W H I T E P A P E R

# How Pumice Pozzolans Super-Charge Concrete Performance

## EXECUTIVE SUMMARY

### SITUATION

Our modern civilization, for all its marvels, is built upon an infrastructure of short-lived, crumbling concrete.

### PROBLEM

Today's standard concretes simply aren't as good as they could be: almost as soon as standard concrete is placed, the process of degradation begins.

### SOLUTION

Adding a high-purity natural pumice pozzolan to the concrete formulation mitigates or completely eliminates the problems inherent in standard concrete.

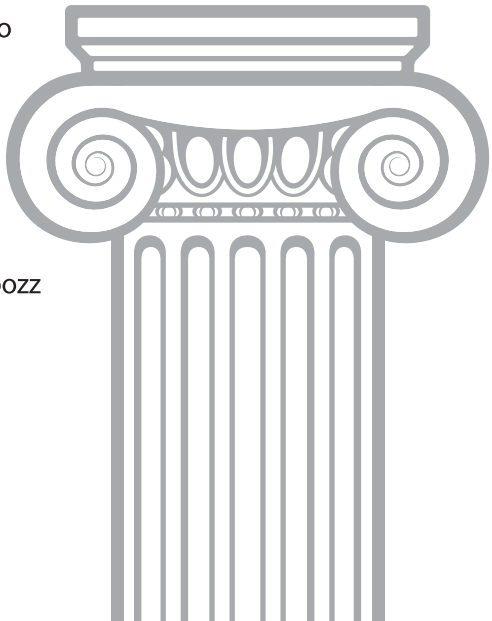
### RESULT

Our failing roads, bridges, and structures can be replaced with a high-performance concrete that expert research has shown to provide significant performance increases in terms of appearance, impermeability, longevity, thermal cracking, resistivity to chemical attacks, and compressive strength. All possible using an abundant, safe, natural pumice pozzolan...the same pozz used by Roman engineers.

The Romans discovered the secret to durable concrete: *pumice.*

A landmark study details how pumice pozzolans give standard concrete a serious performance boost.

Hess POZZ
IDAHO USA



TODAY'S STANDARD CONCRETES simply aren't as good as they could be—and they certainly don't match up to the world class concrete perfected by Roman engineers two millennia ago. Almost as soon as modern concrete is placed, the process of degradation begins. Recent studies suggest that only about 75% of the cement powder is converted to Calcium Silicate Hydrate (CSH), the binder that glues concrete together. Most of the remaining 25% is converted to Calcium Hydroxide (CH), a by-product of the hydration reaction between water and cement—a by-product that has a tendency to create a host of problems that have a deleterious effect on the concrete's long-term performance, and even its appearance.

## What are these potentially damaging effects?

**1.** When the CH migrates out of the concrete's interior via capillary action, it leaves behind a network of porosity that both weakens the concrete and allows for the future ingress of water. This infiltrating water can contain sulfates, chlorides, and other damaging chemicals. In cold climates, the invasive water will freeze, causing freeze-thaw damage to the concrete.

**2.** As for the appearance problem, when the migrating CH reaches the surface of the concrete it will react with Carbon Dioxide in the air, transforming into calcium carbonate and staining the concrete surface—a process known as efflorescence.

**3.** Not all of the CH migrates out of the concrete. What remains will combine or react with other chemicals that may be present in the matrix, or may be brought to the interior of the concrete with the water that permeates through the new pores in the concrete. Among the most damaging of these reactions is a 'sulfate attack'—a reaction between the CH and various forms of sulfate, which can render the concrete completely non-functional. When CH and sulfate combine, an expansive reaction takes place that destroys the concrete from within.

**Roman methods produced a densified, relatively impermeable concrete that is not nearly as susceptible to chemical attack as is modern standard concrete…**

Pantheon in Rome

**4.** Chloride ingress can cause corrosive expansion, creating internal cracking of the concrete as well as eventual destruction of the metal reinforcement within.

**5.** 'Reactive' aggregates within the concrete can combine with the CH, destroying the bond between the aggregate and the CSH, eventually creating fractures in the CSH due to expansive pressures. Known as 'Alkali-Silica Reaction' or ASR, it can destroy the integrity the concrete.

So, what is a responsible concrete engineer to do? Easy. Add a high-purity natural pumice pozzolan to the concrete formulation—like the Romans did—and those problems are mitigated or completely eliminated.

Based on modern studies, Roman concrete appears to have had none of the above issues. Much of it still stands majestically after 2000 years (e.g., Pantheon, Coliseum, Aqueducts, etc).

The Romans didn't have a quick setting cement like we do today. They used hydrated lime—a cementitious product made from limestone which has been heated to drive off the carbon dioxide and transform the Calcium Carbonate into Calcium Oxide (lime) + $H_2O$. Lime does not act like a hydraulic cement on its own, and will only form CSH in the presence of water and pozzolan. Roman cement also reacts at a slower rate than modern cement, and thus takes longer to set. Even so, whether using modern OPC or Roman cement (lime), the end result is

the very same cementitious binder in the concrete: Calcium Silicate Hydrate (CSH).

The Roman's secret ingredient?—pumice pozzolan. They discovered that when lime and water are mixed with a finely graded amorphous silica (known to the Romans as *pulvis puteolanus*, and referred to today as volcanic ash or pumice pozzolan) nearly 100% of the lime is converted to the good stuff—CSH….albeit, at a slower rate than modern cements.

## So what do we learn from this?

**1.** Both Roman cement and modern cement end up producing the same cementitious binder in the concrete—CSH.

**2.** In modern cement formulations, it is the hydraulic reaction between water and the cement powder that forms CSH, and also forms CH as a by-product. Unless the CH is provided a pozzolan to capture it and turn it into additional CSH, it is free to combine with deleterious chemicals, thus potentially damaging the concrete.

**3.** In the ancient Roman concrete formulations, the hydrated lime combines with pumice pozzolan to form CSH without creating any additional deleterious by-products. Thus, Roman methods produced a densified, relatively impermeable concrete that is not nearly as susceptible to chemical attack as is modern standard concrete…unless of course a pozzolan is added to the standard mix design.

**4.** Modern concrete formulations can take advantage of the process used by the Romans to convert liquid phase CH to CSH by adding pozzolan to modern concrete formulations. In doing so, a potentially very destructive by-product is converted into a performance & endurance enhancing agent, rather than left to its own devices to create porosity, efflorescence, and the reactive problems detailed above.

**5.** Modern concrete, without pozzolan, is almost always a disaster waiting to happen: you are never really sure how long your luck will hold out, but you are pretty well assured something unwanted will happen…it is just a matter of time before the unconverted CH degrades the concrete in one manner or another, even if it is only efflorescence.

So, unless you're supplying or designing concrete for projects where durability and long-term performance are not critical, a mix design that does not include a CH-converting pozzolan, is like playing Russian roulette. The longer you play, the more dangerous it gets.

Condemned highway overpass

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## Other advantages from the pozzolanic charge

While chemical resistance is perhaps the biggest benefit to adding pumice pozzolan to concrete formulations, it is by no means the only gained advantage. Extensive (and on-going) studies by the University of Utah and other institutions detail how pumice pozzolans can also:

**Reduce Heat of Hydration Damage**. Natural pumice pozzolans reduce the heat of hydration anywhere from 10 - 40% during the first 100 hours, depending on the ultimate mix design, thus lowering the threat of thermal cracking and allowing for a cooler, more controlled set.

After about 100 hours, the cement-water hydration process wanes while the pumice pozzolan mixes continue to hydrate, filling pores with CSH and densifying the concrete until one of the two remaining hydration agents, Calcium Hydroxide or Pumice Pozzolan, has been consumed.

**Increase Long-Term Compressive Strength**. In the U of U study, a relatively high water/cement ratio of

.485/1 was used for the control and 4 additional mix designs utilizing the pumice pozzolan. The 4 pumice pozzolan mix designs ranged from 3300 PSI to 4600 PSI in 7 days and from 4800 PSI to 7000 PSI in 28 days. Pozzolan quantity and particle size accounted for the variation in strengths. These factors are consistent and predictable, pour after pour. Strength will continue to increase for up to a year or more, eventually surpassing the control (OPC) by anywhere from 10% to 40% in ultimate, long term compressive strength.


Naturally calcined pumice

**Pumice has long been recognized as the original natural pozzolan.**

**Healthy and Safe**. The University of Utah study corroborated previous test data, which indicates that this particular natural pumice pozzolan is free of crystalline silica and other hazardous materials. Pumice is so innocuous, for example, it is used in the dental industry to clean teeth and in the cosmetics industry as an exfoliation agent in skin creams. While other by-product pozzolans struggle with undesirable contaminants, a carefully mined and refined pumice pozzolan is the environmentally safe, health-friendly choice.

**Reduces the Carbon Footprint**. Pumice is naturally calcined by mother nature, ensuring that pumice pozzolan has a minimal contribution to the carbon footprint (CF). Additionally, pumice pozzolan can replace up to 40 percent (by weight) the Portland cement in a concrete mix as a Supplementary Cementitious Material (SCM) helping to offset the cement's CF while enhancing its performance and durability.

**Workability & Set Times**. Pumice pozzolan-based mix designs have set times which are not significantly longer than the 100% cement control (see the University of Utah study). If a quicker set and high early strength are desired, the use of a water reducing agent will offset these properties, as needed.

## In Summary

In summary, pumice has long been recognized as the original natural pozzolan—used by the Romans in their impressive 2000+ year-old concrete structures. A landmark study, released in June 2012 by the University of Utah, details the performance & durability of pumice as a concrete-fortifying pozzolan admixture as well as an SCM—advantages critical for today's high-performance infrastructure requirements and an environmentally conscientious future. *Visit **www.hesspozz.com** for additional information or call the author directly.*

—by **Joseph Thomas**, VP-R&D at Hess Pumice Products of Malad City, Idaho.

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