From: Concrete Construction August 2006 | Posted on: August 1, 2006
Decorative Concrete

Using Metakaolin in Decorative Concrete Mixes

By Joe Nasvik

Derived from kaolin clays mined specifically for the purpose, metakaolin is used as an ingredient in several manufactured products. To produce metakaolin, kaolin clay is heated to a specific temperature range to produce amorphous aluminosilicate, which has high pozzolanic reactivity. When you add metakaolin to concrete it reacts with the calcium hydroxide (CH) produced when portland cement hydrates, creating calcium silicates and aluminates—which is also what results from hydrated portland cement. Metakaolin reacts with CH (which has no strength of its own) to create a supplementary cementitious material with high strength leading to concrete that is more dense and less permeable.

Other pozzolans—coal fly ash, blast furnace slag, rice hull ash, and silica fume—are byproducts from other industries, adding value to the material and as a result, eliminating its disposal. Metakaolin, however, is manufactured and engineered specifically for use with portland cement, and has more than twice the reactivity of most other pozzolans.

Above: This is the control sample, cast without metakaolin. There isn't much color difference compared to the samples with metakaolin, but there is a slight color shift. Below: In this sample we replaced 20% of the portland cement with metakaolin. When we diamond polished a portion of it, there was a very noticeable difference in hardness compared to the control sample. Joe Nasvik**How and where to use it**

Metakaolin is usually considered as a replacement for portland cement, at a proportion of 8% to 20% of the weight of cement. If you are careful about the amount of water in your mix, the addition of metakaolin greatly increases both the compressive and flexural strength of concrete. Benefits include:

- Reducing the permeability of concrete, including chloride permeability
- Helping to control alkali-silica reactivity (ASR)
- Reducing or even eliminating the potential for efflorescence
- Enhancing the workability and finishability of concrete
- Increasing concrete durability
- Lightening the color of concrete making it possible to add lighter integral colors
- Making concrete denser and reducing its shrinkage, due to "particle packing"; combined with fly ash the results are even better
- Not substantially affecting set times when compared to the same mix without metakaolin

Ken McPhalen, manager of technical services for Advanced Cement Technologies, Blaine, Wash., says that the affect metakaolin has on concrete is most often compared to silica fume, not fly ash. He says the Illinois Department of Transportation (ILDOT) uses metakaolin on bridge deck placements to reduce the infiltration of chlorides. It is also being added to the concrete on the Benicia Bridge in California to increase strength and reduce permeability.

For decorative purposes Tony Prisland, a regional sales representative for Burgess Pigment Company, Temple Terrace, Fla., says that pre-cast stone manufacturers, concrete pool deck products, and several

manufacturers of countertop mixes use metakaolin to increase strength and resistance to staining.

Counter tops

Jeffrey Girard, president of The Concrete Countertop Institute, Raleigh, N.C., encourages the use of metakaolin in countertop mixes. Given the small amount of concrete involved in countertops, a 40-pound bag is enough to provide countertops for two or three average kitchens, so the material cost is only $5 or $10 per kitchen. For this small investment you get concrete with increased compressive and flexural strength, greater impermeability, stain resistance, and less shrinkage. He cautions contractors, however, to be careful about the addition of integral color and the use of chemical stains. Make samples first to be sure that the result is what you want.

Right: The two samples shown here were diamond polished to a 400 grit finish. The one on the left has a 20% replacement with metakaolin while the one on the right is the control sample with no metakaolin. Joe Nasvik

Efflorescence

Efflorescence causes problems for decorative concrete contractors because it lightens the appearance of colored concrete and is difficult to remove. Efflorescence occurs when CH is transported by water to the surface of a slab where it combines with carbon dioxide from the atmosphere to make calcium carbonate, which precipitates on the surface as a white residue. Approximately 145 pounds of CH is produced in every yard of concrete. Because metakaolin combines with CH, it can help to control efflorescence. McPhalen says that replacing 20% of the portland cement (by weight) with metakaolin will consume all of the CH in most concrete mixes. In most cases, a 10% replacement will control efflorescence.

There are two types of efflorescence, primary and secondary. Primary efflorescence occurs when mix water not used for hydration migrates to the surface. Secondary efflorescence develops with the passage of time as ground water moves through a slab or when concrete is saturated with water on the surface. McPhalen says the best strategy is to design a mix with 15% class F fly ash and 10% metakaolin. Metakaolin is very reactive and works best during the initial curing period, while the fly ash controls efflorescence over time.

Experimenting

In an effort to determine the affect of metakaolin on efflorescence and color shift, we decided to experiment. Using a standard 6-sack (564 pcy) portland cement mix with ¾-inch stone aggregate, we cast four samples, each containing 1/6 cubic yard. Sample 1 served as the control mix and had no metakaolin. Sample 2 had a 10% replacement of portland cement with metakaolin. The replacement for sample 3 was 15% and for sample 4 was 20%. To check for color shift we added red integral color to the mixes. See the table on page 52 for the mix proportions. We tried several ways to encourage efflorescence so that we could see the differences, but there was very little efflorescence (if we had poured someone's colored patio there would have been efflorescence for sure). Manufacturers of metakaolin tell us that lighter shades of integral color become even lighter with the addition of metakaolin, but the medium intensity of red color we used was largely unaffected.

A special thanks to Butterfield Color for volunteering to help make the metakaolin samples for this column.