

**UNIVERSITY OF BOLTON**

**SCHOOL OF THE BUILT ENVIRONMENT &  
ENGINEERING – RAK CAMPUS**

**BSc(HONS) CIVIL ENGINEERING**

**SEMESTER ONE EXAMINATION 2010/2011**

**SOIL MECHANICS**

**MODULE NO: BLT1013**

Date: Wednesday 19 January 2011

Time: 2.00 pm – 4.00 pm

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**INSTRUCTIONS TO CANDIDATES:**

There are **FOUR** questions.

Answer **THREE** questions.

All questions carry equal marks.

Marks for parts of questions are shown in brackets.

Formulae and Definitions are provided on pages 10 to 12.

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

Detach Figures Q2, Q3-1 and/or Q3-2 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.

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- Q1. (a) Sketch a “Soil Model Diagram” ensuring that you annotate every term on your soil model diagram with the corresponding ‘algebraic term’ for the respective mass and volume of the solids, water and air  
(NOTE: Do NOT simply use the terms  $M_A$ ,  $M_W$ ,  $M_S$ ,  $V_A$ ,  $V_W$  and/or  $V_S$ ).

(3 marks)

- (b) Using the soil model diagram outlined in Q1(a) show the algebraic expression for the following ‘soil properties’;

- (i) Bulk Density,  $\rho_b$
- (ii) Dry Density,  $\rho_d$
- (iii) Degree of Saturation,  $S_r$
- (iv) Air Void Content,  $A_v$

(NOTE: Do NOT simply use the terms  $M_A$ ,  $M_W$ ,  $M_S$ ,  $V_A$ ,  $V_W$  and/or  $V_S$ ).

(6 marks)

- (c) A cylindrical sample of soil has a height of 205mm and a diameter of 102.4mm. The sample was found to have an initial “bulk” mass of 3.735kg. After placing in an oven at 105°C for 24hrs the mass was found to be 3.306kg. The specific gravity,  $G_s$  of the soil particles was determined as 2.71.

Determine EACH of the following soil properties (either using the Soil Model approach as outlined in Q1(a) and Q1(b) or by using the Formulae provided on Pages 9 to 11 at the end of this Examination Paper);

- (i) Bulk density ( $\text{kg/m}^3$ )
- (ii) Bulk unit weight ( $\text{kN/m}^3$ )
- (iii) Moisture content, %
- (iv) Void ratio
- (v) Porosity, %

**Question 1 continued over the page...**

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**Question 1 continued**

- (vi) Degree of saturation, %
- (vii) Air void content, %
- (viii) If the soil volume remains constant, what would be the saturated unit weight of the soil on inundation ( $\text{kN/m}^3$ )

(16 marks)

**Total 25 marks**

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- Q2 (a) Sketch how the results from a 2.5kg 'light', 4.5kg 'heavy' and 'vibrating rammer' compaction tests would plot on the same graph in relationship to the 0% air voids (ie. saturation) line in accordance with BS1377. (5 marks)

- (b) A British Standard 2.5kg 'light' Compaction test on a soil sample ( $G_s = 2.71$ ) gave the following results:

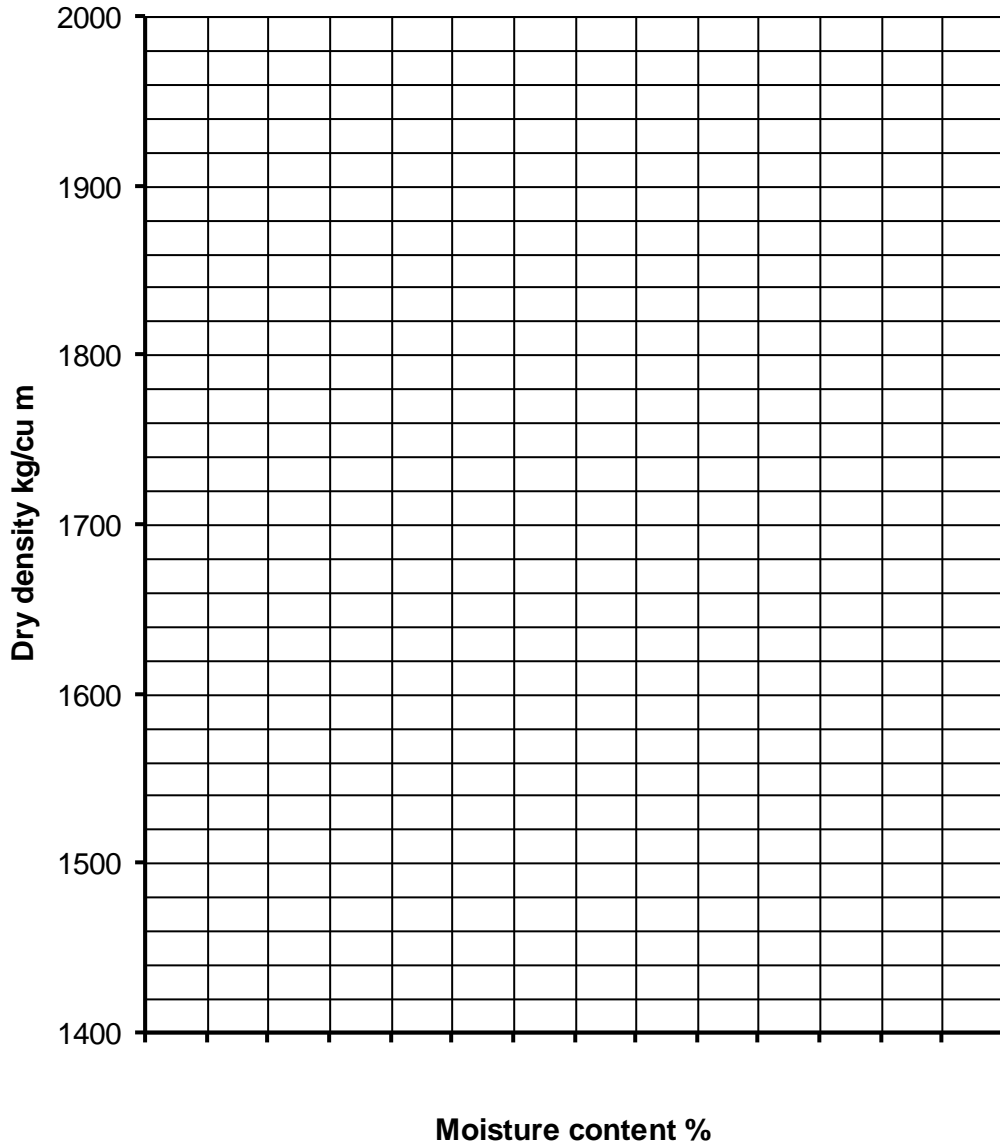
Moisture Content %	Bulk Density ( $\text{kg/m}^3$ )
7	1770
9	1980
11	2170
13	2215
15	2190
17	2150

- (i) Using the data in the table above, carry out any calculations necessary and then plot the results of this compaction test on Figure Q2. From the plotted data on Figure Q2 determine appropriate compaction characteristics for this soil. Ensure that you describe this using the simple terms routinely used in soil mechanics. (12 marks)
- (ii) Calculate the air void content for the soil at 10% moisture content. (1 mark)
- (c) Describe the main features of a Highway Agency 'Method Specification' for project management purposes to control placement of suitable sandy clay soil in an 8m high embankment for the construction of a new motorway. (4 marks)
- (d) State how checks are made on site to decide whether compaction works conform to the requirements of a 'Performance Specification'. (3 marks)

**Total 25 marks**  
**Question 2 continued over the page...**

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**Question 2 continued**

**LIGHT COMPACTION TEST**



**Figure Q2**

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- Q3. (a) Describe how a “coarse” soil would be classified in accordance with BS1377. (5 marks)
- (b) Describe how a “fine” soil would be classified in accordance with BS1377. (5 marks)
- (c) Describe how a soil would be visually described in the field during the sampling stage of a site investigation, and provide examples of soil descriptions to include both “fine” and “coarse” soils. (5 marks)
- (d) The results of a classification test conducted on a soil sample are shown below;

Plastic limit test:

	Test 1	Test 2
Mass of empty tin (g)	17.56	17.65
Mass of tin + wet soil (g)	45.12	42.12
Mass of tin + oven dried soil (g)	40.10	37.60

Liquid limit test:

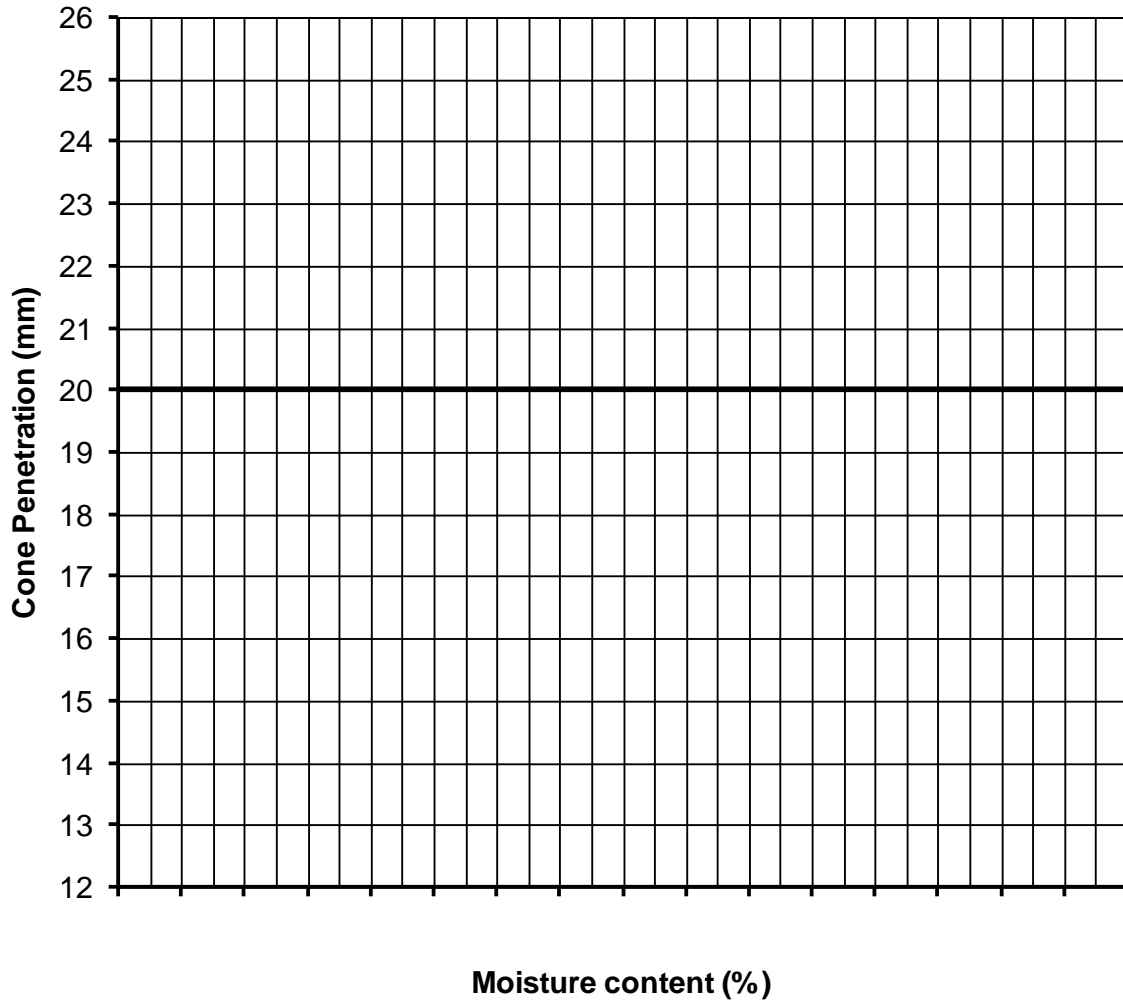
Cone penetration (mm)	16.87	18.92	21.45	23.89
Moisture content (%)	30.57	34.05	37.95	41.91

- (i) Using Fig Q3-1, as appropriate, determine the ‘Index Properties’ for this soil. Ensure that you fully define what the “Index Properties” are for fine-grained soils. (8 marks)
- (ii) Provide a soil classification name and symbol for this soil using Fig.Q3-2. (2 marks)

**Total 25 marks**

**Question 3 continued over the page...**

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**Question 3 continued**



**Figure Q3-1**

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**Question 3 continued over the page...**

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**Question 3 continued**

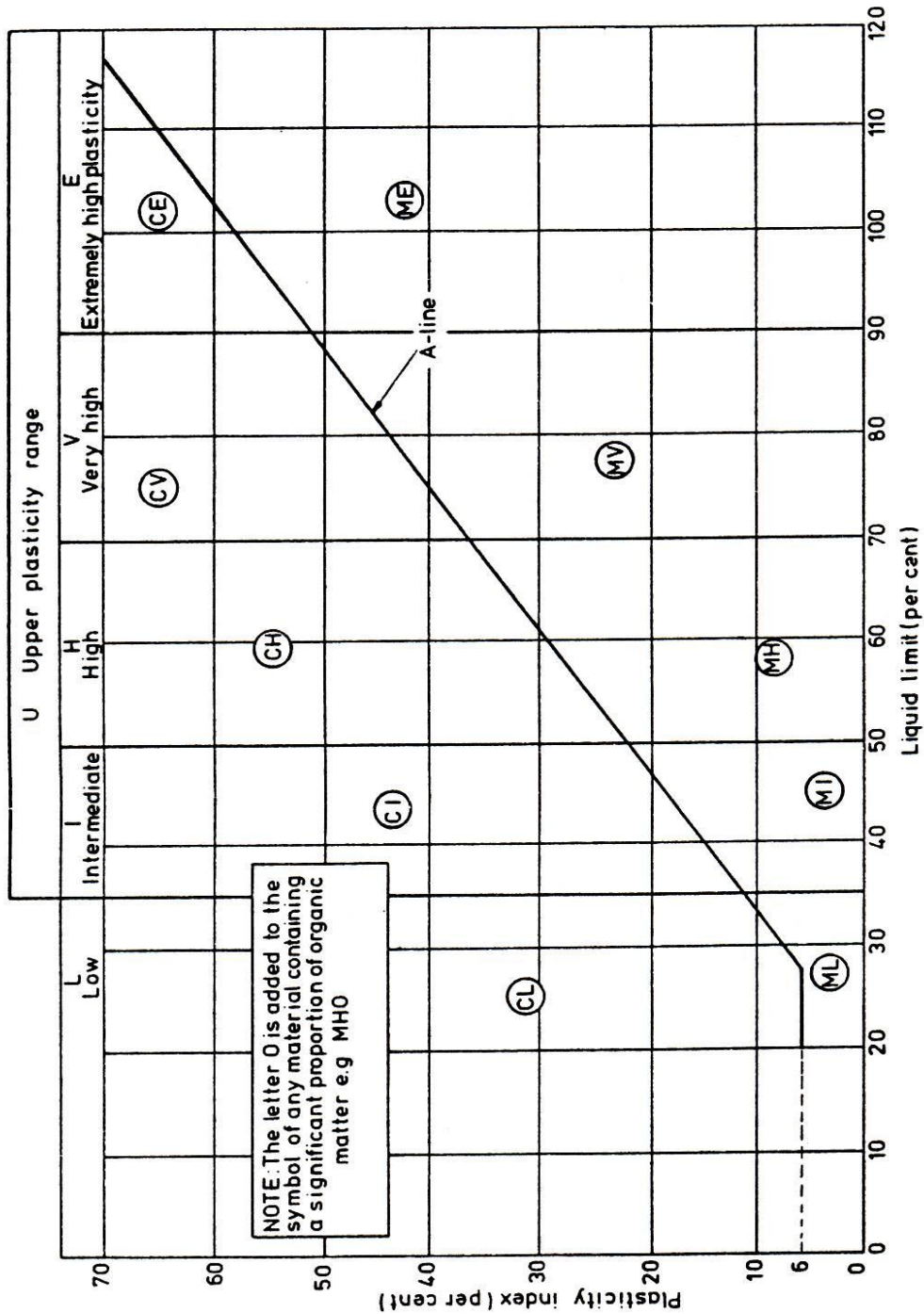


Figure Q3-2

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- Q4. (a) Describe in detail the preliminary office-based compilation of information used for a comprehensive ground investigation of a former industrial site in a town centre location, citing all reference sources you deem appropriate. Also provide an example of how the reference data would influence the intrusive/sampling stage of the ground investigation.  
(7 marks)
- (b) Outline the main methods of undertaking an intrusive ground investigation and describe in detail the full range of equipment that would be used to facilitate a comprehensive ground investigation of a former industrial site in a town centre location, where it is known that mixed sands and clays are expected to rest over sandstone, with the sandstone not being encountered until a depth of around 10m.  
(7 marks)
- (c) Describe, with the aid of a sketch diagram, if necessary, how an SPT test is carried out in firm to stiff sandy CLAY and also in a medium dense coarse GRAVEL. Ensure that your answer shows the equipment parts used and also states how the test results from an SPT test are written down and interpreted. Provide an example of a set of results and thus show how those results would be interpreted for both the CLAY and also the GRAVEL.  
(7 marks)
- (d) Describe how 'disturbed' and 'undisturbed' samples are obtained during a ground investigation.  
(4 marks)

**Total 25 marks**

**END OF QUESTIONS**

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### **TERMINOLOGY, SYMBOLS AND UNITS**

<b><u>Term</u></b>	<b><u>Symbol</u></b>	<b><u>Units</u></b>
Volume	V	m <sup>3</sup>
Litre	l	Litre (= 1 x 10 <sup>-3</sup> m <sup>3</sup> )
Mass	M	kg
Gravity	g	9.81 m/sec <sup>2</sup>
Weight		kN = (kg x 9.81)/1000
Total volume	V	m <sup>3</sup>
Volume of air	V <sub>A</sub>	m <sup>3</sup>
Volume of water	V <sub>W</sub>	m <sup>3</sup>
Volume of voids	V <sub>V</sub>	m <sup>3</sup>
Volume of solids	V <sub>S</sub>	m <sup>3</sup>
Mass of water	M <sub>W</sub>	kg
Mass of solids	M <sub>S</sub>	kg
Weight of water	W <sub>W</sub>	kN
Weight of solids	W <sub>S</sub>	kN
Total weight	W	kN
Specific gravity	G <sub>s</sub>	None
Density of water	ρ <sub>w</sub>	1000 kg/m <sup>3</sup>
Unit weight of water	γ <sub>w</sub>	9.81 kN/m <sup>3</sup>
Void ratio	e	None
Degree of saturation	S <sub>r</sub>	None
Moisture content	w	None
Porosity	n	None
Air void content	A <sub>v</sub>	None
Bulk density	ρ <sub>b</sub>	kg/m <sup>3</sup>
Dry density	ρ <sub>d</sub>	kg/m <sup>3</sup>
Saturated density	ρ <sub>sat</sub>	kg/m <sup>3</sup>
Bulk unit weight	γ <sub>b</sub>	kN/m <sup>3</sup>
Dry unit weight	γ <sub>d</sub>	kN/m <sup>3</sup>
Saturated unit weight	γ <sub>sat</sub>	kN/m <sup>3</sup>

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### **FORMULAE**

	<b>Density kg/m<sup>3</sup></b>	<b>Unit weight kN/m<sup>3</sup></b>
1	$\rho_b = \frac{\rho_w (G_s + e S_r)}{1 + e}$	$\gamma_b = \frac{\gamma_w (G_s + e S_r)}{1 + e}$
2	$\rho_b = \frac{\rho_w G_s (1 + w)}{1 + e}$	$\gamma_b = \frac{\gamma_w G_s (1 + w)}{1 + e}$
3	$\rho_d = \frac{\rho_w G_s}{1 + e}$	$\gamma_d = \frac{\gamma_w G_s}{1 + e}$
4	$\rho_{sat} = \frac{\rho_w (G_s + e)}{1 + e}$	$\gamma_{sat} = \frac{\gamma_w (G_s + e)}{1 + e}$

5  $w G_s = e S_r$

Transposing the above expressions:

From 3 above;

From 3 above;

6  $e = \frac{\rho_w G_s}{\rho_d} - 1$

$e = \frac{\gamma_w G_s}{\gamma_d} - 1$

7  $\rho_d \max = \frac{\rho_w G_s (1 - A_v)}{1 + w G_s}$

$\gamma_d \max = \frac{\gamma_w G_s (1 - A_v)}{1 + w G_s}$

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### **DEFINITIONS**

Density of water, $\rho_w$	$\frac{\text{mass of water}}{\text{volume of water}}$	$\frac{M_w}{V_w}$
Unit weight of water, $\gamma_w$	$\frac{\text{weight of water}}{\text{volume of water}}$	$\frac{W_w}{V_w}$
Specific gravity, $G_s$	$\frac{\text{density of solids}}{\text{density of water}}$	$\frac{\rho_s}{\rho_w}$
Moisture content, $w$	$\frac{\text{mass of water}}{\text{mass of solids}}$	$\frac{M_w}{M_s}$
Void ratio, $e$	$\frac{\text{volume of voids}}{\text{volume of solids}}$	$\frac{V_v}{V_s}$
Degree of saturation, $S_r$	$\frac{\text{volume of water}}{\text{volume of voids}}$	$\frac{V_w}{V_v}$
Porosity, $n$	$\frac{\text{volume of voids}}{\text{total volume}}$	$\frac{V_v}{V}$
Bulk density, $\rho_b$	$\frac{\text{total mass}}{\text{total volume}}$	$\frac{M}{V}$
Dry density, $\rho_d$	$\frac{\text{mass of solids}}{\text{total volume}}$	$\frac{M_s}{V}$
Saturated density, $\rho_{sat}$	$\frac{\text{total saturated mass}}{\text{total volume}}$	$\frac{M}{V}$
Bulk unit weight, $\gamma_b$	$\frac{\text{total weight}}{\text{total volume}}$	$\frac{W}{V}$
Dry unit weight, $\gamma_d$	$\frac{\text{weight of solids}}{\text{total volume}}$	$\frac{W_s}{V}$
Saturated unit weight, $\gamma_{sat}$	$\frac{\text{total saturated weight}}{\text{total volume}}$	$\frac{W}{V}$

**END OF PAPER**