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Producing Fired Bricks Using Coal Slag from a Gasification Plant in Indiana

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ABSTRACT
Integrated gasification combined cycle (IGCC) is a promising power generation technology which increases the efficiency of coal-to-power conversion and enhances carbon dioxide concentration in exhaust emissions for better greenhouse gas capture. Two major byproducts from IGCC plants are bottom slag and sulfur. The sulfur can be processed into commercially viable products, but high value applications need to be developed for the slag material in order to improve economics of the process. The purpose of this study was to evaluate the technical feasibility of incorporating coal slag generated by the Wabash River IGCC plant in Indiana as a raw material for the production of fired bricks. Full-size bricks containing up to 20 wt% of the coal slag were successfully produced at a bench-scale facility. These bricks have color and texture similar to those of regular fired bricks and their water absorption properties met the ASTM specifications for a severe weathering grade. Other engineering properties tests, including compressive strength tests, are in progress.

INTRODUCTION

Integrated gasification combined cycle (IGCC) technology converts coal and/or petroleum coke from a solid phase to a gas phase (consisting mainly of carbon monoxide and hydrogen), which is then burned in a gas turbine, to produce electricity.[1, 2] An important added advantage of the IGCC process is the greater concentration of carbon dioxide in the exhaust gases, which makes carbon capture easier and less costly than for ordinary coal-fired steam boilers, particularly if the plant uses an oxygen-blown system.[3, 4] Also, hydrogen produced from this process can potentially be used as a transportation fuel to generate electricity in fuel cells.[1, 5, 6] IGCC plants are not only cleaner than conventional coal fired power plants, but also have fuel flexibility, particularly the ability to use high-volumes of high-sulfur coal, such as Illinois Basin coals.[2, 7, 8] Gasification of coal and various petroleum products may become an important alternative to conventional coal fired power plants.

IGCC plants produce two major byproducts, bottom slag and sulfur. Currently, there are two IGCC plants in operation in the United States. Tampa Electric IGCC Power Plant located in Polk County, Florida, produces bottom slag and sulfur in sulfuric acid form, whereas, the Wabash River IGCC Power Plant in West Terre Haute, Indiana, produces bottom slag and sulfur in elemental sulfur form. These sulfur byproducts can be processed into commercially viable products, but the slag byproducts are used for low value applications. [9] Development of value-added applications for the slag byproduct can improve the economics of the IGCC technology.

Making fired bricks containing slag of the Tampa Electric IGCC Power Plant, generated from processing a mixture of Illinois Basin coal and petroleum coke, has been previously studied and the results were optimistic.[10] In this study, tests were conducted to determine the technical feasibility of making fired bricks using slag of the Wabash River IGCC plant previously generated from processing Illinois Basin coal. Full-size test bricks were produced by using the bench-scale facility at the Illinois State Geological Survey. The physical appearance, color, texture and water absorption properties of the final fired brick products were compared to regular bricks containing no slag material.

RAW MATERIAL PREPARATION AND SIZE CHARACTERIZATION

The IGCC slag sample and the processed clay and shale raw materials used in making conventional fired bricks were acquired from our industrial partners in bucket-size lots (about 40 pounds). The particles in the as-received slag sample were screened into four size fractions: greater than 8 mesh; - 8 to + 60 mesh; - 60 to +100 mesh; and -100 mesh, with a distribution of 30.2 wt%; 63.8 wt%; 3.6 wt% and 2.4 wt%, respectively (see Figure 1).

The raw feed clay and shale materials that we received had already been processed and run through an 8 mesh screen by a specific brick plant. The raw slag material was prepared by processing the as-received sample through a plate mill until all particles passed through an 8 mesh screen. The particle size distribution of the resulting slag material was reduced to 82 wt% between 8 and 60 mesh, 7.3 wt% between 60 and 100 mesh, and 11.2 wt% less than 100 mesh (see Figure 2).

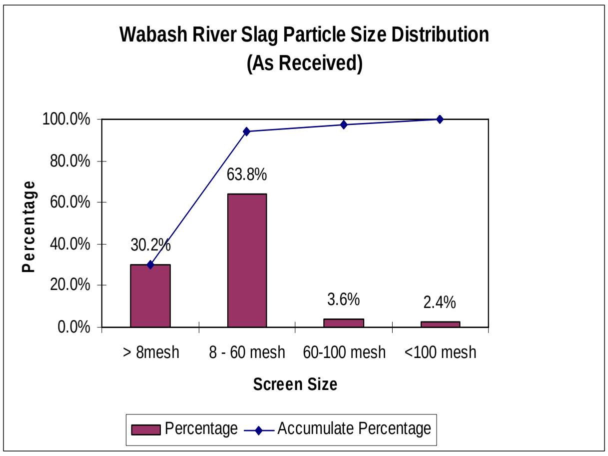

Figure 1: Particle size distribution of the as-received Wabash River slag sample

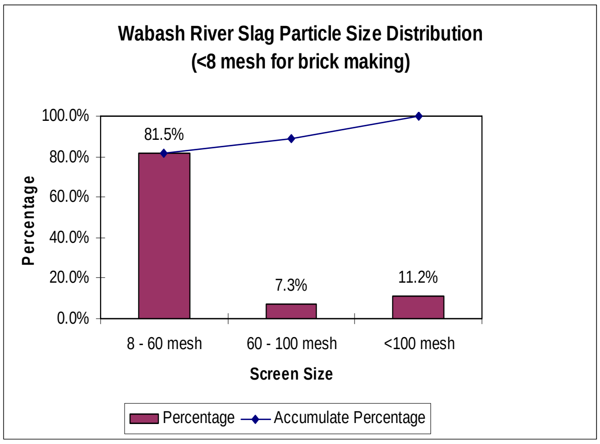

Figure 2: Particle size distribution of processed slag (< 8 mesh) for brick making

BRICK FORMULATION AND GREEN BRICK PRODUCTION

Small batches of full-size (4" x 2.5" x 8.25") green building bricks were produced using our proprietary mold pressed method. These green bricks were produced with the following three formulations:

No. 1	Clay: Shale	14%: 86%
No. 2	Clay: Shale: Slag	14%: 76%: 10%
No. 3	Clay: Shale: Slag	14%: 66%: 20%

All the bricks contained 14 wt% clay. Formulation No.1 contained the mix of clay and shale which is routinely used by a specific brick plant for their conventional bricks. Formulations 2 and 3 contained 10 wt% and 20 wt% slag, respectively, balanced by the shale. The green bricks thus produced were allowed to dry and then were fired using the bench-scale kiln at Illinois State Geological Survey. The firing program used was previously developed for firing bricks containing other solid waste materials, and had a maximum firing temperature of 1955°F.[11] Firing was completed successfully.

FINAL FIRED BRICKS EVALUATION

The total shrinkage, from green brick to fired brick, was measured. The conventional brick shrank 7.1 %, the brick containing 10 wt% slag shrank 4.6%, and the brick containing 20 wt% slag showed a total shrinkage of 0.7%. The results indicated that increasing the slag content significantly reduced the total shrinkage of the bricks.

The fired bricks were sawn in half (Figure 3) and analyzed for their color, appearance, texture, and marketability, based on the participating brick company's specifications. The fired bricks containing slag material had no scum, lime pops, cracks, black hearts or red hearts. They had the red fired color, physical appearance and texture similar to the conventional brick, and are marketable. However, the surfaces of a slag containing brick are rougher than that of a regular brick as seen in Figure 4. Some specific construction applications may benefit from the added surface roughness of the slag-containing bricks.

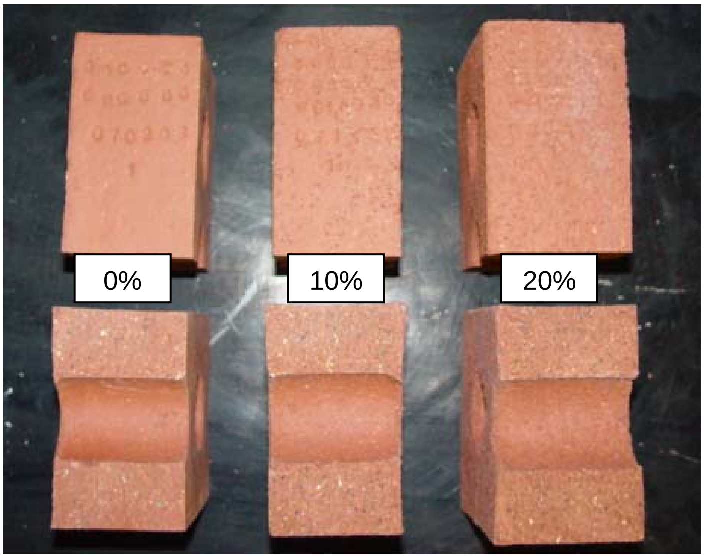

Figure 3: Cross sections of fired bricks containing 0%, 10%, and 20 wt% of slag.

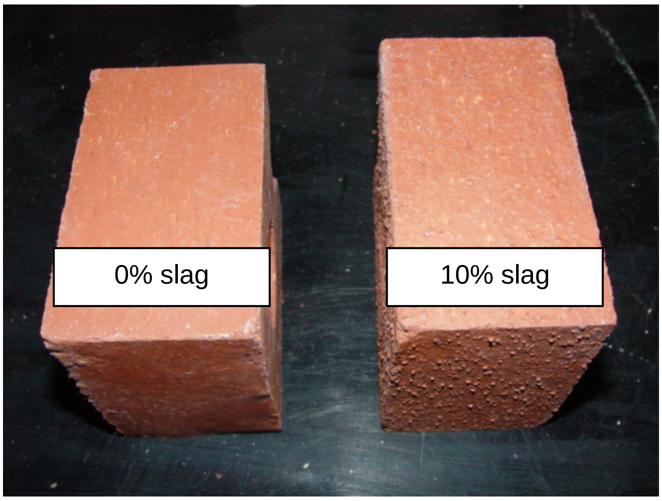

Figure 4: A close view of the surfaces of the conventional brick and a brick containing slag.

The cold water absorption and boiling water absorption capabilities of the final brick products were measured according to the ASTM C67 method, [12] and the data are listed in Table 1. These data were used to classify the bricks according to the ASTM C 62 classification (Table 2).[13]

As shown in Table 1, the bricks which contained slag material absorbed more cold water than the conventional brick. Similarly, the bricks which contained slag material tended to absorb more boiling water than the conventional brick. However, all the bricks had saturation coefficients less than 0.78 and met the ASTM C62 specification for the severe weathering (SW) grade.

Table 1. Water absorption test results and ASTM C62 classification

Brick Formulation	No. 1	No. 2	No. 3
Cold Water Absorption, %	6.15	7.95	10.04
Boiling Water Absorption, %	8.26	11.43	14.70
Saturation Coefficient	0.74	0.70	0.68
ASTM C62 Classification	SW	SW	SW

Table 2. ASTM C 62 specifications for building brick s

ASTM C 62 Class Designation	Minimum Compressive Strength, psi		Maximum 24-h Cold Water Absorption, 8 %*			
			Maximum 5-h Boiling Water Absorption, %		Maximum Saturation Coefficient**	
	5 Bricks Average	Individual Brick	5 Bricks Average	Individual Brick	5 Bricks Average	Individual Brick
Class SW	3,000	2,500	17	20	0.78	0.80
Class MW	2,500	2,200	22	25	0.88	0.90
Class NW	1,500	1,250	no limit	no limit	no limit	no limit

SW, MW, and NW denote severe weathering, moderate weathering, and normal weathering, respectively. * If the cold water absorption does not exceed 8 wt%, then the boiling water absorption, and saturation coefficient specifications are waived; ** The saturation coefficient is the ratio of absorption by 24 hour submersion in cold water to the absorption after 5 hour submersion in boiling water.

CONCLUSION AND RECOMMENDATION

The results of this study indicated that formulations containing 10 and 20 wt% coal slag generated by the Wabash River IGCC plant in Indiana can be used to produce high quality fired bricks. The bricks which contained slag material absorbed more cold water and boiling water than a conventional brick containing no slag material. However, the bricks containing slag material met the ASTM C62 specification for maximum allowable water absorption for the “severe weathering grade”. Measurement of the compressive strengths of the final brick products is in progress. Further studies on the economics of the process developed and the environmental impacts of using brick products made with IGCC slag are in order.

DISCLAIMER STATEMENT AND ACKNOWLEDGEMENTS

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