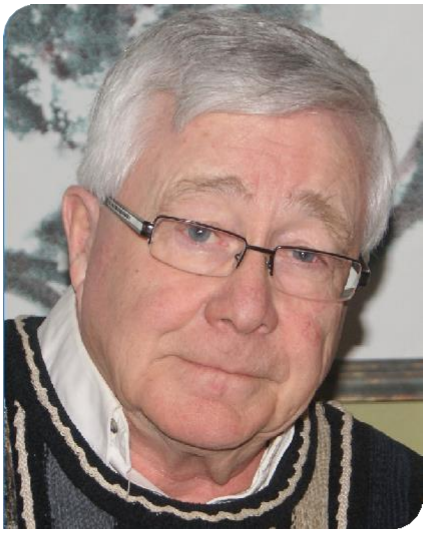
Lu Verne E W Hogg, CEO, ZMM® Canada Minerals Corp.

Natural Pozzolans: Coming full circle

Global demand for natural pozzolans (NPs) is rising once more on the back of declining fly ash supplies. ZMM® Canada Minerals looks at the benefits of this emerging trend...

Above: Natural Pozzolan extraction at ZMM® Canada Minerals Corp.'s TransCanada zeolite / basalt quarry in British Columbia.



Right: Lu Verne E W Hogg, CEO of ZMM® Canada Minerals Corp.

The continuing decline of by-product pozzolans, mainly fly ash, has concrete engineers searching hard for replacements. However, fly ash has not always been around. Indeed natural pozzolans (NP) are a group of supplementary cementitious materials (SCM) that have been proven to enhance, fortify and protect concrete for millennia. 2000 years ago, the Roman Empire constructed the coliseum, the pantheon, roads, aqueducts and piers with natural pozzolans. The concrete infrastructure they left behind still exists today. NPs have proven to be an exceptional solution with qualifiable data and the test of time.

What are NPs?

Cement and concrete producers are utilizing pozzolanic by-products, including ash, slag, silica fume and metakaolin. NPs, in contrast, are sourced from natural mineral and volcanic deposits such as pumice, diatomaceous earth, perlite, metakaolin, zeolite, and combined zeolite/basalt in volcanic flow rocks. Some NPs, including clay or shale, require heat treatment to transform them into pozzolans, while others, like volcanic ash, exhibit pozzolanic behaviour with minimal processing.

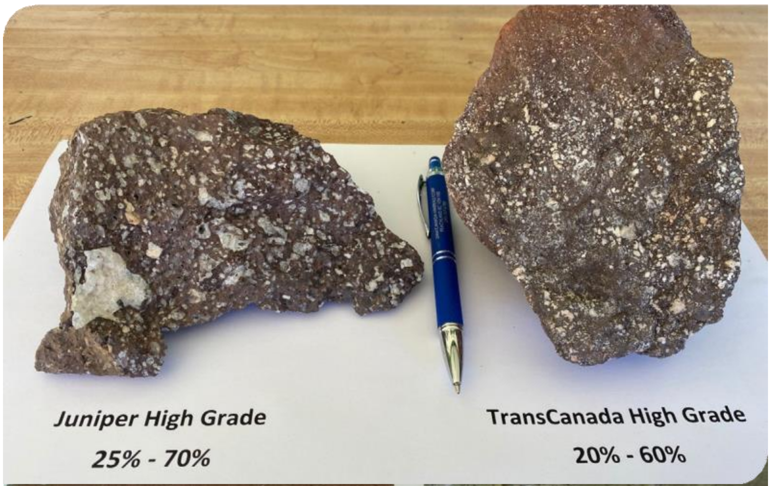
Users require pozzolans that are consistent in terms of colour and their chemical and physical properties. It would be best if they naturally lack toxic and hazardous elements and have been proven to protect concrete over long periods. NPs fit these requirements well.

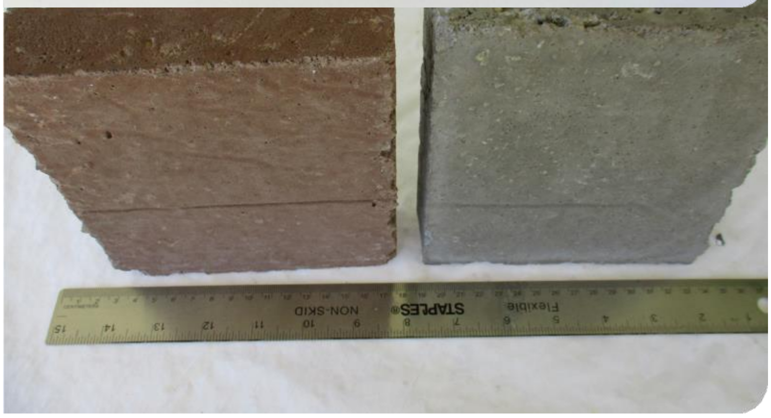
Unfortunately, today's standard concretes aren't as good as they need to be. In particular, they don't match up to the world-class concrete perfected by Roman engineers in terms of durability. Almost as soon as OPC-based concrete is placed, degradation begins. This is because more than 25% of the calcium hydroxide (CH) released by the hydraulic reaction is not converted to calcium silicate hydrate (CSH), the binder in concrete. The excess CH, a by- product of the hydration reaction between water and cement, tends to create a host of problems that have detrimental effects on the concrete's long-term performance and appearance. Unless the CH is pro- vided with a pozzolan to capture it and turn it into additional CSH, it is free to combine with expansive chemicals, damaging the concrete from within.

Generally, pozzolanic reactivity is influenced by particle size, material composition and temperature. As particle size decreases, the total surface area of the particles increases and allows the reactions to occur faster. The composition, specifically the amorphous silica and calcium content, will also impact reactivity. Pozzolans tend to react faster when used in conjunction with a high alkali Port- land cement, or with increasing temperature.

NPs are sustainable, highly effective and consistent in terms of performance, with low embedded greenhouse gas (GHG) emissions. By contrast, coal-fired power plants, which produce fly ash, release approximately 2t of GHG for every 1t of fly ash made, although this is obviously not their sole purpose. For every 1t of cement produced, approximately 0.8t of CO_2 is added to the earth's atmosphere.

NPs can replace up to 30% of cement in a concrete mix design or in cement production, which equates to up to a 30% reduction in the CO_2 footprint of concrete. This leads to a significant environmental benefit. But NPs don't just reduce the amount of cement used, they enhance the quality of the concrete made. NPs improve concrete by converting problem-causing CH to additional CSH – the glue that binds the concrete aggregate.





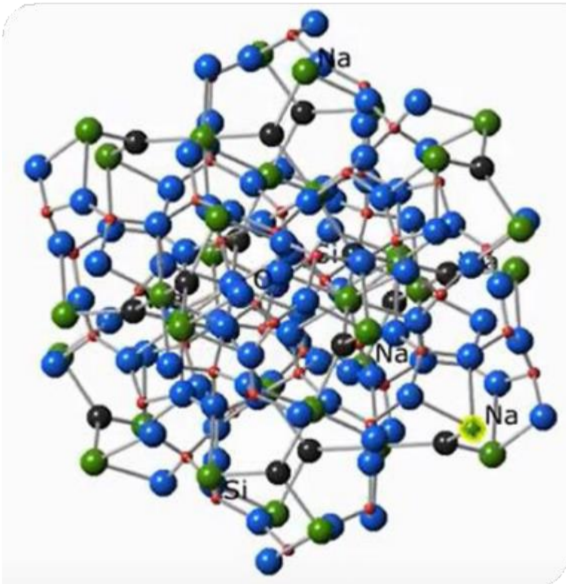
Top: Ore from ZMM® Canada Minerals Corp.'s TransCanada and Juniper quarries.

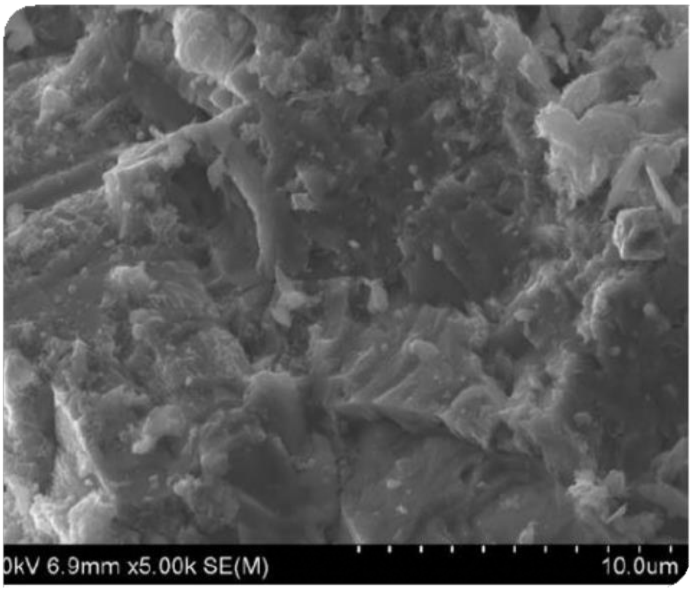
Above: Block samples containing zeolite / basalt NP from the TransCanada (left) and Juniper (right)quarries.

NPs also work very well in mass concrete ap- plications like dams, bridge piers, and foundations where users must maintain low heat to hydration and hold water for prolonged periods of time.

One of the main benefits is that NPs have slower hydration, which, for larger sections, will reduce the heat buildup. NPs retain water, which, when using the correct balance in the mix design, will release water more slowly into the system and create less cracking over time. True NPs have an affinity for water. They react more slowly meaning that, when used in precast applications, the form cannot be turned as quickly.

NPs increase corrosion resistance and sulphate resistance, decrease permeability and absorption and reduce alkali-silica reactivity. These benefits are attributed to the materials' pozzolanic behaviour, which decreases the concrete's permeability and increases density and strength, again by the conversion of CH to CSH. Waste products like fly ash, slag cement and silica fume, also contribute to increased long-term strength gain.





Above Left: Crystal structure of analcime, the zeolite found in the Juniper and TransCanada quarries.

Above Right: Scanning electron microscope (SEM) of zeolite / basalt sample.

"For non-calcined natural pozzolans, replacement rates tend to mirror the replacement levels of fly ash," explains Ken McPhalen, manager of technical services at Advanced Cement Technologies. "On average, you're looking at anywhere from 20% to 30% cement replacement by weight. For metakaolin, it's much lower – around 8% to 10% for most high-performance applications."

Developing resources in Canada

In Canada, ZMM Canada Minerals Corp. is developing two new deposits of zeolite/basalt for use as an NP/SCM. The zeolite/basalt exhibits pozzolanic and cementitious behaviour in its raw form without calcination or extensive processing. All NP must maintain compliance with ASTM C618-19 and AASHTO M295-19 specifications.

Zeolites are a class of minerals with an ordered porous structure. They are mesoporous and microporous with low framework density alumino silicates that possess a regular structure, along with intricate channels. These nanoporous solids have an open pore structure comprising accessible homogeneous nanopores. This leads to an immense surface area within the structure of the zeolite. In fact, one tablespoon of zeolite has an internal molecular surface area the size of a football field. The three-dimensional structure of the natural zeolites, with the aluminosilicate composition, encompasses pores and cavities that are captured by water molecules and alkali earth metals, imparting a cementitious reaction. Basalt, meanwhile, has historically been used as an SCM and an aggregate with a higher specific gravity and lower absorption and abrasive loss.

The inherent properties of the zeolite and basalt mixture lead to an NP with physiochemical proper- ties that increase the material's resistance to fluid intrusion and alkali and sodium intrusion, reduce the progress of the CO_2 degradation front, preserve the cement matrix's ability to delay the reaction of acid gases, and provide the additional benefit of fire resistance. The combination of zeolite/basalt makes it ideal as a high-performance NP.

Emergence of NPs in the US

The US Natural Pozzolan Association (NPA) is a network of natural pozzolan producers that are working to improve the performance and durability of the nation's concrete infrastructure. It represents the interests of natural pozzolan producers and end users across a broad spectrum.

The growth in this industry has been on an exponential path for the last few years and continues to expand at a rapid pace. The US consumed 1Mt of NPs in 2021 and another 1Mt/yr of capacity is coming online in 2022. This will provide 2Mt/yr by early 2023, with further growth anticipated.

NPs are emerging into market ready industry; an exceptional solution backed by quantifiable data and the test of time, with over 2000 years of hard evidence. NPs are sustainable, highly effective, and best of all, performance-consistent pour after pour. A new era of enhanced, high quality, chemical resistant concrete has begun.