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Experimental study on stress strain behavior of steel fibre reinforced concrete

Rakesh DR[1], Kavitha S[2], Dr. T Felix Kala[3]
[1] B.E. Final Year Student, ACS College of Engineering, Mysore Road, Bengaluru, Karnataka, India
[2] Research Scholar, Dr. M.G.R Educational and Research Institute University, Chennai, Tamil Nadu, India
[3] Professor & HOD, Dr. M.G.R Educational and Research Institute University, Chennai, Tamil Nadu, India

Abstract
In a recent days the applications of high strength concrete has increased in many parts of the world. This growth has been possible as a recent developments in technology and demand for high strength concrete there are many advantages in using high strength concrete in building construction. Such as, reduction in member size, reduction in self-weight and early stripping of framework. Reduced member sizes increase amount of rental area and this is beneficial, when there are architectural restrictions on column size or when land prices are very high. The addition of steel fiber to high strength concrete in various volumes fractions, can be lengthen concrete in various volume fraction, can lengthen the time elapsed before cracking and can provide a confinement.
The experimental program was designed to the effect of steel fibers on compressive strength, split tensile strength of high strength concrete and testing of cubes of size (150mm x 150mm x 150mm), cylinders of 150mm diameter, height 300mm, beam (150 x 150 x 700), the mix proportion for M20 grade of concrete. Then the steel fibers were added in the volume fraction of 0%, 0.5%, 1.0% and 1.5% and L/D ratio will be taken as 60.

Keywords: strength concrete, developments, technology, steel fibre

1. Introduction
Concrete in general weak in tensile strength and strong in compressive strength. This weakness in the concrete makes it to crack under small loads, at the tensile end. These cracks gradually propagate to the compression end of the member and finally, the member breaks. The formation of cracks in the concrete may also occur due to the drying shrinkage. These cracks are basically micro cracks. These cracks increase in size and magnitude as the time elapses and the finally makes the concrete to fail. To increase the tensile strength of concrete many attempts have been made. One of the successful and most commonly used methods is providing steel reinforcement in the form of steel Fibers or steel rods.
Fiber Reinforcement Concrete (FRC) can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fiber. Fiber reinforced concrete can offer a convenient, practical and economical method for overcoming micro-cracks and similar type of deficiencies
FRC is a concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers and natural fibers each of which lend varying properties to the concrete. In addition, the character of fiber-reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. The concept of using fibers or as reinforcement is not new. Fibers have been used as reinforcement since ancient times. Historically, horse hair was used in mortar and straw in mud bricks. In the 1900s, asbestos fibers were used in concrete. In the 1950s, the concept of composite material came into being and fiber-reinforced concrete was one of the topics of interest. Once the health risks associated with asbestos were discovered, there was a need to find a replacement for the substance in concrete and other building materials. By the 1960s, steel, glass (GFRC), and synthetic fibers such as polypropylene fibers were used in concrete. Research into new fiber-reinforced concretes continues today.

2. Objectives
- To study the strength characteristics.
- To study the stress strain behavior.
- To study the crack pattern and crushing behavior between controlled cubes and strengthened FRC cubes.
- Steel fibers are to be added at a dosage of 0.5%, 1.0%, and 1, 5% by weight of concrete. This project study presents a detailed experimental study on fiber reinforced concrete at the age of 7, 14, and 28 day.
- Tests to determine the compressive strength, flexural strength, and compare the results with conventional concrete will be carried out.

3. Materials
3.1 Cement
The cement used is Ordinary Portland cement (OPC). Cement is used to bind fine and coarse aggregate together. The cement is used with sand and gravel aggregates to produce concrete. The cement (fig 3.1) used in this experimental work is BIRLA SUPER 53 GRADE cement. All properties of OPC were evaluated referring IS 12269-1987. For this study the estimated amount of cement was collected from a single

source and stored in air tight room. The basic test were conducted as per IS 4031 recommendation.

3.2 GGBS
GGBS is also known as slag cement, due to its hydraulic properties. Addition of GGBS improves the strength and durability of concrete. It is a byproduct of iron blast furnace and it is a non-metallic product and consists of Siliceous, Aluminous and other materials. GGBS has lower heat of hydration and generates less heat during the time of hydration, curing and it increases the fluidity of the concrete.

3.3 Aggregates
The aggregates properties influence the behavior of the concrete. Since the aggregates occupies 80 percent of the total volume of concrete, they are dived into two types

- Fine aggregates
- Coarse aggregates

The aggregates passing through 4.75mm are sieve are consider to be fine aggregate and the retaining behind aggregates. The main purpose of using fine aggregate is to provide the good workability and to bind the coarse aggregates particles. The aggregates are further dived into four zones depending upon on their fineness as per specifications given by the IS 383: 1970, namely Zone I, II, III, IV.

3.4 Steel Fiber
Steel fiber reinforced concrete is a composite material that can be sprayed. Hook end steel fiber improves the shear and torsional structural strength further and reduces requirement of steel reinforcement thus making concrete economical. The steel fibers reinforced concrete by withstanding tensile cracking. The flexural strength of fiber reinforced concrete is greater than the un-reinforced concrete. Reinforcement of concrete by steel fibers is isotropic in nature that improves the resistance to fracture, disintegration, and fatigue. Steel fiber reinforced concrete is able to withstand light and heavy loads.
The Hook end steel fiber has aspect ratio of 60. The typical steel fiber tensile strength ranges between 1100 and 1700 MPA.
To increase the performance of steel fiber in concrete, the important aspects consider are

- Fiber Aspect ratio
- Volume concentration of fiber
- Geometrical shape of fiber

Fig 1

Table 1: Steel fiber properties

Properties	Dimension
Length	30mm
Diameter	0.5mm
Appearance	Clear, Bright, and Hooked
Aspect ratio L/D	60
Carbon content C (%)	0.002
Manganese content Mn (%)	1.40
Silicon content Si (%)	0.370
Nickel content Ni (%)	8.040
Chromium Cr (%)	18.180
Phosphate p(%)	0.039

3.5 Water
Water is one of the important constituents, which combines with cement, aggregates and admixture and facilities the hydration. Potable water is used for the blending and curing of the concrete and the pH value of water was below 6. The water used was free from any acid, oils and salts or sugar materials. The quantity of water used affects the strength of concrete mix. Depending on the workability of concrete the water content was adjusted.

3.6 Mix Design
Mix design was carried out as per IS: 10262-2009 guidelines. The typical nominal concrete mix design calculation is shown in 4.3.1. GGBS is added to the cement with the percentage of 30% as a partial replacement. It is carried out to determine the exact economical proportional of concrete ingredients. The sequential steps followed in mix design are explained below.

Mix Proportional

Cement = 276.5 kg/m^3
Water = 197 liter
Fine aggregate = 704.63 kg/m3
Coarse aggregate = 1033.47 kg/m3
W/C ration = 0.55

Table 2: Mix proportion calculation for current investigation

Cement	Fine aggregate	Coarse aggregate
1	1.78	2.62

Table 3

Designation of Mixture	Grade Of concrete	Cement In Kg/m^3	Fine Aggregate In Kg/m^3	Coarse Aggregate in Kg/m^3	Water in %	Fiber Dosage 3 in Kg/m
M20(0%fiber)	M20	276.5	704.63	1033.47	0.55	0
M20(0.5%fiber)	M20	276.5	704.63	1033.47	0.55	39.5
M20(1.0%fiber)	M20	276.5	704.63	1033.47	0.55	78.5
M20(1.5%fiber)	M20	276.5	704.63	1033.47	0.55	117.75

4. Tests on Concrete

4.1 Compressive strength Test (IS: 516-1959)

The cube samples are used to find out the compression strength, the size of the cube specimen is 150x50x150mm.Cube samples are placed in the compression machine and load is applied until the concrete specimen cracks and failure load is recorded. The specimens were casted, crushed and tested as per IS 516-1959. Results is shown in graph (Fig.2).

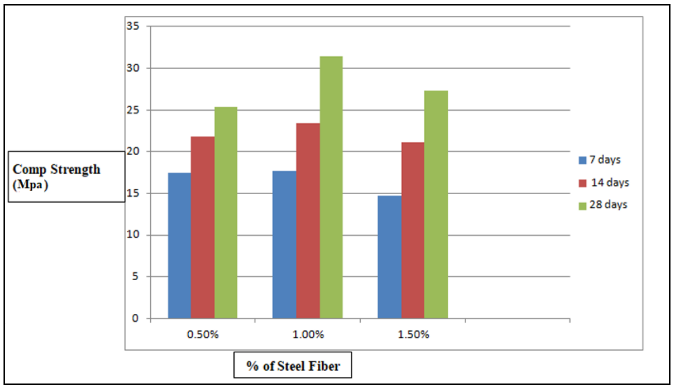

Fig 2: Compressive Strength of Concrete

4.2 Flexure Test (IS: 516-1959)

Flexure tests are performed to find out the flexural modulus or flexural strength of a material. A flexural test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact and then a force is applied to the top of the material through either one or two points of contact until the sample fails. The maximum recorded force is the flexural strength of that particular sample. The size of the beam is 150x150x700mm. The flexural test was conducted as per the IS 516-1959 specification. Results is shown in graph (Fig.3).

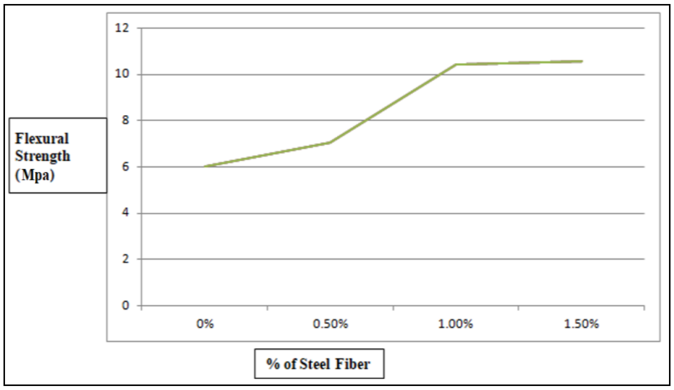

Fig 3

4.3 Stress – Strain behavior Test

The relationship between the stress and strain that a particular material displays is known as that particular material's stress-strain curve. It is unique for each material and is found by recoding the amount of deformation (strain) at distinct intervals of tensile or compressive loading (stress). These curves reveal many of the properties of a material (including data to establish the Modulus of Elasticity).

Stress- strain curves of various materials vary widely, and different tensile tests conducted on the same material yield different results, depending upon the temperature of the specimen and the speed of the loading.

Stress equation = $\sigma = F/A$

Strain equation = $\epsilon = e/l$

4.4 Elastic behavior

The elastic characteristics of a material are a measure of its stiffness. In spite of the nonlinear behavior of concrete, an estimate of the elastic modulus (the ratio between the applied stress and instantaneous strain within an assumed proportional limit) is necessary for determining the stress induced by strains associated with effect. It also needed computing the design stress under load in simple elements, and moments and deflection in complicated structures.

Nonlinearity of the stress-strain Relationship

From typical σ-ϵ curves for aggregates, hydrated cement paste, and concrete loaded in uniaxial compression. It becomes immediately apparent that relative to aggregate and cement paste. Concrete is really not an elastic material. Neither the strain on instantaneous loading of a recovered upon unloading.

Behavior of fiber reinforced concrete under compression Steel Fibers

The increase in strength provided by steel fibers very rarely exceeds 25-28%.With the increase the use of deformed fibers. The fiber quantity is generally limited to 55-65 kg/m^3 or less than 1.0%. At this volume fraction. The increase in strength can be consider negligible for all design purposes.

The composition of the matrix contributes to strength and energy absorption in two ways. The first is its bonding characteristics with the fibers. Second is the brittleness of the matrix which. It plays an important role in behavior of FRC. Normal strength concrete. And the incorporation of fibers makes the composite more ductile. Brittleness more pronounced for concrete containing flyash and silica fume. Hence, a higher fiber volume fraction is required for high strength concrete to produced ductile failure.

Table 4: Elastic moduli Values

S. No	% of Fiber	Secant Modulus (SO) Psi
1	0.5%	$48x10^6$
2	1.00%	$7.32x10^6$
3	1.50%	$6.35x10^6$

5. Stress-strain behaviour for steel fiber concrete
5.1 Stress-Strain behavior for 0.5 % Steel Fiber

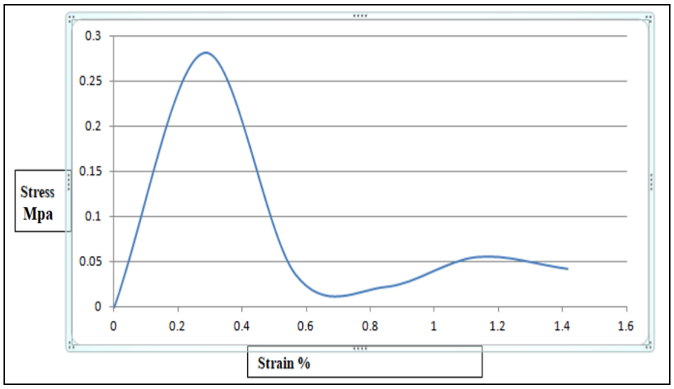

Fig 4

5.2 Elastic modulus of Stress-Strain behavior for 0.5 % Steel Fiber

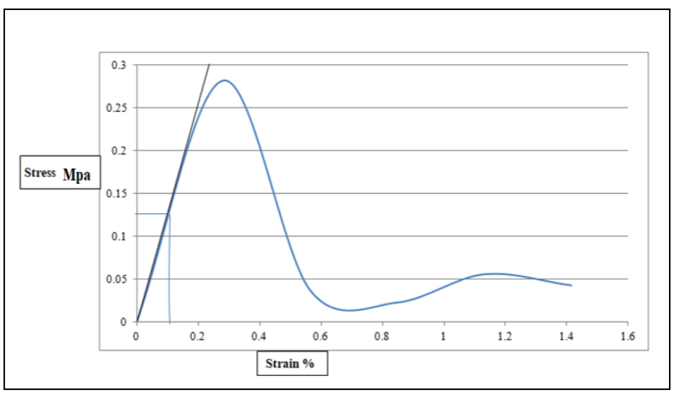

Fig 5

5.3 Stress-Strain behavior for 1.00% Steel Fiber

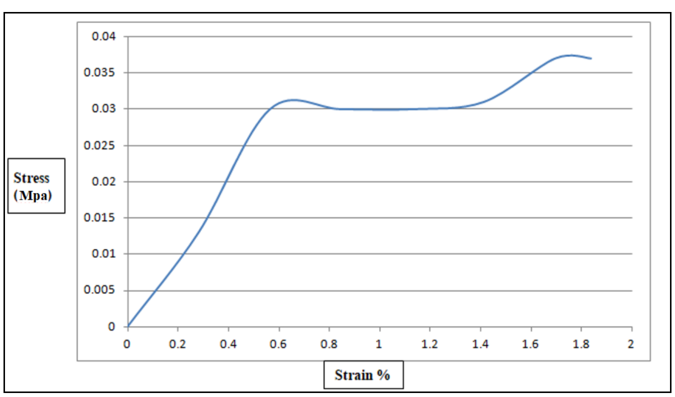

Fig 6

5.4 Elastic modulus of Stress-Strain behavior for 1.00% Steel Fiber

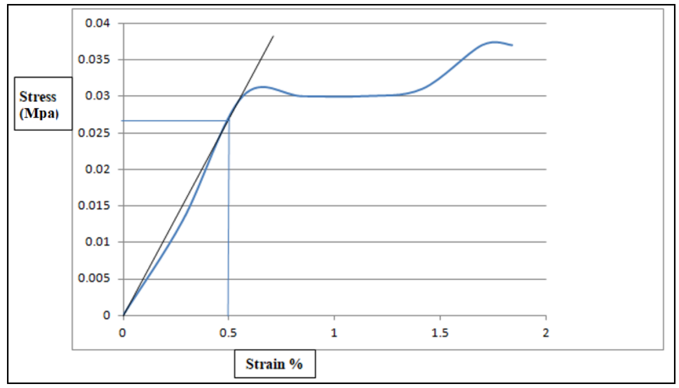

Fig 7

5.5 Stress-Strain behavior for 1.5% of Steel Fiber

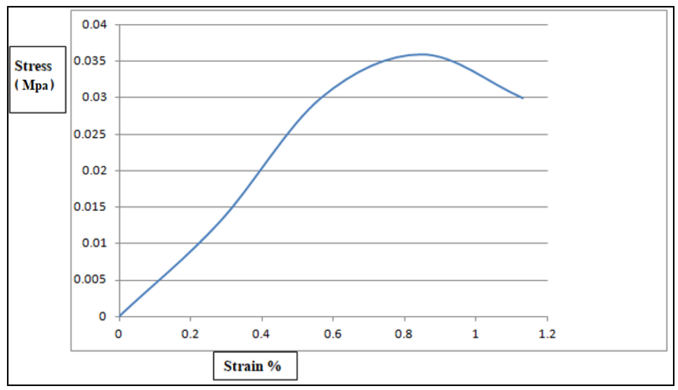

Fig 8

5.6 Elastic modulus of Stress-Strain behavior for 1.5% of Steel Fiber

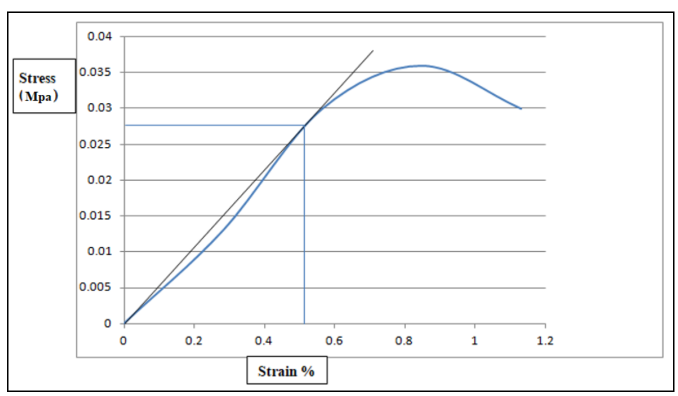

Fig 9

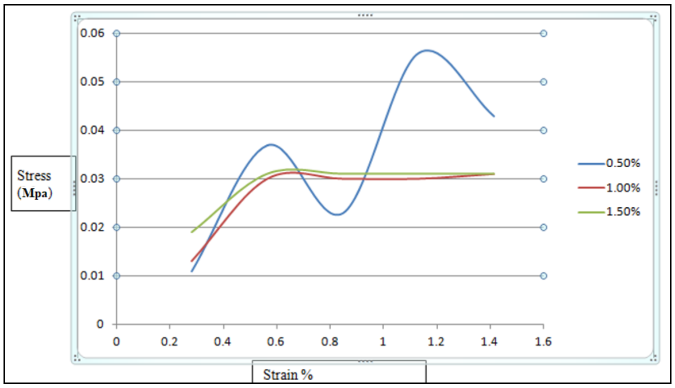

Fig 10

6. Conclusions

- Addition of steel fibers to concrete increases the Compressive strength of concrete
- The addition of steel fibers in concrete, the split tensile strength has increased
- Addition of steel fiber reduces bleeding and it improves the surface integrity of concrete. And also it increases the homogeneity and reduces the probability of cracks
- Finally we conclude that adding 1% of Steel fiber gives the Maximum tensile strength value.
- The addition of fibers to concrete significantly increases its toughness and makes the concrete more ductile
- The randomly-oriented steel fibers assist in controlling the propagation of micro cracks present in the matrix
- Workability of concrete is improves when GGBS as percentage increases
- Slump will lose at the higher percentage of steel fiber and lesser GGBS content
- The specimen allows to estimate the complete stress-strain curve for concrete reinforced with up to 1.5% of steel fiber with hook end since these concrete have compressive strength 20 MPA.

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