

**UNIVERSITY OF BOLTON**  
**SCHOOL OF BUILT ENVIRONMENT &  
ENGINEERING**  
**BSc(HONS) IN CIVIL ENGINEERING**  
**SEMESTER ONE EXAMINATION 2008/2009**  
**SOIL MECHANICS**  
**MODULE NO: BLT1013**

Date: Thursday 22 January 2009

Time: 10.00 am – 12.00 noon

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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 9 to p.11.

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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1. (a) Sketch the “soil model” diagram clearly showing the solids, water and air components. Clearly annotate each part of your soil model diagram.

(7 marks)

- (b) Show how the soil model diagram can be used to produce equations for bulk density, dry density and air void content. Ensure that you state how each term in the equation is obtained from the soil model diagram.

(4 marks)

- (c) A cylindrical sample of soil has a length of 76mm, a diameter of 38mm and a mass of 187g. After drying in an oven the mass of the sample is now 163g.  
The specific gravity,  $G_s$  of the soil particles is 2.7.

Determine EACH of the following soil properties;

- (i) Bulk density ( $\text{kg/m}^3$ )
- (ii) Bulk unit weight ( $\text{kN/m}^3$ )
- (iii) Moisture content (%)
- (iv) Void ratio
- (v) Porosity (%)
- (vi) Degree of saturation (%)
- (vii) Air void content (%)

(14 marks)

**Total 25 marks**

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2. (a) Sketch a typical “dry density” versus “moisture content” curve as produced by the “Heavy” compaction test on a granular soil.

Explain why the curve has this characteristic shape.

(6 marks)

- (b) A British Standard “Light Compaction” test conducted on a sample of cohesive soil (specific gravity of soil particles,  $G_s = 2.7$ ) gave the following;

Moisture Content %	Bulk Density ( $\text{kg/m}^3$ )
8.5	1970
9.8	2097
10.65	2167
12.1	2213
13.9	2205
15.9	2170

Using Figure Q2;

- (i) Plot your experimental values using the table of moisture content versus bulk density provided and describe the compaction characteristics for the soil.

(12 marks)

- (i) Calculate the air void content at the greatest plotted dry density for this soil (ie. at the peak dry density).

(3 marks)

- (c) Describe the two main methods of specifying the earthworks requirements for compaction control using the procedures outlined in the Highway Agency Manual.

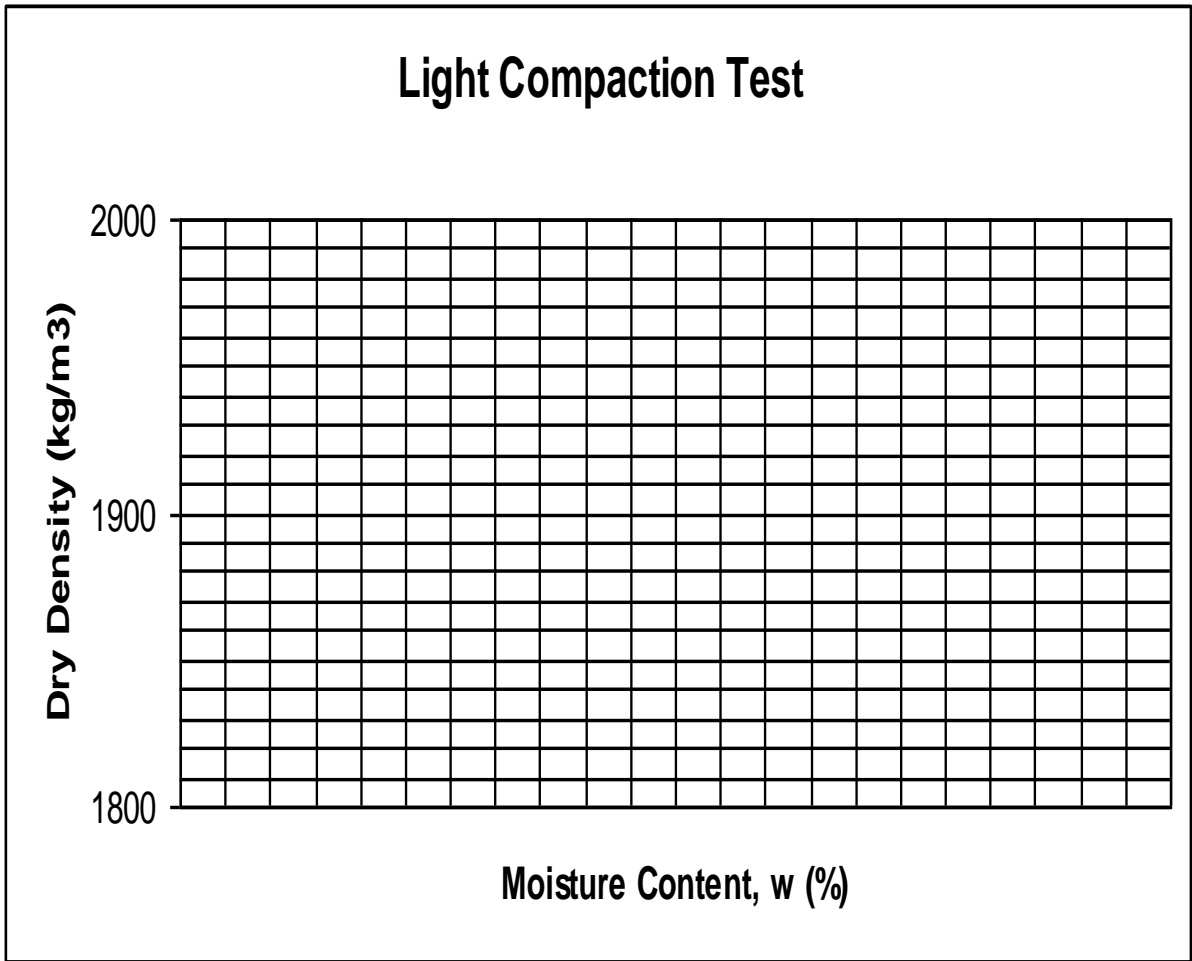
(4 marks)

**Total 25 marks**

**Question 2 continued over the page...**

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**Question 2 continued**

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**Figure Q2**

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3. (a) Describe the classification procedure that would be adopted in a geotechnical laboratory for a "coarse-grained" soil. You may use simple sketches to illustrate your answer if you prefer, but clearly written text should be sufficient to gain full marks for the question. State any appropriate standards that are used when testing to classify the coarse-grained soil. (8 marks)
- (b) Discuss the concept of soil "plasticity" as it relates to "fine-grained soils." (6 marks)
- (c) The results of classification tests conducted on a fine grained soil sample are shown below;

Plastic limit test:

	Test 1	Test 2
Mass of empty tin (g)	16.80	16.60
Mass of tin + wet soil (g)	43.15	42.08
Mass of tin + dry soil (g)	38.80	37.79

Liquid limit test:

Cone penetration (mm)	16.2	18.6	22.1	24.5
Moisture content (%)	33.3	41.8	58.2	67.6

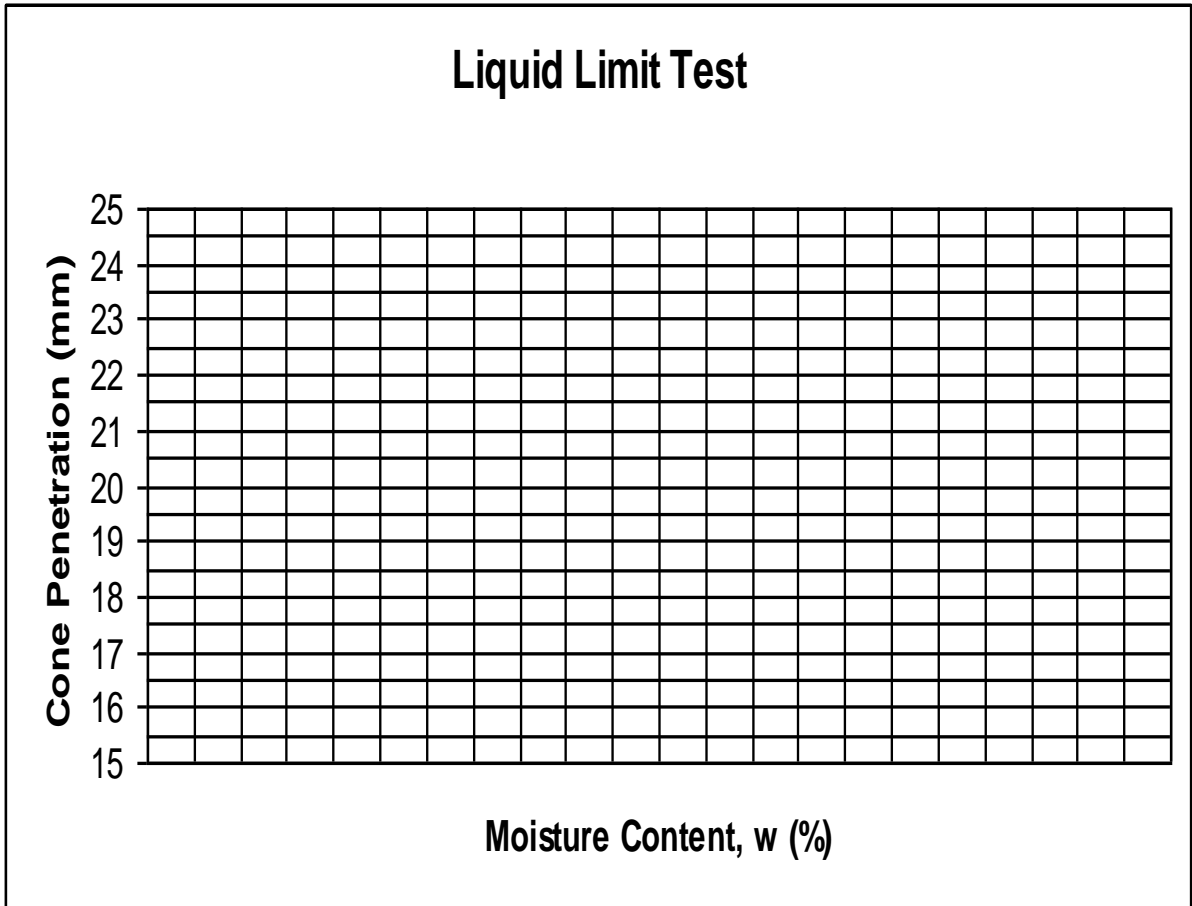
- (i) Determine the Plastic Limit, Liquid Limit (using Fig.Q3-1) and the Plasticity Index values for this soil. (7 marks)
- (ii) Classify the soil (using Fig.Q3-2). (4 marks)

**Total 25 marks**

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

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**Figure Q3-1**

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

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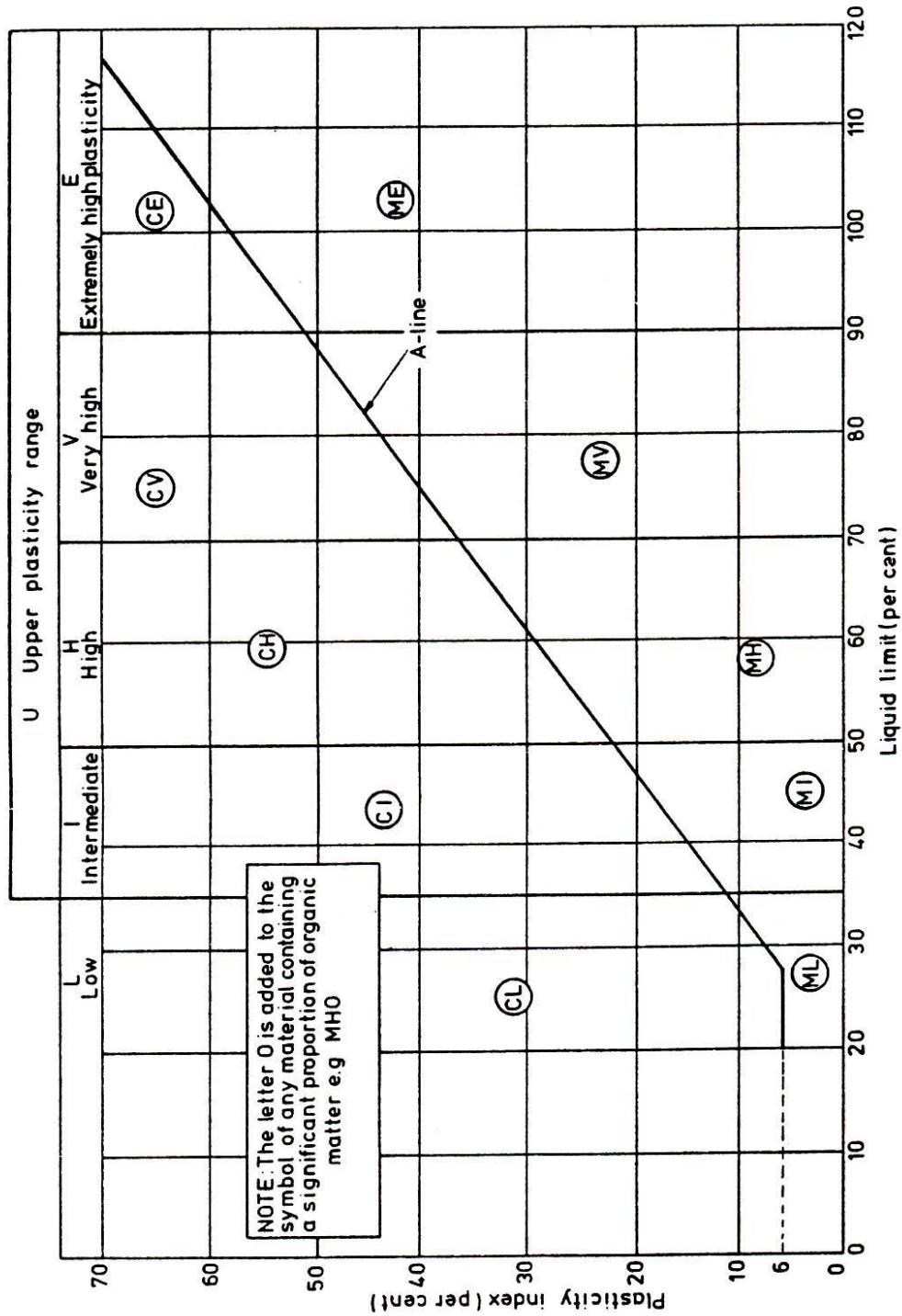


Figure Q3-2

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4. (a) Briefly outline the main objectives of site investigation and in particular describe in detail what reference sources and approaches would be used for a Phase I assessment .  
(10 marks)
- (b) Describe, with the aid of a sketch diagram, if appropriate, the equipment for undertaking cable percussive (shell and auger) drilling.  
(5 marks)
- (c) How would your shell and auger drilling technique vary when drilling in;
- i) sands and gravels below the water table  
(3 marks)
- and;
- ii) firm to stiff clay.  
(3 marks)
- NOTE: Your answer to Q3 i) and ii) must make specific reference to the drilling techniques that would be adopted to successfully progress the borehole and obtain representative samples.
- (d) Describe how an SPT test would be carried out and generally in what soil type. Ensure that your answer states how the testing procedure on site would be adapted to suit varying soil type and particle size.  
(4 marks)

**Total 25 marks**

**END OF QUESTIONS**

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(Formulae and Definitions follow as pages 9 to 11)

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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>	1000kg/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
Water content	w	None
Porosity	n	None
Air Void Content	A <sub>v</sub>	None
Bulk Soil 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>
Soil 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**

#### **Density kg/m<sup>3</sup>**

$$1 \quad \rho = \frac{\rho_w (G_s + S_r e)}{1 + e}$$

$$2 \quad \rho_d = \frac{\rho_w G_s}{1 + e}$$

$$3 \quad \rho_{sat} = \frac{\rho_w (G_s + e)}{1 + e}$$

$$4 \quad w G_s = S_r e$$

Transposing the above expressions:

From 2 above;

$$5 \quad e = \frac{\rho_w G_s}{\rho_d} - 1$$

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

$$6 \quad \rho_d \max = \frac{\rho_w G_s (1 - A_v)}{1 + w G_s}$$

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

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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, $G_s$	$\frac{\text{density of solids}}{\text{density of water}}$	$\frac{\rho_s}{\rho_w}$
Water 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, $n$	$\frac{\text{volume of voids}}{\text{total volume}}$	$\frac{V_v}{V}$
Soil density, $\rho$	$\frac{\text{total mass}}{\text{total volume}}$	$\frac{M}{V}$
Dry density, $\rho_d$	$\frac{\text{mass of solids}}{\text{total volume}}$	$\frac{M_s}{V}$
Saturated density, $\rho_{\text{sat}}$	$\frac{\text{total saturated mass}}{\text{total volume}}$	$\frac{M}{V}$
Soil unit weight, $\gamma$	$\frac{\text{total weight}}{\text{total volume}}$	$\frac{W}{V}$
Dry unit weight, $\gamma_d$	$\frac{\text{weight of solids}}{\text{total volume}}$	$\frac{W_s}{V}$
Saturated unit weight, $\gamma_{\text{sat}}$	$\frac{\text{total saturated weight}}{\text{total volume}}$	$\frac{W}{V}$

**END OF PAPER**