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

Kejin Wang¹, S.P. Shah², Shihao Kawashima², Nishant Garg¹
¹Department of Civil, Construction and Environmental Engineering, Iowa State University, Ames, IA
²Department of Civil and Environmental Engineering, Northwestern University, Evanston, IL

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.

Experimental Work
- Characteized 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 thixotropic behavior of the cementitious system.

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
The authors appreciate the sponsorship of this research by the Oak Ridge Associated Universities (ORAU) - Tennessee Valley Authority (TVA) (Grant No. 7-22976).