NUMERICAL ANALYSIS OF ENGINEERED STEEL FIBERS AS SHEAR REINFORCEMENT IN RC BEAMS

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ABSTRACT

*Using suitable fibers and additives in concrete to enhance its performance is an important consideration in the concrete industry with regard to the structural aspects of concrete. The purpose of this project is to investigate numerically the effectiveness of the engineered steel fiber as shear reinforcement in RC beams. Here steel fibers completely replaces the shear reinforcement (stirrups & links). The dimension of beam taken was 1000*150*150 mm with aspect ratio 80. The beams were reinforced with 10 mm steel bars as secondary reinforcement and 12 mm bars as main reinforcement on the tension side. Numerical analysis using ANSYS R16.1 software package was carried out. The load-deflection curves for the beams with different dosage of fibers were drawn superimposing their numerical values. Initially, in all three cases the curve was linear elastic and about 80% of ultimate load they tend to be non-linear. It was observed that there was fair agreement between the results which indicates some favourable aspects concerning the use of steel fibres as shear reinforcement in concrete beams. It was investigated that the inclusion of steel fibres (Hook End Type) improves the shear strength of RC beams without stirrups by improving the matrix between concrete and steel fibers. Thus this project focuses in the design and analysis using the software ANSYS R16.1 for an alternative steel reinforcement with better or equivalent performance.*

KEYWORDS: *Engineered Steel Fibers, Ansys R16.1, Finite Element Model, Shear Connector, SFRC beam.*

I. INTRODUCTION

Concrete is weak in tension and has a brittle character and relatively low tensile strength. A Plain Concrete beam with no transverse reinforcement when subjected to a combination of moment and shear force, 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).
Steel fibers aids in converting the brittle characteristics of concrete to a ductile one. The principal role of fibers is resisting the formation and growth of cracks by providing pinching forces at crack tips. In addition, a marginal improvement in tensile strength also results. Steel fibres can delay the formation and propagation of cracks by improving the effectiveness of the crack-arresting mechanisms present in beams when applied under high shear stresses. Steel fiber when added to concrete, it significantly improve its post-cracking tensile resistance and toughness.

Steel Fiber reinforced concrete (SFRC) may be defined as a composite material made with Portland cement, aggregate, and incorporating discrete discontinuous steel fibers. The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post-cracking "ductility". If the fibers are sufficiently strong, sufficiently bonded to material it permits the FRC to carry significant stresses over a relatively large strain capacity in the postcracking stage. The fiber reinforcement is in the form of short discrete fibers, they act effectively as rigid inclusions in the concrete matrix. Shear failure of fiber reinforced concrete beams is generally affected by a large number of parameters among which the aspect ratio (a/d) ratio is the most important. The other main parameters are the compressive strength, the longitudinal reinforcement ratio, the aggregate and the presence of transverse stirrups.

The main area of SFRC applications are Runway, Aircraft Parking, Pavements, Tunnel and Canal Lining, Slope Stabilization, Slabs, Shotcreting, Bridge deck slab repairs, Blast Resistant Structures, Thin Shell, Walls, Pipes, Manholes, Dams and Hydraulic Structure, Machine tool frames, lighting poles, water and oil tanks and concrete repairs, Industrial flooring, Explosive resistant structure, Refractory lining, Fabrications of precast products like pipes, boats, beams, staircase steps, wall panels, roof panels, manhole covers, Manufacture of prefabricated formwork moulds of "U" shape for casting lintels and small beams.

Figure 1. Double end Hooked Steel Fiber

II. LITERATURE REVIEW

A lot of research work has been done on shear behaviour and mechanical properties of steel fiber reinforced concrete (SFRC). [9] A study on quality and mechanical properties of engineered steel fibers used as reinforcement for concrete concludes that number of bends is very important, straight fibers are not preferred and aspect ratio plays a vital role.[3] Here fibers are engineered to achieve optimal properties in terms of shape, size and mechanical properties. This fiber advances the broader use of high performance fiber reinforced concrete in structural applications such as in blast and seismic resistant structures and cement sheet products.[11] Some attempted to predict the shear strength of steel fiber reinforced concrete beams with different percentage of steel fiber without web reinforcement and found that the ultimate shear strength of matrix increases significantly by adding fibers to the matrix. [2] The inclusion of steel fibres in concrete, when adopted in ample quantities, improves the shear resistance of beams by increasing the tensile and post-cracking or energy absorption characteristics of the concrete. Steel fibres can delay the formation and propagation of cracks by improving the effectiveness of the crack-arresting mechanisms present in beams when applied under high shear stresses. [4] The significant increase in compressive and split tensile strength is observed with the addition of hooked end steel fibers in plain concrete.[7] Failure mechanism is controlled by combined shear and flexural action. [6] Steel fibres can be used to replace stirrup completely with proper design of concrete. The replacement of vertical stirrups by steel fibres provided effective reinforcement against shear failure.

III. ANALYSIS

Finite Element Analysis (FEA) is a computerized method enables to test in virtual environment before manufacturing prototypes of products in real world. FEA software used here in this study is ANSYS

R16.1. This can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules.
ANSYS R16.1 can import CAD data and also enables to build a geometry with its "pre-processing" abilities. Similarly in the same pre-processor, finite element model (a.k.a. mesh) which is required for computation is generated. After defining loadings and carrying out analyses, results can be viewed as numerical and graphical.

3.1. Methodology

1. Design of beam referring to IS code is done and cross checked using STAAD PRO V8i Analysis. From this the size of the beam is decided as 1000*150*150mm with all reinforcement detailing.
2. Analysis of the beam with simply supported conditions under two point loading is done by varying the dosage of fibers.
3. The most effective dosage of fiber in the beam is selected on certain parameters such as ultimate load carrying capacity, deformation and its shear stress

3.2. Material Property

1. Steel - Young's Modulus E = 200Gpa, Poisson's Ratio μ = 0.3, Density ρ = 7800 kg/m3
2. Concrete (Fiber reinforced concrete) - Young's Modulus E = 26763Gpa (0.5%), 26832Gpa(0.75%), 26220Gpa(1%), Poisson's Ratio μ = 0.15, Density ρ = 2500 kg/m3

(Here E and μ are obtained from the experimental Compressive strength for each % of fiber)

3.3. Element type and Mesh type

1. Concrete - Solid 65 is used since this shows crack patterns also and has no real constants
2. Bar - link 180 with real constants
3. Meshing - Mapped meshing done using hexahedron meshing element

3.4. Boundary Condition

Modelling of the boundary conditions are must in ANSYS R16.1 analysis and often the most critical aspect in achieving sensible, reliable data from a finite element method. Since I have taken simply supported beam for analysis, Ux, Uy = 0 and Uz is set free.

3.5. Geometry and Ansys Results

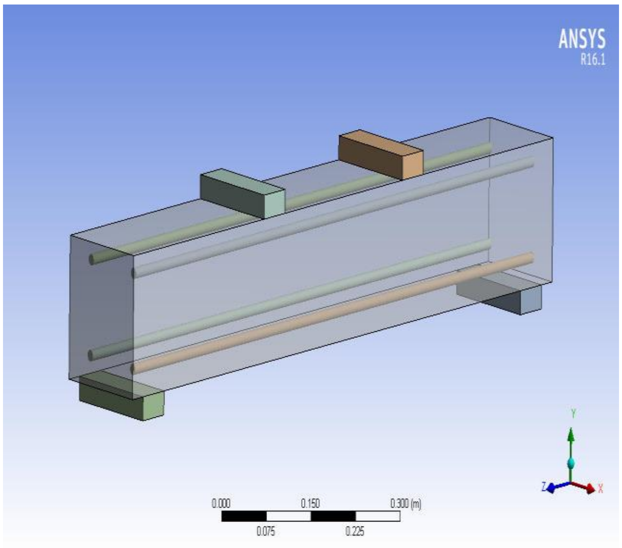

Figure 2. Ansys beam model

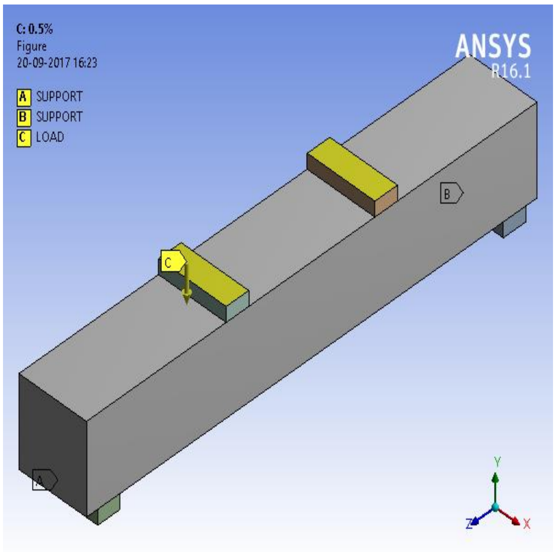

Figure 3. Loading and supports

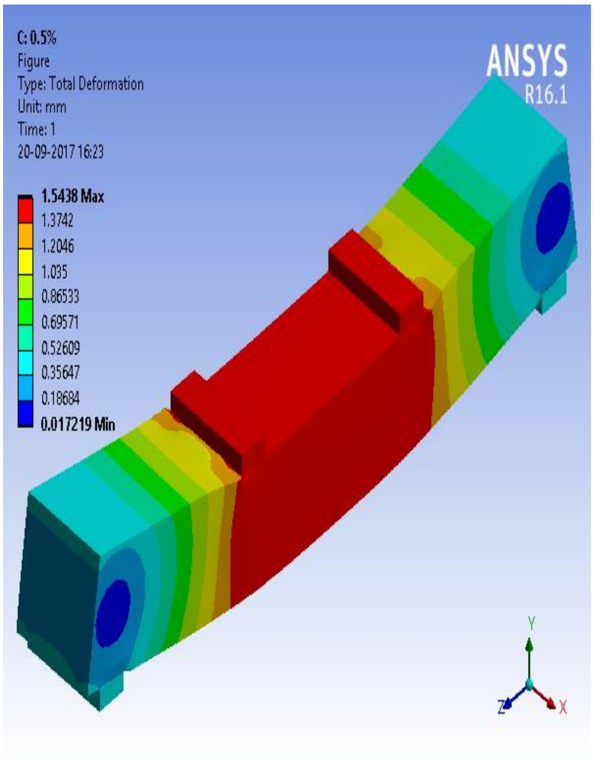

Figure 4. 0.5% - Total deformation

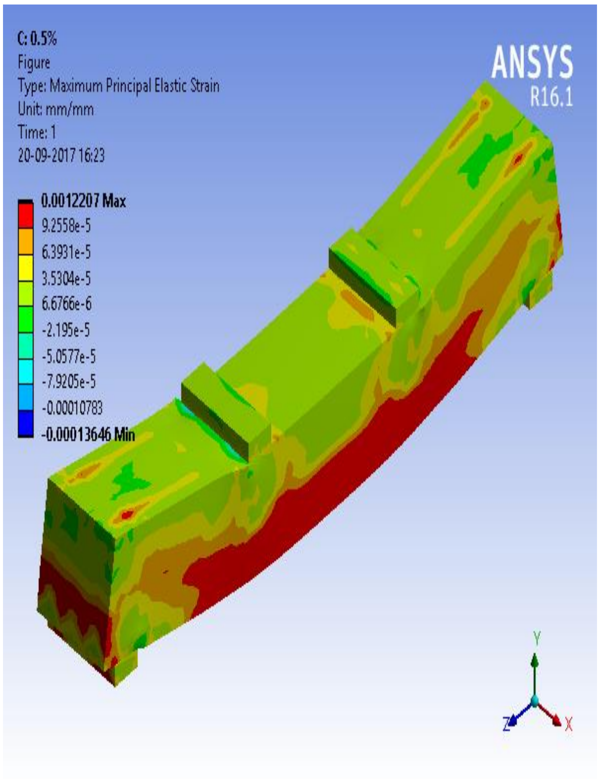

Figure 5. 0.5% - Max Principal elastic strain

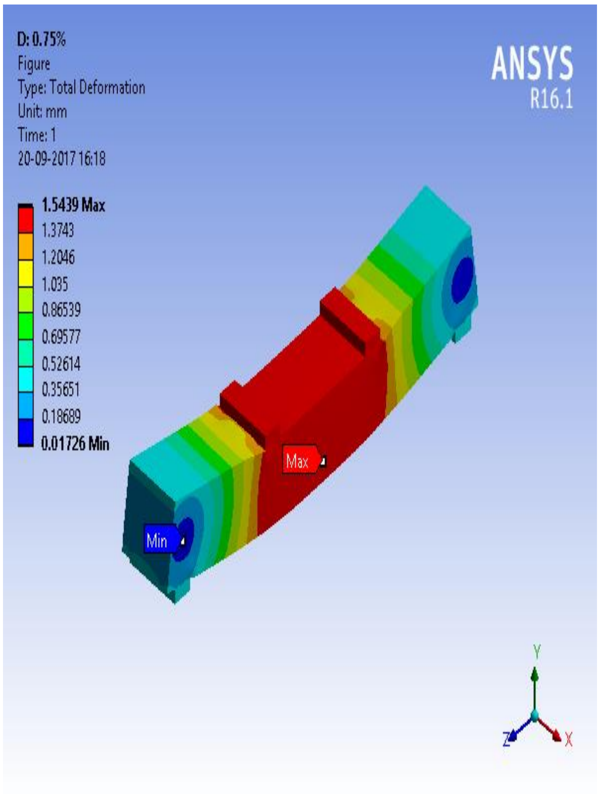

Figure 6. 0.75% - Total deformation

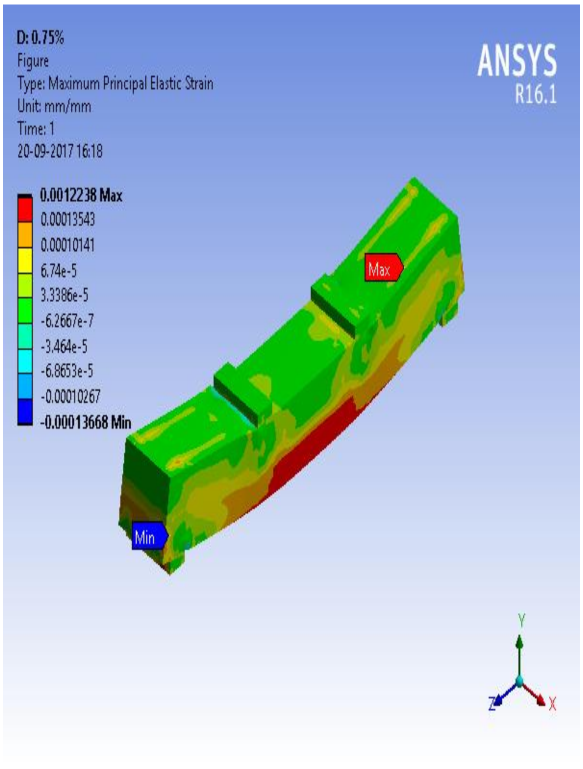

Figure 7. 0.75% - Max Principal elastic strain

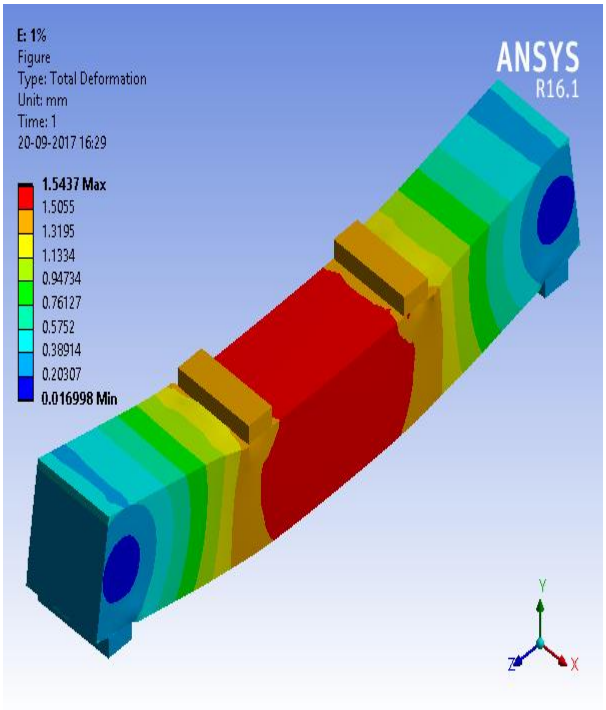

Figure 8. 1% - Total deformation

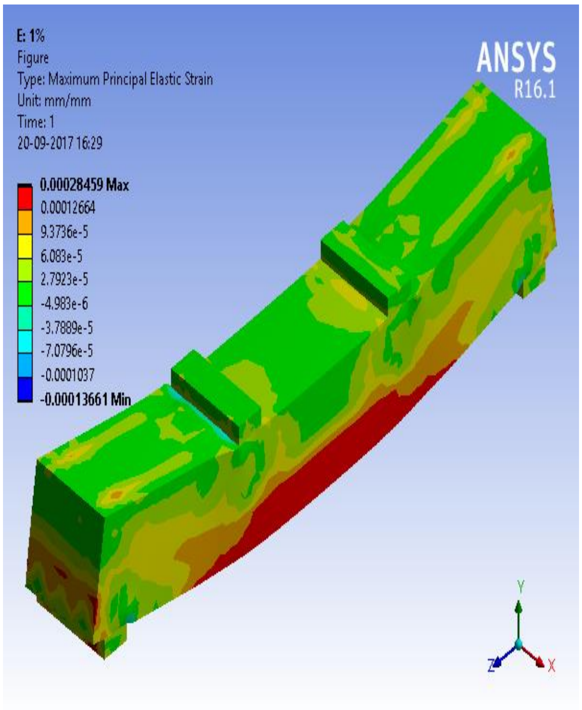

Figure 9. 1% - Max Principal elastic strain

IV. RESULTS AND DISCUSSIONS

When comparing the analytical results of 0.5%, 0.75% and 1% of dosage of fibers , 0.75% dosage gives better results with maximum load carrying capacity and ultimate shear resistance.

Table 1. Heading and text fonts.

S.NO	% OF FIBER DOSAGE	COMPRESSIVE STRENGTH (N/mm2)	MAXIMUM LOAD CARRYING CAPACITY (KN)	DEFORMATION (mm)
1	0.5	28.65	64.94	1.5438
2	0.75	28.80	68.15	1.5439
3	1	27.50	61.04	1.5437

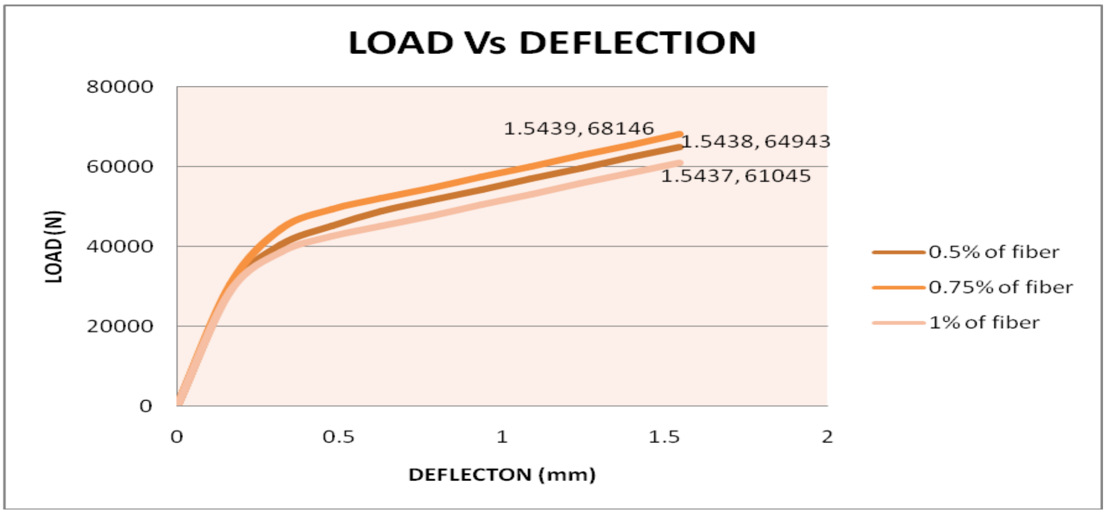

Figure 10. Load Deflection Graph

From table1, it is clear that there is much effect in increasing the fiber content up to 0.75% and beyond 0.75% the variations in deformation and load carrying capacity is getting reduced. And for 0.75% the maximum load carrying capacity is 68.15 KN from analytical investigation. Therefore, the Optimum content of fiber is 0.75%.

V. CONCLUSIONS

Based on the above analytical work on the effectiveness of engineered steel fibers as shear reinforcement in RC beams, the following conclusions have been drawn:

1. The optimum fiber content for this research is 0.75 % of volumetric percentage.
2. Addition of steel fibers increases the load carrying capacity by reducing deformation.
3. Adding beyond the optimum content decreases the compressive strength and load carrying capacity of the SFRC beam.
4. Inclusion of steel fibres (Hook End Type) in the concrete beam improves the matrix between concrete and steel fibers and in turn improves the shear strength of RC beams even without stirrups
5. Hence steel fiber is economically and practically feasible to replace the conventional shear reinforcement.

VI. FUTURE WORK

- The above work can be verified experimentally for different % of steel fiber dosages in SFRC beams under two point loading and the effect of various parameters of steel fibers on RC beam to be studied
- The behaviour of SFRC beam may be studied under dynamic loading and fatigue loading.
- The behaviour of sfrc beam prepared with High Performance Concrete may be studied

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