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How Does Portland Cement Work Anyway?

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Let's talk about Cement

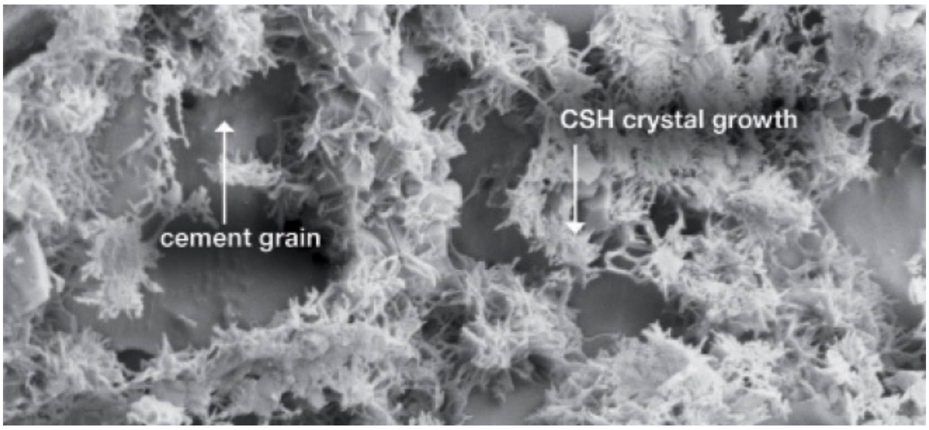
First, shall we address the elephant in the room? The biggest pet peeve of anyone working in the concrete industry is when someone calls concrete “Cement”. They are not the same, and they are not interchangeable. Cement, however, is a key ingredient in concrete. It's the powder that reacts with water to form the glue that holds rock and sand together, making concrete.

How is it made?
Portland Cement is a manufactured product is that made by combining Lime (from limestone typically), Silica (from clay, fly ash, shale, or sand), Alumina (from Aluminum ore or bauxite) and Iron (from clay, iron ore, or mill scale). The materials are crushed and blended to their proper proportions. the blended materials are then fed into a rotary kiln that heats up to 2500-2900°. This superheating partially melts the blended material. At the far end of the kiln, grayish-black pellets called clinker are discharged. Clinker generally contains four major compounds that affect the performance of a cement based on how much of each is present. These compounds are C_3S (Alite), C_2S (Belite), C_3A (Aluminate), C_4AF (Ferrite). The clinker is cooled and then ground to a fine powder. During the grinding process, gypsum is added at about 5% of volume as well as some amounts of unprocessed limestone. The gypsum is added to control

set times when the cement is exposed to water. In addition to the gypsum, some unprocessed ground limestone is added, from 3%-15% depending on the specification. The final fine gray powder that results from grinding is called Portland Cement.

How does it work?
Portland Cement is hydraulic, in that it reacts with water. The Alite and Belite compounds are hydrated to form calcium silicate hydrates (C-S-H) that act like the glue binding the different aggregates and other cement particles together. C-S-H is the compound that gives strength to concrete, and much of the science of concrete is the art of making as much C-S-H molecules and getting them as close together as possible. The Alite portion of C-S-H molecules hydrates rapidly is responsible for the initial set, early strength development and heat of hydration. The Belite portion hydrates at a slower rate and contributes most of the later age strength development.

As a by-product to the formation of C-S-H, calcium hydroxide (C-H) is formed where the is not enough silicates to bind with the calcium and hydrogen. C-H is initially inert from a strength perspective, but is key to the use of supplementary cementitious materials like Fly Ash or Slag. We'll discuss that at length in a later bulletin.



Are there different kinds of cement?
There sure are! Different cement types are used to achieve different concrete properties, although the rise of admixtures and the limits of silo spaces for different cements has led to much decreased use and production of many types of cements. The normal cement you will see today is a Type I/II Portland Cement, which simultaneously meets the requirements of a Type I and Type II cements. This also will be changing soon, as PLC Blended Cements replace Type I/II's as the standard general use cement. [(See Technical Bulletin #1 on PLC's)]

Table 3.7. General features of the main types of portland cement.

	Classification	Characteristics	Applications
Type I	General purpose	Fairly high C_3S content for good early strength development	General construction (most buildings, bridges, pavements, precast units, etc)
Type II	Moderate sulfate resistance	Low C_3A content (<8%)	Structures exposed to soil or water containing sulfate ions
Type III	High early strength	Ground more finely, may have slightly more C_3S	Rapid construction, cold weather concreting
Type IV	Low heat of hydration (slow reacting)	Low content of C_3S (<50%) and C_3A	Massive structures such as dams. Now rare.
Type V	High sulfate resistance	Very low C_3A content (<5%)	Structures exposed to high levels of sulfate ions
White	White color	No C_4AF, low MgO	Decorative (otherwise has properties similar to Type I)

Furthermore, many blended cements are available which pre-blend slag, fly ash, or limestone fines into the cement after production. These products help producers with limited silo capacities produce concrete able to meet diverse specifications and requirements.

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