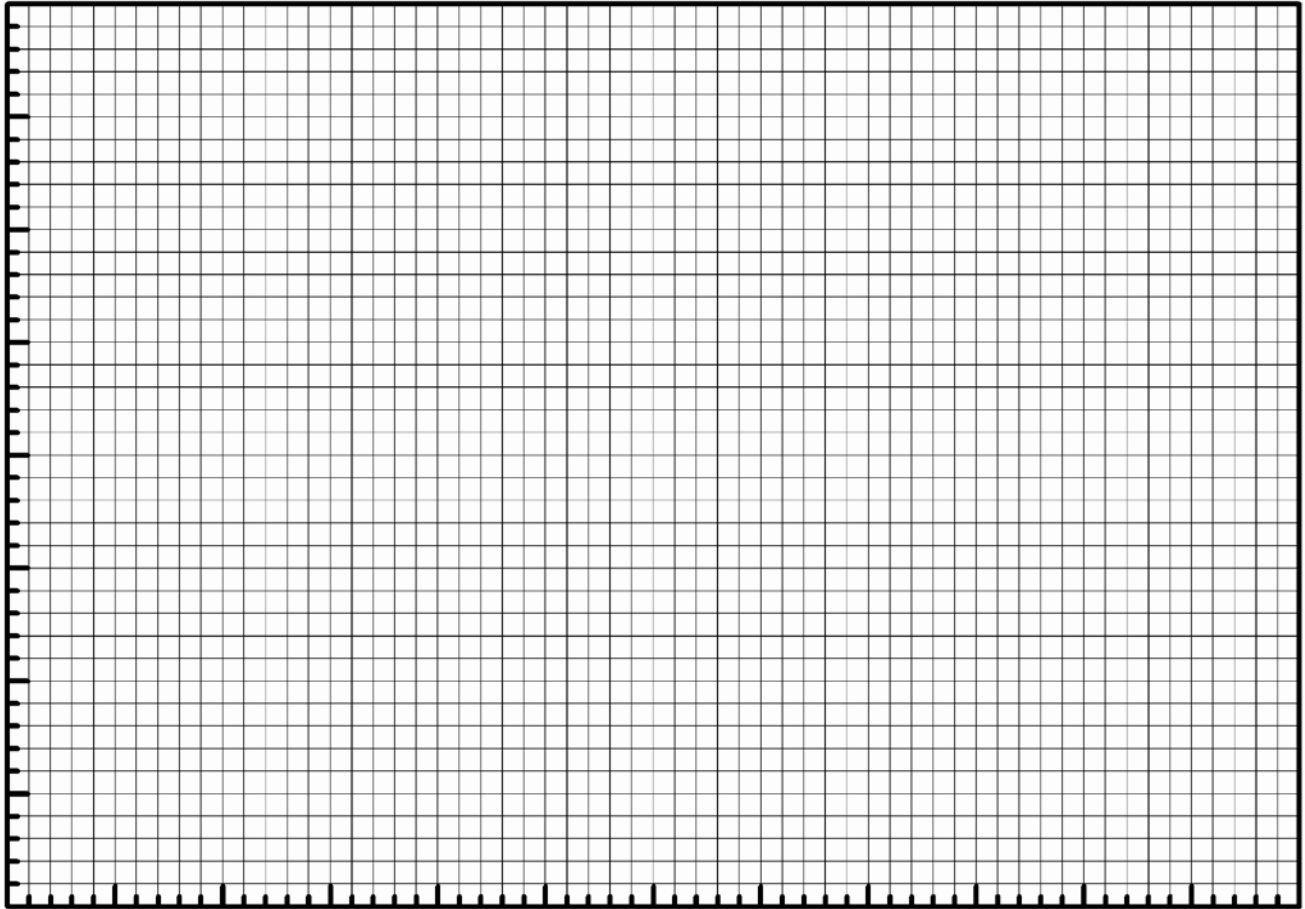
The following results were obtained at failure conditions in a series of **consolidated undrained (CU)** triaxial shear strength tests with pore water pressure measurements on fully saturated clay specimens. Determine the values of the shear strength parameters  $c'$  and  $\phi'$  by plotting **modified shear strength failure envelope ONLY**.

<b>Confining pressure, <math>\sigma_3</math> (kPa)</b>	<b>Deviator stress, <math>(\sigma_1 - \sigma_3)</math> (kPa)</b>	<b>Pore-water pressure, <math>u</math> (kPa)</b>
75	50	40
150	100	80
300	200	160

Answer the questions given below based on the results you have obtained

- What is the **advantage** of plotting the **modified failure envelope** instead of **Mohr's envelope** to determine the shear strength parameters?
- Is the tested clay **normally consolidated or over consolidated clay**? Give reasons.

If an earth dam is constructed using this clay, **can you use** the above **shear strength parameters to determine the long term stability** of the structure. Give reasons.





Have a good summer!!!