POZZOLAN BLENDING OBJECTIVES

- Individual materials are tested for chemical oxides, particle density and LOI.

- Objectives keep the sum of constituents between 72% and 75%.

- Material is blended to conform with ASTM C1697 uniformity ±5.0%.

- LOI is kept below 2.0%.

- Available Alkalis are held at 1.3%.

- Lower the CaO found in Class C ash that can exacerbate sulfate attack and ASR.
**ASTM C1697**

**BLENDED SUPPLEMENTARY CEMENTITIOUS MATERIALS**

**APPENDIX X1 VERIFYING BLEND PROPORTIONS**

- **X1.1** This Appendix provides information for purchasers of blended supplementary cementitious materials about typical methods that manufacturers use to control the blend production process and verify product conformance.

- **X1.2** Mechanical methods, such as weighing individual constituents as each goes to the blending system are adequate to provide production control but chemical analysis as described below is required by this specification for verifying actual blend proportions:
  - **X1.2.1** Ensure weigh feeders are maintained and calibrated before production. Weigh feeders are to provide for general control and adjustment during production.
  - **X1.2.2** Ensure that the analysis method, X-ray fluorescence (XRF) or other qualified method is calibrated within the ranges of materials being tested.

- **X1.2.3** Sample and chemically analyze individual constituents before production begins and at established frequencies during production.

- **X1.2.4** Sample and chemically analyze finished blended supplementary cementitious materials at established frequencies during production runs for quality control purposes and verification of blend proportions.

- **X1.2.5** Proportion analysis, as used here, is a calculation using the chemical analysis of the individual constituents and the resultant blend.
  - **X1.2.5.1** The individual constituents are analyzed and predominant elements are chosen as chemical identifiers.
  - **X1.2.5.2** Those chosen identifiers are then used to calculate the mass % of constituents in the blended supplementary cementitious material.

An example of this calculation follows. This is a basic example for illustrative purposes using one element. A more detailed analysis using multiple elements can be performed using a spreadsheet program such as EXCEL Solver.
BLENDED FLY ASH

Blended fly ashes is a homogeneous blend of sub-bituminous and bituminous coal ash. Combining sub-bituminous and bituminous coal ashes provides consumers the positive attributes of both materials and reduces variations that are sometimes experienced from power plants operating under today’s more stringent environmental climate. The blended fly ash offers end users more benefits versus the sum of their parts. Blended fly ashes can be used in any application where a Class F fly ash is specified.
Appendix X1. Verifying Blend Proportions (summary).

- X1.2 Mechanical methods ... weighing individual constituents as each goes to the blending system . . . but chemical analysis as described below is required . . . for verifying actual blend proportions.
- X1.2.3 Sample and chemically analyze individual constituents before production begins.
- X1.2.4 Sample and chemically analyze finished blended supplementary cementitious materials at established frequencies . . . For quality control purposes and verification of blend proportions.
- X1.2.5.2 Those chosen identifiers are then used to calculate the mass % of constituents in the blended supplementary cementitious material.
### ASTM C1697-10 Appendix X1.2.5.2 (Worksheet)

<table>
<thead>
<tr>
<th>Date</th>
<th>Sample IDs</th>
<th>Type</th>
<th>Miller Total Sum</th>
<th>Gaston Total Sum</th>
<th>Blend % Class C</th>
<th>Blend % Class F</th>
<th>Theoretical Total Sum</th>
<th>Actual Total Sum</th>
<th>Actual vs Theoretical</th>
</tr>
</thead>
<tbody>
<tr>
<td>7/1/13</td>
<td>1480MR; 1612GT; 1652P2A</td>
<td>Monthly</td>
<td>65.73</td>
<td>88.91</td>
<td>51%</td>
<td>49%</td>
<td>77.09</td>
<td>77.96</td>
<td>1.1%</td>
</tr>
<tr>
<td>8/1/13</td>
<td>1723MR; 1921GT; 1937P2A</td>
<td>Monthly</td>
<td>62.89</td>
<td>88.67</td>
<td>51%</td>
<td>49%</td>
<td>75.52</td>
<td>76.2</td>
<td>0.9%</td>
</tr>
<tr>
<td>9/1/13</td>
<td>2071MR; 2056GT; 2143P2A</td>
<td>Monthly</td>
<td>62.85</td>
<td>87.69</td>
<td>51%</td>
<td>49%</td>
<td>75.02</td>
<td>75.78</td>
<td>1.0%</td>
</tr>
<tr>
<td>10/1/13</td>
<td>2335MR; 2296GT; 2352P2A</td>
<td>Monthly</td>
<td>65.39</td>
<td>87.82</td>
<td>51%</td>
<td>49%</td>
<td>76.38</td>
<td>76.51</td>
<td>0.2%</td>
</tr>
<tr>
<td>11/1/13</td>
<td>2422MR; 2614GT; 2571P2A</td>
<td>Monthly</td>
<td>63.61</td>
<td>88.83</td>
<td>51%</td>
<td>49%</td>
<td>75.97</td>
<td>76.72</td>
<td>1.0%</td>
</tr>
<tr>
<td>12/1/13</td>
<td>2680MR; 218GT; 44P2A</td>
<td>Monthly</td>
<td>65.54</td>
<td>88.54</td>
<td>51%</td>
<td>49%</td>
<td>76.81</td>
<td>76.88</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

Calculations: ASTM C1697-10X1.2.5.2 limits +/- 5%
VERIFICATION OF COMPLIANCE

- Industry Specifications
  - ASTM – American Society for Testing Materials
  - AASHTO – American Association of State Highway the
    Transportation Officials
- DOT Specifications
- Headwaters Resources’ Standard Operating Procedures (SOP)
BLENDING IMPACT TO COLOR

Class F Ash  Resulting Blend  Class C Ash
# Summary of Chemical and Physical Properties

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Class F</th>
<th>75% F / 25% C</th>
<th>50% F / 50% C</th>
<th>25% F / 75% C</th>
<th>Class C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon Dioxide, SiO2</td>
<td>47.73%</td>
<td>45.26%</td>
<td>42.74%</td>
<td>40.85%</td>
<td>39.32%</td>
</tr>
<tr>
<td>Aluminum Oxide, Al2O3</td>
<td>28.19%</td>
<td>25.65%</td>
<td>23.21%</td>
<td>21.17%</td>
<td>19.24%</td>
</tr>
<tr>
<td>Iron Oxide, Fe2O3</td>
<td>11.92%</td>
<td>10.51%</td>
<td>9.28%</td>
<td>8.23%</td>
<td>6.22%</td>
</tr>
<tr>
<td>Sulfur Trioxide, SO3</td>
<td>0.32%</td>
<td>0.78%</td>
<td>1.03%</td>
<td>1.27%</td>
<td>1.52%</td>
</tr>
<tr>
<td>Calcium Oxide, CaO</td>
<td>4.02%</td>
<td>8.75%</td>
<td>13.56%</td>
<td>18.51%</td>
<td>23.25%</td>
</tr>
<tr>
<td>Sum Of Oxides (Class)</td>
<td>87.84%</td>
<td>81.42%</td>
<td>75.23%</td>
<td>70.25%</td>
<td>64.78%</td>
</tr>
<tr>
<td>Available Alk.</td>
<td>.75</td>
<td>1.26</td>
<td>1.1</td>
<td>.91</td>
<td>1.33</td>
</tr>
<tr>
<td>Carbon % (Leco)</td>
<td>1.94</td>
<td>1.47</td>
<td>1.06</td>
<td>0.58</td>
<td>0.157</td>
</tr>
<tr>
<td>Specific Gravity gm/cm³</td>
<td>2.38</td>
<td>2.42</td>
<td>2.42</td>
<td>2.46</td>
<td>2.49</td>
</tr>
<tr>
<td>LOI %</td>
<td>2.13</td>
<td>1.57</td>
<td>1.09</td>
<td>0.7</td>
<td>0.31</td>
</tr>
<tr>
<td>Fineness %</td>
<td>24.02</td>
<td>24.02</td>
<td>23.76</td>
<td>22.64</td>
<td>25.1</td>
</tr>
<tr>
<td>Moisture %</td>
<td>0.13</td>
<td>0.11</td>
<td>0.1</td>
<td>0.1</td>
<td>0.106</td>
</tr>
<tr>
<td>Class C</td>
<td>Class F</td>
<td>50/50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------</td>
<td>---------</td>
<td>-------</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slump .25 inch</td>
<td>Unit Wt lb/ft</td>
<td>WC Ratio</td>
<td>Temp. F</td>
<td>1 Day Compressive **</td>
<td>3 Day Compressive **</td>
</tr>
<tr>
<td>6</td>
<td>145.6</td>
<td>6</td>
<td>65</td>
<td>1501</td>
<td>2819</td>
</tr>
<tr>
<td>6</td>
<td>146.3</td>
<td>6</td>
<td>65</td>
<td>962</td>
<td>2245</td>
</tr>
<tr>
<td>6</td>
<td>146.3</td>
<td>6</td>
<td>65</td>
<td>5.2</td>
<td>862</td>
</tr>
<tr>
<td>6</td>
<td>147.1</td>
<td>6</td>
<td>65</td>
<td>5</td>
<td>1007</td>
</tr>
</tbody>
</table>

**3X6 Cylinders all other ages 4X8**
CONCRETE STRENGTH
ASTM C-39

Compressive Strength

- Control
- Class C Ash
- Class F Ash
- 50 / 50

Compressive PSI

Age in Days

1 day 3 days 7 days 14 days 28 days 56
The blending process reduces variability of Class F fly ash from the power plant. The blend in concrete at a 25 percent substitution rate performs better than the control mix and the Class F mix at 28 and 56 days.

**Compressive Strength**

<table>
<thead>
<tr>
<th>Age in Days</th>
<th>Control</th>
<th>Class C Ash</th>
<th>50 / 50</th>
<th>Class F Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 day</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56 days</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SETTING TIME OF CONCRETE
ASTM C-403

Final Set @ 4000
- Control
- Miller
- Gaston
- 50/50

Initial Set @ 500

0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000
0 60 120 180 240 300 360 420 480 540 600
ASTM C-1012 sulfate expansion graph results, Class C fly ash is exceeding maximum expansion limits at six months. Blend does not perform as well as a straight Class F ash; however, performs better than straight Class C fly ash.

"Tilkasky and Carrasquillo (1993); and Dunstan (1976); showed that concrete containing some high-calcium fly ashes are susceptible to sulfate attack, and generally, higher volumes of high-calcium fly ash mixtures have a greater susceptibility to sulfate deterioration" (American Concrete Institute [ACI], 2008, p. 17).

Blending C with F fly ash mitigates problems caused by high CaO C ashes.
ASTM C-1567 DATA

- ASTM C 1567 comparison graph shows the blend outperforms straight Class C’s ability to inhibit alkali silica reactivity expansion.
- Combining Class C and Class F fly ash clearly lowers the percentage of alkali available in Class C fly ash, complimenting the advantages of both products resulting improved concrete durability.
- Added benefit of allowing concrete producers to use higher percentages of fly ash in their concrete products as compared to typical Class F fly ashes.
- Higher percentages of fly ash replacement, improves concrete durability.
Combining Class C and Class F fly ash has the following benefits:

- **Lower CaO**
- **Lower LOI**
- **Lower available Na2O**
BENEFITS C/F BLENDS

• Use of ASTM C-1697
• Performance driven sales with ash that can be tailored to a particular region.
• Ability to maintain constant supplies of material.
• Possibility to use other SCM such as Slag, Silica Fume and natural Pozzolans in blend.
• Ability to beneficiate one source, with another of better properties.
• Provide binary performance product to the market for single silo use.
C-ASH & F-ASH DOT PRE BLEND APPROVALS

- Florida
- Georgia
- Alabama
- Tennessee
- Kentucky
- Pennsylvania
- Louisiana
- Mississippi
- Colorado
IOWA DOT PERMEABILITY DATA

• Iowa DOT undertook a study on paving performance to measure permeability of all allowed state paving mixtures utilizing SCM available in the market and on current projects.

• Class F is only available locally as a component of a locally produced cement blend. The blend contains 20% class F fly ash.

• Iowa DOT allows for the paving mixture to utilize up to a 40% replacement of cement.

• Local pavers routinely use the 20% F cement blend with 20% Class C fly ash, with the result providing faster set time in cool weather and lower permeability.
Ternary Mix Design - Lab Study
Permeability AASHTO T277 - Virginia Cure Method

Coulombs

100% Cement 15% C Ash 30% C Ash Type IS(25)
20% C Ash
Type IS(35)
15% C Ash Type IPF(25)
20% C Ash

w/c = 0.41
w/c = 0.41
w/c = 0.41
w/c = 0.41
w/c = 0.426
w/c = 0.40

>4000
2000-4000
1000-2000
100-1000
<100

High
Moderate
Low
Very Low
Negligible
SUMMARY OF FINDINGS

- Physical Performance improved on tested ashes.

- Utilization of Marginal Ashes Enhanced.

- ASR Mitigation of Blended C/F fly ashes improved over Class C fly ash alone.

- Permeability's were reduced similar to the use of silica fume.

- Resulting blends of class C and class F fly ashes, meet ASTM C-618.
REFERENCES


