LABORATORY 2

SOIL DENSITY

I Objectives

Measure particle density, bulk density, and moisture content and relate to pore space.

II Introduction

A Particle Density

Soil particle density (g / cm^3) is mass of soil solids (oven-dry) per unit volume of soil solids. Particle density depends on the densities of the various constituent solids and their relative abundance.

The particle density of most mineral soils lies between 2.5 and 2.7 g / cm^3. The range is fairly narrow because common soil minerals differ little in density. An average value of 2.65 g / cm^3 is often assumed. In contrast, organic soils have lower particle densities since the density of organic matter is much less than that of mineral particles.

In this laboratory, you will determine the particle density of a particular soil. It is easy to measure the mass of a small sample of soil but not so easy to accurately measure the volume of soil solids that make up this mass. Briefly, the volume of a known mass of soil solids is determined by indirectly measuring the volume of water displaced by the soil solids. The mass of water displaced is actually measured, then the corresponding volume found from the known density of water.

B Bulk Density

Soil bulk density (g / cm^3) is mass of soil solids (oven-dry) per unit of volume of soil. The volume includes all pore space as well as space occupied by soil solids. Soil structure and texture largely determine bulk density. Soil structure refers to the arrangement of soil particles into secondary bodies called aggregates.

Since fine-textured soils generally have more total pore space than coarse-textured soils, the finer soils also generally have lower bulk densities. Bulk density values of fine-textured soils commonly range from 1.0 to 1.3 g / cm^3, while those of sandy soils range from about 1.3 to 1.7 g / cm^3. Despite this general difference in bulk density between sandy and clayey soils, sandy soils are referred to as light and clayey soils as heavy. This terminology refers to relative ease of tillage, not typical bulk densities.

Soil compaction, due to traffic from machinery or livestock or due to natural processes, decreases soil pore space and, therefore, increases bulk density. Since clay particles are plate-like, clay soils can be readily compressed and molded. Such compressibility, together with the low bulk density of clay soils, allows for substantial increases in bulk density when clay soils are compacted. In contrast, sand grains cannot be molded together. Thus, compaction of sandy soils with relatively small porosities does not lead to as great of increase in bulk density as occurs when clay soils are compacted. Although fine-textured soils generally have lower bulk densities than coarse-textured soils, the opposite can be true in compacted soils.

Accumulation of organic matter in soil lowers bulk density in two ways. First, the particle density of organic matter is much less than that of mineral particles. Secondly, organic matter promotes the formation and stabilization of soil aggregates. Due to intra-aggregate pore space the porosity of well-aggregated soil is greater than that of a poorly aggregated soil. Accordingly, bulk density is lower.

In general, bulk density is determined by soil texture and modified by soil structure. Within any textural class a certain range in bulk density is expected and whether, within this range, bulk density is relatively low or high depends on the degree of structural development. Whereas texture is not affected by soil management, soil structure is a fragile property that can deteriorate with intensive cultivation, exposure to raindrops and machinery traffic.

You will also measure the surface bulk density of the same soil for which you determine particle density. You will simply take a core sample of known volume then dry this sample to obtain the mass of soil solids contained in the core volume. This is all the data you need for bulk density.

III Procedures

A Particle Density

1. Weigh a picnometer flask with glass stopper and record mass (Table 1).

2. Fill the flask about half full with air-dry soil. Weigh the flask, stopper and soil. Record the combined mass.

3. Add water to the soil slowly, mixing soil and water thoroughly by vigorous shaking until the flask is full. Allow the air bubbles to rise to the surface. Float foam out of the flask by adding a few more drops of water. Insert stopper, wipe the outside dry, weigh and record.

4. Pour out entire contents into waste bucket and rinse flask. Then refill the flask with water only, stopper, wipe the outside dry, weigh and record.

5. Calculations.

   a. Subtract mass of flask from combined mass of flask and soil to find air-dry mass of soil.

   b. Convert mass of air-dry soil to oven-dry mass (need air-dry moisture content).

   c. Subtract mass of flask + mass of oven-dry soil from the combined mass of flask + soil + water to give mass of water.

   d. Subtract mass of flask + mass of oven-dry soil from the combined mass of flask, soil and water to give mass of water. *This net mass of water fills all space in the picnometer not occupied by soil solids.*

   e. Subtract mass of flask from mass of flask filled just with water.

   f. Subtract mass of water (c) from mass of water (d) to give the mass of water displaced by soil solids.

   g. Convert from mass of water (e) to the corresponding volume of water displaced by soil solids by dividing by the density of water, 1 g / cm^3.

   Calculate particle density.

B Bulk Density

1. Weigh an aluminum can with lid. Record the number and mass (Table 2).

Samples are taken with a core sampler which consists of a metal cylinder, sharpened on one end, and a sampler head with handle for pushing the cylinder into the soil. The dimensions of the core sampler are d = 4.75 cm and h = 6.35 cm.

2. Go outside with your instructor and take a core sample of soil. It is important to avoid compaction and disturbance of normal structure. The soil in the metal cylinder must be trimmed flush with the edge at both ends. Use a spatula.

3. Transfer all the soil from the cylinder to the weighed aluminum can, cut the soil into small pieces, replace the lid, weigh and record.
4. Put in the oven to dry at 105 ^{o}C.

5. After the soil has been dried and cooled, weigh next lab and record.

6. Calculations (Table 3).

   a. Bulk density.

   b. Initial ***gravimetric water content***. Gravimetric water content is mass of water per mass of oven-dry soil, expressed as a percent. For example, if a field-moist soil sample weighs 120 g but its oven-dry mass is 100 g, the loss in mass was due to evaporated water and the gravimetric water content of the field-moist soil, therefore, was

      (120 g - 100 g) / 100 g = 0.20 or 20 %

   c. Initial ***volumetric water content***. Volumetric water content is volume of water per total volume of soil and is expressed as a fraction. In the above example, if the volume of the soil sample was 80 cm^3 and assuming a density of 1 g / cm^3 for water, then the volumetric water content was

      $(20\ g / (1\ g / cm^3)) / 80\ cm^3 = 20\ cm^3 / 80\ cm^3 = 0.25$

   d. ***Porosity***. Porosity is pore volume expressed as a fraction of total soil volume. Porosity can be calculated if bulk and particle densities are known.

      Porosity = 1 - (bulk density / particle density)

IV Worksheet

A Particle Density

Flask	**Flask + Soil**	**Flask + Soil + Water**	**Flask + Water**	**Air-dry Moisture %**	**Particle Density**
g	g	g	g	g	g / cm^3

Calculations

B Bulk Density

Can #	**Can**	**Can + Moist Soil**	**Can + Oven-dry Soil**
	g	g	g

Table 3.

Bulk Density	Gravimetric Water Content	Volumetric Water Content	Porosity
g / cm^3			

Calculations