SCC: CONSIDERING PERFORMANCE TARGETS AND PROPORTIONS

CP3

Joseph A. Daczko, FACI
BASF Construction Chemicals
PRESENTATION OUTLINE

• Definition of Self Consolidating Concrete (SCC)
• SCC Benefits
• SCC Fresh Properties
• Element Characteristics
• Placement Techniques
• Choosing Targets
• Raw Materials
• Proportioning Basics
WHAT IS SCC?

“Self-Consolidating Concrete (SCC) is highly flowable, nonsegregating concrete that can spread into place, fill formwork, and encapsulate the reinforcement without any mechanical consolidation.”
### SCC BENEFITS – PRECAST CASE STUDY ANALYSIS

#### Energy Consumption
- Savings: 10%

#### Form Costs
- Savings: 20%

#### Maintenance Costs
- Savings: 10%

#### Illness Time
- Savings: 10%

Internal Energy Audit showed a $5k per year savings on electricity through the use of SCC - BASF

### Study #1 vs. Study #2

<table>
<thead>
<tr>
<th></th>
<th>Study #1</th>
<th>Study #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Conventional</td>
<td>SCC</td>
</tr>
<tr>
<td>Placement/Consolidation Labor (people)</td>
<td>13</td>
<td>11</td>
</tr>
<tr>
<td>Placement/Consolidation Time (hours)</td>
<td>2.5</td>
<td>2</td>
</tr>
<tr>
<td>Placement/Consolidation total man hours</td>
<td>32.5</td>
<td>22</td>
</tr>
<tr>
<td>Patching Labor (people)</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Patching Time (hours)</td>
<td>8</td>
<td>9.5</td>
</tr>
<tr>
<td>Patching total man hours</td>
<td>16</td>
<td>9.5</td>
</tr>
</tbody>
</table>

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
SCC FRESH PROPERTIES –
**THIS IS WHAT MAKES SCC DIFFERENT**

3 Primary Characteristics

- Filling Ability
- Passing Ability
- Stability
TEST METHODS

- **ASTM C 09.47**
  - Filling Ability (Fluidity)
    - Slump Flow (C 1611)
  - Passing Ability
    - J-Ring (C 1621)
  - Stability
    - VSI (C 1611) - optional
    - Column segregation (C 1610)
    - Rapid penetration (C 1712)
CONCRETE SLUMP FLOW
ASTM C 1611

Procedure:

- Cone can be standard or inverted
- SCC placed in mold
  - One (1) lift
  - No vibration or tamping
- Raise mold
- Measure diameter of spread
  - 2 directions
  - calculate avg. slump flow

Test Results:

Measures slump flow – fluidity

Typical range: 20 – 30 in. (510 – 760 mm)
**VISUAL STABILITY INDEX (VSI)**

**ASTM C 1611**

<table>
<thead>
<tr>
<th>VSI Rating</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 = Highly Stable</td>
<td>No evidence of segregation in slump flow spread or in mixer drum or wheelbarrow.</td>
</tr>
<tr>
<td>1 = Stable</td>
<td>No mortar halo or aggregate pile in the slump flow spread but some slight bleed or air popping on the surface of the concrete in the mixer drum or wheelbarrow is permitted.</td>
</tr>
<tr>
<td>2 = Unstable</td>
<td>A slight mortar halo (&lt; 10 mm) and/or aggregate pile in the slump flow spread and/or highly noticeable bleeding in the mixer drum and wheelbarrow</td>
</tr>
<tr>
<td>3 = Unstable</td>
<td>Clearly segregating by evidence of a large mortar halo (&gt;10 mm) and/or a large aggregate pile in the center of the concrete spread and a thick layer of paste on the surface of the resting concrete in the mixer drum or wheelbarrow</td>
</tr>
</tbody>
</table>

[Image of concrete samples for each VSI rating]
J-RING TEST
ASTM C 1621

Procedure:
1. SCC placed in mold
   - One (1) lift
   - No vibration or tamping
2. Raise mold – concrete passes through J Ring
3. Measure diameter of spread
   - 2 directions, calculate avg. J Ring flow
4. Obtain Slump Flow
5. Determine difference between Slump Flow and J Ring

Test Results:
Measures passing ability
< 1 in. (25 mm) = good, > 2 in. (50 mm) = poor
J-RING TEST
BLOCKING ASSESSMENT
ASSESSING THE J-RING RESULTS

acceptable

Unacceptable due to instability

Unacceptable poor passing ability

Stable Concrete

Mortar/Paste Ring

Concrete

1

2

3

4
COLUMN SEGREGATION
ASTM C 1610

Procedure:
1. SCC placed in column mold
   ➢ One (1) lift
   ➢ No vibration or tamping
2. Let stand for 15 minutes
3. Individually collect concrete from top and bottom ¼ sections
4. Wash concrete through a #4 sieve, collect and dry the retained coarse aggregate
5. Determine the % difference between coarse aggregate mass in top and bottom sections

Test Results:
Measures segregation potential
< 15% ok, < 10% good
RAPID PENETRATION
ASTM C 1712

Procedure:

1. SCC placed in inverted slump cone
   ➢ One (1) lift, No vibration or tamping
   ➢ Strike off top

2. Within 80 +/- 2 seconds position apparatus on top of cone and the hollow cylinder at surface of concrete

3. Take initial reading

4. Release hollow cylinder and wait 30 +/- 2 seconds

5. Take final penetration reading and calculate

Test Results: Measures segregation resistance
< 10 mm = resistant, 10-25 mm = moderately resistant, ≥ 25 mm = not resistant
ANOTHER WAY TO VIEW CONCRETE FRESH PROPERTIES

• Rheology – The science dealing with the deformation and flow of matter.

• Concrete is typically considered a Bingham fluid, which is described in terms of yield stress and plastic viscosity.

• The yield stress is the shear stress required to initiate or maintain flow
  • Yield stress is negatively correlated to slump (low slump = high yield stress)

• The plastic viscosity is the resistance to flow once the yield stress is exceeded.
  • SCC should have a very low yield stress but the plastic viscosity can vary
HOW DOES RHEOLOGY RELATE TO CONCRETE?

Low slump  Moderate slump  Flowing Concrete  SCC

INCREASING YIELD STRESS

INCREASING VISCOSITY
SCC AND VISCOSITY
EVALUATING AN ELEMENT
**REINFORCEMENT LEVEL**

- **Low**  Min. Spacing >200 mm
- **Med**  Min. Spacing 60-200 mm
- **High** Min. Spacing 35-60 mm
Based on the number of corners, section dimensions and travel in unseen locations.
**ELEMENT DEPTH**

- **Low**: < 12”
- **Med**: 1’ - 5’
- **High**: > 5’
SURFACE FINISH IMPORTANCE

Architectural vs. Structural vs. Buried
Determined by required flow from **DISCHARGE** point.
FORM WALL THICKNESS AND ORIENTATION
## Placement Energy

<table>
<thead>
<tr>
<th>Placement Technique</th>
<th>Discharge Rate</th>
<th>Discharge Type</th>
<th>Single Discharge Volume</th>
<th>*Relative Energy Delivered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck Discharge</td>
<td>High</td>
<td>Continuous</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Pumping</td>
<td>Medium/High</td>
<td>Continuous</td>
<td>Medium</td>
<td>High/Medium</td>
</tr>
<tr>
<td>Conveyor</td>
<td>Medium</td>
<td>Continuous</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Buggy</td>
<td>Medium</td>
<td>Discontinuous</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Crane and Bucket</td>
<td>High</td>
<td>Discontinuous</td>
<td>Low</td>
<td>Low/Medium</td>
</tr>
<tr>
<td>Auger (Tuckebilt) Discharge</td>
<td>Medium</td>
<td>Continuous</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Drop Tube</td>
<td>High</td>
<td>Discontinuous</td>
<td>High</td>
<td>High</td>
</tr>
</tbody>
</table>

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
FORMWORK DIMENSION AND RHEOLOGY IMPACT ON CONCRETE FILLING ABILITY AND PLACEMENT RATE

How quickly should I pour?
BRINGING THE THOUGHT PROCESS TOGETHER

<table>
<thead>
<tr>
<th>Member Characteristics</th>
<th>Fresh Properties</th>
<th>Fluidity</th>
<th>Passing Ability</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>low</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td>Reinforcement level</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element shape intricacy</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element depth</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Importance of surface finish</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Element length</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wall Thickness</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coarse aggregate content</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placement Energy</td>
<td>Low</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Medium</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>High</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONTROLLING FRESH PROPERTIES – MIXTURE PROPORTIONS AND ADMIXTURES

- A combination of mixture proportioning techniques, understanding raw materials and advanced admixture technology control SCC fresh properties

<table>
<thead>
<tr>
<th>Admixture Type</th>
<th>Reason for Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-range water reducer (HRWR)</td>
<td>Reduction of water to alter viscosity. Adjust dosage to increase or decrease slump flow.</td>
</tr>
<tr>
<td>Viscosity modifying admixture (VMA)</td>
<td>Enhance viscosity to promote greater mixture stability and reduce bleeding.</td>
</tr>
<tr>
<td>Workability Retaining Admixture</td>
<td>Provide controlled workability/slump flow retention without retardation.</td>
</tr>
<tr>
<td>Accelerating Admixture</td>
<td>Increase early age compressive strength development. Facilitate normal setting in cold temperatures.</td>
</tr>
<tr>
<td>Retarding &amp; Hydration Control Admixtures</td>
<td>Slow the rate of cement hydration to delay setting in hot temperatures and extend workability time.</td>
</tr>
<tr>
<td>Air entraining Admixture</td>
<td>Enhance durability. Increase mixture paste content and promote flow and stability.</td>
</tr>
</tbody>
</table>

Source; Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
PCE – HRWR DOSAGE DIFFERENCE

Source; Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
EFFECTIVENESS OF VISCOSITY-MODIFYING ADMIXTURES (VMA’S)

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
WORKABILITY RETAINING ADMIXTURES

• Workability Retaining Admixtures
  • Dramatically improve workability retention
  • **Provides time delayed dispersion**
  • Minimal impact on set
  • Improvement in both early and later age strength gain
  • Certified as an ASTM Type S
SCC PROPORTIONING FUNDAMENTAL PRINCIPLE - BALANCING AGGREGATES AND PASTE

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
STRIKING THE BALANCE

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author's with air</td>
<td>39%</td>
<td>38%</td>
<td>35-43%</td>
</tr>
<tr>
<td>Author's without air</td>
<td>35%</td>
<td>34%</td>
<td>29-41%</td>
</tr>
<tr>
<td>Domone's</td>
<td>35%</td>
<td>35%</td>
<td>30-42%</td>
</tr>
</tbody>
</table>

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”

<table>
<thead>
<tr>
<th></th>
<th>Average</th>
<th>Median</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;20 mm</td>
<td>31.0%</td>
<td>30.9%</td>
<td>28.3% - 34.9%</td>
</tr>
<tr>
<td>20+mm</td>
<td>32.3%</td>
<td>31.7%</td>
<td>28% - 42.3%</td>
</tr>
</tbody>
</table>

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
# AGGREGATE IMPACT ON CONCRETE PROPERTIES

<table>
<thead>
<tr>
<th>AGGREGATE PROPERTIES</th>
<th>INFLUENCE ON CONCRETE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Sp. gravity</td>
<td>Strength, concrete density</td>
</tr>
<tr>
<td>2 Porosity</td>
<td>Absorption of water and admixtures</td>
</tr>
<tr>
<td>3 Texture</td>
<td>Bond grip</td>
</tr>
<tr>
<td>4 Shape</td>
<td>Water demand, paste volume, rheology of paste</td>
</tr>
<tr>
<td>5 Gradation</td>
<td>Water demand, cohesion, bleeding, segregation, paste volume</td>
</tr>
<tr>
<td>6 Max. aggregate Size</td>
<td>Water demand, paste volume, passing ability</td>
</tr>
<tr>
<td>7 Chemical Stability</td>
<td>Durability</td>
</tr>
<tr>
<td>8 Deleterious Materials</td>
<td>Durability</td>
</tr>
</tbody>
</table>
AGGREGATE SHAPE

FLAT

ELONGATED

ANGULAR

ROUND
The smaller L/E the less distance between the particles is necessary to create workability.
CONSIDERING THE PASTE

Paste
- Paste Volume
- Paste Rheology

Paste Composition
- Water Content
- Powder Content
- Admixtures
  - VMA
  - HRWR

- Powder Composition
- Cement
- SCM's
- Aggregate Fines
- Other Powders

Source: Daczko, Joseph A., “Self-Consolidating Concrete: Applying What We Know”
STRIKING THE BALANCE

Design Programs can only get you so far

Precedent: SCC Mix Design

Total Cementitious:
- Pozzolan: Class F Flyash 20.0%
- Pozzolan: Silica Fume 0.0%

Mix Cost $$

Materials Content
- Paste: 40.3%
- Sand: 29.1%
- Silica Fume: 30.6%

Mix Paste Breakdown
- Sand: 29.1%
- #67 Coarse: 30.6%
- #8 Coarse: 0.0%
- Paste: 40.3%

Coulomb Days
- Estimated BCP Value: Coulomb 1119 Days 56

Optimal Packing

Chemical Admixtures

- Air Entrainment: MB-AE90 0.0 oz/cwt 0.0 oz/eyd 0.0 Volume m3/m3 0.0
- HRWR: Glenium 7700 5.7 oz/cwt 47.0 oz/eyd 0.0 Volume m3/m3 1818
- Set Modifier: Pozzolith NC534 0.0 oz/cwt 0.0 oz/eyd 0.0 Volume m3/m3 0.0
- Corrosion: Rheocrete CNI 0.0 oz/cwt 0.0 oz/eyd 0.0 Volume m3/m3 0.0
- VMA: Rheomix 362 0.0 oz/cwt 0.0 oz/eyd 0.0 Volume m3/m3 0.0

Lower Upper
- Water Content 40.3% 31%
- Mortar Content 68.7% 11%
- Coarseness Factor 81.5% 42% 66%
- Workability Factor 48.8% 27% 39%
- Excess Paste 18640 in³/yd³ 0.0
- Paste Viscosity 7.4 1.8 4.9
- Water / Powder 1.08 0.85 1.10

W/C Ratio: 0.376
Sand/Aqua Ratio: 0.492
cu ft: 27.00
kg/m³: 2238
Design Weight: 3772
Lbs cu ft: 139.72
Mortar % Sand: 48.53%

precast.org/education
SCC: CONSIDERING PERFORMANCE TARGETS AND PROPORTIONS
CP3

Joseph A. Daczko, FACI
BASF Construction Chemicals