# Project Summary

Texas Department of Transportation

# 0-5207: Effects of Texas Fly Ash on Air Entrainment in Concrete

## Background

In order to produce durable concrete in regions exposed to cycles of freezing and thawing, it is essential that concrete be air entrained. Air entrainment is achieved through the use of air-entraining admixtures (AEAs), which have been used successfully for over 60 years. However, there are some practical difficulties in properly entraining air in concrete as many factors impact the ability to generate the desired air-void system, including issues related to materials, mixture proportions, mixing, placing, consolidating, and climatic conditions. In recent years, concrete producers and contractors in Texas have experienced particular difficulties with air-entrained concrete. Some of these difficulties were attributed to changes in the characteristics of fly ash due to the installation of low-NOx burners in coal-burning power plants. Other problems, independent of fly ash, were also reported in which there were significant discrepancies between air content measured in fresh concrete and air content measured in hardened concrete.

Because of the aforementioned problems, the Texas Department of Transportation (TxDOT) initiated this research project with the following main objectives:

- investigate and recommend test methods for assessing fly ash and effects on air entrainment,
- develop guidelines for managing air content when using fly ash,
- investigate test methods to estimate the air-void system using fresh concrete,
- investigate the reported discrepancy between fresh and hardened properties in concrete, and
- investigate the occurrence of air-void clustering in air-entrained concrete.

The above objectives constitute a very diverse set of research topics that are not only fundamental to properties encountered in Texas but throughout the world where air-entrained concrete is used. To meet these objectives, a research team led by Dr. Kevin Folliard was assembled. Dr. Kenneth C. Hover (Cornell University) assisted on the project. The overall findings from these investigations are detailed in two Ph.D. dissertations (Ley 2007; Harris 2007) and one M.S. thesis (Naranjo, 2007). A brief summary of key findings is presented herein.

## What the Researchers Did

In this project, a wide range of materials were evaluated, including a variety of fly ashes, portland cements, aggregates, and chemical admixtures. Particular emphasis was placed on characterizing the different fly ashes, from chemical, mineralogical, and physical perspectives. Significant testing was performed on the various ashes to evaluate their behavior in air-entrained mortar and concrete in an attempt to ultimately correlate fly ash characteristics to the ability to entrain air in field concrete.


## Research Performed by:

Center for Transportation Research (CTR), The University of Texas at Austin

**Research Supervisor:**
Kevin J. Folliard, CTR

**Researchers:**
M. Tyler Ley, CTR
Andy Naranjo, CTR



**Project Completed:** 8-31-07

In addition to the work focusing on fly ash and its impact on air-entrained concrete, significant efforts were also undertaken to better understand the impact of air-void clustering around aggregate particles on the hardened properties of concrete. Research was also performed using an innovative test set-up which allowed for in-situ monitoring of the air-void system in pastes.

## What They Found

Significant progress was made under this project in better understanding the effects of fly ash on air-entrained concrete and in developing rapid screening tests that can be used in the field to evaluate a given fly ash. Considerable progress was also made in understanding the nature of air-entrained bubbles in fresh concrete and the impact of clustering of air voids on hardened concrete properties.

## What This Means

Some of the key findings include:

- Loss-on-ignition (LOI), which is typically viewed as an index of carbon content in fly ash, is not a good indicator of how most of the fly ashes in this study performed in air-entrained concrete. Other parameters, such as surface area, tend to be more useful in predicting the impact of fly ash on air-entrained concrete.
- A modified and improved version of the "Foam Index Test" was developed and has shown potential for being used in the field as a rapid screening test for fly ashes.
- A standard procedure for characterizing ash color has been developed. The procedure includes ash sample preparation, sample imaging with a common desktop color image scanner and image analysis to quantify image color information. The scanning and grayscale analysis methods developed under this project can be used as a quality control tool to identify ashes that may require increased AEA dosage in concrete.
- A modified and improved version of the mortar air test was developed and shows promise in predicting AEA demand in concrete.
- A method was presented to produce an AEA dosage response curve for a given fly ash/AEA combination using only a single concrete mixture. The method was then compared to the standard test for AEA dosage response that uses several sequential mixtures, and the results were found to be closely comparable for most mixtures.
- Unique insight was gained into the formation and stability of air voids in fresh pastes, and the impact of pressurization and de-pressurization was quantified. The findings from this study may shed some light on the impact of construction operations on the air-void system in concrete.
- Clustering of air voids around coarse aggregate particles was observed when concrete was retempered (through the addition of water during the mixing cycle), but no major reductions in strength were observed beyond what would be expected from the higher water content.

### References


Harris, N.J., "Evaluating the Influence of Fly ash on Air-Entrained Concrete," Ph.D. Dissertation, Cornell University, 2007.

Ley, Tyler, "The Effects of Fly Ash on the Ability to Entrain and Stabilize Air in Concrete," Ph.D. Dissertation, The University of Texas at Austin, 2007.

Naranjo, Andy, "Clustering of Air Voids Around Aggregates in Air-Entrained Concrete," M.S. Thesis, The University of Texas at Austin, 2007.



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