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AN EXPERIMENTAL INVESTIGATION ON STRENGTH PROPERTIES OF FIBER REINFORCED CONCRETE (STEEL AND GLASS 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. 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. 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 Pure concrete, steel fibers and Glass Fibers with to volume fraction of 0.0%,0.25%,0.5% , 0.75% and 1% and for aspect ratio and considered for M40 Grade of concrete. The results of the tests showed that the strength properties are enhanced due to addition of glass fibers.

KEYWORDS: Fiber Reinforced Concrete, Steel fibers, Glass Fibers, Volume Fraction, Compressive strength, Aspect Ratio, Mechanical Properties

I. INTRODUCTION
Concrete is one of the most common materials used in the construction industry for centuries. Due to sustainable consumption and growth in the civil infra structure systems, there is a raise in the requirement of construction materials that are designed and used with almost attention to their durability and long term strength. In the past few years, many researchers have been made for the improvement of performance of concrete in various desired characteristics. There is always a search for concrete with higher strength and durability. Concrete has relatively high compressive strength, but much lower tensile strength. Also, Concrete has a very low coefficient of thermal expansion and shrinks as it natures. 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 structures. It is now well established that one of the important properties of Fiber Reinforced Concrete is its superior resistance to cracking and crack propagation. As a result of this ability to arrest crack, 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. However, adding fibers causes relatively little improvement in impact resistance. Steel Fibers transforms the brittle to ductile type of material would increase substantially the energy absorption characteristics of the Fiber composite and its ability

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to with stand repeatedly applied, shock or impact loading. 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. 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. The performance required by the FRC so as to achieve in the finished structure the performance that was assumed in the design

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 behaviour, 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. In view of this, care must be taken in the mixing procedures. Most commonly, when using a transit mix truck or revolving drum mixer, the fibers should be added last to the wet concrete. FRC can be placed adequately using normal concrete equipment. It appears to be very stiff because the fibers tend to inhibit flow; however when vibrated, the material will flow readily into the forms. It should be noted that water should be added to FRC mixes to improve the workability

1.2 CONCEPT 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 pure concrete and FRC (steel and glass fiber) using different proportions (0.0%, 0.25%, 0.50%,0.75%,1.0%) in M40 grades of concrete. The characteristics studied are compressive strength (cube strength, size of specimen 150mm*150mm*150 mm), split tensile strength (cylinder strength, size of specimen 150 mm diameter and 300mm length),flexural strength,(beam strength, size of specimen 100mm*100mm*500mm).

I. LITERATURE REVIEW

It is now well established that one of the important properties of fiber reinforced concrete (FRC) 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. Nguyen Van CHANH " Experimental and theoretical investigation on steel fiber reinforced concrete"
2. Roger Leinen "A study on Steel Fiber Reinforced concrete (SFRC) forindustrial floors especially slabs without joints and slabs on piles".
3. Groth, P., ―Fibre Reinforced Concrete—Fracture Mechanics Methods Applied on Self-Compacting Concrete and Energetically Modified Binders,‖ doctoral thesis, Department of Civil and Mining Engineering, Division of Structural Engineering, Luleå University of Technology, Luleå, Sweden, 2000, 237 pp.

2.2 LITERATURE SURVEY ON CONCRETE

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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.

2.2.1 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 and chloride ingres

2.2.2 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.

2.2 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).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.

2.3 HISTORY OF FRC

FRC 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. 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.

II. FIBER REINFORCED COCRETE

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. Now, why would we wish to add such fibres to concrete? Plain, unreinforced concrete is a brittle material, with a low tensile strength and a low strain capcity. The role of randomly distributes discontinuous fibres is to bridge across the cracks that develop provides some post- cracking ―ductility‖. If the fibres 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. 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. The

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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.

3.2 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.

3.3 APPLICATIONS OF FIBRE REINFORCED CONCRETE

The applications of FRC will depend on the ingenuity of designer and builder in taking advantage of the static and dynamic tensile strength, energy absorption characteristics and fatigue strength.

3.4 STRUCTURAL USE OF FRC

As recommended by ACI Committee 544, 'When used in structural applications, steel and glass fiber reinforced concrete should only be used in a supplementary role to inhibit cracking, to improve resistance to impact or dynamic loading, and to resist material disintegration in structural members where flexural or tensile loads will occur. the reinforcing steel must be capable of supporting the total tensile load'. Thus, while there is no. of techniques for predicting the strength of beams reinforced only with steel fibers, there are no predictive equations for large FRC beams, since these would be expected to contain conventional reinforcing bars as well. An extensive guide to design considerations for FRC has recently been published by the American concrete institute. In this section, the use of FRC will be discussed primarily in structural members which also contains conventional reinforcements.

3.5 FACTORS INFLUENCING THE PROPERTIES OF FRC

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

3.5.1 TYPES OF FIBRES

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.

3.5.2 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 FRC up to 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 FRC 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.

3.5.3 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. The spacing may be calculated as

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distance between the centroids of individual fibres or the number of fibres crossing a unit area of given plane section through material

3.5.4 ORIENTATION OF FIBRES

One of the difference 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. 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.

3.6 CLASSIFICATIONS OF FIBERS

A) Natural Fibres

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.

B) Artificial Fibres

The Artificial fibres can be of both low or high tensile strength. For ex. Nylon, Polypropylene, polyethylene 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.

The use of fibres to arrest the propagation of cracks in concrete structures would be of great advantage in improving the quality of structure built in industrial environments. FRC has got wide uses in overlays, precast units such as purlins, girders, trusses and structures requiring resistance to shocks. FRC can also be used in overlays of air field, highway pavements, heavy duty floors, machine bases etc.FRC can be used in thin precast units subjected to flexural loading like piles, fence posts, steps, manhole covers etc. FRC has also got wide potential for application in situation where toughness is important in structures requiring resistance to thermal shocks such as refractory linings, explosive stores. Pads for vertical take off and air craft tank turning pads.

3.7 TYPES OF ARTIFICIAL FIBRES

3.7.1 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.

Fig.No 3.7.1 Steel fibers

3.7.2 GLASS FIBERS

Glass fiber-reinforced concrete uses fiber glass, much like you would find in fiber glass insulation, to reinforce the concrete. The glass fiber helps insulate the concrete in addition to making it stronger. Glass fiber also helps prevent the concrete from cracking over time due to mechanical or thermal stress. In addition, the glass fiber does not interfere with radio signals like the steel fiber reinforcement does.Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths, or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete

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Fig No- 3.9.5 Glass Fibers

3.8 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

3.9 INGREDIENTS OF FIBRE REINFORCED CONCRETE (FRC)

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**"**.

3.9.1 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 ($4CaO.\ Al_2O_3.Fe_2O_3$).

3.9.2.1 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.

3.9.2.2 COARSE AGGREGATE

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

3.9.3 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.

3.9.4 STEEL FIBRE

Hooked End Steel Fibers with 0.35 mean diameter was used at a volume fraction of 0.00%, 0.25%,0.50%,0.75% and 1.00%

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3.9.5 GLASS FIBER

Glass fiber is made up from 200-400 individual filaments and each fibers of a length of 25mm. was used at a volume fraction of 0.00%, 0.25%,0.50%,0.75% and 1.00%.

I. METHODOLOGY

This chapter describes the materials used, the preparation of the test specimens and the test procedures. They are listed down in this section.

4.2 MATERIALS

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

4.2.1 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 code provisions

4.2.1.1 INITIAL AND FINAL SETTING TIME

We need to calculate the initial and final setting time as per IS: 4031 (Part 5) – 1988. To do so we need Vicar apparatus conforming to IS: 5513 – 1976, Balance, Gauging trowel conforming to IS: 10086 – 1982.

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.

4.2.1.2 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.

Apparatus – Vicat apparatus conforming to IS: 5513 – 1976, Balance, Gauging trowel conforming to IS: 10086 – 1982.

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Fig No- 4.2.1.1 and 4.2.1.2 Vicat apparatus

4.2.1.3 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.

Apparatus: Density bottle (or) Specific gravity bottle, Cement, weighing balance capable of weighing accurately up to 0.1gm, kerosene (free from water).

Fig 4.1.1C) – Pycnometer

The Cement is tested by conducting various tests as per IS: 12269 -1987(53 grade) and the test results obtained are represented in the Table No.- 4.2.1

Table No.- 4.2.1 Test Results of Cement obtained

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%

4.2.2 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

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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

4.2.2.1 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.

Apparatus -

A set of IS Sieves of sizes – 80mm, 63mm, 50mm, 40mm, 31.5mm, 25mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm,4.75mm, 3.35mm, 2.36mm, 1.18mm, 600µm, 300µm, 150µm and 75µm.

Balance with an accuracy to measure 0.1 percent of the weight of the test sample.

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

4.2.2.2 SPECIFIC GRAVITY (FINE AND COARSE AGGREGATES)

Apparatus: Pycnometer bottle (or) Specific gravity bottle, Aggregates (Fine and Coarse), weighing balance capacity not less than 3kg, water

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

4.2.2.3 BULK DENSITY TEST (FINE AND COARSE AGGREGATES)

Apparatus:

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

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

4.2.2.4 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

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Table No.- 4.2.2 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/m³(untraded)	-
	1624kg/m³(ridded)	-

Table No.- 4.2.2 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/m³(untraded)	-
	1563kg/m³(ridded)	-
Abrasion test	34%	40%

Table No.- 4.2.3 A) Details of steel fibers

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

Table No.- 4.2.3 B) Details of Glass fibers

Synod	ASPECT RATIO (L/D)	Length of fiber (mm)
1	100	25

4.2.4 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.

4.3 MIX DESIGN

For ordinary concrete: 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}).**Fc_k=f_{ck}+ts (s).** Fc_k = target average compressive strength at 28 days,F_{ck} = characteristic compressive strength at 28 days =40 Ma, S=Standard deviation=5 (from TableNo.- 1 of IS: 10262:2009) t=1.65 (from TableNo.- 2 of IS: 10262:2009). **Fc_k = 40+1.65(5) =48.25N/mm²** **Cement content (c) = 492.5 kg/m³,Fine aggregate fa = 558 kg/m³,Coarse aggregate Ca = 1132 kg/m³, Water = 191.16 liters, Therefore mix design is 1:1.17:2.30.**

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MIX PROPORTION

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

MIXES ADOPTED
1. Pure Concrete
2. 0.25%,0.50%,075% and 1.0% of Steel fibers are added to Concrete
3. 0.25%,0.50%,075% and 1.0% of Glass fibers are added to Concrete

4.4 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.

4.5 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.

4.6 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.

III. 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 ,0.25%,0.5%0.75% and 1.0% of steel fiber and Glass fibers mixes and subjecting it to loadings until failure.

5.2 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:
- ❖ Slump Test- Workability
- ❖ Compaction Factor

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.

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Table No.- 5.2.1 Slump Cone Test Results

S.No	Concrete type	% Of Fibers Added	Slump Value In "mm"
01	Pure Concrete	0.00%	40
02	Steel Fibers	0.25%	43
03		0.50%	45
04		0.75%	48
05		1.00%	50
06	Glass Fibers	0.25%	38
07		0.50%	40
08		0.75%	43
09		1.00%	48

Fig.No-5.2.1 B) Slump Cone Test

5.2.2 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.

Table No.- 5.2.2 Compaction factor Test Results

S.NO	Concrete Type	% Of Fibers Added	Partially compacted weight (kg)	Fully compacted weight (kg)	Compacting factor
01	Pure Concrete	0.00%	17.540	19.710	0.890
02	Steel Fibers	0.25%	17.200	19.99	0.860
03		0.50%	17.420	19.910	0.875
04		0.75%	17.450	19.815	0.880
05		1.00%	17.80	19.90	0.890
06	Glass Fibers	0.25%	17.450	19.750	0.883
07		0.50%	17.468	19.850	0.880
08		0.75%	17.66	19.850	0.890
09		1.00%	17.899	19.910	0.899

Fig.No-5.2.2 Compaction Factor test

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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.

5.3.2 DESTRUCTIVE TESTS

In destructive test a sample is made and then destroyed to find out the strength of concrete. The tests adopted in this study are only the destructive tests. These tests are done by using Universal Testing Machine (UTM).

5.3.2.1 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.

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

Fig.No- 5.3.2.1 E) Specimens Under Testing

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Table No.- 5.3.2.1 Test Results of Compressive strength Test

(M40 Grades of concrete at 3,7 and 28 days)

Compressive strength Test Results After 3,7 and 28 days (Mpa)					
S.No	Concrete type	% Of Fibers Added	Compressive strength(Mpa)		
			3 Days	7 Days	28 Days
01	Pure Concrete	**0.00%**	**42.25**	**45.33**	**48.29**
02	Steel Fibers	0.25%	43.20	46.55	50.67
03		0.50%	45.12	47.66	54.97
04		0.75%	45.85	48.33	59.30
05		**1.00%**	**46.35**	**48.29**	**61.30**
06	Glass Fibers	0.25%	41.33	44.25	45.25
07		0.50%	43.12	45.45	47.30
08		0.75%	44.66	46.88	49.55
09		**1.00%**	**46.10**	**47.7**	**51.11**

5.3.2.2 SPLIT TENSILE STRENGTH 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.

Fig.No- 5.3.2.2 B) Specimens under testing

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

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Split Tensile Strength Test Results After 3,7 and 28 days (Mpa)					
S.No	Concrete type	% Of Fibers Added	Split Tensile Strength (Mpa)		
			3 Days	7 Days	28 Days
01	Pure Concrete	**0.00%**	**2.3**	**2.6**	**3.0**
02	Steel Fibers	0.25%	2.40	2.55	3.20
03		0.50%	2.45	2.82	3.81
04		0.75%	2.90	3.22	3.50
05		**1.00%**	**3.10**	**3.39**	**4.45**
06	Glass Fibers	0.25%	2.50	2.85	3.10
07		0.50%	2.750	3.00	3.60
08		0.75%	2.90	3.10	3.80
09		**1.00%**	**3.00**	**3.40**	**4.00**

5.3.2.3 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.

Testing Machine: The testing machine used is UTM (universal testing machine). The permissible errors shall be not greater than ± 0.5 percent of the applied load where a high degree of accuracy is required and not greater than ± 1.5 percent of the applied load for commercial type of use. The bed of the testing machine shall be provided with two steel rollers, 38 mm in diameter, on which the specimen is to be supported, and these rollers shall be so mounted that the distance from centre to centre is 60 cm for 15.0 cm specimens or 40 cm for 10.0 cm specimens. The load shall be applied through two similar rollers mounted at the third points of the supporting span that is spaced at 20 or 13.3 cm centre to centre. The load shall be divided equally between the two loading rollers, and all rollers shall be mounted in such a manner that the load is applied axially and without subjecting the specimen to any tensional stresses or restraints.

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

Fig.No 5.3.2.3B) Specimens under testing

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Table No.- 5.3.2.3 Test Results Of Flexural Strength Test (M40 Grades of concrete at 3,7 and 28 days)

Flexural Strength Test Results After 3,7 and 28 days (Mpa)					
S.No	Concrete type	% Of Fibers Added	Flexural Strength (Mpa)		
			3 Days	7 Days	28 Days
01	Pure Concrete	0.00%	5.50	6.0	6.50
02	Steel Fibers	0.25%	6.35	6.95	7.45
03		0.50%	8.00	8.90	9.10
04		0.75%	8.90	9.120	9.88
05		1.00%	10.12	11.50	12.60
06	Glass Fibers	0.25%	5.70	6.10	6.55
07		0.50%	6.40	7.10	7.65
08		0.75%	8.0	8.45	8.88
09		1.00%	9.88	10.75	11.80

VI. RESULT ANALYSIS

In this chapter, all the strength performance of various mixes containing different percentage of steel fibers and glass 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(M40),0.25%,0.50%,0.75%and 1.0% of steel fibers and glass fibers mixes and subjecting it to loadings until failure.

6.2.1. 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 0.25%,0.50%,0.75% and 1.0% of steel fibers and glass fibersCubes with the size of 150mm X 150 mm X 150 mm were tested at the ages of 3,7 and 28 days. The results of the compressive strength test are shown in Table No.- 5.3.2.1.

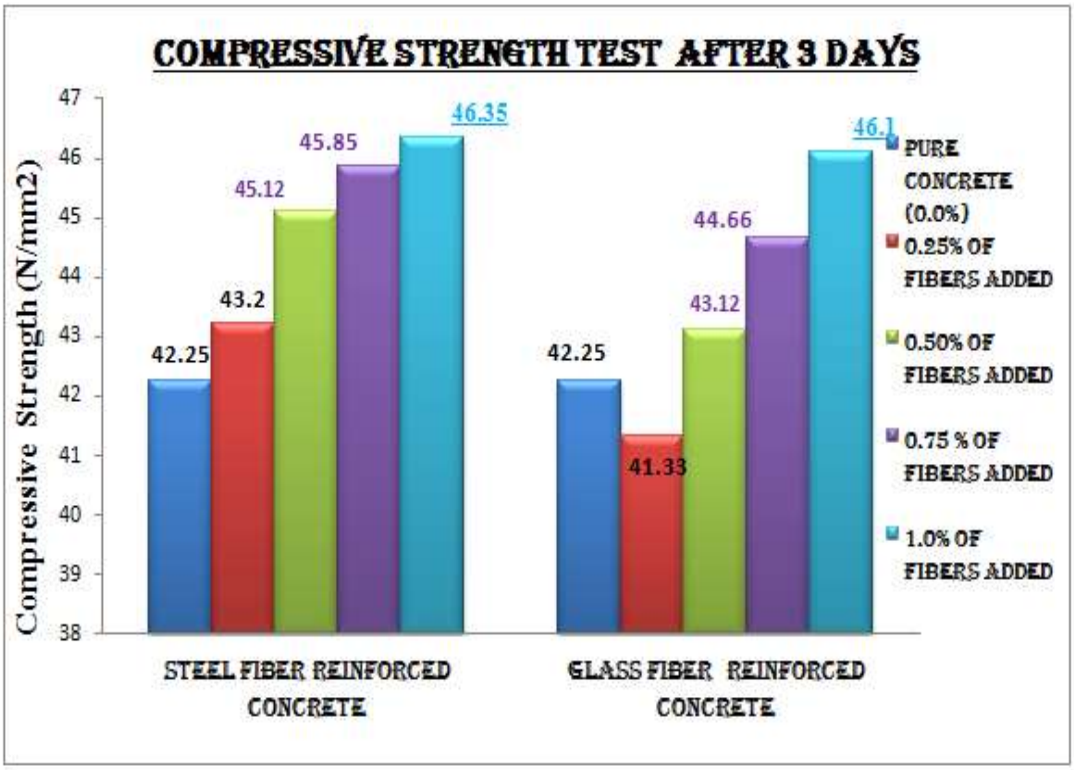

Fig.No -6.2.1 A) Compressive Strength Test After 3 Days

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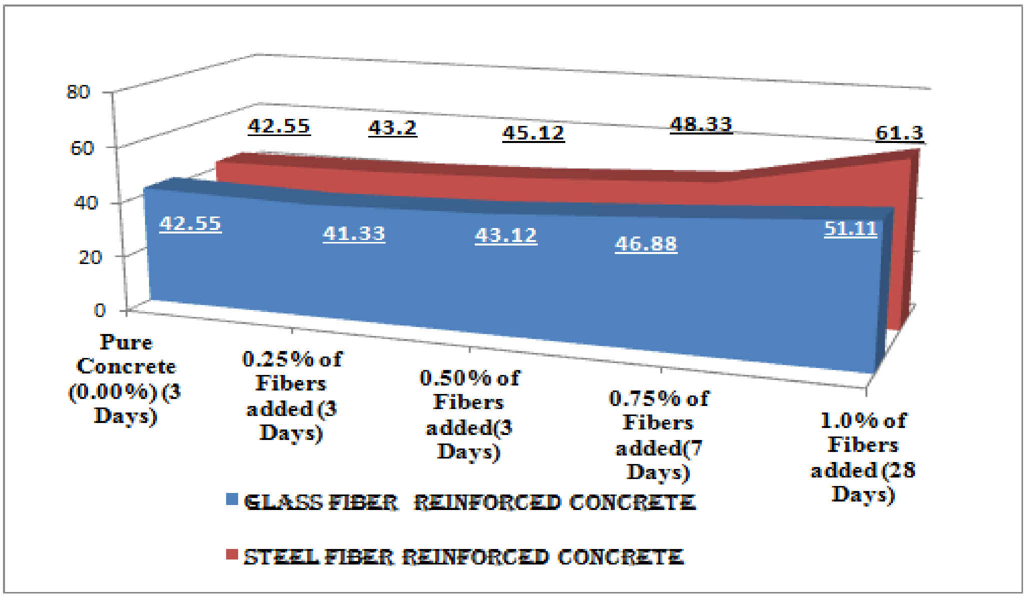

Fig.No -6.2.1 Compressive Strength of Concrete

6.2.2 SPLIT TENSILE STRENGTH 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 0.25%,0.50%,0.75% and 1.0% of steel fibers and glass fibers The Cylinder consist of 150 mm diameter and 300mm Long were tested at the ages tested at the ages of 3,7 and 28 days. The results of the Split Tensile strength test are shown in Table No.- 5.3.2.2

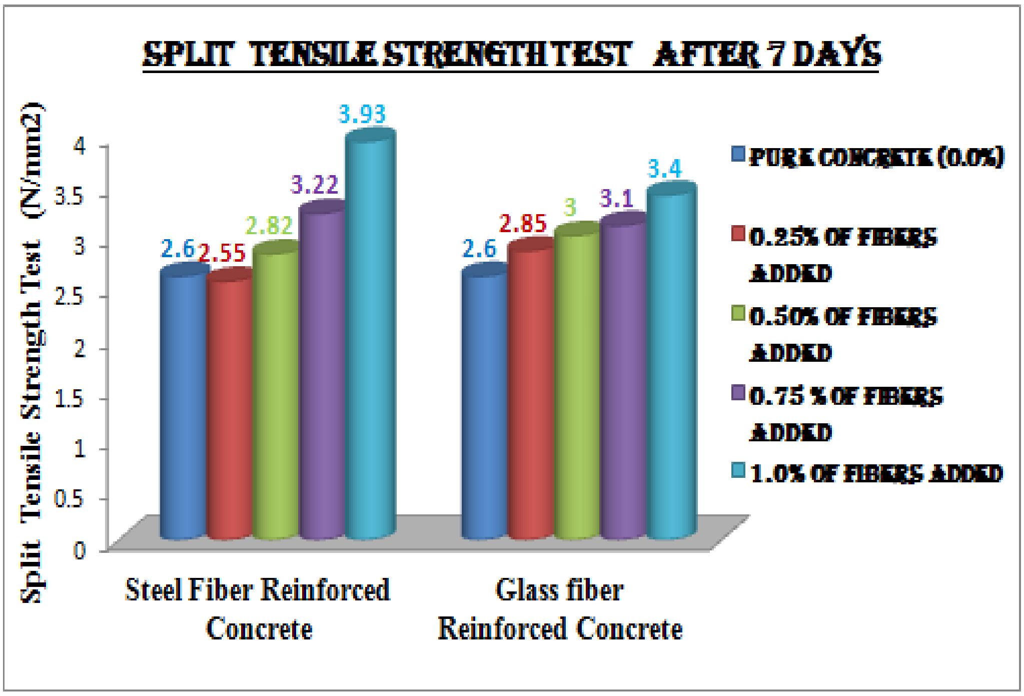

Fig.No -6.2.2 B) Split Tensile strength of Concrete After 7 Days

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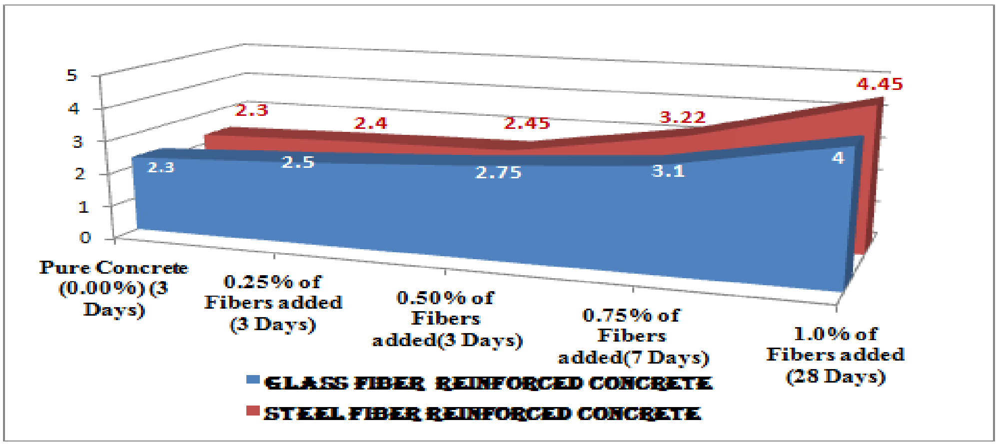

Fig.No -6.2.2 Split Tensile strength Test Results

6.2.3 FLEXURAL STRENGTH TEST

In this section, the main concern is to study the flexural 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 0.25%,0.50%,0.75% and 1.0% of steel fibers and glass fibers.

The size of specimen shall be 10 × 10 × 50 cm tested at the ages tested at the ages of 3,7 and 28 days. The results of the Split Tensile strength test are shown in Table No.- 5.3.2.3

From the graph shown in the Fig.6.2.3 A,B,C specimens are concrete with 100% cement which is compared containing 0.25%,0.50%,0.75% and 1.0% of steel fibers and glass fibers has been observed as an optimal strength than other proportions at 3,7 and 28 days.

From the above graph we can finally obtained the result of flexural strength of concrete with pure concrete and with different proportions of Steel and Glass fibers 0.25%m0.50%,0.75% and 1.00% are added. The test results are gradually increase with the age of curing and added fiber content the maximum age limit of curing in our investigation 28 days. The final results are occurs at 28 days with 1.0% fibers are added.

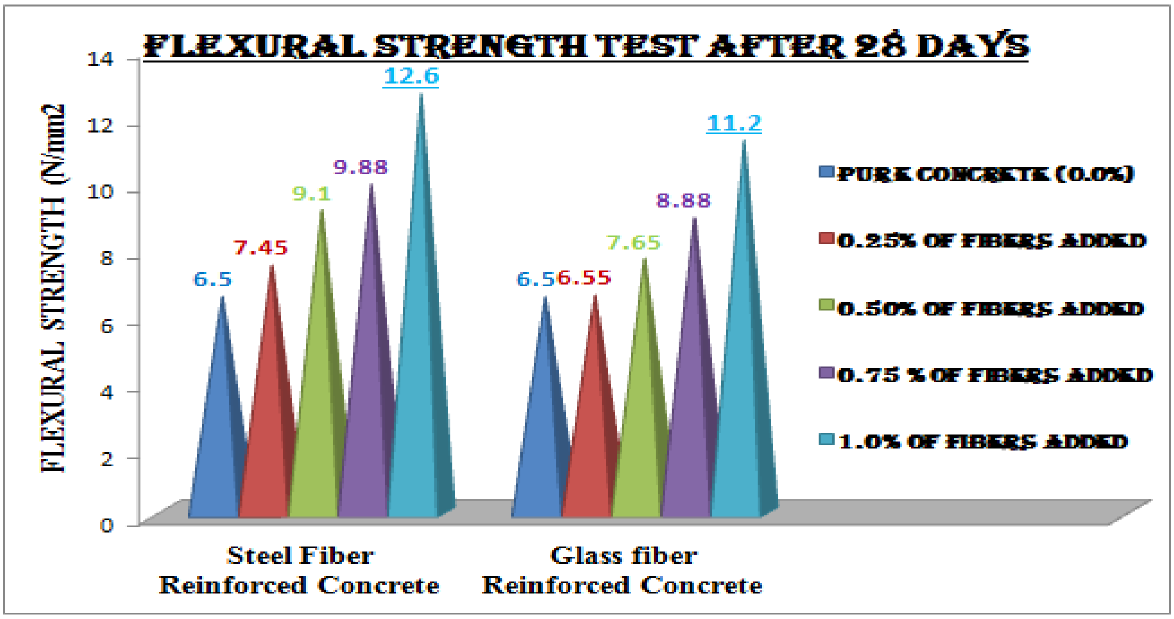

Fig.No -6.2.3 C) flexural strength Test of Concrete After 28 Days

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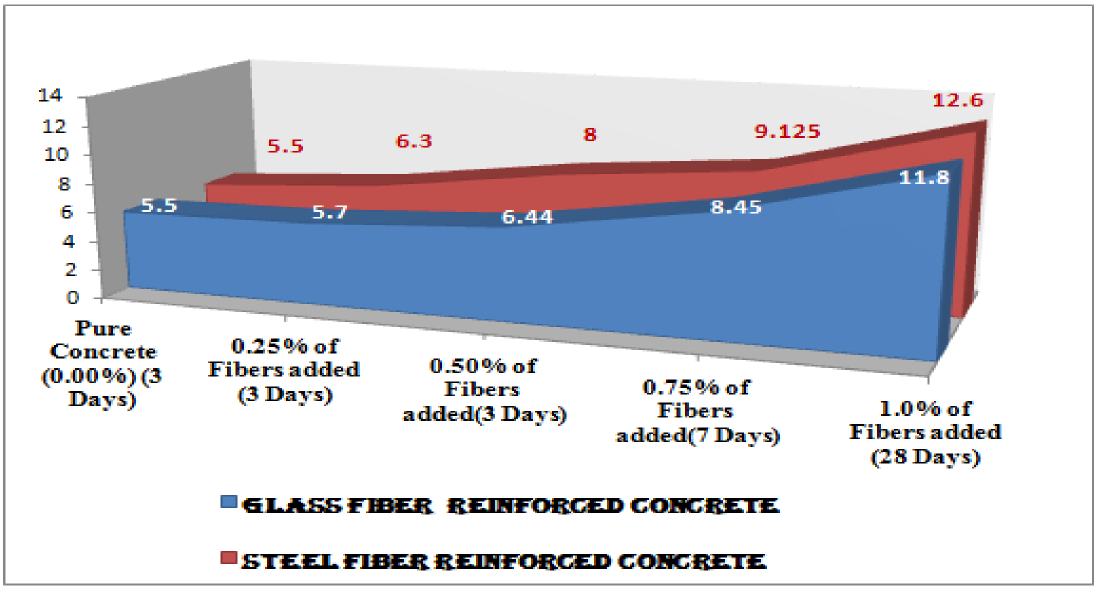

Fig.No -6.2.3 Flexural strength Test Results

VII. 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)

In this investigation we have compared Steel fiber reinforced Concrete(SFRC) and Glass Fiber Reinforced concrete(GFRC) with different percentage of fiber are added (0.25%,0.50%,0.75% and 1.0%) age .The final result is Steel fiber reinforced Concrete(SFRC) is having more strength than Glass Fiber Reinforced concrete(GFRC).

- ❖ In Compressive strength test results the Concrete mix containing 1.0% Steel fibers as maximum improvement of Strength is45.50% observed
- ❖ In Split Tensile strength test results the Concrete mix containing 1.0 Steel fibers as maximum improvement of 39.9% is observed
- ❖ Flexural strength Test results the concrete mix containing 1.0 Steel fibers as maximum improvement of 34.4% is observed.

FUTURE SCOPE

1. For heavy structures in order to decrease secondary reinforcement steel fibers is very much useful.
2. In certain critical places the crack penetration can be arrested by using fibers.
3. By using fibers in concrete, micro crack can be arrested

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