ALTERNATIVE SUPPLEMENTARY CEMENTITIOUS MATERIALS FOR CONCRETE

CHARACTERIZATION CHALLENGES

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The Future of Fly Ash
The Future of Fly Ash

- EPA Cross-State Air Pollution Rule (CSAPR) threatens the supply of Class F fly ash in Texas
- Power plants may move to “cleaner” burning Powder River Basin coal

SCM Availability

From K. Scrivener
Fly Ash Alternatives

We have come full circle...back to the Roman pozzolana
“Natural” Supplementary Cementitious Materials

- Volcanic ash
- Tuffs
- Zeolites
- Pumice
- Perlite
- Diatomaceous earth
- Metakaolin
- Rice husk ash

SCM Characterization

- Most SCMs are not directly manufactured to meet a specification
- Characterization is critical for selection

- There are several standards that define physical and chemical characteristics of SCMs to be used in concrete:
  - ASTM C618, EN 450, AS 3582.1
SCM Chemical requirements

- Chemical requirements focus on oxide analysis (typically measured through x-ray fluorescence)

<table>
<thead>
<tr>
<th>SCM Chemical characterization</th>
<th>Table 1 Chemical Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon dioxide (SiO₂) plus aluminum oxide (Al₂O₃) plus iron oxide (Fe₂O₃), max. %</td>
<td>N</td>
</tr>
<tr>
<td>Sulfur trioxide (SO₃) max. %</td>
<td>7.0</td>
</tr>
<tr>
<td>Moisture content, max. %</td>
<td>3.0</td>
</tr>
<tr>
<td>Loss on ignition, max. %</td>
<td>10.0</td>
</tr>
</tbody>
</table>

*The loss of Class I pozzolans containing up to 12.0% loss on ignition may be approved by the user if either acceptable performance records or laboratory test results are made available.

- Many materials meet the Class N criteria of SiO₂+Al₂O₃+Fe₂O₃>70% but are not good pozzolans

SCM Chemical characterization

- Not all oxides in SCMs are soluble

* Alkalies are Na₂O + K₂O
SCM Chemical characterization

- Multispectral Image Analysis (MSIA) for amorphous phase characterization

Data from K. Aughenbaugh, UT Austin
SCM Chemical Characterization

- Structure of calcined clays is related to reactivity, particularly the coordination environments of Al and Si
- Metakaolin appears amorphous in x-ray diffraction
- New work has modeled the structure using density functional computations and neutron pair distribution function analysis (White et al., Physical Chemistry Chemical Physics, 2010).

![Diagram showing structure of calcined clays with yellow atoms as Si, purple Al, red O, and white H.]

SCM Physical Characterization

| Designation: C 618 – 06a |

![Table showing physical requirements with columns for N, F, and C.]

**TABLE 2 Physical Requirements**

<table>
<thead>
<tr>
<th>Property</th>
<th>Requirement</th>
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<tbody>
<tr>
<td>Strength characteristics</td>
<td>70^2</td>
</tr>
<tr>
<td>Density</td>
<td>0.8</td>
</tr>
<tr>
<td>Soundness</td>
<td>105</td>
</tr>
<tr>
<td>Autoclave expansion</td>
<td>0.8</td>
</tr>
<tr>
<td>Percent retention on 45 μm sieve</td>
<td>5</td>
</tr>
</tbody>
</table>

Notes:
- The density and soundness of individual samples shall not vary from the average established by the two preceding tests, or by all preceding tests if the number is less than ten, by more than:
- The extension of the requirement is 5%.
ASTM C 204
Blaine Air-Permeability

- Rate of flow through a porous bed of material is related to its surface area

\[ S = S_s \frac{S \rho_s (b - \varepsilon_s) \sqrt{T}}{\rho (b - \varepsilon) \sqrt{T_s}} \]

- \( S \) is the specific surface area; \( S_s \) is that of a standard material
- \( T \) is the measured time interval and \( T_s \) is that of a standard material
- \( \rho \) is the density of the material and \( \rho_s \) is the density of the standard material
- \( \varepsilon \) is the porosity of the prepared bed and \( \varepsilon_s \) is that for the standard
- \( b \) is a constant appropriate for the test sample

- \( D \) is the powder density; \( \varepsilon \) is the porosity of the bed; \( A \) is the cross-sectional area of the bed; \( i \) is the hydraulic gradient; \( \nu \) is the kinematic velocity; \( Q \) is the rate of flow

SCM Physical Characterization: Blaine

X1. Illustrative Method for the Determination of the Value for the Constant b

Data from J. Stewart, UT Austin
SCM Physical characterization: Particle Size

- Particle size distribution by laser diffraction

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<table>
<thead>
<tr>
<th>Size (µm)</th>
<th>Belews</th>
</tr>
</thead>
<tbody>
<tr>
<td>0,1</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
</tr>
<tr>
<td>1000</td>
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</tr>
</tbody>
</table>
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Data from K. Aughenbaugh, UT Austin

Laser Techniques (LAS)

- Absorption is dependent on the size and the composition
- Diffraction in LAS is dependent only on the geometry of the particle, not the composition
- Scattering is dependent on the refractive indices and, therefore, the composition, but also the size and shape
Summary and Conclusions

• SCMs, both traditional and alternative, are valuable components of modern concrete mixtures and their use will only increase
• We need to characterize SCMs thoroughly before use in order to:
  • Determine if they are appropriate for use
  • Determine optimal replacement levels
• Characterization tests in the standards are inadequate and new thought must be given to the best means of characterizing this diverse group of materials