# Concrete Tech Tip
# # 27

# Supplementary Cementing Materials (SCM's)

**1. What are Supplementary Cementing Materials?**

The principal cementitious material in most concrete mixes is portland cement. Today, most concrete mixtures contain supplementary cementing materials (SCMs) that make up a portion of the cementitious component in concrete. These materials are generally byproducts from other processes or naturally occurring materials. They may or may not be further processed for use in concrete. Some of these materials are pure pozzolans, which by themselves do not have any cementitious properties, but when used with portland cement, react to form cementitious compounds. Other SCM's such as slag and fly ashes with significant CaO contents, exhibit cementitious properties.

SCMs must meet industry standards established under CSA A3001 in order to be used in concrete. Under CSA A3001, they can qualify either individually, as a component of a blended cement or as a component of a blended supplementary cementing material.

**Supplementary cementing materials. L-R: Fly ash (TypeCI), metakaolin (calcined clay), silica fume, fly ash (Type F), Slag, and calcined shale.**

**The most common Supplementary Cementing Materials used in today's concrete mixes are:**

**Fly Ash:** The byproduct of coal-fired furnaces at power generation facilities and is the non-combusted fine particulates collected from the flue gas stream. Fly ash used in concrete should conform to CSA A3001. The amount of fly ash used in concrete can vary depending on the source and composition of the fly ash and the performance requirements of the concrete. Table 9 in CSA A3001 defines the proportion limits of fly ash in blended hydraulic cements and in blended supplementary cementing materials. Characteristics of fly ash can vary considerably depending on the source of coal. Anthracite or bituminous coal in general has low calcium content and when burned tends to produce fly ash that is more pozzolanic in nature than self-cementitious.
Subbituminous coal, the most commonly found coal in Alberta, may contain significant amounts of calcium and when burned will produce fly ash that exhibits both pozzolanic and cementitious properties. In Canada, CSA defines three Types of fly ash in accordance with calcium oxide (CaO) content. Type F Fly Ash has a CaO content $\leq$ 15%, Type CI (C Intermediate) Fly Ash has a CaO content range that spans >15% $\leq$20% and Type CH Fly Ash has CaO content that exceeds 20%.

**Slag**: **Granulated Blast-Furnace Slag** is a non-metallic byproduct from a blast furnace when iron ore is educed to pig iron. It is defined by CSA as "- the glassy granular material formed when molten blast-furnace slag is rapidly chilled." The **Slag** used as an **SCM** in concrete is known as **Ground Granulated Blast-Furnace Slag** or **Type S** and is defined in CSA A3001 as "product obtained by grinding granulated blast-furnace slag, to which the various forms of calcium sulphate, water, and processing additions may be added at the option of the manufacturer." Slag has cementitious properties but these are enhanced when it is used with portland cement. Slag can be used at portland cement replacement rates of up to 70% in a concrete.

**Silica Fume:** Silica fume is a byproduct from the manufacture of silicon or ferro-silicon metal and is a highly reactive pozzolanic material. It is collected from the flue gas from electric arc furnaces. Silica fume is an extremely fine powder, with particles on average 100 times smaller than cement particles. Silica fume is available as a densified powder. Silica fume for use in concrete should conform, once again, to CSA A3001. Under this standard, CSA defines two Types of silica fume; Type SF and Type SFI based upon silicon dioxide (SiO2) content. Type SF silica fume has a SiO2 content of at least 85%. Type SFI has a SiO2 content of at least 75%.
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It is generally used at a rate of 3% to 10% by mass of cementitious materials in a concrete mix. Applications include concrete structures that need high strength or significantly reduced permeability to water and chemicals. Special procedures are warranted when handling, placing, finishing and curing silica fume concrete.

**Natural Pozzolans:** Various naturally occurring materials possess, or can be processed to possess pozzolanic properties. These SCMs are also covered under CSA A3001. Natural pozzolans are generally derived from volcanic origins. In Western Canada, natural pozzolans that have been commercially produced on a limited basis. Metakaolin has been produced by controlled calcining of Kaolinite clay in southwestern Saskatchewan. This product has been used at rates of 5% to 15% by weight of cementitious materials. Other potential future sources of natural pozzolans may be found in the historically volcanically active area that makes up the Pacific Rim. Other natural pozzolans include calcined shale, volcanic glass, zeolitic trass or tuffs, also simply called "zeolites", rice husk ash and diatomaceous earth.

**2. Why are Supplementary Cementing Materials used?**

Supplementary cementing materials can be used for improved concrete performance in its fresh and hardened state. They are primarily used to enhance the workability, durability and strength of concrete. These materials allow the concrete producer to design and modify the concrete mixture to meet the performance requirements of the concrete application. Concrete mixtures with high portland cement contents are susceptible to cracking and to increased heat generation. These effects can be controlled to a certain degree by using supplementary cementing materials. SCMs such as fly ash, slag and silica fume enable the concrete industry to use hundreds of millions of tonnes of byproduct materials that would be otherwise landfilled as waste. Furthermore the use of SCMs reduces the consumption of portland cement per unit volume of concrete. Portland cement has high energy consumption and emissions associated with its manufacture, which is conserved or reduced when the amount used in concrete is reduced.

**3. How do Supplementary Cementing Materials affect concrete properties?**

**Fresh Concrete:** In general, SCMs improve the consistency and workability of fresh concrete because an additional volume of fines is incorporated in the mixture. Concrete with silica fume is typically used at low water contents with high range water reducing admixtures and the mixtures tend to be cohesive and stickier than plain concrete. Fly ash generally reduces the water demand for required concrete slump while slags influence on water demand will vary depending on its fineness. Concrete setting time may be slower with some SCMs used at higher percentages. This can be beneficial in hot weather. The slower setting can be offset in the winter by reducing the amount of SCMs in the concrete and by incorporating accelerating admixtures. Because of the additional fines, the amount and rate of bleeding of these concretes is often reduced. This is particularly significant when silica fume is used. Reduced bleeding, in conjunction with slower setting characteristics, can cause plastic shrinkage cracking and may warrant special precautions during placing and finishing (see CTT#5).

**Strength:** Concrete mixtures can be proportioned to produce the required strength and rate of strength gain as required for the application. With SCMs other than silica fume, the rate of strength gain might be lower initially, but strength gain continues for a longer period compared to mixtures with only portland cement, frequently resulting in higher ultimate strengths. Silica fume is often used to produce concrete compressive strengths in excess of 70 MPa. Concrete containing SCMs generally needs additional consideration for curing of both the test specimens and the structure to ensure that potential properties are attained. CSA A23.1 defines two categories of High Volume Supplementary Cementing Materials—HVSCM –1 and HVSCM-2 and stipulates additional measures for curing, quality control and field strength development monitoring.

**Durability:** SCMs can be used to reduce the heat generation associated with cement hydration and reduce the potential for thermal cracking in massive structural elements. SCMs modify the microstructure of concrete and reduce its permeability thereby reducing the penetration of water and water-borne salts into concrete. Watertight concrete will reduce various forms of concrete deterioration, such as corrosion of reinforcing steel and chemical attack. Most SCMs can reduce internal expansion of concrete due to chemical reactions such as alkali aggregate reaction and sulphate attack. Resistance to freezing and thawing cycles requires the use of air entrained concrete. Concrete with proper air void system and strength will perform well in these conditions.

The optimum combination of materials will vary for different performance requirements and the type of SCMs. The ready mixed producer with knowledge of the locally available materials can establish the mixture proportions for the required performance. Prescriptive restrictions on mixture proportions can inhibit optimization and economy. While several enhancements to concrete properties are discussed above, these are not mutually exclusive and the mixture should be proportioned for the most critical performance requirements for the job with the available materials.

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