## C - 13: Cement Hydration: Setting Time and Temperature

ASTM C 219-91, Standard Terminology Relating to Hydraulic Cement, defines hydraulic cement as "a cement that sets and hardens by chemical interaction with water and that is capable of doing so under water".

Portland cement consists of cement clinker interground with gypsum to control the set. There are numerous variables that affect the setting time of cement such as cement phase composition, the reaction rate of the individual phases, gypsum content, particle size, water/cement ratio, relative humidity, etc., but one of the major variables is temperature. In most chemical reactions, an increase in temperature will increase the speed of the chemical reaction, and this is true in the setting of cement. Portland cement sets faster at higher temperatures.

Cement hydrates due to the chemical reaction of water with the cement compounds, forming calcium silicate hydrates and calcium aluminate hydrates, etc. Cement will set as long as water is present in a liquid state. Hydration proceeds at a decreasing rate from $C_3A$ and $C_4AF$ through $C_3S$ and $C_2S$. Major long-term strength gains come from the hydration of the $C_3S$ and $C_2S$, with the aluminate and ferrite phases providing little toward long-term strength.

Complex cement hydration reactions are very time and temperature dependent, and can greatly affect the physical properties of the resulting concrete.

During early stages of hydration, the acceleration caused by increased temperature is beneficial to early strength development.

It is; however, detrimental to 28 day strength development.

If temperature increases significantly, different hydration products can be formed. This results in lower long-term concrete strength development and poor concrete performance caused by microcracking, defects in the microstructure of the concrete, shrinkage, etc.

Low temperatures cause a slowing down of the hydration of the cement compounds, resulting in considerably longer setting times. This can lead to disruption of the concrete if freezing should occur before the concrete has gained significant strength.

Typically, cement sets best around 70º F (21º C). This gives it a combination for a reasonably fast setting time and early strength development, along with the opportunity to develop the required ultimate strength and additional physical properties.

Accelerators and retarders, ice water, hot water, changing the type of cement, substituting mineral admixtures for cement content, etc. can be used to alter the setting time to make up for extreme variations in temperature found during concrete placement and anticipated curing conditions. Precautions are well known in the concrete industry and are normally used when placing concrete at extreme temperatures.