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Evaluation of workability characteristics of Self Compacting Concrete

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Abstract – *Self-Compacting concrete (SCC) is a very flowing material that can flow through the reinforcement and fill the formworks without any need of vibration during the concrete placement process. This paper summarizes the workability characteristics of self-compacting concrete.* By following EFNARC guidelines and carrying out trial mixes M30 grade of concrete is designed for Portland Pozzolana Cement. The above mix is added with Poly-Carboxylate ether called SP (super plasticizer) and VMA (viscosity modifying agent). *The optimum percentage of hypo sludge was found out and to this mix, polypropylene fibres of 12mm cut length were varied as 0.2, 0.3 and 0.4 percentages. The workability characteristics of these mixes were observed .Investigation concluded that the flow values of the mix decreased on increasing the percentage of fibres. Tests conducted in this paper include slump flow test,* T_{50cm} slump flow, *J-Ring, L-Box test, U-Box test and V-Funnel test.*

Key Words: Self compacting concrete (SCC), hypo sludge, polypropylene fibres, EFNARC guidelines, super plasticizer, VMA, Poly-Carboxylate ether.

1. INTRODUCTION

Self-compacting concrete (SCC) is considered one of the most recent advances in high-performance concrete in the current industry. It was first developed by Okamura in Japan and was proved economically and durable. It is a special type concrete that can flow through and fill the gaps of reinforcement and corners of formwork without any need of vibration and compaction during the placing process. SCC has favourable characteristics such as high fluidity, good segregation resistance and the distinctive self compacting ability without any need for vibration during the placing process. These concretes are excellent material for the performance of concrete structures with complex shapes or with dense reinforcement. In addition, self-compacting concrete is a perfect architectural concrete providing a smooth surface of constructed elements. An International Organization known as EFNARC guidelines were referred to design the mix design for SCC.

Requirements of SCC: The following are the requirements of SCC

1. Filling ability: Without vibrating the concrete, the SCC has to fill any space within the form work, it has to flow horizontal and vertical directions without keeping air entrapped inside the concrete or at the surface

2. Passing ability: Passing ability is required to guarantee a homogenous distribution of the components of SCC in the vicinity of obstacles.

3. Segregation resistance: The ability of SCC to remain homogeneous in composition during transport and placing.

1.1 Literature Review

Ever since the invention of self consolidating concrete in late 1980s so as to overcome the difficulties of normal concrete that can tend to cause honeycombs in spite of careful compaction process through vibration of fresh concrete in designed moulds, the SCC has made steady inroads into critical constructions.

Lava Kumar et al (2017) An investigation on the mechanical properties of M 50 grade Self compacting concrete (SCC) with replacement of cement by hypo sludge, and addition of polypropylene fibres at different percentages. In this study hypo sludge is used as replacement material in cement at 2, 4, 6, 8 and 10%. For each percentage of replacement of cement with hypo sludge, Recrons 3s fibres were added at 0.2, 0.3, 0.4 and 0.5%. They conclude 4% replacement of cement by hypo sludge is optimum when Recrons 3s fibres are not added and also conclude that 4% replacement of cement by hypo sludge is optimum when 0.3% is maximum for compressive and flexural strength but 0.4% is maximum for split tensile strength.

Ashish Kumashr (2013) This works aims to found performance of concrete by using silica fume a partial replacement of cement and addition of Recron 3s fibres. The compressive strength and the flexural strength of the concrete specimens were determined. The results show that optimum strength was obtained at 0.2% fibre content.

memon et al. observed that the fresh properties of self-compacting geopolymer concrete(SCGC) get decreased when morality is increased, and they observed that the alkaline solution, SP and extra water should be premixed previously addition to the dry mix of concrete to get enhanced workability of SCGC.

Valeria Corinaldesi et al (2011) The authors have investigated the properties of SCC using three types of fibres, namely, Steel, Poly-Vinyl-Alcohol and Poly Propylene high tough fibres. They have added limestone powder and recycled concrete powder as mineral additions. The fresh and hardened concrete properties like workability, strength and shrinkage were evaluated and they found that SCC with

the above fibres and additions behaved well with improved durability.

Oladipupo S. et al (2015) This paper compared the rheological properties and compressive strengths of self-compacting concrete (SCC) and conventional cement concrete. The flow ability and segregation resistance of freshly mixed concrete specimens were examined by the V-funnel apparatus, while the characteristics of passing ability were investigated with the L-box apparatus. Cylindrical concrete specimens of 100 mm diameter × 200 mm length were investigated for compressive strength. The compressive strength results of hardened concrete showed that SCC gained strength slowly compared to the conventional cement concrete due to the presence of admixtures. They found that the compressive strength of a well-designed SCC mix at 28 days is in the range of 85% - 95% of conventional concrete, but shows a potential of greater compressive strength at 90 days and beyond.

1.2 Materials

Cement: Portland Pozzolana Cement is cement manufactured by combining Pozzolanic materials. This cement comprises of OPC clinker, gypsum and Pozzolanic materials in certain proportions. The Pozzolanic materials include fly ash, volcanic ash, calcined clay or silica fumes. These materials are added within a range of 15% to 35% by cement weight. Portland Pozzolana Cement (PPC) is used in the above investigations conforming to IS 1489:1991.

Fine Aggregate: The SCC mixes were prepared by using the clean dry river sand as fine aggregate conformed to IS: 383-1970. Sand specific gravity is 2.67.

Coarse Aggregate: Coarse aggregate of pulverized granite stone conforming to IS: 383-1970 with grain size of max 12.5 mm was employed. Coarse aggregate specific gravity is 2.56.

Water: In general, water fit for drinking is suitable for mixing concrete; impurities in the water may effect the concrete. Setting time, strength and shrinkage promote corrosion of reinforcement. Hence locally available clean drinking water was used in the present work.

Hypo sludge: Hypo sludge is the primary solid waste material from the paper industry. It consists of cellulose fibres, calcium carbonate, silica, magnesium, calcium chloride, china clay and residual chemicals along with water.

The presence of silica, magnesium and calcium in hypo sludge makes it similar to that of cement and hence there is a possibility to replace cement with hypo sludge. The hypo sludge can minimize the demand for cement and reduce the cost of construction.

Chemical composition of cement and hypo sludge

Percents of	Cement	Hypo sludge
SiO_2	19.94	5.5
Al_2O_3	5.15	2
CaO	63.37	49
MgO	1.58	1.6
Na_2O	0.24	1.6

Polypropylene fibres: A manufactured fibre in which the fiber forming substance is any long-chain synthetic polymer composed of at least 85% by weight of an ester of a substituted aromatic carboxylic acid, including but not restricted to substituted terephthalic units.

These fibers were obtained from Reliance Industries limited and it is named as Recron 3S. The physical properties of fibers are shown in figure.

Polypropylene fibre characteristics:

1) Strong,

2) Resistant to stretching and shrinking,

3) Resistant to most chemicals,

4) Quick drying,

5) Crisp and resilient when wet or dry,

6) Wrinkle resistant,

7) Abrasion resistant

Fig 1-Polypropylene fibres

Super plasticiser (SP):

Poly-carboxylate ether

To improve the workability high range water reducing admixture commonly called as super plasticizers was used.

Specifications of poly-carboxylate ether are shown in the table below.

Specification	value
Form	liquid
colour	Nut Brown
pH value	7
Ash content	0.018
Free chloride content	Nil
Water reduction	40%

Viscosity Modifying Agent (VMA): In order to control segregation and bleeding from the fresh SCC, BASF Master Matrix 2 (formerly known as Glenium Stream 2) is used as VMA.

2. METHODOLOGY

In the present investigation, mix proportioning is done using IS 10262:2009 for M30 grade concrete. The resulting mixes are modified after conducting trials at the laboratory by duly following the EFNARC guidelines to achieve the self compacting concrete mix proportion. Mix design followed with the guidelines specified in European Federation dedicated to specialist construction chemicals and concrete systems (EFNARC 2005). The design SCC mix 30MPa was obtained by number of trails with varying quantities of constituent material. The aforementioned mixes are attained after number of trials. Such mixes can be made possible only by using the appropriate ingredients in proper proportions.

2.1 Mixing

Proper mixing is needed to make the concrete workable and to get better strength characteristics. In this investigation, cement is replaced by hypo sludge and added with polypropylene fibres to the optimum percentage of hypo sludge by total weight of cement. First we have measured the quantities calculated according to the design mix.

2.2 J-Ring test

In the J-Ring (Fig 2) a ring of reinforcing bar is fitted around the base of a standard slump cone. The slump flow is then measured with and without J-Ring and the difference calculated. The Visual Blocking Index is used to rate the segregation of the mixture during the test. From the experiment, the workability of self compacting concrete (SCC) value obtained is 9 mm in J-Ring test and it satisfied the EFNARC guidelines. Measured characteristic: Passing ability.

Fig 2- J-Ring test

2.3 L-Box test

The L-Box test is shown in Figure 3. This test evaluates the passing ability of SCC in which the concrete is placed inside the testing apparatus and a grill accompanied with the testing apparatus simulates reinforcement and the height of concrete in vertically and the end of the horizontal portion of the apparatus are measured. The ratio of these two is then used to measure the passing ability. From the experiment, the workability of self compacting concrete (SCC) value is obtained 0.85 mm in L-Box test and it satisfied the EFNARC guidelines. Measured characteristic: passing ability. Measured characteristic: passing ability.

Fig 3- L-Box test

2.4 V-Funnel test

The V-Funnel test consists of a V-shaped apparatus as shown in Fig 4 which consists of an opening at the bottom. The viscosity of the mixture is measured by the time taken to empty the funnel. Using the V-funnel test, the viscosity and the ability to pass through opening at bottom can be obtained. A number of factors along with viscosity, slump flow, size distribution and amount and shape of coarse aggregate affects the V-funnel flow time, not much research has been done so far on the effects of shape of aggregates of SCC. From the experiment, the workability of self compacting concrete (SCC) value is obtained 11.10 sec in V-Funnel test and it is satisfied the EFNARC guidelines. Measured characteristic**:** Viscosity

Fig 4- V-Funnel test

2.5 U-Box test

The test was developed by the Technology Research Centre of the Taisei Corporation in Japan. Sometime the apparatus is called a "box shaped" test. The test is used to measure the filing ability of self-compacting concrete. The apparatus consists of a vessel that is divided by a middle wall into two compartments; an opening with a sliding gate is fitted between the two sections. Reinforcing bar with nominal diameter of 134 mm are installed at the gate with center to center spacing of 50 mm. This creates a clear spacing of 35 mm between bars. The left hand section is filled with about 20 liter of concrete then the gate is lifted and the concrete flows upwards into the other section. The height of the concrete in both sections is measured.

Fig-5 U-Box test

2.6 Slump flow test

The slump flow test is used to assess the horizontal free flow of SCC in the absence of obstructions. The basic equipment used is the same as use in conventional slump test. The test method differs from the conventional one. The slump flow test is shown in Fig 3.6which is generally used to measure the Flow ability of SCC. The test is performed in a similar way as that for conventional concrete but instead of measuring vertical slump distance, the mean spread of concrete horizontally is measured. From the experiment, the flow table value is 675 mm and it is satisfied the EFNARC guidelines.

Fig -1: Flow Table Test

3. Experimental Results

The paper deals with workability characteristics of M30 mix. Firstly a conventional set of SCC mix is laid out which was denoted by SCC0.Optimum percentage of the mix is found out by replacing cement by hypo sludge by total weight with 2, 4, 6 and 8 percentages and is denoted as SCC1, SCC2, SCC3 and SCC4. The optimum percentage was obtained at 2% of PPC mix. To this optimum, Polypropylene fibres of 12mm cut length were added with 0.2, 0.3 and 0.4 percentages and were designated as FRSCC1, FRSCC2 and FRSCC3. The flow table results for the above mixes were tabulated as follows.

SNo	Mix Details	% fibre	Flow Table values(mm)
1	SCC0	0	680
2	SCC1	0	675
3	SCC2	0	660
4	SCC3	0	652
5	SCC4	0	648
6	FRSCC1	0.2	672
7	FRSCC2	0.3	658
8	FRSCC3	0.4	642

Flow table values of self compacting concrete

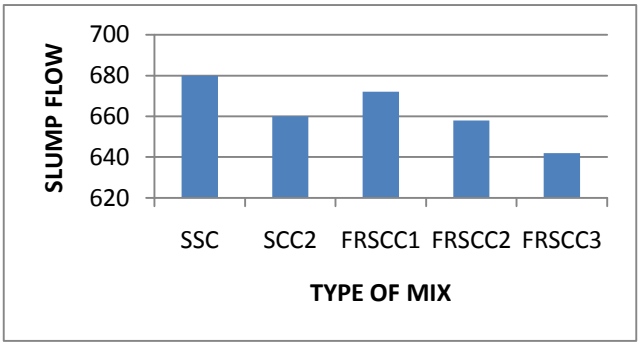

Chart 1- Mix type vs Slump flow values

The addition of hypo sludge into self compacting concrete (SCC) mixes tends to decreases the flow values. As the percentage of fibres increases, the flow values in SCC mixes decreased. The workability and segregation resistance are maintained with increasing percentage of fibres by using super plasticizers and viscosity modifying agent (VMA).

Workability test results of conventional SCC

Test Method	Unit	Value	Recommended values as per EFNARC Guidelines
Slump flow by Abrams cone	mm	680	650-800 mm
T_{50} Slump flow	sec	3.40	2-5 sec
J-Ring	mm	9.00	0-10 mm
V-Funnel	sec	11.10	8-12 sec
L-Box	h_2/h_1	0.85	0.8-1.0
L-Box T_{20}	sec	3.07	-
L-Box T_{40}	sec	5.30	-

Designations:

SCC0 – Conventional mix in SCC

SCC1 – 2% Hypo sludge replaced with SCC

SCC2 - 4% Hypo sludge replaced with SCC

SCC3 - 6% Hypo sludge replaced with SCC

SCC4 - 8% Hypo sludge replaced with SCC

FRSCC1 – 0.2% addition of Polypropylene fibres added to the optimum mix

FRSCC2 – 0.3% addition of Polypropylene fibres added to the optimum mix

FRSCC3 – 0.4% addition of Polypropylene fibres added to the optimum mix

4. CONCLUSIONS

The subsequent conclusions were drawn from the above investigations

1. There is a decrease in the value slump flow when the fibre content increased from 0 to 0.2 and there is a subsequent decrease beyond 0.2%.
2. The Rheological parameters of all other mixes were decreased when compared to conventional mix.
3. The flow table values of all mixes satisfied the EFNARC guide line values, which were recommended as 550 to 800mm.
4. Increase in the percentage of SP enhances the workability properties of the mix. More percentages of SP cause bleeding and segregation effects which can be minimized by the addition of VMA.
5. On addition of 0.2% of polypropylene fibres, the viscosity of the mix decreases and the fresh properties increased. Beyond 0.2% workability properties of the mixes decreased, nevertheless they still met the prerequisite of SCC suggested by EFNARC.

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