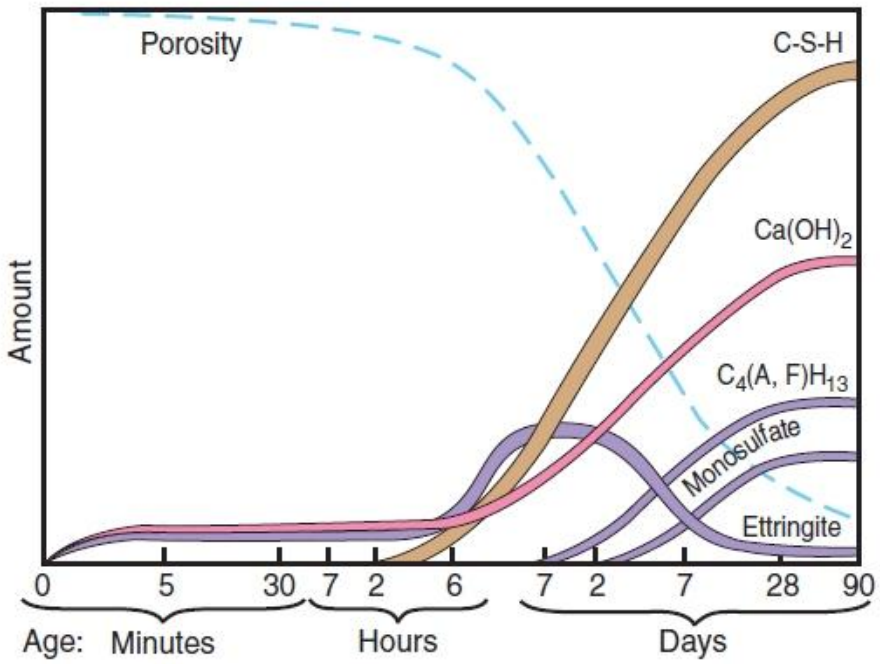
Lecture 3

Hydration and Structure of hydrated cement paste

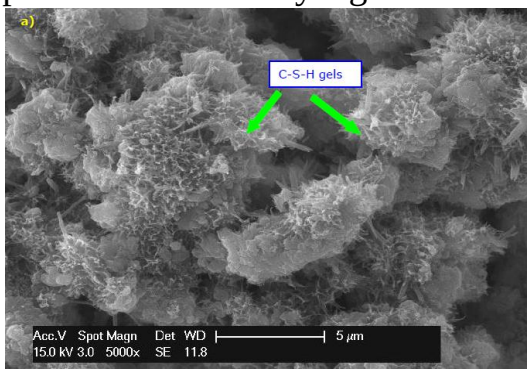
Hydration of Cement

Simply, it is a reaction (series of reactions) between water and main compounds of cement to form the hydrated cement paste/binder. These reactions generate a heat which is called heat of hydration.



Formation of main hydration products with time

After hydration, cement will have an adhesive and cohesive property that makes it capable of bonding minerals fragments into a compact whole. At any age of hydration, cement paste contains the following:



1- Tobermerite – cement gel/CSH: Calcium silicate hydrates

SEM image beside shows the shape of cement gel shape under microscope (Secondary Electron scanning).

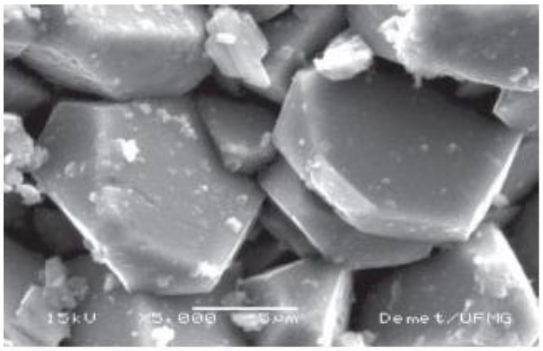
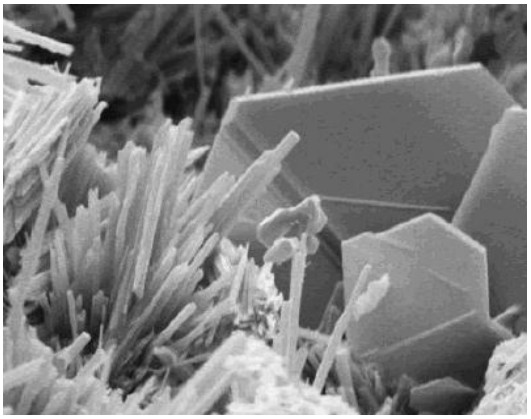


Image amplified 5,000× of the concrete surface showing a detail of the portlandite crystals [$Ca(OH)_2$].

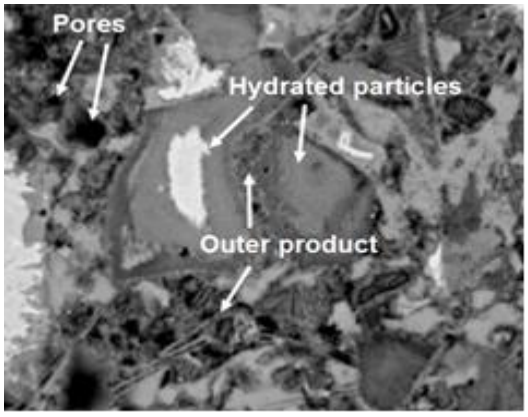
2- Portlandite – CH : another shape of cement gel. SEM image beside shows the shape of second Type of cement gel under microscope (Secondary Electron scanning).

What is the difference between the twos?



3- Ettringite (AFt, AFm)

SEM image beside shows of mono Ettringite AFm with knnedle shape under microscope (Secondary Electron scanning).

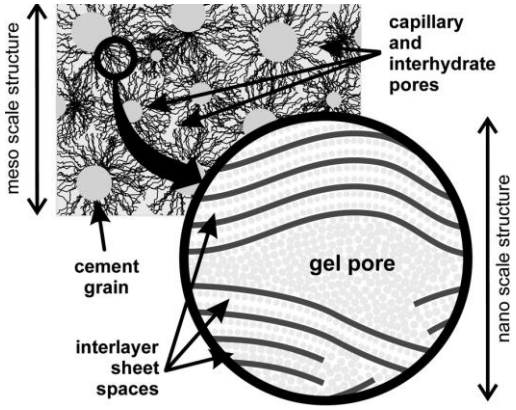


4- Anhydrate cement: SEM image beside shows of un-hydrated cement under microscope (especially at early ages/or if insufficient water is used. (Backscattered Electron scanning).

5- Voids/pores: there are two types of them in a hydrated cement paste:

A- Gel pores: between hydration products (CSH,CH and Ettringite) with a dimension of about 18 °A. These voids form about 28% feom the total volume of solid (hydration products).

B- Capillary voids: continues pores between the hydration products. These voids are randomly distributed with a dimeter up to 1.3mm. They decrease in size with time due to continuous hydration of cement. The size depends on w/c ratio and the curing of concrete.



Why curing for concrete is used and how?

What is the main source of voids in concrete?

Types of water in hydrated cement paste

1- Combined water: part of hydration products which is about 23% of dry cement.

2- Free water: inside gel and capillary pores and a part adsorb in the surface of hydration products.

Water gel (W_g): 28% of solid (hydration products).

What are the differences between these types and how they affect the concrete if they are evaporated?

Volume of hydration products

Understanding of the hydrated cement structure will help us to find the exact volume of these products.

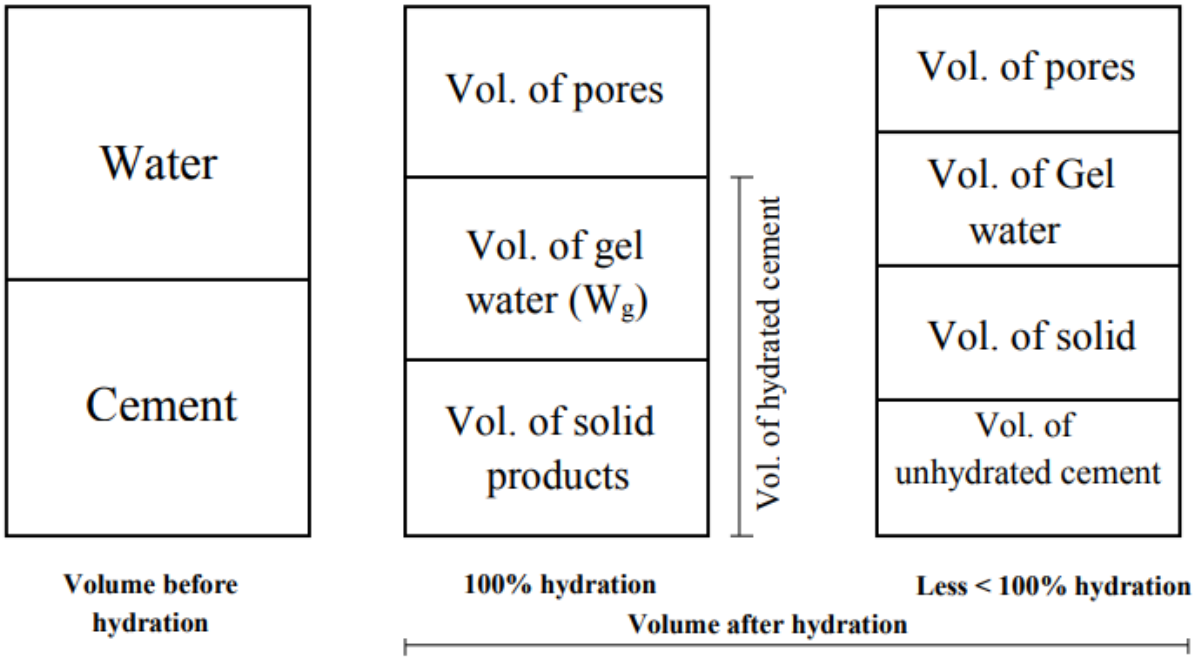
- Volume of solid products V_s = volume of cement V_c + volume of combined water – 0.254 volume of combined water as follow:

$$V_s = V_c + 0.23C - 0.254 \times 0.23C \text{ (empirical equation)}$$

- Gel water = 28% of solid volume

$$W_g = 0.28\ (V_s + W_g)$$

- Volume at t=0 (before reaction/ degree of hydration = 0%) = Volume after set t= time of set (after reaction/ degree of hydration > 0% up to 100%)



- Reaction occurred in a sailed container:

If w/c ≥ 0.42 then, no unhydrated cement will appear after reaction

If w/c ≤ 0.42 then, unhydrated cement will appear after reaction

- Reaction occurred in atmosphere:

If w/c ≥ 0.38 then, no unhydrated cement will appear after reaction

If w/c ≤ 0.38 then, unhydrated cement will appear after reaction