“EFFECT OF MICRO STEEL FIBRE ON PROPERTIES OF CONCRETE”

A Thesis

Submitted in partial fulfillment of the requirements for the award of the degree of

MASTER OF TECHNOLOGY

IN

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With specialization in

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Under the supervision of

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CERTIFICATE

This is to certify that the work which is being presented in the project title **"EFFECT OF MICRO STEEL FIBRE ON PROPERTIES OF CONCRETE"** in partial fulfillment of the requirements for the award of the degree of Master of technology in civil engineering with specialization in "**structural engineering**" and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by TANJEET SINGH during a period from July 2015 to June 2016 under the supervision of **Mr. Abhilash Shukla** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

Cement concrete is the most extensively used construction material in the world. The reason for its extensive use is that it provides good workability and can be moulded to any shape. Ordinary cement concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks, leading to brittle failure of concrete. In this modern age, civil engineering constructions have their own structural and durability requirements, every structure has its own intended purpose and hence to meet this purpose, modification in traditional cement concrete has become mandatory. It has been found that different type of fibers added in specific percentage to concrete improves the mechanical properties, durability and serviceability of the structure. It is now established that one of the important properties of Steel Fiber Reinforced Concrete (SFRC) is its superior resistance to cracking and crack propagation. In this thesis effect of fibers on the strength of concrete for M30 and M40 grade have been studied by varying the percentage of fibers in concrete. Fiber content were varied by 0%, 0.50%, 1%, 1.5% and 2%. Cubes of size 150mmX150mmX150mm to check the compressive strength and beams of size 500mmX100mmX100mm for checking flexural strength and cylinder of size 150mmX200mm for checking the split tensile strength were casted. All the specimens were cured for the period of 7 and 28 days before crushing. The results of fiber reinforced concrete for 7days and 28days curing with varied percentage of fiber were studied and it has been found that there is significant strength improvement in steel fiber reinforced concrete. Also, it has been observed that with the increase in fiber content value increases the strength of concrete. Slump cone test was adopted to measure the workability of concrete. The Slump cone test results revealed that workability gets reduced with the increase in fiber content.

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LIST OF ABBREVATIONS

SFRC	STEEL FIBRE REINFORCED CONCRETE
OPC	ORDINARY POZOLONA CEMENT
F.A	FINE AGGREATE
C.A	COARSE AGGREGATE
UTM	UNIVERSAL TESTING MACHINE
P	LOAD APPLIED
L	LENGTH
FCK	CHARACTERISTIC COMPERSSIVE STRENGTH
Ft	TARGET MEAN STRENGTH
S	STANDARD DEVIATION
MPA	MEGA PASCAL
W/C	WATER CEMENT RATIO
AVG	AVERAGE
d	CROSS SECTION DIMENSION OF SPECIMEN
Fct	TENSILE STRENGTH
Fb	FLEXURE STRENGTH

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Concrete is a composite material containing hydraulic cement, water, coarse aggregate and fine aggregate. The resulting material is a stone like structure which is formed by the chemical reaction of the cement and water. This stone like material is a brittle material which is strong in compression but very weak in tension. 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. The formation of cracks is the main reason for the failure of the concrete. To increase the tensile strength of concrete many attempts have been made. One of the successful and most commonly used method is providing steel reinforcement. Steel bars, however, reinforce concrete against local tension only. Cracks in reinforced concrete members extend freely until encountering are bar. Thus need for multidirectional and closely spaced steel reinforcement arises. That cannot be practically possible. Fibre reinforcement gives the solution for this problem So to increase the tensile strength of concrete a technique of introduction of fibres in concrete is being used. These fibres act as crack arrestors and prevent the propagation of the cracks. These fibres are uniformly distributed and randomly arranged. This concrete is named as fibre reinforced concrete. The main reasons for adding fibres to concrete matrix is to improve the postcracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material. The initial researches combined with the large volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of Fibre Reinforced Concrete.

1.2 FIBRE REINFORCED CONCRETE

Fiber reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity.So we can define fibre reinforced concrete as a composite material of cement concrete or mortar and discontinuous discrete and uniformly dispersed fibre. Fibre is discrete material having some characteristic properties. The fibre material can be anything. But not all will be effective and economical. Some fibres that are most commonly used are:

- Steel
- Glass
- Carbon
- Natural
- NBD

Steel fibre is one of the most commonly used fibre. Generally round fibres are used. The diameter may vary from 0.25 to 0.75mm.The steel fibre sometimes gets rusted and lose its strength. But investigations have proved that fibres get rusted only at surfaces. It has high modulus of elasticity. Use of steel fibres makes significant improvements in flexure, impact and fatigue strength of concrete. It has been used in various types of structures. Glass fibre is a recently introduced fibre in making fibre concrete. It has very high tensile strength of 1020 to 4080Mpa. Glass fibre concretes are mainly used in exterior building façade panels and as architectural precast concrete. This material is very good in making shapes on the front of any building and it is less dense than steel. Use of carbon fibre is not a developed process. But it has considerable strength and young's modulus. Also investigations have shown that use of carbon makes the concrete very durable. The study on the carbon fibres is limited. Mainly used for cladding purpose. Natural fibres are low cost and abundant. They are nonhazardous and renewable. Some of the natural fibres are bamboo, jute, coconut husk, elephant grass. They can be used in place of asbestos. It increases toughness and flexural strength. It also induces good durability in concrete. Disposal of non-biodegradable materials is a serious problem. It creates environmental problems. Reusing is the best option to reduce the waste. These NBD materials are non-corrosive, resistant to chemical attack, light in weight, easy to handle. NBD materials – fibre plastic, jute plastic, polythene, disposal glass, cement bags. Studies conducted so far, proved that the short and discrete, small fibres can improve the flexural load carrying capacities and impact resistance for non-ferrous fibres.

1.3 HISTORY

The use of fibres to increase the structural properties of construction material is not a new process. From ancient times fibres were being used in construction. In BC, horse hair was used to reinforce mortar. Egyptians used straw in mud bricks to provide additional strength. Asbestos was used in the concrete in the early 19th century, to protect it from formation of cracks. But in the late 19th century, due to increased structural importance, introduction of steel reinforcement in concrete was made, by which the concept of fibre reinforced concrete was over looked for 5-6 decades. Later in 1939 the introduction steel replacing asbestos was made for the first time. But at that period it was not successful. From 1960, there was a tremendous development in the FRC, mainly by the introduction of steel fibres. Since then use of different types of fibres in concrete was made. In 1970's principles were developed on the working of the fibre reinforced concrete. Later in 1980's certified process was developed for the use of FRC. In the last decades, codes regarding the FRC are being developed.

1.4 PROPERTIES OF FIBRE REINFORCED CONCRETE

Properties of concrete is affected by many factors like properties of cement, fine aggregate, coarse aggregate. Other than this, the fibre reinforced concrete is affected by following factors:

- Type of fibre
- Aspect ratio
- Quantity of fibre
- Orientation of fibre

TYPE OF FIBRE

A good fibre is the one which possess the following qualities:

- Good adhesion within the matrix.
- Adaptable elasticity modulus (sometimes higher than that of the matrix)
- Compatibility with the binder, which should not be attacked or destroyed in the long term.
- An accessible price, taking into account the proportion within the mix.
- Being sufficiently short, fine and flexible to permit mixing, transporting and placing.
- Being sufficiently strong, yet adequately robust to withstand the mixing process.

ASPECT RATIO

Aspect ratio is defined as the ratio of length to width of the fibre. The value of aspect ratio varies from 20 to 150. Generally the increase in aspect ratio increases the strength and toughness till the aspect ratio of 100. Above that the strength of concrete decreases, in view of decreased workability and reduced compaction.the length of fibre used here is 6mm and diameter of fibre is 0.22mm, aspect ratio is 28.

FIBRE QUANTITY

Generally quantity of fibres is measured as percentage of cement content. As the volume of fibres increase, there should be increase in strength and toughness of concrete. Regarding our fibre, we hope that there will be an increase in strength, with increase in fibre content. We are going to test for percentages of 0, 0.5, 1, 1.5 and 2.

ORIENTATION OF FIBRE

The orientations of fibres play a key role in determining the capacity of concrete. In RCC the reinforcements are placed in desired direction. But in FRC, the fibres will be oriented in random direction. The FRC will have maximum resistance when fibres are oriented parallel to the load applied.

1.5 FIBRE MECHANISM

Fibre work with concrete utilizing two mechanisms: the spacing mechanism and the crack bridging mechanism. The spacing mechanism requires a large number of fibres well distributed within the concrete matrix to arrest any existing micro crack that could potentially expand create a sound crack. For typical volume of fractions of fibres utilizing small diameter of fibres or micro fibres can ensure the required no of fibres for micro crack arrest. The second mechanism termed crack bridging requires larger straight fibres with adequate bond to concrete. Steel fibres are considered a prime example of this fibre type that is commonly referred as large diameter fibres or micro fibres.

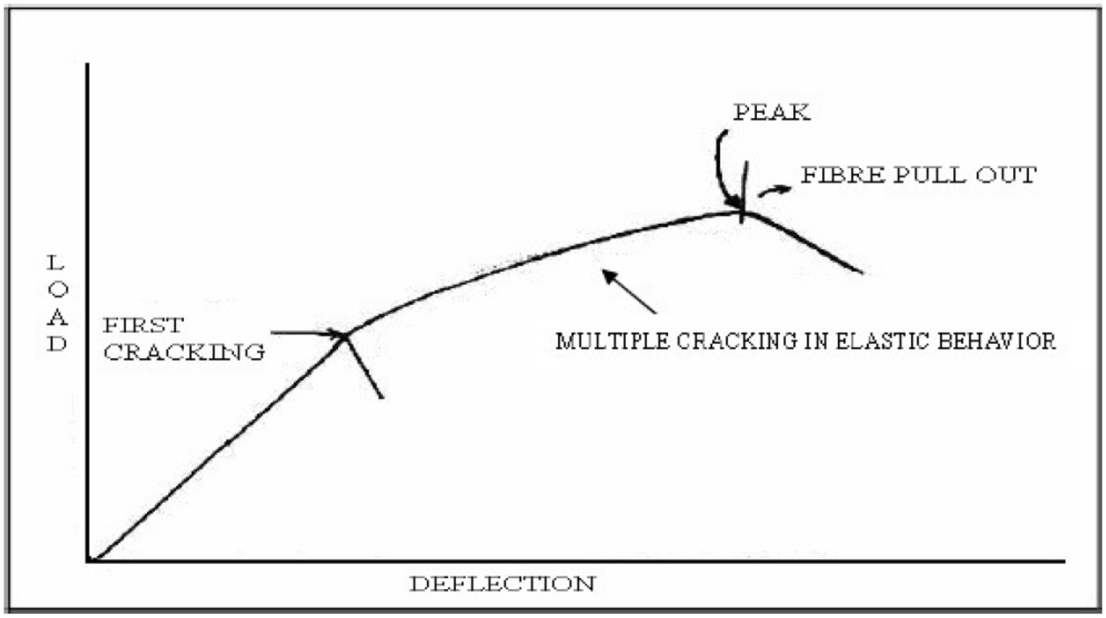

Fig no. 1.1 Fibre Mechanism

FIBRE - MATRIX INTERACTION

The tensile cracking strain of cement matrix is much lower than the yield or ultimate strain of fibres. As a result when a fibre reinforced composite is loaded the matrix will crack long before the fibres can be fractured. Once the matrix is cracked composite continues to carry increasing tensile stress. The peak stress and strain of the concrete composite are greater than those of the matrix alone during the inelastic range between first cracking and the peak.

BRIDGING ACTION

Pullout resistance of fibres (dowel action) is important for efficiency. Pullout strength of fibres significantly improves the post-cracking tensile strength of concrete. As an FRC beam or other structural element is loaded, fibres bridge the cracks. Such bridging action provides the FRC specimen with greater ultimate tensile strength and, more importantly, larger toughness and better energy absorption. An important benefit of this fibre behaviour is material damage tolerance. Bayasi and Kaiser (2001) performed a study where damage tolerance factor is defined as the ratio of flexural resistance at 2-mm maximum crack width to ultimate flexural capacity. At 2% steel fibre volume, damage tolerance factor according to Bayasi and Kaiser was determined as 93%.

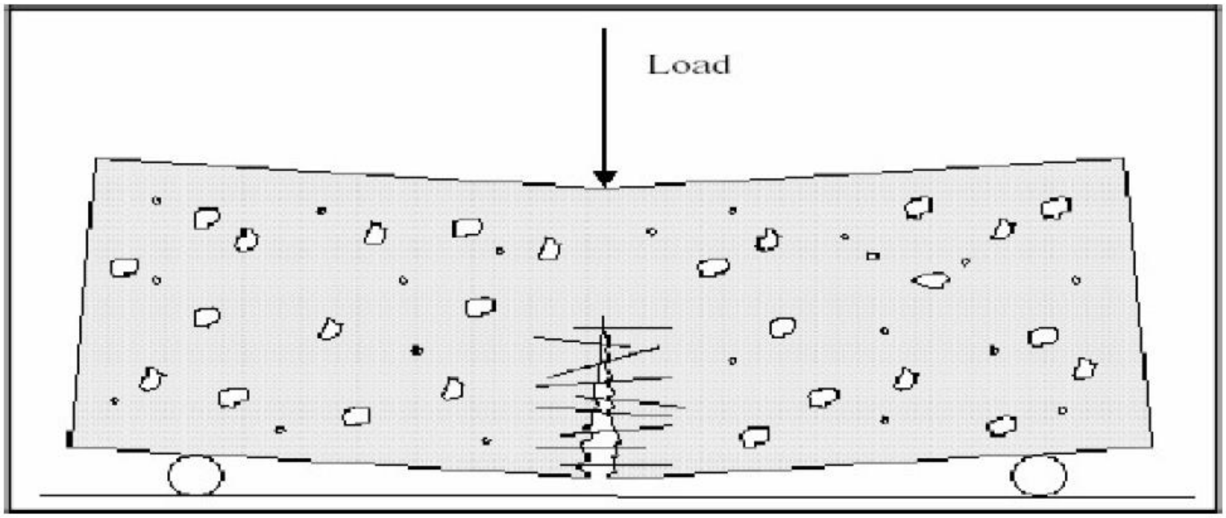

Fig no. 1.2 Pullout Mechanism.

1.6 WORKABILITY

A shortcoming of using fibres in concrete is reduction in workability. Workability of FRC is affected by fibre aspect ratio and volume fraction as well the workability of plain concrete. As fibre content increases, workability decreases. Most researchers limit volume of fibres to 4.0% and aspect ratio to 100 to avoid unworkable mixes. In addition, some researchers have limited the fibre reinforcement index [volume of fibres as % ×aspect ratio] to 1.5 for the same reason. To overcome the workability problems associated with FRC, modification of concrete mix design is recommended. Such modifications can include the use of additives.

1.7 STEEL FIBRE REINFORCED CONCRETE

According to Exodus Egyptians used straw to reinforce mud bricks. There is evidence that asbestos fibre was used to reinforce clay posts about 5000 years ago. Prof. Alberto Fava of the University of La Plata in Argentina points out that the hornero is a tiny bird native to Argentina, Chile, Bolivia and other South American countries; the bird had been painstakingly building straw reinforced clay nests on tree tops since the advent of man. However, N.V. Bekaert is been regarded as the father of “Fibre Reinforced Concrete”.

1.7.1 COMPOSITION OF STEEL FIBRE REINFORCED CONCRETE

The components of Steel Fibre Reinforced Concrete (SFRC) can be explained with the help of the Figure given below.

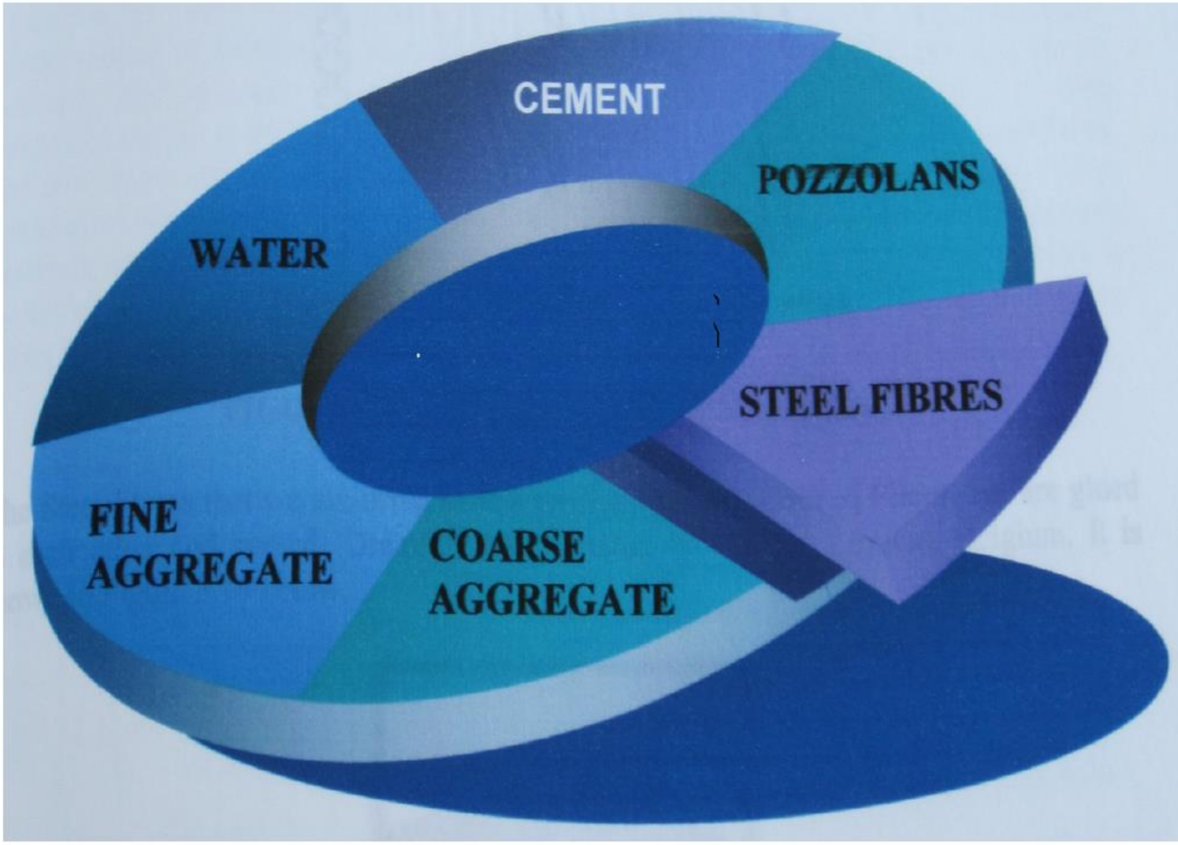

Fig no. 1.3 Components of Steel Fibre Reinforced Concrete

Concrete containing hydraulic cement, water, fine aggregate, coarse aggregate and discontinuous discrete Steel fibres is called Steel Fibre Reinforced Concrete. It may also contain pozzolans and other admixtures commonly used with conventional concrete. Fibres of various shapes and sizes produced from steel, plastic, glass and natural materials are being used. However, for most structural and non-structural purposes, steel fibre is commonly used of all the fibres.

1.7.2 STEEL FIBRES

Fibre

The brass coated micro steel fibre used in the experiment is obtained from Fibre Zone Ahemdabad Gujrat**.** Micro brass coated steel fiber is a new type of additive for reinforcing concrete, which has the high tensile strength, and improve the concrete's unity obviously. Material:low carbon cold drawn steel wire Tensile strength:>2850Mpa Length:6 Diameter:0.2+/-0.02mm Aspect ratio:35-100.).

Micro steel fibers has the advantages comparing with steel bars in the fields below,

- Ultra high performance concrete
- Reactive powder concrete
- Reinforcing mortar

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to the concrete would act as crack arrester and would substantially improve its Compressive and flexural strength properties. This type of concrete is known as fiber reinforced concrete.The straight steel fibers are used. The length of the steel fibers is 6mm and diameter is 0.22mm.

Fig no. 1.4 Brass coated micro steel fibre

1.8 BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE UNDER CONVENTIONAL LOADINGS

1.8.1 BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE

UNDER DIRECT COMPRESSION

Maximum stress a material can sustain under crush loading is known as Compressive strength. The compressive strength of a material that fails by shattering fracture can be defined within fairly narrow limits as an independent property. However, the compressive strength of materials that do not shatter in compression must be defined as the amount of stress required to distort the material an arbitrary amount. Compressive strength is calculated by dividing the maximum load by the original cross-sectional area of a specimen compression test.

1.8.1.1 FOR PLAIN CONCRETE

The stress strain curve of concrete under uniaxial compression shows a linear behaviour up to about 30% of the ultimate strength (fu) because under short term loading the micro cracks in the transition zone remain undisturbed. For stresses above this point, the curve shows a gradual increase in curvature up to about 0.75 fu to 0.9 fu, then it bends sharply almost becoming flat at the top and finally descends until the specimen is fractured. Relation between concrete performance and extent of cracking from the shape of the stress strain curve it seems that, for a stress between 30 to 50% of fu the microcracks in the transition zone show some extension due to stress concentration to the tips however, no cracking occurs in the mortar matrix. Until this point crack propagation is assumed to be stable in the sense that crack lengths rapidly reach their final values it the applied stress is held constant. For a stress between 50 to 75% of fu increasingly the crack system tends to be unstable as the transition zone crack begins When the available internal energy exceeds the required crack release energy, the rate of crack propagation will increase and the system becomes above 75% of fu when complete fracture of the test specimen can occur by bridging of mortar and transition zone cracks.

Based on the described cracking stages, the behaviour of concrete can be viewed at two levels: First, randomly distributed microcracks are formed or enlarged under low level of stresses. When tile stress level reaches a specific value, these microcracks begin to localize (strain localization) and to coalesce into a macrocrack. This macrocrack will agate until the stress reaches its critical stage . Steady state propagation of this macrocrack will result in the strain softening mechanism observed for concrete. This general view of cracking of concrete makes it clear that the first linear elastic portion of loading up to strain localization cannot be described by fracture mechanics but can be quantified using damage mechanics [Krajcinovic 1984].

1.8.1.2 FOR STEEL FIBRE REINFORCED CONCRETE

Compressive strength is little influenced by steel fibre addition. High compressive this can be achieved using silica fume or fly ash. However, the use of steel fibres the mode of failure of high strength concrete from an explosive brittle one to a more ductile one, again showing the increased toughness of SFRC and its ability to absorb energy under dynamic loading. Compressive Strength of SFRC, the fibre type, volume fraction and aspect ratio play important roles in determining the compressive ductility and energy absorption capacity of fibre reinforced concrete. The material behaviour is generally enhanced as the volume fraction and aspect ratio of fibres increase up to limits after which the problems with fresh mix workability and fibre dispersability start to damage the hardened material properties. As the increases in both fibre volume fraction Vr and aspect ratio 1/d lead to improvement of the same nature in the compressive behaviour of the material, their combined effect has been generally analyzed using the Fibre Reinforcing Index Vr1/d. in general. The higher the fibre reinforcing index, the higher is ductility and energy absorption capacity of fibre reinforced concrete. However, for high values of fibre reinforcing index, the problems with workability and fibre dispersability of fresh mix tend to deteriorate the compressive behaviour of the hardened material. Due to their material properties, steel fibres do not at all influence the strength parameters of concrete. Under compressive loading, when microcracking occurs because of transverse tension forces, steel fibres cause crack-closing forces, on the one hand. This leads to an increase of compressive strength. On the other hand, porosity increases when steel fibres are mixed in with the fresh concrete. This effect decreases the compressive Strength of steel fibre reinforced concrete. Both effects in combination have the tendency to cancel each other out. The influence of fibres in improving the compressive strength of the matrix depends on whether mortar or concrete (having coarse aggregates) is used and on the magnitude of compressive strength. Otter and Naaman [1988] showed that use of steel fibres in lower strength concretes increases their compressive strength significantly compared to plain unreinforced matrices and is directly related to volume fraction of steel fibre used.

Ezeldin and Balaguru [1992] conducted tests to obtain the complete stress-strain of steel fibre-reinforced concrete with compressive strengths ranging from 35 MPa to 84 Mpa. The matrix consisted of concrete and three volume fibres fractions of 30 kg/m3, 45 kg/m3 and 60 kg/m3. It was reported that the addition of Straightsteel fibres to concrete increased marginally the compressive strength and the strain corresponding to peak stress.

1.8.2 BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE UNDER FLEXURE

In numerous investigations, it has been displayed that the flexure, shear, torsion, punching, dynamic impact behaviours of structural elements improved by the use of Steel Fibre Reinforced Concrete. The positive effects of SFRC on the flexure behaviour of the structural elements are given as follows by Craig (1984).

- Increases moment capacity and cracking moment,
- Increase the ductility,
- Increases crack control,

- Increases rigidity,
- Preserves the structural integrity after beam exceeds the ultimate load.

1.8.2.1 FACTORS AFFECTING THE FLEXURE BEHAVIOUR OF STEEL FIBRE REINFORCED COCNCRETE.

(a) INFLUENCE OF STEEL FIBRE VOLUME FRACTION

The influence of fibre volume fraction is shown in Figure. For 90 and 120 kg/m3 fibre content, the post-crack increase in load is significant. This increaseessentially provides the improvement in flexural strength and a stable post-crack behaviour. As shown, the bending capacity increases as the fibre volume fraction increases.

Influence of fibre content on the Load Deflection Curves and Influence of fibre length on the Load Deflection Curves.

(b) INFLUENCE OD FIBRE LENGTH

The influence of fibre length is very significant for straight fibres. However, it is an established fact that, longer fibres with higher aspect ratios provide better performance in both strength increase and energy absorption as long as they can be mixed, placed, compacted and finished properly.Sinc straight fibres provide good anchorage, an increase in aspect ratio of Straight fibres has less influence compared with straight steel fibres. However, the difference between fibre lengths becomes even less significant at higher volume fractions.

(c) INFLUENCE OF FIBRE GEOMETRY

Three different fibre geometry, namely Straight fibres, corrugated fibres and deformed-end fibres with equal length are studied on the flexural behaviour of Steel Fibre Reinforced Concrete by Gopalaratnam et al. (1991). According to test results, concrete with Straight fibres have higher tensile strength and post-crack response than the other two types. The drop after the first peak is much more pronounced for corrugated and deformed-end fibres. Comparison of effects of steel fibre shapes on load-deflection curves. There are a number of factors that influence the behaviour and strength of SFRC in flexure. They are fibre orientation and fibre shape, fibre bond characteristics (fibre deformation). Also, factors that influence the workability of SFRC such as water cement ratio, density, air content and the like could also influence its strength. The ultimate strength in flexure could vary considerably depending upon the volume fraction of fibres, length and bond characteristics of the fibres and the ultimate strength of the fibres. Depending upon the contribution of these influencing factors, the ultimate strength of SFRC could be either smaller or larger than its first cracking strength.

1.8.2.2 FLEXURAL BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE

Generally, there are three stages of the load-deflection response of SFRC specimens tested in flexure. The three stages are:

1. A more or less linear response up to point A. The strengthening mechanism in this portion of the behaviour involves a transfer of stress from the matrix to the fibres by interfacial shear. The imposed stress is shared between the matrix and fibres until the matrix cracks at what is termed as "first cracking strength" or "proportional limit".

2. A transition nonlinear portion between point A and the maximum load capacity at point B (assuming the load at B is larger than the load at A). In this portion, and after cracking, the stress in the matrix is progressively transferred to the fibres. With increasing load, the fibres tend to gradually pull out from the matrix leading to a nonlinear load-deflection response until the ultimate flexural load capacity at point B is reached. This point is termed as "peak" strength.

3. A post peak descending portion following the peak strength until complete failure of the composite. The load-deflection response in this portion of behaviour and the degree at which loss in strength is encountered with increasing deformation is an important indication of the ability of the fibre composite to absorb large amounts of energy before failure and is a characteristic that distinguishes fibre-reinforced concrete from plain concrete. This characteristic is referred to as toughness. Load Deflection Curve of Steel Fibre Reinforced Concrete Specimens the nonlinear portion between A and B exists, only if a sufficient volume fraction of fibres is present. For low volume fraction of fibres (Vf < 0.5%), the ultimate flexural strength coincides with the first cracking strength and the load deflection curve descends immediately after the cracking load,
Typical Load Deflection Curves of SFRC Beams with low volume fraction of fibres two concepts are proposed in the literature for explaining the factors that affect the magnitude of the "first cracking strength or proportional limit". One concept relates the "first cracking strength" to the spacing of the fibres in the composite [Romualdi and Batson 1963; Romualdi and Mandel 1964]. The other concept is based on the mechanics of the composite materials and relates the "proportional limit" to the volume fraction of the fibre, aspect ratio and fibre orientation.
In the Fibre spacing concept, it is stipulated that the volume fraction of fibres and fibre aspect ratio must be such that there is a fibre overlap; however, except for this, the fibre aspect ratio L/df which has a significant effect on the flexural strength of SFRC is not a parameter in the fibre spacing approach. Experimental results by some investigators [Edington et al. (1974); Swamy and Mangat (1974)] tend to show that the fibre spacing concept does not accurately predict the first cracking strength of fibre-reinforced concrete. The law of composite materials is believed to be simple and is proven experimentally [shah and Rangan 1971] to be more accurate for the prediction of first cracking strength comparison with the fibre spacing concept. The composite materials approach is based on the assumptions in that the fibres are aligned in the direction of the load, the fibres are bonded to the matrix, and the Poisson's ratio of the matrix is zero. In the law of composite materials the effect of fibres on the cracking behaviour of SFRC composites can be viewed similarly to conventional reinforcing steel in concrete members. However, because the fibres are randomly distributed, an efficiency factor is commonly multiplied by the volume fraction of fibres to account for their random distribution.

1.9 OBJECTIVE

The aim of our project is to use brass coated micro steel fibre in concrete for improving its propreties

- To compare the properties of SFRC with normal concrete.
- Our objective is to add the Steel fibres (straight) to the concrete and to study the strength properties of concrete with the variation in fibre content.
- To study the strength properties of concrete (M30 and M40 Grade) for fibre content of 0.5, 1, 1.5 and 2.0 at 7 and 28 days.
- The strength properties being studied in our thesis are as follows:

1. Compressive strength
2. Split tensile Strength
3. Flexural strength
4. Compaction factor test
5. Slump test

CHAPTER-2

REVIEW OF LITERATURE

2.1 Tensile behavior of high performance hybrid fiber reinforced concrete

Author: P.R.Kannnan Rajkumar and P.R.Kannan Rajkumar[1]

Summary: The actions of fibers at various volumes of fractions in high strength concrete have achieved a good tensile strength. Based on the experimental investigation carried out the following conclusions are drawn. It is possible to produce fiber concrete composites using steel fibers (micro steel), with an enhanced tensile performance compared to concrete without fibers. Fiber inclusion of all types increased compressive strength, although this increase was not that significant and could have been obtained with simpler and more economical methods like reducing water-cement ratio. Micro steel fiber proved to be efficient in strengthening the matrix.

2.2 Performance of steel fibre reinforced concrete

Author: Milind V. Mohod[2]

Summary: Following conclusions were drawn from the work carried out;
1) It is observed that the workability of steel fibre reinforced concrete gets reduced as the percentage of steel fibres increases.
2) Compressive strength goes on increasing by increase in steel fibre percentage up to the optimum value. The optimum value of fibre content of steel fibre reinforced concrete was found to be 1%.
3) The flexural strength of concrete goes on increasing with the increase in fibre content up to the optimum value. The optimum value for flexural strength of steel fibre reinforced cement concrete was found to be 0.75%
4) While testing the specimens, the plain cement concrete specimens have shown a typical crack propagation pattern which leaded into splitting of beam in two piece geometry. But due to addition of steel fibres in concrete cracks gets ceased which results into the ductile behaviour of SFRC.

2.3 Effect of addition of steel fibers on strength and durability of high performance concrete

Author: B. Siva Konda Reddy[3]

Summary: The HPC studied in this research program has displayed an impressive set of material properties and the conclusions are drawn as follows:
1 Addition of steel fibers to plain concrete increased the compressive strength and tensile strength of concrete by 8% & 9% respectively.

2. Addition of steel fibers to HPC increased the resistance to chloride ion penetration.

2.4 Comparative study on Steel fibre reinforced Cum control concrete under flexural and deflection

Author: Shende.A.M.1, Pande.A.M.[4]

Summary: The following conclusions could be drawn from the present investigation.
1. It is observed that flexural strength from steel fibres are on higher side from 3% fibres as compared to that produced from 0%, 1% and 2% fibres.
2. It is observed that flexural strength increases from 13 to 48.35% through utilization of steel fibres. And through utilization of 1% steel fibres flexural strength increases from 13.35 to 23.35%.Through utilization of 2% steel fibres flexural strength increases from 18.35 to 31.65%.Through utilization of 3% steel fibres flexural strength increases from 20.80 to 48.35%.
3. The addition of fibers has significantly enhanced the performance of beam in flexural. During the test it was visually observed that the SFRC specimen has greater crack control as demonstrated by reduction in crack widths and crack spacing.
4. It is observed during testing that when specimen is tested for split tensile strength and flexural strength the control concrete specimen has broken into two pieces while the SFRC specimen retained the geometric integrity .It reveals improved ductility of SFRC due to the addition of steel fibers over control concrete.
5. It is observed that for higher percentage of steel fibre deflection of beam is very less as compare to control beam.

2.5 An experimental investigation on structural performance of steel fibre reinforced concrete beam

Author: Jyoti Narwal, Ajay Goel, Devender Sharma, D.R. Kapoor, Bhupinder Singh[5]

Summary: The following conclusions can be drawn:
I. The addition of steel fibres in the concrete mix resulted in improved structural performance measure in terms of ultimate load carrying capacity, crack widths, deflection and curvature ductility factor of beam specimens of all the series.
II. The optimum fibre volume percentage for all the series was obtained as 1.5%. The further increase in fibre content reduced the load carrying capacity of the specimens due to poor compaction of concrete because of balling of fibres.
III With addition of steel fibres in concrete mix of the specimens the appearance of first crack was delayed. The presence of steel fibres also improved the post cracking behavior of the specimens of all the series due to crack arresting phenomenon.

2.6 Study of Flexural Strength in Steel Fibre Reinforced Concrete

Author: Patil Shweta, Rupali Kavilkar[6]

Summary:
1. The addition of binding wire or a steel fibre into the concrete significantly increases the flexural strength.

2. At constant percentage of fibre=1.5%& by increasing aspect ratio of fibre from 40 tp 70, it is observed that the flexural strength is increased from 36.7% to 58.65% as compared to plain concrete strength.
3. At constant aspect ratio 70 and by increasing percentage volume of fibres from 0.5% to 2.5%, it is observed that the flexural strength is significantly increased from 29.2% to 119.69% as compared to plain concrete.
4. By addition of binding wire as a steel fibre to the concrete, it is observed that the compressive strength slightly decreased.
5. The maximum drop in compressive strength (decrease of 31.10% as compared to plain concrete) is observed with the aspect ratio 70 & percentage volume of fibre of 1.5%.

2.7 Introduction to steel fiber reinforced concrete on engineering performance of concrete

Author: Vikrant S. Vairagade, Kavita S. Kene[7]

Summary: The study on the introduction of effect of steel fibers can be still promising as steel fiber reinforced concrete is used for sustainable and long-lasting concrete structures. Steel fibers are widely used as a fiber reinforced concrete all over the world. Lot of research work had been done on steel fiber reinforced concrete and lot of researchers work prominently over it. This review study tried to focus on the most significant effects of addition of steel fibers to the concrete mixes. The steel fibers are mostly used fiber for fiber reinforced concrete out of available fibers in market. According to many researchers, the addition of steel fiber into concrete creates low workable or inadequate workability to the concrete, therefore to solve this problem of superplasticizer without affecting other properties of concrete may introduce.

2.8 A review study on use of steel fiber as reinforcement material with concrete

Author: Nitin Kumar, Sangeeta[8]

Summary: A lot of review study had been conducted to see the effect of mixing steel fiber as reinforced material with concrete as parent material. A large number of minor and major investigating tests were conducted like compressive, flexure and tensile strength test with steel fiber mixed with concrete at various percentages of steel fiber. Most of the review studies demonstrated that various mechanical, chemical and engineering properties like split tensile strength, compressive strength, impact strength and flexure strength of concrete mixed with different percentages of steel fiber have been improved. From the above discussions it can be said that steel fiber proved to be a good reinforcing material and economically viable for improving the strength and durability characteristics of concrete.

2.9 Studies on steel fibre reinforced concrete – a sustainable approach

Author: Vasudev R, Dr. B G Vishnuram[2.9]

Summary: The variation of direct compressive strength for concrete cubes was found to be inconsistent with the increase in percentage of fibres. The splitting tensile strength was increased by 20-22% for concrete cylinder samples with 0.5% fibre content in M20 and M30 Grade concrete mixes. Much research on readily available fibres was conducted with an additional input of cost for the purchase of fibres. But these tests were thus a true example of sustainable development as the recycling of scraps from lathe shops is done to improve the behavior of concrete.

2.10 Investigation of steel fiber reinforced concrete on compressive and tensile strength

Author: Vikrant S. Vairagade, Kavita S. Kene*, Dr. N. V. Deshpande*[10]

Summary: The following conclusions could be drawn from the present investigation:
1. By addition of 0. 50%, SF3 Fibers shows maximum compressive strength.
2. With same volume fraction, change in length of fiber result nearly minor effect on compressive strength of Fiber Reinforced concrete.
3. It was observed that, the split tensile strength of fiber reinforced concrete was dependent on length of fiber used. By addition of longer length fiber, the split tensile strength increases.
4. By addition of 0. 50%, SF3 Fibers shows maximum split tensile strength over fiber SF1 and SF2.
5. Addition of steel fiber in the concrete effect the workability of concrete. Addition of 0.50% steel Fibers reduces the slump value of fresh concrete. This problem of workability and flow property of concrete can be overcome by using suitable admixtures such as Superplasicizers.

CHAPTER-3

EXPERIMENTAL INVESTIGATIONS

3.1 EXPERIMENTAL PROGRAM

In order to study the interaction of Steel fibres (straight) with concrete under compression, flexure, split and tension, various cylinders were casted respectively. The experimental program was divided into six groups.
Each group consists of cubes, cylinders and beams, of 15x15x15cm,
10 x20cm and 15x15x50cm respectively.

- The first group is the control concrete with 0% fibre
- The second group consisted of 0.5% of Steel fibres , by total volume of concrete
- The third group consisted of 1% of Steel fibres,, by volume of concrete
- The fourth group consisted of 1.5% of Steel fibres by volume of concrete
- The fifth group consisted of 2% of Steel fibres by volume of concrete

3.2 MATERIALS AND TESTS:

3.2.1 CEMENT

Cement acts as a binding agent for materials. Cement as applied in Civil Engineering Industry is produced by calcining at high temperature. It is a mixture of calcareous, siliceous, aluminous substances and crushing the clinkers to a fine powder. Cement is the most expensive materials in concrete and it is available in different forms. When cement is mixed with water, a chemical reaction takes place as a result of which the cement paste sets and hardens to a stone mass. Depending upon the chemical compositions, setting and hardening properties, cement can be broadly divided into following categories.

- Portland Cement
- Special Cement

The cement used in this experimental investigation is ordinary Portland cement 53 grade. Storage of cement requires extra special care to preserve its quality and fitness for use. To prevent its deterioration it is necessary to protect it from rain, winds and moisture.

Fig no. 3.1 Cement

Table 3.1 Chemical composition of O.P.C

Oxide	% content
CaO	60-67
SiO2	17-25
Al2O3	3-8
Fe2O3	0.5-6.0
MgO	0.1-0.4
Na_2O+K_2O	0.1-1.3
SO3	1.0-3.0

3.2.2 FINE AGGREGATE

Fine aggregate was procured from the JUIT campus itself. Initally observation showed the presence of various impurities and moisture. The impurities was removed by sieve analysis . It had cubical or rounded shape with smooth surface texture. Being cubical, rounded and smooth texture it give good workability.Sieve analysis was done to find out fineness modulus which comes out to be 3.14% which is under limit as per IS 383-1970. The specific gravity of Fine aggregate was 2.65.

3.2.3 COARSE AGGREGATES

The Coarse aggregate was taken from JUIT campus. Initial observations showed the presence of dust particles, leaves. The material whose particles are of size as are retained on I.S Sieve No.480 (4.75mm) is termed as coarse aggregate. The size of coarse aggregate depends upon the nature of work. The coarse aggregate used in this experimental investigation are of 20mmS and below sizes, crushed angular in shape. The aggregates are free from dust before used in the concrete.

3.2.4 WATER

Water to be used in the concrete work should have following properties:
• It should be free from injurious amount of soils
• It should be free from injurious amount of acids, alkalis or other organic or inorganic impurities.
• It should be free from iron, vegetable matter or any other type of substances, which are likely to have adverse effect on concrete or reinforcement.
• It should be fit for drinking purposes.
The function of water in concrete
• It acts as lubricant
• It acts as a chemically with cement to form the binding paste for coarse aggregate and reinforcement
.It enables the concrete mix to flow into formwork.

3.2.5 FIBRE

The brass coated micro steel fibre used in the experiment is obtained from Fibre Zone Ahmedabad Gujarat**.**
Micro brass coated steel fiber is a new type of additive for reinforcing concrete, which has the high tensile strength, and improve the concrete's unity obviously.
Material: low carbon cold drawn steel wire Tensile strength :> 2850Mpa Length: 6mmm Diameter:0.2+/-0.02mm Aspect ratio: 35-100.)
Micro steel fibers has the advantages comparing with steel bars in the fields below,

- Ultra high performance concrete
- Reactive powder concrete
- Reinforcing mortar

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such micro cracks, eventually leading to brittle fracture of the concrete. It has been recognized that the addition of small, closely spaced and uniformly dispersed fibers to the concrete would act as crack arrester and would substantially improve its Compressive and flexural strength properties. This type of concrete is known as fiber reinforced concrete. The straight steel fibers are used. The length of the steel fibers is 6mm and diameter is 0.18mm.

3.3 MIXING OF SPECIMEN

Hand mixing is adopted throughout the experimental work. First the materials cement, fine aggregate, coarse aggregate, steel Straight fibres weighed accurately as per the above mentioned calculations.

The sand is laid in a layer of approximately 10cm thick. Then cement is added to the sand and mixed thoroughly to get a uniform colour. The coarse aggregate is spread on the ground and then the cement-sand mixture is mixed with it to get a uniform matrix. The steel Straight fibres of 6 mm lengths are dispersed in the water. The water along with the fibre is added to the mixture and mixed thoroughly to get a uniform mass in colour and consistency. After mixing the fresh concrete is tested for the workability using compaction factor and slump tests.

Fig no. 3.2 Mixing of specimen

Fig no. 3.3 Mixing of concrete

3.4 TESTS ON FRESH CONCRETE

3.4.1 COMPACTION FACTOR TEST

It is one of the most efficient tests for measuring the workability of concrete. This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction called the compaction factor is measured by the ratio of density of actually achieved in the test to the density of the same concrete fully compacted. The sample of concrete to be tested is placed in the upper hopper up to the brim. The trap door of the lower hopper is opened so that the concrete falls into the lower hopper. The trap door of the lower hopper is opened so that the concrete falls into the cylinder. In case of dry mix it is likely that the concrete may not fall in opening the trap door. In such case a slight poking by a rod may be required to see the concrete in motion. The excess concrete remaining above the top level of the cylinder is then cut-off with help of plain blades. The outside of cylinder is wiped clean. The concrete is filled up exactly up to the top level of the cylinder. It is weighed to the lowest 10gm. This is known as the weight of partially compacted concrete. The cylinder is emptied and then refilled with the concrete from the same sample in three layers approximately. The layers are heavily rammed (25blows) to obtain full compaction. The top surface of the fully compacted concrete is carefully struck of level with the top of the cylinder and weighed to the nearest 10gm. This weight is known as the weight of fully compacted concrete.

Compaction factor =weight of partially compacted concrete/weight of fully compacted concrete

The compacting factor is calculated for various percentages of steel fibres. Workability is the property of concrete which determines the amount useful internal work necessary to produce full compaction. As per IS 6461-1972, workability is defined as “the ease which it can be mixed, transported, placed and compacted easily.”

Fig no. 3.4 Compaction testing machine

Table no. 3.2 Compaction factor value

PERCENTAGE OF FIBRES ADDED	COMPACTION FACTOR
0	0.82
0.5	0.79
1	0.77
1.5	0.71
2.0	0.69

3.4.2 SLUMP TEST

Slump test is the most commonly used method for measuring consistency of concrete which can be employed either in laboratory or at site of work. It is not a suitable method for very wet or very dry concrete. It is used conveniently as a control test and gives an indication of the uniformity of concrete from batch to batch. Slump cone - a mould of 1.6 mm thick galvanized metal in the form of the lateral surface of the frustum of a cone with the base 200 mm in diameter, the top 100 mm in diameter and the height 300 mm. The base and the top shall be open and parallel to each other and at right angles to the axis of the cone. The mould shall be provided with a foot piece on each side for holding the mould in place, and with handles for lifting the mould from the sample. Tamping Rod - A round, straight steel rod 16 mm in diameter and approximately 600 mm in length. The tamping end shall be a hemisphere 16 mm in diameter.

PROCEDURE

1. Dampen the slump test mould and place it on a flat, moist, nonabsorbent, rigid surface, like a steel plate.
2. Fill the mould to 1/3 full by volume and rod the bottom layer with 25 evenly spaced strokes.
3. Fill the mould to 2/3 full and rod the second layer with 25 strokes penetrating the top of the bottom layer.
4. Heap the concrete on top of the mould, and rod the top layer with 25 strokes penetrating the top of the second layer.
5. Strike off the top surface of the concrete even to the top of the mould.
6. Remove the mould carefully in the vertical direction (take about five seconds).
7. Immediately invert and place the mould beside the slumped concrete and place the rod horizontally across the mould, and measure the slump, in cm.

Fig no. 3.5 Slump test

Table no. 3.3 Slump test value

PERCENTAGE OF FIBRES ADDED	SLUMP VALUE (in cm)
0	2.1
0.5	1.2
1.0	0.7
1.5	0.6
2.0	0.2

3.4.3 CASTING OF SPECIMENS

For casting the cubes, beam and cyclinder specimens, standard cast iron metal moulds of size150x150x150 cubes, 100x100x500mm beam and 100x200mm cyclinder moulds are used. The moulds have been cleaned of dust particles and applied with mineral oil on all sides, before the concrete is poured into the moulds. Thoroughly mixed concrete is filled into the mould in three layers of equal heights followed by tamping. Then the mould is placed on the table vibrator for a small period. Excess concrete is removed with trowel and top surface is finished to smooth level.

Fig no. 3.6 Casting of specimens

3.4.4 CURING

Curing is the process of preventing the loss of moisture from concrete while maintaining a satisfactory temperature. More elaborately curing is defined as process of maintaining satisfactory moisture content and favourable temperature in concrete during the period immediately following placement, so that hydration of cement may continue until the desired properties are developed to a sufficient degree to meet the requirement at service. After casting the moulded specimens are stored in the laboratory and at a room temperature for 24 hours from the time at addition of water to dry ingredients after this period the specimens are removed from the moulds immediately submerged in clean and fresh water. The specimens are cured for 7 and 28days in the present work.

3.5 TEST ON HARDENED CONCRETE

3.5.1 CUBE COMPRESION TEST

This test was conducted as per IS 516-1959. The cubes of standard size 150x150x150mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of UTM, of capacity 100tones without eccentricity and a uniform rate of loading of 550 Kg/cm2 per minute was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated.
Cube compressive strength (fck) in MPa = P/A

Where,
P= cube compression load
A= area of the cube on which load is applied (= 150 x 150= 22500 mm^2)

Fig 3.7 Compression testing machine

3.5.2 FLEXURAL TEST

SFRC beams of size 100x100x500mm are tested using a flexure testing machine. The specimen is simply supported on the two rollers of the machine which are 600mm apart, with a bearing of 50mm from each support. The load shall be applied on the beam from two rollers which are placed above the beam with a spacing of 200mm. The load is applied at a uniform rate such that the extreme fibres stress increases at 0.7N/mm2/min i.e., the rate of loading shall be 4 KN/min. The load is increased till the specimen fails. The maximum value of the load applied is noted down. The appearance of the fracture faces of concrete and any unique features are noted.
The modulus of rupture is calculated using the formula.
$\sigma_s = Pl/bd^2$, where,
P = load in N applied to the specimen
l = length in mm of the span on which the specimen is supported
b = measured width in mm of the specimen
d = measured depth in mm of specimen at the point of failure

Fig no. 3.8 Flexure testing machine

3.5.3 SPLIT TENSILE TEST

SFRC cylinders of size 10cm (dia) x 20cm (height) are casted. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of a compression testing machine and the load is applied until the failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a horizontal stress of $2P/\pi ld$.

Where, P is the compressive load on the cylinder

l is the length of the cylinder

d is diameter of the cylinder.

The main advantage of this method is that the same type of specimen and the same testing machine as used for the compression test can be employed for this test. This is why this test is gaining popularity. The splitting test is simple to perform and gives more uniform results than the other tension tests. Strength determined in the splitting test is believed to be closer to the true tensile strength of concrete, than the modulus of rupture. Splitting strength gives about 5 to 10% higher value than the direct tensile strength.

Fig no. 3.9 Split tensile testing machine

3.6 SOME PRACTICAL DIFFICULTIES ENCOUNTERED

The various practical difficulties encountered can be summarized as below:

1. The phenomenon of Balling and Lumping of fibres is generally encountered in field problems due to the addition of a fixed percentage of fibres (either on volume basis or on mass basis) directly to the ingredients of concrete during mixing. In order to avoid the occurrence of balling lumping it was proposed to add the fibres only while pouring the concrete into the moulds.

2. The addition of fibres was taken up in three to five layers with approximately equal depths of layers and equal quantity of fibre in each layer. This result in improper or difficulty in penetration of aggregates in the void spaces. Also, it was noticed that 2% volume fraction of fibres further aggravated this problem.

CHAPTER-4

RESULTS AND DISCUSSIONS

Table no. 4.1.1 Compression test values of m30 grade SFRC 7 days curing

Percentage of fibers	**Trial 1**	**Trial 2**	**Trial 3**	**Average compressive strength (in N/mm2)**
0	18.90	19.50	19.28	19.29
0.5	20.60	20.40	20.00	20.32
1	20.90	20.65	20.35	20.80
1.5	21.60	21.95	21.40	21.90
2	22.60	22.90	22.85	22.68

Table 4.1.2 Compression test values of m30 grade SFRC at 28 days curing

Percentage of fibers	**Trial 1**	**Trial 2**	**Trial 3**	**Average compressive strength (in N/mm2)**
0	32.40	32.60	31.95	32.73
0.5	33.70	33.35	33.50	33.88
1	34.60	34.20	34.45	34.68
1.5	36.40	36.80	36.20	36.51
2	37.90	37.40	37.65	37.80

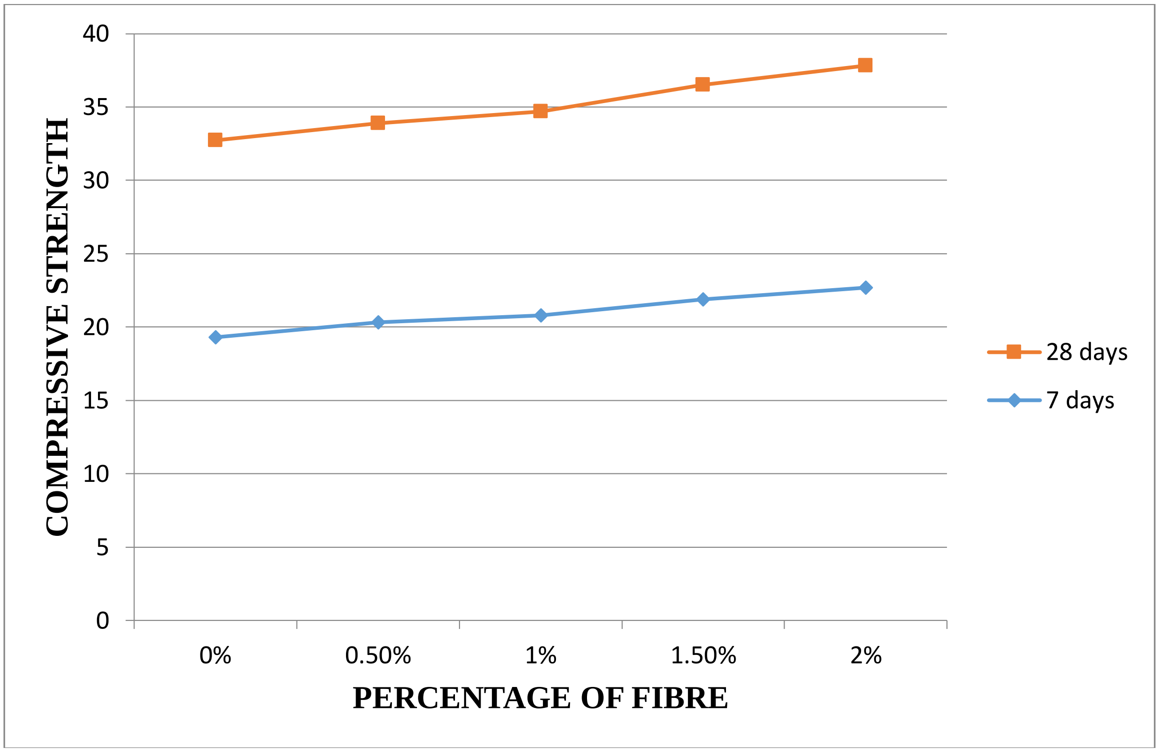

Fig no. 4.1 COMPRESSIVE STRENGTH VS PERCENTAGE OF FIBRE

Table no. 4.1.3 Split tensile test values of m30 grade SFRC at 7 days curing

Percentage of fibers	**Trial 1**	**Trial 2**	**Trial 3**	**Average split tensile strength (in N/mm2)**
0	1.90	1.95	1.98	1.99
0.5	2.20	1.90	1.95	2.05
1	2.33	2.28	2.40	2.34
1.5	2.70	2.45	2.56	2.55
2	2.90	2.86	2.65	2.80

Table no. 4.1.4 Split tensile test values of m30 grade SFRC at 28 days curing

Percentage of fibers	Trial 1	Trial 2	Trial 3	Average split tensile strength (in N/mm2)
0	3.20	3.15	3.20	3.13
0.5	3.30	3.40	3.20	3.43
1	3.85	3.60	3.80	3.90
1.5	4.20	4.30	4.33	4.26
2	4.55	4.48	4.44	4.49

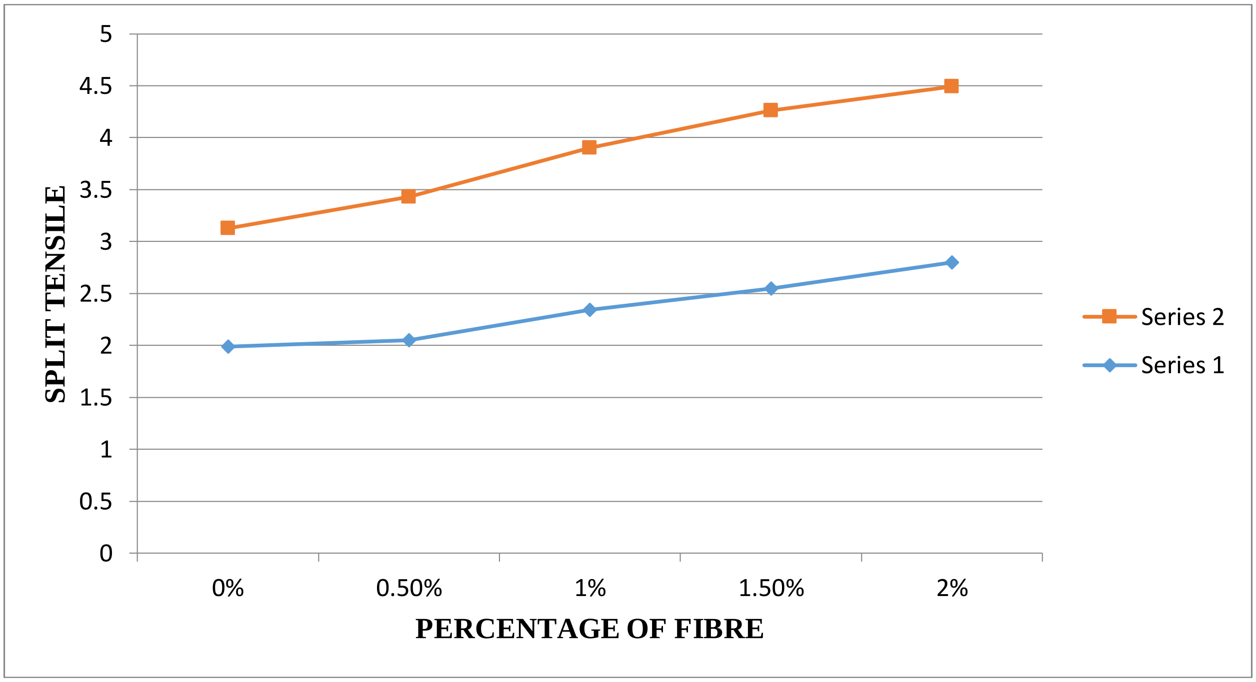

Fig no. 4.2 SPLIT TENSILE STRENGTH VS PERCENTAGE OF FIBRE

Table 4.1.5 Flexural test values of m30 grade SFRC at 7 days curing

Percentage of fibres	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm2)
0	3.98	3.91	3.85	3.93
0.5	4.42	4.50	4.46	4.92
1	4.98	4.86	4.83	4.93
1.5	5.22	5.08	5.13	5.02
2	5.42	5.21	5.24	5.30

Table 4.1.6 Flexural test values of m30 grade SFRC at 28 days curing

Percentage of fibres	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm2)
0	5.20	5.76	5.92	5.96
0.5	6.80	6.66	6.62	6.70
1	7.40	7.50	7.44	7.47
1.5	7.60	7.68	7.55	7.62
2	8.10	8.00	7.6	8.04

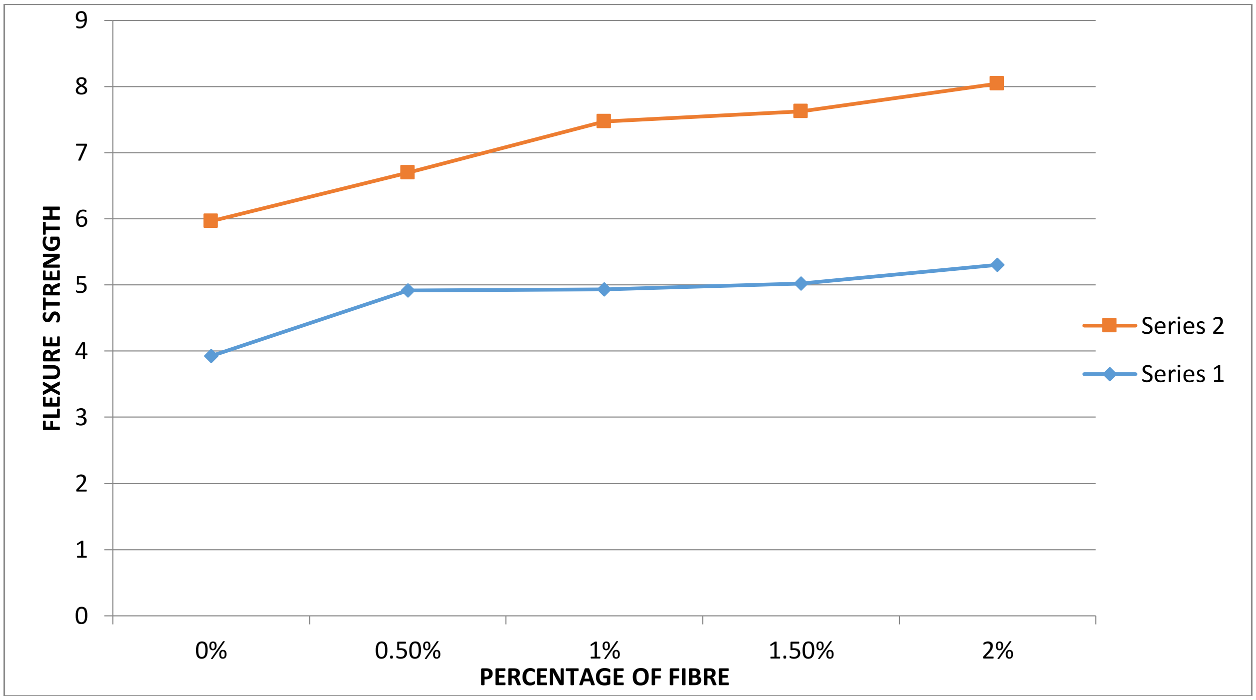

Fig no. 4.3 Flexural strength v/s percentage of fibre

Table 4.2.1 Compression test values of m40 grade SFRC at 7 days curing

Percentage of fibers	Trial 1	Trial 2	Trial 3	Average compressive strength (in N/mm2)
0	27.85	27.60	27.78	27.70
0.5	28.60	28.90	28.79	28.92
1	29.30	29.48	29.33	29.40
1.5	29.95	29.86	29.82	29.91
2	31.20	31.50	31.25	31.30

Table 4.2.2 Compression test values of m40 grade SFRC at 28 days curing

Percentage of fibers	**Trial 1**	**Trial 2**	**Trial 3**	**Average compressive strength (in N/mm2)**
0	42.30	42.80	42.64	42.60
0.5	43.95	43.80	43.72	43.88
1	44.50	44.39	44.45	44.55
1.5	45.50	45.28	45.32	45.33
2	47.60	47.45	47.38	47.40

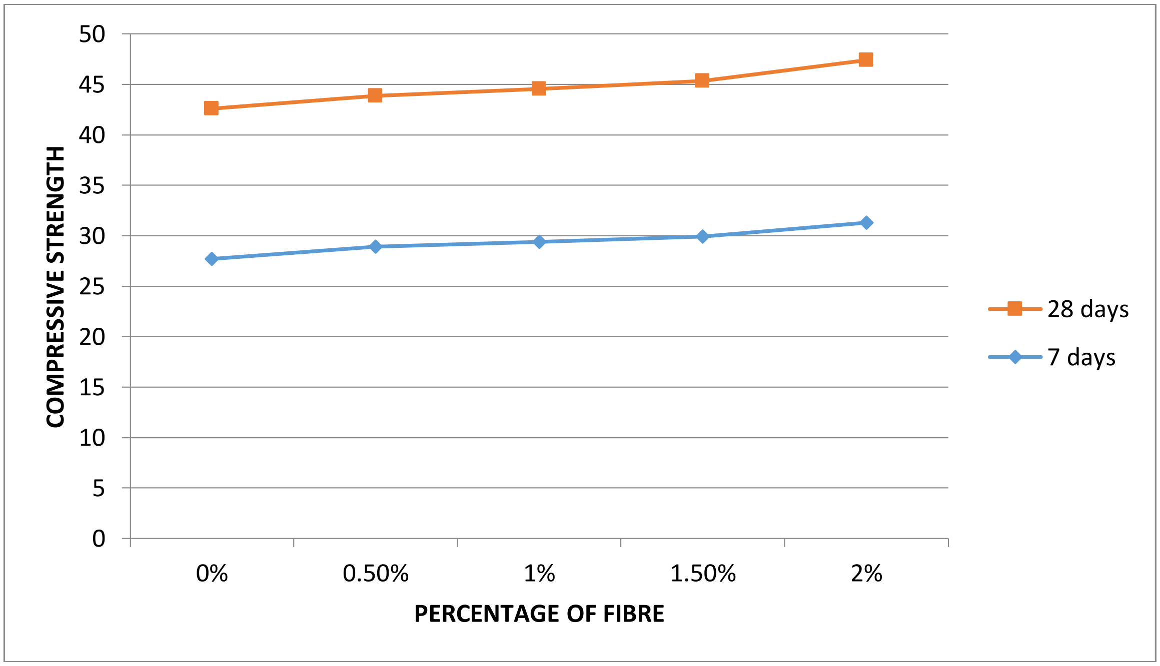

Fig no. 4.4 Compressive strength vs percentage of fibre

Table no. 4.2.3 SPLIT TENSILE TEST VALUES OF M40 GRADE SFRC AT 7 DAYS CURING

Percentage of fibers	**Trial 1**	**Trial 2**	**Trial 3**	**Average split tensile strength (in N/mm2)**
0	2.7	2.66	2.75	2.71
0.5	2.85	2.78	2.75	2.79
1	2.98	2.89	2.91	2.96
1.5	3.20	3.13	3.17	3.16
2	3.55	3.39	3.41	3.43

Table 4.2.4 Split tensile test values of m40 grade sfrc at 28 days curing

Percentage of fibers	**Trial 1**	**Trial 2**	**Trial 3**	**Average split tensile strength (in N/mm2)**
0	4.1	4.08	4.2	4.12
0.5	4.3	4.2	4.21	4.23
1	4.6	4.3	4.44	4.50
1.5	4.48	4.76	4.90	4.82
2	5.25	5.18	5.13	5.21

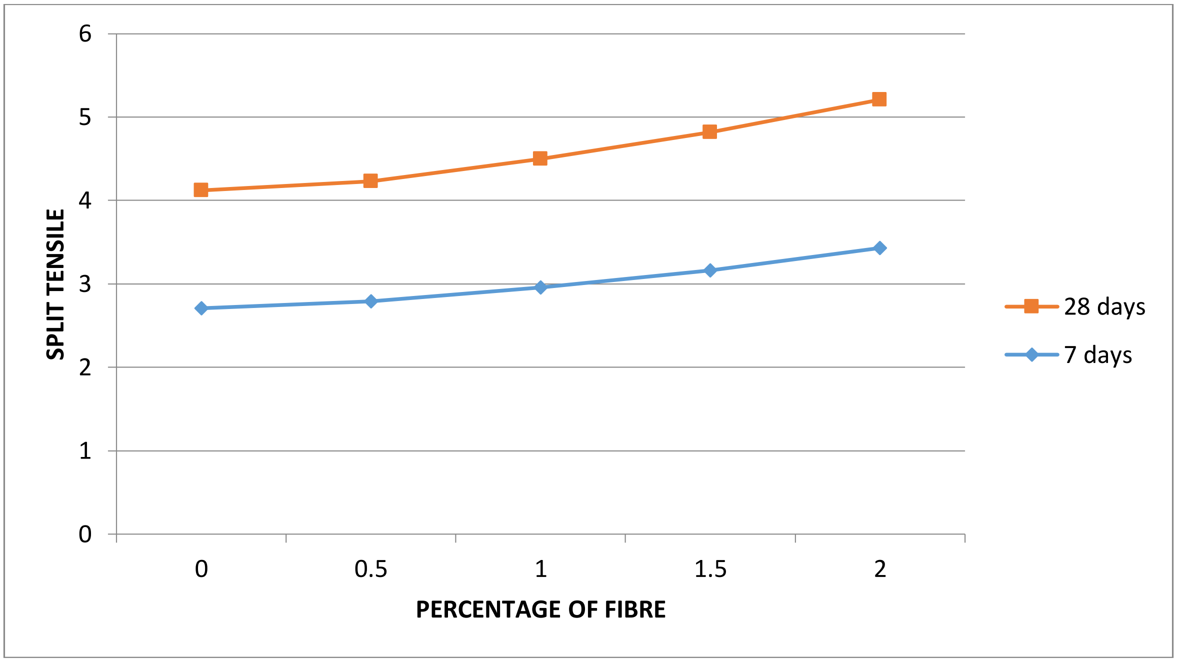

Fig 4.5 Spilit tensile vs percentage of fibre

Table 4.2.5 Flexural test values of m40 grade sfrc at 7 days curing

Percentage of fibres	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm2)
0	4.70	4.62	4.64	4.68
0.5	5.22	5.14	5.08	5.10
1	5.55	5.49	5.43	5.50
1.5	6.10	6.03	5.99	5.05
2	6.60	6.42	6.47	6.50

Table 4.2.6 Flexural test values of m40 grade sfrc at 28 days curing

Percentage of fibres	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm2)
0	6.80	6.95	6.82	6.89
0.5	7.70	7.49	7.32	7.58
1	8.82	8.14	8.10	8.15
1.5	9	8.85	8.78	8.90
2	9.65	9.50	9.43	9.60

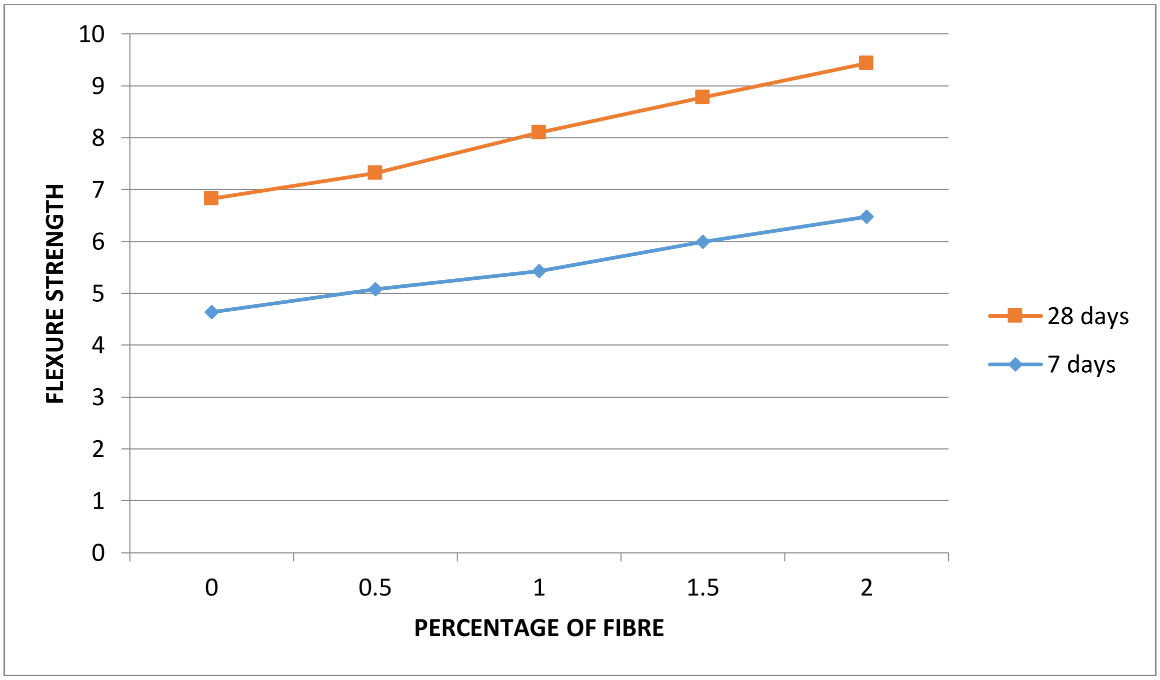

Fig no. 4.6 Flexure strength vs percentage of fibre

DISCUSSIONS

4.3.1 Compressive Strength and Split Tensile Strength (M30):

The variation in the compressive stress and split tensile stress with respect to changes in the fibre content can be observed. From the results obtained, it is clear that the compressive and split tensile strength of concrete is maximum when the fibre content is 2% of the concrete. So comparing the variation of strength between the plain concrete and fibre reinforced concrete (2%).

Comparing the comprssive strength of plain concrete and concrete with various percentages of fibres after 28 days of curing:

Table no. 4.3.1.1

Plain Concrete (N/mm^2)	SFRC (N/mm^2)	Percentage Increase in Strength
0	32.73	0
0.5	33.88	3.51
1	34.68	5.90
1.5	36.51	11.50
2	37.80	15.49

Comparing the split tensile strength of plain concrete and concrete with various percentages of fibres after 28 days of curing:

Table no. 4.3.1.2

Plain Concrete (N/mm^2)	SFRC (N/mm^2)	Percentage Increase in Strength
0	3.13	0
0.5	3.43	9.60
1	3.90	24.60
1.5	4.26	36.10
2	4.49	43.45

From the tables it is clear that the strength of SFRC with 2% fibre has increased By 15.49% for compression, 43.45% under split tension compared to the plain concrete.

4.3.2 Flexural Strength (Modulus of Rupture)

From the results obtained, it is inferred that the most significant increase in the Modulus of Rupture is obtained on addition of 2 percent of fibres. So, comparing the values of modulus of rupture:

Table no 4.3.2

Plain Concrete (N/mm2)	SFRC (N/mm2)	Percentage Increase in Strength
0	5.96	0
0.5	6.70	12.41
1	7.47	25.33
1.5	7.622	27.85
2	8.04	35.23

From the tables it is clear that the strength of SFRC with 2% fibre has increased by 35.23% for flexure compared to the plain concrete.

4.3.3 Compressive Strength and Split Tensile Strength (M40):

The variation in the compressive stress and split tensile stress with respect to changes in the fibre content can be observed. From the results obtained, it is clear that the compressive and split tensile strength of concrete is maximum when the fibre content is 2% of the concrete. So comparing the variation of strength between the plain concrete and fibre reinforced concrete (2%).
Comparing the comprssive strength of plain concrete and concrete with various percentages of fibres after 28 days of curing:

Table 4.3.3.1

Plain Concrete (N/mm2)	SFRC (N/mm2)	Percentage Increase in Strength
0	42.60	0
0.5	43.88	3.0
1	44.55	4.5
1.5	45.33	6.4
2	47.40	11.26

Comparing the split tensile strength of plain concrete and concrete with various percentages of fibres after 28 days of curing:

Table no. 4.3.3.2

Plain Concrete (N/mm2)	SFRC (N/mm2)	Percentage Increase in Strength
0	4.12	0
0.5	4.23	2.6
1	4.49	8.9
1.5	4.80	16.5
2	5.20	26.2

From the tables it is clear that the strength of SFRC with 2% fibre has increased By 11.26% for compression, 26.2% under split tension compared to the plain concrete.

4.3.4 Flexural Strength (Modulus of Rupture):

From the results obtained, it is inferred that the most significant increase in the Modulus of Rupture is obtained on addition of 2 percent of fibres. So, comparing the values of modulus of rupture:

Table no. 4.3.4

Plain Concrete (N/mm2)	SFRC (N/mm2)	Percentage Increase in Strength
0	6.89	0
0.5	7.50	8.8
1	8.10	17.56
1.5	8.90	29.17
2	9.60	31.33

From the tables it is clear that the strength of SFRC with 2% fibre has increased by 31.33% for flexure compared to the plain concrete.

CONCLUSIONS

- The Steel fibres Straight used in this project has shown considerable improvement in all the properties of concrete when compared to conventional concrete like

- The steel fibres are free from water absorption.

- With improved understanding of the link between fibre characteristics and composite or structural performance, the tailoring of fibres for use in high volume construction market exists, particularly for load carrying structural systems and for several applications especially in Earthquake prone areas. The time is not far that such materials will be used in building better and safe constructions for the future.

For M30 concrete:

- Compressive strength by 15.49% for 2% of steel fibres.

- Split Tensile strength by 43.45% for 2% of steel fibres.

- Flexural strength (Modulus of Rupture) by 35.23% for 2% of steel fibres.

For M40 concrete:

- Compressive strength by 11.26% for 2% of steel fibres.

- Split Tensile strength by 26.2% for 2% of steel fibres.

- Flexural strength (Modulus of Rupture) by 31.33% for 2% of steel fibres.

SCOPE FOR FURTHER STUDY

- Further study can be done for determining the deflections and durability of concrete.
- Further study on the seepage characteristics of the steel fibres.
- As the failure of SFRC is ductile, further studies on retrofitting of damaged structures constructed of this concrete can be undertaken.

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ANNEXURE A

MIX DESIGN FOR M30 GRADE CONCRETE

Mix design is the process of selection of suitable ingredients of concrete and to determine their properties with object of producing concrete of certain maximum strength and durability, as economical as possible. The purpose of designing is to achieve the stipulated minimum strength, durability and to make the concrete in the most economical manner Design of M30 concrete mix as per IS: 10262-2009.

M-30 CONCRETE MIX DESIGN		
As per IS 10262-2009 & MORT&H		
A-1	**Stipulations for Proportioning**	
1	**Grade Designation**	**M30**
2	Type of Cement	OPC 53 grade confirming to IS-12269-1987
3	Maximum Nominal Aggregate Size	20 mm
4	Minimum Cement Content (MORT&H 1700-3 A)	310 kg/m^3
5	Maximum Water Cement Ratio (MORT&H 1700-3 A)	0.45
6	Workability (MORT&H 1700-4)	50-75 mm (Slump)
7	Exposure Condition	Normal
8	Degree of Supervision	Good
9	Type of Aggregate	Crushed Angular Aggregate

10	Maximum Cement Content (MORT&H Cl. 1703.2)	540 kg/m^3
11	Chemical Admixture Type	Superplasticiser Confirming to IS-9103
A-2	**Test Data for Materials**	
1	Cement Used	Coromandal King OPC 53 grade
2	Sp. Gravity of Cement	3.15
3	Sp. Gravity of Water	1.00
4	Chemical Admixture	BASF Chemicals Company
5	Sp. Gravity of 20 mm Aggregate	2.884
6	Sp. Gravity of 10 mm Aggregate	2.878
7	Sp. Gravity of Sand	2.605
8	Water Absorption of 20 mm Aggregate	0.97%
9	Water Absorption of 10 mm Aggregate	0.83%
10	Water Absorption of Sand	1.23%
11	Free (Surface) Moisture of 20 mm Aggregate	nil

12	Free (Surface) Moisture of 10 mm Aggregate	nil
13	Free (Surface) Moisture of Sand	nil
14	Sieve Analysis of Individual Coarse Aggregates	Separate Analysis Done
15	Sieve Analysis of Combined Coarse Aggregates	Separate Analysis Done
15	Sp. Gravity of Combined Coarse Aggregates	2.882
16	Sieve Analysis of Fine Aggregates	Separate Analysis Done
A-3	**Target Strength for Mix Proportioning**	
1	Target Mean Strength (MORT&H 1700-5)	$42N/mm^2$
2	Characteristic Strength @ 28 days	$30N/mm^2$
A-4	**Selection of Water Cement Ratio**	
1	Maximum Water Cement Ratio (MORT&H 1700-3 A)	0.45
2	Adopted Water Cement Ratio	0.42
A-5	**Selection of Water Content**	
1	Maximum Water content (10262-table-2)	186 Lit.
2	Estimated Water content for 50-75 mm Slump	160 Lit.

3	Superplasticiser used	0.5 % by wt. of cement
A-6	**Calculation of Cement Content**	
1	Water Cement Ratio	0.42
2	Cement Content (160/0.42)	380 kg/m^3
		Which is greater then 310 kg/m^3
A-7	**Proportion of Volume of Coarse Aggregate & Fine Aggregate Content**	
1	Vol. of C.A. as per table 3 of IS 10262	62.00%
2	Adopted Vol. of Coarse Aggregate	62.00%
	Adopted Vol. of Fine Aggregate (1-0.62)	38.00%
A-8	**Mix Calculations**	
1	Volume of Concrete in m^3	1.00
2	Volume of Cement in m^3	0.12
	(Mass of Cement) / (Sp. Gravity of Cement)x1000	
3	Volume of Water in m^3	0.160
	(Mass of Water) / (Sp. Gravity of Water)x1000	
4	Volume of Admixture @ 0.5% in m^3	0.00160

	(Mass of Admixture)/(Sp. Gravity of Admixture)x1000	
5	Volume of All in Aggregate in m^3	0.718
	Sr. no. 1 – (Sr. no. 2+3+4)	
6	Volume of Coarse Aggregate in m^3	0.445
	Sr. no. 5 x 0.62	
7	Volume of Fine Aggregate in m^3	0.273
	Sr. no. 5 x 0.38	
A-9	**Mix Proportions for One Cum of Concrete (SSD Condition)**	
1	Mass of Cement in kg/m^3	**380**
2	Mass of Water in kg/m^3	**160**
3	Mass of Fine Aggregate in kg/m^3	**711**
4	Mass of Coarse Aggregate in kg/m^3	1283
	Mass of 20 mm in kg/m^3	**924**
	Mass of 10 mm in kg/m^3	**359**
5	Mass of Admixture in kg/m^3	**1.90**
6	Water Cement Ratio	0.42

MIX DESIGN FOR M40 GRADE CONCRETE

M 40 DESIGN PROCEDURE
CONDITIONS –

- Max. size of aggregates – 20 mm
- Min content of cement – 320 kg/m3
- Slump – 120 mm
- Exposure – severe and for pumping purpose
- Max content of cement – 450 kg/m3
- Max water cement ratio – 0.45
- Specific gravity of cement – 3.15
- Specific gravity of coarse aggregates – 2.74
- Specific gravity of fine aggregates – 2.74

DESIGN –

Target mean strength –
Ft = Fck + 1.65* S
Ft – target mean strength
Fck - characteristic compressive strength at 28-day
S – standard deviation
Ft = 40+1.65*5 (S from table 1 of IS 10262:2009)
= 48.75 N/m2
Max water content = 186 lit (for 120 mm slump from table 2 of IS 10262:2009)
Estimated water content for 120mm slump = 186 + (6/10)*18 = 197 lit 55

Calculation of cement –
w/c =0.40
c=w/0.40
c= 197/.40 =492.50 kg/m3 (more than 450 kg/m3 hence we take 450 kg/m3)

CALCULATION OF COARSE AND FINE AGGREGATES –

Proportion of volume of coarse and fine aggregate content
From Table 3 -volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (zone 3) for water-cement ratio of 0.50 =0.62. (from table 3 of IS10262:2009)
In the present case water-cement ratio is 0.40. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. As the water-cement ratio is lower by 0.10. the proportion of volume of coarse aggregate is increased by 0.02 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.40 = 0.64.
For pumpable concrete these values should be reduced by 10 percent.
Therefore, volume of coarse aggregate = 0.64 x 0.9 = 0.576.
Volume of fine aggregate content = 1 - 0.576 =0.424.

MIX CALCULATIONS –
Volume of concrete = 1 m3
Volume of cement = (mass of cement / specific gravity of cement)* (1/1000)
=450/3.15 * 1/1000
=0.142 m3
volume of water = mass of water/ s.g. of water * 1/1000
=197/1 *1/1000 56
=0.197m3
Volume of all in aggregates =(a-(b+c)) =(1- (0.142+0.197)) = 0.66
Mass of coarse aggregates = e * volume of coarse aggregates * specific gravity of coarse aggreagates *1000
= 0.66*0.576*2.74*1000 =1046kg
Mass of fine aggregates = e * volume of coarse aggregates * specific gravity of fine aggreagates *1000
= 0.66*0.424*2.74*1000 =766.76kg

MIX PROPORTION (M40)–
Cement = 450 kg/m3
Water = 197 lit
Fine aggregates = 766.76 kg/m3
Coarse aggregates = 1046 kg/m3
Water-cement ratio = 0.4

ANNEXURE B

Table 1 of IS 10262:2009

Table 1 Assumed Standard Deviation

(*Clauses* 3.2.1.2, A-3 *and* B-3)

Sl No. (1)	Grade of Concrete (2)	Assumed Standard Deviation N/mm² (3)
i)	M 10	3.5
ii)	M 15	
iii)	M 20	4.0
iv)	M 25	
v)	M 30	5.0
vi)	M 35	
vii)	M 40	
viii)	M 45	
ix)	M 50	
x)	M 55	

NOTE — The above values correspond to the site control having proper storage of cement; weigh batching of all materials; controlled addition of water; regular checking of all materials, aggregate grading and moisture content; and periodical checking of workability and strength. Where there is deviation from the above, values given in the above table shall be increased by 1 N/mm^2.

Table 17 – table 1 of IS 10262:2009

Table 2 of Is 10262:2009

Table 2 Maximum Water Content per Cubic Metre of Concrete for Nominal Maximum Size of Aggregate

(*Clauses* 4.2, A-5 *and* B-5)

Sl No.	Nominal Maximum Size of Aggregate mm	Maximum Water Content [1] kg
(1)	(2)	(3)
i)	10	208
ii)	20	186
iii)	40	165

NOTE — These quantities of mixing water are for use in computing cementitious material contents for trial batches.

[1] Water}content corresponding to saturated surface dry aggregate.

Table 18 – table 2 of IS 10262:2009

Table 3 of IS 10262:2009

Table 3 Volume of Coarse Aggregate per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate

(*Clauses* 4.4, A-7 *and* B-7)

Sl No.	Nominal Maximum Size of Aggregate mm	Volume of Coarse Aggregate[1] per Unit Volume of Total Aggregate for Different Zones of Fine Aggregate			
		Zone IV	Zone III	Zone II	Zone I
(1)	(2)	(3)	(4)	(5)	(6)
i)	10	0.50	0.48	0.46	0.44
ii)	20	0.66	0.64	0.62	0.60
iii)	40	0.75	0.73	0.71	0.69

[1] Volumes are based on aggregates in saturated surface dry condition.

Table 19 – table 3 of IS 10262:2009

ANNEXURE C

IMAGES TAKEN DURING THE WORK


TJ
1%


Compression Testing
Machine


Compression Testing Machine