U.S. Department of Transportation
Federal Highway Administration

Use of Supplementary Cementitious Materials (SCMs) in Concrete Mixtures

Observations from the FHWA Mobile Concrete Technology Center (MCTC)

Supplementary Cementitious Materials (SCMs): SCMs are materials used as a partial replacement of portland cement to improve both fresh and hardened concrete properties. The most commonly used SCMs in concrete mixtures are fly ash (Type C, Type F), slag cement, and, to a lesser extent, silica fume. These materials are byproducts of various industries: Fly ash-burning coal in power plants; Slag cement-smelting iron ore; Silica fume-alloying silicon or ferrosilicon.

Cementitious / Hydraulic Material: Hydraulic material (such as portland cement) sets and hardens when it comes in contact with water through a chemical reaction called hydration (ASTM C125-03). Hydration is an irreversible chemical reaction. It results in hydrated cement paste, a strong, stiff material. The primary hydration products are calcium silicate hydrate (C-S-H), which provides strength and performance properties in concrete, and calcium hydroxide (CH), which does not contribute to performance and is prone to chemical attack.

Primary Reaction

Calcium Silicates + Water → C-S-H + CH

Cement   Water → Paste

Pozzolanic Material: A pozzolan is a material that does not react with water by itself, but will chemically react with cement hydration product (CH) and water to form additional C-S-H in concrete.

Primary Reaction

Calcium Silicates + Water → C-S-H + CH

Secondary Reaction

Begins after the cement reaction

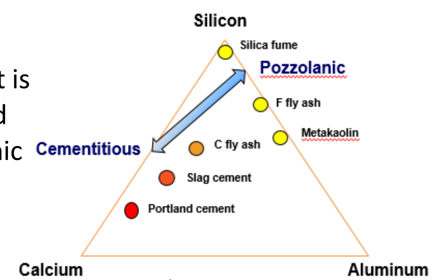
Supplemental Cementitious Material + Water + CH → C-S-H

SCM

Is it Cementitious or Pozzolanic?

In most modern concrete paving mixtures used in the United States, portland cement is supplemented or partially replaced by SCMs. When used in conjunction with portland cement, SCMs contribute to the properties of concrete through hydraulic or pozzolanic activity or both. Cements and SCMs have the same three basic ingredients: Calcium (CaO), Silica (SiO_2), and Alumina (Al_2O_3). Depending on the composition of the three ingredients, they are either classified as cementitious, pozzolanic, or both.

Composition



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Benefits and Implications of using SCMs:

- Increases long term strength but may gain strength more slowly (silica fume is the exception; it gains strength quickly).
- Increases durability by reducing permeability.
- Delays set time by slowing the rate of hydration (silica fume is the exception). This is helpful during hot weather but may not be in cooler weather.
- Reduces risk of thermal cracking by lowering peak hydration temperatures.
- Reduces the amount of CH reaction product. This will reduce the risk of oxychloride formation, a root cause of early joint deterioration found in some midwestern pavements.
- Mitigates alkali-silica reactivity

Considerations for Opening Strengths:

While additional precautions may need to be taken for SCMs in cold weather due to slower set time and strength gain, most other "open to traffic" situations can be accommodated with only an additional day of curing when compared to straight cement mixtures and thereby avoid sacrificing the long-term durability benefits of the SCMs. Using maturity meters, the MCTC has documented that there is only a slight delay in open to traffic strengths with SCMs while still maintaining low permeability, resistance to chemical attack, and reduced shrinkage cracking.

MCTC experience: Over the past 12 years, the MCTC has tested concrete in 35 states and have found only two states not using SCMs. Most states recognize the value of SCMs and understand that they improve concrete properties, with the added benefit that they often improve mix economics.

The intent of this One Pager is to explain the complex chemical reactions of cement and SCMs in a simplistic manner in order to provide a general understanding of these materials. For detailed information on this topic, refer to https://www.fhwa.dot.gov/pavement/concrete/pubs/hif16001.pdf

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