The Secrets of Ancient Roman Concrete

Sarah Pruitt, History.com, 6-21-13

There's no doubt that the ancient Romans were master builders. Many temples, roads and aqueducts constructed during Roman times have held up remarkably well, despite the wear-and-tear--in the form of military invasions, tourist mobs and natural disasters such as earthquakes--they've had to endure. In particular, geologists and engineers have long been fascinated by Roman harbors, many of which stand almost intact after 2,000 years or more, despite constant pounding by seawater. Now, a team of researchers from Italy and the United States has analyzed a sample of concrete taken from a breakwater in Italy's Pozzuoli Bay, at the northern tip of the Bay of Naples, which dates back to 37 B.C. Their findings, reported earlier this month in the Journal of the American Ceramic Society and American Mineralogist, may revolutionize modern architecture.

History contains many references to ancient concrete, including in the writings of the famous Roman scholar Pliny the Elder, who lived in the 1st century A.D. and died in the eruption of Mt. Vesuvius in A.D. 79. Pliny wrote that the best maritime concrete was made from volcanic ash found in regions around the Gulf of Naples, especially from near the modern-day town of Pozzuoli. Its virtues became so well-known that ash with similar mineral characteristics–no matter where it was found in the world–has been dubbed pozzolan.

By analyzing the mineral components of the cement taken from the Pozzuoli Bay breakwater at the laboratory of U.C. Berkeley, as well as facilities in Saudi Arabia and Germany, the international team of researchers was able to discover the "secret" to Roman cement's durability. They found that the Romans made concrete by mixing lime and volcanic rock to form a mortar. To build underwater structures, this mortar and volcanic tuff were packed into wooden forms. The seawater then triggered a chemical reaction, through which water molecules hydrated the lime and reacted with the ash to cement everything together. The resulting calcium-aluminum-silicate-hydrate (C-A-S-H) bond is exceptionally strong.

By comparison, Portland cement (the most common modern concrete blend) lacks the lime-volcanic ash combination, and doesn't bind well compared with Roman concrete. Portland cement, in use for almost two centuries, tends to wear particularly quickly in seawater, with a service life of less than 50 years. In addition, the production of Portland cement produces a sizable amount of carbon dioxide, one of the most damaging of the so-called greenhouse gases. According to Paulo Monteiro, a professor of civil and environmental engineering at the University of California, Berkeley, and the lead researcher of the team analyzing the Roman concrete, manufacturing the 19 billion tons of Portland cement we use every year "accounts for 7 percent of the carbon dioxide that industry puts into the air."

In addition to being more durable than Portland cement, argue, Roman concrete also appears to be more sustainable to produce. To manufacture Portland cement, carbon is emitted by the burning fuel used to heat a mix of limestone and clays to 1,450 degrees Celsius (2,642 degrees Fahrenheit) as well as by the heated limestone (calcium carbonate) itself. To make their concrete, Romans used much less lime, and made it from limestone baked at 900 degrees Celsius (1,652 degrees Fahrenheit) or lower, a process that used up much less fuel.

The researchers' analysis of Roman concrete sheds light on existing modern concrete blends that have been used as more environmentally friendly partial substitutes for Portland cement, such as volcanic ash or fly ash from coal-burning power plants. Monteiro and his colleagues also suggest that adopting materials and production techniques used by the ancient Romans could produce longer-lasting concrete that generates less

carbon dioxide. Monteiro estimates that pozzolan, which can be found in many parts of the world, could potentially replace “40 percent of the world’s demand for Portland cement.” If this is the case, ancient Roman builders may be responsible for making a truly revolutionary impact on modern architecture–one massive concrete structure at a time.