

FINAL TECHNICAL REPORT
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Project Title: **BRICK MANUFACTURE WITH FLY-ASH FROM ILLINOIS COAL**

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ABSTRACT

Fly-ash generated from burning Illinois bituminous coals (generally ASTM class F) has a lower lime content (lower cementing value) than fly-ash produced from lignite and sub-bituminous coals (generally ASTM class C). There is currently a lack of cement-based products with high volumes of class F fly-ash relative to products containing class C fly-ash. The lower lime content of class F fly-ash is an advantage for producing fired bricks. Also, unburned carbon in the ash is not a problem in making fired brick. Most of the fly-ash produced from burning Illinois coals is disposed of in landfills, representing a continuing disposal problem that increases the cost of using Illinois coals. There is a need to develop commercial products that can use high volumes of class F fly-ash produced from burning Illinois coals.

This report covers Phase I of a two-phase (two-year) collaborative project amongst the ISGS, GCM brick company, Ameren Central Illinois Public Service, and Central Illinois Light Company at Edwards Power Plant. Phase I (year 1) focused on assessing the technical and economic feasibility of making fired bricks using high volumes of Illinois class F fly-ash. A total of eleven fly-ash samples were collected at four power plants. Raw material samples of clay and shale were collected from two brick companies. All of the samples were analyzed for metal oxide composition, unburned carbon, and trace metal content. A set of preliminary screening tests for smaller scale test brick production was carried out. In these tests, 20% and 30% of the shale material was replaced by fly-ash with no observable extrusion problems. The fired test bricks had consistent color and physical appearance and were comparable with the test bricks containing no fly-ash substitution. In addition, no scumming was observed. Based on these results, additional test bricks were successfully made with 40%, 50%, 60%, and 70 wt.% fly-ash substitutions. The successful results of Phase I led to Phase II, which focuses on full-scale production demonstration.

According to the U.S. Census Bureau report, fired-brick production is increasing each year. In 1999, the number of bricks produced in Illinois, Indiana, Michigan, and Wisconsin was estimated at 278 million and, nationwide, at about 8.6 billion. Successful results of this research will directly benefit the Illinois coal industry and will provide brick manufacturers and utilities using Illinois coals with additional potential revenue of millions of dollars.

Pages 1 to 10 contain proprietary information.

EXECUTIVE SUMMARY

During 1999, about 82.5 million tons (ACAA 1999) of fly-ash, bottom ash, and boiler slag were produced from coal-burning power plants in the United States. The amount of fly-ash generated from the combustion of Illinois coals is about three million tons, which is typically disposed of in landfills. In general, coal ashes generated from combustion of bituminous coals in Illinois are ASTM class F, whereas those generated from combustion of lignite and sub-bituminous coals of other states are ASTM class C (ASTM C-618-98).

ASTM class C fly-ash has long been recognized and commercially demonstrated as a construction material used mostly in cement, concrete products, structural fills, embankments, road bases, and sub-bases. Although some research has been conducted on the utilization of class F fly-ash in concrete and concrete products, its utilization rate for cement-based products is much less than that of ASTM class C fly-ash. Class F ash has lower cementing values because of its lower lime content. Unburned carbon, as measured by the loss on ignition (LOI), is not a concern for producing fired brick. However, the low lime content of class F fly-ash is an advantage for producing fired bricks instead of cement-based products. Nevertheless, there is a lack of commercial products containing high volumes of class F fly-ash.

The purpose of this investigation is to make marketable fired bricks with class F fly-ash, produced from burning Illinois coals. According to the U.S. Census Bureau report, the production of fired bricks is increasing each year. In 1999, the number of bricks produced in Illinois, Indiana, Michigan, and Wisconsin was estimated at 278 million and, nationwide, at about 8.6 billion. If a large quantity of fly-ash can be used in the manufacture of fired bricks and other related products, the disposal problem will be decreased, and a value-added construction product will be created. Successful results of this research will directly benefit the Illinois coal industry and utilities using Illinois coals and will also benefit the brick manufacturers.

The potential benefits of using fly ash to manufacture fired bricks include energy savings and reduced consumption of raw materials. The clay minerals in coals are fired during coal combustion, so the energy consumption from firing during brick manufacture is not needed, resulting in energy savings. The fly-ash can also function like quartz to speed firing of clay components. Manufacturers of fired-clay products will also be able to reduce clay and shale consumption. They may be able to reduce raw material costs in direct proportion to the amount of fly-ash substituted for raw materials in their products. Recent discussion among investigators suggests that the replacement of fireclay and shale material by fly-ash could save about \$10 per ton for materials, the cost of the energy, and the time required to complete burnout of the clay component that is replaced by ash.

A previous ISGS study (Hughes et al. 1997) provided preliminary evaluation results that showed the suitability of Illinois coal ash for production of fired bricks. Bricks produced in a full-scale run using 20% of class F fly-ash from an Illinois coal were reported to have

met commercial specifications with one exception of unwanted white scum on the surface of the

bricks. The bricks were formed by the extrusion process, which was the method used by more than 93% of brick manufacture in 1998.

Fly-ash mainly contains burned equivalents of the mineral groups that make up the fired-clay raw materials. A certain amount of clay material is needed to provide enough plasticity for good extrusion and good green (unfired) strength. Some relatively refractory minerals are needed during firing to maintain the shape of a brick, while some relatively low melting-point materials are needed to fuse and produce a hard brick. Slonaker (1977) studied class F fly-ash from West Virginia and Pennsylvania to produce fired bricks. Since the fired brick raw materials used in this study contained no clay or shale materials for plasticity, the bricks were formed by dry pressing instead of extrusion. He indicated that fired bricks made from feeds of 72% fly-ash, 25% bottom ash, and 3% sodium silicate met commercial specifications. Unfortunately, Slonaker's results did not lead to commercialization because dry pressing is the method least used in brick manufacturing (only 1.5% in 1998). Thus, the technology transfer for near 100% ash brick production, according to Global Clay Marseilles, would be difficult because additional capital investment for dry pressing is required to retrofit the extrusion method most used by the brick manufacturers.

Based on these previous studies, a two-phase (two-year) project was initiated at the ISGS. Phase I (1999 - 2000) was completed, and Phase II (2000 - 2001) is currently in progress. Phase I focused on assessing the technical and economic feasibility of fired-brick manufacture using high volumes of Illinois class F fly-ash, and Phase II is focusing on full-scale production demonstration, technology transfer, and public outreach.

The results of Phase I are summarized in this report. A total of eleven fly-ash samples were collected from four different power plants and three clay and shale samples were collected from two brick companies. All samples were analyzed for metal oxide composition, unburnt carbon, and trace metal content. A survey was conducted on handling and disposal of fly-ash at utilities burning Illinois coal. A continued market survey for brick consumption and a preliminary economic analysis for making fly-ash containing bricks were performed. The pre-screening smaller scale tests were conducted at Global Clay Marseilles on two fly-ash samples. The forming ability and extrusion properties of various fly-ash and clay materials mixtures were examined. No extrusion problems were observed during the tests with 20% and 30% fly-ash substitution. The fired bricks showed good consistency in color and physical appearance. Also, no scumming was observed. Based on the results, additional test bricks were successfully made with 40%, 50%, 60%, and 70% fly-ash substitutions. The highly successful results of Phase I tests led to Phase II, which is focusing on full-scale production demonstration and commercialization.