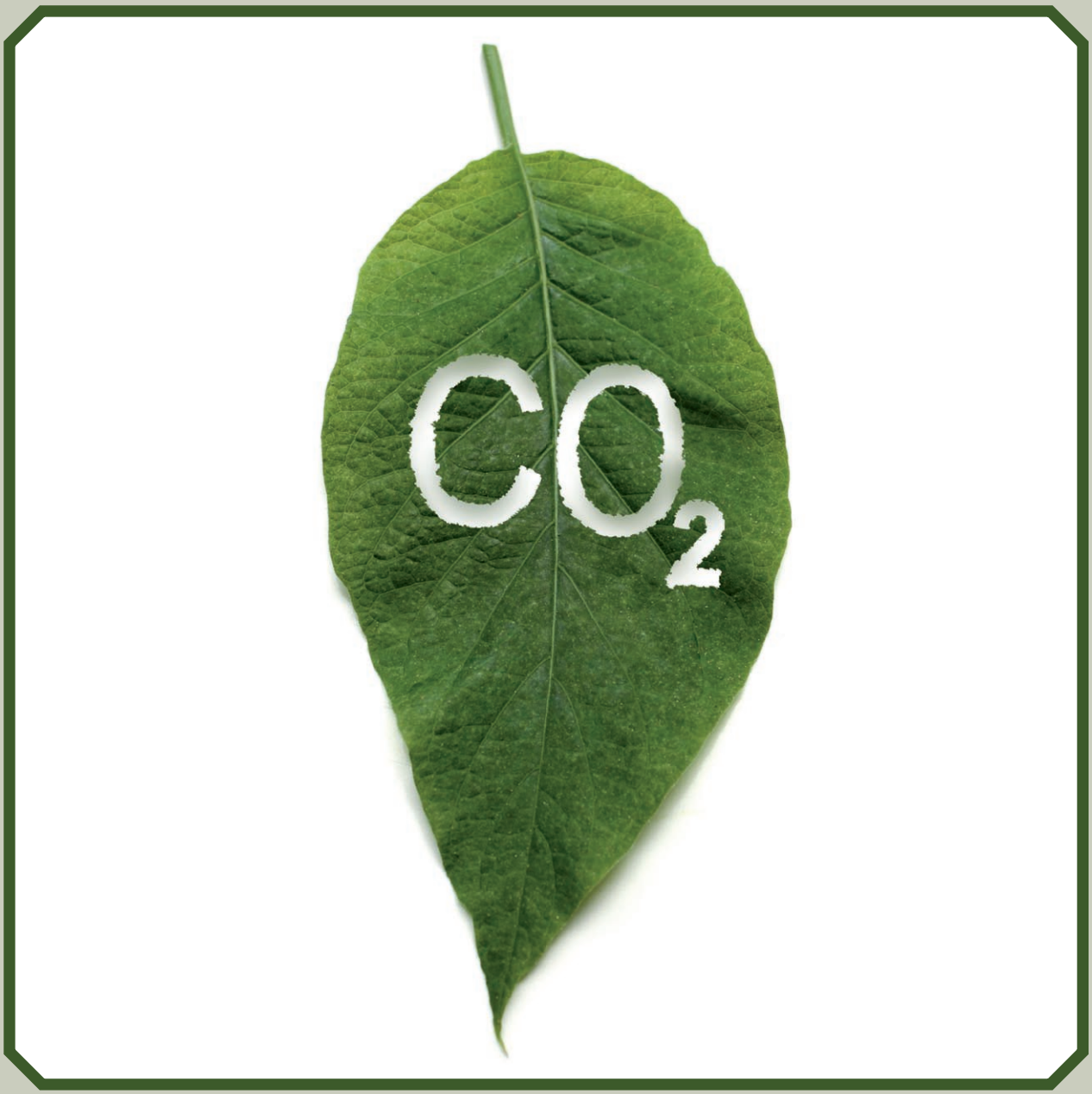


Concrete's *Green Future*

METAKAOLIN'S CONCRETE-IMPROVING BENEFITS CREATE A PRACTICAL PATH TO REDUCING CO_2 EMISSIONS. THIS ARTICLE FROM WHITEMUD RESOURCES INC. EXPLAINS HOW...

New greener building standards

Widespread adoption of new building standards aimed in part at reducing greenhouse gas emissions is presenting the concrete industry with a difficult question: how do you make concrete with constructible properties and a smaller carbon footprint?

Cement manufacturing has received the infamous distinction of being among the top five sources of industrial global greenhouse gas emissions in a

Whitemud's metakaolin plant and mine in Saskatchewan, Canada.

The plant is centrally located in North America and near a railway, allowing bulk quantity shipments throughout Canada and the United States, and on to global markets.

CO_2-obsessed world. Today, approximately 5% of global manmade CO_2 emissions are produced by cement manufacturers. For every tonne of cement manufactured in North America, one tonne of CO_2 is emitted, drawing the ire of environmentalists and green-minded politicians. New regulations and laws, like California's AB-32 Global Warming Solutions Act, are mandating reductions in greenhouse gas emissions. This, in turn, is pushing cement producers and concrete contractors to seek solutions such as less CO_2-intensive supplementary cementing materials (SCM) in order to reduce the carbon footprint of their operations.

Whitemud Resources Inc. offers the concrete industry an economical and environmentally friendly path to achieve that goal. Its branded SCM, Whitemud^{MK}, is a highly reactive metakaolin pozzolan created from kaolin clay. It can replace up to 20% of the cement in concrete.

Metakaolin

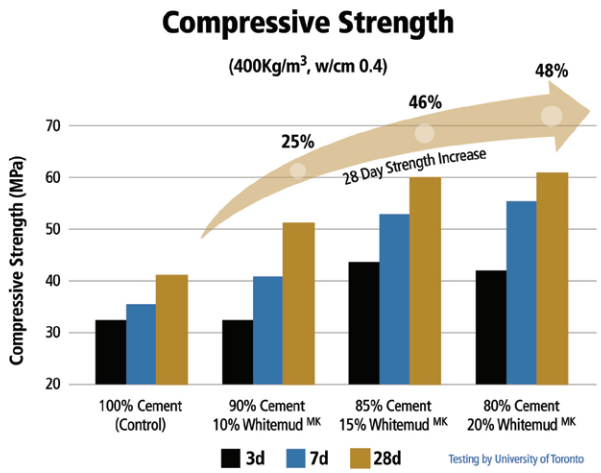
"As a highly reactive pozzolan, metakaolin works well with slag or flyash, allowing larger cement replacements to be achieved and resulting in environmentally friendly concrete that performs," says Professor Doug Hooton, NSERC/CAC Industrial Research Chair in Concrete Durability and Sustainability at the University of Toronto. "In addition, it results in increased durability to sulfate attack, chloride ingress, and alkali-silica reaction, thus increasing sustainability through increased service life."

Metakaolin has long been widely accepted as an SCM across North America and around the world. It is recognised for its ability to shorten concrete setting and stripping times, while increasing compressive and flexural strength and improving durability. These are properties needed to meet the demanding loads of today's "super" structures at building sites from Dubai to China.

According to Kelly Babichuk, Whitemud's President and Chief Operating Officer, contractors have known about metakaolin's performance advantages for years. Until recently, however, the economics just did not work.

"The only things standing in the way of metakaolin's widespread adoption by the construction industry were its cost and availability," Babichuk explains. "Highly-refined metakaolin is more valuable as a coating for high-gloss paper or as a paint additive. The concrete industry used to be the customer of last resort."

Whitemud Resources' kaolin clay mine.



Metakaolin is an SCM that improves the strength and durability of concrete and accelerates strength gain. In ACI 232.1, *Use of Raw or Processed Natural Pozzolans in Concrete Mixtures*, the committee reports that mix designs using an 8 – 12% metakaolin replacement at 0.3 – 0.4 water:cement ratio greatly improved the strength at all ages.

Whitemud Resources, however, has cracked the economic nut, enabling metakaolin to be profitably supplied to the concrete industry. "We've developed a process that produces metakaolin suitable for concrete applications at about one-third the price of metakaolin used for coating paper, and competitive with other SCMs," says Babichuk proudly.

The kaolin clay deposit on Whitemud Resources' leases was not considered bright enough for the paper industry without considerable refinement. It was studied by the Saskatchewan Department of Mineral Resources from 1948 to 1954, but was not immediately put to use. However, the company's management team recognised it as a shining opportunity to meet a growing demand for less carbon-intensive concrete, and acquired Whitemud's first lease in 2003.

"The location of Whitemud's kaolin deposit was fortuitous for a number of reasons," says Babichuk. "Our plant is centrally located in North America and near a railway, allowing us to ship bulk quantities throughout Canada and the United States, and on to global markets."

Whitemud formed in 2004 and gained regulatory approval for mine construction in July 2006. The company's plant in southwest Saskatchewan, 30 miles north of the US border is situated next to 160 million t of kaolin clay ore – enough kaolin to take the company well into the next century. Whitemud holds mineral leases on the deposit totalling over 12 000 acres. Constructed in 2008, the plant is designed to produce 200 000 t of cement-grade metakaolin per year from kaolin ore. The company's goal is to increase annual production to over 1 million t. The first shipment left the plant gate in fall 2008.

While the quality of pozzolans can vary considerably, Whitemud's manufacturing and quality control processes ensure consistent materials performance. The company also developed a much simpler and more environmentally friendly process for producing cement-grade metakaolin. Whitemud mines kaolin clay in an open pit. The kaolin ore is crushed, dried and processed to separate the fine kaolin particles from the sand. The kaolin particles, which are finer than cement, are then heated in a kiln to produce metakaolin.

Reduced emissions

Generating enough heat to fuse the various elements into cement clinker produces major greenhouse gas emissions. Even more CO_2 is produced from the reaction caused by burning the limestone. The kaolin clay to metakaolin reaction, however, does not produce any CO_2. In addition, the Whitemud kiln temperature of 800 °C is just over half the 1500 °C required to produce cement clinker, reducing energy requirements and greenhouse gas emissions.

"Overall our metakaolin manufacturing process produces at least 55% less greenhouse gas emissions than the cement manufacturing process per tonne of material leaving the plant," says Babichuk. "In most applications, a contractor can replace up to 20% of the cement in concrete with metakaolin and other SCMs. With metakaolin, the concrete producer is able to optimise their concrete mixes to reduce the total content of cementing materials per cubic yard of concrete. Therefore, through to the end of the construction process, using Whitemud can lower the overall carbon emissions of concrete work by around 15%."

Furthermore, other SCMs like flyash actually work well with metakaolin within the concrete. Using metakaolin with flyash in a concrete mix further allows the contractor to increase the total SCM content without compromising constructability. "Metakaolin can help overcome the longer set times and slower strength development associated with flyash," says Babichuk.

Secure resource

The main issue with other SCMs, such as flyash, granulated blastfurnace slag (GBS) and silica fume is that they are all waste materials of other industrial processes. Babichuk believes that although utilising waste products from other industries is important, there are drawbacks to relying on a manufacturer for whom SCM is a secondary business. "If you're using SCMs

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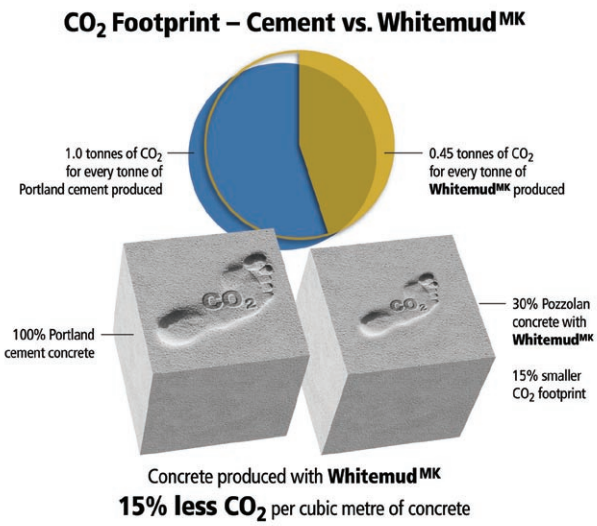
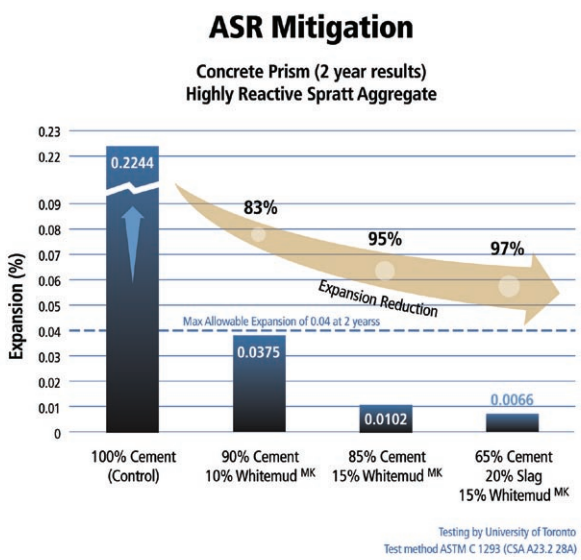


The manufacturing process of Whitemud^{MK} produces 55% less CO_2 per tonne of material produced than the process of manufacturing cement.



Long term (2 year) concrete prism expansion test results demonstrate that Whitemud^{MK} will mitigate ASR even with highly reactive Spratt aggregates.

that are the waste products of industrial processes used to produce steel or electricity, your supply of SCM is dependent upon your supplier's success in marketing their primary products," he asserts. "If the silicon-metal producer you're using closes its plant, for example, there goes your supply of silica fume. That has been a major problem in some markets. Whitemud offers a stable supply of metakaolin worldwide. Supplying contractors and concrete producers with metakaolin is our only business."

Meanwhile, the supply of flyash, currently the least expensive SCM, is under threat from legislation and environmental activists seeking to limit greenhouse gas and mercury emissions from coal-fired power plants. The US Environmental Protection Agency (EPA) might also reclassify flyash as a hazardous material as a result of the Kingston Fossil Plant coal flyash slurry spill in Tennessee. The disaster in December 2008 released 1.1 billion gallons (4.2 million m^3) of flyash slurry into the Emory River and a nearby community. The reclassification of flyash by the EPA would inevitably limit supply and drive up manufacturing, handling, storage, insurance and transportation costs throughout the supply chain.

Metakaolin in the mix

In addition to its numerous environmental benefits, Rick Ketcheson, Whitemud's Director of Technical Services and Product Development, sees metakaolin as having many operational advantages over other SCMs. "Metakaolin contains the highest percentage of alumino-silicates among the SCMs, allowing it to maximise the amount of durable binders in concrete," Ketcheson explains. "It reacts with lime more aggressively than flyash, and is much cheaper than silica fume. Flyash may take up to two months to react with the lime in concrete. Using metakaolin, the reaction may occur within two weeks."

This ability of metakaolin to react quickly with lime to produce cementing compounds can shorten construction timelines. Laboratory and field testing has proven Whitemud's ability to reduce concrete setting and stripping times, allowing contractors to move equipment onto newly placed concrete sooner.

Babichuk is enthused about the long-term benefits to construction companies, building owners and the environment. "Metakaolin has the potential to significantly increase the service life of a structure," he says. "Rebuilding or replacing structures less often would be the ultimate way of conserving resources and reducing greenhouse gas emissions. The design community wants to build structures that last longer, and metakaolin as an SCM can help it achieve that goal."

Increased structural lifetime

Whitemud's ability to increase concrete's resistance to alkali-silica reactivity (ASR) is another way that it helps to prolong the longevity of structures. ASR is causing infrastructure throughout North America to crumble. Metakaolin increases concrete's resistance to ASR by increasing its density and reducing its pore size and

Whitemud's storage and shipping facilities at the plant site.

permeability. Substituting metakaolin for up to 20% of cement also improves concrete's sulfate resistance.

Babichuk admits that metakaolin is not usually foremost in the minds of contractors and engineering firms as an ASR solution, yet it is proven to be the most ASR-resistant pozzolan because of its relatively pure alumina-silicate composition. It could improve the safety of concrete structures, such as bridges and office buildings, by reducing the instances of catastrophic failures where concrete has broken away and fallen into the street. He suggests the need for pozzolan concrete additives is going to increase as the better aggregate quarries in Canada and the US are depleted.

"The availability of good aggregate is diminishing and many quarries in North America are now producing rock and sand that are highly reactive to alkalis," Babichuk notes. "At the same time, there's a diminishing supply of good pozzolans. Pound for pound, metakaolin is the best pozzolan for preventing cement alkalis from reacting with aggregates. Concrete with 25% Class-F flyash content will prevent the ASR reaction. Metakaolin stops ASR at 10 to 15%."

A promising future

Metakaolin has still more benefits. It imparts properties that make concrete easier to work with than many other pozzolans. According to Babichuk, "silica fume is sticky. It is hard to move out of a silo, and it makes the concrete sticky. Whitemud gives concrete a smooth, buttery texture that is easy to work with. Concrete mixtures that incorporate metakaolin flow easily through silos and leave a nice finish."

Whitemud's customers certainly seem to agree. "I liked the metakaolin concrete as soon as it came out of the truck," says Craig Drummer, Senior Superintendent with EllisDon in Calgary. "We were able to get our stripping strengths in three days without accelerators. It allowed us to compress our construction schedule without sacrificing quality. Having Whitemud^{MK} in the mix provides LEED points without adding work and time."

With reviews like these, it is no wonder international interest for Whitemud^{MK} is growing from contractors and cement manufactures alike. Since the fall of 2008, Whitemud^{MK} has been used by contractors in Western Canada, Quebec, Boston and California. At the start of 2010, Whitemud Resources is ramping up production in anticipation of growing demand from customers throughout North America. The company is also awaiting the test results from prospective customers in China, Italy, the Netherlands and South Africa.

Babichuk stresses that contractors do not have to sacrifice performance or incur higher costs to use green concrete: "you can make concrete that can be stripped in one day by putting a lot of cement into it – but producing that cement emitted a considerable amount of CO_2. Metakaolin offers that desired shorter cycle time, while reducing CO_2 emissions and satisfying LEED requirements."

The contractor, the client and the climate all win.