Metakaolin Might

China clay-derived mineral admixture molds new performance possibilities.

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High-reactivity metakaolin (HRM) is well on the way to being established as a value-added concrete admixture. The relatively new product poses a threat to the high prices, if not market share, of microsilica/silica fume in the U.S.

The properties of HRM have been studied and publicized for years. The pozzolanic admixture can serve as a replacement for microsilica/silica fume, providing high compressive strengths and reducing permeability of concrete and the penetration of chloride ions to reinforcing steel. The product can also be used in mix designs where improved properties may be needed, but silica fume is not considered.

Where conventional silica fume leaves a dark coloration to concrete, pure white HRM does not. This is desirable for architectural treatments. At this time, HRM's widest commercial use is in precast elements of high-rise skyscrapers along the booming Pacific Rim. But in April 1996, based on its lab tests, the New York State Department of Transportation approved the use of Engelhard MetaMax HRM as a substitute for microsilica/silica fume in bridge deck applications. However, to date, structural concrete field applications of HRM in the U.S. have been rather limited.

Why HRM?

The benefits of HRM vs. silica fume, are that until now, there has not been a completely white admixture with the attributes of silica fume that can be used for architectural applications. HRM can be used in combination with white cement to get a high-performance white concrete. The HRM permits placement of high-performance concrete next to conventional concrete, because the admixture does not darken the concrete. "You can get good color matching for architectural applications," said Karen A. Gruber, chemist/engineer, MetaMax Metakaolin Admixtures, Engelhard Corp., in Iselin, N.J.

For slab placements, or areas where good finishability (perhaps by hand) is needed, HRM can offer additional benefits. "The benefit is in the handling and finishability," Gruber said. "The larger particle size gives the fresh concrete a 'creamy' kind of texture, instead of a 'sticky' type of texture. It's clear to people who have worked with silica fume concretes, because it can take special techniques to deal with its stickiness and cohesiveness. A metakaolin-modified mix is much easier to finish. In addition, the hydrophilic (water-luring) nature of HRM makes for rapid dispersion in concrete mixes."

Alkali-silica reactivity (ASR) is another bane of concrete which Engelhard feels will yield to HRM, because of its ability to "lock up" lime in concrete mixes.

As Engelhard develops this product, the terms additive and replacement are having less meaning in describing the use of this material. "It's really a supplemental cementitious material," Gruber said. "It ultimately will be the end user who determines what is most convenient, to use it in addition to cement or as partial replacement for cement. It really is dependent on the desired end properties and the cement content of the current mix."

And there may be other applications for HRM in concrete besides providing compressive strengths equivalent to that of silica fume, and lowered permeability. Its "creamy" texture in fresh concrete lends itself to mortars and patching compounds, where it also serves as a workability aid. It can reduce drying shrinkage, so better adhesion of patching and repair materials is possible.

Early-age strength development is another attribute, which could make HRM useful to precast producers, enabling them to turn forms more quickly.

Market development

Engelhard is attempting to keep the price competitive vs. silica fume, to give it wider acceptance. "HRM is comparable in price [to silica fume]," said John Mosko, Engelhard's marketing manager for concrete admixtures. "Since HRM is still relatively new to the market, education and working together with end users is required, in addition to just providing a value-added product." (See "An alternative to silica fume?", Concrete Products, November 1994)

"There are other pozzolans out there, and all of them have their place," Mosko said. "We believe that high-reactivity metakaolin has a place. We take advantage of its high reactivity, its color, its ability to give high early strength, its ASR control, dispersability, and particularly good finishability for a very fine particle size pozzolan." Mosko declines comment on which specific markets Engelhard has targeted.

But bridge decks constitute a target market, because HRM reduces permeability in concrete. "It can reduce permeability, similar to silica fume," Gruber said. "And it can impart the same kind of strength development." Precast elements also hold promise. But so much main line paving is going to bituminous asphalt that Engelhard, at least, hasn't targeted pavements as having much potential.

Despite the difficulties in getting materials specified by government road agencies, Engelhard is forging ahead in getting the material specified. "We've tried to make state DOTs and federal authorities aware of the product, because it is a value-added material that can offer consistency and ease of use in those applications," Gruber said. "A lot of them have experience in using silica fume and are looking for alternatives. Because it's a manufactured material, they feel it's going to be there in the future." (See New York sidebar, page 52).

Engelhard has sold HRM for concrete applications under the MetaMax name in the U.S.

for about three years. With 16 calciners in operation, the company is the world's largest supplier of metakaolin, Mosko said, producing twice what all other makers generate combined. Engelhard's product is sold through a network of distributors, with warehouses worldwide, and a direct sales force.

But Engelhard has its competitors. Chief among them is Advanced Cement Technologies LLC, Blaine, Wash., which manufactures its Powerpozz HRM product in Ione, Calif., just outside Sacramento. A raw kaolin clay is water-washed, filtered to remove impurities, thickened, extruded and kiln-fired. The calcined material is ground and run through a high-efficiency classifier to meet particle size specs, said Advanced Cement Technologies' Christopher H. Wright, vice president of marketing.

And the British-made MetaStar product of ECC (English China Clay) International, Inc. looms as a potential competing material in the U.S. Atlanta-based ECC is preparing to begin production of MetaStar at a Sandersville, Ga., operation, according to recently appointed sales and market manager, Elizabeth Jordan. "The indications we've gotten so far is that the U.S. is a viable market for metakaolin, so we would be interested in entering it with production out of our Sandersville plant," Jordan told Concrete Products. Meta-Star already is available as an imported product from the U.K. headquarters of parent company ECC plc.

Production methods

But getting from raw material to value-added concrete admixture is an involved process.

"High-reactivity metakaolin is the term we use to differentiate our product from metakaolin," Gruber explains. "Metakaolin alone is an all-encompassing term that has been used far back to include calcined clays that may contain some component of kaolin that has been transformed into metakaolin."

Engelhard, which owns vast reserves of kaolin in Georgia, has marketed metakaolin for many different products for at least 30 years. But its MetaMax product has been developed specifically for the construction industry. In brief, the raw material is water-processed and refined, and impurities are removed. Then it's thermally activated to become highly reactive, at that point becoming very similar in performance to a silica fume-type of admixture. Engelhard uses the term high-reactivity to differentiate it from the other types of clays and materials that are unrefined, and therefore less reactive.

Metakaolin is a specific mineralogical phase of alumino-silicate material. It can be over-calcined into a structured form that will not be pozzolanic. "Control is essential, and that's part of what makes high-reactivity metakaolin reactive and pozzolanic," Gruber said.

The raw kaolin is placed in a slurry form after mining. In this form, a variety of water processing steps remove the impurities, and the material is bleached to make it white.

In addition to the controlled thermal activation, pozzolanic activity results from this

pretreatment phase of the kaolin, hence the removal of impurities. The high reactivity results from the fact that there are no other diluents in the material, diluents being materials that are not reactive.

The raw kaolin is a hydrous material, about 14 percent water, bound in the interstices of the kaolin. After the water is driven off - dehydroxylated - the structure collapses, resulting in an amorphous alumino-silicate, the metakaolin phase.

As it exits from the kiln, the material is pulverized, and bagged, or stored in bulk silos. The material is sold in powdered form. "The material is so hydrophilic, and disperses so easily, that there really is no need for it to be put into a slurry form, which can require additional handling and equipment," Gruber said. "The material can be used in paper bags, and added to the back of a load of already-batched ready-mix concrete, and still get proper dispersion, or it can be put into a silo and conveyed with cement."

At most ready-mix plants, admixtures tend to be handled and added in liquid form. "Our product has never been marketed like that," Gruber said. "It could be marketed that way, if someone felt that was the easiest way to handle it. But because of HRM's inherent properties, slurry is not needed. Also, when you have a low water-to-cementitious material ratio, you don't have to worry about the problems of bringing in additional water or materials into the mix."

Engelhard's and Advanced Cement Technologies' products meet ASTM C-618 Class N (natural pozzolan) specifications. Dosages in concrete vary according to the performance needs of the end user, and usually are calculated as a weight percent of the cement content. If higher strength is the target property, dosage would be anywhere from 5 to 9 percent; for maximum chloride resistance, it would be in the 10 to 15 percent range. For chemical resistance, and to control efflorescence, ranges of above 15 percent typically are used.

HRM may be combined with fly ash or slag for synergistic effects in concrete. A ternary blend including HRM and alkali-containing cementitious materials like fly ash or slag can produce high-performance concretes with good economics.

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