Dr. Mei-In M. Chou
hemist

Illinois State Geological Survey

Fired Bricks from Fly Ash

Manufacturing Commercial Brick with Fly Ash from Illinois Coals

The overall goal of the brick manufacturing project at the Illinois State Geological Survey (ISGS) and University of Illinois (UIUC) is to develop processes for making fired bricks commercially using Illinois coal fly ash as one of the raw materials. This fly ash is currently being ponded or landfilled. The development and marketing of commercial bricks made with fly ash should benefit the Illinois coal industry, utilities, and brick manufacturers by reducing the amount of discarded fly ash and by providing an economical brick ingredient.

Fly ash incorporation has been previously studied worldwide using various compositions and sources of fly ash, but no previous studies used Illinois coal fly ash. The few United States studies incorporating fly ash from bituminous coals used a technology that is not easily adopted by the brick industry.

For several years, researchers at the ISGS/UIUC have been working with commercial brick manufacturers to develop high-quality, marketable brick products that use large volumes of Illinois Class F fly ash. This research and development project is funded by the Illinois Department of Commerce and Economic Opportunity through the Illinois Clean Coal Institute (DCEO/ICCI). Participating brick manufacturers include Global Clay Marseilles (now Glen-Gery), J.C. Steel and Son, Colonial Brick Company, Richards Brick Company, and Streator Brick Company. Participating electrical utilities include Ameren CIPS, Central Illinois Light Company, and Dynegy Midwest Generation, Inc. With the collaboration of the industrial sector, the new technology developed in this project is nearing commercialization. The commercial brick producers involved are all interested in expanding their facilities, and one major brick company in Illinois is considering building a new brick plant near a power plant in order to produce fly ash bricks commercially.

Figure 1 Five thousand full-size bricks made in commercial-scale run using a beehive kiln.

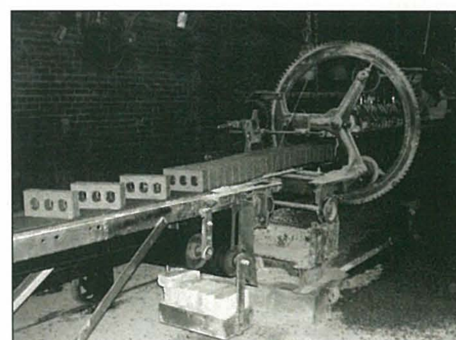

Figure 2 Green fly ash bricks exiting the cutter.

Project developments were reported in the Champaign *News-Gazette* (January 6, 2002 and July 28, 2003). In May 2002, ISGS photographs and fly ash bricks from a commercial production run (Figures 1, 2, and 3) were used by the Chicago Museum of Science and Industry as part of its updated Illinois Clean Coal Technology exhibit. The commercialization opportunities are described at the DCEO Web page (http://www.commerce.state.il.us/coal/index.html).

Figure 3 Bar containing Illinois fly ash, exiting the extruder and ready to move into the cutter.

Fly Ash Generation

Combusting coal in a boiler generates ash as a by-product. The heavier ash particles (bottom ash) remain in the boiler, but the lighter particles (fly ash), carried by the flue gases, are captured in an electrostatic precipitator. According to a report by the American Coal Ash Association, about 71 million tons of fly ash were generated in the United States during 2001. In Illinois, about 3 million tons of fly ash are generated each year.

	Fly Ash-1	Fly Ash-2	Clay	Shale
SiO_2	51.06	51.88	57.69	62.02
Al_2O_3	18.78	21.05	22.38	16.2
Fe_2O_3	12.3	10.33	2.4	6.73
$SiO_2 + Al_2O_3 + Fe_2O_3$	82.14	83.26	82.47	84.95
CaO	4.54	3.17	0.35	0.51
MgO	1.07	0.99	0.63	1.83
Na_2O	0.92	1.41	0.04	0.92
K_2O	2.46	2.4	1.64	3.1
S	0.35	0.34	0.67	0.61
Loss on ignition	5.92	6.04	8.13	4.61

Table 1 Chemical composition (wt%) of fly ash, clay, and shale.

Characteristics of Illinois Coal Fly Ash

The American Society for Testing and Materials (ASTM) classifies fly ash as Class C or Class F according to ASTM standard C618 (Standard Specification for Coal Fly Ash and Raw or Calcined Pozzolan for Use as a Mineral Admixture in Concrete). Class C fly ash, normally produced by burning lignite or subbituminous coal, contains a minimum of 50 wt% of SiO_2, Al_2O_3, and Fe_2O_3 combined. Class C fly ash has pozzolanic and some cementitious properties that make it unsuitable for making bricks. Class F fly ash, normally produced by burning anthracite or bituminous coal, contains a minimum of 70 wt% of SiO_2, Al_2O_3, and Fe_2O_3 combined. The fly ash generated from burning Illinois bituminous coal is Class F fly ash, which has pozzolanic properties. The content of major metal oxides in Class F fly ash is similar to that of the clay and shale generally used to make fired bricks (Table 1), so the substitution of fly ash for a portion of the clay has little effect on the chemical composition of the materials.

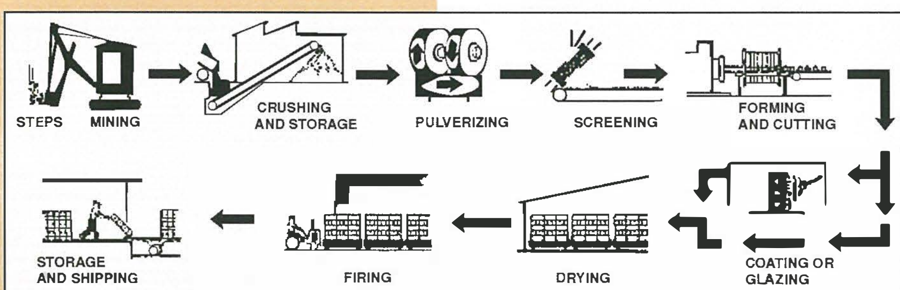

Figure 4 Fired brick manufacturing steps.

Fired Brick Production

The brick-making process typically consists of these steps: (1) mining, (2) crushing and storage, (3) pulverizing, (4) screening and mixing of the raw materials, (5) forming and cutting, (6) drying, (7) firing, and (8) storage and shipping of the fired bricks. Coating and glazing are optional steps carried out after forming and cutting based on market demands (Figure 4). Because fly ash is a fine, powdery material that is readily available from power plants, substitution of fly ash for some of the clay and shale in bricks reduces the first three brick-making steps (mining, crushing and storage, and pulverizing), thereby reducing overall production costs.

ISGS/UIUC Project: Making Fired Bricks from Fly Ash

Laboratory Tests (2000–2001)

A laboratory facility at Global Clay Marseilles (GCM; now Glen-Gery Brick Company) was used to perform the initial project tests. Fly ash obtained from several power plants burning Illinois coals was substituted for parts of the clay and shale that were the two main ingredients of GCM's conventional bricks. The tests focused on determining (1) the chemical and physical properties and unburned carbon contents of the raw fly ashes and of GCM's clay and shale materials and (2) the optimal fly ash/shale/clay formulations and additives for successful extrusion and firing. More than 700 bar-size test bricks were extruded substituting 20 to 70 wt% of fly ash for the clay or shale in GCM's standard clay-rich and shale-rich raw material formulations. All test bricks made with fly ash met or exceeded standard water absorption (<8%) and compressive strength specifications (<0.78) for building bricks intended for severe weather applications (Figures 5 and 6). The bricks made with fly ash had better heat insulation properties than bricks made without fly ash (Figure 7). The results were so encouraging that scale-up test runs were conducted. Results of a market survey and preliminary economic analysis were also promising.

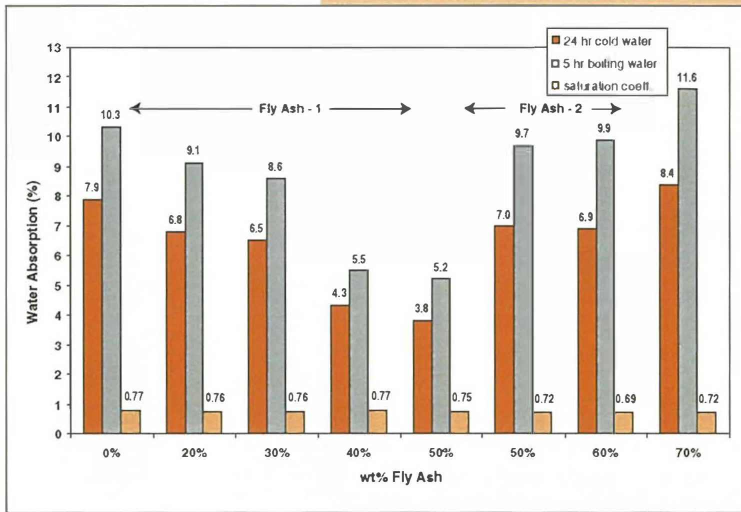

Figure 5 Water absorption properties of bar-size test bricks met ASTM specifications.

Pilot-Plant Tests (2001–2002)

In order to avoid interfering with GCM's commercial production schedule, the pilot-plant extrusion facility at J.C. Steel and Son in North Carolina was used in addition to GCM's in-plant firing facility. Four pilot-plant tests (about 300 bricks per test) were conducted and evaluated. More than 1,000 full-size bricks were produced with fly ash from two Illinois sources in both dry and ponded forms balanced with GCM's clay and shale. Fly ash was substituted for clay and shale at 40 wt% and 50 wt% levels. To address problems such as scum, lime pops, black cores, and bloating, which arose during pilot-plant tests, ISGS established a small-scale facility that included a mixer, a pug mill, a mold press, and a kiln. More than 200 mold-pressed, full-size green and fired bricks were made at this facility for evaluation. After concerns and problems were addressed, a new pilot-scale batch of full-size fired bricks was successfully produced (Table 2 and Figure 8).

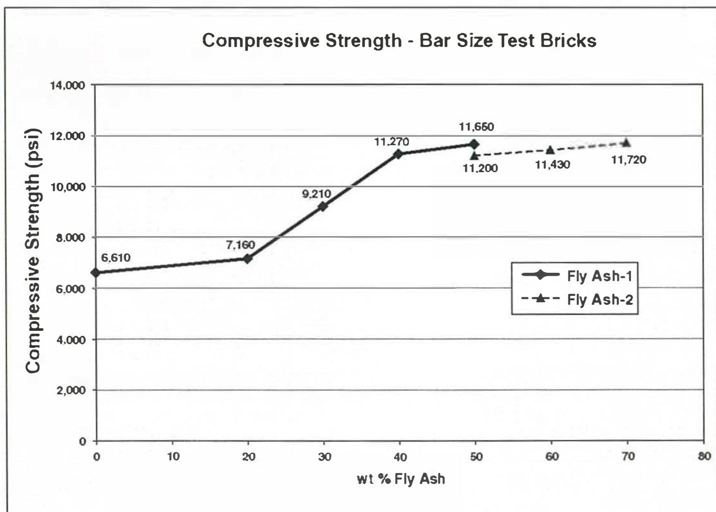

Figure 6 Compressive strength of fired bricks increases as the amount of fly ash increases.

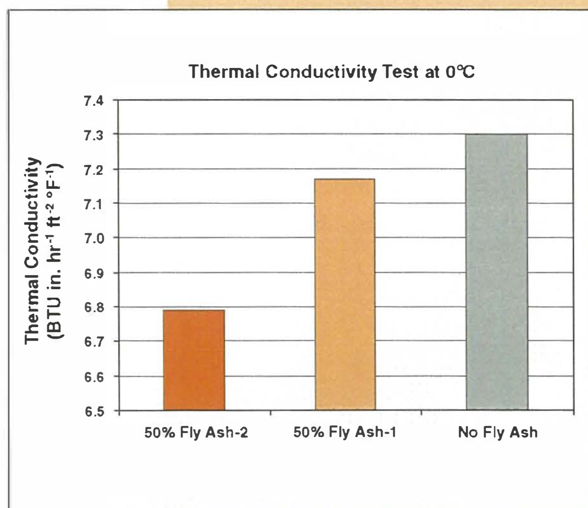

Figure 7 The bricks made with fly ash had better heat insulation properties than bricks made without fly ash.

Commercial-Scale Production and Commercialization (2002–2003)

Commercial-scale production tests are in progress. The first test used a beehive kiln at Colonial Brick Co. in Indiana (Figures 1, 2, and 3). From May 2002 to August 2002, about 15,000 full-size three-hole building bricks and 2,000 no-hole paving bricks were produced for evaluation. The building bricks contained 20, 30, or 40 vol% of fly ash from two different Illinois sources, and the paving bricks produced contained 20 vol% of fly ash from one of these two sources. Both the building and paving bricks met the ASTM standard specifications (data not shown). The second test used a tunnel kiln at Streator Brick Company in northern Illinois. In June 2003, we successfully extruded and fired 2,800 ten-hole building bricks containing 10 and 20 wt% of fly ash (Figure 9). Further tests at Streator Brick Company incorporat-

Table 2 Compressive strength of pilot- and commercial-scale bricks containing 40% fly ash.

40% Fly Ash Brick	Compressive Strength, psi
Pilot scale	12,930
Commercial scale (three-hole)	15,770

Illinois State Geological Survey

ing higher levels of fly ash substitution are planned. The ISGS/UIUC has the technology and expertise to assist industry with commercialization of the process. Since quality of the bricks produced with fly ash depends on the sources and properties of the fly ash and the operation parameters of a specific brick plant, feasibility evaluation should be conducted on a case by case basis.

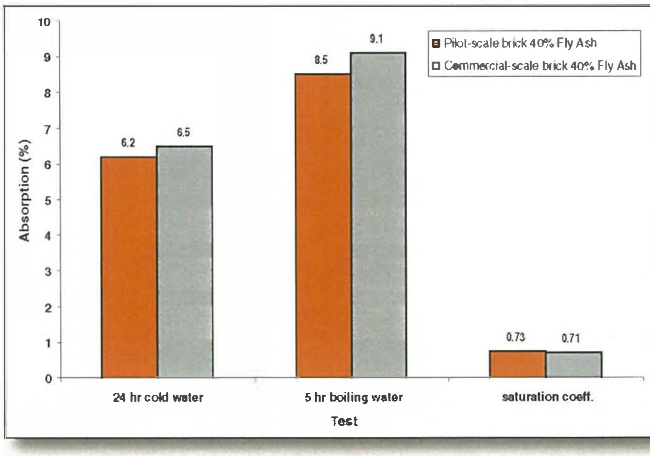

Figure 8 The water absorption properties of pilot-scale and commercial-scale bricks met ASTM specifications.

The ISGS/UIUC team is led by Mei-In (Melissa) Chou, Principal Investigator. Co-investigators are Sheng-Fu J.Chou (ISGS), Vinod Patel (ISGS), and Joseph W. Stucki (UIUC). Francois Botha is the Project Manager of the ICCI, and Daniel Wheeler is the Technical Program Coordinator of the DCEO. This research and development project is administrated by Robert J. Finley, Energy and Earth Resources Center Director, Jonathan H. Goodwin, Assistant to the Chief; and William W. Shilts, Chief.

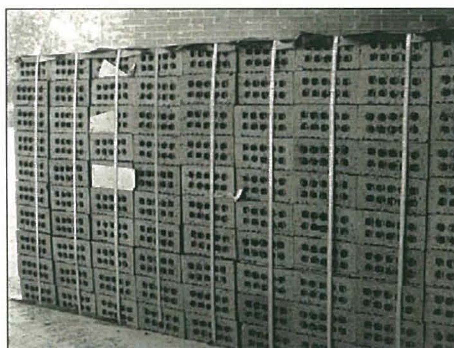

Figure 9 Full-size bricks made in a commercial-scale run using a tunnel kiln.

Illinois Department of Natural Resources

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Published by the Illinois State Geological Survey, a Division of the Illinois Department of Natural Resources

Rod R. Blagojevich, Governor
Joel Brunsvold, Director
Illinois Department of Natural Resources

William Shilts, Chief
Illinois State Geological Survey
615 East Peabody Drive
Champaign, Illinois 61820-6964
(217) 333-4747
http://www.isgs.uiuc.edu

Printed by authority of the State of Illinois
1M-2003

Printed on recycled paper with soybean ink.

Illinois State Geological Survey
615 East Peabody Drive
Champaign, IL 61820-6964
Return service requested