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Utilization of Lightweight Materials Made from Coal Gasification Slags

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Utilization of Lightweight Materials Made from Coal Gasification Slags

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Abstract

The integrated gasification combined-cycle (IGCC) coal conversion process has been demonstrated to be a clean, efficient, and environmentally acceptable method of generating power; however, it generates solid waste materials in relatively large quantities. For example, a 400-MW power plant using 4000 tons of 10% ash coal per day may generate over 440 tons/day of solid waste or slag, consisting of vitrified mineral matter and unburned carbon. The disposal of these wastes represents significant costs. Regulatory trends with respect to solid waste disposal, landfill development costs, and public concern make utilization of solid wastes a high-priority issue. As coal gasification technologies find increasing commercial applications for power generation or production of chemical feed stocks, it becomes imperative that slag utilization methods be developed, tested, and commercialized in order to offset disposal costs.

Praxis is working on a DOE/METC funded project to demonstrate the technical and economic feasibility of making lightweight and ultra-lightweight aggregates from slags left as solid by-products from the coal gasification process. These aggregates are produced by controlled heating of the slags to temperatures ranging between 1600 and 1900°F. Over 10 tons of expanded slag lightweight aggregates (SLA) were produced using a direct-fired rotary kiln and a fluidized bed calciner with unit weights varying between 20 and 50 lb/ft³. The slag-based aggregates are being evaluated at the laboratory scale as substitutes for conventional lightweight aggregates in making lightweight structural concrete, roof tiles, blocks, insulating concrete, and a number of other applications. Based on the laboratory data, large-scale testing will be performed and the durability of the finished products evaluated. Conventional lightweight aggregates are made from pyroprocessing of expansible shale or clay and sell at $30-40/ton. The net production costs of SLA are in the range of $22 to $24/ton. Thus, the technology provides a good opportunity for economic use of gasification slags.

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Utilization of Lightweight Materials Made from Coal Gasification Slags

Praxis Engineers, Inc.
Milpitas, California 95035

Funding Sources: METC, EPRI, and ICCI
Project Objectives

- Develop and demonstrate the technology for producing slag-based lightweight aggregates (SLA)
- Produce 10 tons of SLA Products with different unit weights from two slags
- Collect operational and emissions data from pilot-scale operations
- Laboratory- and commercial-scale evaluation of SLA with conventional lightweight and ultra-lightweight aggregates (LWA and ULWA)
Project Objectives (contd)

Characterize SLA products for leachability and conduct applications testing

Evaluate recovered char for recycle to the gasifier, and for use as a fuel during slag expansion or in the boiler

Conduct preliminary economics of SLA production
Slag, LWA, ULWA, & SLA: Definitions

➤ Slag is a solid residue by-product of coal gasification combined-cycle process.

➤ Gasification slag is vitrified ash containing some unconverted carbon.

➤ Conventional LWA:
- Produced by pyroprocessing clays and shales at 2100°F.
- Unit weight is 50 lb/ft³.
- Used to make lightweight structural concrete, blocks, and roof tiles.
Market price is $20-30/ton.
Definitions (contd)

- Conventional ULWA:
  - Produced by pyroprocessing perlite ores at 2000°F
  - Unit weight is 4-12 lb/ft³
  - Used for horticultural and insulation applications
  - Market price is over $200/ton

- Slag can be expanded under controlled conditions to produce lightweight materials, termed slag-based LWA or SLA:
  - Produced by pyroprocessing at 1600-1800°F
  - Unit weight is 12-50 lb/ft³
  - Blendable with existing raw materials
  - Can be substituted for all or part of the ingredients of some LWA and ULWA applications
MUFFLE BURN TESTS - EXTRUDED MIXTURES

50/50 MIX - COMPLETE CUP BURN - 1900°F
6" Diameter Bench-Scale Fluid Bed Reactor

Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bed Height</td>
<td>3 ft</td>
</tr>
<tr>
<td>Feed Height (Above Grid)</td>
<td>2 ft</td>
</tr>
<tr>
<td>Inside Diameter</td>
<td>0.5 ft</td>
</tr>
<tr>
<td>Temperature</td>
<td>+1420°C</td>
</tr>
<tr>
<td>Fuel</td>
<td>Gas/Oil</td>
</tr>
</tbody>
</table>

Reactor Section Detail

Material Flow

Gas Flow
3'x30' Rotary Kiln Schematic

- FILTER OUTLET TC/PT
- FILTER INLET TC/PT
- I.D. FAN
- FILTER
- GASIFIER SLAG FEED
- FIRING HOOD PT
- CHROMEL THERMOCOUPLES
- AIR + 
  #2 FUEL OIL
- DROP OFF
- SUPPORT ROLLERS
- PRODUCT
Stack Gas Analysis from Rotary Kiln Testing
14 November 1995
### SLA Products Made at Pilot Scale

<table>
<thead>
<tr>
<th>Slag/Size/ Mix Type</th>
<th>Direct-Fired Kiln lb/ft³</th>
<th>Fluidized Bed Expander lb/ft³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slag I: +10M</td>
<td>28-67</td>
<td>24-73</td>
</tr>
<tr>
<td>Char injection</td>
<td>--</td>
<td>16-26</td>
</tr>
<tr>
<td>Slag I: 10x 50M</td>
<td>34-58</td>
<td>--</td>
</tr>
<tr>
<td>Slag I: +50M</td>
<td>38</td>
<td>16-58</td>
</tr>
</tbody>
</table>

#### Extruded Slag I/Clay

| 80/20               | 27-62                    | --                          |
| 50/50               | 21-42                    | --                          |
| 0/100               | 18-41                    | --                          |

#### Slag I/Clay Granules

| 80/20 4 x 20M       | -                        | 30-60                       |
| 80/20 4 x 30M       | --                       | 37-42                       |
| 50/50 4 x 20M       | --                       | 31-65                       |
| 50/50 -8M           | --                       | 43-66                       |

| Slag II: +10M       | 22-82                    | --                          |

#### Slag II/Clay Granules

| 50/50 4 x 20M       | --                       | 33-63                       |
## Production Costs of SLA vs. LWA and ULWA ($/Ton)

<table>
<thead>
<tr>
<th>Cost Item</th>
<th>Shale/Clay LWA&lt;sup&gt;(1)&lt;/sup&gt;</th>
<th>Perlite ULWA&lt;sup&gt;(2)&lt;/sup&gt;</th>
<th>SLA&lt;sup&gt;(3)&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>Rotary Kiln</td>
<td>Vert. Shaft Furnace</td>
<td>Rotary Kiln</td>
</tr>
<tr>
<td>Fuel</td>
<td>011</td>
<td>Natl gas</td>
<td>Coal/char</td>
</tr>
<tr>
<td>Mining/prep</td>
<td>6.00</td>
<td>40.00</td>
<td>-</td>
</tr>
<tr>
<td>Transport</td>
<td>0.50</td>
<td>40.00</td>
<td></td>
</tr>
<tr>
<td>Clay binder</td>
<td></td>
<td></td>
<td>1.45</td>
</tr>
<tr>
<td>Labor</td>
<td>6.23</td>
<td>12.00</td>
<td>6.25</td>
</tr>
<tr>
<td>Fuel</td>
<td>5.09</td>
<td>8.00</td>
<td>1.64</td>
</tr>
<tr>
<td>Power</td>
<td>1.37</td>
<td>4.50</td>
<td>1.35</td>
</tr>
<tr>
<td>M&amp;S</td>
<td>1.85</td>
<td>3.00</td>
<td>1.48</td>
</tr>
<tr>
<td>Other</td>
<td>1.11</td>
<td>2.00</td>
<td>1.10</td>
</tr>
<tr>
<td>Overhead</td>
<td>2.24</td>
<td>10.00</td>
<td>-</td>
</tr>
<tr>
<td>Depreciate</td>
<td>5.71</td>
<td>4.75</td>
<td>4.28</td>
</tr>
<tr>
<td>Interest</td>
<td>excluded</td>
<td>excluded</td>
<td>6.85</td>
</tr>
<tr>
<td>Total</td>
<td>30.10</td>
<td>124.25</td>
<td>24.40</td>
</tr>
</tbody>
</table>

Estimated by (1) Fuller Co., (2) Silbrico, (3) Praxis/Fuller
Conclusions: Slag Processing

➤ Slag I was expanded to unit weights of 30-50 lb/ft\(^3\) and Slag II to 20-50 lb/ft\(^3\) by means of temperature control. Attempts to lower these further resulted in fusion which is a function of slag chemistry.

➤ The entire 1/4” x 50M fraction can be processed in the kiln as a single feed.

➤ Minus 50M fines must be extruded prior to kiln processing. Extruded pellets using 20-50% expansive clay binder yielded product unit weights of 27-33 lb/ft\(^3\) at 1800 -1900°F.
Conclusions: Char Utilization

- Char can be recovered from slag easily and used as a fuel

- A char product containing 45-54% ash was upgraded successfully to 70% carbon

- Char can be utilized as a substitute for 50% of the fuel in a rotary kiln and 80% of the fuel in a fluidized bed system
Conclusions: SLA Economics

- Expansion temperature for slag is 300-400 °F lower than that typically required for expansible clays and shales and represents significant energy savings.

- SLA production costs from a large (440 t/d) facility were estimated at $24.40/ton using rotary kiln and $21.87/ton using fluidized bed vs. $30.10/ton for conventional LWA plant.

- Preliminary analyses also indicate that small SLA plants can be economically attractive if the avoided costs of slag disposal ($10-$20/ton) are factored in.
Planned Product Evaluation (Phase II)

Commercial-scale testing of SLA as a substitute for LWA and ULWA in the following applications:

- Structural concrete using 3/4” coarse and 3/8” LWA
- Lightweight blocks (2-3 blends)
- Insulating concrete (ASTM C 332 Group II concrete, 45-90 lb/ft³)
- Lightweight roof tile aggregate
- Loose fill insulation (ASTM C 549)
- Horticultural applications