W H I T E   P A P E R

Flatline Alkali-Silica Reaction with Pumice-Blended Cement *for Pennies a Yard*

EXECUTIVE SUMMARY

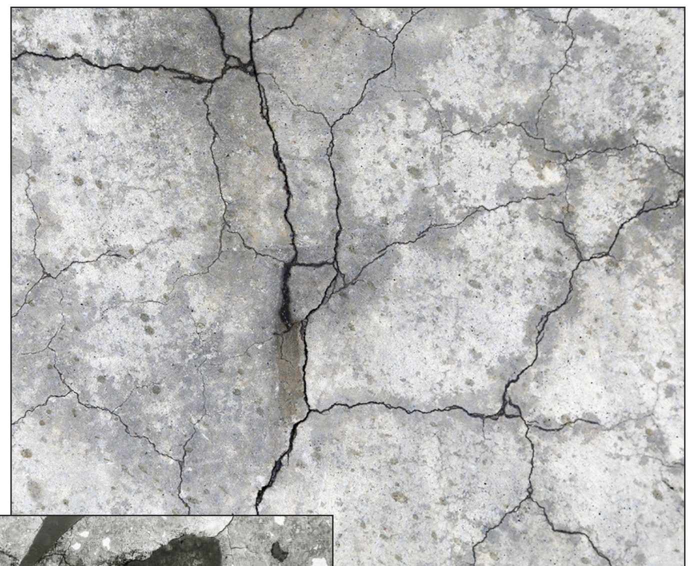
In regions with reactive aggregate, the alkali-silica reaction (ASR) is a pestilence that infects and destroys vital concrete infrastructure. ASR fuels a relentless, slow-motion explosion that shatters both the concrete and the aggregate, significantly shortening the engineered lifespan of the infected structure.

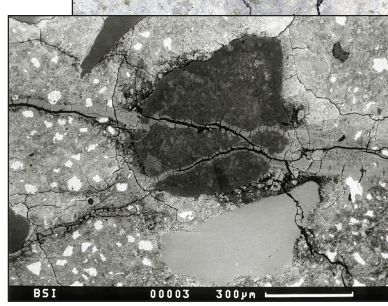
Once the alkali-silica reaction kindles within concrete—triggered by the collision of alkali, silica, moisture, and calcium hydroxide (a deleterious byproduct spawned by the Portland cement+ water hydration reaction)—it cannot be stopped. Failure is imminent.

ASR must be mitigated in the concrete mix design by specifying a consistent, quantifiable supplementary cementitious material (SCM) that flatlines the reaction. Clean, naturally calcined pumice from the massive Hess deposit in southeast Idaho USA is ideal: this carefully refined pumice not only delivers proven ASR mitigation in the presence of even highly reactive aggregates, it does so as a percentage of cement replacement while contributing additional durability benefits to the concrete as well.

When a specially ground superior grade pumice (from the Hess Pumice deposit) is incorporated as an SCM in the concrete mix design, the ASR problem goes away—for just pennies a yard. Even better, the mechanism that flatlines the alkali-silica reaction is one that targets and reclaims deleterious calcium hydrate (CH), converting it to CSH, the chemical binder that makes concrete work. That both removes the trouble-spawning CH from the hydrated concrete paste and repurposes it to amplify the density and strength of the concrete matrix.

There is no way to stop ASR once such chemically-flawed concrete has been placed. The solution? Mitigate it in the concrete mix design.





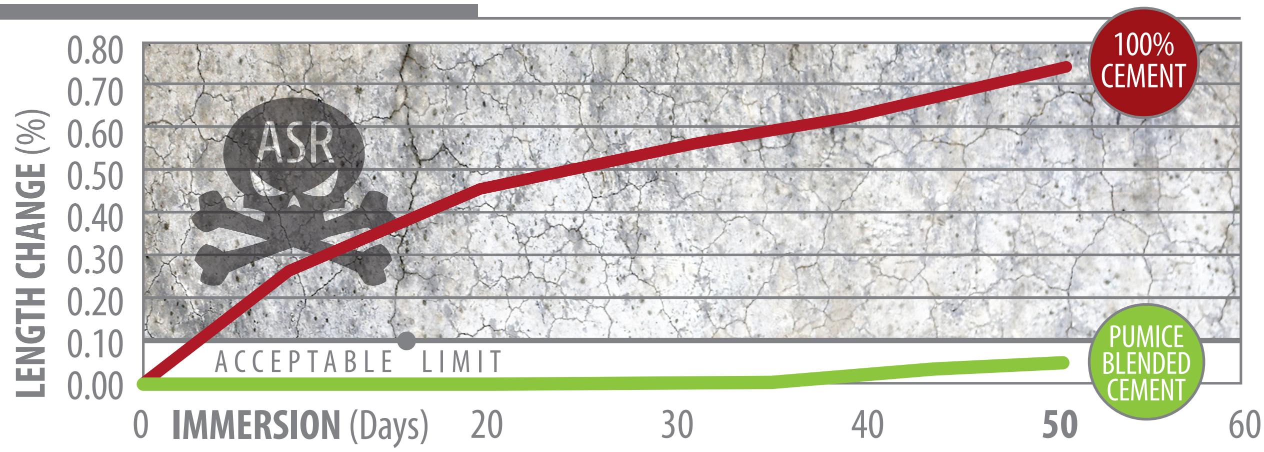
ABOVE: ASR-damaged concrete showing map-cracking and evidence of ASR gel squeezing to surface.

LEFT: Petrographic analysis microphoto of ASR-infected concrete core sample.

IN REGIONS OF THE WORLD with reactive aggregate, Alkali-Silica Reaction (ASR) is a relentless infrastructure assassin. If the seeds of ASR—reactive aggregate and Portland-cement-spawned calcium hydroxide (CH)—are present in cured concrete, that concrete structure will not survive to the end of its engineered lifespan. On most lists that bullet-point top contributors to premature concrete failure, ASR is second only to corrosion of reinforcing steel. The

MITIGATING ASR WITH PUMICE-BLENDED CEMENT

Concrete Mix designs tested according to a modified ASTM C1293 procedure using Type 1 cement and **Highly Reactive** coarse and fine **aggregate** in an accelerated ASR environment (80° C and 1 N NaOH solution) over 50 days.



ASTM C1293 (modified) • University of Utah Study

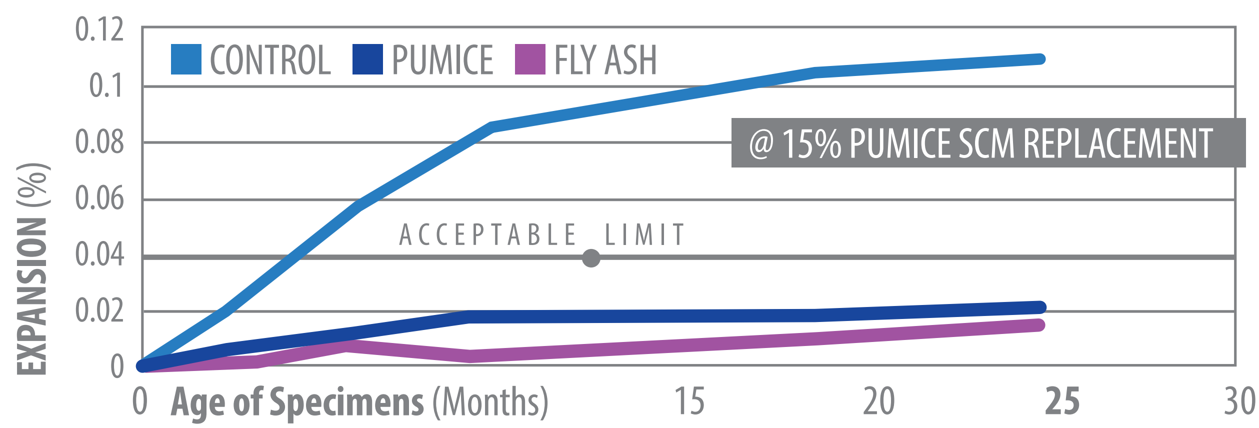
irony in that one-two list relationship is the fact that even mild ASR-fueled map-cracking accelerates the chemical attacks on reinforcing steel.

ASR falls within the broader category of Alkali-aggregate reaction (AAR) and is currently one of the two types of recognized AAR reactions, depending on the nature of the reactive mineral. The alkali-silica reaction (ASR) involves various types of reactive silica (SiO2) minerals; alkali-carbonate reaction (ACR) involves certain types of dolomitic rocks (CaMg(CO3)2). Both types of reaction can result in expansion and cracking of concrete, leading to a reduction in the service life of concrete structures.

Researchers have defined a causal triangle that sets off the chemical ASR train wreck within concrete. The merger of water, Portland cement, and reactive aggregate generate the four essential ingredients of expansive ASR gel—alkalis, silica, free calcium hydroxide (CH), and moisture. Starving the concrete of one of those components can effectively flatline ASR.

The pumice SCM concrete mixture performed very well, and kept expansions below the 0.04% limit of ASTM C 1293, validating the results found from the ASTM C 1567 Accelerated Mortar Bar Test for ASR. The table right lists the average expansion of the concrete prisms at 24 months, along with the range of the data.

MIXTURE	ASR EXPANSION AT 24 MONTHS (%)
CONTROL	0.109 ± 0.020
PUMICE (15%)	0.022 ± 0.007
FLY ASH (15%)	0.016 ± 0.017



ASTM C1293 (modified) • University of Texas-Austin Study

The ASR Train Wreck Explained

Simple explanation: the alkali compounds within Portland cement react with the silica in the aggregate forming a chemical compound with a thirsty affinity for water. As water is absorbed, the resulting gel swells, cracking both concrete and aggregate, opening the concrete to further attack from outside elements—sulfates and chlorides, marine salts, and freeze-thaw—which accelerate the death-march of the structure.

Deep dive: the primary chemical reaction (hydration) between Portland cement and water creates a deleterious compound know as Calcium Hydroxide (CH)—radical free calcium—that, unabated, reacts with alkali and aggregate-contributed silica to form a hydrophilic (water-attracting) gel that expands relentlessly. The reaction will go dormant when starved of moisture, only to swell and expand again when sufficient water is again present.

In many cases, several concrete-destroying mechanisms are acting together. Some of the deleterious CH also migrates to the surface, leaving behind a porous network of microscopic, inter-connected wormholes that provide for easy ingress of water to continue to fuel the expansive ASR gel. Free ingress of water also begins the destructive freeze-thaw cycle. Chlorides and sulfates also join the invasion, attacking the concrete and the reinforcing steel within. As ASR-induced map-cracking spreads to the surface, the death-march of the structure is accelerated.

Once the alkali-silica reaction begins within placed concrete, it cannot be stopped. Several methods are effective in slowing it down—(various drying methods, chemical treatments, stress relief, restraint)—but the hard facts are these: ASR-affected concrete is flawed at the molecular level and will not reach its engineered lifespan.

Defeating ASR

Where concrete engineers have had success combating and defeating ASR is with preventative mix designs. Various ineffective and often impractical methods have been identified and used since the alkali-silica reaction was first identified in the late 1930s, including using low-alkali cement, trucking in non-reactive aggregate, specifying low W/C ratios, using less cement, even air entrainment.

Until now, the most effective and practical solutions involved using SCMs that in one way or another disrupted the corruptive union of alkali, silica, moisture, and CH. These SCMs included lithium nitrate, Metakaolin, silica fume, flash-cooled furnace slag, and a combination of low-alkali cement and Class F fly ash.

Recent research, spurred by studies made on enduring Roman concrete structures (many over 2000 years old), has centered on the use of pumice as an excellent SCM for improving modern concrete performance and lifespan. This historical evidence, combined with current, quantifiable research, has also revealed pumice to be a particularly effective mitigator of ASR.

ASR Miti•Gator™ is a natural pumice SCM mined and refined from the Hess deposit in southeast Idaho: the world's purest commercial deposit of white pumice. It's a simple product with a complex chemical nature that powers a chemical reaction within hydrated concrete that flatlines the alkali-silica reaction.

The ASR Miti•Gator™ Advantage

University-level, ASTM-spec research into ASR prevention conducted specifically using ASR Miti•Gator™ has identified and defined the following effectiveness mechanisms:

1 • ASR Miti•Gator™ directly consumes much of the deleterious CH (a byproduct of the primary hydraulic reaction), preventing the ionic interaction with the alkali that forms thirsty alkali-silica gel. The fact that ASR Miti•Gator is used as a percentage of replacement for Portland cement also means less CH is spawned by the primary hydraulic reaction.

2 • ASR Miti•Gator™ reduces the pH of the concrete pore solution by entrapping free alkalis.

3 • The pozzolanic reaction ignited by introducing finely-processed pumice to the concrete mix design tightens the concrete matrix to block and control moisture infiltration. What little alkali-silica gel that may form is denied moisture and cannot swell.

4 • The pozzolanic reaction provides for a denser, stronger concrete that is more resistant to the expansive pressure caused by any remaining ASR gel.

Beyond its ASR-stomping effectiveness at a molecular level, ASR Miti•Gator provides additional advantages:

5 • The performance benefits of using natural pumice in a concrete mix design go well beyond defeating ASR. Heat of hydration is reduced and compressive strength preserved. The pozzolanic reaction densely welds the concrete matrix, significantly amping resistance to sulfate and chloride attacks (per ASTM C1012) while increasing abrasion resistance and resisting freeze-thaw damage.

6 • Allows for use of standard Portland cement (instead of low-alkali type) and locally-sourced aggregate, reactive or otherwise.

7 • The consistent chemical makeup and performance of ASR Miti•Gator is well-suited for cement replacement (typically 20%), providing both a cost advantage as well as additional benefits to concrete performance and durability that go beyond simply mitigating ASR.

8 • ASR Miti•Gator™ can be tightly optimized as a cement replacement for specific reactive aggregates once the properties of a given aggregate are known. This can lead to the use of economical pumice-blended cements for preventing not only ASR, but to solve other concrete durability issues.

9 • ASR Miti•Gator™ is derived from a plentiful, sustainable source. It is naturally calcined, naturally free of hazardous contaminants, and performs consistently pour after pour.

ASR Miti•Gator's alkali-silica mitigating properties, cost-effective price-point as a cement replacement, and quantifiable performance put destructive ASR clearly in the crosshairs—new concrete structures can be effectively free of ASR, no matter the aggregate source.

The Research

Beginning in 2012, the University of Utah began research into the effectiveness of pumice as an supplementary cementitious material (SCM) to improve the short-lived durability of modern concrete. The durability of Roman concrete provided empirical evidence that pumice (the original pozzolan) was an excellent concrete performance booster, but quantifiable research data was needed.

The results of that study not only quantified the performance of naturally occurring pumice as an effective SCM, but revealed that pumice (in particular the pumice mined and processed from the Hess Pumice deposit) was an impressive mitigator of the alkali-silica reaction. This in turn led to follow-up research into the mechanisms and potency of pumice as a cost-effective ASR-mitigating SCM.

Downloadable summaries of the research conducted by the University of Utah (and others) can be found on the ASR Miti•Gator website: **www.asrmitigator.com**

The Company Behind ASR Miti•Gator™

Hess Pumice Products of Malad, Idaho, is the world leader in processed pumice mining, production, and beneficiation. We ship hundreds of products to thousands of customers across six continents for use in multiple industrial and commercial processes—abrasion, paints and coatings, turf management, soil conditioning for reclamation and engineered landscapes, soilless growing systems, filtration, lightweight aggregate, cementitious grout, spill containment, cleansing exfoliant, blast mitigation, finish plasters, and more—those in addition to our concrete performance-boosting products.

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

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