LAB #1
PHYSICAL PROPERTIES OF SOILS

Due week of Oct. 7th /2013 in the drop box before the start of the your lab section day/time

INTRODUCTION

The fundamental physical properties of soil include particle density, bulk density, porosity and soil moisture content. These basic properties are quantified in any soil science application. *Show all your work/ calculations. Address the mass/ volume expressions and comprehensive questions within your final lab report.*

Particle density is defined as the mass of solids in a unit volume of soil solids. Particle density does not include the pore space of the soil sample, and therefore it is not directly related to porosity, soil texture or soil structure.

Bulk density is defined as the mass of dry soil in the total volume of soil sample (including both solids and pores). Bulk density is affected by soil texture and soil structure. For example, fine-textured soils such as silt and/or clay loams generally have lower bulk densities than sandy soils; since fine materials form aggregates that have entrapped micropores which contribute to higher porosity and lower bulk density. In addition, a well-graded soil (particles of various size) will have a higher bulk density than a well-sorted soil (particles of uniform size) because the fine particles fit between the closely packed larger particles. With respect to soil structure, a loosely packed soil will have a lower bulk density compared to the same soil that is more tightly packed.

Porosity is defined as the proportion of pore space, which may be occupied by water or air, in a given soil sample. Porosity is also dependent on soil texture, soil structure, and bulk density. Porosity can range from 25% in compacted subsoils to more than 60% in well-aggregated, highly organic rich surface soils.

Soil moisture content is defined as the amount of water present in a unit of soil. There are several ways of expressing soil moisture content. The most common include: Gravimetric soil moisture (GSM), which is defined as the mass of water present in a given mass of soil particles and volumetric soil moisture (VSM), which is defined as the volume of water present in a given bulk volume of soil.

PURPOSE

To investigate mass and volume relationships in soils through the determination of the following fundamental properties of two soil samples: bulk density, particle density, soil moisture content and porosity.

OBJECTIVES

- To become familiar with the definition of basic soil properties expressing mass and volume relation of soil solids, water and air.
- To become familiar with the methods commonly employed to determine the fundamental properties of soils.

- To characterise soil samples based on their fundamental properties.

PROCEDURES

Part 1: Soil Densities

A) Particle density is the mass of solid particles per unit volume of solids. It is expressed in grams per centimeter cubed.

Sample Calculation: Particle Density = $\dfrac{\text{mass of soil solids (g)}}{\text{volume of soil solids (cm}^3\text{)}}$

Particle density is measured by displacing water with solid particles. For instance, measuring the volume of water displaced by a known mass of solid particles can be used to calculate the density of the soil particles.

Equipment

10 - 15 g air dried soil	scale
125 mL volumetric flask	distilled water
rubber stopper	small crucible

1) Weigh a clean 125 mL volumetric flask + stopper (W_f).

2) Fill the flask to the 125 mL line (not the top) with distilled water. Place the stopper on the flask and weigh the flask, stopper and the 125 mL of water (W_{fw}).

3) Measure out a mass of dry soil in the range of 10 to 15 grams.

4) Empty the flask of water and add the 10-15 grams of dry soil. Weigh the flask and soil with the stopper in place (W_{fs}).

5) Leaving the soil in the flask, fill the flask half way with distilled water to cover the soil and replace the stopper. Shake vigorously for approximately 3 minutes until all air trapped on the soil particles has been driven off.

6) Fill the flask to the marked line with distilled water. Replace the stopper.

7) Dry the outside of the flask, weigh the flask and contents (W_{fsw}).

8) Calculate the particle density using the formula:

$$\text{Particle Density} = \frac{W_{fs} - W_f}{\{[W_{fw} - [W_{fsw} - (W_{fs} - W_f)]]/\rho_w\}}$$

W_{fw} = mass of flask, stopper and distilled water (g)
W_f = mass of empty dry flask and stopper (g)
W_{fs} = mass of flask, stopper and 10-15 g of soil (g)

W_{fsw}= mass of flask, stopper, water and soil (g)
ρ_w = density of water = 1 g/cm^3

B) Bulk density is the mass of dry soil per unit bulk volume of sample, including pore space. It is expressed in grams per centimeter cubed.

Sample Calculation: Bulk density = $\dfrac{\text{mass of oven dry soil (g)}}{\text{volume of soil sample (cm}^3\text{)}}$

Equipment

metal cylinder	soil samples	large crucible
oven	knife/spatula	
scale	Al dish	

1) Label a large crucible and record weight of empty crucible (W_{lc}).

2) Measure the inside depth and diameter of metal cylinder and calculate the volume of the metal cylinder (V_{mc}). Represents exact volume of soil sample that will be collected.

3) Press metal cylinder down into the soil, place Al dish over exposed end and carefully dig out soil filled cylinder.

4) Once soil filled cylinder is removed, level both ends with a knife or spatula.

5) Empty cylinder into the crucible, weigh damp soil and crucible immediately (W_{lcws}). *Note, W_{lcws} will be used in a later calculation.

6) Place sample in the oven to dry for at least 24 hours at 105°C until constant weight.

7) Repeat steps 1-6 for the second soil sample.

8) **Return the following week** (beginning of your lab time) to weigh the dried soil and crucible (W_{lcds}).

9) Calculate the bulk density using the following formula:

$$\text{Bulk Density} = \frac{(W_{lcds} - W_{lc})}{V_{mc}} = \frac{W_{ds}}{V_b}$$

W_{lc} = mass of crucible (g)
W_{lcds} = mass of oven dried soil and crucible (g)
V_{mc} = volume of metal cylinder (cm^3)
V_b = bulk sample/soil volume (cm^3)
W_{ds} = mass of dry soils in soil sample (g)

Part 2: Porosity

Porosity is the proportion of void space occupied by air and water, in a soil. It is expressed as a percentage of the total volume. Calculate the porosity of the soil sample using the following formula and the values calculated in Part 1.

% porosity = (1 - [(bulk density)/(particle density)]) x 100

Part 3: Soil Moisture

A) Gravimetric Soil Moisture (GSM) - is the mass of water present in a given mass of soil. It is expressed in grams of water per grams of dry soil or as a percent from that ratio.

Sample Calculation: %GSM = [mass of water in soil/ dry soil weight] x 100

Equipment

ceramic crucibles	soil samples
oven	spatula
scale	

1) Label crucible and record weight of empty crucible (W_c).

2) Place soil in a small pre-labelled crucible with the soil filling approximately ¾ of the crucible. Record the mass of the crucible and damp soil sample (W_{cws}).

3) Place the crucible with soil in the oven to dry for at least 24 hours at 105°C until constant weight.

4) Return the following week (at beginning of your lab time) to weigh the dried soil and crucible on the scale (W_{cds}).

5) Calculate the gravimetric soil moisture content using the following formula:

$$\%GSM = [\text{mass of water in sample} / \text{mass of dry soil}] \times 100$$
$$= [((W_{cws} - W_c) - (W_{cds} - W_c)) / (W_{cds} - W_c)] \times 100$$

W_c = mass of empty crucible (g)
W_{cws} = mass of damp sample and crucible (g)
W_{cds} = mass of dry sample and dish (g)

B) Volumetric Soil Moisture (VSM) - is the volume of water present in a given volume of soil. It is dimensionless parameter and can be expressed as a percent. Calculate the volumetric moisture content of the soil samples using the following formula and the values calculated in Part 1.

$$\%VSM = [\text{volume of water in soil} / \text{bulk soil volume}] \times 100$$
$$= [(((W_{lcws} - W_{lc}) - (W_{lcds} - W_{lc})) / \rho_w) / V_{mc}] \times 100$$

W_{lc} = mass of crucible (g)
W_{lcws}= mass of damp soil and crucible (g)
W_{lcds} = mass of oven dried soil and crucible (g)
V_{mc} = metal sampling cylinder = volume of soil sample (cm^3)
ρ_w = density of water = 1 g/cm^3

FINAL REPORT

No formal lab report is required but you must complete the lab component (calculations) and answer all of the provided questions. Your answers must be clear and concise, demonstrating a true understanding of the concepts in question. Your report should be well organized and legible. Please be sure to include a title page that clearly indicates EARTH SC/ ENVIR SCI 2B03, your name, student number, TA name, and lab section.

LAB COMPONENT (26 marks Total)

Provide full solutions to the required calculations. Complete a calculation for each soil type per soil test (particle density, bulk density, porosity, volumetric and gravimetric moisture content). Provide one sample calculation for each test and submit lab data (initialed table).

QUESTIONS (24 marks Total)

Part A: Mass and Volume Relationships - Express each of the following relationships in terms of volumes and/or masses of soil solids, water and air. The first relationship has been worked out for you and refer to Chapter 4 for additional help. **Note, V_b = bulk soil volume or total volume of soil sample.* **(6 marks)**

1. Express void ratio (e) in terms of volumes and/or masses using the volume/mass definition of porosity (n):

$$e = \frac{n}{1 - n} \qquad \text{where } n = \frac{V_v}{V_b}$$

Combining the above formulas gives:

$$e = \frac{\frac{V_v}{V_b}}{1 - \frac{V_v}{V_b}} \qquad e = \frac{\frac{V_v}{V_b}}{\frac{V_b}{V_b} - \frac{V_v}{V_b}}$$

Further simplifying provides:

$$e = \frac{V_v}{V_b - V_v} \qquad \boxed{e = \frac{V_v}{V_s}}$$

2. Express volumetric water content (θ_v) in terms of volumes and/or masses using the volume and/or mass ratios of porosity (n) and saturation (S).

$$\theta_v = nS$$

3. Express porosity (n) in terms of volumes and/or masses using the volume and/or mass ratios of bulk density (ρ_b) and particle density (ρ_s).

$$n = \frac{(\rho_s - \rho_b)}{\rho_s} = 1 - \frac{\rho_b}{\rho_s}$$

4. Express volumetric water content (θ_v) in terms of volumes and/or masses using the volume and/or mass ratios of mass water content (θ_m), bulk density (ρ_b) and density of water (ρ_w).

$$\theta_v = \theta_m \frac{\rho_b}{\rho_w}$$

Part B: Comprehensive Questions (18 marks)

1) Compare and contrast soil sampling by volume versus sampling a mass of soil. Discuss the associated benefits and disadvantages of each sampling technique **(4 marks)**.

2) Discuss how the size of the soil sample influences the results of the various tests completed during this lab. Give a hypothetical field situation where the size of the sample could be important, and an example for when it would not be as important **(3 marks)**.

3) With regards to Figure 4.14 - *Uniformity of grain size and the type of packing arrangement can significantly affect the bulk density of sandy materials*, in your 2B03 textbook which soil (a, b, or c) would have the highest bulk density and which would have the lowest bulk density. Thoroughly explain why, and make specific reference to the change in porosity of each soil **(6 marks)**.

4) In areas with heavy foot traffic, the soils may become compacted. Soil compaction causes increased bulk densities, which can impede plant growth. Explain how increased bulk densities are responsible for the inhibited plant growth **(5 marks)**.

Table of Values Collected During Lab *– submit with final lab report for marks.*

Group Members:				
Test	***Parameter***	***Description***	***Recorded Values***	
			~~Loam~~	***~~Sand~~***
Part 1: Soil Densities				
Particle Density	W_f	mass of empty dry flask & stopper (g)		
	W_{fw}	mass of flask, stopper & distilled water (g)		
	W_{fs}	mass of flask, stopper & soil (g)		
	W_{fsw}	mass of flask, stopper, water & soil (g)		
Bulk Density	W_{lc}	mass of crucible (g)		
	W_{lcws}	mass of crucible & damp soil sample (g)		
	W_{lcds}	mass of oven dried soil and crucible (g)		
	V_{mc}	volume of metal cylinder (cm^3)		
	V_b	bulk sample or soil volume (cm^3)		
Part 3: Soil Moisture				
Gravimetric Soil Moisture	W_c	mass of empty crucible (g)		
	W_{cws}	mass of damp sample and crucible (g)		
	W_{cds}	mass of dry sample and dish (g)		