These materials are manufactured by controlled calcining (firing) of naturally occurring minerals. 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 Supplementary Cementitious Materials Used?

Supplementary cementitious materials can be used for improved concrete performance in its fresh and hardened state. They are primarily used for improved workability, durability, and strength. These materials allow the concrete producer to design and modify the concrete mixture to suit the desired 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 and silica fume enable the concrete industry to use hundreds of millions of tons of by product 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 a high energy consumption and emissions associated with its manufacture, which is conserved or reduced when the amount used in concrete is reduced.

HOW do These Materials 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 added to 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 generally reduce the water demand for required concrete slump. Concrete setting time may be retarded with some supplementary cementitious materials used at higher percentages. This can be beneficial in hot weather. The retardation is offset in winter by reducing the percentage of supplementary cementitious material in the concrete. 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 retarded setting, can cause plastic shrinkage cracking and may warrant special precautions during placing and finishing.

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.