The rheology of control flow concrete

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ACI 237R-07: Self-consolidating concrete

“...highly flowable, nonsegregating concrete that can spread into place, fill the formwork, and encapsulate the reinforcement without any mechanical consolidation.

In general, SCC is concrete made with conventional concrete materials and, in some cases, with a viscosity-modifying admixture.”
Mix proportioning

Conventional concrete

Self-consolidating concrete
Challenges in producing ready-mix SCC

• Mix proportioning is complicated

• High cementitious factor
  • Significant cost increase
  • Difficult to finish
  • Increased shrinkage

• Difficult to produce

• Limited applications

To mitigate risk, you need an increase in both expertise/experience as well as material costs
What if we could have best of both worlds?

- Typical mix proportioning
  - Strength: 3500-6500 psi [25-45 MPa]
- Lower cementitious content
- Superior moisture tolerance
- Higher segregation resistance
- Easier finishability

- Slump flows 16-25” [400 to 635 mm]
- Minimal vibration
- Excellent flowability retention for more than 1 hour
- Fast pumping, rapid placement
Novel admixture formulation

Control flow concrete
- *Is* Conventional Concrete with enhanced flow using novel blend of admixtures
- *Is not* Self Consolidating Concrete with reduced flow
Control flow concrete

Conventional concrete

- Slump: 6-8”

Control flow concrete

- Slump flow: 18-22”

Self-consolidating concrete

- Slump flow: 25-30”
Control flow concrete
Static and dynamic yield stresses

**Static yield stress:**
- stress required to initiate flow
- (rest to flow)

**Dynamic yield stress:**
- stress at which flow stops
- (flow to rest)

CI June 2007, ACI 238
Static yield stress

Stress growth test

- Conventional Concrete
- Control Flow Concrete
- Self-Consolidating Concrete
Flow curve data example

Data point [20/sec]

Torque [Nm]

Spindle speed [RPS]

Torque

Actual Speed
Flow curve results
Balancing rheology

![Graph showing the relationship between static yield stress and plastic viscosity. The graph indicates the range of values for these properties in a SCC material.]
Balancing rheology

![Graph showing the relationship between static yield stress and plastic viscosity. The graph indicates the need for careful proportioning to balance rheology.]
Balancing rheology

![Graph showing static yield stress vs. plastic viscosity](image)

- **Static yield stress [Pa]**
  - 0
  - 500
  - 1000
  - 1500
  - 2000
  - 2500
  - 3000

- **Plastic viscosity [Pa.s]**
  - 0
  - 20
  - 40
  - 60
  - 80
  - 100

**Legend:**
- HRWR overdose
- Proportioning

**Images:**
- Left: Close-up of a concrete sample with visible aggregates.
- Right: Close-up of another concrete sample with a different texture.
Balancing rheology

Static yield stress [Pa]

Plastic viscosity [Pa.s]

HRWR overdose

Proportioning

+ Control flow admix
## Performance comparison example

<table>
<thead>
<tr>
<th></th>
<th>3500 PSI ready mix with HRWR (Conventional)</th>
<th>3500 PSI ready mix with Control Flow Admixture</th>
<th>Self Consolidating Concrete (SCC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-consolidating</td>
<td>No</td>
<td>Semi-consolidating</td>
<td>Yes</td>
</tr>
<tr>
<td>Placement</td>
<td>Difficult</td>
<td>Easy</td>
<td>Easy</td>
</tr>
<tr>
<td>Labor demand</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Segregation risk</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Powder content</td>
<td>500-600 lbs/yd³</td>
<td>500-600 lbs/yd³</td>
<td>&gt;700 lbs/yd³</td>
</tr>
<tr>
<td>Mix design adjustments</td>
<td>None</td>
<td>None or Minimal</td>
<td>Yes (high quality fine aggregates and Needs more powder)</td>
</tr>
<tr>
<td>Moisture tolerance</td>
<td>Tolerant</td>
<td>Tolerant</td>
<td>Needs very close QC</td>
</tr>
<tr>
<td>QC need</td>
<td>Routine</td>
<td>Routine</td>
<td>Extra effort</td>
</tr>
<tr>
<td>Drying shrinkage</td>
<td>OK</td>
<td>OK</td>
<td>Higher</td>
</tr>
</tbody>
</table>

**Conventional Mix Design with Unconventional Performance**
Project highlights with control flow concrete

My Home Vihanga Apartments
Hyderabad, India

Landmark 81
Ho Chi Minh City, Vietnam

Mayo Clinic & MD Anderson Cancer Center
Jacksonville, FL

Tanjong Pagar Centre
Singapore
Landmark 81: Ho Chi Minh City

Tallest building in Vietnam
11th Tallest building in the world

GCP’s Dr. Jiang Jiabiao
Final pour, at 400m