ABSTRACT

During 1994-1997, with financial support from Illinois Clean Coal Institute and industrial cooperators, the Department of Mining and Minerals Resources Engineering at Southern Illinois University (SIUC) has developed, characterized, and demonstrated lightweight (85 pcf - 95 pcf) coal combustion by-products (CCBs) based artificial supports (post and crib members). These were developed utilizing fly ash from two units of the Gibson Power Plant of CINERGY. Their performance was successfully demonstrated on two longwall faces: one in Illinois and one in western Kentucky.

A pilot scale commercial facility was proposed in cooperation with Southern Illinois Power Cooperative (SIPC), Lake-of-Egypt power plant, AMEREN/CIPS Grand Tower (GT) power plant, and SIUC FBC power plant. The goals of the program are to: 1) develop and characterize lightweight materials and artificial supports using CCBs from these plants, and 2) construct and operate a pilot scale commercial facility for fabrication and marketing of CCBs-based artificial supports to mines in the tri-state area. This was to be achieved in two phases.

Phase I: Development and characterization of lightweight structural materials and design of pilot scale commercial facility (September 1, 1997 – August 31, 1998).

Phase II: Construction of a pilot scale facility, fabrication of prototype posts and crib elements, field testing of the supports, and marketing of supports within the tri-state area.

This report presents results of Phase I studies to date on CCBs characterization, mix development, and pilot scale plant design, and was performed in cooperation with the power plants and industrial cooperators. A pilot scale facility has been designed for processing 100 tons of CCBs and admixtures daily. Economic evaluation studies performed in cooperation with industrial cooperators indicate the project to be viable with investment capital payback period of about three years. The Phase II proposal, currently under preparation, recommends locating the pilot scale facility in McLeansboro, IL.

Pages 1 – 25 contain proprietary information.
EXECUTIVE SUMMARY

The goals of the Phase I project are to: 1) develop and characterize lightweight materials and artificial supports using CCBs from the Lake-of-Egypt power plant (SIPC), AMEREN/CIPS Grand Tower (GT) power plant, and SIUC's new FBC power plant and 2) design a pilot scale facility to process 100 tons per day of CCBs and other admixtures. Upon completion of this project, Phase II demonstration studies will be initiated in which a pilot scale facility will be constructed and operated to produce prototype post elements, crib elements, and ultralightweight blocks for use in underground mines. The products will be marketed to tri-state area mines.

Over the course of this project the following tasks were undertaken:

1) Characterization of F-fly ash from the SIPC Lake of Egypt and AMEREN/CIPS Grand Tower power plants, bottom ash from the SIPC Lake of Egypt power plant, and FBC fly ash from the SIUC power plant;
2) Mix development and mix characterization;
3) Characterization of prototype supports;
4) Design of a pilot scale facility; and
5) Economic evaluation studies.

The results to date on various tasks are summarized below.

**Characterization Studies**

1. The F-fly ash, bottom ash, and FBC fly ash were characterized for physical properties (particle size distribution, bulk density) and chemical properties (loss on ignition, oxide composition, pH, leaching characteristics).
2. Unburned carbon in the F-fly ash was studied in detail for its physical and chemical characteristics.
3. The mean particle size ($D_{50}$) for SIPC F-fly ash, GT F-fly ash, and FBC fly ash are 0.0086 inch, 0.011 inch, and 0.0054 inch respectively. The $D_{50}$ value for bottom ash is 0.79 inch. Bulk density values for SIPC F-fly ash, GT F-fly ash, and FBC fly ash are 59.9 pcf, 52.6 pcf, and 42.4 pcf, respectively.
4. SIPC Lake-of-Egypt F-fly ash has about 8% unburned carbon. Scanning electron microscopy studies indicate it to be highly porous with rough-textured spherical particles. Pore sizes range from manometer to micron in size. Fly ash particles are contained in the pore structure.
5. GT F-fly ash has about 6% unburned carbon.
6. F-fly ash is highly acidic initially (pH ≈ 3) when it is mixed with water. Over a period of 16 hours, the pH slowly increases to about 8.
7. SIUC FBC fly ash has about 18% CaO as compared to about 32% for ADM FBC fly ash. Preconditioning studies for SIUC FBC with about 15% water indicated that it could be used without preconditioning.
8. Foaming characteristics of the SIPC and GT F-fly ashes are extremely poor while FBC fly ash has excellent foaming characteristics.

9. FTIR studies of foaming chemicals from several suppliers have shown them to be very similar. The cost of the chemical should be the prime consideration for its selection.

10. A procedure has been developed for optimizing foam requirements for achieving a desired density. The procedure indicates that for a mix containing CCBs, there is an optimum water/powder ratio at which foam should be added. Furthermore, there is an optimum foam/powder ratio beyond which air entrainment is not possible.

Mix Development and Mix Characterization

1. Over 65 different mix designs incorporating F-fly ashes, FBC fly ash, lime, and bottom ash were attempted. Most of these mixes contain over 60% F-fly ash. Strength values obtained at different densities are 10% to 15% lower than were obtained with F-fly ash from the Gibson power plant. This is primarily because of the chemical characteristics of the F-fly ashes used in this study.

2. The approximate modulus ratio (elastic modulus to compressive strength ratio) is 100, about 50% of what was achieved for mixes with Gibson fly ash.

Characterization of Prototype Supports

1. Twenty-five (25) large size samples 5 in. x 5 in. x 24 in. utilizing GT F-fly ash have been prepared and tested for compressive strength and elastic modulus. Strength data are about 15% lower than was achieved with the Gibson F-fly ash.

2. The concept of a disposable PVC mold has been developed to improve post-failure characteristics of prototype post supports and to reduce labor costs in manufacturing. This concept appears very promising.

Economic Evaluation Studies

1. Studies based on a pilot scale facility design and market forces have been performed in cooperation with industry partners. The results are discussed in the body of the report.

2. The results reveal the project to be technically and economically viable. A pay-back period of 3-4 years can be achieved. Air-entainment, fibers, disposable molds, and labor costs are the most critical.

3. The results further suggest that economics of the project can be improved through economies of scale and automation of the plant.

It is expected that a Phase II proposal for construction and operation of the facility will be developed and submitted to the State of Illinois by the end of September, 1998.

The remainder of this report contains proprietary information and is not available for distribution except to the sponsors of this project.