

# Concrete in Practice

What, why & how?



## CIP 30 - Supplementary Cementitious Materials (SCMs)

### WHAT are SCMs?

In its most basic form, concrete is a mixture of cement, sand, coarse aggregate and water. The primary cement used is portland or blended cement. Most concrete mixtures contain SCMs that make up a portion of the cementitious component in concrete. SCMs are generally byproducts from other processes or natural materials. Some SCMs may need to be further processed by drying, calcining, or grinding for use in concrete. Some SCMs are pozzolans, which do not have any cementitious properties, but when used with cement, react to form cementitious compounds. Other materials, such as slag cement and Class C coal ash, exhibit cementitious properties.

For use in concrete, SCMs should meet requirements of established standards. More than one SCM may be used in concrete mixtures. SCMs may be part of a blended cement or as separately batched materials at the concrete plant.

**Coal Ash** refers to fly ash or bottom ash, byproducts from coal-fired furnaces at power generation facilities, or harvested from landfills or disposal ponds. Fly ash is fine particulate material removed from flue gases while bottom ash is that which settles at the bottom. Coal ash used in concrete should conform to specification ASTM C618. The quantity of coal ash used in concrete can vary from 15% to 65% by mass of the cementitious materials, depending on the source and composition and the performance requirements of the concrete. Characteristics of coal ash can vary significantly depending on the type of coal burnt and the source of the material. Class F coal ash is normally produced when burning anthracite or bituminous coal. Class F coal ash is pozzolanic. Class C coal ash typically results from burning lignite or subbituminous coal and typically has cementitious and pozzolanic properties. As defined in ASTM C618, Class F coal ash contains up to 18% calcium oxide (CaO), while the CaO content of Class C coal ash exceeds 18%. Processing of coal ash containing bottom ash or material that is harvested is typically necessary before it is acceptable for use in concrete.

**Slag Cement** is a non-metallic manufactured byproduct from a blast furnace when iron ore is reduced to pig iron. The liquid slag is rapidly cooled to form granules, which are then ground to a fineness similar to cement. Slag cement used as a cementitious material should conform to the specification, ASTM C989. Three grades - 80, 100, and 120 are defined in C989, with the higher grade contributing more to strength potential. Slag cement has cementitious properties but these are enhanced when it is used in



Courtesy: PCA

### Types of SCMs

combination with cement. Slag is used at 20% to 80% by mass of the cementitious materials.

**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 gases from electric arc furnaces. Silica fume is an extremely fine powder, with particles about 100 times smaller than an average cement particle. Silica fume is available as a densified powder. Silica fume for use in concrete should conform to specification ASTM C1240. It is generally used at 3 to 10% by mass of cementitious materials. Applications include concrete structures that need high strength or significantly reduced permeability to water and chemicals. Special procedures are warranted when handling, placing and curing silica fume concrete.

**Natural Pozzolans.** Various naturally occurring materials possess, or can be processed to possess pozzolanic properties. These materials should conform to requirements for Class N in specification, ASTM C618. Natural pozzolans are generally derived from volcanic origins. In the US, commercially available natural pozzolans include **metakaolin** and **calcined shale or clay**. These materials are manufactured by controlled calcining (firing) of naturally occurring materials. Metakaolin is produced from relatively pure kaolinite clay and it is used at 5% to 15% by mass of the cementitious materials. Calcined shale or clay is used at higher percentages by mass. Other natural pozzolans include **volcanic ash, pumicites, zeolitic trass or tuffs, rice husk ash and diatomaceous earth**. Some natural pozzolans are calcined to achieve pozzolanic properties.

**Ground Glass Pozzolan (GGP)** is obtained from recycling container glass used in packaging products,

plate glass used for glazing buildings and automobiles and E-glass from glass fibers. The first two are soda-lime-silica glass materials. Glass from these sources is ground to very fine powders that have pozzolanic properties when used in concrete. GGP for concrete should conform to ASTM C1866, which provides two classifications: Type GS sourced from soda-lime-silica glass and Type GE sourced from E-glass. GGP can be used at similar mass percentages of the cementitious materials as is coal ash.

SCMs that comply with individual specifications can be combined to produce a blended SCM that conforms to ASTM C1697. This is useful when traditional SCMs are in short supply or the beneficial characteristics of the individual materials are combined in the blend.

### WHY are SCMs Used?

SCMs can be used for improved concrete performance in its fresh and hardened state. They are primarily used to improve the workability, durability, and strength of concrete. SCMs allow the concrete producer to design and modify the concrete mixture to meet the performance requirements for a wide range of concrete applications.

SCMs such as fly ash, slag cement, and silica fume enable the concrete industry to beneficially use several million tons of byproduct materials that would otherwise be landfilled as waste. SCMs are an essential option to minimize the embodied carbon of concrete mixtures to support sustainable construction initiatives.

### HOW do SCMs Affect Concrete Properties?

**Fresh Concrete:** In general, SCMs improve the **consistency** and **workability** of fresh concrete because an additional volume of fines in the mixture. Concrete with silica fume is typically used at low water contents with high range water reducing admixtures and these mixtures tend to be cohesive and stickier than other concrete mixtures. Coal ash and slag cement generally reduce the water demand for required concrete slump. Some natural pozzolans have a higher water demand. Concrete **setting time** may be slower with some SCMs used at higher percentages. This slower setting time can be beneficial in hot weather. The slower setting time is addressed in winter by reducing the content of SCM in concrete and by using accelerating admixtures. Because of the additional fines, the amount and rate of **bleeding** of these concretes is often reduced. This is especially 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 CIP 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 cement, frequently resulting in higher ultimate strengths. Silica fume is often used to produce concrete compressive strengths in excess of 10,000 psi [70 MPa]. Concrete containing SCM generally needs additional consideration for curing of test specimens and the structure to achieve the potential properties.

**Durability** - SCMs can be used to reduce the heat generation associated with cement hydration and reduce the potential for thermal cracking at early ages and in massive structural members. SCMs modify the microstructure of concrete and reduce its permeability thereby reducing the penetration of water and water-borne chemicals into concrete. Watertight concrete will reduce various forms of concrete deterioration, such as corrosion of reinforcing steel and chemical attack. Most SCMs can minimize deleterious cracking of concrete due to chemical reactions such as alkali silica reaction and sulfate attack.

The optimum combination of cementitious materials will vary for different performance requirements and the type of SCMs used. The ready mixed concrete 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 for performance, economy, and achieving sustainable concrete mixtures. 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.

### References

1. ASTM Standards C618, C989, C1240, C1696, C1866, Volume 04.02, ASTM International, West Conshohocken, PA, [www.astm.org](http://www.astm.org).
2. *Use of Natural Pozzolans in Concrete*, ACI PRC 232.1, American Concrete Institute, Farmington Hills, MI, [www.concrete.org](http://www.concrete.org)
3. *Use of Fly Ash in Concrete*, ACI PRC 232.2, American Concrete Institute, Farmington Hills, MI.
4. *Guide to use of Slag Cement in Concrete and Mortar*, ACI PRC 233, American Concrete Institute, Farmington Hills, MI.
5. *Guide for the Use of Silica Fume in Concrete*, ACI PRC 234, American Concrete Institute, Farmington Hills, MI.
6. *Ground-Glass Pozzolan for Use in Concrete*, Kaminsky, Krstic, Rangaraju, Tagnit-Hamou, and Thomas, ACI Concrete International, Farmington Hills, MI., Nov. 2020, pp. 24-32
7. *Pozzolanic and Cementitious Materials*, V.M. Malhotra and P. Kumar Mehta, Gordon and Breach Publishers
8. CIP 5, Plastic Shrinkage Cracking, NRMCA Concrete in Practice Series, Alexandria, VA, [www.nrmca.org](http://www.nrmca.org)

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