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STRUCTURAL BEHAVIOUR OF STEEL FIBER REINFORCED CONCRETE BEAM

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ABSTRACT

Concrete is a brittle material which has a low strength and limited ductility. These weak points of concrete can be resolved by including fibers made up of various materials with high technical specifications. This special type of concrete is known as special types of concrete which exhibits superior properties in terms of ductility, fracture energy, toughness method, strength and durability method due to the addition of steel fibers when compared to conventional concrete. Special types of concrete has a varied application area. In practice, steel fibers which have different dimensions and aspect ratios are used. These variable characteristics of steel fibers have highly influence on the performance of SFRC.The project presents results of an experimental investigation carried out to study the properties of reinforced cement concrete and special type of concrete containing mixed fibres of different aspect ratio. An experimental programme was planned in which workability tests were conducted to investigate the properties of the fresh concrete mixes. Meanwhile, the properties of the concrete were investigated using compressive tests, split tensile tests and flexural strength tests. And effect of fibres when it is distributed in hinged zone of structural element was also examined to achieve economy by reducing steel fibre content in concrete mix. The results indicate that the Mixed special type of concrete consisting of maximum macro fibres and minimum micro fibres) can be adjusted as the most appropriate combination to be employed in SFRC for compressive test, tensile test and flexural test. However, good workability was obtained as the percentage of fibres increased in the concrete mix. And there is little amount of variation in properties of concrete between fibres in full length of the beam and fibres in hinged zone of the beam.

INTRODUCTION

GENERAL

Mostly, all the structures are made of concrete which around us, but now also there is some problem to use concrete as a building material. Generally, the Concrete structures having very low tensile strength and limited ductility, because of that using steel reinforcement is a necessary one to bridge the cracks and increase the tensile capacity of concrete. The self weight of concrete structure is greater than the steel structures with the same load carrying capacity which requires large support, the transportation and handling cost will be increased.

The environment around the structures having many harmful substances which may penetrate into the concrete through the cracks and pores, it will cause corrosion to the reinforcement. Therefore the maintenance is very important in all concrete structures. So that additional cost is needed during the service life of concrete structures.

To overcome the disadvantage of concrete, the Steel fibre reinforced concrete (SFRC) can be used. Steel fibre reinforced concretes are designed in such a way that, which may satisfy all the demands during production, construction and service life of structure. It has been proved that steel fibres

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can be used to control cracking and deflection in structural member. Addition of steel fibres to concrete structures makes it highly ductile and improves the energy absorption capacity. It has high potential application in building frames due to its high seismic energy absorption capacity. The combination of both macro and micro steel fibres in a concrete mix offer more attractive engineering properties rather than single type of fibres**.**

FIBRE REINFORCED CONCRETE

Advanced cement based materials and improved concrete construction techniques provide opportunities for the design of structures to resist severe loads resulting from earthquakes, impact, fatigue, and blast environments. Conventional concrete cracks easily. Brittle nature of concrete which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibres (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low resistance, high shrinkage and cavitation resistance, low durability, etc. Christo Ananth et al. [16] proposed a system, this fully automatic vehicle is equipped by micro controller, motor driving mechanism and battery. The power stored in the battery is used to drive the DC motor that causes the movement to AGV. The speed of rotation of DC motor i.e., velocity of AGV is controlled by the microprocessor controller. This is an era of automation where it is broadly defined as replacement of manual effort by mechanical power in all degrees of automation. The operation remains an essential part of the system although with changing demands on physical input as the degree of mechanization is increased.

STUDY OF MATERIAL PROPERTIES

GENERAL

This chapter discuss about the materials and their properties for the experimental investigation. Two different aspect ratio of fibres, ie. Macro and Micro crimped steel fibres are used in casting the FRC beam separately and mixed together.

MATERIALS USED

Cement

Cement is a material, generally in powder form, that can be made into paste usually by addition of water. Ordinary Portland cement of 53 grade is used for this experiment study. IS :12269 - 2013 specifies the requirements of cement. The cement has a specific gravity of 3.15.

Aggregates

Aggregates are the major ingredients of concrete. It acts as economical space filler. IS: 383 - 1970 specifies the requirements of aggregate. They are inert and are broadly divided into two categories i.e, fine and coarse aggregate depending on their size. The crushed rock is used as coarse aggregate and river sand preferred for fine aggregate

Coarse aggregates

Coarse aggregate shall consist of clean, hard, strong, dense, non-porous and durable pieces of crushed stone. They shall not consist pieces of disintegrated stones, soft, flaky, elongated particles, salt, alkali, vegetable matter or other deleterious materials. The sizes of aggregates used in the investigation are 60% 20mm aggregates and 40% 12.5 mm aggregates.

Fine aggregates

Naturally available fine aggregate is used for casting the specimens. The fine aggregate was passing through 4.75mm sieve and had a specific gravity of 2.64. The grading zone of fine aggregate was zone II as per IS 383 -1970.Fine aggregates shall not contain dust, lumps, soft or flaky materials, mica or other deleterious materials.

Water

Water should be potable and free from acids, oils, alkalies and other organic impurities as per IS: 456 - 2000.

Steel fibres

The steel fibres used in the concrete are flat crimped macro fibres and round crimped micro fibres procured from kasthuri metal composites, Maharashtra.

Flat crimped macro fibres

The view of flat crimped macro steel fibres shown in Figure 4.1 and specification given in Table 4.1.

Fig. 1: Flat crimped macro steel fibres

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Table-1 Specification of flat crimped macro fibres

Parameters	*Specifications*
Length of fibre	38 mm
Aspect ratio	76
Diameter (d)	0.5mm
Width (w)	2 mm – 2.5 mm
Tensile Strength	400 MPa to 600 MPa
Appearance and Form	Clear, bright and undulated along the length
ASTM Specification	ASTM A820 M04 Type 1
Material Type	Low Carbon Drawn Flat Wire

Round crimped micro fibres

The view of round crimped micro steel fibres and specification.

Fig. 2: Round crimped micro steel fibres

Table.2: Specification of round crimped micro fibres

Parameters	*Specifications*
Length of the fibre	15mm
Aspect ratio	50
Diameter	0.3mm
Tensile strength	750 MPa to 1100 MPa
Appearance and form	Clear, bright and undulated along the length
ASTM specification	ASTM A820 M04 Type I
Material type	Low Carbon Drawn Wire

Mix proportioning

The concrete mix has been designed for M25 grade as per IS 10262-2009. Proportion of concrete should be selected to make the most economical use of available materials to produce concrete of required quality. The mix ratio for casting the specimen used is 1:1.44:2.48 and water cement ratio is 0.5. Volume fractions of 1.5% steelfibres are used with different proportion of macro and micro steel fibres. Materials required for one cubic meter of concrete.

Table.3: Materials required for one cubic meter of concrete

Cement (kg)	*Fine Aggregate (kg)*	*Coarse Aggregate (kg)*	*Water (kg)*	*Steel fibres (kg)*
438	631	1087	219	115

EXPERIMENTAL PROGRAMME

GENERAL

The specimens such as cubes, cylinders and beams were casted and tested for optimize the proportion of macro and micro steel fibres and effect of fibres in hinged zone of structural element were also examined. For all the concrete mixes 1.5 % volume fractions of steel fibres were used. Specimen Identification for all the beams.

Table.4: Specimen identification for all the beam specimens

Specimen Identification	*Proportions by weight in %*		*Distribution Zone*
	Micro Fibres	*Macro Fibres*	
C	0	0	-
S1	100	0	Full length of the beam
S2	75	25	Full length of the beam
S3	50	50	Full length of the beam
S4	25	75	Full length of the beam
S5	0	100	Full length of the beam
SH	25	75	Hinged zone of the beam

TESTING

The concrete mix has been tested for workability by using slump cone. After curing , hardened concrete is tested for various tests such as compressive strength test, Split tensile strength test and flexural strength test.

Slump Cone Test

The slump cone test was conducted based on IS: 1199-1959, which is used to measure the workability of the concrete.

Compressive Strength Test

It is the most common test conducted on hardened concrete based on IS: 516 - 1959.

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Fig. 3: Testing of cubes

Split Tensile Strength Test

Concrete is strong in compression and weak in tension. One of the indirect methods available is split tensile test conducted based on IS: 516 - 1959. After 28 days curing, the cylinder specimen was taken out form the curing tank and allowed to dry for about few hours.

Fig. 4: Testing of cylinder

Flexural Strength Test

Beams are tested under two point loading based on IS: 516 - 1959. After 28 days curing of concrete, the test specimen was allowed to dry then placed in the universal testing machine.

Fig. 5: Testing of beams

RESULTS AND DISCUSSION

WORKABILITY TEST

The Slump value measured as per IS :1199 -1959 on control samples and steel fibre reinforced concrete.

Table.5: Workability of plain concrete and steel fibre reinforced concrete

Specimen Identification	Fibre mix proportions by weight		Slump value (mm)	Degree of workability
	Micro fibres	Macro fibres		
C	0	0	105	High
S1	100	0	87	Medium
S2	75	25	81	Medium
S3	50	50	77	Medium
S4	25	75	65	Medium
S5	0	100	55	Medium

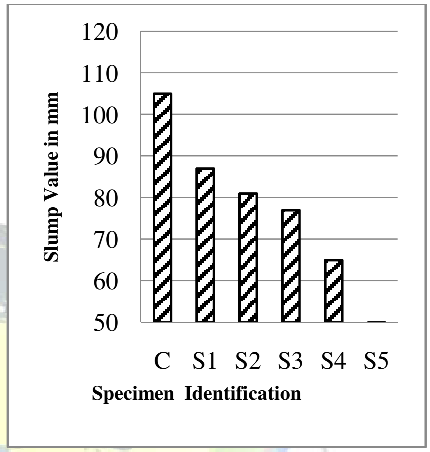

Fig.6:Results for workability test

COMPRESSIVE STRENGTH

Table.6: Compressive strength results of plain concrete and SFRC

Specimen Identification	Fibre mix proportions by weight		Compressive strength (N/mm^2)
	Micro fibres	Macro fibres	
C	0	0	32
S1	100	0	38.94
S2	75	25	35.61
S3	50	50	33.96
S4	25	75	33.03
S5	0	100	32.12

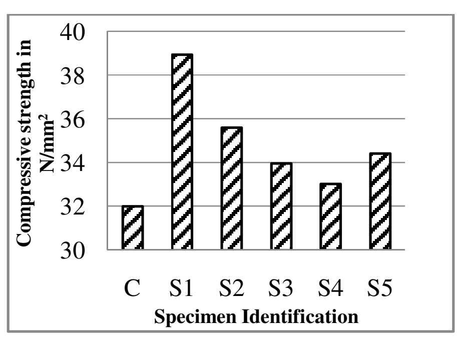

Fig. 7: Results for compressive strength test

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SPLIT TENSILE STRENGTH

The split tensile strength test conducted as per IS: 516 - 1959 on control mix and steel fibre concrete with different proportions of macro and micro fibres are presented.

Table.7: Split tensile strength results of plain concrete and SFRC

Specimen Identification	Fibre mix proportions by weight		Split Tensile strength (N/mm^2)
	Micro fibres	Macro fibres	
C	0	0	2.5
S1	100	0	3.01
S2	75	25	3.12
S3	50	50	3.453
S4	25	75	3.665
S5	0	100	3.33

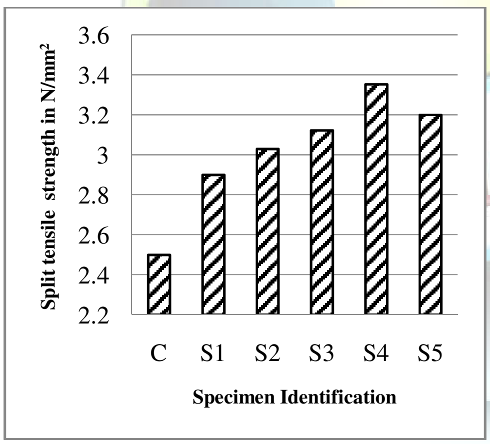

Fig. 8:Results for split tensile strength test

FLEXURAL STRENGTH

Load- deflection behaviour

Load Vs deflection curve plots for all beams with or without macro and micro steel fibres were drawn and Comparisons of load deflection behaviour for all the beams.

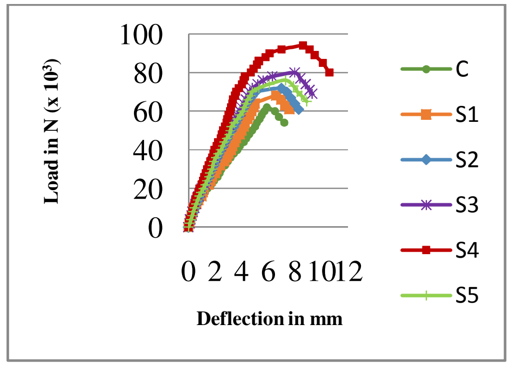

Fig. 9: Load deflection behaviour for all the beams

Table.8: Experiment test results for all the beams

Specimen Identification	First crack load kN	Ultimate load kN	Ductility factor	Energy absorption Capacity Nmm (x 10^3)	Stiffness N/mm (x 10^3)
C	11	62	1.55	290.14	8.33
S1	12	68	1.86	334.58	9.3
S2	13	72	1.75	424.69	10.8
S3	15	80	2.22	536.73	11.42
S4	16	94	2.38	740.32	13.79
S5	14	76	2.14	459.88	9.52

Load Carrying Capacity

The load carrying capacity of the beam was increased by the addition of steel fibres to the concrete.

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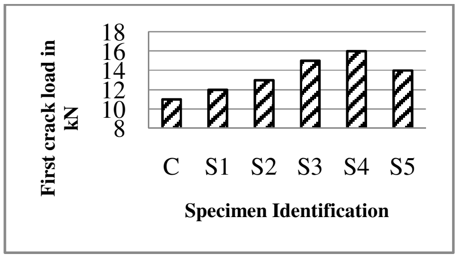

Fig. 10: First crack load for all the beams

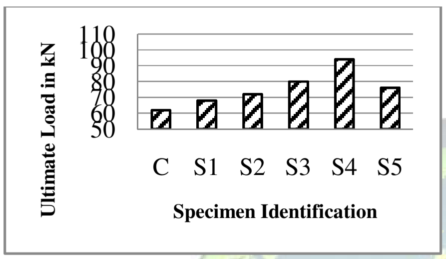

Fig. 11: Ultimate load carrying capacity for all the beams

Stiffness characteristics

Stiffness is defined as the load required to cause unit deflection of the beam. A tangent is drawn for the curve at load of P= 0.75Pu

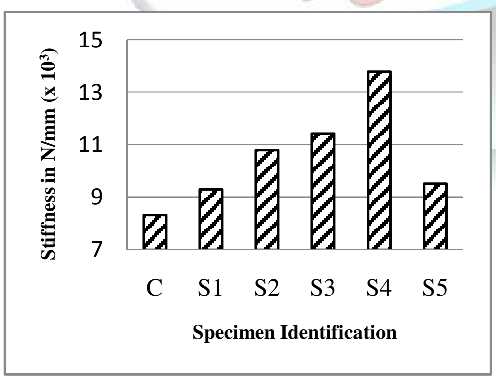

Fig. 12: Stiffness characteristics for all the beams

Fig. 13: Failure pattern for all the beams

From the above test results, Fibre combination of 75% macro fibres and 25% micro fibres at 1.5% volume fraction gives the most appropriate combination as regards to the highest in the flexural and split tensile strength.

RESULTS AND DISCUSSION

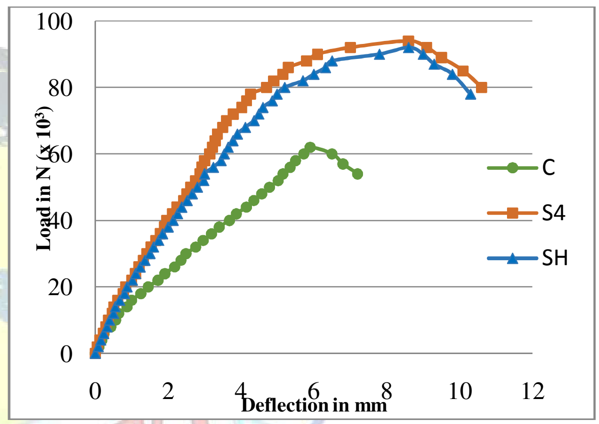

Fig. 14: Comparison of Load deflection behavior of three types of beams

Table.9: Comparison of three types of beam results

Specimen Identification	First crack load kN	Ultimate load kN	Ductility factor	Energy absorption Capacity Nmm (x 10^3)	Stiffness N/mm (x 10^3)
C	11	62	1.55	290.14	8.33
S4	16	94	2.38	740.32	13.79
SH	16	92	2.38	678.48	12.5

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Load carrying capacity

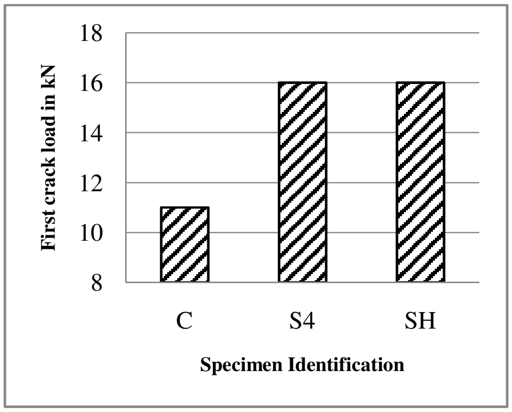

Fig. 15: Variation in First crack load for the three types of beams

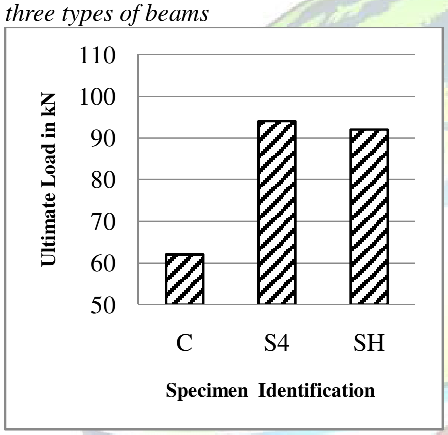

Fig. 16: Variation in Ultimate load for the three types of beam

Energy absorption capacity

The Energy absorption capacity for the SH beam is 9.1% less than S4 beam and which is 2.34 times greater than C beam. The variation in energy absorption capacity for the above three types beams.

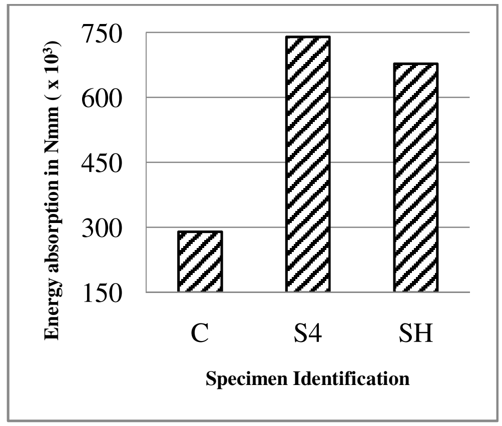

Fig.17: Variation in Energy absorption capacity for the three types of beams

Stiffness

The Stiffness for the SH beam is 10% less than the S4 beam and 50% greater than C beam. The variation in stiffness characteristics.

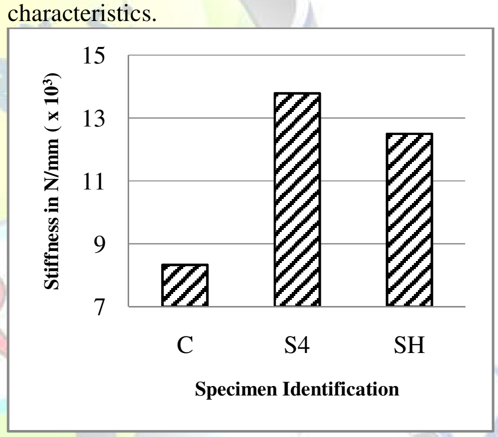

Fig. 18: Variation in Stiffness for the three types of beams

CONCLUSIONS

GENERAL

An experimental programme was carried out to investigate the combined effect of macro and micro steel fibres in fresh and hardened state of concrete and the effect of fibres when it is distributed only in hinged zone of structural element were also examined.

SALIENT CONCLUSIONS

Based on the experimental investigation, the main conclusions that can be drawn are as follows.

- The Concrete with micro fibre has better workability and perform good in compression as compared to concrete with macro fibres.

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- Fibre combination of 75% macro fibres and 25% micro fibres at 1.5% volume fraction (S4) gives the most appropriate combination as regards to the highest in the flexural and split tensile strength.
- The first crack load and ultimate load for S4 beam has been increased by the amount of 50% & 51.6% respectively as compared to control beam.
- The ductility factor and energy absorption capacity for S4 beam is greater than Control beam by the amount of 53.5% & 2.55 times respectively.
- The stiffness for S4 beam is 66.67% higher than conventional beam and it shows better stiffness characteristics as compared to all other beams.
- The variation between the S4 beam and SH beam is below 10% for all the parameter. So that fibres placed only in hinged zone is sufficient and economical by reducing the fibre content in the beam as compared to fibres in full length of the beam.

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