# Pozzolans Unpuzzled

## As Mineral Admixtures, Fly Ash and Other Waste Products Add Strength and Durability to Concrete

by Bruce King, P.E.
Civil Engineer
Sausalito, California

Portland cement is the glue that holds rock and sand together as concrete, and it does so very well, but comes with a high environmental price tag. Cement is produced by firing limestone and clay minerals at very high temperatures, emitting a ton of carbon dioxide (greenhouse) gas for every ton of cement produced; by some accounts, cement production worldwide accounts for 8 percent of the total carbon dioxide emissions from human activity. (The production of lime is similar, but uses about one third the energy.) Ordinary portland cement concrete is also relatively permeable, leaving it subject to degradation of many types. The solution to both of these problems is emerging in the increased usage of pozzolans—supplemental mineral admixtures that react with portland cement hydration products to produce additional binder.

The use of pozzolans began many decades ago, but has seen a pronounced surge in the 1990s. This has been caused not so much by environmental considerations, as by the growing recognition that the intelligent use of certain pozzolans can greatly increase both the strength and durability (longevity) of concrete structures. Typically, the siliceous pozzolan reacts with otherwise unused cement hydration products (weak calcium hydroxide becomes strong calcium silicate hydrate). Though some pozzolans are manufactured specifically to augment concrete mixes in various ways, and others are mined directly from the earth (the name "pozzolan" derives from early uses of a cementitious volcanic ash mined near Pozzolano, Italy), the most commonly used ones are waste products from industry. Restrictions on pozzolan usage are described in Section 1904 of the 1994 and 1997 editions of the *Uniform Building Code*™.

*The views expressed here are those of the author and do not necessarily reflect the opinion or agreement of the International Conference of Building Officials.*

Four such pozzolans (from waste materials) now in use are fly ash, silica fume, slag and rice hull ash.

**Fly Ash**

Fly ash (also known as coal ash or fuel ash) is the residue collected from the smokestacks of coal-fired power plants, and is therefore abundantly available worldwide. Class F fly ash needs portland cement with which to react (a true pozzolan), whereas some Class C fly ashes are in themselves cementitious and have been combined with lime or even calcium carbonate soils to produce moderately strong concretes.

Historically thought by many engineers to be mere "filler" without added value, fly ash usage has been restrained by building codes to 25 or 35 percent of total cementitious material in a concrete mix. Also, many engineers, out of ignorance, are still wary of using any fly ash, but that attitude is rapidly changing. Coastal communities and states are finding that large-scale fly ash usage decreases the porosity of concrete, thereby making it last far longer in saltwater environments (the same is true of northern states where roads are salted in winter). Research in Canada, the United States and Europe is producing mixes that are 60-percent fly ash and 40-percent cement, attaining long-term strengths in excess of their all-cement counterparts. With fly ash so abundantly available (at about half the cost of cement), code restrictions on its use being lifted and our understanding of its desirable properties growing, market conditions alone will impel increasing usage.

**Silica Fume**

Silica fume (or condensed silica fume) is a waste product of the silicon metal industry. A super-fine powder of almost pure amorphous silica, it reacts very well with hydrating portland cement, resulting in dramatic increases in both strength and durability. Though difficult (and expensive) to handle, transport

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and mix, it has become the chosen supplement for super high-strength concretes (such as for high-rise buildings), often in combination with fly ash as well as cement.

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**Slag**

Blast furnace slag [or more exactly, ground, granulated blast furnace slag (GGBFS)] is a processed waste product of iron production, widely used in Europe and coming into increased usage in North America. Though technically not a pozzolan, in that GGBFS is mildly cementitious in itself, the combination of GGBFS with portland cement achieves a similar desirable array of results.

**Rice Hull Ash**

The least known of the four pozzolans discussed, but possibly the most promising on a global scale, is rice hull ash (or rice husk ash). The world's primary staple crop is rice, the milling of which generates 100 million tons of hulls, or chaff, annually. Like straw, the hulls have historically been burned in the fields, but the resulting pollution is causing increasing health problems. Research in India and the United States has found that if the hulls (or straw) are burned at a controlled low temperature, the ash collected can be ground to produce a pozzolan very similar (and in some ways superior) to silica fume. Rice hull ash is now being used in concrete applications in the United States, particularly in the rice-growing regions (California, Texas, Arkansas and Louisiana), where it is produced in biomass power plants.

Driven by the growing need both to utilize wastes effectively and to increase the durability of concrete structures, the use of pozzolans in concrete is increasing and is widely expected to increase further in the decades to come. ■