USE OF BLAST FURNACE SLAG AS A SUSTAINABLE MATERIAL IN CONCRETE PAVEMENTS

Shervin Jahangirnejad, Ph.D., Thomas Van Dam, Ph.D., P.E., FACI, LEED AP, Dennis Morian, P.E., Kurt Smith, P.E., Rohan Perera, Ph.D., P.E., Samuel Tyson, P.E.

INTRODUCTION

WHAT IS SLAG?
Slag materials are by-products of metallurgical processes that include metals production from ore and refinement of impure metals. They are residues from lime-based inorganic fluxes used in metal purification that solidify upon cooling.

TYPES OF FERROUS SLAG
- Iron Slag commonly known as Blast Furnace Slag (BFS)
- Steel-making Slag commonly known as Steel Slag

WHAT IS BFS?
Blast furnace slag is a non-metallic product made of silicates, aluminosilicates of calcium, and other bases and is developed in a molten condition together with iron in a blast furnace.

TYPES OF BFS
- Air-Cooled BFS (ACBFS)
- Expanded BFS
- Granulated BFS
- Pelletized BFS

PAVEMENT-RELATED BFS APPLICATIONS
- Graded aggregate bases for pavements
- Plain and reinforced concrete aggregates
- Macadam surfaces and bases
- Backfill
- Slope protection
- Lightweight base or fill
- Cement manufacturing
- Highway base and subbase

CHEMICAL COMPOSITION OF ACBFS

<table>
<thead>
<tr>
<th>Component</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Components</td>
<td>95</td>
</tr>
<tr>
<td>Lime (CaO)</td>
<td>30 – 40</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>28 – 42</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>5 – 22</td>
</tr>
<tr>
<td>Magnesia (MgO)</td>
<td>5 – 15</td>
</tr>
<tr>
<td>Minor Components</td>
<td>5</td>
</tr>
<tr>
<td>Sulfur (CaS, other sulphides, sulfates)</td>
<td>1 – 2</td>
</tr>
<tr>
<td>Iron (FeO, Fe₂O₃)</td>
<td>0.3 – 1.7</td>
</tr>
<tr>
<td>Manganese (MnO)</td>
<td>0.2 – 1</td>
</tr>
<tr>
<td>Rare Components</td>
<td>0 – 1</td>
</tr>
</tbody>
</table>


REFERENCES


PHYSICAL PROPERTIES OF ACBFS

<table>
<thead>
<tr>
<th>Property</th>
<th>ACBFS Aggregate</th>
<th>Natural Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particle Shape and Texture</td>
<td>Angular and roughly cubical with rough texture</td>
<td>Well rounded, smooth (gravel) to angular and rough (crushed stone)</td>
</tr>
<tr>
<td>Specific Gravity</td>
<td>2.0 – 2.5</td>
<td>2.4 – 2.9</td>
</tr>
<tr>
<td>Absorption Capacity</td>
<td>1 – 8 percent</td>
<td>0.8 – 3.7 percent</td>
</tr>
<tr>
<td>Angle of Friction</td>
<td>40 – 45 degrees</td>
<td>30 – 45</td>
</tr>
<tr>
<td>Loss of Mass Using LA Machine</td>
<td>35 – 45 percent</td>
<td>15 – 30 percent</td>
</tr>
<tr>
<td>California Bearing Ratio</td>
<td>&gt; 100</td>
<td>80 – 100</td>
</tr>
<tr>
<td>Mohs Hardness</td>
<td>5 – 6</td>
<td>3 – 8</td>
</tr>
</tbody>
</table>

ACBFS SUSTAINABILITY FEATURES

Making effective use of ACBFS rather than disposing of it as waste, leads to economic, environmental, and social benefits. Therefore, the suitable use of ACBFS has positive impacts on sustainability.

Economic Benefits:
- The beneficial use of ACBFS is an economic advantage for:
  - The iron producers who financially profit from the sale of the material while avoiding disposal costs.
  - The direct user of ACBFS (e.g., ready-mix producer, contractor) because ACBFS is a relatively inexpensive reclaimed aggregate compared to most naturally-derived material.
  - The client/public who realizes overall cost savings due to the reduced price of the material during initial construction.

Environmental and Social Benefits:
- Examples of environmental benefits:
  - Less natural material needs to be mined, transported, and processed when ACBFS is used. This means reduced disturbances of the land, energy consumption and pollution and greenhouse gases generation from mining and transportation of natural aggregate.
  - Increasing use of ACBFS also leads to reduced waste production, resulting in less storage of materials in unsightly stockpiles or requiring disposal in permanent landfills.

CONSIDERATIONS IN USING ACBFS IN CONCRETE AS A COARSE AGGREGATE

- Effects of Chemical Composition and Physical Properties
  - Iron and Dicalcium Silicate Unsoundness
  - Calcium Sulfide
  - Texture
  - Absorption
  - Specific Gravity

- Effects on Fresh and Hardened Concrete
  - Workability, Air Content, and Unit Weight
  - Strength and Modulus Values
  - Concrete Coefficient of Thermal Expansion
  - Freeze-Thaw Durability
  - Surface Friction

- Design Considerations

CONCLUDING REMARKS

The considerations presented in this poster are expected to contribute to improved performance for concrete pavements incorporating ACBFS coarse aggregate. Nevertheless, they are subject to further development and refinement as more definitive long-term studies of ACBFS concrete pavement performance become available.

CONSTRUCTION CHARACTERISTICS

- Concrete Production
- Placement
- Curing
- Joint Sawing
- Construction Quality Control

CONSTRUCTION MATERIALS

- Use of Air-Cooled Blast Furnace Slag as Coarse Aggregate in Concrete Pavements—A Guide to Best Practice

FHWA REPORTS

- Use of Air-Cooled Blast Furnace Slag as Coarse Aggregate in Concrete Pavements—A Guide to Best Practice

REFERENCE