# UNIVERSITY COLLEGE LONDON

University of London

# EXAMINATION FOR INTERNAL STUDENTS

For The Following Qualifications:-

*B.Eng.* *M.Eng.* *M.Sc.*

**Civil Eng 2004: Soil Mechanics part II**

COURSE CODE : **CIVL2004**

UNIT VALUE : **0.50**

DATE : **17-MAY-06**

TIME : **10.00**

TIME ALLOWED : **3 Hours**

06-C0275-3-110

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**CIVL2004 SOIL MECHANICS II**
**Second Year B.Eng./M.Eng. Degree**
**2006 Examination**

**3 HOURS**

*Answer 4 QUESTIONS only. All questions carry 25 marks.*

Q1. (a) Explain what is meant by isotropic compression and by one-dimensional compression. Sketch diagrams using v-lnp' and q'-p' axes to illustrate the relative positions of the isotropic and one-dimensional normal compression lines relative to the critical state line. Where possible give practical examples to illustrate each type of compression and hence identify which you believe to be more commonly relevant to geotechnical design.

**[7 marks]**

(b) Data shown in Table 1.1 were obtained for isotropic compression and swelling of a specimen of soft clay. The initial water content of the soil was 41%. Calculate the values of the parameters N, $\lambda$ and $\kappa$ for this soil.

**[11 marks]**

(c) What would be the specific volume of a specimen of the same soil subjected to a vertical effective stress of 200kPa under one-dimensional compression?

**[7 marks]**

The value of $G_s$ is 2.7 and the value of $K_0$ for the normally consolidated clay is 0.5. The spacing of the isotropic and one-dimensional compression lines in v-lnp' space (i.e. $N-N_0$) may be assumed to be 0.100.

| p' (kPa) | $\varepsilon_v$ (%) |
|---|---|
| 100 | 1.03 |
| 200 | 5.50 |
| 350 | 8.78 |
| 700 | 12.95 |
| 350 | 12.54 |
| 200 | 12.02 |

Table 1.1

Q2. (a) Show how in clay peak states depend on stress level and overconsolidation ratio.

**[4 marks]**

(b) Table 2.1 gives results from triaxial tests on two samples of clay. Samples A and B were compressed isotropically to reach normally consolidated states at mean effective stresses p'=200kPa and p'=400kPa respectively. They were then sheared drained at constant cell pressure. The specific volumes of the samples at the start of shearing were recorded to be 1.99 for sample A, and 1.90 for sample B.

Determine the critical state parameters (M, $\Gamma$, $\lambda$) for the clay.

**[14 marks]**

**Question 2 continues.**

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(c) A third sample C was tested in the triaxial apparatus. Sample C was compressed isotropically to reach a normally consolidated state at p'=200kPa with a specific volume v=1.99, and was then sheared undrained.

Determine the final stress state (p',q') and final pore water pressure in the sample. You will assume that the pore water pressure at the start of shearing was equal to zero.

**[7 marks]**

| **Sample A (drained)** isotropically normally consolidated to p'=200kPa before shearing | | | **Sample B (drained)** isotropically normally consolidated to p'=400kPa before shearing | | |
|---|---|---|---|---|---|
| axial strain $\varepsilon_a$ (%) | deviatoric stress q' (kPa) | volumetric strain $\varepsilon_v$ (%) | axial strain $\varepsilon_a$ (%) | deviatoric stress q' (kPa) | volumetric strain $\varepsilon_v$ (%) |
| 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 39 | 2.2 | 1 | 78 | 2.5 |
| 2 | 82 | 3.5 | 2 | 163 | 3.9 |
| 4 | 148 | 4.8 | 4 | 296 | 5.2 |
| 8 | 194 | 5.9 | 8 | 388 | 6.3 |
| 12 | 211 | 6.4 | 12 | 414 | 6.7 |
| 16 | 218 | 6.5 | 16 | 437 | 6.8 |
| 22 | 219 | 6.5 | 22 | 438 | 6.8 |

Table 2.1

Q3. (a) Using the theory of parabolic isochrones, show that in the short term the degree of consolidation, $U_t$, is given by:

$$U_t = \frac{2}{\sqrt{3}}\sqrt{T_v}$$

where $T_v$ is the time factor.

**[11 marks]**

(b) Figure 3.1(a) shows the cross section of a wide embankment, 2m high, constructed from a compacted fill on a soft clay foundation. The fill has a bulk unit weight $\gamma = 21\text{kN/m}^3$. The soft clay has the following properties: coefficient of consolidation, $c_v = 2.10^{-7}\ \text{m}^2/\text{s}$, and coefficient of compression, $m_v = 2.10^{-3}\ \text{m}^2/\text{kN}$. Calculate the long term settlement at the centre-line, and the time taken for 95% of this settlement to occur.

**[6 marks]**

(c) At a second section, shown in Figure 3.1(b), there is a similar construction, but the embankment here is constructed initially to a height of 3m. The upper 1m of this embankment will then be removed when the settlement at the centre-line has reached a value corresponding to the ultimate settlement reached at the section shown in Figure 3.1(a). After what time period should this upper 1m of the embankment be removed?

**[8 marks]**

**Question 3 continues.**

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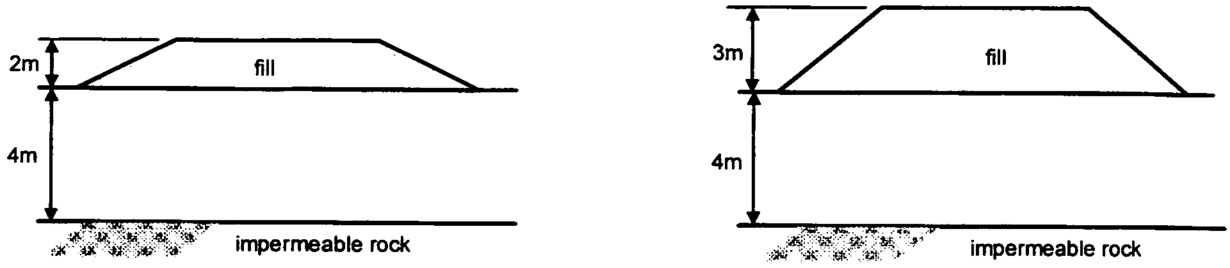

(a) (b)

Figure 3.1

NOTE: $U_t<1/3$ $U_t = 2/\sqrt{3}\,\sqrt{T_v}$

$U_t>1/3$ $U_t = 1 - 2/3\,\exp(1/4 - 3T_v)$

Q4. What is the ultimate load capacity of a foundation 2m square founded at a depth of 2m in granular soil, if:

(a) the water table is at great depth

**[5 marks]**

(b) the water table is at foundation level

**[5 marks]**

(c) the water table is at ground level

**[5 marks]**

(d) If the working load applied on the foundation is half of the ultimate load capacity calculated above what is the factor of safety on the friction angle for cases (a) and (c).

**[10 marks]**

The unit weight of the soil is 18.5kN/m$^3$ dry and 20kN/m$^3$ when it is saturated. The angle of friction of the soil is $\phi'=36°$. Relevant tables and charts are given in the Appendix at the end of the paper.

Q5. A group of bored piles is to be constructed in London clay to provide the foundation for an office block. Figure 5.1 shows the geometry of the piles. The undrained shear strengths of the clay determined from the site investigation are given in Table 5.1. The in situ pore pressures were found to be hydrostatic with the water table at the ground surface, and the unit weight of the clay was measured at 19kN/m$^3$.

Calculate the required depth of the piles for a required capacity of 12MN following two different methods. You will calculate the end bearing capacity using an undrained approach with a value of $N_c$ of 9.0. You will calculate the shaft friction using each of the following methods:

(a) $\alpha$ -method for the shaft friction with a value of $\alpha = 0.45$

**[10 marks]**

**Question 5 continues.**

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(b) $\beta$ -method for the shaft friction with a value of $\beta = 0.4$

**[10 marks]**

(c) Calculate the settlement of the individual pile, using Burland & Cooke's method.

**[5 marks]**

| **Depth (m)** | **Undrained shear strength, $S_u$ (kPa)** |
|---|---|
| 4.9 | 101 |
| 9.3 | 102 |
| 11.5 | 149 |
| 12.1 | 150 |
| 18.0 | 148 |
| 26.8 | 151 |
| 35.5 | 154 |

Table 5.1

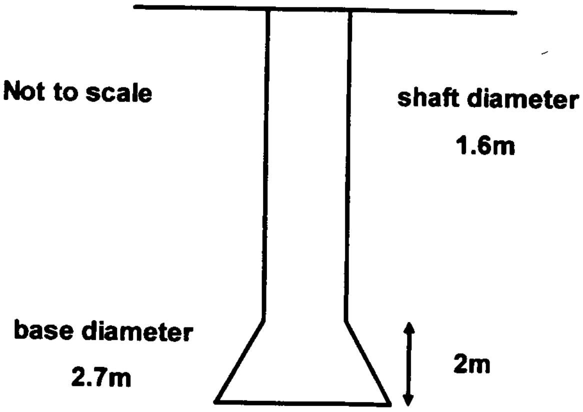

Figure 5.1

Q6. A flexible square footing, 4m wide, applies a stress of 80kPa to a very deep layer of clay. The shear modulus G of the clay has been determined as 15MPa.

(a) Draw a profile of the immediate settlement for a section running from the centre of the footing diagonally to one corner of the square. What is the area of most serious differential settlement?

**[12 marks]**

(b) Calculate the consolidation under the centre of the foundation, demonstrating that below 10m depth the contribution to that settlement is negligible. The coefficient of compressibility $m_v$ is 0.4m$^2$/MN at the surface, decreasing linearly with depth to 0.1m$^2$/MN at 10m. You may use a value of A = 0.4 to apply Skempton & Bjerrum's correction. It is assumed that the influence factors to calculate stresses under a square footing are equal to those under a circular footing of same area. Relevant tables and charts for the influence factors are given in the Appendix at the end of the paper.

**[13 marks]**

Q7. (a) Explain what are a 'first time' slide and a reactivation. Relate your answer with the strength parameters of the soil, using sketches when appropriate.

**[5 marks]**

(b) Explain the classification of landslides in terms of pore water pressure and the strength parameters one should use to analyse the slope. Use sketches to show the stress paths (total and effective) followed by a soil element in an excavation (unloading) and in a landfill (loading), identifying the different pore-water pressure stages according to that classification.

**[14 marks]**

(c) Calculate the factor of safety of the infinite slope shown in Figure 7.1.

**[6 marks]**

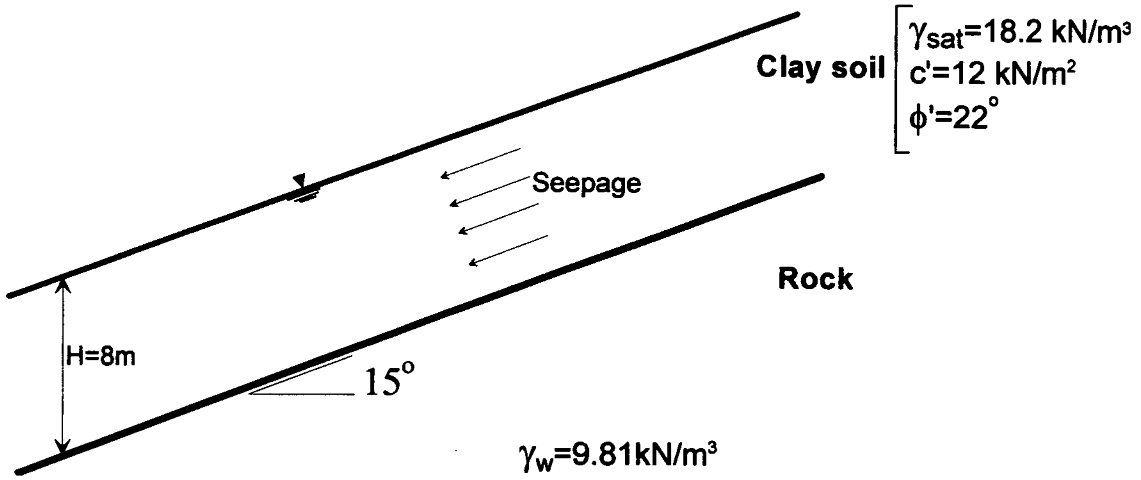

Figure 7.1

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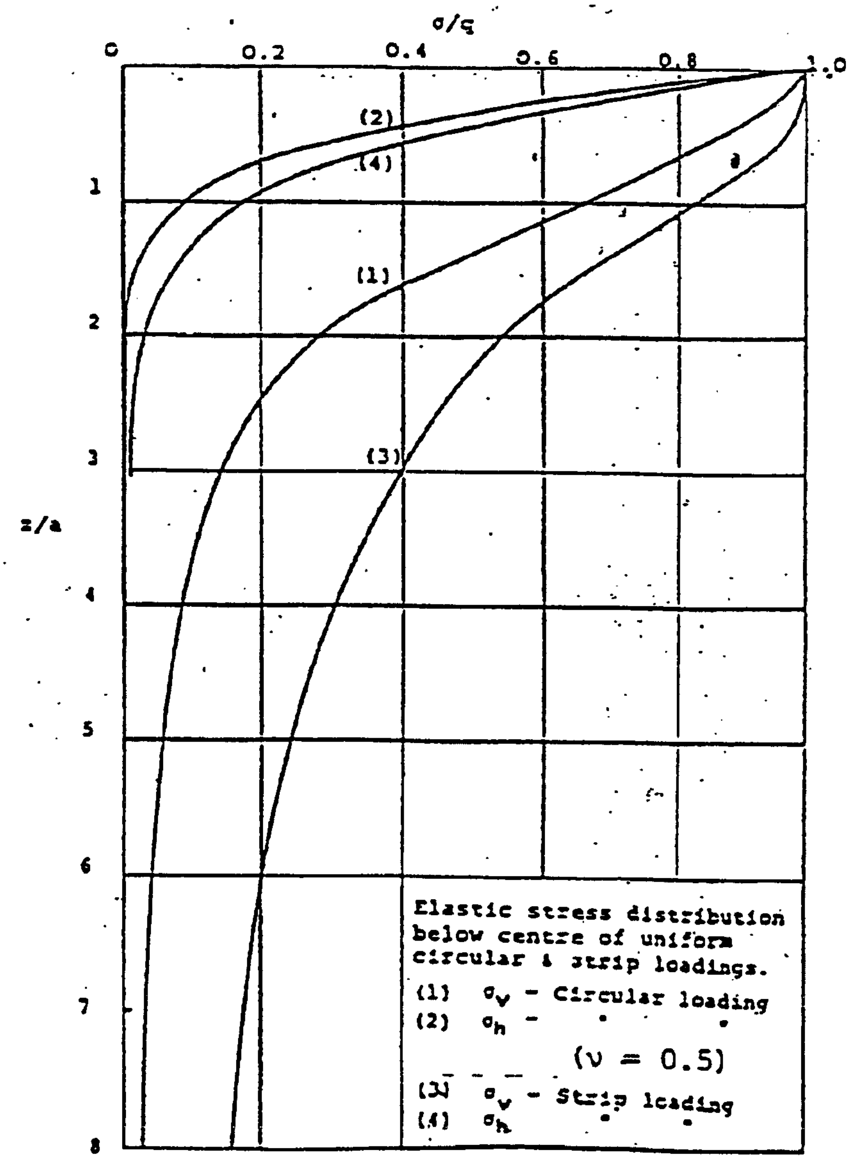
# APPENDIX

## Influence factors for rectangular loading: corner settlement

| L/B | $I_p$ | L/B | $I_p$ | L/B | $I_p$ | L/B | $I_p$ |
|---|---|---|---|---|---|---|---|
| 1 | 0.561 | 1.6 | 0.698 | 2.4 | 0.822 | 5 | 1.052 |
| 1.1 | 0.588 | 1.7 | 0.716 | 2.5 | 0.835 | 6 | 1.11 |
| 1.2 | 0.613 | 1.8 | 0.734 | 3 | 0.892 | 7 | 1.159 |
| 1.3 | 0.636 | 1.9 | 0.75 | 3.5 | 0.94 | 8 | 1.201 |
| 1.4 | 0.658 | 2 | 0.766 | 4 | 0.982 | 9 | 1.239 |
| 1.5 | 0.679 | 2.2 | 0.795 | 4.5 | 1.019 | 10 | 1.272 |

## Elastic stress distribution below centre of uniform centre and strip loading



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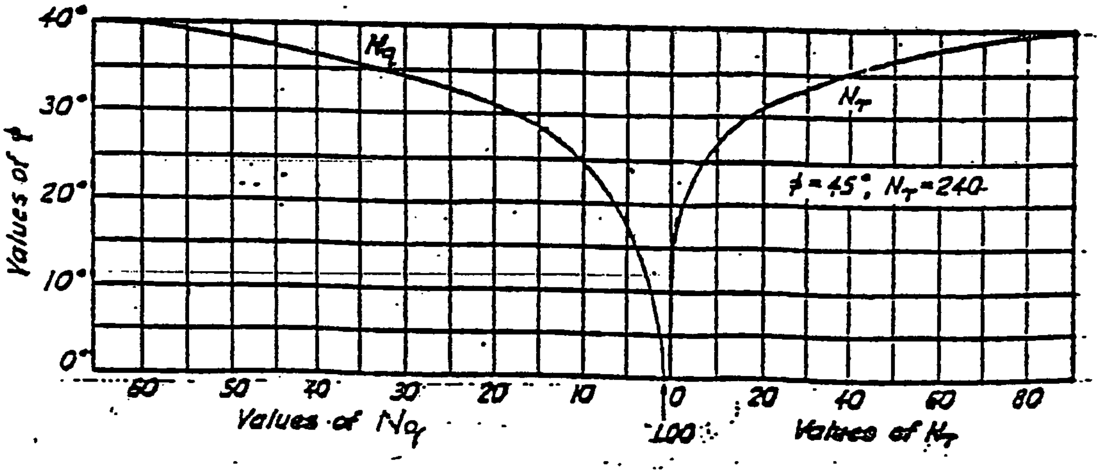
## Bearing capacity factors for drained loading (Terzaghi & Peck, 1968)



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