Ancient Roman Concrete

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Ancient Roman concrete has withstood the attack by elements for over 2,000 years. The basic construction techniques of the Romans must be better than those of modern practice as judged by comparing the products. Can we learn from the Romans in some way to improve our concrete?

Ancient Roman texts report that Roman concrete consisted of just three parts: a pasty, hydrated lime; pozzolan volcanic ash; and a few pieces of fist-sized rock. If these parts were mixed together in the manner of modern concrete and placed in a structure, the result would certainly not pass the test of the ages. The riddle plaguing the minds of concrete specialists: How did the Romans around the time of Christ build such elaborate, ageless structures in concrete?

Solving the riddle of ancient concrete consisted of two studies: (1) understanding the chemistry and (2) determining the placement of Roman concrete. To understand its chemical composition, we must go back in time. Well before the time of Christ, people of the Middle East made balls for their fortifications and homes by pounding moist clay between forms, often called pise work. To protect the surface of the clay from erosion, the ancients discovered that a moist coating of thin, white, burnt limestone would chemically combine with the gases in the air to give a hard protective shield.

We can only guess that the event of discovering pseudo-concrete occurred some 200 years before Christ when a lime coating was applied to a wall made of pozzolan volcanic ash near the town of Pozzouli in Italy. A reaction took place between the chemicals in the wall of the volcanic ash (silica and small amounts of alumina and iron oxide) and the layer of lime (calcium hydroxide) applied to the wall. Later, they found that mixing a little volcanic ash in a fine powder with the moist lime made a thicker coat, but it also produced a durable product that could be submerged in water- something that the plaster product of wet lime and plain sand could not match. To explain this chemical difference, we must examine the atomic structure.

Common plaster is made with wet lime and plain sand. This sand has crystalline atomic structure whereby the silica is so condensed there are no atomic holes in the molecular network to allow the calcium hydroxide molecule from the lime to enter and react. The opposite is true with wet lime- pozzolan conact. The pozzolan has an amorphous silica atomic structure with many holes in the molecular network. When mixing the wet lime with pozzolan, the calcium hydroxide enters the atomic holes to make a concrete gel which expands, bonding pieces of rock together. The fine powder condition of the pozzolan provides a large surface area to enhance the chemical reaction.

We find parts of the complex chemistry of Roman concrete bonding gel matching that of modern concrete bonding gel. The pozzolan-wet lime gel gave permanence to the ancient concrete.

Explaining the placement of ancient concrete solved the second part of the riddle. Research by the Bureau of Reclamation (Reclamation) played a key role here. Chemistry alone will not make good concrete. People make good concrete. Although a new concrete product called roller- compacted concrete (RCC) had been developed, Reclamation's refinements made it an economical candidate for dam construction. In 1987, Reclamation built the large Upper Stillwater Dam (made of RCC) in eastern Utah. RCC consists of a mixture of 40 percent Portland cement and 60 percent fly ash, a by-product of electric powerplants. By coincidence, the fly ash contained the same amorphous siclica compounds as the ash from volcanos. And hydrated Portland cement released the calcium compound recognized in the lime part of the Roman concrete formula. When Reclamation mixed these two parts for their dam, a bonding gel was formed to tie inert rock pieces of the hatch together. These rocks were used as a strong filler material much in the same manner as is used in standard concrete practices. So we can easily relate the calcium hydroxide molecules from the Portland cement to that of the ancient lime, and the amorphous silica of the fly ash to the volcanic pozzolan. Thus, we have established a reasonable relationship for the concrete components that make the gel for both modern and ancient concrete.

The similarity of the ingredients of the modern and ancient concrete has been explained, but there is more. Studies of the placement process are very important in making durable concrete. Reclamation mixed their components (cement, ash, and rock) with as little water as possible to give stuff, "no-slump" concrete; spread it in layers on the dam; and pounded it into place by large vibrating rollers to make RCC.

The Romans mixed their components (wet lime and volcanic ash) in a mortar box with very little water to give a nearly dry composition; carried it to the job site in baskets placing it over a previously prepared layer of rock pieces; and then proceeded to pound the mortar into the rock layer. Vitruvius, the noted Roman architect (circa

20 BC) mentioned this process in his formulas for concrete, plus the fact that special tamping tools were used to build a cistern wall. Close packing of the molecular structure by tamping reduced the need of excess water, which is a source of voids and weakness. But also close packing produces more bonding gel than might be normally expected. Again, we have a similarity in the Roman and modern RCC practices.

We have learned that Roman concrete was a simple mixture of wet lime and pozzolan in specific ratios to match the desires of Roman architects. We have also learned that the Romans followed a placement method of tamping the stiff mortar in the voids of a rock layer. And interestingly enough, the new concrete (RCC) which has been developed by Reclamation follows closely that of the Romans.

For more information on ancient Roman concrete see website: www.romanconcrete.com