UNIVERSITY OF BOLTON

FACULTY OF ADVANCED ENGINEERING AND SCIENCES

MSc IN CIVIL ENGINEERING

SEMESTER ONE EXAMINATION 2011/2012

GEOTECHNICAL MODELLING AND ANALYSIS

MODULE NO: BLT4017

Date: Thursday 19 January 2012 **Time: 2.00 pm – 5.00 pm**

INSTRUCTIONS TO CANDIDATES:

There are FOUR questions.

Answer THREE questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Supplementary Data Sheet on p.10.

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

Detach Table Q4(c)-2 and insert into your Answer Booklet using Treasury Tags.

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) The UK National Foreword to EC8 (ie.BS EN 1998) states : “There are generally no requirements in the UK to consider seismic loading, and the whole of the UK may be considered an area of very low seismicity in which the provisions of EN1998 need not apply. However, certain types of structure, by reason of their function, location or form, may warrant an explicit consideration of seismic actions. It is the intention in due course to publish separately background information on the circumstances in which this might apply in the UK.”

Discuss the rationale behind this statement and highlight the implications for foundation design using BS EN 1998-5 in the United Kingdom. Using specific examples of other internationally recognised design codes discuss how EC8 compares, highlighting any shortcomings and also appraising how it will be adopted across Europe and the wider international community.

(7 marks)

b) With publication of the National Annex to BS EN 1997-2 in November 2009 foundation design in the UK will move towards full implementation in 2010. Evaluate the main changes being introduced from both a technical and political perspective as viewed by UK designers, developers, consultants and clients as EC7 becomes more commonly adopted. Ensure that your discussions critically debate adoption of BS EN 1997, and why, despite publication of BS EN 1997-1 on 30 November 2007, this has not, to date, been widely adopted by Industry.

(5 marks)

c) Describe the use of DA1, DA2 and DA3 within EC7 and highlight the main differences in approach compared to BS8004.

(4 marks)

d) Using Table Q1(d) determine the minimum width of a 0.5m thick, concrete, square, pad foundation to satisfy ULS requirements in accordance with EC7 using DA1 for a permanent vertical load of 800kN and a variable vertical load of 180kN. Also calculate the safe net bearing pressure using the current BS8004 method. The bearing surface of the concrete foundation is on soft clay 1 m below ground level and the groundwater table is coincident with ground level. The concrete, soil and groundwater properties are;

$\gamma_{k\ conc}$ = 24kN/m^3; c_u= 30kPa; γ_{sat} = 18kN/m^3; γ_w = 10kN/m^3

(17 marks)

Total 33 marks

Question 1 continued over the page…

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Question 1 continued

BS EN 1997 (EC7) DESIGN APPROACH 1 (DA1)

			Combination 1			Combination 2		
Partial Factor Set			A1	M1	R1	A1	M1	R1
Actions	Permanent (G) - Unfavourable	γ_G	1.35			1.0		
	Permanent (G) - Favourable	$\gamma_{G,fav}$	1.0			1.0		
	Variable (Q) - Unfavourable	γ_Q	1.5			1.3		
Soil	Coefficient of Shearing Resistance (tan ø)	$\gamma_ø$		1.0			1.25	
	Effective Cohesion (c′)	$\gamma_{c'}$		1.0			1.25	
	Undrained Strength (c_u)	γ_{cu}		1.0			1.4	
	Unconfined Compressive Strength (q_u)	γ_{qu}		1.0			1.4	
	Weight Density (γ)	γ_γ		1.0			1.0	
Resistance	Bearing Resistance (R_v)	γ_{Rv}			1.0			1.0
	Sliding Resistance (R_v)	γ_{Rh}			1.0			1.0
	Earth Resistance	γ_{Re}			1.0			1.0
	Earth Resistance - Retaining Structures							
	Earth Resistance - Slopes							
	Prestressed Anchorages	γ_a			1.1			1.1

BS EN 1997 (EC7) DESIGN APPROACHES 2 & 3 (DA2 / DA3)

			Design Approach 2 (DA2)					Design Approach 3 (DA3)			
			Combination 1			Slopes					
Partial Factor Set			A1	M1	R2	A1	M=R2	A1	A2	M2	R3
Actions	Permanent (G) - Unfavourable	γ_G	1.35			1.35		1.35	1.0		
	Permanent (G) - Favourable	$\gamma_{G,fav}$	1.0			1.0		1.0	1.0		
	Variable (Q) - Unfavourable	γ_Q	1.5			1.5		1.5	1.3		
Soil	Coefficient of Shearing Resistance (tan ø)	$\gamma_ø$		1.0				GEO	STR	1.25	
	Effective Cohesion (c′)	$\gamma_{c'}$		1.0						1.25	
	Undrained Strength (c_u)	γ_{cu}		1.0						1.4	
	Unconfined Compressive Strength (q_u)	γ_{qu}		1.0						1.4	
	Weight Density (γ)	γ_γ		1.0						1.0	
Resistance	Bearing Resistance (R_v)	γ_{Rv}			1.4						1.0
	Sliding Resistance (R_v)	γ_{Rh}			1.1						1.0
	Earth Resistance	γ_{Re}									1.0
	Earth Resistance - Retaining Structures				1.4						
	Earth Resistance - Slopes				1.1						
	Prestressed Anchorages	γ_a			1.1						1.0

Table Q1(d)

Please turn the page

2. a) It is proposed to develop a former infilled alluvial channel alongside an existing canal situated in a geological valley to the west of Manchester with mixed use retail, car parking and a sports stadium / hotel complex. The site is underlain by 20m of soft alluvial clays. Prior to construction the whole site may be subjected to a surcharge to reduce future settlements. The surcharge will be coarse granular material and its depth will be such that the vertical stress applied to the ground exceeds that which will be applied by proposed site infrastructure and any localised filling of around 60 to 80kN/m^2. The surcharge is to be left in place for a certain time period so that future settlement of no more than 25mm in a 10-year period will occur after construction. Loads from the Sports Stadium are likely to require piling to underlying firm to stiff clays and sandstone beneath the site. Explain and evaluate the underlying assumptions in a methodology for determining the length of time for which the surcharge must be in place (define and justify all assumptions contained within the methodology).

(10 marks)

b) During the proposed surcharging, and also during the initial construction stage, it may be necessary to use soil instrumentation and supplementary investigations plus a range of in-situ construction details may be required to accelerate any anticipated settlements. Outline and discuss the practical difficulties when installing appropriate instrumentation at this site. Evaluate typical monitoring tolerances and assess whether the proposed works can accommodate adverse data obtained from any ‘early’ monitoring carried out. Ensure that your answer outlines a full range of instrumentation that might be used and then justifies the use of each specific type of instrument for this project.

(13 marks)

c) Outline the main theoretical basis for consolidation of the 15m of soft alluvial clays, and also state how the rate of consolidation would be increased to reduce the time period to reach an acceptable degree of consolidation within a much shorter time period, if the soil properties are;

$c_v = 4m^2/yr$; $c_h = 7m^2/yr$; $m_v = 0.8m^2/MN$

NOTE: It is not necessary to carry out detailed calculations, but rather to state how calculations would be carried out and what the theoretical assumptions are behind such a set of calculations. Students should use annotated sketch diagrams to demonstrate their understanding.

(10 marks)

Total 33 marks

Please turn the page

3. a) It is proposed to construct a piled 30-storey high-rise apartment building, with the lower 6-storeys being an hotel with associated basement car park at a location immediately above and adjacent to an existing underground railway tunnel. The tunnel is located with its crown at a level of -4m AOD in fractured Bunter Sandstone close to Liverpool City Centre. This proposed scheme requires loads to be applied from the structure at ground level, as shown in Figure Q3(a), with the corresponding ground levels indicated in the Table to the right hand side of this foundation plan.

Weathered Bunter Sandstone occurs at a level of 10m AOD beneath stiff to very stiff clays which occur immediately from ground level. It is known that coring was necessary to advance site investigation boreholes beneath a level of 8m AOD.

Evaluate the practical and technical considerations necessary when proposing a system of piling works, to reduce the likelihood of unfavourable loads being transferred from the new building to the existing tunnel.

(10 marks)

b) Explain the full process, from initial concept to detailed analysis, of modelling the impact of the building loads on the tunnel for a range of potential foundation solutions.

(10 marks)

c) What strategy is likely to be required from the tunnel owner, Network Rail, and what, if any, monitoring works or other precautions would you envisage to enforce their legal requirements. Ensure that you develop logical arguments both for and against the proposed piling works. In answering this question also state the full range of monitoring and instrumentation that would be installed for compliance purposes, where instruments should be located and also debate measuring accuracy/tolerances that would be required. NOTE: State any additional ground investigation and/or computer modelling that might be required to facilitate a thorough assessment.

(13 marks)

Total 33 marks

Question 3 continued over the page…

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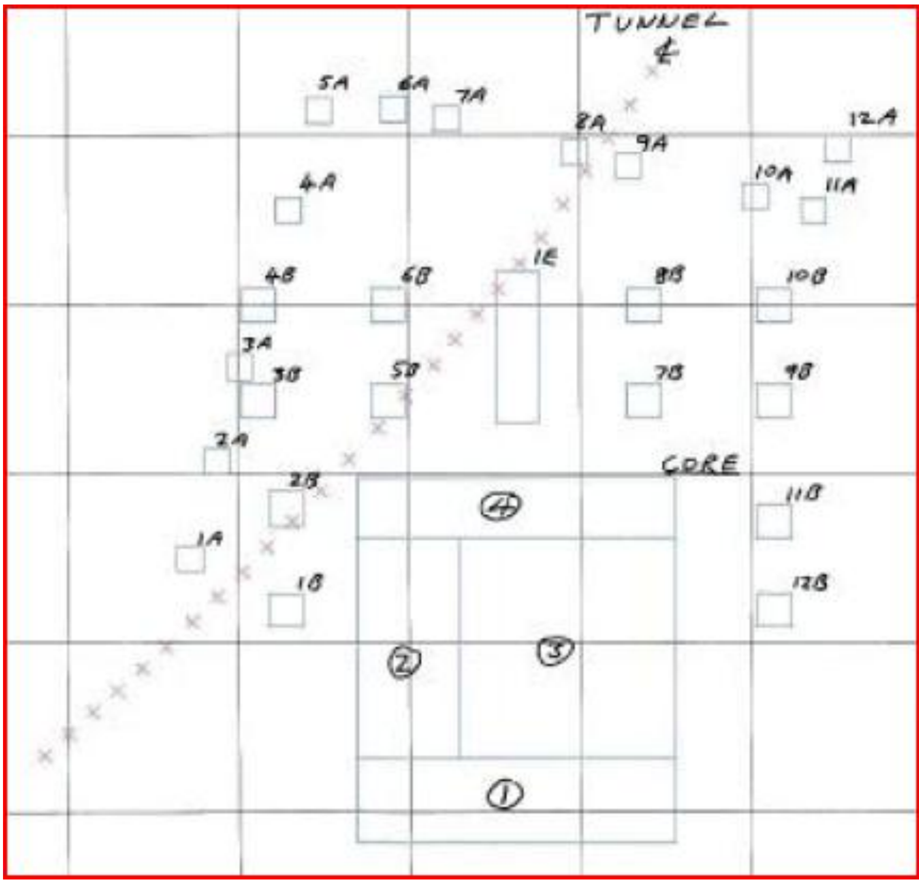
Question 3 continued



Footing	Loads (DL+LL) (kN)	Level (mAOD)
1A	2700	13.1
2A	2700	13.1
3A	2700	13.1
4A	2700	13.1
5A	3675	13.1
6A	3675	13.1
7A	3675	13.1
8A	3675	13.1
9A	3675	13.1
10A	3675	13.1
11A	3675	13.1
12A	3675	13.1
1B	2700	12.85
2B	2700	12.85
3B	3100	12.85
4B	5300	12.85
5B	6050	12.85
6B	4300	12.85
7B	6050	12.85
8B	5200	12.85
9B	6050	12.85
10B	5200	12.85
11B	2700	12.85
12B	2700	12.85
1E	15000	12.65
CORE 1	44100	11.35
CORE 2	31500	11.35
CORE 3	102250	11.35
CORE 4	38500	11.35

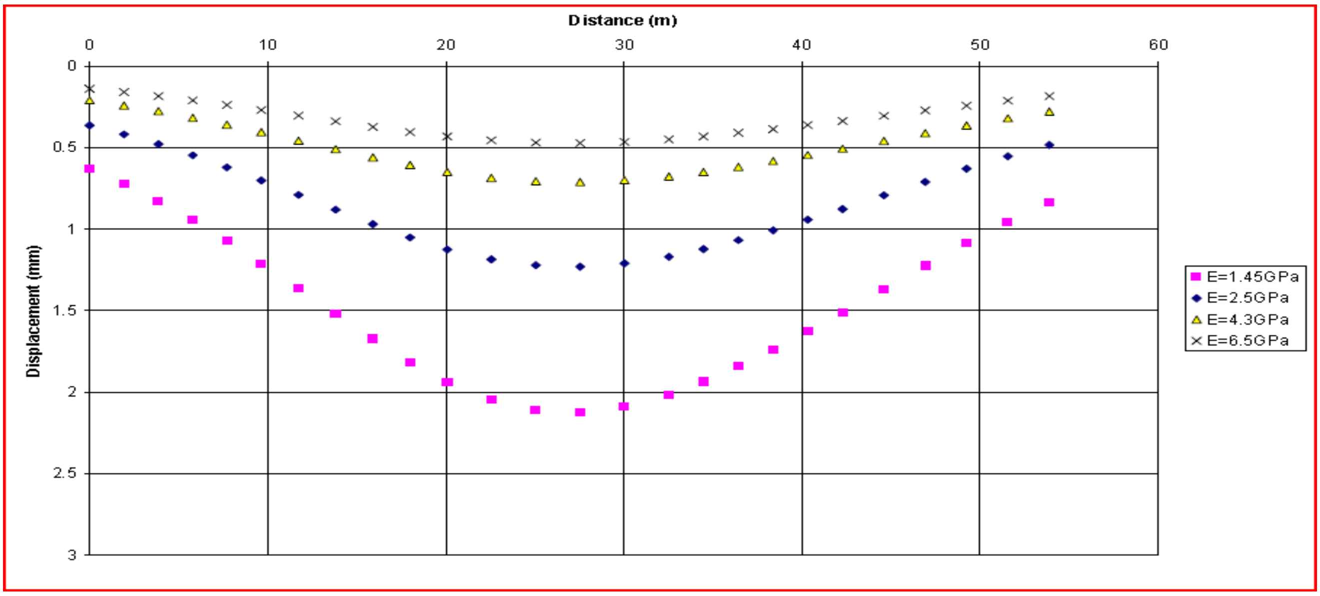


Fig Q3(a) Loading to Ground in Vicinity of Tunnel and Predicted Crown Displacement

Please turn the page

4. a) There are many commercially available software packages available to model geotechnical problems. Give three examples of typical geotechnical problems that benefit from the use of such modelling software. Include a summary of the most common commercially available software packages.

(8 marks)

b) How are slope stability assessments being altered as implementation of BS EN 1997 becomes more widely accepted by geotechnical consultants. State specifically how this will affect slope stability calculations and how commercially available software will need to be modified to be compatible.

(8 marks)

c) Using traditional geotechnical theory and soil properties derived by assessing site investigation data from undrained and drained triaxial testing analyse the slope provided in Figure Q4(c)-1 and determine its factor of safety using the table provided in Table Q4(c)-2. Identify with justification the most appropriate form of modelling to undertake for this slope, taking account of the undrained and drained soil parameters available. Soil parameters are as follows;

Saturated unit weight, γ_{sat} = 18.81 kN/m^3
Unit weight of Water, γ_w = 9.81 kN/m^3

Shear Strength parameters;

c_u = 65kN/m2   c' = 14.5 kN/m^2
Φ_u = 0^o Φ' = 15^o

(12 marks)

d) What instrumentation could be installed and monitoring undertaken for the slope outlined in Q4(c)-1 if there were concerns over its stability as part of a temporary works placement of a 2m high layer of surcharge material 3m back from its crest and also of excavation of a 1.5m deep service trench 2m away from its toe. What practical steps could be taken to improve stability during excavation of this trench and placement of temporary surcharge if there were concerns that stability might be compromised?

(5 marks)

Total 33 marks

Question 4 continued over the page…

Question 4 continued

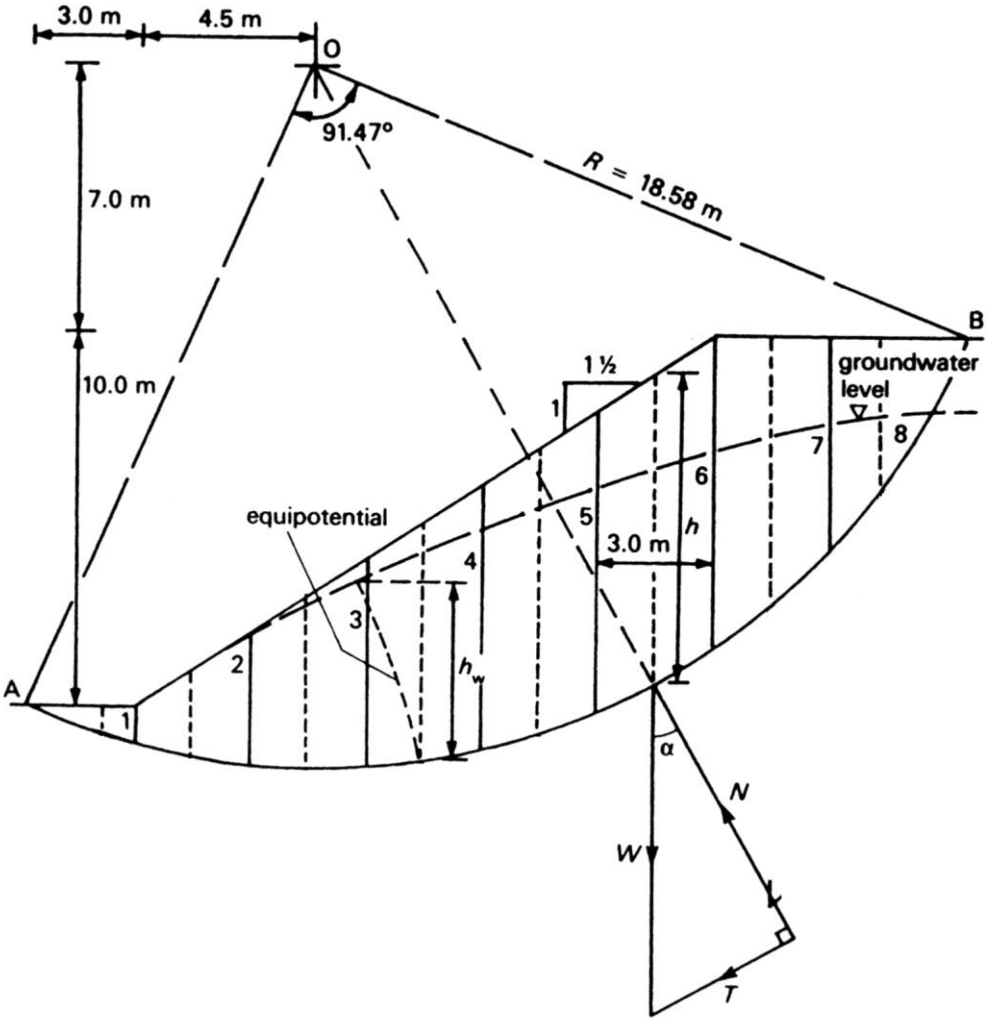


Figure Q4(c)-1 (showing construction for α on Slice No. 6)

Question 4 continued over the page…

Question 4 continued

Slice No.	Slice Width b (m)	Slice Height h (m)	α (°)	h_w (m)	Weight W (kN)	W sin α	W cos α	l b / cos α (m)	u l	(Wcos α - ul)
1	3.0	0.6	-17.25	0.6						
2	3.0	2.2	-9.80	2.2						
3	3.0	4.5	0.00	3.8						
4	3.0	6.3	9.80	4.8						
5	3.0	7.6	19.00	5.5						
6	3.0	8.1	29.50	5.4						
7	3.0	7.1	40.00	4.1						
8	3.8	4.0	53.00	1.9						
					Sum Σ				**Sum** Σ	

Table Q4(c)-2

Candidate Number / Seat Number ……………………………………………………….

END OF QUESTIONS

Please turn the page (for Supplementary Data Sheet)

Please turn the page

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SUPPLEMENTARY DATA SHEET

$$\text{Gross } q_{ult} = cN_c s_c d_c i_c + p_0 N_q s_q d_q i_q + 0.5\gamma B N_\gamma s_\gamma d_\gamma i_\gamma$$

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	$1 + 0.4\ R$	$d_q - (1 - d_q)/(N_c \tan \phi)$
d_q	1.0	$1 + 2R \tan \phi\ (1 - \sin \phi)^2$
d_γ	1.0	1.0

Note: If $D/B \leq 1$ 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	$1 – mH\ BLc_u N_c$	$i_q - (1 - i_q) / (N_c \tan \phi)$
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: $S = H / (V_T + BLc' \cot \phi)$
$m = (2 + \text{Aspect Ratio}) / (1 + \text{Aspect Ratio})$
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.

Slope Stability

$$F = \frac{c' R\, \theta_{rad} + \Sigma\, (W \cos \alpha - u\, l) \tan\phi'}{\Sigma\, W \sin\alpha}$$