Darrell Elliot is a native of New Orleans and has been involved in the concrete construction industry over 30 years. He is Technical Services Manager for Buzzi Unicem USA. He has worked on a wide variety of projects and applications representing millions of yards of concrete placed. Darrell is a past president of the Louisiana Chapter of ACI. He is a Sustaining Member and a Fellow of ACI International. Darrell serves on ACI Committees: 207, Mass Concrete; 211, Proportioning Concrete Mixes; 233, Ground Slag in Concrete; Chairman of Committees 305, Hot Weather Concreting; 363, High-Strength Concrete; C610, Field Technician Certification; and E701, Materials for Concrete Construction. Darrell serves on ASTM Committees: C-01, Cement; C-09, Concrete and Concrete Aggregates; and C-13, Concrete Pipe. Darrell has been an instructor for PCA and NRMCA training programs. He holds several ACI certifications, and serves as an examiner for the certification of others.

Cementitious Materials
Darrell F. Elliot, FACI
Technical Service Manager
Buzzi Unicem USA
Cementitious Materials

Cements:
- Portland Cements
- Blended Cements
- Special Cements
- Slag Cement (GGBFS)

Pozzolans:
- Fly Ash
- Clays & other Ashes

Ashes:
- Silica Fume

1. Stone is first reduced to 125 mm (5 in.) size, then to 30 mm (1/8 in.), and stored.

2. Raw materials are ground to a powder and blended.

3. Burning changes raw materials into cement clinker. Note the preheater, precalciner, and chiller.

4. Clinker with gypsum is ground into portland cement and shipped.
Other Cements

- Air-Entrained (C150)
- Blended (C595 & C1157)
- White
- Masonry
- Mortar
- Rapid-Setting
- Repellant
- Calcium Aluminate
- Oil-Well

Slag Cement

Ground Granulated Blast-Furnace Slag

Glassy granular material formed when molten blast-furnace slag is rapidly quenched in water.

Ground and batched into concrete either separately or as a blended cement.

Hydraulic cement and has pozzolanic properties.
Fly Ash

Finely-divided residue that results from the combustion of pulverized coal.

Spherical particles.

Two types depending on CaO content.

Specification: ASTM C618
High lime content; light color due to lower carbon and iron contents.

Originates from burning lignite and subbituminous coal.

Pozzolanic / Cementitious Reaction.

Class C Fly Ash

Low lime (CaO) content; dark color due to presence of unburned carbon coal.

Originates from burning anthracite and bituminous coal.

Pozzolanic Reaction.

Class F Fly Ash

Raw Fly Ash
**Ultra-Fine Fly Ash**

Finely-divided residue that results from the production of silicon & ferrosilicon metal

Spherical particles.

Specification: ASTM C1240

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**Metakaolin**

Calcined Kaolin clay

Mined in Georgia

Washed in water

Calcined

Fine white powder

Pozzolanic Reaction.

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**Silica Fume**

Finely-divided residue that results from the production of silicon & ferrosilicon metal

Spherical particles.

Specification: ASTM C1240

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**Molten Silicon Metal**

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**Silica Fume By-Product**

Silicon Metal Manufacturing Plant

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**Portland Cement**

Silica Fume
Dry, Compacted Silica Fume

Silica Fume Slurry

Supplementary Cement Materials
- Generally reduce materials cost
- Contribute to improved concrete strength & durability properties
- Reduce heat of hydration
- Utilizes materials otherwise landfilled
- Reduces carbon dioxide production and energy consumption

Fineness

<table>
<thead>
<tr>
<th>Material</th>
<th>Micron</th>
<th>Blaine</th>
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<tbody>
<tr>
<td>Portland</td>
<td>20-30</td>
<td>3500 - 4000</td>
</tr>
<tr>
<td>GGBFS</td>
<td>10-15</td>
<td>4000 - 6000</td>
</tr>
<tr>
<td>Fly Ash</td>
<td>5-60</td>
<td>3000 - 5000</td>
</tr>
</tbody>
</table>

Chemical Composition

<table>
<thead>
<tr>
<th></th>
<th>Portland Cement</th>
<th>Slag Cement</th>
<th>Fly Ash Class C</th>
<th>Fly Ash Class F</th>
<th>Silica Fume</th>
</tr>
</thead>
<tbody>
<tr>
<td>CaO</td>
<td>↑ 65</td>
<td>42</td>
<td>24</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>SiO₂</td>
<td>↓ 22</td>
<td>38</td>
<td>40</td>
<td>55</td>
<td>98</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>4</td>
<td>8</td>
<td>17</td>
<td>26</td>
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</tr>
<tr>
<td>Fe₂O₃</td>
<td>3</td>
<td>Trace</td>
<td>6</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>MgO</td>
<td>2</td>
<td>7</td>
<td>5</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>SO₃</td>
<td>3</td>
<td>–</td>
<td>4</td>
<td>6</td>
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</tr>
<tr>
<td>Na₂O+K₂O</td>
<td>1</td>
<td>.4</td>
<td>–</td>
<td>–</td>
<td>.4</td>
</tr>
<tr>
<td>LOI</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>Low</td>
</tr>
<tr>
<td>Variations:</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Hydration of Portland Cement

Cement + Water

\[ \text{C-S-H} + \text{Ca(OH)}_2 + \text{Other} \]

What is a Pozzolan?
Pozzolans are siliceous or aluminosiliceous materials that in themselves possess little or no cementitious value but will, in finely divided form and in the presence of water, chemically react with the calcium hydroxide released by the hydration of portland cement, to form compounds possessing cementitious properties.

Pozzolanic Reaction in Concrete

\[ \text{Ca(OH)}_2 + \text{Pozzolan} \]

\[ \text{more} \ldots \text{ C-S-H} \]

Effect of Pozzolanic Reaction
<table>
<thead>
<tr>
<th>Rocket Stages</th>
<th>Blended Hydraulic Cements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Portland C 3A Ignition</td>
<td>ASTM C 595….. (Was 5 Types, Now 2)</td>
</tr>
<tr>
<td>Portland C 3S First stage</td>
<td>Pozzolan-Modified Portland Cement</td>
</tr>
<tr>
<td>Portland C 2S Second Stage</td>
<td>Portland-Pozzolan Cement</td>
</tr>
<tr>
<td>Slag C 1ST Third Stage</td>
<td>Slag-Modified Portland Cement</td>
</tr>
<tr>
<td>Slag/Ash/SF Pozz Fourth Stage</td>
<td>Portland Blast-Furnace Slag Cement</td>
</tr>
</tbody>
</table>

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<tr>
<th>Blended Hydraulic Cements</th>
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<tbody>
<tr>
<td><strong>ASTM C 595….. (Was 5 Types, Now 2)</strong></td>
<td><strong>ASTM C 595….. New Types</strong></td>
</tr>
<tr>
<td>Type I(PM) (P &lt; 15%)</td>
<td>Portland-Limestone Cement</td>
</tr>
<tr>
<td>Type IP (15% &lt; P &lt; 40%)</td>
<td>Ternary Blended Cement</td>
</tr>
<tr>
<td>Type I(SM) (S &lt; 25%)</td>
<td></td>
</tr>
<tr>
<td>Type IS (25% &lt; S &lt; 70%)</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Blended Hydraulic Cements</th>
<th>Blended Hydraulic Cements</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ASTM C 595….. New Types</strong></td>
<td></td>
</tr>
<tr>
<td>Type IL (L &lt; 15%)</td>
<td>Type IL (5% &lt; L &lt; 15%)</td>
</tr>
<tr>
<td>Type IT (P &lt; 40%)</td>
<td>(L &lt; 15%)</td>
</tr>
<tr>
<td>(SCM &lt; 70%)</td>
<td>(P &lt; 40%)</td>
</tr>
</tbody>
</table>