FINAL TECHNICAL REPORT
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Project Title: **UTILIZATION OF ILLINOIS FLY ASH IN MANUFACTURING OF CERAMIC TILES**

ICCI Project Number: 97-1/3.1D-4
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ABSTRACT

The overall objective of the project is to utilize fly ash, produced by burning Illinois basin coal which is currently being landfilled (due to lack of resource utilization), as raw material to manufacture value-added ceramic tiles and to commercialize the technology.

Several steps are necessary to achieve this objective. In the first phase of this project funded last year, ceramic tiles with characteristics superior to wall tiles and similar to floor tiles were produced under laboratory conditions. The objective of this year's project was to manufacture fly ash tiles in a commercial tile manufacturing plant. This has been accomplished at M.E. Tile Co., located in Harvey, IL, by using the fly ash produced at Baldwin power plant.

Ceramic tiles are commonly made using primarily three processing methods: dry pressing, wet pressing, and slip casting. Use of the dry pressing method under laboratory conditions to make fly ash tiles was accomplished in last year's project. As M.E. Tile Co. manufactures tiles primarily using wet pressing and slip casting methods, these two processing methods are being used in the present phase.

A large number of ceramic tiles containing more than 70% fly ash were successfully made at this tile plant. These fly ash tiles exhibited lower firing shrinkage and water absorption than those of the standard clay and talc-based tiles manufactured by M.E. Tile Co. This indicates that fly ash based tiles are dimensionally more stable and have the potential for floor and outdoor applications.

In order to make them aesthetically appealing, the fly ash-based tiles were glazed with sixteen different colors and textures using commercially available glazing compounds sold to the ceramic tile industry. This clearly suggests that the proposed route of fly ash utilization to commercially produce fly ash tiles is achievable and can be implemented without much difficulty.

Pages 1-13 contain proprietary information.

EXECUTIVE SUMMARY

The fine particulate material that is electrostatically precipitated or mechanically collected from the stack gases of power plants burning pulverized coal is called fly ash. Annually, the state of Illinois produces over 5% of the 59 million tons of fly ash generated in the U.S. Approximately 20% of this is utilized by the cement and concrete industry and the majority of the rest is landfilled. Any non-concrete utilization of the fly ash currently being disposed will not only be environmentally sound and cost effective, but also will create a stable year-round demand.

The overall objective of this project is to utilize fly ash generated in Illinois as raw material for manufacturing value-added ceramic wall and floor tiles. Considering the size of the tile industry, a considerable fraction of the fly ash produced in Illinois can be utilized to prepare ceramic tiles. As raw materials contribute to the major cost in running a tile plant, replacement of costly raw materials by fly ash is attractive to tile manufacturers. The state economy also will benefit from such an undertaking.

The four steps envisioned as necessary to prove this concept and commercialize this technology are: Step I - laboratory-scale investigation to validate the concept; Step II - scale-up investigation in a commercial tile manufacturing facility; Step III - address the parameters and develop data necessary for commercialization of this technology; and Step IV - implementation of this technology to manufacture commercial tiles.

Step I was completed successfully in last year's program. The accomplishments made in that program clearly indicated the great potential of fly ash to be an effective replacement for the raw materials used in manufacturing ceramic tiles. It has also been demonstrated that such fly ash utilization is technologically possible without compromising any of the characteristics of commercial tiles, as prescribed by the Tile Council of America. However, actual utilization potential depends upon the success in demonstrating that similar results can be achieved in a commercial tile manufacturing plant. In order to accomplish this objective, Step II has been undertaken as the focus of the present investigation.

M.E. Tile Co., an Illinois tile manufacturing plant located in Harvey, Illinois, collaborated with us in accomplishing the goal of this year's program. It is a specialty tile manufacturer, and produces 600 different kinds of tiles primarily using two methodologies, slip casting and wet pressing, and has more than 150 different glazes in their product line.

The production process used in the last year's program is commonly known as dry pressing. Although the slip casting and wet pressing processing approaches undertaken in this year's program are different, each methodology is used to achieve the same goal. A successful completion of this program proves that all three approaches are equally applicable in manufacturing fly ash-based tiles.

Slip Casting

An aqueous slurry containing fine clay particles in suspension is traditionally known as slip. In this procedure, a self-supporting shape, called cast, is produced by pouring the specially formulated slip into a permeable gypsum mold to partially remove the water. The cast is then dried and later fired to make tile bodies. A number of parameters, both physical and chemical, influence the quality of the slip.

The slip casting procedure followed here is the same as those used by M.E. Tile Co. The starting composition was similar to that used by M.E. Tile Co. except that two-thirds of the raw mix was replaced by Baldwin fly ash. The addition levels of fly ash and the rest of the ingredients were varied, and numerous slips were made to evaluate the slip characteristics. Initially, substantial difficulty was encountered in forming a good slip when this formulation was used. Slip characteristics were also evaluated upon separation of approximately 8% magnetic material from the Baldwin fly ash. However, with the introduction of a few commonly available inexpensive additives, stable slips were made with fly ash contents varying from 10 to 87%.

Although stable slips with desired pourable characteristics were developed, adhesion to gypsum molds used for forming tile bodies was occasionally encountered. A battery of parameters were investigated to overcome the problem of adhesion, which could interfere with the quality control process. The recent results obtained from this strategic investigation indicate that the adhesion may not be caused by any chemical reactions between the cast and the mold. Rather, it may be attributed to the characteristics of the slip. Based upon the knowledge developed in this investigation, significant improvement has been made, and a number of fly ash tile bodies have been prepared by slip casting.

Wet Pressing

In wet pressing, relatively less water is used, and the resulting material has consistency of putty. This procedure has the advantage of higher production rates, while the intricate surface designs of tiles are adequately reproduced. Upon pressing, the mix flows and takes the shape of the mold, and the tile body is formed.

The solid ingredients used for wet pressing contained over 70% fly ash. The solids were mixed with water, vacuum extruded to form a cylinder, which was then cut and pressed to form tile bodies. These bodies were then air-dried before firing and glazing.

Clay tiles made of M.E. Tile formulations were also produced at the same time for comparison. The firing shrinkage of the fly ash tiles was less than those of the clay and talc-based tiles, and indicates the superior dimensional stability of fly ash-based tiles. The water absorption of wet pressed tiles were also approximately 7% lower than those of clay and talc-based tiles. The lower water absorption of fly ash-based tiles is a positive feature as this brings the promise of making tiles for floor and outdoor applications.

Glazing

Although mostly aesthetic, glazing is an important step in tile manufacturing, and often a significant research effort is required to develop glazing compositions for a particular tile body. Glazing also improves the surface durability of tiles. A glaze is a special glass designed to melt on the surface of a ceramic body and to stay adhered upon cooling. Various glaze defects may occur due to mismatch of the thermal expansion of the glaze and the tile body.

In a preliminary investigation, the wet pressed fly ash-based tiles were glazed with sixteen different colors and textures using glazing compositions that are commercially available for the ceramic tile industry. It is quite encouraging to note that the thermal expansion coefficients of the fly ash tile bodies and those of the glazes used are very

close. The photographs of a few of these tiles are shown in Figures 1-12, and a few have been delivered to ICCI for demonstration.

The results obtained in this program demonstrate that fly ash tiles are similar to clay tiles in many respects. The concept of making tiles with high fly ash contents is, therefore, very realistic and can be achieved using the facilities and equipment that exist within commercial tile manufacturing plants.