The Cementitious and Pozzolanic Properties of Fluidized Bed Combustion Fly Ash

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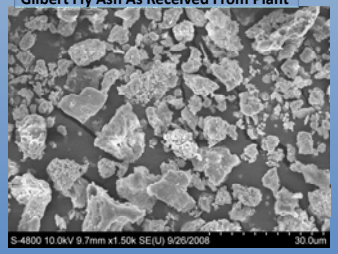
E.A. Gilbert Generating Unit

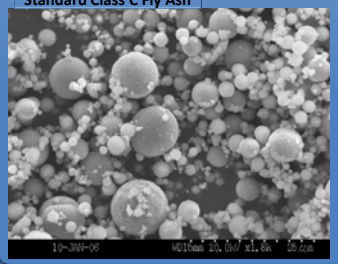
The East Kentucky Power Cooperative (EKPC) operates the Spurlock Power Station in Maysville, KY. In April 2005, EKPC brought online a new 268-megawatt FBC unit. This Circulating Fluidized Bed Combustion unit, known as the Gilbert Unit, is the cleanest coal combustion unit in Kentucky. Fly ash from the Gilbert Unit was examined to determine its cementitious and pozzolanic properties.

Physical Characteristics

Gilbert Fly Ash As Received From Plant



Standard Class C Fly Ash

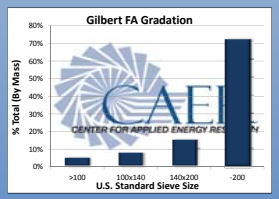


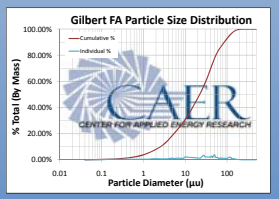
While FBC units offer excellent benefits for the environment, the coal combustion products from these units have drastically different properties from CCPs produced in traditional combustion. FBC fly ash differs from PCC fly ash as it is not fused or spherical and it is high in sulfate. These properties make FBC fly ash fall outside of the ASTM C-618 specification for pozzolans. The Gilbert FBC fly ash was also found to have a much higher surface area than standard fly ash.

Abstract

The focus of our work is to develop an understanding of the potential for Fluidized Bed Combustion (FBC) fly ash to serve as an additive in Portland cement concrete. FBC fly ash from the E.A. Gilbert Generating Unit of the Spurlock Power Station in Maysville, KY was used in this study. In fluidized bed combustion, coal is burned in the presence of limestone at much lower temperatures than conventional pulverized coal combustion (PCC). It also produces both a fine fly ash and a coarse bottom ash product. The FBC fly ash differs from PCC fly ash as it is not fused or spherical and it is high in sulfate. Although this material is outside of the ASTM C-618 specification, it is non-crystalline, has a relatively high surface area and does have the potential to be both pozzolanic and cementitious. Samples were tested for particle size distribution, mineralogy, chemistry and BET surface area. The FBC fly ash was pre-hydrated to slake raw lime then fractions were screened and hydraulically classified. These materials were tested in mortar cubes using ASTM procedures to examine water demand and the compressive strength. The FBC fly ash material was found to initially retard strength development but rapidly gained strength, achieving strength index values as high as 94% in 7 days. Mortar bars were created to test the potential for shrinkage and expansion. Further insight into the potential use of FBC fly ash in construction was made through the examination of concrete cylinders. Compressive strength testing of these cylinders confirmed previous results from mortar cube strength analysis.

Gradation Analysis



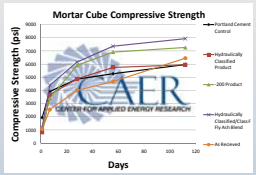


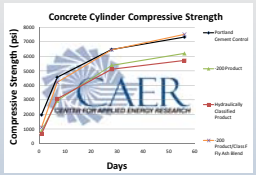
The gradation of the raw FBC fly ash was initially assessed using a series of standard sieves. Additional quantities of Gilbert fly ash were sieved to obtain a large sample of product passing the No. 200 (0.074mm) sieve. This material, referred to as "Gilbert -200 Product" for this research, was analyzed for its comparative suitability as a construction material in further experimentation. As an alternative to traditional sieve gradation analysis, particle size analysis was conducted using a CILAS 1064 Particle Size Distribution Analyzer. The results of this analysis confirmed data obtained from the mechanical sieving.

Acknowledgments

We would like to thank our colleagues, Robert Jewell and Robert Rathbone for their help with this work and also the support of East Kentucky Power Cooperative, in particular the staff at the Spurlock Power Station.

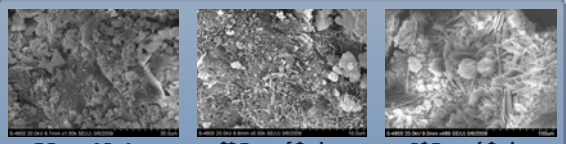
Compressive Strength





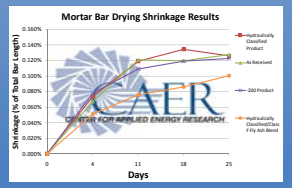
The Gilbert fly ash was tested for its compressive strength. Mortar cubes were prepared and tested for their compressive strength in accordance with all applicable ASTM specifications and procedures. Mortar cubes were made using samples of the Gilbert hydraulically classified product, -200 product, a 50%/50% blend of hydraulically classified product and class F fly ash, and Gilbert fly ash as received. In addition, the compressive strength of concrete cylinders was tested in a similar manner.

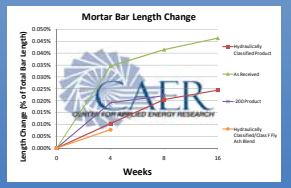
Gilbert Fly Ash As Received Mortar Cube Strength Development



Above is a series of SEM imagery for the Gilbert fly ash as received mortar cubes after 7, 28, and 56 days of curing. Barely any portlandite crystal growth is evident after 7 and 28 days, but large amounts of crystallization are evident after 56 days. This late crystal growth is evidence that the high 112 day compressive strength is not anomalous. The early lower strength values may also be due to a common ion effect as a consequence of the high lime content of the CFBC fly ash.

Dimensional Stability





An important aspect of any potential construction material is its tendency to expand or contract over time. Excessive expansion or shrinkage can lead to cracking or weakening of hardened concrete mixtures. Long-term length change was examined using the ASTM C-157 standard test method. Short-term shrinkage was determined by following ASTM C-596. Overall, Gilbert FBC fly ash showed excellent dimensional stability, with very low shrinkage and expansion values.