UNIVERSITY OF BOLTON

SCHOOL OF THE BUILT ENVIRONMENT & ENGINEERING

MSc CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2010/2011

GEOTECHNICAL ENGINEERING

MODULE NO: BLT4021

Date: Tuesday 18 January 2011 **Time: 2.00 pm – 5.00 pm**

INSTRUCTIONS TO CANDIDATES:

There are FIVE questions.

Answer FOUR questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Supplementary Geotechnical Data are provided on pages 8 to 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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1. A 7m high reinforced concrete gravity wall, 2m wide at its top and 3m wide at its base, is resting upon and also retains 7.0m of granular soil. A cross section through the wall is shown in Figure Q1.

   Other relevant parameters are:

Granular Soil	Bulk Unit weight	19.0 kN/m^3
	Saturated Unit Weight	20.5 kN/m^3
	Effective friction angle ϕ'	27°
	Ultimate bearing capacity of base	150 kN/m^2
Reinforced concrete	Unit weight 24 kN/m^3	
Groundwater	3.0m below upper retained surface Unit Weight of Water 10kN/m^3	
Surcharge	10kN/m^2 at retained ground level	

Formulae $K_a = (1-\sin\phi) / (1+\sin\phi)$

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

(13 marks)

b) Determine the height of the resultant thrust above the base of the retaining wall and determine the factor of safety against overturning, in bearing capacity and also against sliding of the base.

(4 marks)

c) Consider what other methods of retaining a difference in height of 7m, as given in Fig Q1, might be adopted and evaluate what factors would influence the final selected method? Ensure that your answer covers a full range of practical and design issues plus justifies your conclusions by comparing and contrasting a comprehensive range of alternatives (NOTE: use sketches and technical discussion to justify your answer).

(8 marks)

Total 25 marks

Question 1 continued over the page…

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Question 1 continued

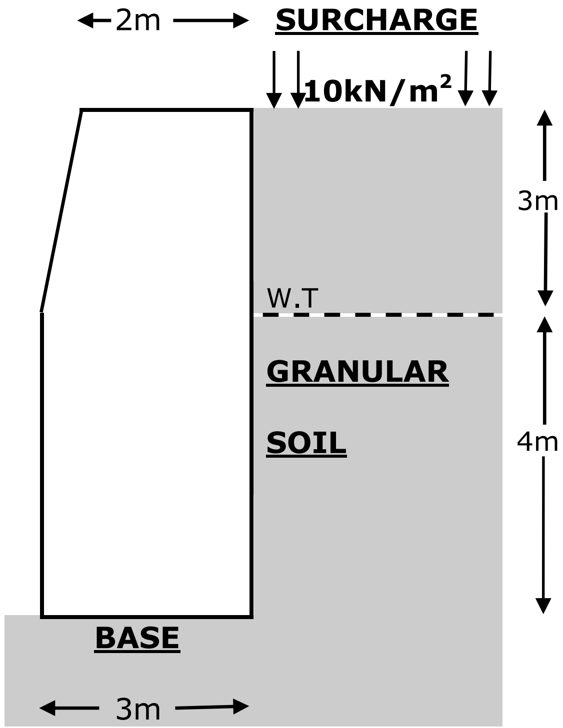

Figure Q1

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2. a) A pad foundation, 3.0m square is to be located at a depth of 2.0m in a uniform bearing stratum of firm clay. The water table level is at an assumed depth of 2.0m below ground level (from a recent and reliable site investigation). The clay soil properties are as follows;

Bulk unit weight	γ = 19.5 kN/m^3
Saturated unit weight	γ_{sat} = 21.5 kN/m^3
With respect to Total Stresses	c_u = 65.0 kN/m^2
	Φ_u = 0^0
With respect to Effective Stresses	c^l = 11.0 kN/m^2
	Φ^l = 28^0

Determine the safe bearing load that the foundation can support for both short term and long term cases and justify your calculations and assumptions made when finalising your answer.

(17 marks)

<u>NOTE:</u> Use the Supplementary Geotechnical Data sheets provided on pages 8 to 9 (as appropriate).

b) Discuss the full range of shallow foundation design methods commonly adopted for granular soils, ensuring that you specifically provide a design rationale and justification for the full range of design methods you present in your answer.

(8 marks)

Total 25 marks

Please turn the page

3. a) The final National Annex to BS EN 1997 as introduced on 31st December 2009 intended to have a positive impact upon geotechnical engineering in the UK. Following the imminent end of the co-existence period between new and old design codes in the UK, summarise the main changes that will arise by implementation of BS EN 1997 when carrying out the assessment of safe bearing capacity for foundation designs in the United Kingdom.

Ensure that your answer <u>briefly</u> discusses any changes to the way in which the calculations will be carried out and also states the different approaches that will be available throughout Europe. Ensure that your answer provides an example of determining a foundation design load (use the data provided in Q2). Also ensure that you illustrate the differences between the foundation methodology for design both pre- and post-December 2009.

(14 marks)

b) The design approach in the UK is ‘different’ to that to be adopted across many other EU Member States such that the geotechnical design approach for other civil engineering situations will also be modified following adoption of the final National Annex to BS EN 1997. State what these main differences are and explain why differences in approach are being adopted. In particular articulate why designs are divided into those for ‘slopes’ or for ‘non-slopes’.

(6 marks)

c) Define the Limit State Design approaches that will be relevant following implementation of BS EN 1997 and discuss the underlining strategy behind this change in design methodology. Discuss the way in which this change will impact upon design and risk.

(5 marks)

Total 25 marks

4. a) A CFA pile (25m long and 600mm in diameter) is to be installed into the following soil profile;

Depth m	Description	Unit Weight kN/m^3	c_u kN/m^2	Adhesion Factor α
0 – 2	Soft CLAY	21.0	35.0	0.6
2 – 15	Firm to stiff CLAY	22.0	55.0	0.45
15 - 50	Very stiff CLAY	22.5	145.0	0.45

The above clay strata are all taken to be fully saturated.

i) Determine the safe load carrying capacity of the pile.
<u>NOTE:</u> Clearly state any assumptions made in your calculations

(12 marks)

ii) Propose some changes to achieve a greater load carrying capacity. Ensure that your answer discusses two alternative pile options and briefly outlines the advantages and disadvantages of using <u>each</u> alternative.

(4 marks)

b) How would the calculations change if the firm to stiff clay in Q4 a) i) was replaced by a medium dense gravely sand with an average ‘N’ value of 25, and the Very stiff clay was a very dense sandy gravel with an ‘N’ value of >50.

(4 marks)

c) A driven pile is to be installed into a loose to medium dense, becoming dense to very dense, fine to coarse sand and gravel. Briefly outline the design philosophy adopted and illustrate within your answer what criterion on site verifies that you have achieved the design goal. Also briefly discuss any testing methods that might be used to verify the carrying capacity of the pile both during and after its installation.

(5 marks)

Total 25 marks

5. a) Briefly discuss the design of rock sockets for a piled foundation supporting a column load of 27MN for a high-rise building in central Manchester. Assume that the underlying rock has a weathered zone and is Bunter Sandstone. Answers to this question should provide an estimate of all usual assumptions used in calculations for the design of rock sockets.

(10 marks)

b) A retaining wall, supporting an 8.0m vertical drop below the level of an adjacent canal, is to be designed to prevent disturbance to the adjacent canal using a secant piled walling technique. The underlying ground is firm to stiff sandy clay. Discuss the reasons why a secant pile wall is preferred and also evaluate how the proximity of the canal, being some 3m away, affects the design proposals.

(7 marks)

c) Ground raising on a site with firm clay is envisaged to provide a relatively level final profile whilst buildings will require piled foundations to be taken down to bedrock at 25m below ground level. Concern is expressed by a piling contractor that there may be differential movement between site infrastructure and the buildings. The soils from ground level to 25m are a variable mixture of soft to firm, sandy clays. Evaluate the ground improvement options that could be adopted, highlighting the advantages and limitations of each proposed technique.

(8 marks)

Total 25 marks

END OF QUESTIONS

Please turn the page (for Supplementary Geotechnical Data)

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SUPPLEMENTARY GEOTECHNICAL DATA

Gross $q_{ult} = cN_cs_cd_ci_c + p_0N_q s_qd_qi_q + 0.5\gamma BN_\gamma s_\gamma d_\gamma i_\gamma$

BEARING CAPACITY FACTORS

ϕ	0	5^0	10^0	15^0	20^0	25^0	30^0	35^0	40^0	45^0	50^0
N_c	5.14	6.5	8.4	11.0	14.8	20.7	30.1	46.1	75.3	133.9	266.9
N_q	1.0	1.6	2.5	3.9	6.4	10.7	18.4	33.3	64.2	134.9	319.1
N_γ	0	0.1	0.4	1.2	3	6.8	15.1	33.9	79.5	200.8	568.5

SHAPE FACTORS

Shape of Foundation	Strip	Rectangle	Circle or Square
s_c	1.0	$1 + (B/L)(N_q/N_c)$	$1 + (N_q/N_c)$
s_q	1.0	$1 + (B/L)\tan\phi$	$1 + \tan\phi$
s_γ	1.0	$1 - 0.4(B/L)$	0.6

DEPTH FACTORS

Depth Factor	ϕ=0: Undrained Clay	ϕ>0, Drained Clay or Sand
d_c	$1 + 0.4R$	$d_q - (1 - d_q)/(N_c \tan\phi)$
d_q	1.0	$1 + 2R\tan\phi(1 - \sin\phi)^2$
d_γ	1.0	1.0

Note: If $D/B \le 1$ then $R = D/B$, if $D/B>1$ then $R = \tan^{-1}D/B$ (in radians)

INCLINATION FACTORS

Inclination Factors	ϕ=0: Undrained Clay	ϕ>0, Drained Clay or Sand
i_c	$1 – mH\ BLc_uN_c$	$i_q - (1 - i_q) / (N_c \tan\phi)$
i_q	1.0	$(1 - S)^m$
i_γ	1.0	$(1 - S)^{m+1}$

H is the total horizontal force and V_T is the total vertical force.

Note: $S = H / (V_T + BLc' \cot\phi)$
m = (2 + Aspect Ratio) / (1 + Aspect Ratio)
Where aspect ratio = (length in direction of load) /(length perpendicular to load)
= B/L for loads along short axis, L/B for loads along long axis.

Active and Passive Pressures

Active Pressure Coefficient $K_a = \dfrac{1-\sin\phi}{1+\sin\phi} = \tan^2(45° - \dfrac{\phi}{2})$

$$p_a = p_0K_a - 2c\sqrt{K_a}$$

Please turn the page

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

$$\boldsymbol{p_p = p_0 K_p + 2c\sqrt{K_p}}$$

The Peck, Hanson and Thorburn Method for foundations on sand or gravel.

For other situations
- **Strip Footings**, reduce q_a by 20%
- **Width B > 1m**, use same q_a
- **Width B <1m**, use q_a = 10.5NB
- **Other overburden pressures p′:** Multiply N by

$$C_N = 0.77 \log_{10} (2000 / p')$$

Peck, Hanson and Thorburn.
A 1m wide square or rectangular foundation with an overburden pressure of 100kN/m² and a static water table has a safe bearing capacity of
q_a = 10.5N kN/m²
Where N is the lowest SPT result within a depth equal to the width of the foundation below foundation level.

Note how the values for narrow (<1m) footings are determined by their true bearing capacity while the values for wider footings are determined by the need to restrict settlement.