

Structure of hydrated cement

At any stage of hydration, the hardened paste consists of:

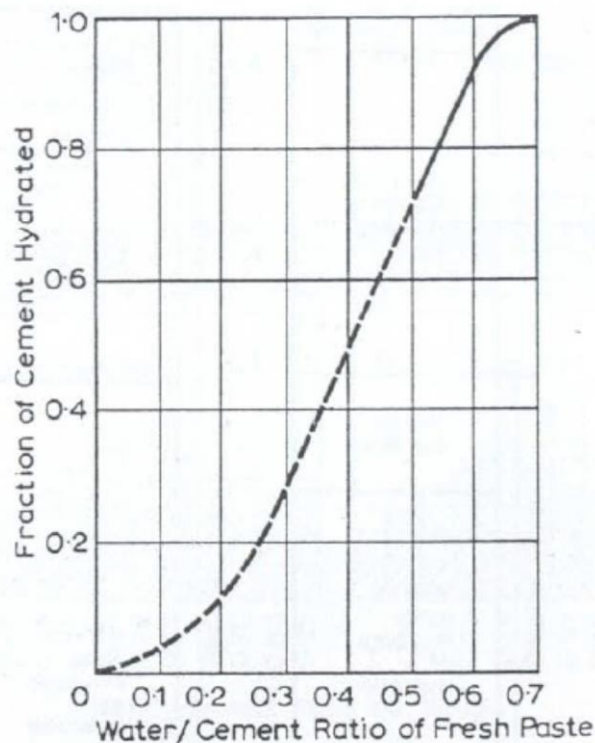
1. crystallized hydrates of the various compounds (calcium silicates hydrate, tricalcium aluminates hydrate and calcium ferrite) , referred to collectively as gel.
2. Crystals of Ca(OH)_2 produced from the hydration of the silicates.
3. Some minor components.
4. un hydrated cement.
5. Voids
 - Capillary pores
 - Gel pores

a- Capillary pores: the capillary pores at any stage of hydration represent that part of the gross volume which has not been filled by the products of hydration. The volume of the capillary system is reduced with the progress of hydration.

Thus the capillary porosity of the paste depends on:

- The water/cement ratio of the mix. When w/c ratio > 0.38 – The gel volume is not enough to fill all the available voids.
- The degree of hydration, which influence by the type of cement.

b- Gel pores: The gel pores are interconnected interstitial spaces between the gel particles. The gel pores are much smaller than the capillary pores. It could be contain large amount of evaporable water.



Relation between the water/cement ratio and the degree of hydration at which the capillaries cease to be continuous^{1,26}

Water held in hydrated cement paste

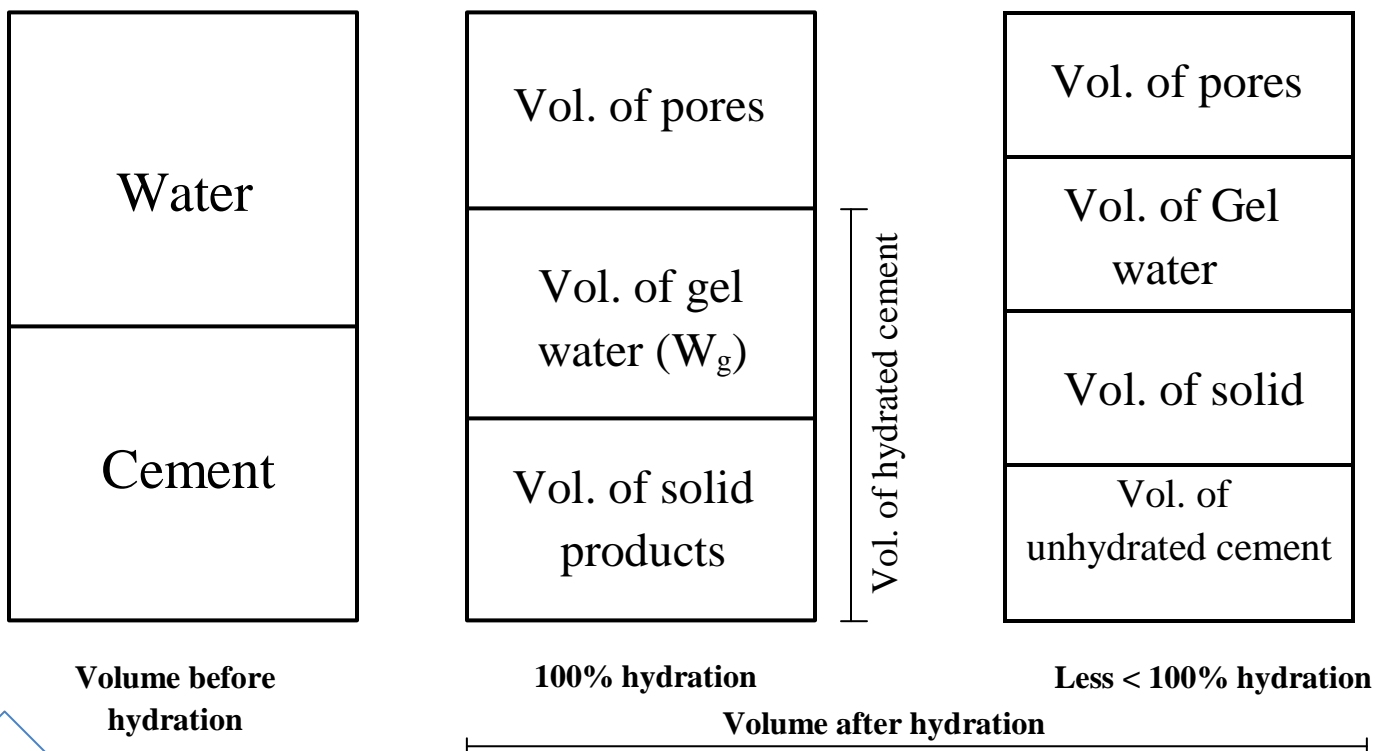
We can see that water in hydrated cement is held with varying degrees of firmness and can be classified as:

1. **Free water:** present in the capillary pores – with weak firmness, and evaporate quickly leaving the paste.
2. **Chemically combined water:** form a definite part of the hydrated compounds.
3. **Gel water:** which found
 - a) Gel pores
 - b) Part of it is held by the surface force of the gel particles - It is known as *the adsorbed water*.

A convenient division of water in the hydrated cement into two categories:

- **Evaporable water** – includes water in the capillary pores and some water in the gel pores.
- **Non-evaporable water** – includes nearly all chemically combined water and also some water not held by chemical bonds. The amount of non-evaporable water increases as hydration proceeds.

Volume of Hydration Products



Volume before hydration = volume after hydration

Water before hydration = water after hydration

100 % hydration

Combined water (non-evaporable water) = $0.23 * \text{weight of cement}$

Contraction in volume of the hydration = $0.254 * \text{non-evaporable water}$

$$= 0.254 * 0.23 * \text{weight of cement}$$

$$\text{Volume of cement} = \frac{\text{weight of cement}(w)}{\text{specific gravity}(G)}$$

Specific gravity of cement = 3.15

Specific gravity of water = 1

Volume of solid products = vol. of cement + vol. of non-evaporable water- contr. in volume

Less than 100% hydration

Vol. of solid = $0.489 x$

Vol. of combined water = $0.23 x$

Vol. of gel water = $0.19 x$

Vol. of pores = $0.059 x$

X= weight of cement to be hydrated