

Lecture Three: Porosity Measurement

3.1. Laboratory measurement

We mentioned earlier that porosity is the ratio of the volume of the pores to the total volume,

$$\text{Porosity } (\emptyset) = \frac{\text{Pore volume}}{\text{Bulk volume}} = \frac{\text{Bulk volume} - \text{Grain volume}}{\text{Bulk volume}} \quad \dots\dots (2-1)$$

Therefore it is measured in the laboratory by measuring two of the following values and calculates the mentioned ratio:

- 1) Bulk volume, V_b
- 2) Matrix volume, V_m OR Grain volume, V_g
- 3) Pore volume, V_p

3.1.1. Bulk Volume Calculation

1- From Dimensions

Usually the core is cylindrical in shape, so its volume is calculated from the volume law of the cylinder

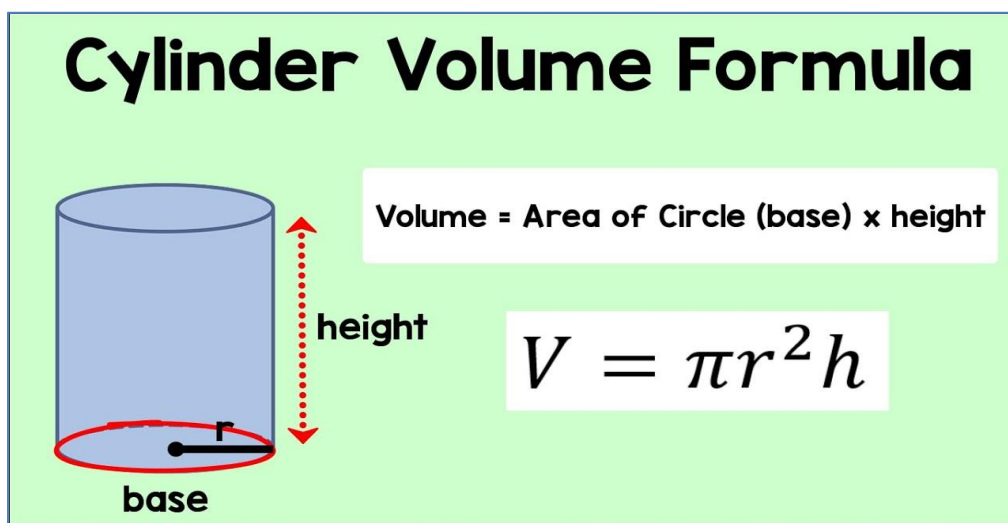


Fig 3-1 cylinder volume

2- Displacement Method

The Bulk volume of the core sample can be measured by the fluid displaced by the core sample, measured volumetrically or gravimetrically.

Volumetric methods measure the change in volume when the sample is immersed as follows:

- (1) The core is dropped into liquid and the volume change of liquid is observed.
- (2) One must prevent test liquid from entering pores space of sample by coating the core with paraffin, or by saturating the rock with the fluid into which it is immersed.

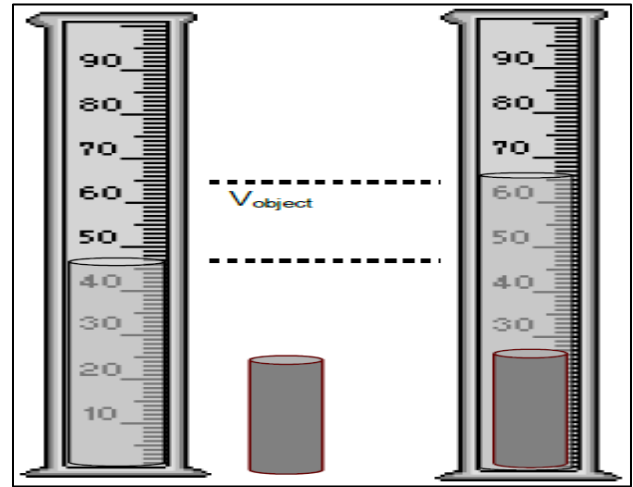


Fig 3-2 Volumetric Displacement method

$$V_{Bulk} = \text{Change in liquid volume} \dots (3-1)$$

Gravimetric methods observe the loss in weight of the sample when immersed in a fluid in comparison with its weight when saturated with that fluid.

$$W_{wtr} = W_{sat} - W_{wet} \dots (3-2)$$

$$V_b = \frac{W_{wtr}}{\rho_{wtr}} \dots (3-3)$$

where :

W_{wtr} = Weight of water displaced

W_{sat} = Weight of saturated core sample

W_{wet} = Weight of saturated sample immersed in water

ρ_{wtr} = Water density

V_b = Bulk volume

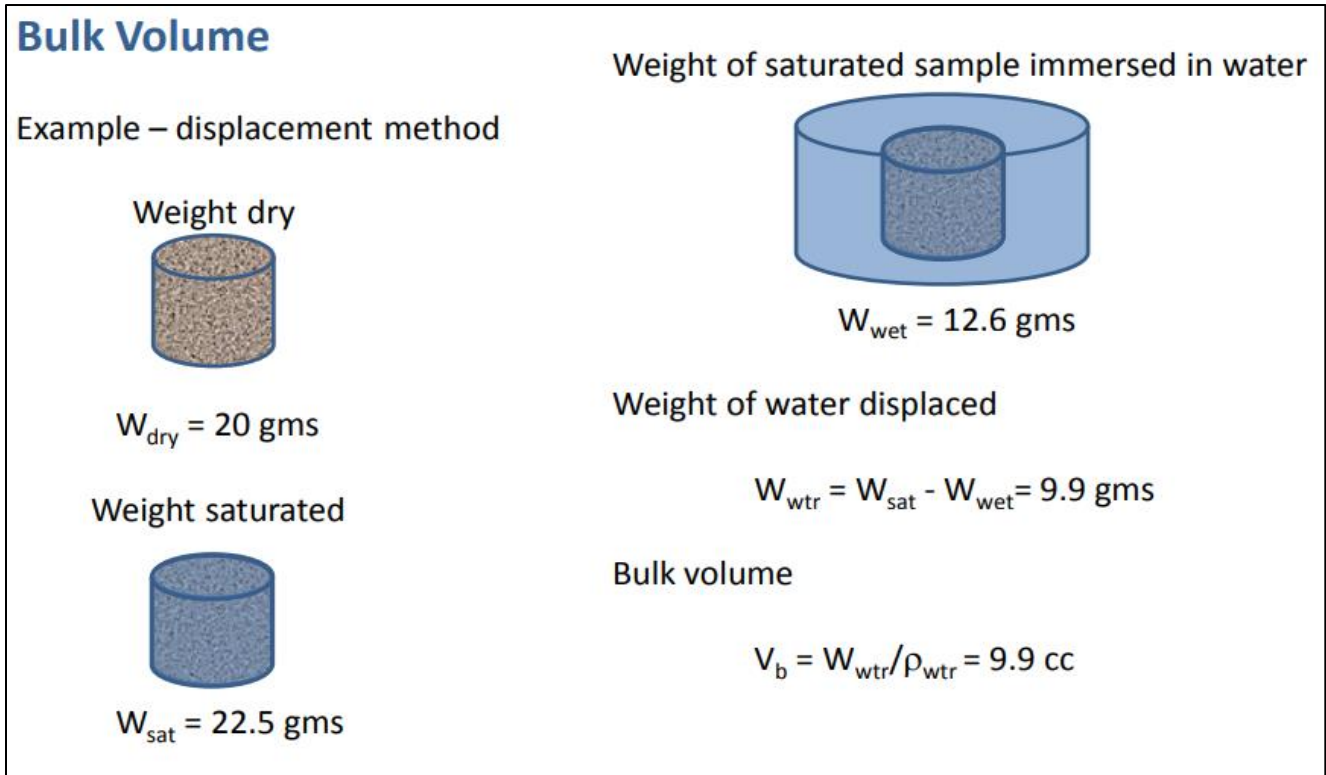


Fig 3-3 Gravimetric Displacement method

3.1.2. Matrix Volume Calculation

1- Direct Method

The most direct method for determining grain volume is to measure the weight of a dried sample and to divide by the density of the rock matrix. Unfortunately, the rock densities are often not accurately known. As follows:

$$V_m = \frac{\text{dry weight of core sample}}{\text{matrix density}} \dots\dots (3-4)$$

Table (3-1) Matrix Density

Lithology	ρ_m (g/cm ³)
Quartz	2.65
Limestone	2.71
Dolomite	2.87

2- Displacement Method

This method is similar to method for bulk volume determination. In this method, a core sample is crushed and the resulting rock grains are placed into a graduated cylinder along with a known volume of liquid. The volume of the rock grains can then be determined from the apparent volume change of the liquid after immersion.

The disadvantage of this method is that it is destructive. Once the sample is pulverized, it cannot be used for further testing. Since we have crushed the core sample to its constituent rock grains, the porosity determined from the immersion of these grains is the total porosity, ϕ_t .

3- Boyle's Law Method

The device consists of two chambers of known volume, Reference chamber and Sample chamber.

In this experiment compressed air or helium gas can be used. The best economically is compressed air, while the most accurate is helium gas because of the smallest helium particles, which allows it to penetrate into the smallest pores.

It uses Boyle's Law of gases for the grain volume determination:

$$P_1V_1 = P_2V_2 \quad \dots\dots (3-5)$$

Measurement Method:

- 1- The core sample is placed into sample chamber of an experimental apparatus, valve 1 is closed, valves 2 and valve 3 are opened.
- 2- The air vacuum pump is running long enough and then the valves 2& 3 are closed.
- 3- Valve 1 is opened, as a result the compressed air moves from the source to the reference chamber, this movement stops when the pressure in the reference chamber equals the pressure of the source, and at this point P1 is recorded.
- 4- Valve 1 is closed, valve 2 is opened, and thus compressed air is transferred from the reference chamber to the Sample chamber. The pressure stabilization is waited in the two chambers and P2 value is recorded.

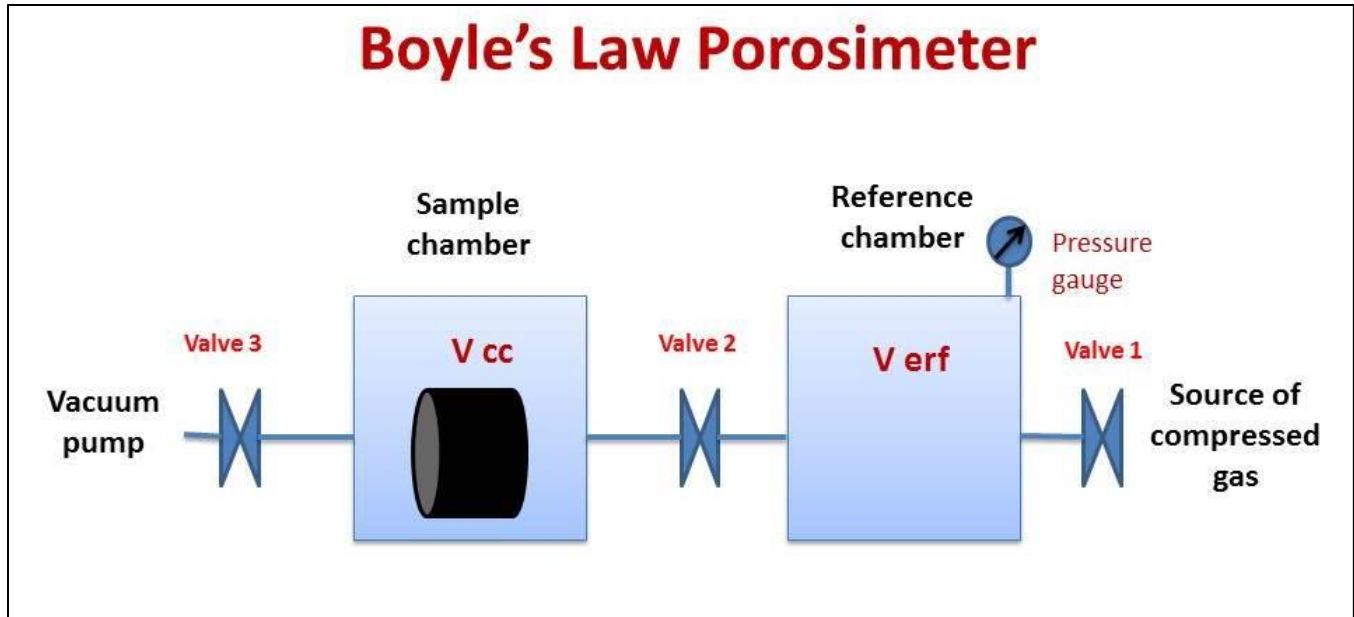


Fig 3-4 Boyle's Law Method

Applying Boyle's Law of Gases and assuming constant temperature, we get

$$P_1 V_1 = P_2 V_2$$

$$P_1 V_{ref} = P_2 (V_{ref} + V_{cc} - V_g)$$

$$V_g = (V_{ref} + V_{cc}) - \frac{P_1}{P_2} V_{ref} \quad \dots\dots (3-6)$$

where:

P_1 = Reference chamber pressure when valve 2 is closed. (Psia)

P_2 = Reference chamber and Sample chamber pressure after opening valve 2. (psia)

V_{ref} = Volume of Reference chamber

V_{cc} = Volume of Sample chamber

V_g = Matrix or grain volume

The advantages of this method are that it is non-destructive and can be very accurate. Since the gases can only enter or leave the connected pores, the porosity obtained from the Boyle's Law Method is the effective porosity, ϕ_e .