Performance of SCC Made with Limestone Fillers

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Manufactured Calcium Carbonate

Calcium Carbonate 95%
Magnesium Carbonate 2%

Cumulative Volume (%) vs. Equivalent Spherical Diameter (µm)

- 3 µm - Calcium carbonate
- 8 µm - Calcium carbonate
- Type GU Cement

BETOCARB by OKA
Selection of Calcium Carbonate
Cast-in place SCC  w/p = 0.42

Surface settlement (%)

Time (min)

Type GU
CC8-20%
CC8-30%
CC3-30%
CC3-20%

8 µm
3 µm
Objective

Investigate performance of manufactured calcium carbonate (CC3) in air-entrained SCC:

• **Cast-in-place SCC** for commercial applications
  • 28-d $f'c \geq 32$ MPa

• **Precast-prestressed structural applications**
  • 28-d $f'c \geq 55$ MPa, $\geq 30$ MPa after 18 h of steam curing

• **Precast architectural applications**
  • 28-d $f'c \geq 35$ MPa, $\geq 15$ MPa after 18 h of steam curing
<table>
<thead>
<tr>
<th>SCC</th>
<th>Binder (kg/m³)</th>
<th>w/p</th>
<th>Polysac-caride VEA (mL/m³)</th>
<th>PC-based HRWRA Targeted slump flow</th>
<th>AEA Targeted air volume</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cast-in-place, Commercial</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type GU cement 0, 10, 15, 20% CC3</td>
<td>425</td>
<td>0.42</td>
<td>750</td>
<td>630 mm</td>
<td>6%-9%</td>
</tr>
<tr>
<td><strong>Precast, prestressed</strong></td>
<td></td>
<td></td>
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<tr>
<td>Type III cement 0, 10, 15, 20% CC3</td>
<td>460</td>
<td>0.35</td>
<td>0</td>
<td>650 mm</td>
<td>6%-9%</td>
</tr>
<tr>
<td><strong>Precast, architectural</strong></td>
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<td></td>
</tr>
<tr>
<td>Type I/II cement 0, 10, 15, 20% CC3</td>
<td>480</td>
<td>0.38</td>
<td>580</td>
<td>650 mm</td>
<td>6%-9%</td>
</tr>
</tbody>
</table>
## Testing Program

### Cast-in-place and precast SCC

<table>
<thead>
<tr>
<th>Fresh state</th>
<th>Slump flow</th>
<th>V-funnel flow (65x75 mm)</th>
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<tbody>
<tr>
<td></td>
<td>Air volume</td>
<td>Rheometer</td>
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<tr>
<td></td>
<td>Filling capacity</td>
<td>Surface settlement</td>
</tr>
<tr>
<td></td>
<td>L-box</td>
<td>Segregation index</td>
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<tr>
<td></td>
<td>J-ring</td>
<td>Temperature rise</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical properties</th>
<th>Compressive strength @ 1, 7, 28 d</th>
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<tbody>
<tr>
<td></td>
<td>Flexural strength @ 28 d</td>
</tr>
<tr>
<td></td>
<td>Elastic modulus and Poisson’s ratio @ 28 d</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Shrinkage</th>
<th>Drying Shrinkage after 7 d of water curing</th>
</tr>
</thead>
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<tr>
<th>Durability</th>
<th>Frost resistance (ASTM C666 Proc. A)</th>
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<tr>
<td></td>
<td>Air-void system (ASTM C457)</td>
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<tr>
<td></td>
<td>Scaling resistance (ASTM C672)</td>
</tr>
<tr>
<td></td>
<td>Rapid chloride-ion penetration (ASTM C1202)</td>
</tr>
</tbody>
</table>
HRWRA demand (L/m³)

- **Cast-in-place**
  - Commercial w/p = 0.42
  - Precast w/p = 0.35
  - Prestressed w/p = 0.35
  - Architectural w/p = 0.38

Control
10% CC3
15% CC3
20% CC3

- **Precast**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3

- **Architectural**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3
Unit Cost ($C/m^3)

- **Cast-in-place**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3

- **Commercial**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3

- **Precast**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3

- **Prestressed**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3

- **Precast Architectural**
  - Control
  - 10% CC3
  - 15% CC3
  - 20% CC3
Rheology

Cast in-place commercial applications

\[ \Phi = 630 \pm 20 \text{ mm} \]

![Graph showing the relationship between calcium carbonate CC3 (%)
and plastic viscosity (Pa.s).](image-url)
Surface settlement (%)
Form Pressure - Cast-in-place commercial SCC

Acceleration of C₃S hydration: initial reaction of CC with aluminate phase of cement to form calcium aluminate monocarbonate
Semi-adiabatic temperature rise

Cast-in-place commercial SCC

Age of concrete (h)

Temperature (°C)

20% CC3
15% CC3
10% CC3
GU
Semi-adiabatic temperature rise

Cast-in-place commercial SCC

Temperature (°C)

Age of concrete (h)

Steam-cured Precast SCC

Control  CC3-10%  CC3-15%  CC3-20%

20% CC3  15% CC3  GU

Age of concrete (h)
Compressive Strength

Moist curing - Cast-in-place SCC

Compressive strength (MPa) vs. Time (day)

- GU
- 10% CC3
- 15% CC3
- 20% CC3

Compressive Strength graph showing the development of compressive strength over time for different concrete mixtures.
Steam Curing

Precast prestressed

Temperature of steam-curing chamber

Age of concrete (h)

Temperature (°C)

Control  CC3-10%  CC3-15%  CC3-20%
Compressive Strength (MPa)
18-h Steam Curing - Precast SCC

- Precast
- Prestressed
- w/p = 0.35
- w/p = 0.38

OPC
10% CC3
15% CC3
20% CC3
Compressive Strength (MPa)
Moist curing @ 28 d - Precast SCC

Precast
OPC
10% CC3
15% CC3
20% CC3

Prestressed

Architectural
OPC
10% CC3
15% CC3
20% CC3
Drying shrinkage

Precast architectural SCC

Shrinkage (µm/m) vs. Time (day)

- 10% CC3
- 20% CC3
- 15% CC#
- GU
Freeze-thaw durability factor (%)
Scaling resistance (g/m²)

Cast-in-place
Commercial
w/p = 0.42

Precast
Prestressed
w/p = 0.35

Precast
Architectural
w/p = 0.38

- OPC
- 10% CC3
- 15% CC3
- 20% CC3

CSA A23.1 ≤ 500 g/m²
For 10% - 15% cement replacement with Betocarb3

- Increase in packing density
  - Significant increase in static stability (cast-in-place and precast architectural SCC)
  - ~ 10% - 20% reduction in unit cost
- Acceleration of $C_3S$ hydration
  - Faster cancellation of form pressure
  - Limited loss in compressive strength @ 1 d
  - $\geq$ compressive strength after steam curing for precast SCC
- Adequate air-void system
  - High freezing and thawing resistance
  - Adequate scaling resistance for precast SCC and $\leq$ 10% for cast-in-place SCC