Compressive Strength and Modulus of Elasticity of Self-Compacting Concrete

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Abstract—The topic on ‘Compressive Strength and Modulus of Elasticity of Self-Compacting Concrete’ contain trial mixes for SCC with effects of admixtures and various contents of cement and Ash. The study involves a ‘Relative Slump Cone Test’ for fixing the w/p ratio, analysis of hardened properties of concrete with compressive strength testing machine and the study of modulus of elasticity.

Keywords—Compaction, Compressive Strength, Fly Ash, Super Plasticizer, Viscosity Modifying Agent, Water/Paste Ratio.

I. INTRODUCTION

SCC has been developed to ensure adequate compaction and facilitate placement of concrete in structures with congested reinforcement and in restricted areas. SCC was developed first in Japan in the late 1980s to be mainly used for highly congested reinforced structures in seismic regions. As the durability of concrete structures became an important issue in Japan, an adequate compaction by skilled labours was required to obtain durable concrete structures.

The requirement led to the development of SCC and its development was first reported in 1989, as in [11]. SCC can be described as a high performance material which flows under its own weight without requiring vibrators to achieve consolidation by complete filling of formworks even when access is hindered by narrow gaps between reinforcement bars, as in [19].

The mix proportioning of self-compacting concrete is shown and compared with those of normal concrete and RD (Roller Compacted concrete for Dams) concrete. The aggregate content is smaller than conventional concrete that requires vibrating compaction.

SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete such as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flowability of SCC makes it possible to fill the formwork without vibration. Since its inception, it has been widely used in large construction in Japan. Recently, this concrete has gained wide use in many countries for different applications and structural configurations.

The SCC nature shows the basic concept. The method for achieving Self-Compactability involves not only high deformability of paste or mortar. But, also resistance to segregation between coarse aggregate and mortar when the concrete flows through the confined zone of reinforcing bar, as shown in Fig.1. Homogeneity of SCC is its ability to remain un-segregated during transport and placing.

II. DESIGN OF SCC

A. General

The first step of the process is to fix the W/P ratio by performing a ‘Relative Slump Cone Test’, and then optimizing the dosage of Super-Plasticizer by ‘Marsh Cone Test’ keeping fixed percentage of VMA (0.31%).

B. Determination of W/P Ratio for the Self-Compacting Concrete.

Flow cone to determine relative slump flow:

Tests are conducted on mortar (cement, Fly Ash, sand and water) for different water/powder ratios (usually 1.1, 1.2, 1.3 & 1.4) using a flow cone, as shown in Fig.2. The water powder ratio is based on an absolute (solid) volume. As per different trial mix, the test results of flow cone are shown in Table I.
C. Tests Conducted for Fresh Properties of Self Compacting Concrete

There are three key fresh properties of SCC for mix design purposes in the lab and for compliance purposes on site.
- Filling ability,
- Passing ability and
- Resistance to segregation

Based on the EFNARC Guidelines, slump flow, visual stability, L-box, U-box, V-funnel, J-ring, filling box and column segregation tests are some of the available testing methods used to evaluate fresh properties.

D. Mix Design

The characteristics of powder and super plasticizer largely affect the mortar property and therefore, the proper water powder ratio and super plasticizer dosage cannot be fixed without trial mixing at this stage. Therefore, once the mix proportion is decided, self-compact ability has to be tested by slump-flow L-box and v-funnel tests. Test results are shown in Table II and III.

Ingredients used in mix design: The mix contains Cement (OPC 53), Fly Ash (Grade F), Polycarboxylic Ether based Super Plasticizer, Viscosity Modifying Agent, Coarse Aggregate (10-20mm), Fine Aggregate (Sand Zone II), Potable Water.

Laboratory tests are conducted for the observation of the specific gravity of different ingredients with proper care. All the equipments used are of standard quality and performing well. The Ingredient values are as:
- SP. Gravity for C.A - 2.92
- SP. Gravity for F.A -2.6
- SP. Gravity for Fly Ash - 2.3
- SP. Gravity for Cement - 3.15
- Entrapped Air - 2%
- Voids – 0.98

Table II: Trial Mixes

<table>
<thead>
<tr>
<th>Trial Mix</th>
<th>W/P</th>
<th>Cement</th>
<th>Fly Ash</th>
<th>C.A 10mm</th>
<th>F.A</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>1.1</td>
<td>300</td>
<td>250</td>
<td>751.88</td>
<td>814.54</td>
<td>224.32</td>
</tr>
<tr>
<td>B2</td>
<td>1.2</td>
<td>300</td>
<td>200</td>
<td>798.91</td>
<td>865.48</td>
<td>218.62</td>
</tr>
<tr>
<td>D1</td>
<td>1.1</td>
<td>400</td>
<td>200</td>
<td>673.46</td>
<td>729.58</td>
<td>259.23</td>
</tr>
<tr>
<td>D21</td>
<td>1.0</td>
<td>400</td>
<td>200</td>
<td>762.83</td>
<td>825.39</td>
<td>213.94</td>
</tr>
<tr>
<td>D22</td>
<td>1.2</td>
<td>400</td>
<td>200</td>
<td>735.19</td>
<td>735.19</td>
<td>256.72</td>
</tr>
<tr>
<td>D3</td>
<td>1.3</td>
<td>400</td>
<td>150</td>
<td>774.93</td>
<td>774.93</td>
<td>249.86</td>
</tr>
</tbody>
</table>

Table III: SCC Fresh Properties

<table>
<thead>
<tr>
<th>Trial Mix</th>
<th>Slump 50 in Sec.</th>
<th>Dia in mm</th>
<th>T0 in sec</th>
<th>T5 in Sec</th>
<th>h2/h1</th>
<th>Time in Sec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>2.0</td>
<td>650</td>
<td>5.0</td>
<td>8</td>
<td>1.0</td>
<td>4.36</td>
</tr>
<tr>
<td>B2</td>
<td>4.0</td>
<td>640</td>
<td>6.0</td>
<td>7</td>
<td>0.9</td>
<td>6.0</td>
</tr>
<tr>
<td>D1</td>
<td>1</td>
<td>770</td>
<td>3.4</td>
<td>3.96</td>
<td>0.92</td>
<td>1.21</td>
</tr>
<tr>
<td>D21</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
<td>N.A</td>
</tr>
<tr>
<td>D22</td>
<td>1.43</td>
<td>780</td>
<td>3.23</td>
<td>4.0</td>
<td>0.8</td>
<td>1.63</td>
</tr>
<tr>
<td>D3</td>
<td>1.33</td>
<td>650</td>
<td>3.79</td>
<td>4.81</td>
<td>0.875</td>
<td>3.03</td>
</tr>
</tbody>
</table>

III. TEST RESULTS

A. Determination of Compressive Strength

The cubes are cast having size 150 x 150 x150mm for different trial mix and are tested for the compressive strength. The 7-days and 28-days strength are conducted, which are shown graphically, as shown in Fig.4.
Fig. 4 Test Results for Compressive Strength

**B. Test Results for Modulus of Elasticity**

Modulus of elasticity is the property that influences the safety, durability and service life of reinforced concrete. In addition, it also gives indication of density and stiffness of aggregate paste matrix of SCC.

**TABLE IV MODULUS OF ELASTICITY**

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Trial Mix</th>
<th>Modulus of Elasticity N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B1</td>
<td>24673</td>
</tr>
<tr>
<td>2</td>
<td>B2</td>
<td>26258</td>
</tr>
<tr>
<td>3</td>
<td>D1</td>
<td>18486</td>
</tr>
<tr>
<td>4</td>
<td>D21</td>
<td>20825</td>
</tr>
<tr>
<td>5</td>
<td>D22</td>
<td>20901</td>
</tr>
<tr>
<td>6</td>
<td>D3</td>
<td>17505</td>
</tr>
</tbody>
</table>

The graphs shows modulus of elasticity, conducted for different cylinders, cast for trial mixes.

From the test results conducted for relative slump cone test, compressive strength and Modulus of Elasticity following discussion are drawn:

- From Table I and III it is seems that when w/p ratio is lower flow obtained for concrete is also lower and it is not up to the requirement of SCC. Therefore, when flow obtained is lower it is necessary to increase the w/p ratio for given cement and fly ash content.
- It is observed that having higher cement content is giving more cohesive mix and also having high compressive strength.
- It is seen that D21 is not fulfilling SCC requirement for fresh concrete. But, D22 with same cement and fly ash content with higher w/p ratio and higher water fulfills SCC requirements and also giving Compressive strength at 28-days.
- Modulus of Elasticity of different mixes as obtained in Table IV shows that they are comparable with normal cement concrete.

**V. CONCLUSION**

From the discussion and test results, the conclusion drawn are that, values are having comparable results within satisfying range, the effects of w/p ratio, cement content and fly ash plays a key role in formation of SCC and its strength. Thus, mix design procedure and various tests conducted for SCC had governed satisfied results.

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