A new look at C-S-H nucleation and growth

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C-S-H (Calcium-Silicate-Hydrate) is very likely the most widely synthesized material by mankind. As the main component of hydrated Portland cement, the binder phase in concrete, it is estimated that over 3 Gt of C-S-H are produced every year. For a synthetic phase this widely used, surprisingly large gaps in our scientific understanding still persist regarding its crystal structure, its compositional variability and its mechanism of nucleation and growth.

Admittedly, C-S-H is not an easy phase to deal with. It usually shows to be nanocrystalline and fraught with irregularities such as defects, stacking faults, and broad solid solution series. Also in terms of nucleation and growth, our present day models are incomplete and often rely to heavily on classical models developed for crystalline materials. This while most of the collected evidence indicates that C-S-H follows a clearly different path to nucleation and growth, non-classical paths that have been explored before in the field of zeolite synthesis or, more recently, in geochemistry.

This contribution collects and reviews literature and non-published experimental data on C-S-H nucleation and growth and reinterprets them using non-classical nucleation and growth mechanisms.

It is commonly known that C-S-H develops long-range order only over time, initially formed C-S-H being highly disordered. Moreover it is recently observed that C-S-H precipitates are limited in size. Rather then growing large crystals at the expense of smaller ones, a meshwork of small crystallites is preserved over long hydration times.

Similarly, one of the more peculiar recent findings from ^{1}H NMR spectroscopy is that C-S-H formed early on during cement hydration has a significantly lower density and higher water content than C-S-H formed at later stages.

Combined, this may imply that surface energies and surface water adsorption (also called gel water) may play an important role in keeping the C-S-H phase in a “metastable” nanocrystalline and relatively low density state required to guarantee the performance and durability of concrete structures.