UNIVERSITY OF BOLTON

SCHOOL OF ENGINEERING

MSc IN CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2018/2019

ADVANCED GEOTECHNICAL MODELLING ANALYSIS AND DESIGN

MODULE NO: CIE7001

Date: Tuesday 15th January 2019 Time: 14:00 – 17:00

INSTRUCTIONS TO CANDIDATES:

There are FOUR questions.

Section A - Answer TWO questions

Section B - COMPULSORY question

Marks for parts of questions are shown in brackets.

Supplementary Geotechnical information is provided on pages 6-9.

Lined Graph Paper and Supplementary Answer Sheets are available for use.

Ensure that you write your Candidate Number or Desk Number on each Figure, Supplementary Sheet or Sheet of Graph Paper you use to answer the selected questions.

State all assumptions made.

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SECTION A – Answer TWO questions

Question 1

Figure Q1 shows a 55° plane strain slope in a $c_u \, and \, \phi_u = 0$ soil:

(a) Calculate the upper bound values for the stability number $\gamma H/c_u$ using the collapse mechanism shown in Figure Q1 and assuming that no surcharge is applied at the upper ground surface of the slope $(q = 0)$.

(15 marks)

(b) The same plane strain slope is now subjected to a vertical uniform load (q). Assuming the soil to be weightless $(\gamma H/c_u = 0)$ and using the same collapse mechanism shown in Figure Q1, calculate the load parameter q/c_u.

(5 marks)

(c) Construct the interaction diagram whereby $(\gamma H/c_u)$ is plotted versus (q/c_u) and derive the relationship between the two upper bound values for the given problem. Compute the critical upper bound value for the load parameter q/c_u and subsequently the value of (q) for the given soil parameters $(c_u = 20\,kPa, \ \gamma = 18\,KN/m^3, \ and \ H = 6\,m)$.

(8 marks)

(d) What remedial actions you suggest to improve the stability of the slope shown in Figure Q1? Discuss and use sketches to illustrate your answer as appropriate.

(7 marks)

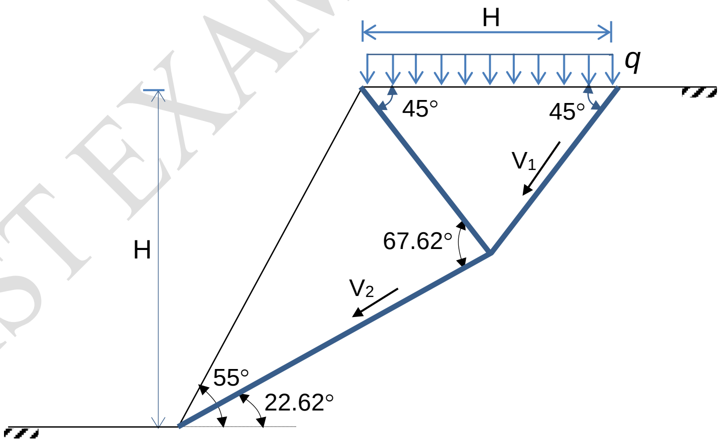

Figure Q1

Total 35 marks

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Question 2

a) A 0.6 m diameter conventional bored pile is to be installed on a site which underlain by 2.0 m of newly placed granular fill ($\gamma_{dry} = 18\frac{kN}{m^3}, \delta = 35^{\circ}, K = 0.7$) over 1.0 m of soft peat ($c_u = 20\frac{kN}{m^2},\ \alpha = 1.0$) over a layer of firm clay ($c_u = 110\ \frac{kN}{m^2}$, $\alpha = 0.5$) of considerable thickness. The peat and granular fill are expected to exert negative skin friction on the pile as the peat compresses under the newly placed fill.

i) What is the required length of pile, if the pile is to carry a working load of 900 kN with a factor of safety against failure of 2.5?

(15 marks)

ii) In an effort to minimise cost, an underreamed pile is to be used. If the shaft is to be 0.6 m diameter and 10 m in length, what is the required diameter of the underream?

(8 marks)

b) A pile group consists of a rectangular 4x3 group of bored pile, each 0.5 m in diameter and 10 m in length. The spacing between the pile centres is 1.5m in a clay of undrained strength 100 kPa. The shaft adhesion factor is 0.5. Calculate the capacity of the group and the pile efficiency.

(12 marks)

NOTE: Use the Supplementary Geotechnical Data sheets provided.

Total 35 marks

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Question 3

A reinforced soil wall with a vertical face is to be constructed at the edge of an embankment which is 8.0 m high. The fill used throughout the embankment and wall is dry and has a unit weight $\gamma = 18\,kN/m^3$ and an internal friction angle $\phi = 30^{\circ}$. The reinforced soil block forming the wall has uniform width 6.0 m. At 4.4 m depth in the wall it is proposed to use geogrid reinforcement with design strength 25 kN/m and frictional resistance at geogrid-soil interface $\delta_r = 25^{\circ}$. A 1.0 m wide strip of geogrid supports a section of the face of the wall which is 1.0 m wide and 0.8 m high.

a) For a strip of geogrid at 4.4 m depth, calculate the Factor of Safety (FoS) for tensile and pull out failure. Assume that the active zone behind the wall is an unmodified 'active wedge', that any changes in stress due to compaction can be ignored, and neglect the effect of rotational equilibrium on vertical stress in the reinforced soil block.

(12 marks)

b) Revise the estimates of FoS for tensile and pull-out failure for the geogrid at 4.4 m depth if an eccentricity represented by a rectangular distribution of vertical stress in the reinforced fill is assumed (Schlosser method).

(15 marks)

NOTE: Use the Figures in the data sheet to represent the locus of maximum tension in the geogrid, and to account for the effects of compaction for K on the face of the wall).

c) Provide brief answers to the following points:

i) Name two other considerations of equilibrium, which may affect the required length of the reinforcement.

ii) The reinforced soil wall relies on its own weight for stability – would a surcharge applied at the surface improve or reduce the "safety" of the design, and why?

iii) What factors principally account for the influence of compaction on the lateral earth pressure acting on the face of the wall?

(8 marks)

Total 35 marks

END OF SECTION A

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SECTION B - COMPULSORY

Question 4

A 5m high flexible sheet pile wall is embedded 7.0m into a uniform soil. A cross section through the wall is shown in Figure Q4. Other relevant parameters are:

Bulk unit weight = 19.0 kN/m^3, Saturated Unit Weight = 20.5 kN/m^3
Effective friction angle $\phi' = 23°$
Ground water: 1.0m below upper retained surface,
Ground water is at the ground level on the excavation side
Unit Weight of Water: 9.81kN/m^3
Surcharge: 10kN/m^2 at retained ground level

a) Determine, by calculation, the resultant thrust acting on the back of the retaining wall. **(15 marks)**

b) Determine the factor of safety, in appropriate modes failure, and thus evaluate the adequacy of the embedment depth of the sheet pile retaining wall. **(8 marks)**

c) Discuss how a greater factor of safety might be achieved by modifying or adding design/structural elements to the existing sheet pile retaining wall and also propose alternative designs that could be made to achieve a greater factor of safety, should that prove desirable for a similar situation. **(7 marks)**

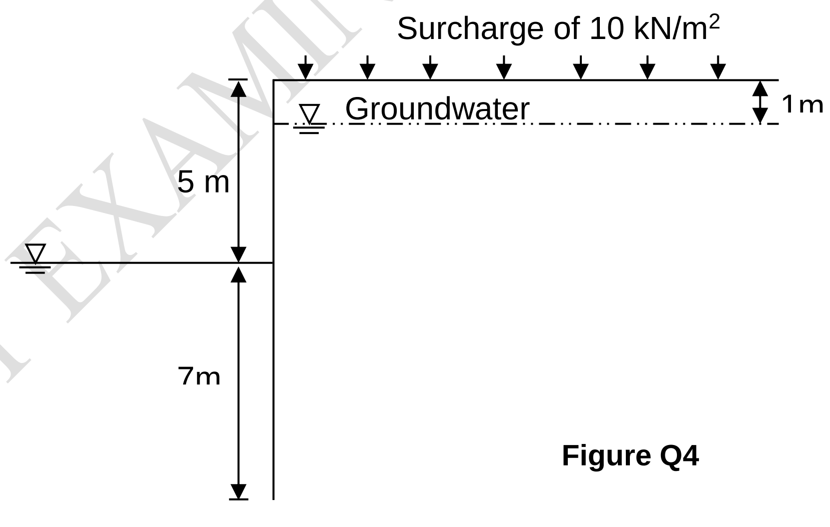

Figure Q4

Total 30 marks

END OF QUESTIONS

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Supplementary Geotechnical Information

1. <u>Piled Foundations</u>

$$Q = Q_b + Q_s$$

$$= \frac{\pi \times d^2}{4} q_b + \pi \times d \times \tau_s \times l$$

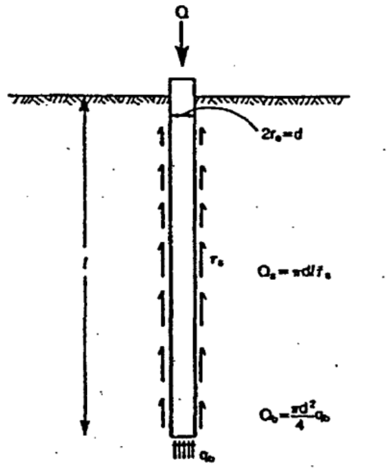

Figure 1a

<u>In clay</u>**:**

$q_b = N_c c_u \quad with \quad N_c = 9$

$\alpha - method: \qquad \tau_s = \alpha c_u$

$\beta - method: \qquad \tau_s = \beta \sigma_V' \quad with \quad \beta = K tan\delta$

K relates to type of pile and past history of the soil.

Driven piles: use $K = 1.5 \times K_0$

Bored piles: use $K = (1 + K_0)/2$

- <u>Undrained condition (Skempton's chart):</u>

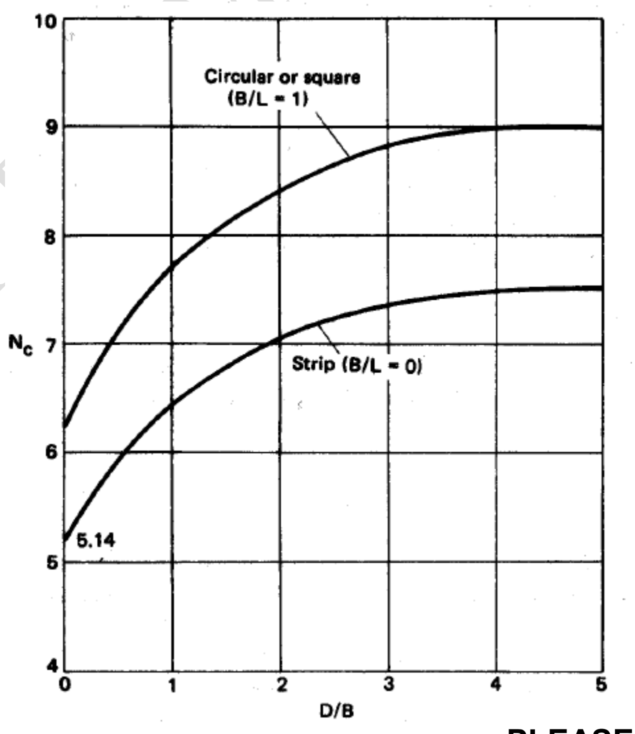

Figure 2a

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Factor of Safety:

- *For straight shafted piles:*

Without a pile test: $Q = (Q_s + Q_b)/2.5$

With a pile test: $Q = (Q_s + Q_b)/2$

- *For underreamed piles without a pile test, use the lesser of:*

With a pile test: $Q = (Q_s + Q_b)/2.5 \quad and \quad Q = Q_s + \frac{Q_b}{3}$

- *Negative skin friction:*

With a pile test: $WL + NSF = Q_{ult}/F \quad where \quad F = 2.5$

Underreamed piles without a pile test, Working load (*WL*) is the lesser of the values given by the above and:

$$WL + NSF = Q_s + Q_b/3$$

Pile Groups

- *Efficiency*

$$\eta = \frac{Q_{group}}{n \times Q_{single}}$$

- *Axial capacity in clay:*

$$Q_{block} = A_s \times c_u + A_b \times N_c \times s_c \times c_u$$

N_c: is the Skempton value of N_c for a buried strip footing
s_c: is the change factor for the block, $s_c = (1 + 0.2\, B/L)$
A_b: is the base surface area of the pile group as a block
A_s: is the side surface area of the pile group as a block

$$\frac{1}{Q_{group}^2} = \frac{1}{Q_{block}^2} + \frac{1}{(n \times Q_{single})^2}$$

- *Axial capacity in sand:*

Axial capacity not normally a problem. Efficiencies often > 1 due to compaction during driving. Typically:

$$Q_{group} \approx 2 - 3 \times nQ_{single}$$

Usually settlement controls design.

2. Embedded Retaining Walls

Active pressure coefficient:

$$K_a = \frac{1-\sin\phi}{1+\sin\phi} = \tan^2(45° - \frac{\phi}{2})$$

$$\sigma_{ha} = \sigma_V K_a - 2c\sqrt{K_a}$$

Passive pressure coefficient:

$$K_p = \frac{1+\sin\phi}{1-\sin\phi} = \tan^2(45° + \frac{\phi}{2})$$

$$\sigma_{hp} = \sigma_V K_p + 2c\sqrt{K_p}$$

3. Reinforced Soil Wall

- The locus of maximum tension force in reinforcement is usually approximated by the two lines shown in Figure 7a.

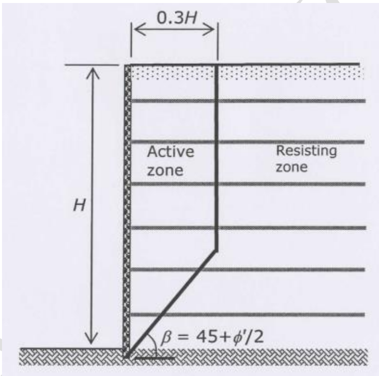

Figure 3a

- The coefficient of lateral earth pressure acting on facing is given in Figure 8a.

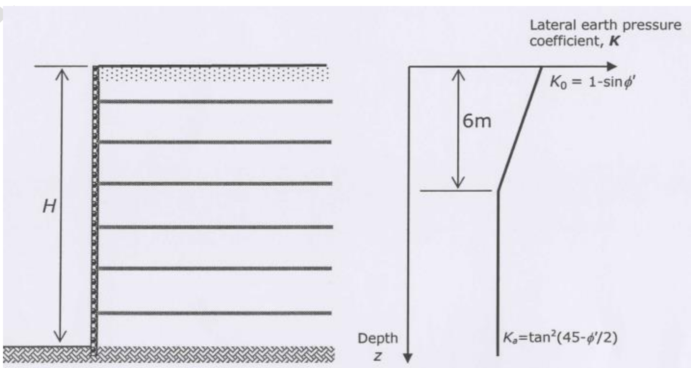

Figure 4a

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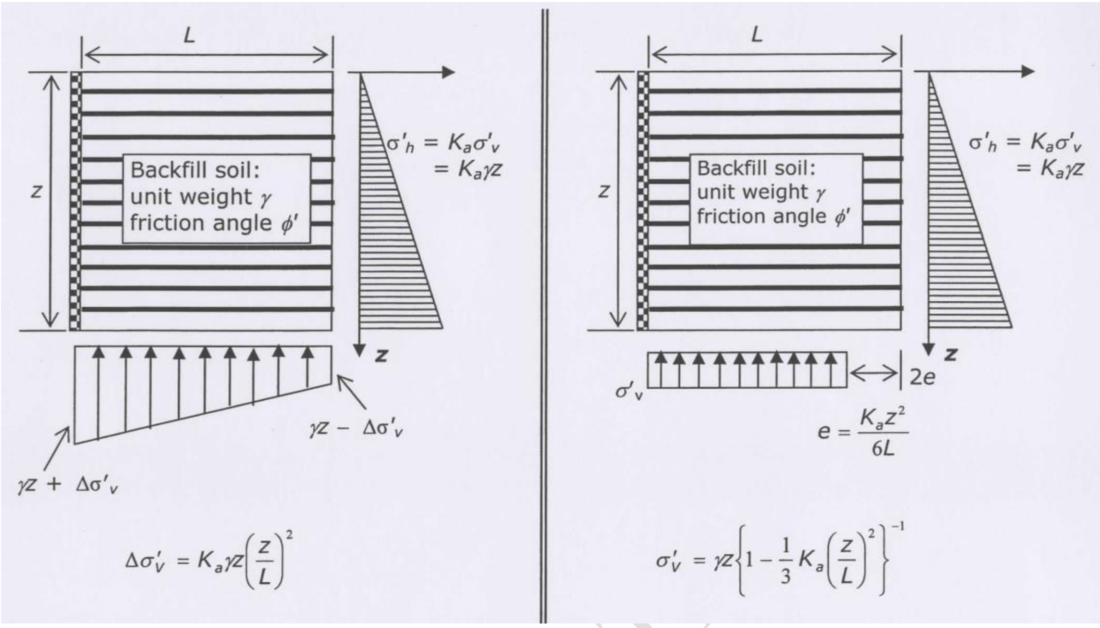
- The vertical stress in a horizontal plane in the reinforced soil wall can be approximated by two methods: (1) Bolton (1977) and (2) Schlosser (1978), which are shown in Figure 9a.



Bolton method **Schlosser method**

Figure 5a

- Factor of safety against tensile failure for strip reinforcement:

$$Fs_{,T} = \frac{\sigma_r \times b_r \times t_r}{T_{r,max}}$$

- Factor of safety against pull out failure for strip reinforcement with uniform vertical stress distribution:

$$Fs_{,po} = \frac{2 \times b_r \times l_{r,po} \times \sigma'_V \times \tan(\delta_r)}{T_{r,max}}$$

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