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PERFORMANCE OF CONCRETE WITH ADDING OF STEEL FIBERS

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ABSTRACT

Concrete made with Portland cement has certain characteristics: it is relatively strong in compression but weak in tension and tends to be brittle. These two weaknesses have limited its use. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. These cracks are major cause of weakness in concrete particularly in large on site applications leading to subsequent fracture and failure and general lack of durability. Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers.
Fiber- reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibres that are uniformly distributed and randomly oriented – each of which lend varying properties to the concrete. In addition, the character of fibre-reinforced concrete changes with varying concretes, fibre materials, geometries, distribution, orientation, and densities. In this experimental investigation, an attempt has made to find out strength related tests like Compressive Strength, Split Tensile Strength, Flexural Strength using hooked end Steel Fibers with to volume fraction of 0.5% and 1% and for aspect ratio and considered for M40 Grade of concrete. Number of specimens were casted, cured and tested. The real contribution of the fibers is to increase the toughness of the concrete, under any type of loading and permit the fiber reinforced concrete to carry significant stress over a relatively large strain capacity in the post cracking stage. The results of the tests showed that the strength properties are enhanced due to addition of fibers.

Keywords: Concrete, Coarse Aggregate, Fine Aggregates, Fibers, Fiber Reinforced Concrete, Hooked End Steel Fibers, Aspect Ratio, Mechanical Properties.

I. INTRODUCTION

Concrete made with Portland cement has certain characteristics: it is relatively strong in compression but weak in tension and tends to be brittle. These two weaknesses have limited its use. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. These cracks are major cause of weakness in concrete particularly in large on site applications leading to subsequent fracture and failure and general lack of durability. The weakness in tension can be overcome by the use of conventional rod reinforcement and to some extent by the inclusion of a sufficient volume of certain fibers
Concrete is used extensively as a construction material because of its versatility. It is good in compression, but weak in tension. This drawback can be overcome by providing steel in tension zone. This technique called **"**REINFORCED CEMENT CONCRETE**"**, improves the load carrying capacity of concrete members. At the same time durability of concrete is also important. Durability is mainly affected due to cracks developed by creep and shrinkage. This can be avoided by using certain chemical admixtures. But once a crack develops in the member there are no barriers to stop the propagation of such cracks.

In an attempt to control the so formed cracks has led to the development of FIBRE REINCORCED CONCRETE (FRC), obtained by dispersing in concrete, very small sized reinforcement called fibres. The small closely spaced fibres so used act like crack arresters, substantially improve the static and dynamic strengths.

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1.1 Technology for producing FRC

FRC in general, can be produced using conventional concrete practice, though there are obviously some important differences. The basic problem is to introduce a sufficient volume of uniformly dispersed to achieve the desired improvements in mechanical behavior, while retaining sufficient workability in the fresh mix to permit proper mixing, placing and finishing. The performance of the hardened concrete is enhanced more by fibers with a higher aspect ratio, since this improves the fiber-matrix bond. On the other hand, a high aspect ratio adversely affects the workability of the fresh mix. In general, the problems of both workability and uniform distribution increase with increasing fiber length and volume.

1.2 Scope of the present investigation

The adequate and economic application of any material to field problems demands extensive knowledge of its performance under different loads. An extensive application of FRC can be seen in both industrial structures and civil engineering fields. Therefore, the thorough knowledge of the properties of FRC is quite essential. A lot of work has been carried out on FRC using low strength concrete like M20, M30 etc. A little work has been done on FRC high strength concrete. Here in this work an attempt has been made to bring out certain characteristics of high strength FRC using M40, grades of concrete. The characteristics studied are compressive strength (cube strength and cylinder strength), flexural strength, modulus of elasticity, split tensile strength.

1.3 Synopsis

Fiber reinforcement is widely used as the main and unique reinforcing for industrial concrete floor slabs, shot Crete and prefabricated concrete products. It is also considered for structural purposes in the reinforcement of slabs on piles, tunnel segments, concrete cellars, foundation slabs and shear reinforcement in prestressed elements. Ensuring the quality and performance of the fibers and ultimately the FRC is critical and the challenge faced by engineers involved in designing this project is to unambiguously specify the performance required by the FRC so as to achieve in the finished structure the performance that was assumed in the design.

II. LITERATURE REVIEW

It is now well established that one of the important properties of steel fiber reinforced concrete (SFRC) is its superior resistance to cracking and crack propagation. As a result of this ability to arrest cracks, fiber composites possess increased extensibility and tensile strength, both at first crack and at ultimate, particular under flexural loading; and the fibers are able to hold the matrix together even after extensive cracking. The net result of all these is to impart to the fiber composite pronounced post-cracking ductility which is unheard of in ordinary concrete. The transformation from a brittle to a ductile type of material would increase substantially the energy absorption characteristics of the fiber composite and its ability to withstand repeatedly applied, shock or impact loading. Steel fibre reinforced concrete is emerging as a superior construction of material than plain cement concrete due to its better engineering properties. The research and development in FRC has been going on since last three decades. Romuldi. J.P. and Batson G.B. are the pioneers who stressed the importance of FRC as a construction material, since then extensive research has been done on various aspects of FRC. A brief review of the important investigations concerned with FRC is presented in the following articles.

1. **Shah,S.P**., and **Rangan,B.v., "**Fibre Reinforced Concrete Properties,**"** ACI journal, Tital No.68-14, February 1971,pp.126-135.
2. **Narayanan,R.,** and **Kareem-Palanjian,** A.S., **"** Effect of Fibre addition on concrete Strengths,**"** Indian Concrete Journal, Apr-1984,pp.100-103.
3. **Gopalratnam,V.**S.: Shah,S.P.: Batson, G.B: Criswell,M.E.,; Ramakrishna,V., and Wecharatanna,M., **"**France Toughness of Fibre Reinforced Concrete.**"** Materials Journal, Title No. 88-M41, V.88, No.4, July-August. 1991,pp.393-353.

2.1 Literature survey on concrete

Concrete is the most widely used human-made product in the World. In contrast to its internal complexity, versatility, durability, and economy, it has been the most extensively used construction material with a production over six billion tons every year. Concrete is used to make pavements, building structures, foundations, roads, overpasses, parking structures, brick/block walls and bases for gates, fences and poles. Concrete is primarily a proportionate mixture of aggregate, cement, and water.

In India, Conventional concrete is often produced with four basic components namely Cement, Water (binder), the Crushed or uncrushed Stone and Natural Sand or Stone Dust. In addition to the above ingredients, one or two additional chemicals are also added to the recipe of concrete in order to enhance some properties. Certain

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materials of mineral origin are also added to concrete to enhance their strength and durability properties of concrete materials such as fly ash, silica fume, which are generally very fine, may be finer than cement, when added to concrete in right proportion can improve the strength and durability of concrete drastically and high strength and high performance concrete is obtained in this manner. So modern concrete can have more four ingredients mentioned earlier and like many other composites, property of concrete can be suitably tailored for specific construction related performance. The cement and water will form a paste that hardens as a result of a chemical reaction between the cement and water. This paste acts as glue, binding the aggregates (sand and gravel or crushed stone) into a solid rock-like mass. The quality of the paste and the aggregates dictate the engineering properties of this construction material. During hydration and hardening, concrete will develop certain physical and chemical properties, among others, mechanical strength.

2.2 High performance concrete

High Performance Concrete is a special type of concrete meeting typical combination of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. It possesses high-workability, high-strength, and high durability. The High Performance Concrete ensures long-time durability in structures when exposed to aggressive environments. Durability of concrete is its ability to resist weathering action, chemical attack, abrasion and all other deterioration processes. Weathering includes environmental effects such as exposure to cycles of wetting and drying, heating and cooling, as also freezing and thawing. Chemical deterioration process includes acid attack, expansive chemical attack due to moisture.

2.3 High strength concrete

From the general principles behind the design of high-strength concrete mixtures, it is apparent that high strengths are made possible by reducing porosity, in homogeneity, and micro cracks in the hydrated cement paste and the transition zone. The utilization of fine pozzolanic materials in high strength concrete leads to a reduction of the size of the crystalline compounds, particularly, calcium hydroxide. Consequently, there is a reduction of the thickness of the interfacial transition zone in high-strength concrete. The densification of the interfacial transition zone allows for efficient load transfer between the cement mortar and the coarse aggregate, contributing to the strength of the concrete. For very high-strength concrete where the matrix is extremely dense, a weak aggregate may become the weak link in concrete strength.

2.4 Definition of FRC

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. ACI committee 544(1,2). Now, why would we wish to add such fibers to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capacity. The role of randomly distributes discontinuous fibers is to bridge across the cracks that develop provides some post-cracking “ductility”. If the fibers are sufficiently strong, sufficiently bonded to material, and permit the FRC to carry significant stresses over a relatively large strain capacity in the post-cracking stage.

2.5 History of FRC

SFRC was introduced commercially into the European market in the second of the 1970’s. No standards or recommendations were available at that time which was a major obstacle for the acceptance of this new technology. Initially steel fiber was mostly used as a substitute for secondary reinforcement or for crack control in less critical parts of the construction. The history of modern glass fibers really only stretches back to the 1930s.Mass production of glass stands was accidentally discovered in 1932. By a researcher at the owenslllions, who accidentally directed a jet of compressed air at a stream of molten glass and produced fibers

2.6 Advantages of fibre reinforced concrete

The addition of fibre considerably increases the area under the stress strain curve and improves the tensile strength of the member. The advantages of FRC can be summarized as follows:

1) Inclusion of fibres delays the occurrence of first tensile crack. This increases tensile strain capability Of the matrix.
2) It gives the member a well defined post cracking behavior resulting in an increase of post-crack ductility.
3) It improves the energy absorption capacity of the member by enhancing the crack resistance.
4) It also improves the resistance of the member to the impact forces

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2.7 Basic concepts of FRC

All cement based materials are essentially anisotropic and heterogeneous in nature. These contain micro cracks and interfacial discontinuities which are root causes for the propagation of cracks and result in low tensile strength. Such problems caused the evolution of the FRC. The incorporation of short fibres in a relatively brittle cement matrix transforms uncontrolled tensile crack propagation into a slow controlled process. These fibres when provided in adequate proportion, the tensile strains in the concrete can be raised to several folds before failure.

Thus without the fibres the racks run through the matrix very easily. If the cracks are present and if breaking strain of fibres is much greater than the cracking strain of the cement, the fibres remaining in place bridge the cracks. This condition is fulfilled even if the crack in the matrix runs across the fibres. The fibre price remain unbroken. At this stage if the straining is continued the weak cement will break again at another place and again will be held together by the fibres bridging the cracks

2.8 Factors influencing the properties of FRC

The properties of FRC are largely depended on the effective transfer of stress between the and the fibres. Following factors influence the characteristics and the performance of FRC matrix

1) Types of Fibres
2) Aspect Ratio
3) Fibre volume and spacing
4) Orientation of fibres
5) Mix and compaction factor

Fibre type:

The properties of fibre composite is a combined effect of both fibres and matrix. Properties of composite depends on the fibre parameters like diameters, density, modulus of rupture, resistance towards chemical attack, Poission's ratio, elongation etc. Among manmade and natural fibres, steel fibres are better due to their high young's modulus. Natural fibres are not used much in current construction due to its low modulus of elasticity, susceptible to insect and fungal attack.

Aspect Ratio:

Strength of fibres varies with fibre length and diameter. The ratio of length to the diameter of fibre is called the aspect ratio. Increase of aspect ratio increases compressive strength of SFRC upto 60% and beyond this the rate of increase reduces. Thus there is optimum aspect ratio, which varies with type of fibres. If the ratio is less than the optimum, the strength of SFRC reduces. If it is greater than optimum then balling of fibres takes place.Balling of fibres is the tendency of the fibres to unite together while mixing with the matrix and aggregate. Balling causes reduction in the workability of concrete.

Fibre Volume and Spacing:

Volume of fibres is expressed as percentage fraction of volume of concrete. Strength of FRC is found to be linear function of volume of fibres. There is a limit up to which the volume of fibres can be increased. Critical fibre volume is defined as the volume of fibres which could continue to carry the load sustained by FRC before cracking and even after the matrix cracks. The load carrying capacity of fibres after matrix cracking depends on the fibre volume fraction. As the volume of fibre increases spacing decreases.(7) The spacing may be calculated as distance between the centroids of individual fibres or the number of fibres crossing a unit area of given plane section through material.

Fibre Orientation:

One of the differences between conventional reinforcement and fibre reinforcement is that a conventional reinforcing bar is oriented in the direction desired while fibres are randomly oriented. The direction of fibre distribution influences the resistance to crack propagation and tensile strength. Perpendicular fibres have no resistance against crack propagation and tensile strength, whereas parallel fibres have about 30% more toughness than randomly distributed ones.(18) It is interesting to know that the ratio of tensile strength of randomly oriented fibres to parallel fibres is o.85. It is well matching with the theoretically predicted ratio for modulus of elasticity of fibre reinforce composite.

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III. MATERIALS

Fibre reincorced concrete (FRC), obtained by dispersing in concrete, very small sized reinforcement called fibres. The small closely spaced fibres so used act like crack arresters, substantially improve the static and dynamic strengths. That is the properties like toughness, impact resistance and stiffness under different loading conditions are improved. Naturally the properties of fibres influence the properties of FRC composites. When the fibre reinforcement is in the form of short discrete fibres, they act effectively as rigid inclusions in the concrete matrix. Physically, they have thus the same order of magnitude as aggregate inclusions; steel fibre reinforcement cannot therefore be regarded as a direct replacement of longitudinal reinforcement in reinforced and prestressed structural members. However, because of the inherent material properties of fibre concrete, the presence of fibres in the body of the concrete or the provision of a tensile skin of fibre concrete can be expected to improve the resistance of conventionally reinforced structural members to cracking, deflection and other serviceability conditions. The fibre reinforcement may be used in the form of three – dimensionally randomly distributed fibres throughout the structural member when the added advantages of the fibre.

Definition

Fiber reinforced concrete (FRC) may be defined as a composite materials made with Portland cement, aggregate, and incorporating discrete discontinuous fibers. The performance of fibers depends on both the dosage (kg/m^3) and the fibers parameters (tensile strengths, length, diameter and anchorage). A key factor for quality fiber is the relationship between the length and diameter of the fibers. The higher l/d ratio, the better the performance.

The natural fibres like jute, coir, horse hair etc. have got low tensile strength and low elastic modulus. By addition of such fibres static strengths are not improved, while the dynamic properties are improved.

The Artificial fibres can be of both low or high tensile strength. For ex. Nylon, Polypropylene, have got low tensile strength. Steel, Glass, Carbon have got high strength. The earlier three fibres are suitable for the mains structures as they are lease affected by the corrosion.

Types of artificial fibres

Steel fibers

The use of steel fibers has led to the improvement of the concrete's mechanical properties such as material toughness in tension and also durability. Many types of steel fibers are used for concrete reinforcement. Round fibers are the most common type and their diameter ranges from 0.25 to 0.75 mm. Rectangular steel fibers are usually 0.25 mm thick, although 0.3 to 0.5 mm wires have been used in India. Deformed fibers in the form of a bundle are also used. The main advantage of deformed fibers is their ability to distribute uniformly within the matrix.

Figure No- 3.00 Steel fibers

Polypropylene fibers

The capability of durable structure to resist weathering action, chemical attack, abrasion and other degradation processes during its service life with the minimal maintenance is equally important as the capacity of a structure to resist the loads applied on it. Although concrete offers many advantages regarding mechanical characteristics and economic aspects of the construction polypropylene fiber-reinforced concrete (PFRC) has provided a technical basis for improving these deficiencies. This paper presents an overview of the effect of polypropylene

(PP) fibers on various properties of concrete in fresh and hardened state such as compressive strength, tensile strength, flexural strength, workability, bond strength, fracture properties, creep strain, impact.

Figure No- 3.01 Polypropylene fibers

Glass fibers

Figure No- 3.02 Glass Fibers

Benefits of steel fibres

- Improves structural strength
- Improves ductility and load bearing capacity
- Improves impact and abrasion resistance
- Reduces crack width and post crack propagation
- Reduces steel reinforcement requirements

3.1 Types of steel fibers

3.1.1Hooked end steel fibers

Steel fiber with hooked ends is made using high-quality low-carbon steel wire. A kind of high-performance steel fiber, with the characteristics of the high tensile strength, good toughness, low prices, etc. The product is widely used in concrete strengthening.

Hooked ends steel fiber is made in accordance to the country standard YB/T151-1999 Standard for Steel Fibers for Concrete Uses, and the JG/T3064-1999 Standard of Steel Fiber for Concrete Building

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Figure No-3.1.1 Hooked End Steel Fibers

3.2 Ingredients of concrete

Concrete is used extensively as a construction material because of its versatility. It is good in compression, but weak in tension. This drawback can be overcome by providing steel in tension zone. This technique called **"**REINFORCED CEMENT CONCRETE**"**, improves the load carrying capacity of concrete members. At the same time durability of concrete is also important. Durability is mainly affected due to cracks developed by creep and shrinkage. This can be avoided by using certain chemical admixtures. But once a crack develops in the member there are no barriers to stop the propagation of such cracks. In RCC it leads the corrosion of the reinforcement slowly and finally it results in the failure of the structure.

3.2.1 Cement

Cements may be defined as adhesive substances capable of uniting fragments or masses of solid mater to a compact whole. Portland cement was invented in 1824 by an English mason, Joseph Aspin, who named his product Portland cement because it produced a concrete that was of the same colour as natural stone on the Isle of Portland in the English Channel.

Raw materials for manufacturing cement consist of basically calcareous and siliceous (generally argillaceous) material. The mixture is heated to a high temperature within a rotating kiln to produce a complex group of chemicals, collectively called cement clinker. Cement is distinct from the ancient cement. It is termed hydraulic cement for its ability to set and harden under water. Briefly, the chemicals present in clinker are nominally the four major potential compounds and several minor compounds. The four major potential compounds are normally termed as Tricalcium silicate ($3CaO.SiO_2$), declaim silicate ($2CaO.SiO_2$), tricalcium aluminates ($3CaO.Al_2O_3$) and tetra calcium aluminoferrite ($4CaO.\ Al_2O_3.Fe_2O_3$).
The American Society for Testing and Materials (ASTM) Standard C 150, Specification for Portland cement, provides for the following types of Portland cement:

- Type I General Portland cement
- Type II Moderate-Sulphate-Resistant Cement
- Type III High-early-strength cement
- Type IV Low–heat-of-hydration cement
- Type V High-sulphate-resistant cement

3.2.2 Coarse and fine aggregates

- All aggregates shall comply with the requirements of IS: 383-1970
- The nominal maximum size of coarse aggregate shall be as large as possible subject to the following
- In no case greater than one-fourth the minimum thickness of the member, provided that
- The concrete can be placed without difficulty so as to surround all prestressing tendons and reinforcements and fill the corners of the for m.
- It shall be 5 mm less than the spacing between the cables, strands or sheathings where provided
- Not more than 40 mm; aggregates having a maximum nominal size of 20 mm or smaller are generally considered satisfactory
- Coarse and fine aggregates shall be batched separately
- Specification for coarse and fine aggregates from natural sources for concrete *second revision*

The problem is more complicated when the fibres are introduced into a concrete rather than a mortar matrix because they are separated not by a fine grained material which can move easily between them, which may lead

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to bunching of fibres. The uniform fibre distribution is more difficult to achieve as the aggregate size increases from 5mm to 10 mm to 20mm. In a normal concrete mix the particle finer than 5 mm occupy about 54% of the volume

Fine Aggregate*:* River sand passing through 4.75 mm sieve and conforming to grading zone II of IS: 383-1970 was used as the fine aggregate. Normal river sands are suitable for high strength concrete. Both crushed and rounded sands can be used. Siliceous and calcareous sands can be used for production of HSC

Coarse Aggregate: Crushed granite stone with a maximum size of 20 mm was used as the coarse aggregate. The properties of aggregates used

3.2.3 Steel Fibre: Hooked End Steel Fibers with 0.35 mean diameter was used at a volume fraction of 0%, 0.5%,1%.

3.2.4 water

The Requirements of water used for mixing and curing shall conform to the requirements given in IS: 456-2000. However use of sea water is prohibited

IV. METHODOLOGY

This chapter describes the materials used, the preparation of the test specimens and the test procedures. They are listed down in this section. The materials used in this study were cement, sand, aggregates (both fine and coarse) and water. The description of each of the material is described in the following sections.

4.1 Tests on materials

4.1.1 Cememnt

Cement used in this study was KCP brand Ordinary Portland Cement of grade 53. The cement was kept in an airtight container and stored in the humidity controlled room to prevent cement from being exposed to moisture. and various tests were conducted as per codal provisions

4.1.1 a) Initial and final setting time

Initial setting time

Place the test block under the rod bearing the needle. Lower the needle gently in order to make contact with the surface of the cement paste and release quickly, allowing it to penetrate the test block. Repeat the procedure till the needle fails to pierce the test block to a point 5.0 ± 0.5mm measured from the bottom of the mould. The time period elapsing between the time, water is added to the cement and the time, the needle fails to pierce the test block by 5.0 ± 0.5mm measured from the bottom of the mould, is the initial setting time.

Final setting time

Replace the above needle by the one with by a circular attachment. The cement should be considered as finally set when, upon applying the needle gently to the surface of the test block, the needle makes an impression therein, while the attachment fails to do so. The period elapsing between the time, water is added to the cement and the time, the needle makes an impression on the surface of the test block, while the attachment fails to do so, is the final setting time. In other words the paste has attained such hardness that the centre needle does not pierce through the paste more than 0.5 mm

4.1.1 b) Consistency test

The basic aim is to find out the water content required to produce a cement paste of standard consistency as specified by the IS: 4031 (Part 4) – 1988. The principle is that standard consistency of cement is that consistency at which the Vicar plunger penetrates to a point 5-7mm from the bottom of Vicar mould.

4.1.1 c) Specific gravity test

Specific gravity: It is the ratio between the weight of a given volume of material and weight of an equal volume of water. To determine the specific gravity of Cement, kerosene which does not react with cement is used

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Fig 4.1.1 A) - Vicat apparatus

Fig 4.1.1C) – Pycnometer

Table No- 4.1.1 TEST RESULTS OF CEMENT

Characteristics	Test results	IS:12269-1897 specifications
Initial setting time (minutes)	45 minutes	>30 minutes
Final setting time (minutes)	580 minutes	<600 minutes
Consistency	29%	-
Specific gravity	3.15	3.15
Fineness	4.9%	<10%

4.1.2 Coarse and fineaggregates

Locally available graded aggregate of maximum size of 20mm is used for our present investigation. Testing of coarse aggregates was done as per IS: 383-1970. The 20mm aggregates used were first sieved through 20mm sieve and then retained on 4.75 mm sieve. They were then washed to remove impurities such as dust, clay particles and organic matters thereby dried to surface at dry condition. The coarse aggregate is also tested for its various properties by using IS: 2386-1963

4.1.2.1 Sieve analysis (fine and coarse aggregates)

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

$$\textit{Fineness Modulus} = \frac{\sum(\textit{Cumulative retained percentage})}{100}$$

4.1.2.2 Specific gravity (fine and coarse aggregates)

Sieve analysis helps to determine the particle size distribution of the coarse and fine aggregates. This is done by sieving the aggregates as per IS: 2386 (Part I) – 1963. In this we use different sieves as standardized by the IS code and then pass aggregates through them and thus collect different sized particles left over different sieves.

$$\textit{Specific Gravity} = \frac{(W_2 - W_1)}{(W_2 - W_1) - (W_3 - W_4)}$$

4.1.2.3 Bulk density test (fine and coarse aggregates)

Density containers, Weighing balance, Tamping rod of 16mm dia. and 60cm long.

- For F. A- 3lit capacity, 15cm inside dia. and 17cm inside height containers are used.
- For C. A- 15lit capacity, 25cm inside dia. and 30cm inside height containers are used.

$$\textit{Bulk Density} = \frac{(W_2 - W_1)\ \textit{in kg}}{\textit{Capcity of container in lit}}$$

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4.1.2.4 Aggregate crushing value test

This test helps to determine the aggregate crushing value of coarse aggregates as per IS: 2386(Part IV)–1963. The apparatus used is cylindrical measure and plunger, Compression testing machine, IS Sieves of sizes – 12.5mm, 10mm and 2.36mm

$$Aggregate\ Crushing\ Value = \frac{B}{A} \times 100\%$$

Table no.- 4.1.2 Test results of fine aggregate

Property	Test results	IS:2386-1963 Specifications
Fineness modulus	3.4	-
Specific gravity	2.65	2.6-2.8
Bulk density	1475kg/m^3(untraded)	-
	1624kg/m^3(ridded)	-

Table no.- 4.1.2 Test results of coarse aggregate

Property	Test results	IS:2386-1963 Specifications
Fineness modulus	7	-
Specific gravity	2.7	2.6-2.8
Crushing value	22%	<30%
Bulk density	1483kg/m^3(untraded)	-
	1563kg/m^3(ridded)	-
Abrasion test	34%	40%

Table no.- 4.1.2 Details of steel fibers

Synod	ASPECT RATIO (L/D)	Length of fiber (mm)
1	100	30

4.1.3 Water

Water is needed for the hydration of cement and to provide workability during mixing and for placing. There is not much limitation for water except that the water must not severely contaminated. In this study, normal tap water was used.

4.1.4 Mix design

Mix design for M40

Target strength:

In order that not more than the specified portions of test results are likely to fall below the characteristic strength (F_{act}), the concrete mix has to be designed for somewhat higher target average compressive strength (Fa_{ct}).

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$Fc_k=f_{ck}+ts$ (s) ,Fc_k = target average compressive strength at 28 days, F_{ck} = characteristic compressive strength at 28 days =40 Map,S=Standard deviation=5 (from TableNo.- 1 of IS: 10262:2009)**,** t=1.65 (from TableNo.- 2 of IS: 10262:2009)**,** Therefore,**, Fc_k = 40+1.65(5) =48.25 N/mm^2. Cement content (c) = 492.5 kg/m^3.Fine aggregate (fa) = 558 kg/m^3, Coarse aggregate (Ca) = 1132 kg/m^3, Water= 191.16 liters. Therefore mix design is 1:1.17:2.30.**

QUANTITIES OF INGREDIENTS

Mix	Cement(Kg)	Fine aggregate(kg)	Coarse aggregate(kg)	Water (kg)	W/C
M40	478.95	556.51	1129.87	191.58	0.4

MIX PROPORTION

	Mix	Cement	FA	CA	W/C
Ratio	M40	1	1.17	2.30	0.4

Mixes adopted

1. C1 – Nominal mix 2. C2 – 0.5% Steel fibers added 3. C3 – 1.0% Steel fibers added

4.1.5 Mixing procedure

The mixing procedures were divided into three stages. In the first stage, all the binders (cement, met kaolin) were weighted accordingly and mixed by hand until all the constituents mixed uniformly. This was to make sure that all the binders were mixed thoroughly to produce a homogenous mix. The second stage involves mixing the binders with the aggregates for about 5 minutes. At the final stage, measured water was added into the concrete mix. This step was crucially important to make sure that the water was distributed evenly so that the concrete will have similar water-binder ratios for every specimen. After that, the concrete was then poured into the mould.

4.1.6 Preparing test specimens

Moulds of distinct sizes and shapes (cubes, cylinders and beams) are used to produce the specimens. The concrete was poured into the mould in three layers where each layer was compacted using a tamping rod. The specimens were removed from the moulds after 24 hours and are cured by dipping in moist environment.

4.1.7 Curing

In this study, the specimens were cured by placing in water for about 7,14 and 28 days. The specimens were cured until they were ready to be tested at the designated ages.The test specimens shall be stored on the site at a place free from vibration, under damp matting, sacks or other similar material for 24 hours ± ½ hour from the time of adding the water to the other ingredients. The temperature of the place of storage shall be within the range of 22° to 32°C. After the period of 24 hours, they shall be marked for later identification, removed from the moulds and, unless required for testing within 24 hours, stored in clean water at a temperature of 24° to 30°C until they are transported to the testing laboratory. They shall be sent to the testing laboratory well packed in damp sand, damp sacks, or other suitable No.- material so as to arrive there in a damp condition not less than 24 hours before the time of test. On arrival at the testing laboratory, the specimens shall be stored in water at a temperature of 27° ± 2°C until the time of test. Records of the daily maximum and minimum temperature shall be kept both during the period of the specimens remain on the site and in the laboratory.

4.2 Experimental study

In this chapter, The experimental program is designed to understand whether the addition of fibers in high strength concrete and normal strength concrete favours strain hardening and increase of amount of fibers produces identical enhancement of mechanical properties. Different strengths are determined by creating specimens of normal mix ,0.5% and 1.0% of steel fiber mixes and subjecting it to loadings until failure.

4.2.1 Lab tests on fresh concrete

Each batch of concrete shall be tested for consistency immediately after mixing, by one of the methods described in IS: 1199-199. The Methods are: **1. Slump Test- Workability 2. Compaction Factor**

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4.2.1.1 Slump test - workability

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 199 is followed. The apparatus used for doing slump test are Slump cone and tamping rod. Slump cone dimensions :Bottom diameter: 20cm, Top diameter: 10cm. Cone height: 30cm

Reporting of Results: The slump measured should be recorded in mm of subsidence of the specimen during the test. Any slump specimen, which collapses or shears off laterally, gives incorrect result and if this occurs, the test should be repeated with another sample. If in the repeat test also, the specimen shears, the slump should be measured and the fact that the specimen sheared, should be recorded

S.NO	Concrete Type	Slump Value(mm)
01	C1 – Nominal mix	40
02	C2 – 0.5% Steel fibers added	45
03	C3 – 1.0% Steel fibers added	49

SLUMP CONE TEST

4.2.1.2 Compaction factor test

The compacting factor test is designed primarily for use in the laboratory, but it can also be used in the field. The 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 compacting factor is measured by the density ratio.

When maximum size of aggregate is large as compare with mean particle size the drop into bottom container will produce segregation and give unreliable comparison with other mixes of smaller maximum aggregate sizes. The method of introducing concrete into mould bears no relationship to any of the more common methods of placing and compacting high concrete. Compaction factor test establishes the fact that with increase in the size of coarse aggregate the workability will decrease.

Compacting factor = (Weight of partially compacted concrete)/(Weight of fully compacted concrete)

S.NO	Concrete Type	Partially compacted weight (kg)	Fully compacted weight (kg)	Compacting factor
01	C1 – Nominal mix	17.540	19.710	0.890
02	C2 – 0.5% Steel fibers added	17.420	19.910	0.875
03	C3 – 1.0% Steel fibers added	18.0851	20.320	0.895

Suggested ranges of workability of concrete measured in accordance with IS 1199 are given below:

S.NO	Degree of workability	Slump Test value		Compacting Factor	Use for which concrete is suitable
		mm	In		
01	Very low	0-25	0-1	0.78	Very dry mixes; used in road making. Roads vibrated by power operated machines.
02	Low	25-50	1-2	0.89	Low workability mixes; used for foundations with light reinforcement. Roads vibrated by hand operated Machines.

4.2.2 Lab tests on hardened concrete

There are two kinds of tests which are done on hardened concrete. These are:

i). Non-destructive tests
ii). Destructive tests.

4.2.2.1 Non-destructive tests

In Non-destructive test, the sample is not destroyed and this test is very useful in determining the strength of existing buildings or structures. The Non-destructive tests conducted on concrete are as follows:

1. **Rebound Hammer test**

Rebound hammer for in situ evaluation of compressive strength of grade of concrete

2. **Ultrasonic pulse velocity test**

Ultra sonic pulse velocity apparatus for the detection of cracks in the concrete

4.2.2. Destructive tests.

In destructive test a sample is made and then destroyed to find out the strength of concrete. The destructive tests conducted on concrete are as follows:

a. Compressive strength test
b. Tensile strength test
c. Flexural strength test

The tests adopted in this study are only the destructive tests. These tests are done by using Universal Testing Machine (UTM).

4.2.2.1 Compressive strength test

According to Indian Standard specifications **(IS : 516-1959)** ,the compression test on cubes of size 150mm X 150 mm X 150 mm were conducted. Compressive test is the most common test conducted on hardened concrete , partly because it is an easy test to perform and partly because most of the desirable characteristics properties of the concrete are qualitatively related to its compressive strength . Metal moulds preferably steel bar 16mm in diameter , 0.6m long and bullet pointed at the lower end serves as a tamping bar. The test cube specimens are made as soon as practicable concrete with neither segregation nor excessive laitance . The concrete is filled in to the moulds in layers approximately 5cm deep , each layer is compared by the tamping rod in 25 strokes. The test specimens are stored in a place free from vibration , in moist air of at least 90% relative humidity and at a temperature of 27°C for 24 hours. After thus period the specimens are marked and removed from the moulds and unless required for test within 24 hours, immediately submerged in clean fresh water or saturated lime solution and kept their until taken out just prior to test. The dried specimens are then tested on compressive testing machine.

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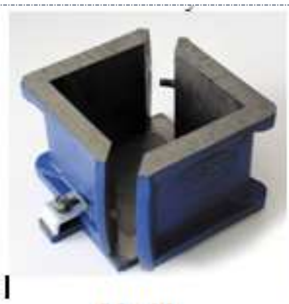
Mould


placing of concrete


De-Moulding


Curing

$$Compression\ Strength = \frac{Load\ in\ N}{Area\ in\ mm^2}$$

Minimum three specimens should be tested at each selected age. If the strength of any Specimen varies by more than 1 per cent of average strength, results of such specimen should be rejected. Average of three specimens gives the crushing strength of concrete


Specimen after Testing in Compression testing machine

Table No- 4.2.2.1 Compressive strength test results

(M40 grades of concrete at 7 and 28 days)

S.No	Type of Concrete	Compressive strength(Mpa)	
Number of days		7 days	28 days
01	C1 – Nominal mix	45.5	48.29
02	C2 – 0.5% Steel fibers added	47.66	54.51
03	C3 – 1.0% Steel fibers added	54.97	61.03

4.2.2.2 Split tensile test

The tensile strength is one of the basic and important properties of the concrete . The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However , the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure.

Apart from the flexural test the other methods to determine the tensile strength of concrete can be broadly classified as (a) direct method (b) indirect method. The direct method suffers from a number of difficulties related to holding the specimen properly in the testing machine without introducing stress concentration , and to the application of un axial tensile load which is free from eccentricity to the specimen. As the concrete is weak in tension even a small eccentricity to

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the load will induce combined bending and axial force condition and the concrete fails at apparent tensile stress other than the tensile strength. As there are many difficulties associated with the direct tension test a, number of indirect methods has been developed to determine the tensile strength In these tests in general a compressive force is applied to a concrete specimen in such a way that the specimen fail s due to tensile stresses developed in the specimen. The tensile stress at which the failure occurs is termed as the tensile strength of concrete.

The splitting tests are well known indirect tests used for determining the tensile strength of concrete sometimes referred to as split tensile strength of concrete. The test consist of applying a compressive line load along the opposite generators of a concrete cylinder 15 cm diameter and 30 cm long placed with its axis horizontal between the compressive platens . Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter as obtained from an elastic analysis.
The magnitude of the tensile stress f_t (acting in a direction perpendicular to the line of action of applied loading) is given by the formula **(IS : 816-1999)** .

$$Split\ Tensile\ Test, Tsp = \frac{2P}{\pi DL}$$

Table No- 4.2.2.2 Split tensile strength test results

(M40 grades of concrete at 7 and 28 days)

S.No	Type of Concrete	Split Tensile Strength Test (Mpa)	
Number of days		7 days	28 days
01	C1 – Nominal mix	2.60	3.18
02	C2 – 0.5% Steel fibers added	2.82	3.81
03	C3 – 1.0% Steel fibers added	3.39	4.45

4.2.2.3 Flexural strength test

It is the ability of a beam or slab to resist failure in bending. It is measured by loading un-reinforced 5x5 inch (10 x 10 cm) concrete beams with a span three times the depth (usually 18 in.). The flexural strength is expressed as "Modulus of Rupture" (MR). Flexural MR is about 12 to 20 percent of compressive strength depending on the type, size and volume of coarse aggregate used. However, the best correlation for specific materials is obtained by laboratory tests for given materials and mix design.

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The flexural strength of the specimen shall be expressed as the modulus of rupture f_s, which, if '*a*' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0.5 kg/sq cm as follows

$$f_s = \frac{P \times l}{b \times d^2}$$

The flexural strength of the specimen shall be expressed as the modulus of rupture f_s, which, if '*a*' equals the distance between the line of fracture and the nearer support, measured on the centre line of the tensile side of the specimen, in cm, shall be calculated to the nearest 0. kg/sq cm as follows:

Table No- 4.2.2.3 Flexural strength test results
(M40 grades of concrete at 7 and 28 days)

S.No	Type of Concrete	Flexural Strength Test (Mpa)	
Number of days		7 days	28 days
01	C1 – Nominal mix	6.05	6.20
02	C2 – 0.5% Steel fibers added	8.90	9.20
03	C3 – 1.0% Steel fibers added	11.50	12.05

V. RESULTS AND DISCUSSION

In this chapter, all the strength performance of various mixes containing different percentage of steel fibers will be discussed. All the tests conducted were in accordance with the methods described in this chapter. Different strengths are determined by creating specimens of normal mix ,0.5% and 1.0% of steel fiber mixes and subjecting it to loadings until failure

5.1 Compressive strength

In this section, the main concern is to study the compressive strength of concrete containing various percentages of steel fibers in combination. Control specimens are concrete with 100% cement which is compared with the strength performance of concrete containing 0.5% and 1.0% of steel fiber.

Cubes with the size of 150mm X 150 mm X 150 mm were tested at the ages of 7 and 28 days. The results of the compressive strength test are shown in Table No.- **4.2.2.1**. Where each value from the results of two cubes.

From the graph shown in the Fig**.5..1**.specimens are concrete with 100% cement which is compared containing 0.5% and 1.0% of steel fiber, (normal mix ,0.5% and 1.0% of steel fibers) has been observed as an optimal strength than other proportions at 7 and 28 days.

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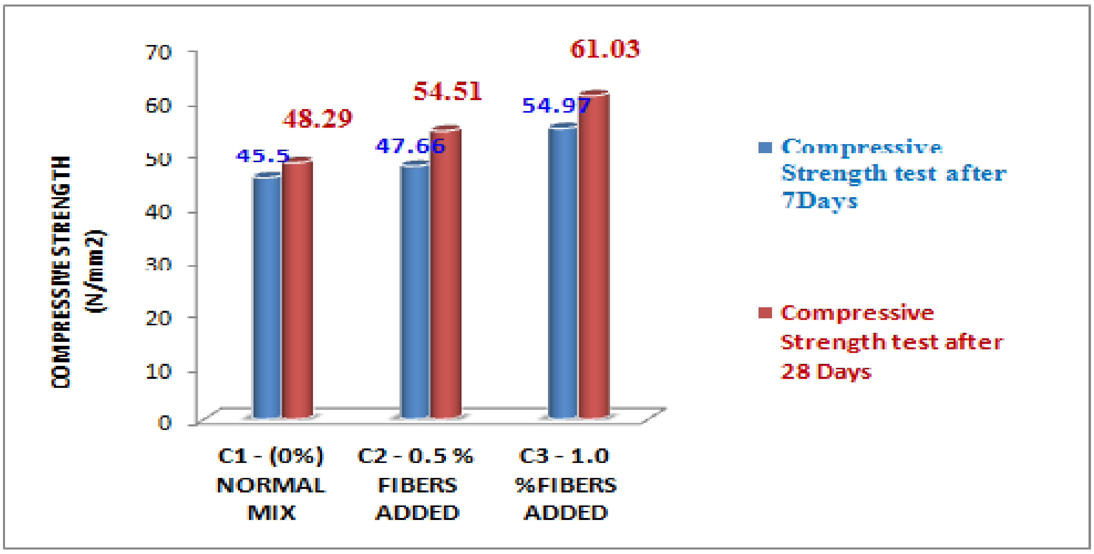


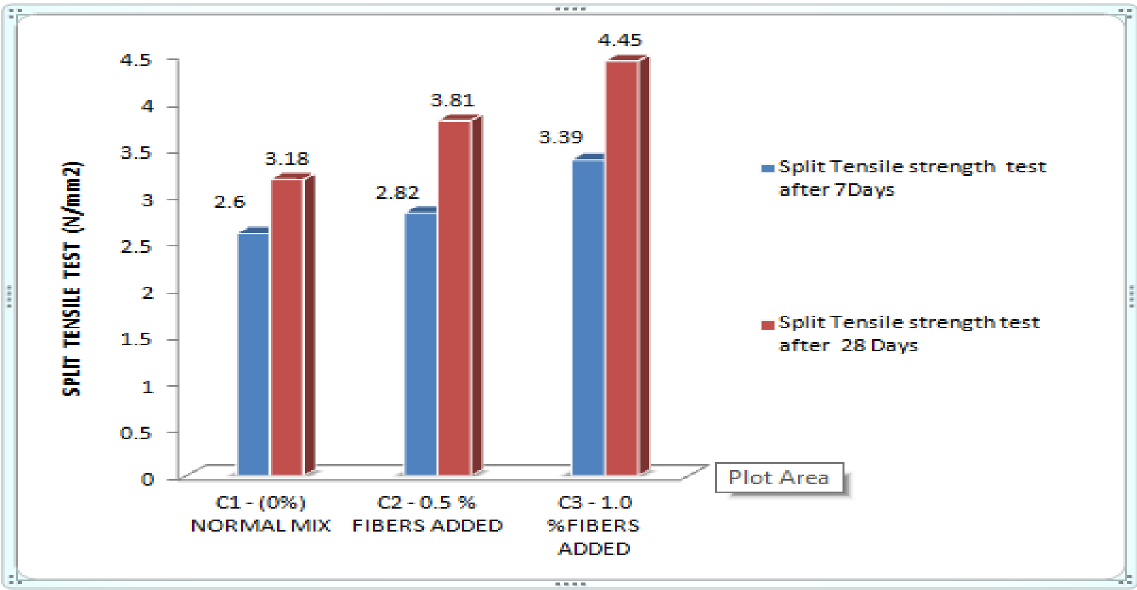
Graph 5.1 showing Compressive Strength of Three types of concrete(C1,C2,C3)

5.2 Split tensile test

In this section, the main concern is to study the Split Tensile strength of concrete containing various percentages of steel fibers in combination. Control specimens are concrete with 100% cement which is compared with the strength performance of concrete containing 0.5% and 1.0% of steel fiber.

The Cylinder consist of 150 mm diameter and 300mm Long were tested at the ages tested at the ages of 7 and 28 days. The results of the Split Tensile strength test are shown in Table No.- **4.2.2.2** Where each value from the results of two cubes.

From the graph shown in the Fig.**5.2** specimens are concrete with 100% cement which is compared containing 0.5% and 1.0% of steel fiber, (normal mix ,0.5% and 1.0% of steel fibers) has been observed as an optimal strength than other proportions at 7 and 28 days.



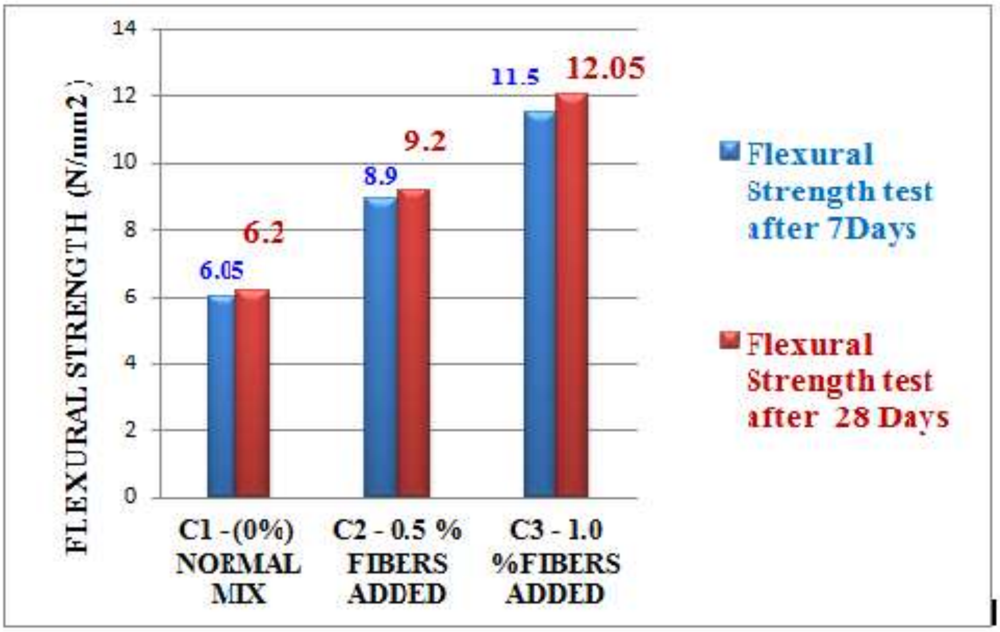
Graph 5.2 showing Split Tensile Test of Three types of concrete(C1,C2,C3)

5.3 Flexural strength test

In this section, the main concern is to study the flexural strength test of concrete containing various percentages of steel fibers in combination. Control specimens are concrete with 100% cement which is compared with the strength performance of concrete containing 0.5% and 1.0% of steel fiber.

The size of specimen shall be 10 × 10 × 50 cm tested at the ages tested at the ages of 7 and 28 days. The results of the Split Tensile strength test are shown in Table No.- **- 4.2.2.3**. Where each value from the results of two cubes.

From the graph shown in the Fig.**5.3** specimens are concrete with 100% cement which is compared containing 0.5% and 1.0% of steel fiber, (normal mix ,0.5% and 1.0% of steel fibers) has been observed as an optimal strength than other proportions at 7 and 28 days.



Graph 5.3 showing Flexural Strength Test of Three types of concrete(C1,C2,C3)

VI. CONCLUSION

Fiber reinforced concrete and high strength concrete are being widely used as important constructional materials due to their excellent properties. An extensive knowledge of the properties is necessary in order to make best and economic use of the material. In this context, present experimental investigation aims to find the different strength characteristics of high strength FRC. (M40)

1. In **Compressive strength test** results the Concrete mix containing 1.0% Steel fibers (C - 3) as maximum improvement of 26.3% is observed.
2. In **Split Tensile strength test** results the Concrete mix containing 1.0 Steel fibers (C - 3) as maximum improvement of 39.9% is observed
3. In **Flexural strength Test** results the concrete mix containing 1.0 Steel fibers (C - 3) as maximum improvement of 84.4% is observed.
4. For heavy structures in order to decrease secondary reinforcement steel fibers is very much useful.
5. In certain critical places the crack penetration can be arrested by using fibers.
6. By using fibers in concrete, micro crack can be arrested.

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