Measuring Water Content and Density

1.1. Sample collection method

1.1.1. Measuring water content using the frying pan method

This method of measuring water content is carried out on site. It is subject to a standard [AFN 96c]. The procedure is as follows:

– weigh an empty and dry container: tare T;

– yake the soil sample to be studied;

– weigh the container filled with the soil to be tested: the total wet mass $m_{th}$;

– heat the soil enough to dry it out completely but without breaking it down (for clay). A Bunsen burner, camping gas or methylated spirits can be used…;

– weigh the container with the dry soil: the total dry mass $m_{td}$.

The water content of the soil $w$ is then given by the formula:

$$w = \frac{m_{th} - m_{td}}{m_{td} - T}$$  \[1.1\]

1.1.2. Measuring water content using the oven-dry method

This method is carried out in a laboratory and is subject to a standard [AFN 95c]. The approach is the same as before, but the soil is heated using
an electric oven at 105°C for a minimum of 4 and 24 h if possible. This method enables:

– the prevention of clay decomposition;
– the evaporation of all the free water contained within the soil.

It is also possible to use a microwave oven. This process is subject to a standard [AFN 96b].

1.3.1. Measuring dry density using a membrane densitometer

This measurement is carried out in situ with a membrane densitometer or a sample of soil on a core taken from the soil. In both cases, a wet density is measured and then converted into a dry density as follows:

– the water content of the soil taken is measured using one of the previous methods, with w as the water content;
– a sample of soil of mass m_h is taken, which then breaks down into a grain mass m_s and a mass of water m_w [1.2]. If the water content w is known, the water mass of the sample can be determined [1.3]. If the volume of the sample V is known, the wet density can be determined [1.4] and the dry density deduced [1.6]. Measuring the volume is done following the membrane densitometer method or using the external volume of the core.

\[
m_h = m_s + m_w \quad [1.2]
\]

\[
m_w = w \cdot m_s \quad [1.3]
\]

\[
\rho = \frac{m_h}{V} = \frac{m_s}{V} + w \cdot \frac{m_s}{V} \quad [1.4]
\]

\[
\rho = \rho_d \cdot (1 + w) \quad [1.5]
\]

\[
\rho_d = \frac{\rho}{1+w} \quad [1.6]
\]

The densitometer is a device that measures cavity volume (Figure 1.1). To use it, a hole is dug in the soil whose volume is to be determined. The device is first filled with water and a membrane is placed at its base. The procedure is as follows:
– the densitometer is positioned at the surface of the ground to be tested after some surface stripping;
– the piston is pressed so that the flexible membrane is applied onto the ground surface and an initial volume reading is taken;
– the superior part of the device is removed, leaving the perforated disk (on the left in Figure 1.1);
– a hole is made in the ground to match the diameter of the densitometer;
– the extracted soil is weighed and its water content determined;
– the densitometer is repositioned back onto the perforated disk;
– the membrane is pushed into the hole by pushing on the densitometer’s piston, and a final volume reading is taken;
– the volume of the hole is determined by the difference between the two volumes;
– the wet density is determined following the formula [1.4] and the dry density following formula [1.6].

Figure 1.1. Membrane densitometer (taken from www.lindqvist-international.com)
1.1.4. Measuring dry density using the excavation method

This method consists of making a hole on the surface of the ground, measuring the total wet weight and the water content of the extracted soil. The hole is then lined and filled with water, measuring the volume introduced, giving the volume occupied by the soil. Formula [1.6] gives the dry density.

![Figure 1.2. Measuring the density of surface waste a) excavation by shovel b) filling the excavated and lined pit using a water tank, ADEME [ADE 05]](image)

1.2. Method without sample collection

These are methods that use the radioactive sources listed below [AGE 03]:

– $\gamma$ rays are provided by a radioactive source of radium, beryllium or cesium 137. The rays are absorbed even more when the medium traveled through is more compact or denser. The rays that are backscattered by the ground are measured with a Geiger–Müller counter.

– Rays from fast neutrons provided by a radioactive source of americium 241, beryllium is slowed when the medium is rich in hydrogen atoms. Since water is the material present in the soil that is richest in hydrogen, it is considered that these measures are suitable for the measurement of water content in the soil. Slow neutron detectors enable the measurement of the moisture in the environment.

Measurements are taken from backscatter or surface transmission, from drilling, or between two boreholes. The device is calibrated beforehand for
reference materials whose compactness or water content is known. The difference in receiving $\gamma$ rays or neutrons between reference materials and the soil is put into a chart that then provides the density or water content of the soil. The volume tested is in the order of $\text{dm}^3$.

Figure 1.3. Deep neutron probe (from Campbell Pacific Nuclear)

Figure 1.4. Probe in position for measuring the water content and density of the soil surface (from CPN MC-3 Portaprobe)
Figure 1.5. Probe in position for measuring the water content and density of the layer between the radioactive source and the detector (from CPN MC-3 Portaprobe)