DETERMINATION OF BULK DENSITY AND POROSITY IN A GIVEN SAMPLE

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1. Introduction

A soil sample was analyzed to determine the volume of the soil sample, which could therefore determine the air volume, bulk density, and porosity of the sample.   The air measurement could then be used to determine how water will move through the soil, how root growth will occur, how gas will exchange, and also the amount of water that can be stored in a soil sample. Air volume measurement is key to plant growth and determination of the quality of the soil.

2. Materials and Methods

The volume of the air was determined using the “clod method”, through a two trial analysis of soil samples. An air dried or slightly moist soil ped’s volume was measured. This was done through first choosing a ped or naturally formed aggregate and tying a piece string around the sample. This was done so that as little compaction as possible would take place, so as to keep the pore space unaffected. This ped was weighed and dipped paraffin wax until the sample was entirely covered, without any obvious air bubbles.

This paraffin covered ped was weighed on the scale to determine its mass, then to determine the actual volume of air needs to be determined by using a water-filled beaker. The water filled beaker is first weighed and then the ped is submerged underneath the water line and weighed. In order to weigh the volume, it is necessary to keep the ped from touching the bottom or sides of the beaker. It is possible to convert the submerged weight into volume due the tenets of Archimedes Principle of volume displacement. When a the aggregate was placed in water the measure of the water displacement indicates the volume of the sample.

The overall process to find the bulk density of the sample required a multi-stepped process and a variety of different measurements. In addition to the previously described measurements of: the aggregate mass, the aggregate and wax mass, and the submerged aggregate weight (which therefore relates the volume), there are also several other measurements that are necessary. This includes the standardized measurements of the paraffin block weight and the paraffin block volume, which was used to create a standardized measurement of the wax density. (Blake and Hartage, 1986)

The actual equation to determine bulk density is as follows:

$$\rho_b = \frac{W}{V_{aggregate} - V_{paraffin}}$$

In this equation, "W" indicates the weight of the dry soil that has to be corrected for water content (θ); here it was necessary to find the water content of the soil through an oven drying process. The equation for the weight of the dry soil is as follows:

$$W = \left(\frac{W_{aggregate}}{1+\theta}\right)$$

The other variable that needed to be further defined in this equation was the volume of the paraffin. This was indicated in the following equation:

$$\left(W_{agg.and\ paraffin} - W_{aggregate}\right) \times \left(\frac{1}{\rho_{paraffin}}\right)$$

In addition to finding the bulk density the porosity was also found, using the bulk density as one of the components for the solution. The porosity indicates the amount of pore or air space there is in a soil sample. The equation for porosity is as follows:

$$f = 1 - \left(\frac{\rho_b}{\rho_p}\right)$$

3. Results and Discussion

The average bulk density was found to be 1.41 g/cm^3, as calculated through the previously stated equation. The following results indicate the process that was used to calculate the bulk density of the first sample:

$$\rho_b = \frac{5.231g}{5.144\ cm^3 - 1.648\ cm^3}$$

$$\rho_b = 1.496\ \frac{g}{cm^3}$$

This bulk density was used to then in turn find the porosity. The average porosity of the sample was 0.47. This was determined through the previously discussed equation using the calculate bulk density. These results for the first sample are as follows:

$$f = 1 - \left(\frac{1.496 \frac{g}{cm^3}}{2.65 \frac{g}{cm^3}} \right)$$

$$f = 0.435$$

These results indicate typical bulk density. Since bulk densities usually range from 1.0 to 2.0 g/cm^3. As a medium range bulk density this indicates a medium weight soil. Looking at this from an engineering standpoint the bulk density can indicate the ease at which the soil will move. A heavier soil will not be as easy to move as a lower density. Also it could be conceived that a lower bulk density will yield more surface area that a higher bulk density.

The porosity can then be used to find the volume of air that is found within the sample. The porosity equation states that the porosity is equal to the volume of the air divided by the total volume. Since the total volume and the porosity has already been found it was possible to rearrange the equation to find that approximately 1.52 cm^3 of the sample is air volume and therefore 6.54% of the sample. Then using the water content amount at .0937 and the measured volume of the soil and the water , it was possible to find that the water volume was 0.328 cm^3 at 6.54% and the soil volume was 3.168 cm^3 and 63.16% of the total sample. These results are visually reproduced in the following pie chart:

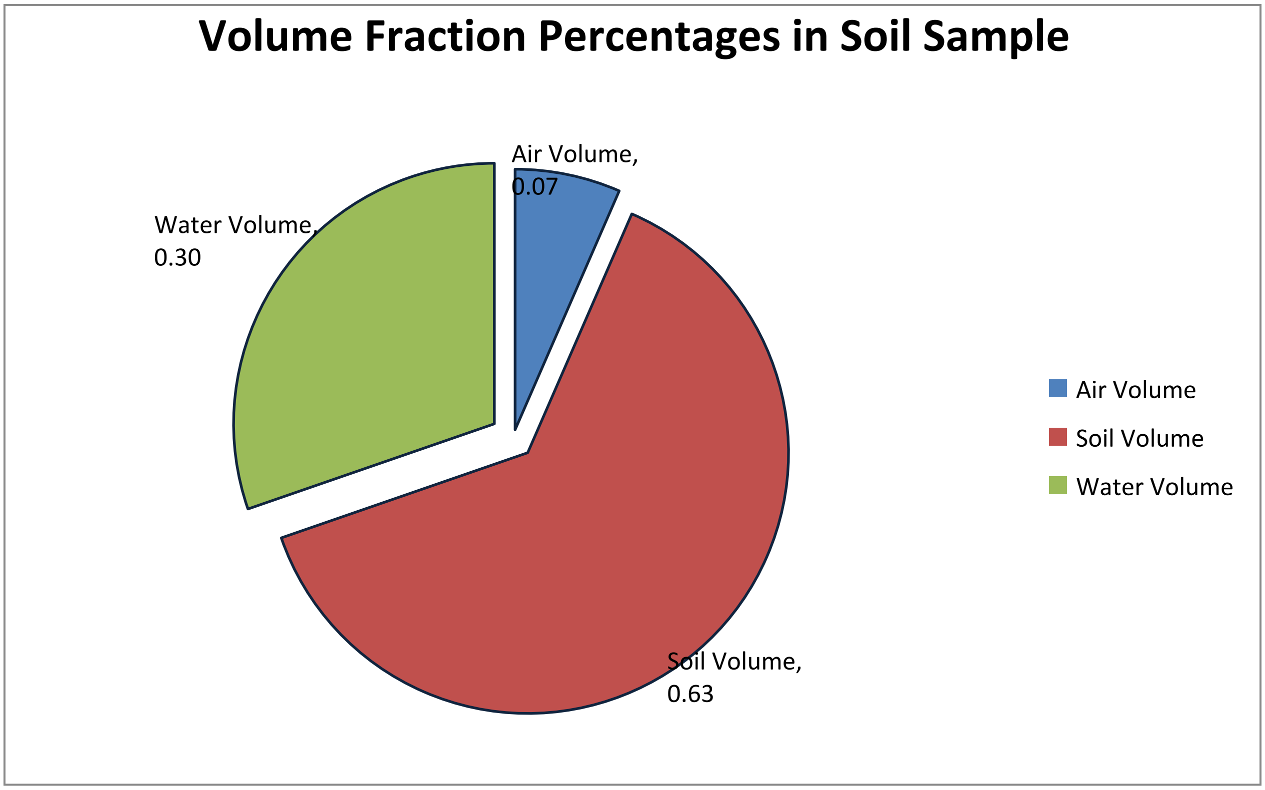

Chart 1. This chart displays the volume fractions of air, water, and soil found within the sample.

This samples results can be compared with the another sample to show the difference in bulk density and porosity is dependent on the environment. The sample analyzed in this lab was obtained from a mountainous, forest in Northeastern Pennsylvania below the heavy level of leaf litter. Another classmates sample was obtained locally outside of Selinsgrove, Pennsylvania within a agricultural field. The results of the agricultural field indicated a lower average bulk density at 1.029 g/cm^3 and a higher porosity at 0.612. This indicates that there is better soil aeration and the soil is less dense in the agricultural field as opposed to the forest soil. This is not a surprising factor considering the amount of tillage that would have been done to such an area, compared to the relatively untouched forest area. Here, earth worms and insects would have kept the soil pretty well aerated and porous. It can be seen that both results indicate that there is enough pore space for successful water drainage and plant root support. These calculated results for the comparison of the forest area soil and the agricultural area soil can be seen in the following table.

Table 1: This table denotes the results of two trials done of two different types of soils. The first two samples indicate two trials of the forest soil discussed and the third and fourth samples describe the agricultural soil that was used as a comparison.

Results and Data Table				
	Sample 1	Sample 2	Sample 3	Sample 4
Aggregate and String Weight ($W_{aggregate}$)	5.721 g	4.312 g	5.36 g	13.54 g
Aggregate, wax, and string weight ($W_{aggregate\ w/\ paraffin}$)	7.139 g	5.801 g	7.56 g	15.18 g
Submerged weight ($W_{water} = V_{aggregate}$)	5.144 g	4.638 g	5.72 g	12.61 g
$W = W_{aggregate}/(1+\theta)$	5.231 g	3.941 g	4.323 g	10.919 g
Paraffin block weight (M_{wax})	3.66 g	3.66 g	3.66 g	3.66 g
Paraffin block volume(V_{wax})	4.25 cm^3	4.25 cm^3	4.25 cm^3	4.25 cm^3
Wax Density ($M_{wax}/V_{wax} = \rho_{paraffin}$	0.861 cm^3	0.861 cm^3	0.861 cm^3	0.861 cm^3
Bulk Density	1.496 g/cm^3	1.318 g/cm^3	1.062 g/cm^3	0.996 g/cm^3
Porosity	0.432	0.502	0.599	0.624

4. References

Blake, B.R. and K.H. Hartge. 1986. Bulk Density *In* Methods of Soil Analysis, ASA Monograph No. 9 Madison WI. pp. 363-375.