NON DESTRUCTIVE STUDIES ON FIBER REINFORCED SELF COMPACTING CONCRETE DUCTILE BEAMS

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Abstract

Self-Compacting Concrete (SCC) is one of the most important developments in the building industry. This paper is taken up with the objective to evaluate the performance of self compacting concrete for M30 grade using steel fibres and by adding suitable super plasticizer. In this experimental study , the effects of adding cement with steel fiber , quartz flour and combination of them with different percentage of adding (0%, 0.25%, 0.50%, 0.75%, 1%) and (0%, 5%, 10%, 15%, 20%) on fresh, hardened states and non destructive test of concrete investigate. The optimum combination of quartz and steel fibres reinforced concrete comparing the mixes with the conventional concrete. The quartz flour with ultra-fine particles can fill the voids and make better resistance to permeability and also because of better bonding. Hence using this combination of quartz powder in self compacting beam to study about the strength and ductile property with normal and ductile detailing in beams and compared with conventional self-compacting concrete. The self-compacting concrete itself is brittle in nature, the addition of fibers increase the tensile strength and ductility properties. By using mineral admixtures, it enhance the flow properties also increase properties of concrete.

Key words: self-compacting concrete, steel fiber, quartz powder, ductility, Non destructive test.

I. INTRODUCTION

Self-compacting concrete (SCC) is defined as the concrete which can be placed and compacted into every corner of formwork purely by means of its self-weight by eliminating the need of either external energy input from vibrators or any type of compacting effort.

The intention behind developing this concrete was the concerns regarding the homogeneity and compaction of cast-insitu concrete with intricate of paste (i.e) highly reinforced structures and improvement of overall durability and quality of concrete due to lack of skilled labours.

This concrete is highly flow able and cohesive and enough to handle without segregation. It is also named as self-levelling concrete, super workable concrete, and Self –consolidating concrete, high flow able concrete and Non –vibrating concrete.

Increase of water-to-cementations material increases the flow ability of cement paste at the cost of decrease in its viscosity and deformability are the primary requirements of SCC. SCC has the ability to flow as well as deform without segregation. Therefore in order to maintain deformability along with flow ability in paste, Super plasticizer is must in concrete. With Super plasticizers, the paste can be made more flow able with little decrease in viscosity. An optimum combination of W/P ratio and Super plasticizers for achieving the self-compatibility can be derived for fixed aggregate content concrete.

II. Material Properties

2.1 CEMENT

The ordinary Portland cement confirming to IS 12269-1987 was used for the preparation of specimens.OPC 53 grade was used.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>CHEMICAL CHARACTERISTICS</th>
<th>OPC -53 IS 12269-1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Lime saturation factor in %</td>
<td>Max 0.8- Min.1.02</td>
</tr>
<tr>
<td>2</td>
<td>Alumina iron ratio % -min</td>
<td>0.66</td>
</tr>
<tr>
<td>3</td>
<td>Insoluble residue % max</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>Magnesia % max</td>
<td>6</td>
</tr>
<tr>
<td>5</td>
<td>Sulphuric anhydride</td>
<td>2.5% Max. When C3A is 5 or less 3% Max.</td>
</tr>
<tr>
<td>6</td>
<td>Loss of ignition</td>
<td>4</td>
</tr>
</tbody>
</table>
a. WATER
Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving gel, the quantity and quality of water is required to be looked into very carefully. In practice, very often great control on properties of cement and aggregate is exercised, but the control on the quality of water is often neglected. Since quality of water affects the strength, it is necessary for us to go into the purity and quality of water.

b. COARSE AGGREGATE
Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and effect economy. The maximum size of aggregate is generally limited to 20 mm. Aggregate of size 10 to 12mm is desirable for structures having congested reinforcement. Wherever possible size of aggregate higher than 20mm also use.

c. FINE AGGREGATE
Fine aggregates can be natural or manufactured. The grading must be uniform throughout the work. The moisture content or absorption characteristics must be closely monitored as quality of SCC will be sensitive to such changes. It confirming to zone II of IS 383 -1970. Sand is used in the word which has the particle was less than 4.75 mm.

d. ROLE OF QUARTZ FLOUR AS MINERAL ADMIXTURE
Quartz powder is manufactured by crushing crystalline quartz Lumps to various sizes and is also known as white silica sand quarts powder have the high silica content , mechanical and chemical weathering and makes an excellent resistance Quartz , most common of all minerals is composed of silica dioxide , or silica ,sio2.

e. FIBER IN SELF COMPACTING CONCRETE
Steel fiber: small fibres tend to be used where control of crack propagation is the most important design consideration. High fibre count (number of fibres per kg) permits finer distribution of steel fibre reinforcement throughout the matrix and consequently, greater crack control during drying process. On the other hand, because they exhibit better matrix anchorage at high deformations and large crack widths, longer, heavily deformed fibres afford better post-crack "strength".
f. MASTER GLENIUM SKY 8233
1. Polycarboxylic ether based, high range water reducing new second generation super plasticizer concrete admixture developed for ready mix concrete and precast industry that needs high early and final strengths and durability.
2. Improves concrete early and final compressive and flexural strengths, adherence to steel, and impermeability compared to traditional super plasticizers.

<table>
<thead>
<tr>
<th>Table 2.3 Properties of Master Glenium sky 8233</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect</td>
</tr>
<tr>
<td>Relative Density</td>
</tr>
<tr>
<td>pH</td>
</tr>
<tr>
<td>Chloride ion content</td>
</tr>
</tbody>
</table>

III. PROPERTIES OF FRESH CONCRETE

3.1 INTRODUCTION
A concrete mix can only be classified as self-compaction if it has the following characteristics.
1. Filling Ability
2. Passing Ability
3. Segregation Resistance
Immediately after the mixing, the value of Slump flow, J-ring, V-funnel, and L-box tests were determined for finding out passing ability, filling ability and segregation resistance respectively, for SCC by the following methods.

3.2 SLUMP FLOW TEST
1. About 6 liters of concrete is needed to perform the test, sampled normally.
2. Place base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly.
3. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel.
4. Raise the cone vertically and allow the concrete to flow out freely.
5. Measure the final diameter of the concrete in two perpendicular directions.
6. Calculate the average of the two measured diameters. (This is the slumpflow in mm).

Fig 3.1 Slump Flow Test

3.3 J-RING TEST
1. About 6 litre of concrete is needed to perform the test, sampled normally.
2. Moisten the base plate and inside of slump cone,
3. Place base-plate on level stable ground.
4. Place the J-Ring centrally on the base-plate and the and the slump-cone centrally inside it and hold down firmly.
5. Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel.
6. Remove any surplus concrete from around the base of the cone.
7. Raise the cone vertically and allow the concrete to flow out freely.
8. Note the time taken for the concrete to touch the ring (500 mm dia)
9. Measure the final diameter of the concrete in two perpendicular directions.
10. Calculate the average of the two measured diameters. (in mm).
11. Measure the difference in height between the concrete just inside the bars and that just outside the bars.

Fig 3.2 J-Ring Test

3.4 V-FUNNEL TEST

1. About 12 litre of concrete is needed to perform the test, sampled normally.
2. Set the V-funnel on firm ground.
3. Moisten the inside surfaces of the funnel.
4. Keep the trap door open to allow any surplus water to drain.
5. Close the trap door and place a bucket underneath.
6. Fill the apparatus completely with concrete without compacting or tamping, simply strike off the concrete level with the top with the trowel.
7. Open within 10 sec after filling the trap door and allow the concrete to flow out under gravity.
8. Start the stopwatch when the trap door is opened, and record the time for the discharge to complete (the flow time). This is taken to be when light is seen from above through the funnel.

Fig 3.3 V-Funnel Test
3.5 L-BOX TEST

1. About 14 litre of concrete is needed to perform the test, sampled normally.
2. Set the apparatus level on firm ground, ensure that the sliding gate can open freely and then close it.
3. Moisten the inside surfaces of the apparatus, remove any surplus water.
4. Fill the vertical section of the apparatus with the concrete sample.
5. Leave it to stand for 1 minute.
6. Simultaneously, start the stopwatch and record the times taken for the concrete to reach the 200 and 400mm marks.
7. When the concrete stops flowing, the distances “H1” and “H2” are measured.
8. Calculate H2/H1, the blocking ratio.
9. The whole test has to be performed within 5 minutes.

IV. TEST OF HARDENED CONCRETE

Testing of hardened concrete plays an important role in controlling and confirming the quality of concrete works.

4.1 COMPRESSION TEST:

1. Its most common test conducted on hardened concrete and an easy test to perform.
2. Most of desirable characteristics properties of concrete are qualitative related to it compressive strength.
3. The test were carried out on 150x150x150 mm size cube , as per IS 516-1959.

![Fig 4.1: Cube For Compressive Strength Test](image1)

![Fig 4.2: Compressive Strength Test](image2)

4.2 SPLIT TENSILE STRENGTH FOR SCC

One of the important properties of concrete is “tensile strength” as structural loads make concrete vulnerable to tensile cracking. Tensile strength of concrete is much lower than its compressive strength. The split tensile test of self compacting concrete with various percentage of quartz powder adding.
4.3 NON-DESTRUCTIVE TEST ON BEAM

ULTRASONIC PULSE VELOCITY TEST

An ultrasonic pulse velocity (UPV) test is an in-situ, non-destructive test to check the quality of concrete and natural rocks. In this test, the strength and quality of concrete or rock is assessed by measuring the velocity of an ultrasonic pulse passing through a concrete structure or natural rock formation. Higher velocities indicate good quality and continuity of the material, while slower velocities may indicate concrete with many cracks or voids.

This test is done to assess the quality of concrete by ultrasonic pulse velocity method as per IS : 13311 (PART 1)- 1992.

The pulse velocity in concrete may be influenced by:

1. Path length
2. Lateral dimension of the specimen tested
3. Presence of reinforcement steel
4. Moisture content of the concrete

With the path length \( L \), (i.e. the distance between the two probes) and time of travel \( T \), the pulse velocity \( V = \frac{L}{T} \) is calculated. Pulse velocity will not be influenced by the shape of the specimen, provided its least lateral dimension (i.e. its dimension measured at right angles to the pulse path) is not less than the wavelength of the pulse vibrations.

\[ \text{THE PULSE VELOCITY (V) = } \frac{L}{T} \]

**Table : 4.1 Pulse Velocity Range**

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PULSE VELOCITY BY CROSS PROBING (KM/S)</th>
<th>CONCRETE QUALITY GRADING</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Above 4.5</td>
<td>EXCELLENT</td>
</tr>
<tr>
<td>2</td>
<td>3.5 to 4.5</td>
<td>GOOD</td>
</tr>
<tr>
<td>3</td>
<td>3 to 3.5</td>
<td>MEDIUM</td>
</tr>
<tr>
<td>4</td>
<td>Below 3.0</td>
<td>DOUBTFUL</td>
</tr>
</tbody>
</table>

REBOUND HAMMER TEST:

The non-destructive tests are the group of useful methods to evaluate the strength of construction materials without causing damage. Rebound hammer is an instrument or a device, which is used to assess the relative compressive strength of concrete based on the hardness at or near its exposed surface.
- The surface should be smooth, clean and dry.
- The loose surface should be rubbed off with a grinding wheel or stone, before testing.
- The point of impact should be at least 20mm away from the edge or sharp discontinuity.
- The test should not be conducted on the rough surface resulting from incomplete compaction of concrete, loss of grout, spoiled or tooled surface.


**Fig : 4.4 Rebound Hammer Test On Beam**

4.4 GEOMETRY OF DUCTILE DETAILING BEAM
To check the performance of the self compacting concrete in real structure, a beam with steel reinforcement is casted and tested in the loading frame. The beam is designed as a ductile beam with more spacing in middle than in support. The size of the beam is 1.5x0.15x0.2 m (LXBXH) and 2 no’s of 12 mm dia bar in top reinforcement and 3 no’s of 12 mm dia bar at bottom and reinforcement 8mm bars used as stirrups and are spaced at a distance of 125 mm c/c at mid span, 80 mm c/c at the support.

**Fig 4.5 : Geometry Of Ductile Detailing Beam**

4.5 SPECIFICATION OF BEAM:

<table>
<thead>
<tr>
<th>SPECIMEN DETAILS</th>
<th>SPECIMEN ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>SELF COMPACTING CONCRETE WITH GENERAL DETAILING</td>
<td>SCC-1</td>
</tr>
<tr>
<td>SELF COMPACTING CONCRETE WITH DUCTILE DETAILING</td>
<td>SCC-FR-2</td>
</tr>
</tbody>
</table>
4.6 CASTING OF BEAM:
The notational of beam I is scc-1, it represent self compacting concrete with general detailing having concrete grade of M30.

Fig: 4.6 Casting Of Beam –SCC-1

4.7 CASTING OF BEAM-II:
The notational of beam-II is scc-fr-2, it represent self compacting concrete with steel fiber and ductile detailing having concrete grade of M30.

Fig : 4.7 Casting Of Beam-SCC-FR-2

V. TEST RESULT FOR FRESH AND HARDED CONCRETE

1. Slump flow, J-ring, V-funnel, and L-box tests were determined for finding out passing ability, filling ability and segregation resistance respectively, for SCC by the following methods.
2. The compressive strength test were carried out on 150x150x150 mm size cube, as per IS 516-195

<table>
<thead>
<tr>
<th>MATERIAL</th>
<th>SCC I</th>
<th>SCC II</th>
<th>SCC III</th>
<th>SCC IV</th>
<th>SCC V</th>
<th>EFNARC LIMIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>cement</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
<td>-</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>1.4</td>
<td>-</td>
</tr>
<tr>
<td>Water</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
<td>0.38</td>
<td>-</td>
</tr>
<tr>
<td>Steel fiber</td>
<td>0%</td>
<td>0.25%</td>
<td>0.50%</td>
<td>0.75%</td>
<td>0.100%</td>
<td>-</td>
</tr>
<tr>
<td>Quarts powder</td>
<td>0%</td>
<td>5%</td>
<td>10%</td>
<td>15%</td>
<td>20%</td>
<td>-</td>
</tr>
<tr>
<td>SLUMP FLOW (mm)</td>
<td>625</td>
<td>710</td>
<td>700</td>
<td>700</td>
<td>745</td>
<td>600-800</td>
</tr>
<tr>
<td>J-RING (h1~h2) mm</td>
<td>4</td>
<td>3.3</td>
<td>3</td>
<td>2.5</td>
<td>2</td>
<td>&lt;10</td>
</tr>
<tr>
<td>V-FUNNEL sec</td>
<td>12</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td>8</td>
<td>8-12</td>
</tr>
<tr>
<td>L-BOX (h2/h1)</td>
<td>0.12</td>
<td>0.10</td>
<td>0.11</td>
<td>0.8</td>
<td>0.9</td>
<td>&gt;=0.8</td>
</tr>
<tr>
<td>COMPRESSIVE STRENGTH @ 28 DAYS</td>
<td>36</td>
<td>36.43</td>
<td>37</td>
<td>36.6</td>
<td>39.1</td>
<td></td>
</tr>
</tbody>
</table>
From the test result, the compressive strength for the SCC-5 is greater than the SCC-1 (nominal) at 28 days. This compressive strength for 20% of quartz powder is higher than the other mixes.

### 5.2 SPLIT TENSILE STRENGTH FOR SCC

The split tensile test of SCC with various percentage of quartz powder adding some different percentage with steel fiber and super plasticizer.

**Table: 5.2 Split Tensile Strength**

<table>
<thead>
<tr>
<th>S NO</th>
<th>CONCRETE MIX ID</th>
<th>SPLIT TENSILE STRENGTH N/mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>SCC -C</td>
<td>3.08</td>
</tr>
<tr>
<td>2</td>
<td>SCC-FR( 0.25 % )-QP( 5%)</td>
<td>3.24</td>
</tr>
<tr>
<td>3</td>
<td>SCC-FR (0.50 % )-QP (10%)</td>
<td>3.61</td>
</tr>
<tr>
<td>4</td>
<td>SCC-FR (0.75%)-QP (15 %)</td>
<td>3.49</td>
</tr>
<tr>
<td>5</td>
<td>SC-FR (0.100 % )-QP(20%)</td>
<td>3.21</td>
</tr>
</tbody>
</table>

From the result, the split tensile strength obtained for the scc-3 is greater than the scc-1 (nominal) at 28 days.
5.3 NON-DESTRUCTIVE TEST ON BEAM

ULTRASONIC PULSE VELOCITY TEST

This test is done to assess the quality of concrete by ultra sonic pulse velocity method as per IS : 13311 (PART 1)-1992. Pulse velocity will not be influenced by the shape of the specimen, provided its least lateral dimension (i.e. its dimension measured at right angles to the pulse path) is not less than the wavelength of the pulse vibration.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>BEAM- I (SCC – 1) VELOCITY = L/T</th>
<th>BEAM- II (SCC-FR-II) VELOCITY = L/T</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.7 Excellent</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>4 Good</td>
<td>5.5 Excellent</td>
</tr>
<tr>
<td>3</td>
<td>3.5 Good</td>
<td>4.2 Excellent</td>
</tr>
<tr>
<td>4</td>
<td>4.2 Good</td>
<td>3.4 Good</td>
</tr>
<tr>
<td>5</td>
<td>6 Excellent</td>
<td>4 Good</td>
</tr>
</tbody>
</table>

Based on the test result of ultra sonic pulse velocity, the self compacting concrete with ductile detailing gives good quality of concrete i.e., it ensures that concrete quality is good in terms of density, uniformity, homogeneity etc.,

REBOUND HAMMER TEST:

IS 13311 (Part 2): 1992, BS 6089-81 and BS 1881-202 explains the standard rebound hammer test procedure. Rebound hammer is an instrument or a device, which is used to assess the relative compressive strength of concrete based on the hardness at or near its exposed surface.

<table>
<thead>
<tr>
<th>S.NO</th>
<th>BEAM 1- (SCC -1) R- NO Compression strength</th>
<th>BEAM – 2 – (SCC- FR-2) R- NO Compression strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>28 36</td>
<td>29 39</td>
</tr>
<tr>
<td>2</td>
<td>28 36</td>
<td>27 39</td>
</tr>
<tr>
<td>3</td>
<td>28 36</td>
<td>27 39</td>
</tr>
<tr>
<td>4</td>
<td>26 34</td>
<td>28 38</td>
</tr>
<tr>
<td>5</td>
<td>26 34</td>
<td>32 38.6</td>
</tr>
<tr>
<td>6</td>
<td>30 37</td>
<td>30 38</td>
</tr>
<tr>
<td>7</td>
<td>30 37</td>
<td>29 36</td>
</tr>
<tr>
<td>AVG</td>
<td>28 36</td>
<td>29 36</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

Based on the experimental study conducted on self compacting concrete with quartz powder and steel fiber beam and conventional beam specimen, the following conclusion were concluded.

1. The compressive strength and non destructive test results for the SCC-5 is greater than the SCC-1 (nominal) at 28 days. This compressive strength for 20% of quartz powder is higher than the other mixes.

2. The results obtained are nearly satisfying the limits recommended by EFNARC. The slump flow (diameter) increases with addition of quartz powder in increasing percentages. Similarly, the time obtained in J-ring, V-funnel and L-box tests decreases with the increase of quartz powder and steel fiber. The slump flow and L-box values of SCC mix with steel fiber are found to satisfy the EFNARC limits. Hence, it is concluded that further increase in percentage of steel fibers may not satisfy the EFNARC limits.

3. The split tensile strength obtained for the scc-3 is greater than the scc- 1 (nominal) at 28 days.

4. Based on previous studies, fiber reinforced self compacting concrete with quartz powder beam normally produce better strength than conventional beam, here it proves that the presence of ductility detailing.
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