Durable Concrete: The Future and Use of Supplementary Cementitious Materials

Silica Fume

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Durable Concrete: The Future and Use of Supplementary Cementitious Materials

Silica Fume
The Silica Fume Association
38860 Sierra Lane, Lovettsville, VA
http://www.silicafume.org/
What is Silica Fume?

American Concrete Institute defines silica fume as “very fine non-crystalline silica produced in electric arc furnaces as a by-product of the products of elemental silicon or alloys containing silicon.” (ACI 116R) – dark gray in color.

When silicon metal and/or high silicon alloys are produced in electric arc furnaces the smoke or fume that goes up the stack is collected.

This fume is very fine and high in silicon content. Amorphous (non-crystalline) silicon dioxide is soluble in concrete. Crystalline silicon dioxide (sand) is not.
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Courtesy of The Silica Fume Association
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Silica Fume

VDOT specification is AASHTO M307

<table>
<thead>
<tr>
<th>Table 1 – Chemical Requirements</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Silicon dioxide (SiO$_2$), min percent</td>
<td>85.0</td>
</tr>
<tr>
<td>Moisture content, max percent</td>
<td>3.0</td>
</tr>
<tr>
<td>Loss on ignition, max percent</td>
<td>6.0</td>
</tr>
</tbody>
</table>
Silica Fume

How does it work?

Because of its chemical and physical properties, it is a very reactive SCM that densifies concrete and consumes excess alkalis during hydration similar to the Fly Ash, Metakaolin and Slag Cement.

Silica Fume typically replaces about 7 to 10% of the cement by weight.

Strength gain delays or fluctuating air content are typically not issues.

The biggest issue is proper mixing technique.

Concrete containing silica fume can have very high strength and can be very durable.
Approved SCM’s (Mineral Admixtures) are found on VDOT’s Materials Division’s Approved List No. 24

http://www.virginiadot.org/business/resources/Materials/ApprovedLists/Materials_Approved_Lists.pdf
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Where does this leave us?

Answer the last question

3. What is the future for SCMs at VDOT?

Underlying question:

Should we even consider designing straight portland cement concrete mixes?
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Goal for VDOT concrete continues to be:

- reduce the infiltration of road salt and sulfates, as well as
- mitigate ASR - VDOT specifies two options for the Contractor:
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Underlying question:

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First Goal for VDOT concrete:

- reduce the infiltration of road salt and sulfates and other detrimental substances

How do we know we have produced concrete with less sponge-like characteristics?
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To reduce the infiltration of road salt and sulfates and other detrimental substances, VDOT specifies a maximum permeability (coulombs) using VTM 112 for each Class of concrete.

This gives some assurance of concrete durability.
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Decision Factors:

• Virginia has excellent aggregates

• Tests to determine the reactivity of aggregates were suspect/variable

• Concrete needs to be less susceptible to the infiltration to road salt
Underlying question:

Should we even consider designing straight portland cement concrete mixes?

Mitigate ASR

VDOT specifies two options for the Contractor:

1. Perform an ASTM test to determine ASR potential
2. Use a minimum amount of an approved mineral admixture for each mix design.
VDOT Road and Bridge Specifications, Section 217.02(a):

- Perform ASTM C227 with a maximum expansion of 0.15% at 56 days
- To meet this requirement, this typically requires the addition of a mineral admixture

However, this may option not reduce the infiltration of road salt and sulfates (reduce permeability). Also, there may be a permeability specification for the concrete. This approach would typically not meet the permeability specification.
### VDOT Road and Bridge Specifications
#### Section 217.02(a)

<table>
<thead>
<tr>
<th></th>
<th>Total Alkalies of Cement is less than or equal to 0.75%</th>
<th>Total Alkalies of Cement is greater than 0.75% and less than or equal to 1.0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class F Flyash(^1)</td>
<td>20%</td>
<td>25%</td>
</tr>
<tr>
<td>GGBF Slag(^1)</td>
<td>40%</td>
<td>50%</td>
</tr>
<tr>
<td>Silica Fume(^1)</td>
<td>7%</td>
<td>10%</td>
</tr>
<tr>
<td>Metakaolin(^1)</td>
<td>7%</td>
<td>10%</td>
</tr>
</tbody>
</table>

\(^1\) Minimum % cement replacement by weight
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SCMs
- Fly Ash – Class F
- Metakaolin
- Slag Cement
- Silica Fume

Or using a Blended Cement (still complying with previous Table)

- Type IL is treated like a Type I
  * Type IP – cement blended with fly ash
  * Type IS – cement blended with slag cement

* may require more mineral admixture to be added
SCMs all work similarly by consuming excess calcium hydroxide, producing calcium silicates.

Typical values of SiO$_2$ and fineness.

<table>
<thead>
<tr>
<th>SCM</th>
<th>SiO$_2$, %</th>
<th>Fineness, m$_2$/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash, Class F</td>
<td>~50</td>
<td>~420</td>
</tr>
<tr>
<td>Metakaolin</td>
<td>~51</td>
<td>16,000 to 20,000</td>
</tr>
<tr>
<td>Slag Cement</td>
<td>~35</td>
<td>~400</td>
</tr>
<tr>
<td>Silica Fume</td>
<td>85 min. (97)</td>
<td>15,000 to 30,000</td>
</tr>
<tr>
<td>Type I Cement</td>
<td>~20</td>
<td>~370</td>
</tr>
</tbody>
</table>
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Advantages of using SCMs

Potential utilization of a waste product (other than metakaolin)
Reduce heat of hydration (less cement); reduce maximum temperature
Improves sulfate resistance
Mitigates alkali-silica reaction
Reduces permeability
Underlying question:

Should we even consider designing straight portland cement concrete mixes?

Not based upon experience and the research reports generated by the Virginia Transportation Research Council.
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1. What are Supplementary Cementitious Materials?

2. Why are they used in hydraulic cement concrete mixes?

3. What is the future for Supplementary Cementitious Materials at VDOT?

Underlying question:
Should we even consider designing straight portland cement concrete mixes?

No!!!
Questions?

- Thomas H. Adams, American Coal Ash Association
- A.J. Marisca, BASF
- (Henry Prenger, LaFarge/Holcim)
- Larry J. Lundy, P.E., VDOT