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Structural behaviour of High Strength Steel Fibre Reinforced Concrete (HS-SFRC) block pavement

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Abstract: An experimental program was carried out to investigate the structural behaviour of High strength steel fibre reinforced(HS-SFRC) block pavements. High strength plain cement concrete blocks (HSC) were also casted for comparison purpose. Three different fibre contents (0.5% , 0.75% & 1.0% by volume fraction) were considered. The results obtained have shown that the addition of the steel fibres has increased the compressive strength, flexural strength, tensile strength and abrasion resistance and the deflection of beam and pavement block was decreased at the age of 28 days. It is observed that strength properties of HS-SFRC 1.0% are high compared to 0.5% & 0.75% of fibre content. It is clearly shown that the increase in strength is due to the increase in fibre content. The test results were compared with High strength concrete (HSC – control mix).
Keywords : Abrasion resistance, Compressive strength, HS-SFRC, HSC, Universal testing machine.

1. Introduction

Concrete is widely used, versatile structural material and is the backbone of construction industry. All cement based materials and composites are essentially discontinuous, an isotropic and heterogeneous. These materials contain bon micro-cracks and interfacial discontinuities, which are the root cause for unstable crack propagation and low tensile strength. Fibre reinforced cement concrete were developed to overcome these problems associated with cement based materials. Incorporation of short discrete fibres in a relatively brittle cement matrix transforms uncontrolled and unstable tensile crack propagation into a slow controlled growth. This gives the cement based materials a maximum ductility overcoming its low tensile strength properties. High strength concrete with compressive strength higher than 41Mpa is being used in the construction of buildings. One major drawback of high strength concrete is that it is brittle. An ideal solution to overcome the serious disadvantages of high strength concrete is to add steel fibres in the concrete to convert it into a ductile material and avoid sudden failure. [1]Balasubramanian et al have investigated the Flexural toughness, ductility was increased and slow down the propagation of tensile crack. It was found that, the ability to slow down the propagation of tensile cracks, improving the post-cracking behaviour is due the random distribution of discrete fibres. Steel fibre reinforced concrete (SFRC) composite is used for structures subjected to impact loading. [2]Krishnamoorthy et al have investigated the fatigue strength was increased by the addition of steel fibres. The strains were measured behaviour of steel fibre reinforced concrete in direct compression. The number of cycles was extended upto one million. Strains were measured at different stages of fatigue cycling. The study shows that the fatigue strength increases with increase in fibre content. [3]Ramakrishnan et al have investigated impact strength flexural strength and toughness were increased due to shape, size, type and aspect ratio of steel fibres. The greatest advantage in adding fibres to concrete is the improvement in flexural strength in both static and fatigue loading. [4]Abhay Mahadeorao Shende investigated the flexural strength, tensile strength, compressive strength and load - deflection results were obtained higher in 3% of fibre content with aspect ratio of 50 compared to 0%, 1% and 2% with aspect ratio of 60 and 67. Y. [5]Mohammadi investigated the compressive strength, split tensile strength and flexural strength were increased in the fibre combination of 65% of 50mm +35% of 25mm long fibres. Due to increased percentage of short fibres gives better workability. Ravishankar (2006)[6] investigated the results shows rupture modulus was increased due to the addition of steel fibres in the concrete. [6]G. Niranjana et al investigated the results obtained the flexural strength, compressive strength, abrasive resistance and impact strength of concrete were increased by the addition of steel scrap fibres in the plain concrete.

2. Experimental Investigations

The experimental program comprises of casting and testing of cubes of size 150 x 150 x 150mm were tested at 3 days ,7 days and 28 days of curing for compressive strength, cylinders of 150mm diameter and 300mm height for split tensile strength, beams of 100 x 100 x 500mm size for flexural strength and young's modulus, sphere of size 130mm for abrasion resistance and pavement blocks of size 250 x 250 x100mm were casted and tested at 28 days of curing to determine the load carrying capacity, stress strain relation and deflection of the specimens of M_{50} grade of concrete (HS-SFRC and HSC) The mix proportions of high strength concrete with three different percentage of fibres (0.50%,0.75% and 1.0%) were presented in Table 1.

2.1 Materials used

2.1.1 Cement

Ordinary Portland cement of 53 grade manufactured by (L &T 53 grade) confirming to IS 12269 was used. The specific gravity of the cement was 3.1. The initial setting and final setting time were found as 30 minutes and 300 minutes respectively.

2.1.2 Fine Aggregate

Locally available river sand passing through 4.75mm IS sieve was used. The specific gravity of the sand is found to be 2.65.

2.1.3 Coarse Aggregate

Crushed granite aggregate available from local sources has been used. The aggregate passing through 12.5mm and retained on 10mm IS sieve was used in preparation of HS-SFRC and HSC blocks.

2.1.4 Fibres

The present investigation aims at producing SFRC with locally available fibres. Hooked Steel wire fibres of 0.5mm diameter and aspect length of 60 were used. The required fibre length of 30mm was cut by using shear cutting equipment. The ultimate tensile strength of fibre was 46kg/cm^2.

2.1.5 Water

Portable fresh water was used for mixing and curing of concrete.

2.1.6 Casting of the specimen

Cubes of 150 x150 x150mm were cast to determine the compressive strength, cylinders of 150mm diameter and 300mm depth were cast to evaluate the tensile strength, beams of 100x100x600mm were cast to determine the flexural strength, deflection of beam and pavement blocks of 250 x 250 x 100 mm were cast to determine the load carrying capacity and deflection of pavement block and 130mm diameter spheres were cast to evaluate the % loss of weight after 500 revolution (abrasion resistance). The specimens were de-moulded after 24 hours and water cured for 28 days.

2.1.7 Testing of the specimen

The testing cubes, cylinders were done in compression testing machine, beams and blocks were tested in universal testing machine and abrasion test has been carried out by using Los Angel's abrasion testing machine. Table 2 shown the test results of compressive strength, split tensile strength, flexural strength, young's modulus and abrasion resistance.

Table 1 Mix Proportion

S. No.	Type of block	Cement , sand & coarse aggregate	% of fibre content	W/C ratio	Mode of vibration
1.	HSC	1:1:2.8	-	0.39	Hand tamping
2.	HS-SFRC-(0.5%)	1:1:2.8	0.5	0.39	Hand tamping
3.	HS-SFRC-(0.75%)	1:1:2.8	0.75	0.39	Hand tamping
4.	HS-SFRC (1.0%)	1:1:2.8	1.0	0.39	Hand tamping

3. Results and Discussion

3.1 Compressive Strength

Fig.1 shows the age of curing versus compressive strength of concrete. The test results indicates that the compressive strength of HSC and HS-SFRC (0.5%,0.75% and 1%) were shown in table 2. Compressive strength of HS-SFRC mixes are slightly increased by the addition of fibre content.

3.2 . Split Tensile Strength

Split tensile strength of various mixes were presented in Table 2. The tensile strength was increased by 23% by addition of 0.5% of steel fibres, 32% was increased by addition of 0.75% and 44% was increased by addition of 1% by volume fraction. The tensile strength was increased due to the increased percentage of fibre content.

3.3 Flexural strength

The results of the flexural strength of various mixes were shown in Table 2. The results obtained the flexural strength was increased by 21% by the addition of 0.5% of fibre content , 27% was increased by the addition of 0.75% of fibre content and 29% was increased by the addition of 1% of fibre content.

3.4 Abrasion resistance

The abrasion resistance of HSC and HS-SFRC with different percentage of fibre content (0.5%,0.75% and 1.0%) shown in Fig.2 and presented in Table 2. The percentage loss of weight was decreased by 27% in HS- SFRC(1.0%) mix, 13% in HS-SFRC(0.75%) mix and 11% in HS-SFRC(0.5%) mix compared to HSC (control mix). So that the loss of weight was decreased due to the increased percentage of addition of steel fibres. It was clearly indicated that the abrasion resistance was improved in 1% of fibre content compared to other mixes.

Table 2 Test Results for HS - FRC with various fibre content

S. No.	Type of mix	Compressive Strength N/mm^2	Split tensile Strength N/mm^2	Flexural Strength N/mm^2	Young's modulus $x10^4$ N/mm^2	Loss of weight %
1	HSC	52.87	3.86	6.29	2.78	9.60
2.	HS-FRC(0.50%)	53.33	5.02	7.63	3.11	8.52
3.	HS-SFRC(0.75%)	55.67	5.72	8.64	3.29	8.3
4.	HS-SFRC(1.0%)	57.20	6.93	8.90	3.67	6.95

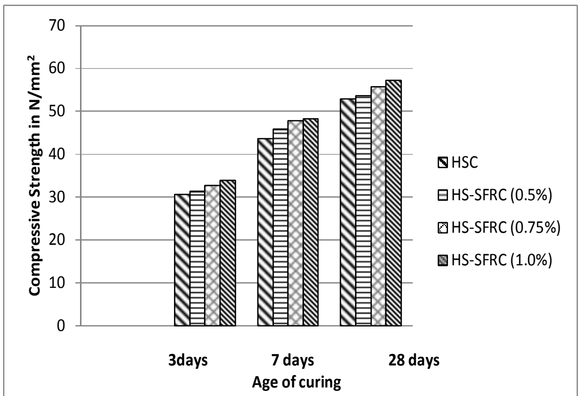

Fig.1 Age of concrete vs compressive strength

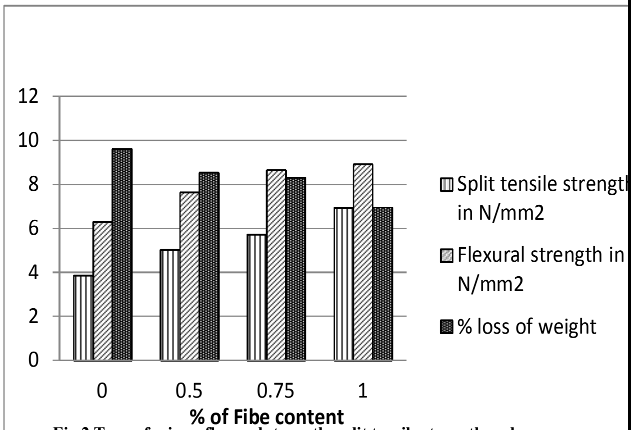

Fig.2 Type of mix vs flexural strength, split tensile strength and

3.5 Modulus of Elasticity

In fig.3 shown the type of mixes versus young's modulus. The modulus of elasticity was increased in HS-SFRC (1%) compared to the control mix (HSC specimen). It was observed that modulus of elasticity was increased by addition of fibre content.

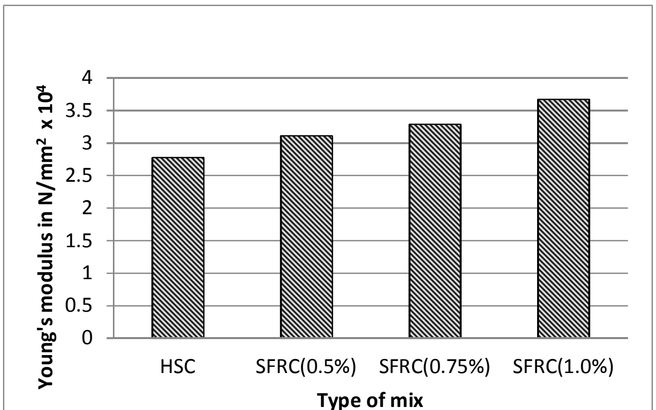

Fig. 3 Type of mix vs Young's modulus

3.6 Ultimate load

The ultimate load carrying capacity of HS-SFRC(1.0%) block pavement was increased by 33% and deflection was quite less compared to that of HSC block pavement. The ultimate load carrying capacity of the four series of mixes were shown in fig.4 . The load carrying capacity was increased and the strain, deflection were decreased due to increase in the fibre content. The mode of failure was changed from brittle into ductile.

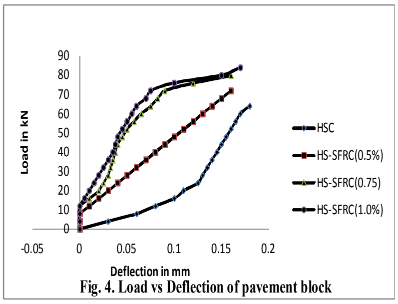

Fig. 4. Load vs Deflection of pavement block

4.Conclusion

The following conclusions are drawn based on the experimental investigations

- Compressive strength and split tensile strength were slightly increased due to the increased percentage of fibre content.
- Flexural strength was also increased by the addition of steel fibres.
- The observed deflection in HS-SFRC blocks were quite less when compared to HSC block
- The ultimate load carrying capacity of HS-SFRC block also increased with increase in fibre content compared to HSC block.
- The percentage loss of weight was decreased in HS-SFRC(1%) compared to other mixes. So that the abrasion resistance to wear was improved by the addition of fibre content.
- It was concluded that the strength was increased due to the increased in fibre content.
- The static modulus of elasticity was also increased in HS-SFRC with different percentage of fibre content compared to the control mix.
- It was observed that the mode of failure was changed from brittle into ductile.

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