Scientists Unlock the Mystery Behind Roman Concrete's Amazing Longevity

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Ancient marine structures like this breakwater off the coast of Tuscany, Italy, are helping scientists understand the remarkable longevity of Roman concrete. (Photo: J.P. Oleson)

By Matt Hickman

Bloodlust, bad haircuts and the use of urine as a tooth whitener aside, the Romans did a whole lot of things right.

For starters, Romans — connoisseurs of conveyance that they were — developed the world's first highways, erected massive bridges and aqueducts and introduced the world to the convenience of sewers. But perhaps most notably, the master builders of the Roman Empire constructed hulking concrete edifices that were *really* built to last.

Calling Roman concrete "an extraordinarily rich material in terms of scientific possibility," Philip Brune, a research scientist at DuPont Pioneer and expert in ancient Roman construction, goes on to tell the Washington Post that it "is the most durable building material in human history, and I say that as an engineer not prone to hyperbole."

Kudos aside, the exact reason why Roman concrete — known as *opus caementicium*, with ingredients including volcanic ash, calcium oxide or quicklime and hunks of volcanic rock which served as an aggregate — is so damned durable has remained a mystery. Why has it withstood the test of time while modern concrete, which uses carbon-intensive Portland cement as a bonding agent, tends to crack and crumble into the sea over a relatively short time when exposed to salt water?

In addition to seawalls and subaquatic structures, the Romans built numerous millennia-spanning monuments such as the Colosseum with concrete made from lime, rock and volcanic ash. (Photo: Maria Globetrotter/flickr)

According to a new study published in American Mineralogist, the answer has been sitting in front of us all along: Salt water, the same substance that hastens corrosion in modern concrete, is what has enabled some Roman piers and seawalls to stand strong for millennia.

More specifically, researchers have found that Roman concrete's seawater-aided endurance results from a chemical reaction that occurs when salt water seeps into the concrete fabric and comes in contact with the volcanic ash. The reaction creates aluminous tobermorite, a mineral that's difficult to produce in laboratory settings. This rare concrete crystal serves as a naturally occurring reinforcement that's matchless in modern times.

Click here to watch "How seawater strengthens Roman concrete":
https://youtu.be/ikH6Vmb0pog

The great Roman author Pliny the Elder was certainly on to something when he wrote circa 79 A.D. in his "Naturalis Historia" that frequent lashings by an angry sea only made Roman harbors and seawalls more resilient … "a single stone mass, impregnable to the waves and every day stronger."

"Contrary to the principles of modern cement-based concrete, the Romans created a rock-like concrete that thrives in open chemical exchange with seawater, " Marie Jackson, the study's lead author and a geologist at the University of Utah, tells the BBC. "It's a very rare occurrence in the Earth."

A University of Utah press release goes on to explain the chemical process:

> The team concluded that when seawater percolated through the concrete in breakwaters and in piers, it dissolved components of the volcanic ash and allowed new minerals to grow from the highly alkaline leached fluids, particularly Al-tobermorite and phillipsite. This Al-tobermorite has silica-rich compositions, similar to crystals that form in volcanic rocks. The crystals have platy shapes that reinforce the cementing matrix. The interlocking plates increase the concrete's resistance to brittle fracture.

"We're looking at a system that's contrary to everything one would not want in cement-based concrete," Jackson explains. "We're looking at a system that thrives in open chemical exchange with seawater."

Excellent. So does this research mean that — some day down the line — we'll experience a rebirth of ancient Roman building techniques? Will this antediluvian building material be used to as first line of defense when protecting our cities from rising seas unleashed by a rapidly warming planet?

Perhaps … but not so fast.

The author of a new study on the chemical process that makes ancient concrete so durable believes that the seawater-strengthened material is the right fit for a proposed Welsh power plant that harnesses the power of the tides. (Rendering: Tidal Lagoon Power)

A millennia-old solution for a newfangled power plant?

With the exact ingredients of Roman concrete having been discovered some time ago, Jackson and her fellow mineral cement sleuths now have a greater understanding of the chemical process behind the remarkable longevity of aquatic structures found across the ancient Roman Empire.

Yet the exact method employed by Roman builders when mixing this ultra-durable building material remains a mystery. After all, if we knew exactly how they did it, wouldn't we have started replicating Roman concrete long ago?

"The recipe was completely lost," Jackson says in a press release.

While long-lasting, Roman concrete also lacks the compressive strength of Portland cement-based concrete, limiting its applications. And in a society that demands immediate results, structures that take decades — centuries, even — to gain optimum strength don't seem likely to gain serious traction anytime soon.

And there's another formidable obstacle: The basic aggregate found in Roman concrete — volcanic rock collected by Roman builders from the region around present day Naples — isn't easy to come by.

"Romans were fortunate in the type of rock they had to work with," Jackson says. "They observed that volcanic ash grew cements to produce the tuff. We don't have those rocks in a lot of the world, so there would have to be substitutions made."

And substitutions Jackson is making. Determined to find a satisfactory modern-day facsimile to reactive Roman concrete, Jackson has teamed with geological engineer Tom Adams to develop a "replacement recipe" composed of aggregate materials (read: rocks) collected from across the American West mixed with seawater pulled straight from the San Francisco Bay.

The modern application of this ancient knowledge

As the duo work to develop a potential seawater-aggregate mix that could yield the same crack-healing chemical reaction as the Pliny the Elder-beloved building material of civilizations past, Jackson is already thinking of potential applications for modern-day Roman concrete.

Earlier this year, she identified a proposed seawall in Swansea, Wales, as a structure in which Roman concrete would be a highly preferable choice over modern concrete reinforced with cement and steel. She believes that such a structure could potentially hold strong for upwards of 2,000 years.

"Their technique was based on building very massive structures that are really quite environmentally sustainable and very long-lasting," Jackson told the BBC in January. "I think Roman concrete or a type of it would be a very good choice. That project is going to require 120 years of service life to amortise [pay back] the investment."

Despite promises of longevity and putting an end to the planet-harming cement manufacturing process, there are sizable caveats that come along with the idea of protecting Swansea's tidal lagoon — the world's first tidal lagoon power plant — with a Roman-style seawall. As the BBC elaborates, local steel manufacturers are banking on the ambitious project being built with cement-based, steel-reinforced concrete. The environmental cost of transporting huge amounts of volcanic ash — sourced from who knows where — to the Welsh coast is also an issue.

“There’s many applications but further work is needed to create those mixes. We’ve started but there is a lot of fine-tuning that needs to happen,” Jackson tells The Guardian. “The challenge is to develop methods that use common volcanic products — and that is actually what we are doing right now.”