BULK DENSITY AND PARTICLE DENSITY, WATER CONTENT

(adapted from Laboratory Manual for Soil Science, Thien and Graveel)

Soil water and air occupy voids in the soil, called pore spaces. The pore system in soil provides the conduits for air and water exchange and houses roots and microbes. Soil porosity is the amount of pore volume (% of pore space). A medium textured, well-aggregated soil contains about 50% pore space and is in good condition for plant growth when the pores hold an equal distribution of air and water. Pore size affects pore activity. Big pores, macropores, facilitate free-water drainage, aeration, evaporation, and gas exchange. Mesopores, medium-size pores, are essential to capillary water distribution, and micropores provide water storage sites. Macropores are most prevalent in sandy soils and well-aggregated soils, but can be converted to micropores by compaction. Medium-textured soils have an abundance of mesopores. Clays promote aggregation but can also be readily compacted. Clays also increase water storage by providing an abundance of micropores. Thus, texture and structure, plus the level of induced compaction, are the main properties governing amount and type of pore space in the soil. Organic matter affects porosity through its enhancement of soil aggregation.

Porosity can be calculated if bulk density and particle density are known. Bulk density is soil mass divided by unit volume. In its natural state, a soil's volume includes solids and pores, therefore, a sample must be taken without compaction or crumbling to correctly determine **bulk density** (*Dm*).

$$D_m (g / cm^3) = \frac{p}{V} \;,$$

D_m – soil bulk density (g m^{-3})
p – Oven dry soil weight (g),
V – volume of cylinder (cm^3)

Bulk density of mineral soils commonly ranges from 1.1 to 1.5 g cm^{-3} in surface horizons. It increases with depth and tends to be high in sands and compacted pan horizons, and tends to be low in soils with abundant organic matter. Tillage operations loosen soils and temporarily lower bulk density, while compaction processes raise bulk density. High bulk densities correspond to low porosity. Natural soil-forming processes that increase aggregation reduce bulk density, but excessive tillage and raindrop impact on bare soil destroy aggregation and increase bulk density.

Particle density is the volumetric mass of the solid soil. It differs from bulk density because the volume used does not include pore spaces.

$$De \text{ (g/cm}^3\text{)} = \frac{p}{v}$$

where $v = n + p - m$,
p – oven-dry soil weight (g),
n – flask weight with distilled water (g),
m – flask weight with distilled wayer and soil (arter boiling) (g),
v – volume of soil taken for analysis (cm^3).

Particle density represents the average density of all the minerals composing the soil. For most soils, this value is very near 2.65 g cm^{-3} because quartz has a density of 2.65 g cm^{-3} and quartz is usually the dominant mineral. Particle density varies little between minerals and has little practical significance except in the calculation of pore space.

Porosity is that portion of the soil volume occupied by pore spaces. This property does not have to be measured directly since it can be calculated using values determined for bulk density and particle density. Finding the ratio of bulk density to particle density and multiplying by 100 calculates the percent solid space, so subtracting it from 100 gives the % of soil volume that is pore space.

Total porosity can be found

$$P_{tot}(\%) = \frac{D_e - D_m}{D_e} \times 100,$$

where, P_{tot} – total porosity (%)

D_e – density of solid particles (g cm^{-3})

D_m – bulk density (g cm^{-3})

II. Laboratory Analysis:

Bulk density, water content at the measurement, maximum water holding capacity, field capacity,

1. Take soil sample out of the box, clean cylinder from outside and weight the sample.
2. Cover the bottom of the sample with filter paper and tight with rubber band;
3. Put the sample to the bowl and fulfil the bowl with the water so that only the bottom of the cylinder will be in the water;
4. Cover the cylinders with plastic and leave for 24 hours;
5. Take fulfilled samples off from bowl, set for a 10 min on the moist filter paper, weight the sample;
6. Put the sample on the sandbox (60 hPa suction; pF1.8), leave there for 2 weeks;
7. Take samples from sandbox and weight.
8. Dry the soil sample to a constant weight (24 hours in a hot-air oven at 105 degrees C).
2. Weigh the sample, clean the cylinder. Record the weight of the empty cylinder and calculate the volume of the cylinder. (Volume of a cylinder is pi x radius squared x height).

Calculate the bulk density, porosity and water content of sample (at sampling, maximum, pF1.8).

Particle Density

1) Fill 100 ml with distilled water; weight the flask with the water.
2) Weight ca 20 g oved dry soil; put it in to the flask (emptied from water).
3) Include to the soil ca 25 ml distilled water, shake and boil slowly ca 10 min to remove air from the soil.
4) After cooling, fulfil the flask with the distilled water and weight again.

Calculations of water content

1) Water content on the field:

$$V_f(\%) = \frac{W_f - W_d}{W_d} \times 100 \times D_m,$$

where, V_f – water content at field (vol%),
W_f – weight of wet (as it was on the field) soil (g)
W_d – weight of oven dry soil (g)
D_m – bulk density (g cm^{-3})

(You will get gravimetric water content if you will not multiply the result with Dm)

2) Maximum water holding capacity:

$$V_{\max}(\%) = \frac{W_{\max} - W_d}{W_d} \times 100 \times D_m,$$

where, V_{max} – maximum water content after saturation (vol%),
W_w – weight of wet soil after saturation and short stay on filter paper (g)
W_d – weight of oven dry soil (g)
D_m – bulk density (g cm^{-3})

3) Water content at field capacity (pF1.8):

$$V_{fc}(\%) = \frac{W_{fc} - W_d}{W_d} \times 100 \times D_m,$$

where, V_{max} – maximum water content after sandbox at pF1.8 (vol%),
W_w – weight of wet soil after sandbox (g)
W_d – weight of oven dry soil (g)
D_m – bulk density (g cm^{-3})

4) Aeration porosity at field capacity:

Paer (%) = $P_{tot} - V_{fc}$,

where,
P_{tot} – total porosity (%)
V_{fc} – soil water content at pF1.8 (%)