Basic Concrete Materials & Methods
Section 03050

ENGELHARD
MetaMax®
High-reactivity metakaolin for concrete

1. Product Name

Engelhard MetaMax® High-reactivity metakaolin (HRM)

The White High-Reactivity Pozzolan for Architectural Concrete and High-Performance Cement-Based Systems

2. Manufacturer

Engelhard Corporation

3. Product Description

Basic Use: Engelhard MetaMax high-reactivity metakaolin (HRM) is an ultrafine pozzolan that enhances the strength, durability, and workability of portland cement concrete and cement-based products. Use MetaMax HRM as an admixture in cast-in-place and precast concrete, glass fiber reinforced concrete (GFRC or GRC), mortars and grouts, concrete masonry units, and other cement-based products.

ARCHITECTURAL CONCRETE: Unlike most highly reactive pozzolanic materials, MetaMax HRM is a bright white powder. It will not darken the appearance of concrete, but will improve the quality of color from batch to batch. This makes it an ideal choice for use in architectural concrete where visual and aesthetic concerns are critical.

HIGH-PERFORMANCE CONCRETE: Where aesthetics are not of uppermost concern, MetaMax HRM should still be considered as an alternative to silica fume. While silica fume is widely used in high-performance concrete, it produces a mixture that can be difficult to place and finish. MetaMax HRM can match or exceed the performance of silica fume, yet it produces mixtures that are significantly easier to handle and finish. Further, MetaMax HRM can enhance mixtures containing fly ash to result in higher-performance cement-based systems.

MetaMax® HRM was used in over 40,000 pieces of precast glass fiber reinforced concrete (GFRC) required for the restoration of Shepard Hall at the City College of New York. Before selecting the cladding material, the architects subjected 11 concrete products to six months of rigorous accelerated aging tests. The concrete with MetaMax HRM was one of only two products which passed the durability testing and met the aesthetic requirements for a bright, off-white hue. Of the two finalists, the system with MetaMax HRM was the less-expensive solution to the owners' needs.

Other Uses: Engelhard also produces the following products in the MetaMax family:

PLASTER AND STUCCO: Engelhard MetaMax® Plaster Additive PA was developed for use in plaster and stucco. It is especially beneficial in swimming pool plaster that must withstand aggressive chemical environments while maintaining the highest levels of visual appeal. As a high-performance pozzolan, MetaMax PA produces a stronger, more durable plaster finish. MetaMax PA high-reactivity metakaolin also makes plaster creamier, so it is easier to apply and creates a more attractive finish. And its white color is ideal for white and colored plasters and exposed aggregate finishes. Other benefits include reduced permeability, spot etching, cracking, mottling, efflorescence, and "fade" of colored finishes.

MetaMax® HRM used in high-performance concrete on dual four-lane bridges carrying I-87 over the Hudson River.

GROUTS AND MORTARS: Engelhard MetaMax® EF high-reactivity metakaolin has an "extra fine" particle size. This makes it suitable for use in cement mixtures which require increased viscosity and extra "body." In grouts, mortars, and patching compounds, for example, MetaMax EF metakaolin enhances mixture cohesion, so thicker layers can be built up. The cohesiveness also improves the anti-washout resistance of materials placed underwater. And in shotcrete and gunite, MetaMax EF metakaolin imparts rebound control and sag resistance. These applications also benefit from the increased strength and decreased permeability MetaMax EF can provide.

Composition: MetaMax HRM products consist of metakaolin, an amorphous aluminosilicate formed by controlled calcination of kaolinite. Kaolinite is a naturally occurring crystalline mineral that is abundant in central Georgia where Engelhard's manufacturing facilities are located. Unlike other pozzolanic materials, MetaMax HRM is not a by-product.

In the manufacturing process, specially selected kaolinite ore is beneficiated in slurry form to remove impurities and achieve a tailored particle size distribution. The slurry is spray dried and then calcined under optimal heat-treatment conditions to result in a product with maximum pozzolanic activity and a consistently white color. The particle-size distribution is finer than fly ash particles to enhance reactivity, yet is coarser than silica fume particles to reduce water demand and improve workability. (See TABLE 1 and FIGURE 5.)

VISUAL EFFECT OF METAMAX® HRM UPON CONCRETE			
	MetaMax HRM	Portland Cement Without Admixtures	Silica Fume
Ingredients			
Concrete With White Cement			
Concrete With Gray Cement			
Colored Concrete With White Cement & Mineral Oxide Pigment			

TABLE 1: The white color of MetaMax HRM provides a distinct advantage over silica fume, as it does not darken the color of concrete. These samples show the effect of MetaMax HRM and silica fume in concrete made with white and gray portland cement.

Color: MetaMax HRM is a bright white-colored powder similar in shade to white portland cement. Since it does not darken concrete, it can be used in concrete where light-reflectance, color control, and attractive appearance are required.

4. Technical Data

Product Standard: MetaMax HRM exceeds chemical composition requirements of ASTM C 618 – *Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use as a Mineral Admixture in Concrete for Class N (Natural) Pozzolans.*

Quality: MetaMax products are produced in a facility certified under ISO-9002 – *Quality Systems – Model for Quality Assurance in Production, Installation, and Servicing.* Statistical process quality control methods are maintained to ensure consistent lot-to-lot color and performance.

Pozzolanic Properties: MetaMax HRM is a highly reactive pozzolan that reacts with calcium hydroxide in concrete. Calcium hydroxide [$Ca(OH)_2$], also known as lime, is formed as a by-product of cement hydration. Calcium hydroxide does not contribute to the strength of concrete. In fact, it even contributes to conditions which are detrimental to a structure's long-term performance and appearance. MetaMax HRM at 10% loading, however, can consume up to 50% of free lime in a mixture within seven days, providing significant early strength development in high-performance concrete.

Increased Strength: MetaMax HRM can increase both the early strength and the fully cured strength of concrete as a consequence of its pozzolanic reaction. (See TABLE 2.)

COMPRESSIVE STRENGTH (PSI)					
Testing Age (Days)	Control Formulation	Addition of 8% Silica Fume	Addition of 8% MetaMax® HRM	Replacement of 8% of Cement With Silica Fume	Replacement of 8% of Cement With MetaMax® HRM
7	8260	9842	11172	9240	10192
28	9660	12404	13244	11788	12012
365	13650	17360	17850	16940	18074

TABLE 2: The addition of MetaMax HRM leads to significant improvements in strength that are as good as or better than silica fume whether MetaMax HRM is added as a cement replacement or as an addition to the cement. The mix design for the control and the samples with the pozzolans as replacement had a water-to-cementitious ratio of 0.4. In samples where the pozzolans are added to the cement, the water-to-cementitious ratio is 0.37.

Improved Durability: MetaMax HRM reduces concrete's vulnerability to chemical attack by densifying concrete and lowering its lime content. Calcium hydroxide is soluble in water, allowing it to leach out of concrete and create voids that increase the porosity and permeability of concrete. This makes it vulnerable to chloride ion ingress, sulfate attack, corrosion, and other degradation. On the other hand, the cementitious products formed by the pozzolanic reaction of MetaMax HRM and calcium hydroxide are not water soluble and, instead, create denser concrete with lower porosity and permeability. (See FIGURE 3.) In addition, the purity of MetaMax HRM allows more consistent air entrainment when compared to other ultrafine pozzolans, ensuring more reliable protection against freeze-thaw damage. Plus, the lower water demand of MetaMax HRM with respect to silica fume produces concrete that is less prone to plastic shrinkage cracking, another common contributor to concrete deterioration.

Resistance to Alkali-Silica Reactivity (ASR): Silica, present in various types of reactive aggregates, can dissolve in the highly alkaline environment of concrete. This ASR produces a gel at the paste-aggregate interface. The gel expands in the presence of moisture and produces internal tensile stresses. These stresses can crack the aggregate and the surrounding paste and, in severe cases, can ultimately weaken the concrete.

RESISTANCE TO CHLORIDE ION MIGRATION

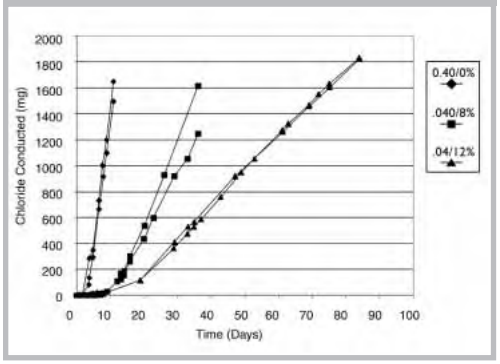

FIGURE 3: Permeability allows chloride ions and moisture to penetrate concrete and leads to corrosion of steel reinforcing. Test data demonstrates that chloride migration is dramatically retarded by MetaMax HRM and that chloride migration decreases as MetaMax HRM dosage rates are increased. The 0.4 in the legend is the water-to-cementitious ratio. At each dosage of MetaMax HRM, the samples were tested in duplicate to assess the reproducibility, which is very good.

MetaMax HRM, however, lowers the alkalinity of the pore solution by consuming much of the free lime. This decreases the silica solubility and the propensity for alkali-silica reactivity. (See FIGURE 4.) *Note that, while the reduction in pH due to MetaMax HRM is sufficient to mitigate against ASR, it is not drastic enough to impinge on the oxide coating that helps protect steel reinforcement against corrosion.*

RESISTANCE TO ALKALI-SILICA REACTIVITY (ASR)

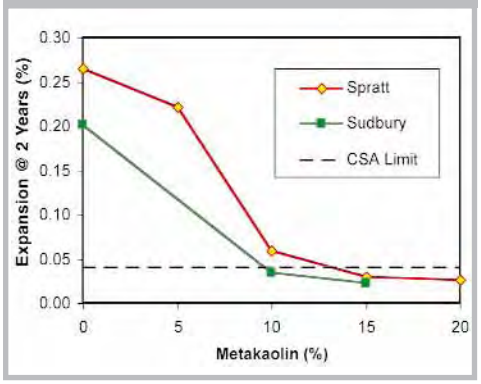

FIGURE 4: Expansion caused by ASR can cause cracking in concrete and lead to increased corrosion. MetaMax HRM reduced expansion due to ASR by 80% when tested for in accordance with CAN/CSA A23.2-14A – *Methods of Test for Concrete* (similar to ASTM C 1293 – *Determination of Length Change of Concrete Due to ASR).* Spratt and Sudbury are locations in Ontario, Canada, from where the reactive aggregates were collected.

Efflorescence Control: Dissolved calcium hydroxide can migrate to the surface of a structure and form unattractive efflorescent deposits. Progressive consumption of calcium hydroxide by MetaMax HRM lowers the amount of calcium hydroxide and decreases efflorescence.

Improved Workability: Workability of a concrete mixture is determined, in part, by the size of particles in the mixture. Silica fume, for example, has an average particle size of 0.4 microns in diameter. The extremely small size of these particles correlates to a very high particle surface area. As a consequence, silica fume concrete requires the use of additional water to coat the surface area of all particles. This high water demand produces a mixture that is said to be "sticky," making the material hard to place and finish and requiring compensatory use of high-range water reducers.

MetaMax HRM, on the other hand, has a mean particle diameter of approximately 1.2 microns – small enough to be highly reactive, yet large enough to significantly reduce water demand when compared to silica fume. (MetaMax EF high-reactivity metakaolin has an extra fine particle size distribution.) (See FIGURE 5.)

PARTICLE SIZE DISTRIBUTION

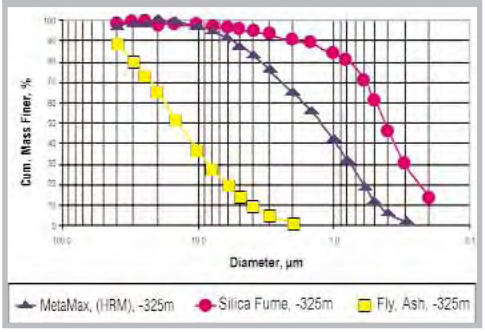

FIGURE 5. Particle size distribution (measured on Sedigraph 5100 – x-ray sedimentation) of MetaMax HRM, silica fume, and fly ash after sieving the samples through 325 mesh.

Depending upon the specific mixtures and techniques used, concrete with MetaMax HRM:

- Consolidates easily into forms.
- Moves readily under vibration with less segregation.
- Provides good pumpability.
- Produces a cohesive mixture that feels "buttery" or "creamy" and flows with minimal effort when troweled.
- Generates less bleed water, improving surface appearance.
- Uses less high-range water reducer compared with mixtures with silica fume.
- Lowers water demand compared to other ultrafine pozzolans.
- Can be cured with conventional techniques.
- Makes cleanup of mixers and tools easier.

Environmental Considerations: MetaMax HRM is a nontoxic and environmentally safe material. Engelhard reclaims the mines from which its kaolinite is extracted. Since production of MetaMax HRM generates an estimated 80% less CO_2 than does production of portland cement, use of MetaMax HRM to reduce the portland cement in a mixture can reduce the emission of greenhouse gas. MetaMax HRM also contributes to a sustainable environment by making concrete more durable and extending the service life of concrete structures.

Mixture Design: Optimum dosage of MetaMax HRM varies depending upon project requirements and other materials in the mixture. As a general guideline, add 10% to 15% MetaMax HRM by weight of portland cement (10 to 15 pounds of MetaMax HRM per 100 pounds of portland cement) to increase strength, control efflorescence, and reduce permeability, and add 15% to 20% for increased resistance to chemical attack and ASR.

Use of MetaMax HRM on a replacement basis should allow the amount of portland cement in a mixture to be reduced. MetaMax HRM can also be combined with fly ash or other pozzolanic materials for synergistic effects, including early strength development in fly ash concrete.

Test data demonstrating the performance of various concrete mixtures containing MetaMax HRM is available from Engelhard. For additional information on mix design, consult a qualified materials engineer and applicable publications available from the American Concrete Institute (ACI) and the Portland Cement Association.

5. Installation

Mixing: MetaMax HRM should generally be added to a concrete batch after portland cement and before any high-range water reducer (superplasticizer) is added.

Placing and Finishing: Concrete made with MetaMax HRM can be placed and finished using conventional concrete techniques.

Precautions: Concrete work should be performed in accordance with ACI and other applicable requirements.

Avoid excessive inhalation, ingestion, and skin and eye contact. Observe safety precautions appropriate for type of work being performed. Do not mix metakaolin directly with styrene monomer. See Material Safety Data Sheet (MSDS). Keep dry prior to use.

Building Codes: MetaMax HRM is accepted under ACI 318-02 – *Building Code Requirements for Structural Concrete and Commentary.*

MetaMax® HRM is also recommended for plasters, grouts, mortars, and spray-applied concrete.

DOT Approvals: MetaMax HRM is approved for use by various Departments of Transportation and Port Authorities. Contact Engelhard for current information.

6. Availability and Cost

Availability: MetaMax HRM is available worldwide through distributors.

Packaging: MetaMax HRM is available in 55 pound (25 kg) sacks; 2,000 pound (907 kg) super sacks; and in bulk truck or rail quantities.

Costs: While pricing for MetaMax HRM can be obtained from Engelhard distributors, it is generally preferable to contact a concrete producer or concrete product manufacturer directly to determine the cost of concrete mixtures or products containing MetaMax HRM.

The true cost of a concrete admixture is not its price per unit measure, but its effect on the overall value and performance of the concrete. In this regard, use of MetaMax HRM is typically competitive with other concrete mixtures offering similar performance. For example:

- MetaMax HRM can reduce the need for high-range water reducers and air-entraining agents, particularly in comparison to concrete mixtures containing silica fume.
- MetaMax HRM can be used as a partial replacement for portland cement, reducing the amount of cement required.
- MetaMax HRM may permit use of normal portland cements and locally available aggregates instead of more expensive grades of cement and special aggregates when higher early strengths, resistance to alkali-silica reactivity (ASR), or other performance attributes are required.
- Higher early strengths can allow faster stripping of forms or cycling of molds, reducing construction or fabrication time.

7. Disclaimer

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8. Maintenance

Structures built with concrete mixtures containing MetaMax HRM should be maintained in the same manner as other concrete structures. Use of MetaMax HRM, however, can improve the durability of concrete, reducing the structure's maintenance requirements, extending its service life, and providing enhanced life cycle cost benefits.

9. Technical Services

Material specialists at Engelhard are available to assist in the design of concrete mixtures containing MetaMax HRM. Contact Engelhard Technical Support at 478-628-7309 or email metamax@engelhard.com.

10. Additional Information

- Material Safety Data Sheet
- Research and Laboratory Reports
- Reprints of Published Articles
- www.engelhard.com/metamax
- Samples are available upon request.

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