Supplementary Cementitious Materials

Definition of a natural pozzolan (pozzolanic materials)

Pozzolan is defined as a siliceous or siliceous and aluminous material, which in itself possesses little or no cementitious value but will, in finely divided form and in the presence of moisture, chemically reacts with calcium hydroxide at ordinary temperatures to form compounds possessing cementitious properties.

1. Silica fume as a pozzolanic material

1.1—General

Silica fume is a by-product of the ferrosilicon industry. It is also known as micro silica, condensed silica fume, or silica dust. Silica Fume consists of very fine particles with a surface area between 13,000 and 30,000 m^2/kg. Its particles are approximately 100 times smaller than the average cement particle. Because of its extreme fineness and high silica content, silica fume is a highly pozzolanic material that is used to enhance mechanical and durability properties of concrete. It may be added directly to concrete as an individual ingredient or in a blend of Portland cement and silica fume.

Interest in the use of silica fume resulted from the strict enforcement of air pollution measures designed to stop release of the material into the atmosphere. Initial use of silica fume in concrete was mostly for cement replacement, along with water-reducing admixtures (WRAs). Eventually, the availability of high-range water-reducing admixtures (HRWRAs, often referred to as superplasticizers) allowed new possibilities for the use of silica fume to produce high levels of performance.

1.2 Using silica fume in concrete

Silica fume was initially viewed as a cement replacement material, but currently the most important reason for its use is the production of high-performance concrete, where adding silica fume provides enhancements in concrete properties (compressive strength and with very high levels of durability).

Because of the fineness of the material, adding silica fume to concrete mixtures usually increases water demand. To produce high-performance, durable concrete, it is necessary to maintain (or decrease) the water-cementitious material ratio (*w*/*cm*). Consequently, HRWRAs are used to obtain the required performance and workability.

1.3 Silica fume as a cementitious material

Silica fume is typically used in quantities ranging from 7 to 12% of the mass of the cementitious material. Silica fume should conform to requirements in ASTM C 1240.

Table1: Chemical Requirements

SiO_2, min%	85.0
Moisture content, max%	3.0
Loss on ignition, max, %	6.0

Table 2: Physical Requirements

Percent retained on 45-μm (No. 325), max, %	10
Accelerated pozzolanic strength activity index With Portland cement at 7 days, min percent of control	105
Specific surface, min, m^2/g	15

2. Physical properties and chemical composition of silica fume

2.1—Color

Most silica fumes range from light to dark gray. Because SiO_2 is colorless; the color is determined by the non-silica components, which typically include carbon and iron oxide. In general, the higher the carbon content, the darker the silica fume

2.2—Specific gravity

The specific gravity of silica fume is approximately 2.2, as compared with about 3.1 for Portland cement.

2.3—Bulk density

The bulk density of commercially available densified silica fume ranges from approximately (400 to 720 kg/m^3).

2.4—Fineness, particle shape, and oversize material

Silica fume consists primarily of very fine smooth spherical glassy particles with a surface area of approximately (20,000 m^2/kg). The extreme fineness of silica fume is illustrated by the following comparison with other fine materials

- Silica fume: (13,000 to 30,000) m^2/kg
- Fly ash: (280 to 700) m^2/kg
- Ground-granulated blast-furnace slag: (350 to 600) m^2/kg
- Portland cement: (300 to 400) m^2/kg

Individual silica fume particles have a diameter of less than 1 μm, which is approximately 1/100 of the size of an average cement particle.

2.5—Chemical composition

The silica fumes generally contain more than 90% silicon dioxide (SiO_2). The chemical composition of the silica fumes varies with the type of alloy that is being produced. Silica fume is composed primarily of pure silica in non-crystalline form. It has a very high content of amorphous silicon dioxide and consists of very fine spherical particles. Small amounts of iron, magnesium, and alkali oxides are also found

Table 3: Chemical composition of silica fume samples

Oxides	Sandvik and Gjorv (1992)	Hooton and Titherington (2004)	Yazıcı (2008)
SiO_2	92.1	96.65	92.26
Al_2O_3	0.5	0.23	0.89
Fe_2O_3	1.4	0.07	1.97
CaO	0.5	0.31	0.49
MgO	0.3	0.04	0.96
K_2O	0.7	0.56	1.31
Na_2O	0.3	0.15	0.42
SO_3	-	0.17	0.33
LOI	–	2.8	2.27