Abstract

The self-compacted concrete is an innovative product in civil engineering field of India. The necessity of this product was felt by civil engineers to overcome in the issue of workmanship, in structural concreting of thickly/heavily re-in forced sections in execution of concreting. This product was first developed in Japan in 1997 and followed by Europe and U.S.A. Substantial research was carried out with regard to the properties of SCC Because of the well-controlled conditions; the introduction of SCC in the precast concrete industry was successful. With regard to the application in situ, the development is slower, because of the sensitivity of the product. In this paper the mechanical properties of SCC in comparison to conventional concrete are discussed. Examples of applications are shown, both for prefabricated concrete elements and in-situ structures. In this study the area has been covered is making the design mix of self-compacted concrete and it’s performance – economic comparisons with prevailing conventional grade of concrete of M-40 grade.

Keywords: Self-compacting concrete; Super plasticizer; Mix design; Conventional concrete

Introduction

Self-compacting concrete (SCC) was first developed in Japan, in the early nineties of the previous century, under the stimulating leadership of Prof. Okamura. The main idea behind self-compacting concrete was, that such a concrete is robust and relatively insensitive to bad workmanship. In Western Europe the idea was picked up at the end of the last century. The main drive to develop self-compacting concrete’s was the option to improve the labor conditions at the building site and in the factory (noise, dust, vibrations). During recent years self-compacting concrete developed to research item nr. 1. A large number of research projects were carried out, followed by recommendations for potential users. Especially for the precast concrete industry self-compacting concrete was a revolutionary step forward. Contrary to that, casting of SCC at the construction site was regarded with more reservation. Because of the well-controlled forced sections in execution of concreting. This product was first developed in Japan in 1997 and followed by Europe and U.S.A. Substantial research was carried out with regard to the properties of SCC. Because of the well-controlled conditions; the introduction of SCC in the precast concrete industry was successful. With regard to the application in situ, the development is slower, because of the sensitivity of the product. In this paper the mechanical properties of SCC in comparison to conventional concrete are discussed. Examples of applications are shown, both for prefabricated concrete elements and in-situ structures. In this study the area has been covered is making the design mix of self-compacted concrete and it’s performance – economic comparisons with prevailing conventional grade of concrete of M-40 grade.

Keywords:

- Faster construction
- Reduction in Site manpower
- Better surface finish
- Easy placing
- Improved durability
- Greater freedom in design
- Thinner concrete sections
- Absence of vibration, reduced noise levels
- Safer working environment

Properties of self-compacting concrete

The remaining fresh and hardened properties are same as traditional concrete. It has been observed that performance wise SCC is more capable than conventional concrete because of its fluidity. This can reach all possible corners of form shutter, without giving any compaction efforts whereas in conventional concrete needs additional effort for its compaction [3,4].

Slump flow and T500 test: The slump-flow and T500 time is a test to assess the flow ability and the flow rate of self-compacting concrete in the absence of obstructions. It is based on the slump test to measure two parameters the flow speed and the flow time. The result is an indication of the filling ability of self-compacting concrete. The T500 time is also a measure of the speed of flow and hence the viscosity of the self-compacting concrete [5,6].

The first step is to prepare the cone and base plate then place the cleaned base in a stable leveled position, fill the cone without any agitation or Roding, and strike off surplus from the top of the cone. Allow the filled cone to stand for not more than 30s; during this time remove any spilled concrete from the base plate and ensure the base plate is damp all over but without any surplus water (Figure 2).

Lift the cone vertically in one movement without interfering with the flow of concrete. If the T500 time has been requested, start the stop watch immediately the cone ceases to be in contact with the base plate and record the time taken to the nearest 0.1 s for the concrete to reach the 500 mm circle at any point. Without disturbing the base plate or Concrete. Measure the largest diameter of the flow spread and record it as to the nearest 10 mm.

Then measure the diameter of the flow spread at right angles to the nearest 10 mm and record as to the nearest 10 mm. Check the concrete spread for segregation. The cement paste/mortar may segregate from the coarse aggregate to give a ring of paste/mortar extending several...
millimetres beyond the coarse aggregate. Segregated coarse aggregate may also be observed in the central area. Report that segregation has occurred and that the test was therefore unsatisfactory [7-11].

Then the slump-flow is the mean of dm and dr expressed to the nearest 10 mm, and the T500 time is reported to the nearest 0.1 s.

**V-funnel test:** The V-funnel test is used to assess the viscosity and filling ability of self-compacting concrete with a maximum size aggregate of 20 mm. A V shaped funnel is filled with fresh concrete and the time taken for the concrete to flow out of the funnel is measured and recorded as the V-funnel flow time [10-12].

V-funnel, made to the dimensions (tolerance ± 1 mm), fitted with a quick release, watertight gate at its base and supported so that the top of the funnel is horizontal. The V-funnel shall be made from metal; the surfaces shall be smooth, and not be readily attacked by cement paste or be liable to rusting. However container is needed to hold the test sample and having a volume larger than the volume of the funnel and not less than 12 L (Figure 3).

**L-box test:** The L-box test is used to assess the passing ability of self-compacting concrete to flow through tight openings including spaces between reinforcing bars and other obstructions without segregation or blocking. There are two variations; the two bar test and the three bar test. The three bar test simulates more congested reinforcement [13-15].

The main concept of this test is to allow a measured volume of fresh concrete to flow horizontally through the gaps between vertical, smooth reinforcing bars and the height of the concrete beyond the reinforcement is measured.

L-box, have the general arrangement and the dimensions (tolerance ± 1 mm) as shown in Figure 4. The L-box shall be of rigid construction with surfaces that are smooth, flat and not readily attacked by cement paste or be liable to (Table 1).

**Tests applied on hardened concrete**

The hardened self-compacted concrete properties are same i.e. Cube compressive strength, Flexural beam strength. In some cases the permeability tests also conducted in hardened cube cylinders (Figure 5).

The compressive strength $\sigma_{\text{comp}}$ (in MPa), of the specimen is calculated by dividing the maximum load carried by the cube specimen during the test by the cross sectional area of the specimen [16-19] (Tables 2 and 3).

$$\sigma_{\text{comp}} = \frac{\text{Breaking Load}}{\text{Cube Cross Sectional Area}}$$

The compressive strength was determined at different ages 7 and 28 days.

The unit weight, the harden concrete density may be found out by this formula

Concrete Density=$\frac{\text{Weight of Cube}}{\text{Volume of Cube}}$

**Presentation on Mix Design SCC**

**Stipulations for proportioning**

a) Grade designation: M-40 (Flowable Concrete)

b) Type of cement: ULTRATECH OPC-53 Conforming to IS 12269

c) Maximum nominal size of aggregate: 20 mm

d) Minimum cement content: 320 kg/m³

e) Maximum water-cement ratio: 0.40 (As per Morth Table 1700-3)

f) Workability: Flowable (after 60 min flow 650 mm) As per EFNARC

g) Exposure condition: Severe (For congested reinforced concrete)

h) Method of concrete placing: Pumping

i) Degree of supervision: Very good

j) Type of aggregate: Crushed angular aggregate

k) Characteristics flexural strength: 40 Mpa

l) Chemical admixture type: Superplasticizer Auramix-400 (PC20)
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Test data for materials
a) Cement used: ULTRATECH OPC-53 conforming to IS 12269
b) Specific gravity of cement: 3.15
c) Chemical admixture: Super plasticizer conforming to IS 9103
d) Specific gravity
   Coarse aggregate: 1) 20 mm-2.935
   2) 10 mm - 2.924
   Fine aggregate: 2.6
e) Water absorption
   Coarse aggregate: 1) 20 mm-0.42% (Limit maximum 2%)
   2) 10 mm-0.44% (Limit maximum 2%)
   Fine aggregate: 1.32% (Limit maximum 2%)

f) Free surface moisture
   Coarse aggregate: NIL
   Fine aggregate: NIL
g) Sieve analysis
   Coarse aggregate: NIL

**Target mean strength for mix proportioning**

Where

\[ FCK = 52 \, \text{N/mm}^2 \]

FCK: Target avg. compressive strength at 28 days
(As per MORTH table 1700.5)

The standard deviation is considered as 52 Mpa which is maximum during the production of M 40 grade concrete and this is considered for fixing the Target compressive strength which is mentioned in MORTH Table 1700 – 5.

**Calculation of cement content**

Select Total cement content: 470 Kg

Cement Content: 470 (Approx.)

**Selection of water cement ratio**

Adopting W/C Ratio=0.39

0.39<0.4

Hence OK.

**Selection of water content**

470 × 0.39=183.3

**Mix calculations**

(a) Volume of concrete=m³

(b) Volume of cement=(mass of cement/Sp. Gravity of cement) × (1/1000)

=(470.0/3.15) × (1/1000)

=0.149 m³

(c) Volume of water=(mass of cement/Sp. Gravity of water) × (1/1000)

=(183.3/1) × (1/1000)

=183.3 m³

(d) Volume of chemical admixture

Superplasticizer @ 0.60 percent by mass of cement=(mass of admixture/Sp. Gravity of admixture) × (1/1000)

0.6% =(2.82/1.1) × (1/1000)

=0.0026 m³

(f) Mass of 20 mm (CA) =e × volume of 20 mm × specific gravity of coarse aggregate × 1000

=456.67 kg

(g) Mass of 10 mm (CA) =e × volume of 10 mm × specific gravity of coarse aggregate × 1000

=556.06 kg

**Table 1: SCC properties requirements as per EFNRC 2005.**

<table>
<thead>
<tr>
<th>Method</th>
<th>Unit</th>
<th>Minimum Range</th>
<th>Maximum Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump flow (Abram Cone)</td>
<td>mm</td>
<td>550</td>
<td>850</td>
</tr>
<tr>
<td>7500 mm Slump flow</td>
<td>S</td>
<td>2</td>
<td>9</td>
</tr>
<tr>
<td>V-funnel</td>
<td>S</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>L Box (h2/h1)</td>
<td>-</td>
<td>0.7</td>
<td>1.0</td>
</tr>
</tbody>
</table>

**Table 2: Performance comparisons (SCC Vs conventional concrete).**

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Characteristics</th>
<th>Flow able Concrete</th>
<th>Traditional Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nominal size Aggregate</td>
<td>12.5 mm</td>
<td>20 mm</td>
</tr>
<tr>
<td>2</td>
<td>Workability</td>
<td>Excellent</td>
<td>Stiff</td>
</tr>
<tr>
<td>3</td>
<td>Compaction Efforts</td>
<td>Not Required</td>
<td>Required</td>
</tr>
<tr>
<td>4</td>
<td>Cost of Production</td>
<td>Same</td>
<td>Same</td>
</tr>
<tr>
<td>5</td>
<td>Workmanship</td>
<td>Fantastic</td>
<td>Good</td>
</tr>
</tbody>
</table>
(h) Mass of FA = $e \times \text{volume of fine aggregate} \times \text{specific gravity of fine aggregate} \times 1000$

Mix proportion for trial number

(a) Cement=470.0 kg/m$^3$
(b) Water=198.62 kg/m$^3$

d)Coarse aggregate

Table 4 shows the detailed picture of the mix proportion of the cement and water ratio.

Workability of trial mix

Table 5 shows the flow test for the workability of the trial mix.

Conclusion and Remarks

1. The Trial mix design complies with specification requirements of flow.
2. The proposed mix have flow value w.r.t to laboratory temperature and humidity conditions which may differ in mix produced from plant. To maintain the flow as per the placing requirement, slight modification in admixtures dosage may be required to be done
3. Compressive strength at 7 days and 28 days are found satisfactory.

Conclusion

1. In spite of its short history, self-compacting (or – consolidating) concrete has confirmed itself as a revolutionary step forward in concrete technology.
2. SCC is a relatively new form of concrete which is used for general applications. The main advantage that SCC has over standard concrete is its high compressive strength and self-compacting properties, include high flowability, workability, and passing ability.
3. The effect of using recycled aggregates on the fresh and hardened properties of SCC need to be investigated
4. It can be shown by cost analysis, that SCC in precast concrete plants can be more economically produced than conventional concretes, in spite of the slightly higher material price. Cost comparisons should always be made on the basis of integral costs.
5. The effect of fibers (Steel, Carbon, propylene and Glass) and polymers (Epoxy, SPR) addition on the mechanical properties of SCC need to be taken into consideration for further research
6. Another super plasticizer and silica fume trade markets to be used to study the fresh.

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