QUALITY ASSURANCE & TRANSPORTATION OF CCP’s

Dave Diedrick
Lafarge
May 2, 2008
Our Goals:

- Basics of Fly Ash as a Cementitious Material
  - Classification
  - Quality Assurance
  - Performance
  - Markets & Transportation of CCP’s
Our Goals:

- Basics of Fly Ash Production
  - Coal
  - Combustion
  - Collection
Where Does Fly Ash Come From?

Coal → Pulverizer → Boiler → Precipitator → Silo

Factors that effect fly ash quality:

• Type of coal
• Fineness of pulverization
• Type of boiler
Coal Combustion

- Coal – stored chemical energy
- Processing – pulverizing
- Combustion – release of energy
- Combustion by-products – flue gases, mineral residue
Fly Ash Collection

- Electrostatic Precipitators
- Baghouses – Fabric Filters
- Hoppers
- Storage Silos
What is Fly Ash?
Fly Ash

Pozzolan

Coal Combustion Product

Supplementary Cementitious Material

Mineral Admixture

Finely Divided Material
Fly Ash

Finely divided residue resulting from the burning of coal at coal fired power plants.
Cement & Cementitious Materials

- Cement – Manufactured
- Slag – By-product/Manufactured
- Fly Ash – By-product
Standards for Fly Ash in Concrete

- **ASTM C311**
  - Standard test method for sampling and testing fly ash or natural pozzolans for use as a mineral admixture in Portland Cement Concrete

- **ASTM C618**
  - Standard specification for coal fly ash and raw or calcined natural pozzolan for use as a mineral admixture in concrete
ASTM C 618 Classification

- **Class F**
  - ASTM C 618 requires:
    - $\text{sum of } \text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{FeO}_3, \text{ min } \% = 70.0$
  - Technically class F also meets class C

- **Class C**
  - ASTM C 618 requires:
    - $\text{sum of } \text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{FeO}_3, \text{ min } \% = 50.0$
  - Some consider class C if over 10% CaO
Class C Fly Ash

- Normally produced from burning lignite or subbituminous (western) coal
- Higher calcium oxide content, lower silicate content
- Not only pozzolanic, but has cementitious properties as well
- Light grayish buff to buff in color
- Higher density (specific gravity) 2.5 to 2.8
Class F Fly Ash

- Normally produced from burning bituminous (eastern) coal
- Lower calcium oxide content, higher silicate content
- Has pozzolanic, but no cementitious properties
- Light gray to dark gray in color
- Lower density (specific gravity) 2.2 to 2.5
Pozzolanic

Finely divided siliceous or siliceous and aluminous material which by itself possesses little or no cementitious value. However, in the presence of moisture, it will chemically react with calcium hydroxide at ordinary temperatures to form cementitious compounds.

\[
\text{Cement + Water} = \text{CSH (Glue)} + \text{CaOH}
\]

\[
\text{CaOH} + \text{Fly Ash} = \text{CSH}
\]
Cementitious

Finely divided material that in the presence of water will harden and gain strength over time.
<table>
<thead>
<tr>
<th></th>
<th>Portland Cement</th>
<th>Class F Fly Ash</th>
<th>Class C Fly Ash</th>
<th>Class C Fly Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂ (silicon dioxide)</td>
<td>21.1</td>
<td>40.6</td>
<td>52.3</td>
<td>40.6</td>
</tr>
<tr>
<td>Al₂O₃ (aluminum oxide)</td>
<td>4.8</td>
<td>11.8</td>
<td>20.4</td>
<td>18.7</td>
</tr>
<tr>
<td>Fe₂O₃ (iron oxide)</td>
<td>2.2</td>
<td>1.4</td>
<td>7.2</td>
<td>6.4</td>
</tr>
<tr>
<td>CaO (calcium oxide)</td>
<td>63.8</td>
<td>38.6</td>
<td>3.4</td>
<td>16.9</td>
</tr>
<tr>
<td>MgO (magnesium oxide)</td>
<td>4.2</td>
<td>4.6</td>
<td>0.98</td>
<td>4.2</td>
</tr>
<tr>
<td>SO₃ (sulfur trioxide)</td>
<td>2.9</td>
<td>0.2</td>
<td>0.92</td>
<td>2.7</td>
</tr>
<tr>
<td>Na₂O (sodium oxide)</td>
<td>0.61</td>
<td>0.11</td>
<td>0.96</td>
<td>1.68</td>
</tr>
<tr>
<td>K₂O (potassium oxide)</td>
<td>0.14</td>
<td>0.08</td>
<td>2.11</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Quality Assurance

- No control over the burning of the coal or over the type of coal burned
- Can be selective of fly ash used for concrete
  - Must meet ASTM C 618, State DOT, and applicable project spec
  - Must meet fly ash suppliers internal specifications
  - Must be consistent
Sampling Fly Ash

- **Grab**: a sample that is taken in a single operation from a conveyor delivering to bulk storage, from bags or from a bulk shipment.

- **Regular**: a sample that is constructed by combining equal portions of grab samples that were taken at predetermined times or locations from any single lot.

- **Composite**: a sample that is constructed by combining equal portions of grab or regular samples.
Minimum Sampling and Testing Frequency

- **Daily or every 400 tons:**
  - moisture content, LOI, fineness (retained on #325 sieve)

- **Monthly or every 3200 tons (C 618 Report):**
  - composite sample
  - SiO₂, Al₂O₃, FeO₃, SO₃, moisture content, LOI, fineness, strength activity, water requirement, soundness (autoclave expansion)
Daily Tests

- Moisture Content: percent of moisture based on mass lost during drying at 105 to 110° C
- Loss On Ignition (LOI): percent of material lost on ignition at 750 +/- 50° C (using material remaining from moisture content determination)
- Fineness: amount retained when wet-sieved on a 45-μm (No. 325) sieve
LOI (Loss on Ignition)

- Small sample of fly ash is ignited at 750 ± 50 degrees C
- The loss in mass is expressed as a percentage of the total initial mass
- LOI is an indication of the carbon content
- ASTM C 618: 6.0% max
  - 12% for class F based on acceptable service records or lab testing (don’t recommend) *
Fineness

- Amount retained on #325 sieve
- Amount retained considered too coarse to react
- ASTM C 618: 34% maximum retained
- Coarser = Less Reactive
The Foam Index test is used as an indicator of changes in the surface area (adsorption capacity) of carbon present in fly ash. These changes may adversely affect the entrained air content of concrete products.
Foam Index Testing Method

- Set amount of cement, fly ash and water or fly ash and water are introduced into a jar, capped and shaken
- Diluted drops of AE admix are added in small increments and shaken after each addition
- Determine how many drops are required to produce a stable foam on the surface
- The number of drops is the foam index
Foam Index

- Each ash source has a foam index baseline
- LOI may not change but foam index could fluctuate
- Consistency is key
Foam Index Over Time

Pleasant Prairie Unit 1 Foam Index versus time

Date

Foam Index in Drops
## ASTM C 618, Table 1

**Chemical Requirements**

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sum of SiO$_2$, Al$_2$O$_3$, and Fe$_2$O$_3$, min, %</strong></td>
<td>70.0</td>
<td>50.0</td>
</tr>
<tr>
<td><strong>SO$_3$, max, %</strong></td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td><strong>Moisture Content, max, %</strong></td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td><strong>LOI, max, %</strong></td>
<td>6.0</td>
<td>6.0</td>
</tr>
</tbody>
</table>
### ASTM C 618, Table 2

**Physical Requirements**

<table>
<thead>
<tr>
<th>Requirement</th>
<th>F</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness, max, %</td>
<td>34</td>
<td>34</td>
</tr>
<tr>
<td>Strength Activity Index, percent of control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>At 7 days, min</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>At 28 days, min</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Water Requirement, max</td>
<td>105</td>
<td>105</td>
</tr>
<tr>
<td>Soundness, Autoclave expansion or contraction, max, %</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>Uniformity requirements:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density, max variation from average, %</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Fineness, max variation percentage points from average</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>
Strength Activity & Water Requirement

- Mortar cubes vs. cement control
  - 20% fly ash by weight, equal flow
  - Water requirement as a percent of the control calculated

- ASTM C618
  - Strength Activity, min. % of control: 75% of control at 7 or 28 days (meeting 7 days satisfies C618)
  - Water Requirement, max. % of control: 105
Autoclave Soundness

- Hardened paste bars subjected to 420F at 300psi
- Low w/c ratio: 0.23
- Measurement of expansion or contraction
- Excessive expansion may result from free lime, free magnesium or cement/fly ash incompatibility
**FLY ASH SOURCE:** PLEASANT PRAIRIE  
**COMPOSITE DATE:** 11-Mar to 17-Mar.08  
**SAMPLE IDENTIFICATION:** PPX080311-0317  

### CHEMICAL ANALYSIS

<table>
<thead>
<tr>
<th>Component</th>
<th>SI</th>
<th>AL</th>
<th>FE</th>
<th>SiO₂+Al₂O₃+Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>SO₃</th>
<th>Moisture content</th>
<th>LOI</th>
<th>Na₂O</th>
<th>K₂O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon dioxide (%)</td>
<td>42.18</td>
<td></td>
<td></td>
<td>68.3</td>
<td>19.57</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.43</td>
<td>0.75</td>
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<tr>
<td>Aluminum oxide (%)</td>
<td>20.01</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Iron oxide (%)</td>
<td>3.34</td>
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<tr>
<td>SiO₂+Al₂O₃+Fe₂O₃ (%)</td>
<td></td>
<td></td>
<td></td>
<td>50 Min</td>
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</tr>
<tr>
<td>CaO (calcium oxide) (%)</td>
<td>50 Min</td>
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<tr>
<td>MgO (magnesium oxide) (%)</td>
<td>3.92</td>
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</tr>
<tr>
<td>SO₃ (sulfur trioxide) (%)</td>
<td>1.05</td>
<td></td>
<td></td>
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<tr>
<td>Moisture content, %</td>
<td>0.05</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loss On Ignition, %</td>
<td>0.70</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Na₂O (sodium oxide) %</td>
<td>1.43</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K₂O (potassium oxide) %</td>
<td>0.75</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### PHYSICAL ANALYSIS

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
<th>ASTM C 618</th>
<th>AASHTO M 295</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fineness, amount retained on #325 sieve, %</td>
<td>18.4</td>
<td>34 Max</td>
<td>34 Max</td>
</tr>
<tr>
<td>variation, points from average</td>
<td>1</td>
<td>5 Max</td>
<td>5 Max</td>
</tr>
<tr>
<td>Density, Mg/m³</td>
<td>2.53</td>
<td>5 Max</td>
<td>5 Max</td>
</tr>
<tr>
<td>variation from average, %</td>
<td>1</td>
<td>5 Max</td>
<td>5 Max</td>
</tr>
<tr>
<td>Strength Activity Index</td>
<td>109</td>
<td>75 Min</td>
<td>75 Min</td>
</tr>
<tr>
<td>with Portland Cement at 7 days, % of cement control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement: Lafarge Algoma Type IV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water Requirement</td>
<td>94</td>
<td>105 Max</td>
<td>105 Max</td>
</tr>
<tr>
<td>% of cement control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soundness, autoclave expansion or contraction, %</td>
<td>0.01</td>
<td>0.8 Max</td>
<td>0.8 Max</td>
</tr>
</tbody>
</table>

We hereby certify that the fly ash represented by the above chemical and physical analysis meets the requirements of ASTM C 618 and AASHTO M 295.

---

ASTM C 618 Note 5 - Finely divided materials may tend to reduce the entrained air content of concrete. Hence, if a mineral admixture is added to any concrete for which entrainment of air is specified, provision should be made to ensure that the specified air content is maintained or air content tests and by use of additional air-entraining admixture or use of an air-entraining admixture in combination with air-entraining hydraulic cement.

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Steven K. Butler  
Quality Assurance Manager  
Lafarge North America  
4/4/2008  
Report Date  
C-copy
Fly Ash Performance in Concrete

- Strength Development
- Air Entrainment
- Water Demand
- Time of Set
- Heat of Hydration
- ASR Mitigation
- Sulfate Resistance
Fly Ash is a coal combustion product that has pozzolanic or pozzolanic/cementitious properties that complement the properties of cement enhancing the durability and performance of concrete.
Summary

- Consistency – High quality fly ash is a uniform material with consistent chemical and physical properties.

Different fly ashes have different properties: difficult to make general statements about the properties of fly ashes.
CHALLENGE - Distributing the Product to the Market

- Once the material has been classified and QA has been performed the key is to then insure adequate supply to the market
  - Concrete
  - Non-Traditional (non-concrete)
  - Raw Feed
  - Etc
Fly Ash Production vs. Sales
Demand Curve

**Implications**

- Storage
- Market development (Non Traditional, Exports)
- Stockouts
Transportation
Fly ash application with Lafarge vane feeder
Ash Storage Operations
Traditional Silo Storage
Questions?