

*Improving  
Class F Fly Ash Concrete  
with  
MetaMax<sup>®</sup>  
High Reactivity Metakaolin (HRM)*

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# Improving Class F Fly Ash Concrete with MetaMax<sup>®</sup> High Reactivity Metakaolin (HRM)

*Engelhard MetaMax<sup>®</sup> high reactivity metakaolin is a white, thermally activated aluminosilicate pozzolan that has been manufactured specifically for the construction industry. When added to hydraulic cement-based systems, MetaMax can increase the compressive strength and decrease the permeability of the mixture. MetaMax reacts with the calcium hydroxide that forms as a by-product of the cement hydration to form additional cementitious products.*

*Fly ash is used in cement to improve performance and to reduce cost. However, fly ash contains additional alkali that can react with MetaMax to further enhance the performance of the mixture. In this study, the compressive strength of a concrete containing MetaMax in conjunction with the fly ash was significantly higher than fly ash concrete. Also, according to rapid chloride analysis, a significant reduction in chloride ion penetration was seen when the MetaMax was added to the concrete containing fly ash.*

## INTRODUCTION

This report summarizes a laboratory study of a typical 0.5 water-to-cement ratio, air-entrained, high performance fly ash concrete. MetaMax metakaolin was added to the original mixture and compared to an equivalent addition of Class F fly ash to determine whether a similar effect could be achieved solely by increasing the fly ash concentration.

The concrete mixes studied were:

- the original fly ash mixture,
- the fly ash mixture with a 7.5% addition (based upon the weight of cementitious material) of MetaMax<sup>®</sup> high reactivity metakaolin, and
- the fly ash mixture with an additional 7.5% addition (based upon the weight of cementitious material) of fly ash.

## CONCRETE MIXTURE PROPORTIONS

Table 1 lists the actual mixture proportions for each concrete. The fly ash used in this study was a Class F (low calcium oxide) fly ash. The MetaMax<sup>®</sup> was added as a dry powder in conjunction with the Type I cement and the fly ash.

The water-to-cement ratio was maintained at 0.50. The same amount of a Type A water reducer (3 oz./100 lb. cement) was added to all of the concretes. Adjustments were made in the Type F high-range water reducer (HRWR) to maintain a slump of  $6 \pm 0.5$  inches. The air-entraining agent was adjusted to produce an air content of 6-8%. The coarse aggregate was a nominal ¾-inch stone. The concrete was prepared in a 2 ft<sup>3</sup> electric concrete mixer. Table 2 shows the evaluation of the fresh concrete.

Table 1. Mixture Proportions per eubic yard.

	Original Fly Ash	MetaMax metakaolin addition	Additional fly ash
Type I cement (lb.)	500	500	500
Class F Fly Ash (lb.)	100	100	145
MetaMax metakaolin (lb.)	0	45	0
Fine Aggregate (lb.)	1340	1340	1340
Coarse Aggregate (lb.)	1740	1740	1740
Type A water reducer (oz.)	15	15	15
Air-entraining agent (oz.)	5	9	9
Type F HRWR (oz.)	33	97	61

Table 2. Fresh Concrete Properties.

	Original Fly Ash	MetaMax metakaolin addition	Additional fly ash
Slump (in.)	6½	6¼	7
Air (%)	7.4	7	7.4
Unit Weight (lb/ft <sup>3</sup> )	141.1	142.3	142.7

## COMPRESSIVE STRENGTH EVALUATION

Two 4x8-inch cylinders were tested at each age. The cylinders were moist-cured in a relative humidity chamber until testing. The cylinders were capped with sulfur clay. Table 3 shows the compressive strength development.

The fly ash concrete containing MetaMax metakaolin developed higher strength than either of the concretes containing fly ash alone.

Table 3. Compressive strength development (ASTM C-39).

TESTING AGE (DAYS)	COMPRESSIVE STRENGTH (psi)		
	Original Fly Ash	MetaMax metakaolin addition	Additional fly ash
3	3320	4550	3760
7	4500	6820	5030
28	5920	9010	6900
56	6880	9470	7600
90	6960	9550	7720
180	7440	9870	8160

## EVALUATION OF RAPID CHLORIDE PENETRATION

The testing was performed according to AASHTO T-277-89 guidelines. The center sections of two 4x8-inch cylinders were tested. The average charge passed through the two sections are in Table 4.

The MetaMax metakaolin/fly ash concrete received a very low permeability rating and was significantly less than either fly ash concrete.

Table 4. Rapid chloride penetration evaluations.

	Charge Passed, Coulombs (rating)
Original Fly Ash	2500 (moderate)
MetaMax Metakaolin Addition	800 (very low)
Additional Fly Ash	1500 (low)