History of Pozzolana

Lime and limestone are among the oldest materials used by mankind for construction purposes. Some of the oldest structures built of limestone include the pyramids of Egypt. Long before the invention of Portland cement in 1824, mortars and concretes composed of mixtures and fillers and raw or heat-treated lime were used for construction throughout the world.

Malinowski et al. (1993) report that the oldest example of hydraulic binder, dating from 5000-4000 B.C., was a mixture of lime and natural pozzolana, a diatomaceous earth from the Persian Gulf. The next oldest reported use was in the Mediterranean region. The pozzolan was volcanic ash produced from two volcanic eruptions: one, sometime between 1600 and 1500 B.C. on the Aegean Island of Thera, now called Santorin, Greece; the other in 79 A.D. at Mt. Vesuvius on the bay of Naples, Italy. Both are volcanic ashes or pumicites consisting of almost 80% volcanic glass (pumice and obsidian).

According to the Roman engineer Marcus Vitruvius Pollio (Vitruvius Pollio 1960), who lived in the first century B.C., the cements made by the Greeks and the Romans were of superior durability, because “neither waves could break, nor water dissolve” the concrete. In describing the building techniques of masonry construction, he indicated that the Romans developed superior practices of their own from the techniques of the Etruscans and the Greeks. The Greek masons discovered pozzolan-lime mixtures sometime between 700-600 B.C. and later passed their use of concrete along to the Romans in about 150 B.C. During the 600 years of Roman domination, the Romans discovered and developed a variety of pozzolana throughout their empire (Kirby et al. 1956).

During archaeological excavations in the 1970s at the ancient city of Camiros on the Island of Rhodes, Greece, an ancient water-storage tank having a capacity of 600 m3 (785 yd3) was found. Built in about 600 B.C., it was used until 300 B.C. when a new hydraulic system with an underground water tank was constructed. For almost three millennia this water tank has remained in very good condition, according to Efstathiadis (1978). Examination of the materials used for this structure revealed that the concrete blocks and mortar used were made out of a mixture of lime, Santorin earth, fine sand (<2mm [<0.08 in.]) and siliceous aggregates with sizes ranging between 2 and 20mm (0.08 and 0.79 in.). The fresh concrete was placed into wooden sidewall molds.

The amount of amorphous material usually determines the reactivity of a natural pozzolan. The constituents of a natural pozzolan can exist in various forms, ranging from amorphous reactive materials to crystalline products that will react either slowly or not at all.

Generally, amorphous silica reacts with calcium hydroxide and alkalis more rapidly than does silica in the crystalline form (quartz). As is the case with all chemical reactions, the larger the particles (the lower the surface area per unit volume) the less rapid the rate of reaction is. Therefore, the chemical composition of a pozzolan alone does not clearly determine its ability to combine with calcium hydroxide and alkalis.

Examples of natural pozzolana

The following are some natural pozzolana produced in various parts of the world.

Santorin earth is produced from a natural deposit of volcanic ash of dacitic composition on the island of Thera, in the Agean Sea, also known as Santorin, which was formed about 1600-1500 B.C. after a tremendous explosive volcanic eruption (Marinatos 1972).

Rhenish trass, a natural pozzolan of volcanic origin (Lovewell 1971), has been well known since ancient Roman times. The material is a trachytic tuff that differs from place to place and is found in the Valley of the Rhine River in Germany. Similar tuffs have been used in Bavaria.

Gaize is a pozzolan found in France that is not of volcanic origin but a porous sedimentary rock consisting mainly of opal. The material is usually calcined at temperatures around 900 C (1620 F) before it is used as a pozzolan or as a component of Portland-pozzolan cement.

Volcanic tuffs, pumicites, diatomaceous earth, and opaline shales are found principally in the United States in Oklahoma, Nevada, Arizona, and California. They showed that concretes containing pozzolanic materials exhibited certain desirable properties such as lower cost, lower temperature rise, and improved workability. According to Price (1975), an example of the first large-scale use of Portland-pozzolan cement, composed of equal parts of Portland cement and a rhyolitic pumicite, is the Los Angeles aqueduct in 1910-1912.

Pozzolana are produced from a deposit of pumice ash or tuff comprised of trachyte found near Naples and Segni in Italy. Trachyte is a volcanic rock comprised primarily of feldspar crystals in a matrix of siliceous glass. Pozzolana are products of an explosive volcanic eruption in 79 A.D. at Mount Vesuvius, which engulfed Herculaneum, Pompeii, and other towns along the bay of Naples. The deposit near Pozzuoli is the source of the term “pozzolan” given to all materials having similar properties. Similar tuffs of lower silica content have been used for centuries and are found in the vicinity of Rome.

The studies of natural pozzolana by the United States Bureau of Reclamation (USBR) in the 1930s and 1940s encouraged their use for controlling heat of hydration and alkali silica reaction of concrete in large dams.

Some natural pozzolana have been used in much the same way as fly ash. Other natural pozzolana of high reactivity, such as metakaolin, have been found to perform similarly to silica fume, and are used in a similar manner. Portland-pozzolan cement containing 25% interground calcined Monterey shale was produced during the 1930s and 1940s. The California Division of Highways used this cement in the 1930s in several structures, including the Golden Gate Bridge and the San Francisco-Oakland Bay Bridge.

Literature: ACI 232.1R-00, December 6, 2000
www.metakaolin.info

Pantheon, Rom – one of the historical examples for use of pozzolana