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Analysis of Steel Fibre Reinforced Concrete Beam without Conventional Shear Reinforcement

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Abstract— In recent times developments of new materials and production methods have increased within the field of construction. Using suitable fibres and additives in concrete to advance its performance is an important consideration in the construction industry with regard to structural aspects of concrete. Concrete is inherently a brittle material with highly weak post peak behaviour. When adding fibres in to the concrete these fibres act as secondary reinforcement in the concrete structures to restrain crack propagation. The purpose of this project was to investigate the shear strength of steel fibre reinforced concrete beams with and without shear reinforcement. Fibre volume fraction is varied as 1%, 2%, 3%, 4% & 5%. The main variable investigated in addition to the effect of steel fibres, was the influence of a possible size effect, Hence beams of 3 dimensions were modelled and analysed 200x250x1500mm, 200x500x3600mm and 300x700x6000mm. Analyse of the results indicate some favourable aspects concerning the use of steel fibres as shear reinforcement in concrete beams. The project focuses in the design and analysis using the software ANSYS 15, for an alternative steel reinforcement with better or equivalent performance.
Keywords— steel fibre; concrete beam

I. INTRODUCTION

When subjected to a combination of moment and shear force, a reinforced concrete (RC) beam with either little or no transverse reinforcement can fail prematurely in shear before reaching its full flexural strength. This type of shear failure is sudden in nature and usually catastrophic because it does not give ample warning to inhabitants. To prevent shear failures, beams are traditionally reinforced with stirrups. In general, the use of stirrups is expensive because of the labour cost associated with reinforcement installation. Also, casting concrete in beams with closely-spaced stirrups could be difficult and might lead to voids and associated poor bond between concrete and reinforcing bars. An alternative solution to stirrup reinforcement is the use of randomly oriented steel fibres, which have been shown to increase shear resistance. The use of deformed steel fibres in place of minimum stirrup reinforcement is currently allowed in ACI Code Section 11.4.6 (ACI Committee 318, 2008). The benefits of using steel fibres reinforcement for shear resistance, however, have not been fully exploited yet, primarily due to lack of understanding of the role which steel fibres play on the shear behaviour of beams with and without stirrup reinforcement. In recent times development of new materials and production methods have increased within the field of construction. One example is the use of steel fibres for various applications. Due to its ability to distribute and prevent cracks from appearing steel fibres have proved rather effective as crack controlling reinforcement, particularly in slabs. By replacing parts of the conventional reinforcement by steel fibres a new, more rational way of production has been developed. The favourable properties provided by fibres have lead to increased research efforts aiming at finding other areas of application for steel fibres reinforced concrete. One area where steel fibres may prove effective is as shear reinforcement in concrete beams. Steel fibre when added to concrete, steel fibres. Significantly improve its post-cracking tensile resistance and toughness. SFRC has been used extensively in construction of industrial floors, bridge deck overlays, airport runways, highway pavements, tunnel linings, spillways, dams, slope stabilizations, and many precast products.

A. Steel fibres

Steel fiber reinforced concrete has superior resistance to cracking and crack propagation. Fiber composites posses increased extensibility and tensile strength. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fiber composite and its ability to withstand repeatedly applied shock or impact loading. Satisfactory improvement in various strengths is observed with the inclusion of steel fibers in the plain concrete. Maximum gain in strength of concrete is found to depend upon the amount of fiber content. Steel fiber technology actually transforms a brittle

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material into a more ductile one.

Fig 1**:** Steel fibers

II. LITERATURE REVIEW

Jonas Gustafsson ,Keivan Noghabai [1](2013)their purpose was to investigate if steel fibres can replace stirrups as shear reinforcement in high strength concrete beams. Thus, twenty beams were fabricated with various types and amounts of fibres. For comparison reasons, beams reinforced with stirrups and no shear reinforcement whatsoever were also tested. The main variable investigated, in addition to the effect of steel fibres, was the influence of a possible size effect. Hence, beams of three dimensions were produced. Analysis of the results indicates some favourable aspects concerning the use of steel fibres as shear reinforcement in high strength concrete beams. However, a comparison of test results with some equations, suggested to apply for fibre reinforced concrete beams in shear, shows that there are some uncertainties connected to the design. Failures of small beams considerably more ductile compared to the larger beams

Yoon-Keun Kwak marc O Eberhard,Woo-suk kim & Jubum kim [2](2002)studied the feasibility of using fibre reinforced concrete as a replacement for the conventional shear reinforcement in beams. Twelve tests were conducted on reinforced concrete beams with three steel fibre-volume fractions (0,0.5 and 0.75%),three shear span-depth ratios(2,3 and 4) and two concrete compressive strengths (31 and 65 MPa) .The results of 139 tests of fibre reinforced concrete beams without stirrups were used to evaluate existing and proposed empirical equations for estimating shear strength. They were found addition of steel fibres consistently decrease the crack spacing & sizes, increase the deformation capacity & failure mode changed from brittle mode to a ductile one.

III. ANALYSIS

Finite element analysis (FEA) is a computerized method for predicting how a product reacts to real-world forces, vibration, heat, fluid flow, and other physical effects. Finite element analysis shows whether a product will break, wear out, or work the way it was designed. It is called analysis, but in the product development process, it is used to predict what is going to happen when the product is used.FEA software ANSYS has been used in this study.

A. Methodology

A reinforced concrete beam of geometry in the fig:3 is selected based on various literature surveys. Then using the analytical FEA software ANSYS WORKBENCH the joint is modelled and analysed for the various cases under consideration as explained below. The study can be divided to 2 sections.

1) Beam with detailing as per the IS code
2) Reinforced concrete beam and steel fibre reinforced concrete beam different percentages of fibres and sizes.

The performance of each cases are compared with the performance of beam as per the codes (section 1) under the two point loading. Then the most effective size beam with equivalent performance is selected based on certain parameters such as load carrying capacity, shear stress and deformation.

B. Material properties

1) Concrete-M30concrete,Elastic Modulus=5000$\sqrt{fc}$, Poisson ratio=0.2
2) Steel- Elastic Modulus=20000MPa,Fe 415, Poisson ratio=0.3
3) Steel fibres-When steel fibres are added to mortar, Portland cement concrete or refractory concrete, the flexural strength of the composite is increased from 25% to 100% **-** depending on the proportion of fibres added and the mix design. Steel fibre technology actually transforms a brittle material into a more ductile one you use in an equation. Double hooked steel fibers are used by modifying the properties of plain concrete with stress strain behaviour calculated using following equation.

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$$\frac{\sigma}{f_{cf}} = \frac{\beta\frac{\varepsilon}{\varepsilon_{pf}}}{\beta - 1 + (\frac{\varepsilon}{\varepsilon_{pf}})}$$

The stress strain curve is as shown in fig:2 for different percentage 1%,2%,3%,4% & 5%

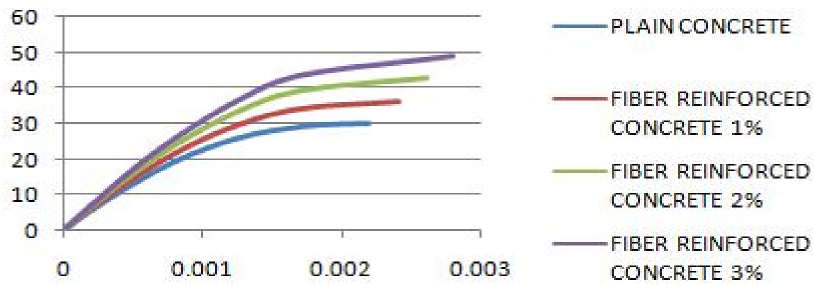

Fig 2**:** Steel fibres stress strain behavior

C. Elements used

The suitable elements are selected from the ANSYS library. Concrete and steel fibre reinforced concrete is modelled using Solid 65.steel bars are modelled using Link 180.

IV. GEOMETRY

The geometry of small, medium and large size beam as in fig 3 is modelled using ANSYS software.

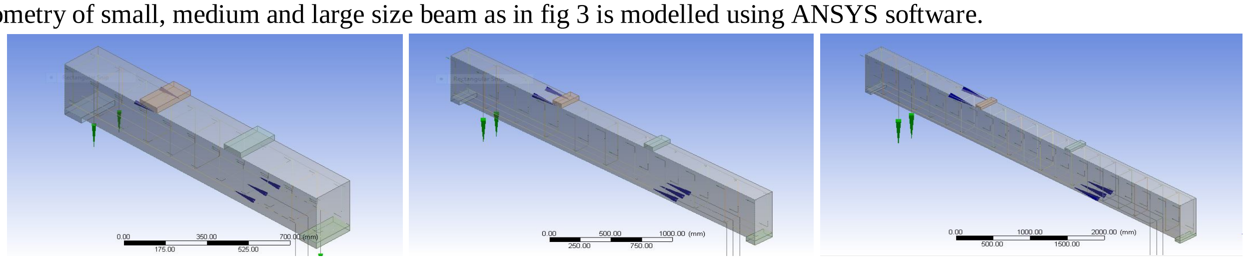

Fig 3: Geometry

D. Boundary and load conditions

During analysis both ends of beams are simply supported. Modelling of the boundary conditions is often the most critical aspect in achieving sensible, reliable data from a finite element model. Two point loading applied as given in fig 4.it represents the loading of small, medium and large size beams.

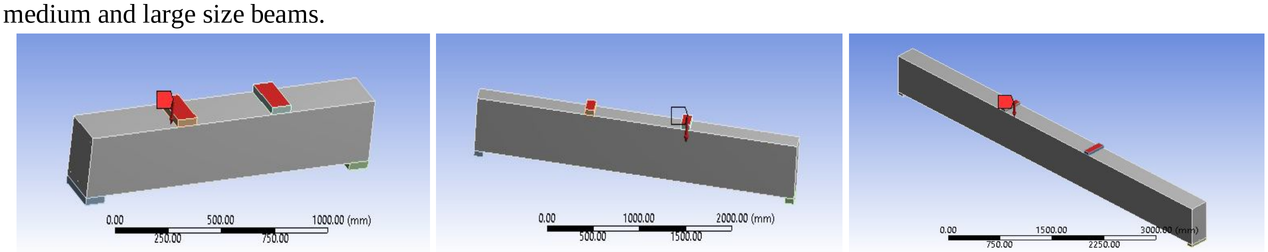

Fig 4: Two point loading

E. Results and discussions

The fig5 shows the shear stress developed in the small, medium and large size RC and SFRC 3% beams after the analysing.

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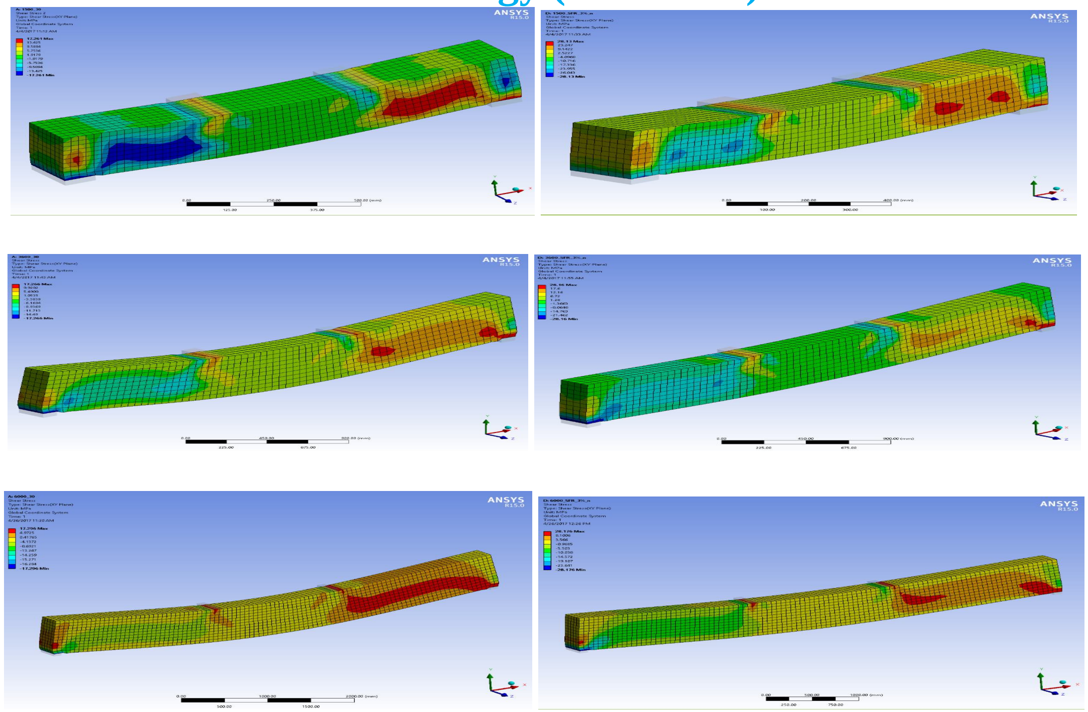

Fig 5: Shear stress of the beams

The results for the section of study are as given in the table 1. This result serves as a benchmark for the further studies.

Table 1: Result Of Various Beams

BEAM SIZE	TYPE	DEFORMATION (mm)	SHEAR STRESS (N/mm^2)
200x250x1500	RC beam	1.0356	17.261
	SFRC 1%	0.90557	20.886
	SFRC 2%	0.79399	24.51
	SFRC 3%	0.61703	28.13
	SFRC 4%	0.5745	26.843
	SFRC 5%	0.4352	26.634
200x500x3600	RC beam	0.72021	17.266
	SFRC 1%	0.68718	20.902
	SFRC 2%	0.6203	24.531
	SFRC 3%	0.5703	28.16
	SFRC 4%	0.4321	27.324
	SFRC 5%	0.6174	25.836
300x700x6000	RC beam	0.7995	17.296
	SFRC 1%	0.78131	20.929
	SFRC 2%	0.72809	24.559
	SFRC 3%	0.6713	28.176
	SFRC 4%	0.7654	27.756
	SFRC 5%	0.71506	25.771

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In section 2 of study the beam size 200 x 250 x 1500 mm, 200 x 500 x 3600 mm and 300 x 700 x 6000 mm is combined with 5 percentages of steel fibres the results are summarized in table 1.from the results it is observed that the optimum fibre percentage is 3%. From the table it can be seen that there is much effect in increasing the fibre content up to 3%, beyond 3 % the variations in deformation is negligible. Hence it can be concluded that the effective alternate steel fibres that can perform equivalent to the conventional shear reinforcement in beams.

V. CONCLUSIONS

A. By increasing amount of steel fibre, deformation gets reduced. Addition of steel fibres can partially substitute stirrups & have same effect in terms of shear strength. The load deformation curve of the small size beam RC and SFRC with various percentage steel fibre is shown in fig.7

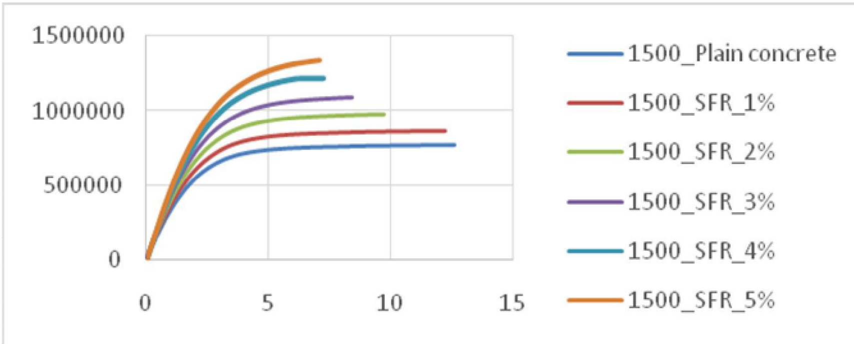

Fig 7: Load Deformation Curve

B. Small sized SFRC beams performs better deformation characteristic compared to other sizes.

C. The shear strength of beam which depends on concrete property is improved by adding steel fibre. Hence steel fibre is economically and practically feasible to replace the conventional shear reinforcement with the new proposed one

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