Use of Performance Cements in Colorado and Utah: Laboratory Durability Testing and Case Studies

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What Are ASTM C1157 Portland-Limestone Cements?

- Portland cement clinker is interground with 10 to 12 percent limestone
- Offer equivalent, or even improved, performance to ordinary portland cements
- May be customized to address specific performance requirements
  - Sulfate resistance, low heat of hydration, high early strength
What Are ASTM C1157 Portland-Limestone Cements?

- Often include, or can be blended with, appropriate supplementary cementitious material to further lower the amount of clinker
  - Fly ash, slag cement, and/or natural pozzolans
- Will reduce carbon footprint without sacrificing cost or performance
What Makes Portland-Limestone Cement Perform?

- The limestone is more finely ground than clinker since it is softer
  - This allows better particle packing
- Early hydration products nucleate on the fine limestone particles
- Carbo-aluminates form due to reactions between limestone and aluminates
  - Accentuated with fly ash and slag cement
History of Use

- Currently the most commonly used cement in Europe
  - Decades of use
  - Up to 20 percent limestone allowed in EN197-1 CEM II/A and 35 percent in CEM II/B

- Allowed in Canada since 2008
  - Up to 15 percent limestone

- ASTM C595 and AASHTO M 240 are balloting a limestone cement classification
Verifying Durability

- **Strength and set**
  - Requirements are met through concrete mix design
- **Sulfate resistance**
  - Test cement by ASTM C1012
- **Alkali-silica reactivity**
  - Demonstrate ASR mitigation of mix through ASTM C1567
Verifying Durability

- **Permeability**
  - Rapid chloride permeability ASTM C1202

- **Freeze-thaw**
  - Freeze-thaw resistance ASTM C666
  - Salt scaling resistance ASTM C672

- **Shrinkage**
  - Drying shrinkage ASTM C157
# How Do Portland-Limestone Cements Perform?

<table>
<thead>
<tr>
<th></th>
<th>Devil’s Slide (500#) GU vs C150</th>
<th>Portland (500#) GU vs C150</th>
<th>Devil’s Slide (564#) GU vs C150</th>
<th>Portland (564#) GU vs C150</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strength 28D</strong></td>
<td>Better</td>
<td>Better</td>
<td>Better</td>
<td>Equal</td>
</tr>
<tr>
<td><strong>Sulfate</strong></td>
<td>MS</td>
<td>MS</td>
<td>MS</td>
<td>MS</td>
</tr>
<tr>
<td><strong>ASR</strong></td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
</tr>
<tr>
<td><strong>Freeze-Thaw</strong></td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
</tr>
<tr>
<td><strong>Salt Scaling</strong></td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
</tr>
<tr>
<td><strong>Shrinkage</strong></td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
</tr>
<tr>
<td><strong>Permeability</strong></td>
<td>Equal</td>
<td>Equal</td>
<td>Equal</td>
<td>Slightly More</td>
</tr>
</tbody>
</table>
How Do Portland-Limestone Cements Perform in the Field?

- Equal or improved to C150 cements
  - Strength
  - Set time
  - Water demand
  - Compatibility with fly ash
  - Compatibility with admixtures
- Improved finishability
- Lower environmental impact
Devil’s Slide, Utah Cements

- **Type V clinker**
  - $C_3A <5\%$

- **ASTM C150 Type II/V**
  - High sulfate resistance
    - $C_3A <5\%$
  - $<5\%$ limestone per ASTM C150
  - Naeq $<0.60\%$

- **ASTM C1157 Type GU/MS**
  - General use/Moderate sulfate resistance
    - ASTM C1012, sulfate performance test
  - 10% limestone
Utah Case Studies

Performance & Lower Environmental Impact
Lost Creek Road Morgan, Utah

- Rural County Road
  - Constructed 2009
- Major Truck Traffic
  - Devil’s Slide Cement Plant
- Construction Limitations
  - Hand Placed
- Mountain weather issues
  - Harsh Winters
- Performance System
  - 10% Limestone Cement
  - 20% Class F Flyash
UDOT Spec- Mix Design

<table>
<thead>
<tr>
<th>Material</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C1157 Cement</td>
<td>486 lbs</td>
</tr>
<tr>
<td>ASTM C618 Class F</td>
<td>124 lbs</td>
</tr>
<tr>
<td>Water</td>
<td>267 lbs</td>
</tr>
<tr>
<td>ASTM C33 #57</td>
<td>1765 lbs</td>
</tr>
<tr>
<td>ASTM C33 Sand</td>
<td>1095 lbs</td>
</tr>
<tr>
<td>Air</td>
<td>6%</td>
</tr>
<tr>
<td>ASTM C260 AE</td>
<td>5 oz</td>
</tr>
<tr>
<td>ASTM C494 Type A</td>
<td>7 oz</td>
</tr>
<tr>
<td>ASTM C494 Type F</td>
<td>15 oz</td>
</tr>
</tbody>
</table>

- Compressive strength
  - design 4000 psi, average 5120 psi
- Flexural strength
  - design 650 psi, average 720 psi
- Mix with portland-limestone cement had better strength gain than historic C150 cement
Ready Mix Maintenance Facility

- Constructed 2008-2009
- LEED Certification
  - Silver or Gold
- 13, 915 Square feet
- Performance System
  - 10% Limestone Cement
  - 20% Class F Flyash
# Maintenance Facility-Mix Designs

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM C1157 Cement (Interior Floor)</td>
<td>414 lbs</td>
</tr>
<tr>
<td>ASTM C618 Class F</td>
<td>103 lbs</td>
</tr>
<tr>
<td>Water</td>
<td>258 lbs</td>
</tr>
<tr>
<td>ASTM C33 #57</td>
<td>1796 lbs</td>
</tr>
<tr>
<td>ASTM C33 Sand</td>
<td>1469 lbs</td>
</tr>
<tr>
<td>Air</td>
<td>1.5%</td>
</tr>
<tr>
<td>ASTM C260 AE</td>
<td>1 oz</td>
</tr>
<tr>
<td>ASTM C494 Type A</td>
<td>12.9 oz</td>
</tr>
</tbody>
</table>

- **Compressive strength**
  - Footing Design 3500 psi
    - 28 Day Field ave 4318
  - Walls Design 4000 psi
    - 28 Day Field ave 5216
  - Interior Floor Design 4000 psi
    - 28 Day Field ave 4545
104th South, Salt Lake City, Utah

- Pooled Fund Ternary Study
  - University of Utah (Tikalsky)
  - 10% Limestone Cement
  - 25% Class F Fly ash
- Single days production
- Control Section Strength*
  - Compressive 4454 psi
  - 28Day
- Actual Test Section Strength*
  - Compressive 5396 psi
  - 28Day
UofU Meldrum Building

- Constructed 2009-2010
- LEED Certification
  - Silver or Gold
- Technical SCC mixtures
- Architectural Finishes
- Performance System
  - Tikalsky (104th Design)
  - 10% Limestone Cement
  - 20% Class F Flyash
UofU Meldrum Building

- Lightweight
- Winter Placement
- Compressive strength
  - SCC Design 4000 psi
    - 7 Day Field Range-
    - 6100-6600 psi
    - 28 Day Breaks not required
Portland, Colorado Cements

- Type II clinker
  - $C_3A < 8\%$

- ASTM C150 Type I/II
  - General use/Moderate sulfate resistance
    - $C_3A < 8\%$
    - <5% limestone per ASTM C150
    - Naeq >0.70%

- ASTM C1157 Type GU/MS
  - General use/Moderate sulfate resistance
    - ASTM C1012, sulfate performance test
    - 10% limestone
Colorado Case Studies

Performance & Lower Environmental Impact
Achieved LEED Gold

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<tr>
<th>Material</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>ASTM C1157 Cement (Interior Floor)</td>
<td>388 lbs</td>
</tr>
<tr>
<td>ASTM C618 Class F</td>
<td>129 lbs</td>
</tr>
<tr>
<td>Water</td>
<td>250 lbs</td>
</tr>
<tr>
<td>ASTM C33 #57</td>
<td>1725 lbs</td>
</tr>
<tr>
<td>ASTM C33 Sand</td>
<td>1465 lbs</td>
</tr>
<tr>
<td>Air</td>
<td>1.5%</td>
</tr>
<tr>
<td>ASTM C260 AE</td>
<td>0 oz</td>
</tr>
<tr>
<td>ASTM C494 Type A &amp; B</td>
<td>15 oz ea</td>
</tr>
</tbody>
</table>

- Compressive strength
  - Interior Floor Design 3000 psi
    - 28 Day Field avg 4320
  - Curb & Sidewalk 4500 psi
    - 28 Day Field avg 5660
  - Pier Design 3000 psi
    - 28 Day Field avg 4510
- 25% Class F fly ash
City of Denver Concrete Paving
40th & Havana and Holly Street
City of Denver Concrete Paving

- Aligns with Denver Greenprint Program
- Ready-mix concrete supply
- 25% Class C fly ash
- 40th & Havana - side by side comparison of ASTM C150 I/II and ASTM C1157 GU cements
  - No noticeable performance differences
  - Winter construction
US HW 287 Near Lamar, CO
US HW 287 Near Lamar, CO

- 6.5 Miles PCCP
- 20% Class F fly ash
- 28-day flexural strength average = 695 psi
- Contractor received quality incentive per CDOT specifications
- Used in concrete paving on a regular basis
SUSTAINABLE?

Built in 126 AD, the Roman Pantheon Dome was constructed entirely from concrete. In 2010, the dome protects its 90th generation.

CHECK.
Over 100 miles of paving in Colorado
Thank You!

Any Questions?

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