Self Compacting Concrete

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Normal Concrete

Traditionally Concrete is made by mixing:

- CEMENT
- WATER
- COARSE AND FINE AGGREGATES

The four main properties of concrete are:

- WORKABILITY
- COHESIVENESS
- STRENGTH and
- DURABILITY

- Workability means how easy it is to:
  - PLACE
  - HANDLE
• COMPACT and
• FINISH a concrete mix
• *Never try to make a mixture more workable by just adding more water because this lowers the strength and durability of concrete*

• Compressive Strength is governed by Abram’s law
• Proper compaction results in concrete with an increased density which is stronger and more durable
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So,

- By adding more water
- In fresh state- leads to segregation & bleeding
- In hardened state- leads to durability problems

To make a more workable mix:

- Add more CEMENT PASTE
- Use WELL GRADED aggregates
- Use an ADMIXTURE

Release of Trapped Water from Cement Flocs by the action of Admixtures

Flocculated cement particles (left) in the absence of SP & Deflocculated (right) in the presence of SP
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So, what is Normal Concrete?

- Cement: 300-450Kg/m³
- Max. W/C ratio: 0.55
- Grade of Concrete: M20 - M40
- Permits the use of :
  - Mineral Admixtures (Fly Ash, Silica Fume, GGBS, Rice Husk Ash, Metakaoline)
  - Chemical Admixtures

Problems persist......

- Lack of adequate compaction in normal concrete
- Compaction requires the use of heavy, noisy, expensive, energy-consuming vibrators – sometimes non available
- More advanced complex RC design - high density of reinforcing bars, complex shapes - shortage of skilled labour for supervision
There is a quest amongst concrete engineers for a still higher strength/higher performance/higher ductility concrete

The answer could be ...... SCC

Self-Compacting Concrete (SCC)

Defined by researchers as: “concrete that is able to flow and consolidate under its own weight, completely fill the formwork of any shape, even in the presence of dense reinforcement, while maintaining homogeneity and without the need for any additional compaction”
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Origin

- Introduced to the concrete industry, in Japan, primarily, through the work of Professor Okamura in the late 1980’s.
- Motivation behind this was the gradual reduction of skilled labor, which led to the reduction in the quality of construction work, affecting adversely, the durability of concrete due to poor compaction.

MATERIALS

SELF-COMPACTING CONCRETE

![Professor Okamura Image]
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- SCC has more powder content and less coarse aggregate
- Fillers used can be flyash, ground granulated blast furnace slag, condensed silica fume, rice husk ash, lime powder, chalk powder & quarry dust
- SCC incorporates high range water reducers (HRWR, Superplasticizers) & frequently, viscosity modifying agent in small amount.

From traditional concrete to SCC

Potential Benefits of SCC

Contractor

- Reduced labor requirement & cost
- Reduced plant requirement
- Reduced remedial work
- Reduced noise, improved site health & safety
- No vibrating equipment required, Reduces placing costs
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Designer / client

- Use in more complex design & heavy reinforcement
- Improved aesthetics & durability
- Quicker construction time
- Less variation in the production of concrete & more homogeneous concrete
- Better surface finish

FRESH SCC REQUIREMENTS

Filling ability

Stability

Passing ability
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Fresh SCC Properties

Filling ability

“The ability of SCC to flow into and fill completely all spaces within the formwork, under its own weight.”

Fresh SCC Properties

Passing ability

“The ability of SCC to flow through tight openings such as spaces between steel reinforcing bars without segregation or blocking.”
Fresh SCC Properties

- Segregation resistance

“The ability of SCC to remain homogeneous in composition during transport and placing.”

CHARACTERISTICS OF SCC

- If SCC should not segregate- it must have mortar rich in fines & is also able to transport the coarse aggregate & keep them in viscous suspension
- Cement cannot be the only finer/filler material
- Mineral admixtures are used to enhance the deformability & stability of concrete
- Chemical admixtures are a must for achieving excellent flow at low water content. VMA reduces bleeding & improves the stability of the concrete mixture

Compared to Conventional Concrete, SCC has

- Higher powder content in the order of 450-600 Kg/m$^3$
- Lower water/cement ratio. Typical range of water is 160 to 185 kg/ m$^3$ & water/binder ratio, by volume in the range of 0.7 to 1.25. Volume of paste 0.36 to 0.43
- Lower coarse/fine aggregate ratio
- Use of superplasticizers & VMA compatible with cement in small percentages.

TEST METHODS FOR DETERMINING FRESH SCC PROPERTIES

- FILLING ABILITY
  - Slump flow & $T_{50cm}$ slump flow
- V-Funnel

- PASSING ABILITY
  - L-Box
  - U-box
  - J-ring
  - Fill Box

- SEGREGATION RESISTANCE
  - V-Funnel at $T_5$ Minutes
  - GTM Screen stability test

Slump flow (spread)

- Most popular method
- Assess the horizontal free flow of concrete in the
- Measures the filling ability
- Normal range of flow recommended
  - 650 mm to 800 mm

![Slump Flow Diagram](Image)
TEST METHODS

Slump flow (spread)
- Secondary measurement of T50 cm can be made
- Represents time taken in seconds to reach horizontal diameter of 500 mm
- Recommended limits are 2 sec to 5 sec

V-Funnel Test
- To assess the flowability of fresh concrete
- The time taken for concrete to flow through the narrow end is measured
- Measures viscosity of concrete
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V-Funnel Test

- Recommended value for V-funnel flow
- < 12sec

TEST METHODS

L-Box Test

- Passing ability of fresh concrete.
- T 20 cm and T 40 cm marks of horizontal section of L – box are the indications of ease of flow of concrete.
- Recommended values of flow time are:
  - T 20 cm = 1 ± 0.5 sec
  - T 40 cm = 2 ± 0.5 sec
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L-Box Test

- Height of the concrete at the end of the horizontal section is expressed as a proportion of that of remaining in the vertical section (H2/H1).
- Recommended value for blocking ratio:
  - Blocking ratio H2/H1 ≥ 0.80.

U-Box Test

- Also called as ‘Box-shaped’
- Measures the filling ability of concrete.
- The difference in height of two sections is measured.
- Recommended value:
  - difference in the height of the limbs < 30 mm
J-Ring Test

- Measures passing ability of concrete
- Can be used in conjunction with Slump flow test, combination can test filling ability & passing ability
- The difference in height, in between the concrete inside and that just outside the J-ring is measured
- Difference in height of maximum of 10 mm is considered appropriate
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J-ring Test

- Simple test.
- Bars can be of different diameters and also varied spacing:
  - Preferably three times the maximum aggregate size
- Used in conjunction with slump flow test

$V_{5\text{min},\text{flow time}}$

- This is secondary parameter of the V-funnel test
- Measures time of flow of concrete after time gap of 5min
- Indicates the tendency for segregation
- Recommended value is:
  - $< +3 \text{ sec of time at zero hours}$
SUGGESTED VALUES OF ACCEPTANCE FOR DIFFERENT TEST METHODS OF SCC - EFNARC -2002

<table>
<thead>
<tr>
<th>METHOD</th>
<th>UNIT</th>
<th>MINIMUM</th>
<th>MAXIMUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump flow</td>
<td>mm</td>
<td>650</td>
<td>800</td>
</tr>
<tr>
<td>J-ring</td>
<td>cm</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>V-funnel</td>
<td>cm</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>U-box</td>
<td>cm</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>L-box</td>
<td>cm</td>
<td>0</td>
<td>1.0</td>
</tr>
<tr>
<td>U-box</td>
<td>cm</td>
<td>0</td>
<td>20</td>
</tr>
<tr>
<td>FT-box</td>
<td>cm</td>
<td>0</td>
<td>200</td>
</tr>
<tr>
<td>CIDM excess</td>
<td>cm</td>
<td>0</td>
<td>15</td>
</tr>
</tbody>
</table>

Acceptance of SCC

Combinations may be-

- Slump flow, V-funnel and U-box tests (Japan)
- Slump flow and L-Box (Sweden)
- J-ring and U-box

Slump flow, U-Box/L-Box, V-funnel (at 5min.)

Characteristics of SCC in Hardened state

Typical Properties of hardened SCC

<table>
<thead>
<tr>
<th>Items</th>
<th>SCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-binder ratio( %)</td>
<td>25 to 40</td>
</tr>
<tr>
<td>Compressive strength (age: 28 days) (MPa)</td>
<td>40 to 80</td>
</tr>
<tr>
<td>Compressive strength (age:91 days) (MPa)</td>
<td>55 to 100</td>
</tr>
<tr>
<td>Splitting tensile strength (age: 28 days) (MPa)</td>
<td>2.4 to 4.8</td>
</tr>
<tr>
<td>Elastic modulus (GPa)</td>
<td>30 to 36</td>
</tr>
<tr>
<td>Shrinkage strain (x10⁻⁶)</td>
<td>600 to 800</td>
</tr>
</tbody>
</table>
### Differences in performance of SCC and CVC

<table>
<thead>
<tr>
<th>Properties of SCC</th>
<th>Expectation</th>
<th>Reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation in strength across depth of structure</td>
<td>Can take place for SCC</td>
<td>No difference (between SCC and CVC)</td>
</tr>
<tr>
<td>Creep and drying shrinkage</td>
<td>Higher for SCC</td>
<td>No significant difference</td>
</tr>
<tr>
<td>Early age shrinkage and cracking</td>
<td>Higher for SCC</td>
<td>Higher for SCC</td>
</tr>
<tr>
<td>Strength and elastic modulus</td>
<td>No difference</td>
<td>No difference</td>
</tr>
<tr>
<td>Durability</td>
<td>Better for SCC</td>
<td>Better for SCC</td>
</tr>
</tbody>
</table>

### Typical SCC Mixes from various parts of the world

<table>
<thead>
<tr>
<th>Mix Ref.</th>
<th>W/C</th>
<th>Cement Kg/m³</th>
<th>Filler Kg/m³</th>
<th>Type of filler</th>
<th>F.A.</th>
<th>C.A.</th>
<th>ms (mm)</th>
<th>Powder Kg/m³</th>
<th>Water (litr)</th>
<th>SP /VMA (litr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Philippe et. al., France</td>
<td>0.53</td>
<td>350</td>
<td>150</td>
<td>Lime stone</td>
<td>860</td>
<td>790</td>
<td>14</td>
<td>500</td>
<td>187</td>
<td>5.4 / 3.4</td>
</tr>
<tr>
<td>Vieria et. al., Portugal</td>
<td>0.78</td>
<td>205</td>
<td>358</td>
<td>fly ash / Lime stone</td>
<td>786</td>
<td>786</td>
<td>19</td>
<td>563</td>
<td>161</td>
<td>5.6</td>
</tr>
<tr>
<td>Gomes et.al.Spain</td>
<td>0.42</td>
<td>455</td>
<td>183</td>
<td>Lime stone/silica fume</td>
<td>765</td>
<td>807</td>
<td>12</td>
<td>638</td>
<td>191</td>
<td>14.4</td>
</tr>
<tr>
<td>David C et. al, France</td>
<td>0.39</td>
<td>396</td>
<td>256</td>
<td>Lime stone</td>
<td>723</td>
<td>760</td>
<td>12</td>
<td>652</td>
<td>155</td>
<td>5.3 / 4.7</td>
</tr>
</tbody>
</table>

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<th>Water (litr)</th>
<th>SP /VMA (litr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zhu et.al., UK</td>
<td>0.58</td>
<td>330</td>
<td>200</td>
<td>GGBS</td>
<td>870</td>
<td>750</td>
<td>10</td>
<td>530</td>
<td>192</td>
<td>5.3</td>
</tr>
<tr>
<td>Henderson, UK</td>
<td>0.48</td>
<td>400</td>
<td>150</td>
<td>Fly ash</td>
<td>765</td>
<td>795</td>
<td>20</td>
<td>550</td>
<td>190</td>
<td>6.0 /6.0</td>
</tr>
</tbody>
</table>
### Applications of Self-Compacting Concrete in Japan

**Osaka Gas Station**


![Image of Osaka Gas Station](image)

**Akashi-Kaikyo (Straits) Bridge**

Longest suspension bridge Length 3911m and central span of 1991m

![Image of Akashi-Kaikyo Bridge](image)

<table>
<thead>
<tr>
<th>Source</th>
<th>w/c</th>
<th>SP</th>
<th>SPAD</th>
<th>Aggregate Type</th>
<th>Density</th>
<th>Air Void</th>
<th>Slump</th>
<th>UCC</th>
<th>UCM</th>
<th>Flow</th>
<th>VD</th>
<th>Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brouwers et al., Netherlands</td>
<td>0.55</td>
<td>320</td>
<td>153</td>
<td>Lime Stone</td>
<td>1016</td>
<td>687</td>
<td>16</td>
<td>473</td>
<td>174</td>
<td>5.21</td>
<td></td>
<td></td>
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<tr>
<td>A.A. Maghsoudi et al., Iran</td>
<td>0.42</td>
<td>400</td>
<td>100</td>
<td>Lime Stone</td>
<td>870</td>
<td>750</td>
<td>20</td>
<td>500</td>
<td>168</td>
<td>2.6</td>
<td></td>
<td></td>
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<tr>
<td>Van K Bui et al., America</td>
<td>0.62</td>
<td>349</td>
<td>209</td>
<td>Flyash</td>
<td>736</td>
<td>805</td>
<td>19</td>
<td>558</td>
<td>216</td>
<td>1.65</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
240,000 m³ of SCC

Application of SCC in RCC girders
Applications in India
Lecture-6

Bangalore International Airport

Summary

• One of the outcomes of using High Strength Concrete is slender members and consequently, very dense reinforcement. Normal methods of vibration are not effective – Hence, SCC.

• SCC has various other applications. It is especially suited to pre-cast/prefab products. In Japan, they now use for casting composite columns, steel tubes with shear lugs inside filled with SCC and no other reinforcement. Very tall columns have been made.

• Very few national standards exists as of now for SCC (Japan, Europe, Italy etc.,)

• SCC mixes are very sensitive to variation in water.

• Water curing is absolutely necessary for 3 to 7 days.

• SCC should be treated as high quality concrete and not meant for low strength applications

• SCC can be advantageously used for all types of work with proper understanding of its behavior

• It is a matter of time SCC replacing Normal Concrete even in INDIA