

Behaviour of Fibre Reinforced Concrete

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ABSTRACT: Here fine fibres used in our mix are 0.3mm diameter and 10 mm which can be easily placed with high percentages. These fibres easily transfer stresses and act as a composite concrete unit to take up extremely high loads with high compressive strength in HPFRCC.

In the case of High Performance Fibre Reinforced Cement Concrete Composites (HPFRCC), since concrete is dense even at the micro-structure level, tensile strain would be much higher than that of the conventional SFRC, SIFCON & SIMCON. This in turn will improve cracking behaviour, ductility and energy absorption capacity of composites in addition to durability. The structural applications of HPFRCC, because of extremely high strength, will reduce dead load significantly as compared to normal weight concrete thereby offering substantial cost saving and by providing improved seismic response, longer spans, and thinner sections, less reinforcing steel and lower foundation cost. In this paper we are studying the behaviour of HFRCC with varying percentages in cubes, cylinders, beams, brackets and beam column junctions.

KEYWORDS: HPFRCC High Performance Fibre Reinforced Cement Composites, SFRC Steel FIBRE Reinforced Concrete, SIFCON Slurry infiltrated concrete, SIMCON Slurry infiltrated Mat concrete.]

I. INTRODUCTION

HPC can be achieved by further lowering water-to-cement ratio, but without its certain adverse effects on the properties of the material. However, from a structural point of view, one understands usually that high strength, high ductility and high durability, which are regarded as the most favorable factors of being a construction material, are the key attributes to HPC. For adequate ductility in beam-column junction, use closely spaced hoops as transverse reinforcement was recommended in the ACI-ASE committee 352 report (ACI 2002). However, due to congestion of reinforcement, casting of beam-column joints will be difficult and will lead to honeycombing in concrete at these joints. FIBRE reinforced concrete (FRC) can sustain a portion of its resistance following cracking to resist more cycles of loading. Since beam-column joints in building frames have a crucial role in the structural integrity of building, they must be provided with adequate stiffness and strength to sustain load transmitted from beams and columns.

II IMPORTANT MATERIALS

2.1 Silica Fume: Silica fume with specific surface area of 2200 m²/kg and specific gravity of 2.02 was used in the experimental study. This silica fume is conforming to IS: 15288-2002. It is supplied by 'Elkem' having grade 920 D. It is a dry silica fume powder. It improves the performance of concrete and mortar formulations. It acts physically to optimise particle packing of the concrete or mortar mixture and chemically as a highly reactive pozzolana.

2.2 Steel Fibres: Steel fibres obtained from 'Vinayaka Shot Pvt. Ltd. Indore'. As shown in Figure. 1, steel fibres were straight type having length 10 mm and diameter 0.2 mm and having aspect ratio of 22.22 was used. They shall be added in the proportion of 2% to 12% (by weight of concrete material) to the concrete mixes and mixed in the machine. Properties of steel fibre are tensile strength 1920 MPa, Carbon content 0.82% and density 7.85 m/cm².



Fig. 1. Steel Fibres

2.2. Super Plasticizer: The trade name of the super plasticizer is ‘Auramix 400’ where as its brand name is “Fosroc”. Auramix 400 is a unique combination of the latest generation superplasticizers, based on a polycarboxylic ether polymer with long lateral chains having relative density of 1.02 at 25°C. This significantly enhances cement dispersion. At the beginning of the mixing operation, an electrostatic dispersion occurs but to separate and disperse the ability of cement particles. This mechanism reduces the water demand in self compacting concrete or in flowable concrete.

III CONCRETE MIX

High performance concrete mix was designed to achieve around M80 grade concrete using admixture as per ACI Committee 211.4-08. Several trial mixes were carried out to achieve HPC using high range water reducing agent (HRWR) super plasticizer and silica fume. Water-cement ratio was adjusted to have slump of 100 ± 5 mm. The detail of the trial mixes are tabulated in Table 1. HRWR dosage of 1.4% by weight of cement and silica fume dosage of 11% by weight of cement provided a concrete mix with approximately compressive strength 80 MPa, under normal water curing after 28 days without fibre. Straight steel fibre in varying fibre volume fraction corresponding to 3%, 6%, 9%, and 12% of concrete material were used to produce steel fibre reinforced high performance concrete of higher grades using same mix proportion.

Table 1. Mix Proportion of Different Trial Mixes

| Mix Design | Cement (Kg) | Silica Fume (kg) | Fly Ash | Coarse Aggregate (kg) | | Fine Aggregate (kg) | Water Cement Ratio | HRWR (%) | Average Strength | |
|------------|-------------|------------------|----------|-----------------------|------|---------------------|--------------------|------------|------------------|--------------|
| | | | | 10mm | 20mm | | | | 7 Days | 28 Days |
| M1 | 450 | 45 | 90 | 398 | 597 | 742 | 0.27 | 0.7 | 46.59 | 62.45 |
| M2 | 460 | 58 | | 460 | 690 | 800 | 0.27 | 1.8 | 55.34 | 68.90 |
| M3 | 465 | 93 | - | 460 | 690 | 800 | 0.27 | 1.2 | 54.24 | 65.55 |
| M4 | 470 | 47 | 94 | 393 | 589 | 732 | 0.27 | 0.8 | 58.79 | 68.45 |
| M5 | 475 | 53 | - | 1055 | | 700 | 0.28 | 1.4 | 63.85 | 80.55 |
| M6 | 480 | 60 | | 460 | 690 | 800 | 0.28 | 1.4 | 56.45 | 67.65 |
| M7 | 500 | 50 | 100 | 385 | 577 | 717 | 0.27 | 0.7 | 59.22 | 72.23 |
| M8 | 525 | 63 | - | 440 | 660 | 800 | 0.24 | 1.4 | 60.85 | 75.66 |
| M9 | 575 | 72 | | 440 | 660 | 800 | 0.22 | 1.2 | 60.25 | 74.55 |
| M10 | 563 | 63 | - | 1100 | -- | 800 | 0-28 | 1.4 | 56.35 | 73.45 |

IV. METHODOLOGY

In the beginning of project work, raw materials (ingredients) required for casting of concrete cubes were collected and necessary data required for mix design was obtained by various tests in laboratory. Mix design is carried

out according to ACI Committee 211.4-08. Recommended guidelines for concrete mix design to get the designed compressive strength and workability. The procedure for design of micro silica in concrete mixes is according to IS: 15388-2003. The trial mix M5 was selected from various trial mixes and same proportion was used because of maximum strength and economy, hence M5 was used for casting of concrete cubes, cylinders and beams with different percentages of steel fibres varying from 3% to 12% of concrete material.

- Materials are weighted by weigh batching.
- Steel fibres were added 0%, 3%, 6%, 9% and 12% to the total concrete material.
- Concrete cubes of size 150 mm X 150 mm X 150 mm and cylinders of size 100 mm X 200 mm and beams of size 100 mm X 100 mm X 500 mm of “Forty five” each were casted for compressive strength, split tensile strength and flexural strength respectively.
- Method of test for determining the compressive strength of samples is according to IS: 516-1959, “Methods of test for strength of concrete”.
- Each set consist of 3 cubes, 3 cylinders, 3 beams and the test strength of the samples has been taken as the average strength of three specimens.
- It is observed that the individual variation of specimen strength with in ± 15 percent of average strength. Thus the test results are quite consistent and reasonable.
- Workability of fresh concrete with and without steel fibres is measured by slump test apparatus
- Beam column joints were casted with M5 concrete mix in the junction portion and after the 20% length of joint remaining portion concrete M20 was placed in the beams and columns.

VCASTING AND TESTING OF BEAM COLUMN JOINTS.

Beam-column sub-assemblages used as moment resisting frames as shown in Figure will be constructed using HPDSPC in the joint region with varying quantities of steel fibres, fibre aspect ratio and fibre orientation in the critical section. Besides loading measurements, frame displacements, diagonal joint strain and rebar strain adjacent to the joint will also be measured to investigate stress-strain behavior, load deformation characteristics, joint shear strength, failure mechanism, ductility associated parameters, stiffness and energy dissipated parameters of the beam column sub-assemblages will also be evaluated.



Fig.2: Casting of beam column joint



Fig. 3. Testing Set- up.

Analytical study will also be conducted by modeling beam column sub assemblage using appropriate software to determine HPDSPC grade corresponding to moment, shear and axial forces to be resisted. The effect of FIBRE aspect ratio, FIBRE volume contents and FIBRE types on failure mechanism of HPDSPC will also be investigated by estimating fracture energy and characteristic length. Finally a design procedure for the optimum design of HPDSPC corresponding to moment, shear forces and axial forces for the reinforced concrete beam-column joint sub-assemblage will be proposed.

VI. RESULTS AND DISCUSSION

The compressive strength of sample is carried out according to IS: 516, "Method of test for strength of concrete". The result of specimen strength under normal water curing at ages 7 days, 14 days and 28 days have been reported in Table 2 , Table 3 brackets test results and Table 4 shows beam column results.

Table 2. Strength of Concrete Mix by adding Different Percentage of Fibres

| Sr. No | Fibre %age | Average Compressive Strength | | | Average Split Tensile Strength | | | Average Flexural Strength | | |
|--------|------------|------------------------------|--------------|--------------|--------------------------------|-------------|--------------|---------------------------|--------------|--------------|
| | | 7 Days | 14 Days | 28 days | 7 Days | 14 Days | 28 days | 7 Days | 14 Days | 28 days |
| 1 | 0% | 63.85 | 70.85 | 80.55 | 4.08 | 4.61 | 5.30 | 5.96 | 6.77 | 7.75 |
| 2 | 3% | 69.87 | 83.85 | 97.05 | 4.95 | 5.54 | 6.37 | 7.28 | 8.32 | 9.45 |
| 3 | 6% | 66.15 | 78.66 | 91.22 | 6.12 | 6.93 | 7.96 | 8.62 | 9.74 | 11.20 |
| 4 | 9% | 60.85 | 70.85 | 80.67 | 7.12 | 7.96 | 9.15 | 10.22 | 11.62 | 13.28 |
| 5 | 12% | 50.95 | 58.85 | 69.45 | 8.28 | 9.32 | 10.75 | 11.66 | 13.22 | 15.15 |

20.48 % increase in compressive strength. 102.83% increase in split tensile strength,95.48% increase in flexure strength

Table 3. Tension Test On Brackets

| Sr.No. | Fibre % | Average Failure Load in KN | Average Elongation% |
|--------|---------|----------------------------|---------------------|
| 1. | 0% | 5.58 | 5.55 |
| 2. | 3% | 7.04 | 7.14 |
| 3. | 6% | 8.93 | 8.92 |
| 4. | 9% | 9.16 | 10.513 |
| 5. | 12% | 9.313 | 14.667 |

Increase in failure load from 0 % TO 12% = 66.89 %,Increase in elongation % from 0 % TO 12% = 164.27 %

Table. 4. Beam Column Junction showing cracks at various cycles of Loading

| Sr.No. | Fibre % | Maximum Load For First Crack Loading In KN | Maximum Load For Second & More Cracks Loading In KN | Maximum Load For Multiple Cracks Failure Loading In KN |
|--------|---------|--|---|--|
| 1. | 0% | 117.30 | 79.90 | 44.42 |
| 2. | 03% | 138.20 | 90.40 | 76.5 |
| 3. | 06% | 162.90 | 77.30 | 65.60 |
| 4. | 09% | 171.30 | 100.70 | 66.50 |
| 5. | 12% | 187.5 | 123.8 | 90.10 |

Increase In First Crack Load Increase From 0 % To 12% = 59.85%
 Increase In Second & Minor Cracks Load Increase From 0 % To 12% = 54.94%
 Increase In Third & Multiple Crack Load Increase From 0 % To 12% = 102.83%

(a)Concrete Cube. The cubes with fibres content did not break at failure as the case with cubes without fibres. The cube with maximum fibre content 12 broke at less load due to less compressive strength but got distorted due to high tensile stress.



Fig.4. Failure of cube with breaking completely due to fibres

(b)Concrete Cylinder Split tensile strength of cylinders was found out at 7 days, 14 days and 28 days. It was noticed contrary to the samples without fibres the samples reinforced with high fibre content did not split into two halves but with fibres the cylinder inspite of the failure did not break into two halves due to rigid bonding by fibres.



Fig.5. (i) Cylinder before test (ii) Cylinder at failure does not break due to fibres

(c) **Beam cracks** .After the load test, the average depth and width of the specimen at the failure section must be measured to the nearest mm . It was found that the specimen without fibres failed at lower load into two pieces and fibre reinforced DSP concrete beam failed but did not break into two pieces as earlier due to micro structure bonding by fibres.



Fig.6. (i) Beam before test



(ii)At Failure of beam specimen with fibres does not break and without fibres breaks.

(d) **Dog bone specimen** As there were no fibres in the specimen the elongation was less, the concrete was brittle and failure took place by breaking the specimen into two halves, however as fibre was introduced with increasing percentage the bracket though failed by a wide breaking crack in the middle but there was bonding due to fibres and the specimen did not break completely.



Fig.7. (i)Bracket Specimen(ii)Breaks at failure without fibre (iii) Does not break at failure with fibres.

e) **Beam column joints Cracks**. At zero percent fibres there were multi cracks at lower peak load and as the fibres started increasing the crack width started decreases and failure load started increasing as shown in the figures below.



Fig.8 (i) RC Joint 0% Fibre Cracks (ii) RC Joint 3% Fibre Cracks (iii) RC Joint 0% Fibre Backside Cracks



Fig.9(i) RC Joint 6% Fibre Cracks (ii) RC Joint 9% Fibre Cracks (iii) RC Joint 12% Fibre Cracks

VII. CONCLUSION

On the basis of experimental results, it is observed that compressive strength for 3% and there is 20.48 % increase in compressive strength. Split tensile strength is maximum for 12% fibres with 102.83% increase in split tensile strength. Also for 12 % fibres 95.48% increase in flexure strength. Fibres percentages are taken with respect to concrete material. All the strength properties are observed with fibre of diameter 0.3mm and length 10mm with aspect ratio of 33.33. The fine FIBRES used in our mix are 0.3mm diameter and 10 mm long. Due its fine thickness and small length they are easily placed with high percentage and in our case up to 12% .The fine FIBRES easily transfer stress and act as a composite concrete unit to take up extremely high loads with compressive strength up to 100MPa and help in safety of human life due to prolonged failure of the beam column joints with formation of multiple fine cracking.

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