High-reactivity Metakaolin

Field study shows new mineral admixture boosts concrete compressive strength and maintains workability and finishability

By Anne Balogh

A recent study comparing concrete slabs with and without high-reactivity metakaolin (HRM), a high-performance mineral admixture that yields results comparable to silica fume, found that HRM improves concrete properties while offering good workability and finishability. According to the concrete supplier and contractor involved in the experiment, the nonpozzolanic control concrete and the HRM-modified concrete had similar handling properties. However, the concrete containing HRM had a creamier texture, set somewhat faster, and generated less bleedwater. This study is one of several that have been conducted in the United States to evaluate HRM performance.

Englehard Corp.

The concrete test slab containing HRM had almost no bleedwater, which allowed finishers to get on the slab sooner. The finishers also noted that the HRM concrete had a creamy texture and did not stick to their equipment.

What Is HRM?

HRM is a refined form of an ASTM C 618, Class N (natural) pozzolan that is produced by calcining purified kaolinite clay at a specific temperature range. (Calcining involves heating a material to a high temperature to alter its physical composition.) But unlike industrial byproducts, such as silica fume, fly ash, and blast-furnace slag, HRM is water-processed to lighten its color, remove inert impurities, and control particle-size distribution. The carefully controlled refining process results in an almost 100%-reactive white powder that is consistent in appearance and performance from lot to lot.

HRM shows promise as a mineral admixture for high-performance architectural concrete. Because of its white color, HRM does not darken concrete as silica fume does. This makes it ideal for color matching and other architectural applications because it produces concrete similar in color to conventional exposed concrete.

The particle size of HRM is significantly smaller than cement particles, yet not as fine as silica fume. Typically added to concrete at rates of 5% to 10% by weight of cement, HRM improves concrete performance by combining chemically with free lime—a byproduct of portland-cement hydration—to form additional cementitious materials.

The results of a 1993 study conducted by Construction Technology Laboratories Inc., Skokie, Ill., show that the compressive and flexural strength development of HRM mixes is significantly greater than that of a nonpozzolanic control mixture and similar to that of silica-fume mixtures (see Table 1). The study also found that HRM concrete:

- Requires 25% to 35% less superplasticizer than silica-fume concrete to achieve a comparable slump (at water-cementitious materials ratios above 0.35)
- Has a very low chloride permeability, similar to that of silica-fume concrete
- Exhibits less drying shrinkage than conventional portland-cement concrete, and drying shrinkage similar to that of silica-fume concrete

HRM was introduced to the U.S. market late last year, and many ready mix producers are currently evaluating HRM-modi-

Table 1. Compressive Strength Results (psi)

Testing Age	Control	5% HRM	10% HRM	5% Silica Fume	10% Silica Fume
3 days	3460	5040	5980	5370	5550
7 days	4810	6900	7610	6350	6390
28 days	5950	8480	9150	8040	8360
90 days	7460	10,000	9320	8920	9240
365 days	8580	11,350	10,460	9210	9910

(Source: Construction Technology Laboratories Inc.)

In a laboratory test comparing HRM-modified concretes, a control Type I portland-cement concrete, and silica-fume-modified concretes, the HRM mixtures had significantly greater compressive strengths than the control mixture and had strengths similar to the silica-fume mixtures. The values are averages of three moist-cured 6 x 12-inch cylinders.

fied concrete for commercial applications. Though HRM concrete is similar in price to silica-fume concrete, it can offer economic benefits to the contractor resulting from its easy finishability and quick cleanup.

Field Study Confirms HRM's Advantages

The results of the recent field study of HRM-modified concrete generally support the results obtained in previous tests. The field test compares two concrete slabs placed at a manufacturing facility in Georgia: a control slab containing only Type I cement and a test slab containing HRM in an amount replacing 9%, by weight, the amount of cement in the control (see Table 2). Each slab is 4 inches thick and contains about 8 cubic yards of concrete. The test was conducted by the project's concrete supplier, Gray Concrete Service, Gray, Ga., and its contractor, Santel Contractors, McIntyre, Ga. The HRM was supplied by Engelhard Corp., Iselin, N.J.

Both concretes had a water-cementitious materials ratio of 0.43 and slump of 8 inches. Aside from the cement and HRM levels, the concretes had the same mix proportions. The HRM-modified concrete required no additional superplasticizer to achieve the 8-inch slump.

The compressive strength specification for the control mixture was 3000 psi at 28 days. In strength tests conducted by Preston Testing and Engineering Co. Inc., Macon, Ga., measurements at 28 days were 5070 psi for the HRM concrete and 4540 psi for the control mixture. The results are averages of three moist-cured 6x12-inch cylinders.

Gray Concrete added the HRM to the test concrete after the mixture had been batched into the ready mix truck. The concrete was then mixed for 10 minutes. Visual inspection showed that the HRM readily dispersed into the mixture.

Santel Contractors placed the slabs on different days with differing air temperatures. Air temperature for the HRM-modified slab was 65°F, while that for the control slab was 48°F. The finishers noted that the concrete containing HRM set faster than the control concrete, partially due to the higher air temperature and partially to the HRM.

The slab with HRM was hand troweled to a smooth finish, then it was broom finished to increase surface traction. The finishers said the concrete was creamy, did not stick to their equipment, and cleaned off the equipment easily.

"The test and control concretes had almost the same performance," says David Mann, sales manager at Gray Concrete. "They mixed, blended, and poured the same and had no color difference when set."

Table 2. Concrete Mix Proportions (per cubic yard)

Material	Control Slab	HRM-modified Slab
Type I portland cement (lb)	564	514
High-reactivity metakaolin (lb)	0	50
Fine aggregate (lb)	1,208	1,208
#67 coarse aggregate (lb)	1,900	1,900
Air-entraining agent (oz)	4	4
Superplasticizer (oz)	45	45
Water (lb)	242	242

(Source: Gray Concrete Service)

The field test compared two concrete slabs placed at a manufacturing facility. The control slab contains only Type I cement and the test slab contains HRM in an amount replacing 9%, by weight, the amount of cement in the control. The mix proportions for all other components are identical.

There were some differences, however. The slab with HRM had almost no bleedwater and appeared to set 5% to 8% faster than the control slab, even after the air-temperature difference was accounted for. According to Mann, these differences were beneficial: "The lack of bleedwater reduces permeability. There was less need for sealing, and workers could begin to finish the HRM-modified slab faster than the control slab, where they had to wait until bleedwater was gone."

Reference

Michael A. Caldarone, Karen A. Gruber, and Ronald G. Burg, "High-reactivity Metakaolin: A New Generation Mineral Admixture," *Concrete International,* November 1994, pp. 37-40.

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