Self Compacting Concrete
An Economical Approach

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Self Compacting Concrete (SCC) has been promoted in the Middle East for the last eighteen years. Although targeted at the high quality end of the marketplace there has been little commercial success, despite the many advantages and savings in use of SCC. The majority of its applications have been small niche pours into congested rebar, domes, or thin wall sections. Self Compacting Concrete by its definition has to be fluid, self-compactible with high segregation resistance. To achieve these properties and to reach extremely high specification targets it is normal to use a high dose of new generation poly-carboxylate admixture plus a rheology modifier into the concrete mix. The use of these admixtures and change in mix design increase the cost significantly above that of conventional high quality concrete and this is seen as the major factor that has prevented wider use of SCC.

This paper therefore studies the production of SCC with a specification for exceeding that of conventional concrete, currently in use in the Middle East, and gives a concrete mix with all the application advantages of SCC, without an excessive cost increase.

High durability concrete will be discussed throughout this paper. It will be classed as that which has to be manually placed and include durability enhancers; GGBFS, Micro silica and PFA in the mix designs. The high durability conventional concrete in question will have a total cementitious content of between 450 to 500kg per meter cube, and coarse to fine aggregate ratio will be as 60:40 percent, and concrete will be produced at water cement ratio of 0.40 (maximum).

High durable conventional concrete has to be well vibrated to achieve good compaction. It should be noted that with conventional concrete, water would tend to migrate to the surface of the coarser particles when vibrated causing porous and weak inter facial zones, which will affect the concrete durability. Therefore there will always be a difference in durability parameters of conventional concrete in a laboratory with tightly controlled conditions, compared to site batch concrete.

Awareness of self-compacting concrete has spread across the world and specifically in the Middle East and India, prompted by concerns with poor compaction and concrete durability.

In the U.A.E., and specifically in Dubai, there are a significant number of high-rise structures under construction and many more expected. Normal concrete technology has been extended through SCC for easier placement of concrete, associated with other benefits. Specific instructions are necessary for designing, producing, transporting and handling of such concrete. Its innovative aspects lie in its fresh properties and the potential benefits to the contractors.

The UAE, Middle East and Far East markets including India are currently experiencing a change in concrete durability specifications, such that on-site only SCC mixes can meet the requirements with continued repeatability.

What is Self Compacting Concrete

SCC is a concrete, which in its plastic state, flows silently under its own weight and maintains homogeneity while completely filling the formwork of any shape, even around congested reinforcement. Compaction of concrete is achieved by its own movement properties.

Khayat et al defines SCC as

“A highly flowable, yet stable concrete is one that can spread readily into place and fill the formwork without any consolidation and undergoing any significant segregation”.

Materials & Mix Designs

SCC can be made out of similar materials as used for conventional concrete for structural use. Maximum size of
the coarse aggregate will be dependent on the minimum spacing allowed for reinforcement layouts. Even a 40mm size of aggregate may be used. Graded aggregates will be of a great help. Fine sand content less than 150 microns will be very useful for better cohesion and reduced segregation.

Mix Design, Admixture and Cement

The objective of traditional concrete mix design is always to work out the most effective proportioning of materials to achieve the concrete properties in plastic and hardened state.

But before looking at designing a mix for SCC, an understanding is needed of the properties required for self-compaction and how it will be optimized using normally available materials. There are two main properties, which should be looked into, that is, as a highly fluid concrete, with segregation resistance.

To achieve highly fluid concrete, a low yield stress is required and for high segregation resistance, a highly viscous concrete is needed.

Fluidity and concrete viscosity may be varied by re-proportioning the aggregates or by using high-grade super-plasticisers in concrete mixes. Viscosity modifiers can also be used for segregation resistance, but it will increase the yield stress of the paste, thereby affecting the mobility of the mix.

Advances in superplasticiser technology have played a major role, and new generation superplasticisers based on polycarboxylate ethers promote good workability retention, and can be added at any stage of the batching cycle.

Fine particles play an integral part in SCC mix designs, as SCC mixes are made with high fines. On an average the SCC mix will have 400kg to 600kg of cement. This cement weight of 500kg/m³ of concrete can be replaced partly by pulverized fuel ash, ground granulated blast furnace slag and silica fumes. These cement replacements will enhance the concrete properties of the mix in the plastic state and hardened state of the concrete. These cement replacements will further add durability properties to the concrete. Even limestone powder is used extensively in Europe. All fillers must be assessed for their effect on water demand, to achieve the optimum level of water for the mix.

Typical guideline criteria are given in Table 1. These guidelines may be amended as per the country’s requirement of concrete specifications and locally available materials.

Water demand is very critical to SCC mix design and specifically related to segregation. It is advisable to design the mix conservatively to maintain the plastic state concrete properties.

Water demand and admixture dosage should be economically adjusted to retain the fluidity of concrete towards 90/120 minutes after batching.

A slump cone flow spread of 650 mm at the time of placing the concrete will be quite acceptable to meet almost all properties in plastic and hardened state of concrete.

Hardened state properties of SCC

Compressive Strength

At constant water cement ratios, the characteristic strength of SCC will be slightly above or at least equal to the

![Fig 1](GGBS mix design)

<table>
<thead>
<tr>
<th>Materials</th>
<th>Properties</th>
<th>Practical Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse aggregate</td>
<td>Well graded to reduce inter particle friction and prevent blocking</td>
<td>In practice it may vary between 700-900kg/m³</td>
</tr>
<tr>
<td>Sand</td>
<td>Very well graded sand available at local source. Should contain fine materials passing through 150 micron sieve</td>
<td>Should be &gt;50% of the total aggregate content</td>
</tr>
<tr>
<td>Cement + Fillers</td>
<td>High content required</td>
<td>Typically 500kg/m³</td>
</tr>
<tr>
<td>Water</td>
<td>Dependent on fillers and fines</td>
<td>Typically between 130 litres to 150 litres (free water)</td>
</tr>
<tr>
<td>Water/(Cement + Filler) ratio</td>
<td></td>
<td>0.28 to 0.34 for tropical Middle East conditions</td>
</tr>
<tr>
<td>Admixtures</td>
<td>Dosage to be tailored to meet the durability properties of Plastic and hardened state of concrete</td>
<td>May vary between 3.0 to 6.0 ltrs per m³. Follow manufacturer’s advice</td>
</tr>
<tr>
<td>Paste &amp; Mortar</td>
<td>Paste &gt;40% by mix vol. Sand &lt;50% by mortar vol.</td>
<td></td>
</tr>
</tbody>
</table>

Table 1
conventional concrete of similar grade. (see Fig. 1&2)

Above results indicate that the characteristic compressive strength of 60N/mm² can be easily achieved. In addition to the above information, lower water to cementitious ratio with fines will help to achieve the rheological properties of concrete will make difficult to keep the strengths down.

The author of this paper was involved in re-proportioning the mix while using the similar quantity of fines, as mentioned in Fig. 2, and could enable to reduce the admixture dosage within limits. The details of the compressive strengths achieved are shown in Fig 3.

Drying Shrinkage

Drying Shrinkage of SCC has been noticed to be similar to that of conventional concrete or lower, which is contrary to that expected from the lower aggregate content, which is partially expressed by the similar water content of SCC and high durability conventional concrete. The high fine content in the SCC mix may indicate slightly higher figure on drying shrinkage as compared to conventional concrete.

In the UAE and in Middle East most SCC mixes are designed on very low water cementitious ratio that enables the mix to achieve lower drying shrinkage as shown in Table 2. Attention to curing is very important for the tropical conditions prevailing in the Middle East, and India to ensure that the low drying shrinkage figures obtained in the laboratory are transformed to site. (Table 2)

Care should be taken to ensure the concrete is cured correctly.

Bond Strength

Bond Strength behavior of conventional concrete is dependent on the reinforcing bar location, deformation of bar pattern, fluidity of concrete mix and in general contact with rebar. Interlocking of aggregates in SCC is far superior in comparison to conventional concrete, which is due to the uniform distribution of aggregates over the full cross section and the higher volume of cement binder matrix. Therefore the bond strength between concrete and reinforcement for medium to high strength concrete in SCC is higher than that of conventional concrete.

Durability

Few indices of durability have been investigated in self-compacting concrete when compared to the same grade of conventional concrete. The results are listed in table 3, which are recorded at 28 days age.

Summary and Economics

Self Compacting Concrete will be seen by the contractor as a material which will be useful, but demands different working practices and as such it has more advantages than disadvantages. These should be balanced against each other and economics can be worked, while listing and evaluating each parameter. In most of the cases and situations, the resultant effect will be in the favor of Self Compactin...
Compacting Concrete – as an improvement in ease and spread of placement, quality of finish and reduced overall cost in addition to the usual technical benefits of complete and assured compaction and minimizing the voids.

A summary of advantages can be listed as below

- Very less dependence on skilled work force.
- Faster placing time – enhances total production period to be reduced.
- Improved surface finish – means cost of making good.
- Noise elimination leads to safe working environment.
- Some approximation of the offset costs can be calculated.

Estimates of these show the following in UAE Dirhams per cubic metre.

<table>
<thead>
<tr>
<th>Properties</th>
<th>Conventional Concrete</th>
<th>SCC</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Man Power</td>
<td>2.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Vibration</td>
<td>2.00</td>
<td>0.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Finishing</td>
<td>2.00</td>
<td>0.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Curing</td>
<td>2.00</td>
<td>2.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Repairs</td>
<td>18.00</td>
<td>0.00</td>
<td>18.00</td>
</tr>
<tr>
<td>Formwork</td>
<td>15.00</td>
<td>20.00</td>
<td>-5.00</td>
</tr>
<tr>
<td>Plaster</td>
<td>5.00</td>
<td>0.00</td>
<td>5.00</td>
</tr>
<tr>
<td>Overheads</td>
<td>5.00</td>
<td>3.00</td>
<td>2.00</td>
</tr>
<tr>
<td>Total</td>
<td>51.00</td>
<td>27.00</td>
<td>25.00</td>
</tr>
</tbody>
</table>

(Above are shown as Typical Values, which may vary from Country to country.)

In summary, it is clear that self-compacting concrete offers some significant advantages over conventional concrete. Some of the economic applications may be listed, like, precast elements, exposed walls and columns, water tight basements, congested reinforcement locations and column encasements.

References

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Authors Bio

Dr. Kapoor has spent approximately 30 years in the field of Concrete Technology, while working in Middle East and Far East and advising customers, ready mix concrete manufacturers, suitable mix designs and appropriate use of concrete admixtures to achieve the highest degree of concrete durability for enhanced structural life.

The Toyohashi University of Technology demonstrated its wireless power transmission technology using electric field coupling with automobile tires and the same concrete as used for public roads in Yokohama, Japan recently.

A research group led by Takashi Ohira, professor at the university’s Department of Electrical and Electronic Information Engineering, has been engaged in the research aimed at using wireless power transmission technologies based on electric field coupling (or inductive coupling) for transmitting power to a running vehicle. The differences from the group’s past research results are (1) that electricity as large as 50-60W was transmitted to life-size automobile tires and (2) that there was a 10cm-thick concrete block between the metal plate on the transmission side and the tire. The efficiency of power transmission from the metal plate under the concrete, which is the same as used for public roads in Japan, to the light bulb attached to the tire, is 80-90% or higher, Ohira said.

As for the second improvement, the research group said that it will become possible to use the technology with 20cm or thicker concrete, which is sometimes used for actual roads, because of the high conductivity of concrete. To put the technology into practical use, the electric power needs to be increased by 100 times. But the group said that the parts needed for it are relatively cheap and that there is no major problem.

Credits: The Toyohashi University of Technology