Concrete in Practice
What, why & how?
NRMCA

CIP 30 - Supplementary Cementitious Materials (SCMs)

WHAT are SCMs?

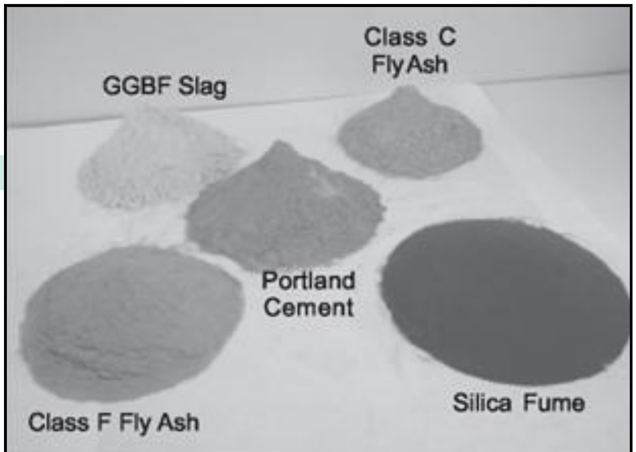
In its most basic form, concrete is a mixture of portland cement, sand, coarse aggregate and water. The principal cementitious material in concrete is portland cement. Today, most concrete mixtures contain supplementary cementitious materials that make up a portion of the cementitious component in concrete. These materials are generally byproducts from other processes or natural materials. They may or may not be further processed for use in concrete. Some of these materials are called pozzolans, which by themselves do not have any cementitious properties, but when used with portland cement, react to form cementitious compounds. Other materials, such as slag cement and ASTM C618 Class C fly ash, do exhibit cementitious properties.

For use in concrete, supplementary cementitious materials, need to meet requirements of established standards. They may be used individually or in combination in concrete. They may be added to the concrete mixture as a blended cement or as a separately batched ingredient at the ready mixed concrete plant.

Some examples of these materials are discussed below.

Fly Ash is a byproduct of coal-fired furnaces at power generation facilities and is the non-combustible particulates removed from the flue gases. Fly ash used in concrete should conform to specification ASTM C618. The amount of fly ash in concrete can vary from 15% to 65% by mass of the cementitious materials, depending on the source and composition of the fly ash and the performance requirements of the concrete. Characteristics of fly ash can vary significantly depending on the source of the coal. Class F fly ash is normally produced when burning anthracite or bituminous coal and generally has a low calcium content. Class F fly ash is pozzolanic. Class C fly ash is produced when subbituminous coal is burned and it typically has cementitious and pozzolanic properties. As defined in ASTM C618, the sum of silicon, aluminium, and iron oxides should be greater than 50% for Class C fly ashes and should be greater than 70% for Class F fly ashes.

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 portland 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



Types of Cementitious Materials

cementitious properties but these are enhanced when it is used with portland cement. Slag is used at 20% to 70% 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 inclued 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 are also covered under the 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 glass, zeolitic trass or tuffs, rice husk ash and diatomaceous earth.**

WHY are SCMs Used?

Supplementary cementitious 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 increased heat generation. These effects can be controlled to a certain degree by using supplementary cementitious materials.

Supplementary cementitious materials such as fly ash, slag cement and silica fume enable the concrete industry to use hundreds of millions of tons of byproduct materials that would otherwise be landfilled as waste. Furthermore, their use 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.

HOW do SCMs Affect Concrete Properties?

Fresh Concrete: In general, supplementary cementitious materials 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 these mixtures tend to be cohesive and stickier than plain concrete. Fly ash and slag cement generally reduce the water demand for required concrete slump. Concrete **setting time** may be slower with some supplementary cementitious materials used at higher percentages. This can be beneficial in hot weather. The slower setting time is offset in winter by reducing the percentage of supplementary cementitious material in the concrete and be 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 supplementary cementitious materials 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 10,000 psi [70 MPa]. Concrete containing supplementary cementitious material generally needs additional consideration for curing of both the test specimens and the structure to ensure that the potential properties are attained.

Durability - Supplementary cementitious materials can be used to reduce the heat generation associated with cement hydration and reduce the potential for thermal cracking in massive structural elements. These materials 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 supplementary cementitious materials can reduce internal expansion of concrete due to chemical reactions such as alkali aggregate reaction and sulfate attack. Resistance to freezing and thawing cycles requires the use of air entrained concrete. Concrete with a 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 supplementary cementitious materials. 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 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.

References

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