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## AN EXPERIMENTAL STUDY ON THE BEHAVIOR OF SELF COMPACTING CONCRETE AND HYBRID FIBER REINFORCED SELF COMPACTING CONCRETE

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### ABSTRACT

Self compacting concrete (SCC) is an innovative concrete that does not require vibration for placing and compaction. It is able to flow under its own weight, completely filling formwork and achieving full compaction, even in the presence of congested reinforcement. The hardened concrete is dense, homogeneous and has the same engineering properties and durability as conventionally vibrated concrete (CVC). Self Compacting Concrete offers a rapid rate of concrete placement, with faster construction times and ease of flow around congested reinforcement. The elimination of vibrating equipment improves the environment on and near construction and precast sites where concrete is being placed, reducing the exposure of workers to noise and vibration. The improved construction practice and performance, combined with the health and safety benefits, make SCC a very attractive solution for both precast concrete and civil engineering construction..

### 1. INTRODUCTION

Self Compacting Concrete, in principle, is not new. Special applications such as underwater concreting have always required concrete, which could be placed without the need for compaction (Bartos, 2000). In such circumstances vibration was simply impossible. Early self-compacting concretes relied on very high contents of cement paste and, once superplasticizers became available, they were added in the concrete mixes. The mixes required specialized and well-controlled placing methods in order to avoid segregation, and the high contents of cement paste made them prone to shrinkage. The overall costs were very high and applications remained very limited.

The introduction of “modern” self leveling concrete or SCC is associated with the drive towards better quality concrete pursued in Japan around 1983, where the lack of uniform and complete compaction had been identified as the primary factor responsible for poor performance of concrete structures (Dehn et al., 2000). Due to the fact that there were no practical means by which full compaction of concrete on a site was ever to be fully guaranteed, the focus therefore turned onto the elimination of the need to compact, by vibration or any other means. This led to the development of the first practicable SCC by researchers Okamura and Ozawa, around 1986, at the University of Tokyo and the large Japanese contractors (e.g. Kajima Co., Maeda Co., Taisei Group Co., etc.) quickly took up the idea. The contractors used their large in-house research and development facilities to develop their own SCC technologies. Each company developed their own mix designs and trained their own staff to act as technicians for testing on sites their SCC mixes

### 2. HYBRID FIBRE REINFORCED SELF COMPACTING CONCRETE (HYFRSCC)

Self Compacting Concrete usually offers several high performance properties in terms of mechanical behaviour and durability over conventional Vibrated Concrete (CVC). These properties could even be improved by incorporating fibres in SCC, thus obtaining Fibre Reinforced Self Compacting Concrete (FRSCC) (Torrijos et al 2008). The fibres in concrete serve as crack arresters and contribute to an increased energy absorption compared with plain concrete. Depending on parameters such as fiber volume, fiber-type, fiber geometry, and fiber aspect ratio, fiber inclusion to concrete improves the characteristics such as tensile strength, compressive strength, elastic modulus, crack resistance, durability, fatigue strength, resistance to impact and abrasion, shrinkage, expansion, thermal characteristics and fire resistance to different extent. The steel fibre is the most common fibre type in the construction industry; plastic, glass and carbon fibres contribute to a smaller part to the market,



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### 3. CONSTITUENT MATERIALS USED

The test specimens were cast using cement, fine aggregate, coarse aggregate, fly ash, super plasticizer, water, viscosity modifying agent and steel fibres, recron fibres. The materials, in general, conformed to the specifications laid down in the relevant Indian Standard Codes. The materials used for making concrete specimens were having the following characteristics:

#### **Cement**

Ordinary Portland Cement (OPC) having grade 43 from a single lot was used throughout the course of the investigation. The physical properties of the cement as determined from various tests conforming to Indian Standard IS: 1489-1991 are listed in Table 3.1. All the tests were carried out as per recommendations of IS: 4031-1988. Cement was carefully stored to prevent deterioration in its properties due to contact with the moisture.

#### **Fine aggregate**

River sand was used as fine aggregate. Clumps of clay and other foreign matter were separated out from before using it in concrete.

#### **Coarse aggregate**

Locally available crushed stone aggregates of 12.5mm nominal maximum size were used as coarse aggregate.

#### **Fly ash**

Fly ash is one of the most extensively used by-product materials in the construction field resembling Portland cement). It is an inorganic, non combustible, finely divided residue collected or precipitated from the exhaust gases of any industrial furnace.

Using fly ash admixtures as replacement for cement, workability and long-term strengths concretes. In such cases, they act like small balls to reduce interparticle friction. Fly ashes are also used in concrete mixes in order to reduce the heat of hydration, permeability, and bleeding.

Fly-ash being used in our Project was brought from Ambuja Cement Plant located in Roop nagar, Punjab

#### **Fibres**

Steel fibres and polypropylene fibres have been used in the production of HyFRSCC, but these may reduce flow ability and passing ability. Trials are therefore needed to establish the optimum type, length and quantity to give all the required properties to both the fresh and hardened concrete. Fibres can be used to improve the stability of HyFRSCC, as these help prevent settlement and cracking due to plastic shrinkage of the concrete. Steel fibres are used to modify the ductility/toughness of the hardened concrete. Recron fibres are used to minimize the minor cracks. Their length and quantity is selected depending on the maximum size of aggregate and on structural requirements. If they are used as a substitute for normal reinforcement, the risk of blockage is no longer applicable but it should be emphasized that using HyFRSCC in structures with normal reinforcement significantly increases the risk of blockage. Corrugated steel fibres of 0.6mm diameter and 12mm in length at different fibres volume fractions and recron fibres of 12mm in length in the range of 0.5%, 1.0% and 1.5% as total volume fraction of fibres, each volume fraction contains three different mix- proportions of 75-25%, 50-50% and 25-75% of steel - polypropylene fibres were used.



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*Steel Fiber*



*Recron Fiber*

### Super plasticizer

Gelenium-51 is used as Super-plasticizer which is based on a unique carboxylic etherpolymer with long lateral chains which was being brought from BASF, Chandigarh. Specific gravity of Gelenium-51 is 1.08.

### Viscosity modifying admixture

Gelenium Streams-II which was bought from BASF, Chandigarh. Specific gravity is 1.01

## 4. CASTING AND CURING OF TEST SPECIMENS

The casting of the various specimens was done under laboratory conditions using standard equipment. Three series of specimens were cast, of similar length will be used in different combinations i.e. 75-25%, 50-50%, 25-75% and by volume at a total fibre volume fraction of 0.5%, 1.0% and 1.5%. Each batch consisting of three standard beam specimens for flexural strength tests, six cubes for compressive strength tests and three cylinders for split tensile strength tests. The cubes, beams and cylinders were cured for 28 days.

For each batch of concrete mixed, the quantities of various ingredients i.e. cement, fine aggregate, coarse aggregate, super-plasticizer, fly ash, viscosity modifying agent and water were kept ready in required proportions. Initially coarse aggregates and fine aggregates were mixed in a mixer for about one minute to get a uniform mix in a dry condition. Then, cement and fly ash was added to this dry mix and turned over twice or thrice in the dry state itself in a tilting type rotary drum mixer for about half a minute to get a uniform mix in a dry condition which was indicated by the uniform color and no concentration of either material was visible. About 75% of the total water was then added slowly to get a uniform mix. After the mix becomes uniform, the fibres were gradually sprinkled by hand while the mixer drum was in motion. In specimens where fibres were used, the fibres were kept as per the desired mix proportions by weight, in a tray, and then sprinkled by hand into the mixer. After this, the super-plasticizer and viscosity modifying agent is added to the remaining water, and this remaining water mixture is thus added to the mixer and the mixing was continued for about one minute. Utmost care was taken to prevent agglomeration of fibres and their random distribution was ensured as far as possible.

The moulds for casting the specimens were cleaned, brushed and oiled and placed on a flat platform. The homogeneous concrete mix, already prepared was placed in the specimen moulds in two layers. After casting and finishing the surface, the specimens were allowed to harden for 24 hours at room temperature. These were then removed from the moulds and were marked with their respective designations and placed in the curing tanks.

## 5. TESTS ON CONCRETE

The fresh properties tests and hardened properties tests conducted in this study for SCFRC are given below. All the workability tests were conducted according to EFNARC guidelines (2005).

### Fresh properties tests

The three key fresh properties of SCC are:



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- Filling ability
- Passing ability
- Segregation Resistance

Following tests are recommended to check these three properties

- Slump flow test (total spread and T50 time): primarily to assess filling ability, Suitable for laboratory and site use
- L-box test: primarily to assess passing ability, suitable for laboratory use
- J-ring test: primarily to assess passing ability, suitable for laboratory and site use
- Sieve stability test: to assess segregation resistance, suitable for laboratory and site use.
- V-funnel test: partially indicates filling ability and blocking, suitable for laboratory and site use.
- Visual stability index: indicates the segregation resistance by visualization, suitable for laboratory and site use.

### 6. RESULT ANALYSIS

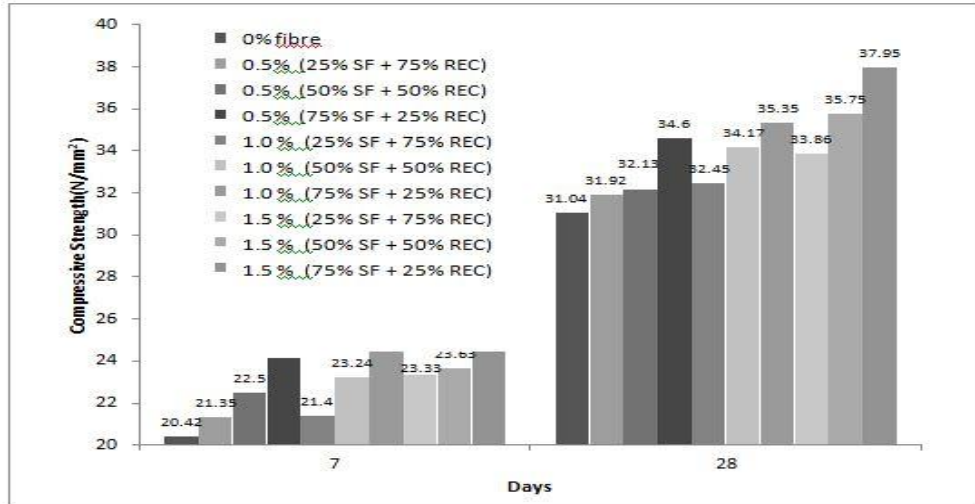
Mix ID	Volume Fraction $V_f$ (%)	REC+SF (%)	Slump flow time $T_{500}$ (sec)	V-Funnel time (sec)	Slump Flow dia (mm)	$J_{500}$ (sec)	J-ring height (mm)	L-box ( $h_2/h_1$ )
S1	0	0	2.6	7	795	3.5	2	1
S2	0.5	75+25	3.5	8.5	735	5	4	0.9
S3	0.5	50+50	3.2	8	750	4	3	0.93
S4	0.5	25+75	3	7.5	770	3.7	3	0.96
S5	1	75+25	4.1	9.3	700	4.8	6	0.86
S6	1	50+50	3.8	8.8	705	4.6	5	0.87
S7	1	25+75	3.7	8.5	715	4.4	5	0.89
S8	1.5	75+25	4.7	10.5	680	6	8	0.83
S9	1.5	50+50	4.5	10	690	5.7	7	0.84
S10	1.5	25+75	4.4	9.5	695	5.4	6	0.85



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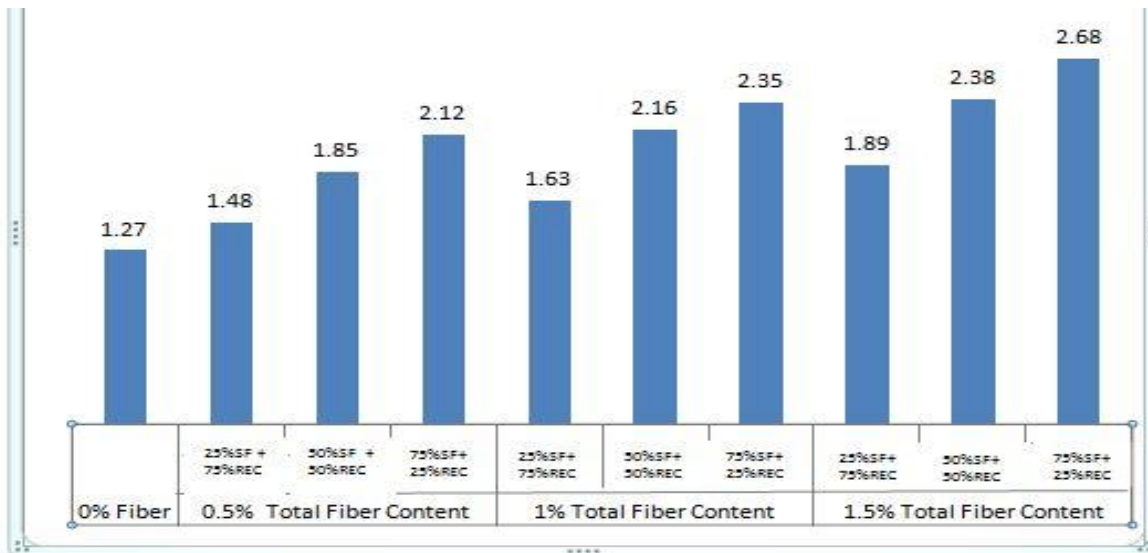
## 7. COMPRESSIVE STRENGTH

Compressive Strength for HyFRSCC mixes with different Total Fiber Content



## 8. TENSILE STRENGTH

Split Tensile Strength for HyFRSCC mixes with different fiber content



## 9. CONCLUSIONS

The following conclusions were drawn from the present experimental study

1. Flowing ability and passing ability of the concrete decreases as the quantity of fibres increases.
2. Maximum increase in compressive strength of mix having fiber content 0.5%, 1.0% and 1.5% was 18.11%, 19.88% and 26.73% respectively for 7 days and 11.4%, 13.88% and 22.26% respectively for 28 days, have



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been observed at volume fraction of 75% SF + 25% REC i.e. higher compressive strength have been observed with mix having higher fiber content and higher volume fraction of steel fiber i.e. 75% of total fiber content.

3. Maximum increase in split tensile strength of mix having fiber content 0.5%, 1.0% and 1.5% was 28.34%, 85.03% and 111.02% respectively for 28 days have been observed at volume fraction of 75% SF + 25% REC i.e. higher split tensile strength have been observed with mix having higher fiber content and higher volume fraction of steel fiber i.e. 75% of total fiber content.
4. It is recommended to use hybrid fibre SCC containing steel and polypropylene fibres in long span bridges & thin structural elements such as plates & shells roofs, cantilever roofs

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