Study on strength characteristics of concrete by replacement of fine aggregates and fibre addition to cement using SCC

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Abstract. The present investigation is on strength characteristic of hardened concrete with materials re-placement of fine aggregates and addition of fibre by using self-compacting concrete method which is an advanced technology used in improving the construction methodology. The SCC requires an admixture like Poly Carboxylate Ether (PCE) based superplasticizer (Master Gluement SKY 8630) used as curing compound to improve the efficiency of self-compacting concrete SCC in terms of its performance. As the nominal fine aggregate cost is increasing the re-placement of fine aggregates is done by by-products of steel industry and query dust. Grade of concrete, dosage of admixtures, self-curing compounds, and time of curing are parameters to be considered for investigation. The performance studies include water retention, compressive test and split tensile test. The result analysis shows that crusher dust and foundry sand show increase in tensile and flexural strength at 0.2% of fibre addition. The grade of concrete is M30 is taken for investigation.

Keywords: Foundry sand, crusher dust, recron 3s fibre, scc, compressive strength, tensile strength, flexural strength

1. Introduction

Concrete technology has advanced significantly during the last few decades. For developers of concrete materials and employed in concrete design with specific needs, the performance of concrete technology and ingredients offers an infinite number of possibilities. Over the previous decade, self-compacting concrete (SCC) technology has shown to be an exceptional advanced technology in concrete production. Concrete has a great flowability and natural stability, allowing it to flow freely in between the reinforcements, filling formwork without substantial consolidation or segregation [1, 2]. The SCC eliminates the need for compaction, saving time, money, and energy. The inclusion of silica fume fly ash and ground granulated blast-furnace slag increased the strength and performance of the material [3, 4]. When compared to the same concrete containing only cement, the inclusion of SF and FA could increase the fluidity, resulting in a lower requirement for super-plasticizer to achieve a similar slump flow.

2. Research Significance

Deficiency in proper curing methods and difficulty in vibration give rise to development of concrete as self-curing and compacting concrete. Present work deals with the strength of concrete by replacement of fine aggregates with foundry sand and crusher dust which increases the binding and strengthens property and also by adding fibre Recron 3S by the weight of the cement which decreases the crack formation externally [5].
3. Methodology

3.1 Experimental program

The experiment deals with the strength of concrete by using an advance technology SCC “self-compacting concrete” where replacement of fine aggregates and addition of fibre to the weight of cement. The concrete mix is of grade M30 the replacement of fine aggregates are percentages (%) of different fine aggregates other than nominal sand. The tests conducted to analysis the performance of self-curing and self-compacting concrete include water retention, strength characteristics of concrete like Compression, Split tensile and Flexural. The mixes with different proportions are considered given in table 1.

| Table 1. Details of different mix proportions |
|-----------------------------------------------|
| Compounds | SCC \( N_0 \) | SCC \( N_{0.2} \) | SCC \( N_{0.4} \) | SCC \( F_0 \) | SCC \( F_{0.2} \) | SCC \( F_{0.4} \) | SCC \( C_0 \) | SCC \( C_{0.2} \) | SCC \( C_{0.4} \) |
|-----------|----------------|----------------|----------------|-------------|-------------|-------------|-------------|-------------|-------------|
| Cement    | 450            | 450            | 450            | 450         | 450         | 450         | 450         | 450         | 450         |
| Water     | 202.5          | 202.5          | 202.5          | 202.5       | 202.5       | 202.5       | 202.5       | 202.5       | 202.5       |
| W/C ratio | 0.45           | 0.45           | 0.45           | 0.45        | 0.45        | 0.45        | 0.45        | 0.45        | 0.45        |
| Fine aggregates | 836.5 | 836.5 | 836.5 | 816 | 816 | 816 | 853.5 | 853.5 | 853.5 |
| 10mm Coarse aggregates | 840 | 840 | 840 | 840 | 840 | 840 | 840 | 840 | 840 |
| Chemical admixture | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 | 4.05 |
| Fiber (Recron 3s) in gm | 0 | 0.9 | 1.8 | 0 | 0.9 | 1.8 | 0 | 0.9 | 1.8 |

3.2 Materials

The binding material (cement) which is used in the observation of strength characteristic was ordinary Portland Slag Cement (OPSC) with the brand JAYAPEE cement confirming to IS455-1989. The specific gravity of the cement is 2.94. The initial and final setting is 190min and 235min. The nominal sand of fineness modulus 2.44 is used as fine aggregates for comparison where replaced with foundry sand and crusher dust where fineness modulus is 2.01 and 2.57 respectively [6, 7]. The fineness modulus of coarse aggregates is 6.51. The chemical admixture Poly-carboxylate ether-based super plasticizer is used in this study [8]. It is of type F and high water reducing admixture confirming to ASTM-C494. The physical properties of the materials which are required for testing are tested and used for experiment. There also addition of fibre by the weight of cement to concrete mixture to improve the quality of plaster and concrete physical properties are shown in table 2 [9, 10].

| Table 2. Physical Properties of fibre-recron 3s |
|-----------------------------------------------|
| Properties | Test Values |
|-------------|-------------|
| Cut length  | 12mm        |
| Effective diameter | 30microns    |
| Specific gravity | 1.35        |
| Tensile strength | About 6000 kg/cm² |
| Melting point | >250°C       |
| Acid resistance | Excellent    |
| Alkali resistance | Good        |
| Young’s modulus | >5000 MPa    |
3.3 Experimental setup
The experiment is conducted by collecting the materials and testing the properties of each material which is used in the production of the concrete mixes. The Recron 3s fiber which is used in grams is considered by the weight of the powder cement is added to mix upto 0.4% along replacement of fine aggregates with sand, foundry sand and crusher dust. In SCC the requirement of the water quantity is more compare to conventional concrete so, chemical admixture is used to maintain the water by cement ratio at 0.45 and also to increase the flow ability of the mix.

4. Results and Discussion
The table 3 shows the results of fresh concrete properties using SCC of different mix proportions

| Table 3. Fresh concrete properties |
|-----------------------------------|
| Mix notations | T₃₀(s) | Slump flow(mm) | V-funnel flow(s) | L-box blocking Ratio |
| SCCN₀ | 6 | 640 | 36 | 0.72 |
| SCCN₀₂ | 6 | 630 | 40 | 0.68 |
| SCCN₀₄ | 6 | 610 | 42 | 0.66 |
| SCCF₀ | 20 | 320 | 64 | 0.40 |
| SCCF₀₂ | 20 | 310 | 64 | 0.40 |
| SCCF₀₄ | 20 | 300 | 64 | 0.40 |
| SCCC₀ | 5 | 680 | 28 | 0.88 |
| SCCC₀₂ | 5 | 670 | 29 | 0.82 |
| SCCC₀₄ | 5 | 650 | 32 | 0.75 |

| Table 4. Compressive strength of mixes at different days of concrete |
|---------------------------------------------------------------|
| MixNotations | Compressive Strength(MPa) |
|---------------|--------------------------|
|                | 3rd day | 7th day | 28th day |
| SCCN₀ | 21.34 | 28.44 | 40.00 |
| SCCN₀₂ | 22.00 | 29.33 | 42.22 |
| SCCN₀₄ | 17.55 | 25.33 | 38.00 |
| SCCF₀ | 19.25 | 25.92 | 39.25 |
| SCCF₀₂ | 21.04 | 26.82 | 41.12 |
| SCCF₀₄ | 17.33 | 21.48 | 39.00 |
| SCCC₀ | 19.85 | 33.48 | 46.81 |
| SCCC₀₂ | 21.77 | 34.00 | 47.33 |
| SCCC₀₄ | 20.88 | 30.81 | 45.48 |
Figure 1 Compressive strength of mixes at different days of concrete

From the table 4 and figure 1 it is clear that increase in fibre Recron 3s as percentage to different industrial waste i.e foundry sand and crusher dust using Portland slag cement the compressive strength values are increasing from 0 to 0.2 percent and starts decreasing gradually from 0.2 to 0.4 percent. It is observed that the SCC with crusher dust has shown better performance at 0.2% of Recron 3s fiber compare to other different mixes.

| MIX NOTATIONS | Split tensile strength (MPa) |
|---------------|----------------------------|
|               | 3rd day  | 7th day  | 28th day |
| SCCN₀         | 2.05     | 2.36     | 3.18     |
| SCCN₀.2       | 2.61     | 2.47     | 3.32     |
| SCCN₀.4       | 2.39     | 2.30     | 3.20     |
| SCCF₀         | 1.52     | 2.50     | 3.96     |
| SCCF₀.2       | 2.22     | 2.58     | 4.20     |
| SCCF₀.4       | 2.12     | 2.04     | 3.80     |
| SCCC₀         | 2.50     | 3.88     | 4.03     |
| SCCC₀.2       | 2.30     | 3.38     | 3.25     |
| SCCC₀.4       | 2.01     | 3.18     | 3.20     |
Figure 2 Strength of Split Tensile test mixes at different days of concrete

From the above table 5 and figure 2 it is clear that as the percentage of fiber Recron 3s increases including the replacement of different industrial wastes i.e. foundry sand and crusher dust using Portland slag cement the split tensile strength increases from 0 to 0.2 percent and starts decreasing gradually from 0.2 to 0.4 percent where as in crusher dust values are gradually decreasing from 0 to 0.4 percent. It is observed that the SCC with foundry sand has shown better performance in split strength at 0.2% of Recron 3s fiber compared to other different mixes.

Table 6 Strength of Flexural test of mixes at different age of concrete

| Mix Notations | Flexural strength(MPa) |
|---------------|-----------------------|
|               | 3rd | 7th | 28th |
| SCCN₀         | 3.21 | 4.82 | 6.47 |
| SCCN₀.2       | 3.76 | 4.92 | 6.74 |
| SCCN₀.4       | 3.33 | 4.39 | 5.13 |
| SCCF₀         | 2.94 | 4.55 | 4.98 |
| SCCF₀.2       | 3.92 | 4.66 | 5.73 |
| SCCF₀.4       | 3.46 | 3.46 | 5.45 |
| SCCC₀         | 5.02 | 5.76 | 6.5  |
| SCCC₀.2       | 4.63 | 5.25 | 7.13 |
| SCCC₀.4       | 4.50 | 5.00 | 6.20 |
Figure 3: Strength of Flexural test of mixes at different age of concrete

From the above table 6 and figure 3 it is clear that as the percentage of fiber Recron 3s increases including the replacement of different industrial wastes i.e. foundry sand and crusher dust using Portland slag cement the flexural strength increases from 0 to 0.2 percent and starts decreasing gradually from 0.2 to 0.4 percent where as in crusher dust values are gradually decreasing from 0 to 0.4 percent. Also with increase in of SCC the split tensile strength is increasing. It is observed that the SCC with conventional sand has shown better performance in flexural strength at 0.2% of Recron 3s fiber compared to other different mixes.

5. Conclusions
- Mixes of different materials were prepared for M30 grade concrete with the replacement of aggregates by foundry sand and crusher dust with the addition of Recron 3s fiber i.e (0, 0.2 and 0.4) percentage by the weight of PSC cement.
- As the fiber percentage increases the values of slump has slight variation, but the slump flow is decreased by a percentage of 1.5% to 4.9% for conventional sand, 3.22% to 6.66% for foundry sand and 1.49% to 4.61% for crusher dust whereas the V-funnel flow with respect to time increases with decrease in the slump flow for all different mixes.
- The compressive strength of M30 design mixes at 28 days shown increase in strength with the addition of Recron 3s fibre by the weight of cement upto 0.2% and at 0.4% it is decreased in all the three different design mixes.
- The maximum percentage increase in compressive strength is 18.32% for conventional sand, 20.58% for foundry sand and 1.11% for crusher dust at 0% of fiber where compared to compressive strength of crusher dust at 0.2% of Recron 3s fiber addition.
- The split tensile characteristic of M30 design mixes at 28th day shows increases in strength with the addition of Recron 3s fiber by the weight of cement upto 0.2% and at 0.4% it is decreased for conventional sand and foundry sand whereas for crusher dust strength decreases by the addition of Recron 3s fiber from 0% to 0.4%.
- The maximum percentage increase in split tensile strength is 32.07% for conventional sand, 6.06% for foundry sand and 4.22% for crusher dust at 0% of fiber where compared to split tensile strength of foundry sand at 0.2% of Recron 3s fiber addition.
The flexural characteristic of M30 design mixes at 28th day increase in strength with the addition of Recron 3s fiber by the weight of cement upto 0.2% and at 0.4% it is decreased for conventional sand and foundry sand whereas for crusher dust strength decreases by the addition of Recron 3s fiber from 0% to 0.4% results.

The maximum percentage increase in flexural strength is 10.20% for conventional sand and 43.17% for foundry sand compared to flexural strength of crusher dust without the addition of Recron 3s fiber.

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