Increasing Use of Fly Ash in Concrete
Through Nanomaterial Modification, Multiscale Characterization, and Improved Processing

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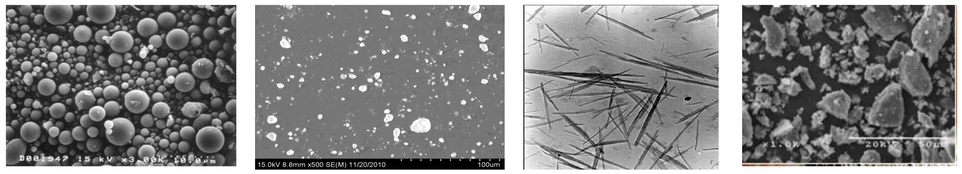
Purpose of Investigation

More than 120 mn tonne of fly ash and other coal combustion products (CCPs) are produced in the US each year. Only about 40% of these materials are used, while the rest are generally disposed. The purpose of this study is to increase the use of fly ash in concrete, specifically for pavement and self-consolidating concrete applications.

Objectives of Investigation

- To develop a new generation high volume fly ash concrete by incorporation of nano-materials.

- To understand the relationships between various ingredients of concrete through characterization at multiple scales.



Fly ash | Nano-Limestone | Nano-clay (Actigel) | Type I Cement

Experimental Work

- Characterized raw materials (cementitious materials and additives) using various techniques (XRD/XRF, Raman spectroscopy, PSD, etc).
- Assessed pozzolanic reactivity of the given set of six different fly ashes.
- Studied the effect of clay materials (Actigel, Metakaolin, and Concresol) on engineering properties (flow behavior, compressive strength, heat of hydration, etc.) of mortar mixes made with high volume of fly ashes.
- Investigated the effect of nano-limestone addition on flow and strength of the nano-material-modified fly ash – cement systems.
- Explored the ultrasonic technique for nano-material dispersion and effect of Actigel on thixtropic behvior of the cementitious system.

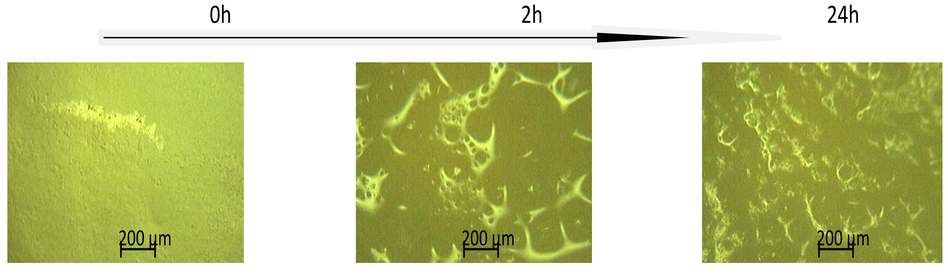


Figure 5: Progression of a fly ash-cement paste's hydration studied by Raman micro-spectroscopy

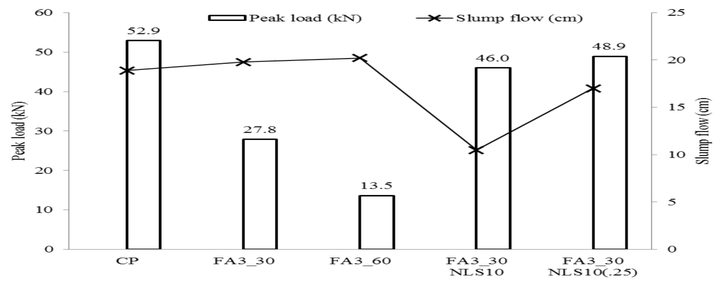


Figure 1: Effect of NLS on 1-d paste strength and flow

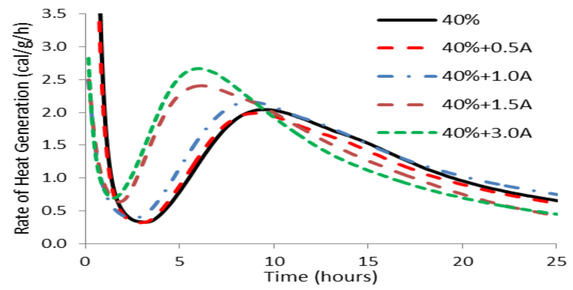


Figure 2: Effect of Actigel Content on Rate of Heat Generation

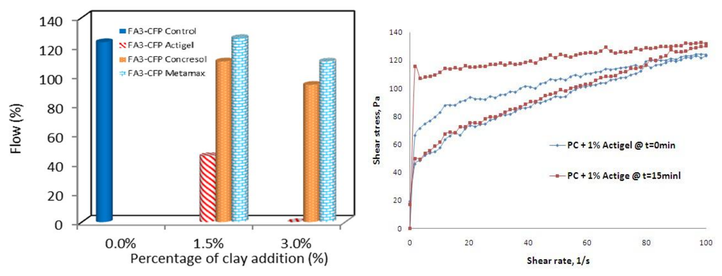
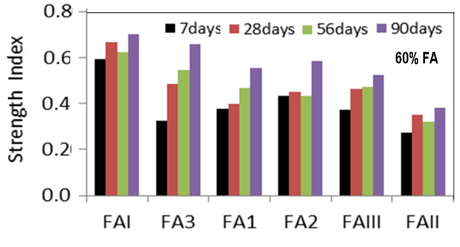


Figure 3: Effect of clays on flow and thixotropic behavior



← Figure 4: Strength Indexes of the Fly Ashes Studied

Table 1: Effects of dispersion on flow of cement paste with and without nano-clay

Mix	Mixer	Slump flow diameter (cm)
AG0	Planetary mixer	18.2
	Blender	23.8
AG0.5	Planetary mixer	18.3
		11 (clays pre-dispersed)
	Blender	11

Results & Conclusions

The following major results are obtained:

- Nanolimestone (NLS) significantly helped in recovering the early age strength (24h) of HVFA pastes. (Figure 1)
- Actigel (A) played an important role in controlling the rheology of mixtures due to its flocculation behavior. It affected the setting times by making the paste set earlier than expected as seen by its heat of hydration. (Figure 2)
- Metakaolin was found to be most effective among all the clays used in the study to restore the strength and flow performance of fly ash modified mortars. (Figure 3)
- Significant differences in the reactivity of six fly ashes was obtained based on their Strength Index and hydration study by Raman spectroscopy . (Figure 4 & 5)
- High degree of clay dispersion increases surface interactions between nanoclay and cement particles, leading to enhanced flocculation or reduced slump flow. (Table 1)

Future Directions

- To develop optimal mix designs for pavement concrete and self-consolidation concrete (SCC) using HVFA.
- To evaluate engineering properties of the concrete.
- To improve dispersion of nanoparticles in cement system.

Acknowledgement

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