Sustainable Paving with Slag Cement

Henry B. Prenger, P.E.
Lafarge Cement
Back in the Day
Bethlehem Steel Corporation
Sparrows Point Plant
Bethlehem’s ‘L’ Blast Furnace
Opening a Tap-Hole on ‘L’ Furnace
Grinding Mill
Reduced CO₂ to Produce Concrete and Concrete Products

Carbon Dioxide Emissions (lb/cy)

- RM 3000 psi: 385, 269, 220
- RM 5000 psi: 555, 382, 307
- Precast: 812, 550, 438
- Block: 367, 260, 213

- 100% Portland
- 35% Slag
- 50% Slag
Percentage Savings
Material, Energy and Greenhouse Gas

<table>
<thead>
<tr>
<th></th>
<th>Virgin Material</th>
<th>Energy</th>
<th>Carbon Dioxide</th>
</tr>
</thead>
<tbody>
<tr>
<td>3ksi RM 50% Slag</td>
<td>7%</td>
<td>30%</td>
<td>43%</td>
</tr>
<tr>
<td>5ksi RM 50% Slag</td>
<td>10%</td>
<td>34%</td>
<td>45%</td>
</tr>
<tr>
<td>Precast 50% Slag</td>
<td>15%</td>
<td>37%</td>
<td>46%</td>
</tr>
<tr>
<td>Block 50% Slag</td>
<td>6%</td>
<td>29%</td>
<td>42%</td>
</tr>
</tbody>
</table>
Blue Circle Cement Executive Team, U.K.
Glo Bull Warming
What's new

Lafarge is looking back at the Copenhagen conference and reaffirming its commitment to the fight against climate change.

Copenhagen 2009 - time to take stock

"The low-carbon economy: it's time to start building."
- Bruno Lafont

Low-energy housing

Reduction of CO2 emissions: 18%
Energy efficiency: 13%
Natural resources: 10%
Safety & security: 6%
Comfort & quality of life: 6%
Not affected to sustainable construction: 47%
Performance Benefits

- Improved strength
  - Increased psi per pound of cementitious material
- Improved durability
  - Reduced permeability
  - Increased resistance to ASR
  - Increased resistance to sulfate attack
- Increased life cycle
Portland Cement Reaction

Portland Cement + Water → Calcium-Silicate Hydrate + Calcium Hydroxide
Slag Cement Reaction

Slag Cement + Water \rightarrow Calcium-Silicate Hydrate

More Calcium-Silicate Hydrate

Slag Cement + Water + Calcium Hydroxide \uparrow
From Portland Cement

From Portland Cement
Slag Cement Reaction

Aggregate

Portland Cement

Slag Cement

Aggregate

Calcium Silicate Hydrate

Voids

Portland Cement Slag Cement Concrete System

Portland-Slag Cement Concrete System

Lafarge graphic standards for slide shows / Corporate Communications Department
June 2000
Compressive Strength

28 Day Compressive Strength

- 517 Cementitious Factor
- 564 Cementitious Factor
- 658 Cementitious Factor

psi

Straight Portland 25% Slag 50% Slag
Cement 25% Slag 50% Slag
Cement 25% Slag 50% Slag
Cement

June 2000
Flexural Strength

28 Day Flexural

- 517 Cementitious Factor
- 564 Cementitious Factor
- 658 Cementitious Factor

psi

Straight Portland, 25% Slag Cement, 50% Slag Cement, Straight Portland, 25% Slag Cement, 50% Slag Cement, Straight Portland, 25% Slag Cement, 50% Slag Cement
Time of Set Characteristics

- **Initial, 50 F**
- **Initial, 73 F**
- **Initial, 90 F**

```
Slag Cement Replacement (%)

<table>
<thead>
<tr>
<th>Time of Set (Hours)</th>
<th>0%</th>
<th>30%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

---

LaFARGE NORTH AMERICA

Lafarge graphic standards for slide shows / Corporate Communications Department  June 2000
George Bush Intercontinental Airport
George Bush Intercontinental Airport

- 83,300 cubic yards mainline a runway
- Approximate Savings
  - Material saved 10,200 metric tons
  - Energy saved 29,155 mbtu
  - Reduced carbon footprint
    9,400 metric tons of CO₂
- Life Cycle 365
  - 120 years service life
Florida I-95

- 120,000 cubic yards of mainline paving
- 60% slag cement replacement
  - 11.1 m lbs. not extracted from the earth
  - 44.0 mbtu power saved
  - Carbon footprint lowered by 33 m lbs. of CO₂
Andrews Air Force Base
US Route 1 - Delaware
CONCRETE PAVING PROJECTS USING SLAG CEMENT

Runways and Taxiways, Atlanta Hartsfield, Atlanta, GA
Apron and Taxiways, Baltimore-Washington International, Baltimore, MD
Aircraft Parking Apron, Myrtle Beach, SC
Apron Parking, Oceanna, Naval Base, Norfolk, VA
Apron Paving, Langley AFB, VA
Airport Taxiways, Norfolk, VA
Apron and Taxiways, Charlottesville, VA
Terminal Paving and Taxiway, Richmond, VA
Runway Paving, Salisbury, MD
Second Runway and Taxiways, Raleigh-Durham, NC
Runway and Taxiway, Seymour Johnston AFB, NC
Runway and Taxiways, Savannah, GA
Apron and Taxiways, Reagan National, Washington, DC
Apron and Taxiways, Dulles International, Chantilly, VA
Taxiways, Newark, NJ
Apron and Taxiways, Andrews AFB, MD
Apron and Taxiways, Patuxent Naval Air Station, MD
Taxiways, Hunter Field, GA
Air Cargo Apron Paving, Norfolk, VA
Apron and Taxiways, Manchester, NH
Apron Paving, Boston, MA
Apron and Taxiways, Martin State Airport, Essex, MD
Runway and Taxiways, Dover AFB, DE
I-684, Hampton, VA
 State Route 128, DE
I-95, Fredericksburg, VA
 State Route 1, DE
I-97, Baltimore, MD
US 113, Sussex County, DE
I-64, Hampton, VA
Route 23 @ Route 30, Lancaster, PA
I-295, Jacksonville, FL
State Route 300, GA
I-80, Columbia and Luzerne Counties, PA
I-895, Richmond, VA
I-95, SC
I-66, VA
I-495, DE
Conclusions

Slag cement makes concrete more sustainable

- Improved project life cycle
- Lower mined material use
- Lower embodied energy and emissions
- Lower urban heat island impact