STUDY ON THE BEHAVIOUR OF STEEL FIBER REINFORCED CONCRETE OF VARIOUS PERCENTAGES

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ABSTRACT

In recent years the applications of high strength concrete have increased many part of the world. This growth has been possible as a result of recent developments in technology and demand for high strength concrete there are many advantages in using high strength concrete in building construction. Such as reduction in member size, reduction in self weight and early stripping of formwork. Reduced member sizes increase amount of rental area and this is beneficial, when there are architectural restrictions on column size or when land prices are very high

The addition of steel fibers to high strength concrete in various volumes fractions, can be lengthen concrete in various volume fraction, can lengthen the time elapsed before cracking and can provide a confinement.

As in the case of conventional concretes the use of the steel fibers substantially increase the energy at break of high strength concretes. Although the initial costs may be high, significant long term. Saving would be ensured in reducing the needs for maintenance, repair and rehabilitation.

The experimental programmer was designed to the of effect of steel fibers on compressive strength, split tensile strength of high strength concrete and testing of cubes of size (150mm x 150mm x 150mm), cylinders of 150mm diameter, height 300mm.the mix proportion for M30 grade of concrete 1:0.91: 2.41 with w/c ratio 0.37 was obtained. Then the steel fibers were added in the volume fraction of 0%, 0.25%, 0.5%, 0.75%, 1.0%, and 1.25%.

The experiential results shown that the addition of steel fibers improves the crack arresting capacity of concrete .the addition of steel fibers prove that there is significantly enhancing the energy absorbing capacity of specimens. The optimum percentage of fibers is 1.0% in compression, and 1.25% in split tensile strength to get the maximum benefit of high strength concrete. At the 1.0% percent of steel fibers the ductility was find out more.

Using of Materials

Classification of sand:

Classification of sand is given below

- Fine sand 0.075mm to 0.425mm
- Medium sand 0.425mm to 2mm
- Coarse sand 2mm to 4.75 mm

Various Types of sand:

Pit Sand, River Sand, Sea sand

Pit Sand (Coarse sand)

Pit Sand is obtained by forming pits into soil from 'Quarries'. It consists of sharp angular grains which are free from salts. It is coarse sand which is usually used in concreting and has reddish yellow color normally.

River Sand

This sand is obtained from banks or beds of rivers. River sand is fine and consists of fine rounded grains. The color of river sand is almost white and grayish. River sand is usually available in clean condition and is used for plastering.

Sea Sand

This sand is obtained from sea shores. It has fine rounded grains and light brown color. Sea Sand contains salts which attract moisture from atmosphere. Such absorption causes dampness and disintegration of work. Sea sand also retards setting action of cement. Due to these reasons, sea sand is generally avoided for engineering purposes. It is used only as a local material for non-structural purposes.

Sand for construction works

Different construction works require different standards of sand for construction.

- Brick Works: Finest modulus of fine sand should be 1.2 to 1.5 and silt contents should not be more than 4%.
- Plastering Works: Finest modulus of fine sand should not be 1.5 and silt contents should not be more than 4%.

Concreting Works: Coarse Sand should be used with finest modulus 2.5 to 3.5 and silt contents should not be more than 4%.

FINE AGGREGATE

Table 1.4: Properties of fine aggregate

S. No.	Sieve Size	Wt. of material retained (gm)	Cumulative wt. retained (gm)	Cumulative % wt. retained	% weight passing
1	4.75mm	0	0	0	100
2	2.36mm	0	0	0	100
3	1.18mm	130	130	26	74
4	600μ	210	340	68	32
5	300μ	140	480	96	4
6	150μ	16	496	99.2	0.8

Total dry weight=500gm

Σ Cum % retained=289.2

Fineness Modulus of Fine Aggregate= (Σ Cum. % retained)/(100)=2.89

Zone-II

Average Bulk density of Sand=1.636gm/cm^3

Coarse Aggregate*:*

Crushed granite Aggregate was used as coarse aggregate. The coarse aggregate was obtained from a local crushing unit having 20mm MSA, 20mm 16mm, and 10mm well graded aggregate according to IS: 383is used in this investigation. The bulk density & specific gravity of the coarse aggregate sand used were 1.62g/cc, 2.82.

Physical Properties ofCoarse Aggregate

S.No.	Characteristics	20 mm	10 mm
1	Type	Crushed	Crushed
2	Specificgravity	2.82	2.68
3	Total waterabsorption	3.62	1.58
4	Fineness modulus	6.35	6.03

d) Water: Potable water was used in the experimental work for both mixing and curing.

Note:

- If the above quality of sand is not available due to any reason, the blending of sand should be done by adding more coarse sand to achieve the required finest modulus.
- Washed sand should be used at site for getting more strength in construction work.

Bulking of sand

Due to moisture in each particle of sand, sand gets a coating of water due to surface tension which keeps the particles apart. This causes an increment in volume of sand known as Bulking.

Checking the Quality of Sand

The following methods are used to check the quality of sand

- To check the quality of fine aggregates or sand; put some quantity of sand in a glass of water. Then it is vigorously shaken and allowed to settle. If the clay is present in sand, its distinct layer is formed at the top of sand.
- To detect the presence of organic impurities in sand, a solution of sodium hydroxide or caustic soda is added to sand and stirred. If the color of solution changes into brown, it shows presence of impurities.

Cement

Ordinary port land cement is the most important type of cement. The Ordinary Portland cement was classified into three grades namely

1.Ordinary Portland Cement 33 grade-IS269:1989

2.Ordinary Portland Cement 43 grade-IS8112:1989

3.Ordinary Portland Cement 53grade-IS12269:1987

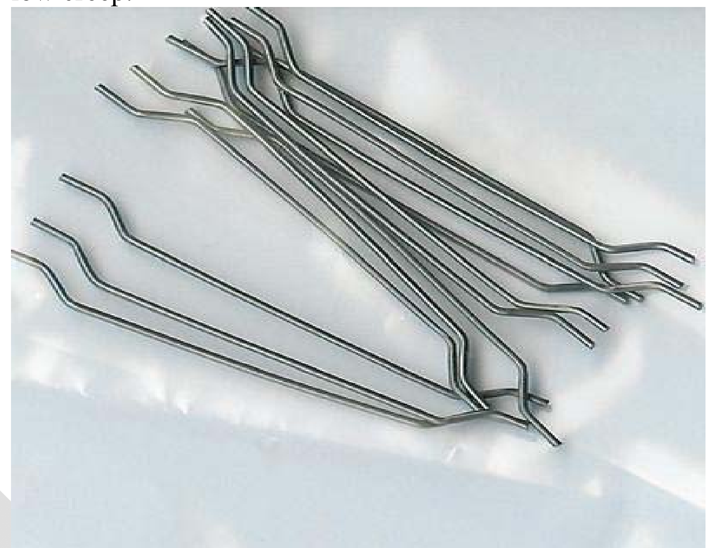
depending upon the strength of the cement at 28 days when tested as per IS 4031-1988. If the 28 days strength is not less than 33N/mm^2 it is called 33 grade cement if the strength is not less than 43N/mm^{2}it is called 43grade cement and if the strength is not less than53N/mm^2 it is called 53grede cement

1.12Types of Fiber

Fibers are classified into two categories namely hard intrusion and soft intrusion fibers having a higher elastic modulus than the cement matrix can be termed as hard intrusion and intrusion and fibers having a lower elastic modulus are called as soft intrusion.

a) Steel Fibers

Steel fibers are probably the only fibers that can be used for long-term load bearing applications they are stable in cement matrix and need no longer be a design or cost-inhibiting factor steel fiber are classified as collated steel fiber stainless steel fibers epoxy coated steel fibers steel fabric reinforcement straight indented crimped, twisted hooked saddled or deformed end tri-dimensional are the forms of steel fibers steel fibers have high tensile strength (0.5-2 GPA) and modulus of elasticity (200 MPA),a ductile/plastic stress-strain characteristic and low creep.



b) Glass Fibers

Glass fibers are produced in a process in which molten glass is drawn in the form of filaments through the bottom of a heated platinum tank glass fibers reinforced cementations composites have been developed mainly for the production of thin sheets components with a paste or mortar mix and about 5% fiber content. Other applications have considered, either making reinforcing bars with plastics or by making similar short, rigid units impregnated with epoxy, to be dispersed in the concrete during mixing. In the practice, the main applications of the glass fiber reinforcement are in thin sheets. Glass fibers are classifies as E-glass, alkali resistant resin coated and resin bonded glass fiber, second generation of alkali resistant fibers also known a CEM-FILL glass fiber etc. Alkali resistant glass fibers are produced in U.S.A, England, Canada and Japan.

c)Synthetic Fibers

Synthetic fibers are manufactured fibers resulting from research and developed in the petrochemical and textile industries there are two different physical fiber from monofilament fibers and fibers produced from fibrillated tape fiber type that have been tried in cement concrete matrices include acrylic carbon nylon polyester polyethylene and polypropylene.

d) Carbon Fibers

Carbon fibers are substantially more expensive than other fiber type but the strength and stiffness characteristics are superior to steel carbon fiber is inert in aggressive environment abrasion resistant and stable at high temperatures with relatively high stiffness however carbon fibers are more vulnerable than glass fiber to surface damage and subsequent weakening and must be used in the clumped form embedded in or sized with resin coating this include random addition of short fibers in matrix.

e)Acrylic Fibers

Acrylic fibers have been used to replace asbestos fiber in many fiber reinforced concrete products acrylic fibers have also been added to conventional concrete at low volumes to reduce the effects of plastic shrinkage cracking.

f) Aramid Fibers

Aramid fibers are two and half times as strong as glass fibers and five times as strong as steel fibers, per unit mass. Due to relatively high cost of these fibers aramid-fiber-reinforced concrete has been primarily used as an asbestos cement replacement in certain strength applications.

g) Nylon Fibers

Nylon is a generic name that identifies the family of polymers. Nylon fiber properties are import by the base polymer type, addition of different levels of additive, manufacturing conditions and fiber dimensions. Currently only two types of nylon fibers are marketed for concrete. Nylon is heat stable hydrophilic, relatively inert and resistant to a wide variety of materials. Nylon is particularly effective in imparting impact resistant and flexural toughness, sustain and increasing the load carrying capacity of concrete following first crack.

h) Polyester Fibers

Polyester fibers are available in monofilament form and belong to the thermoplastic polyester group they are temperature sensitive and above normal service temperatures their properties may be altered polyester fibers have been used at low contents (0,1% by volume) to control plastic shrinkage cracking in concrete.

i) Polyethylene Fiber

Polyethylene fiber has been produced for concrete in form with wart-like surface deformation polyethylene in pulp form may be an alternative to asbestos fiber concrete reinforced with polyethylene fibers at contents between 2 and 4% by volume exhibits linear flexural load deflection behavior up to first crack followed by an apparent transfer of load to the fibers break

j) Polypropylene Fiber

Polypropylene fiber was first used to reinforce concrete in the 1960s.polypropylene is a synthetic hydrocarbon polymer the fiber of which is made using extrusion by hot drawing the material through the by Polypropylene fibers are tough but have low tensile strength and modulus of elasticity they have a plastic stress strain characteristics polypropylene fibers have been reported to reduce unrestrained plastic and drying shrinkage of concrete at fiber content of 0.1 to 0.3% by volume.

k) Natural Fiber

Natural reinforcing materials can be obtained at low cost and low levels of energy using local manpower and technology utilization of natural fibers as from of concrete reinforcement is of particular interest to less developed regions where conventional construction materials are not readily available or are too expensive sisal fiber reinforcement concrete has been used for making roof tiles corrugated sheets pipes silos and tanks elephant grass reinforced mortar has been used for low-cost housing projects. Wood – cellulose-fiber reinforced cement has commercial applications in the manufacture of flat and corrugated and non-pressure pipes natural fiber can be either unprocessed or processed.

l) Unprocessed Natural Fiber

Products made with unprocessed natural fibers such as coconut coir sisal sugarcane biogases bamboo jute wood and vegetable fiber have been tested in a number of countries problems have been reported with the long term durability of some of the productThe properties of concrete made using unprocessed natural fiber depend on a number of factors including the type and length of fiber as well as volume fraction to show some improvement in mechanical properties the minimum fiber content is of the order of 3% by volume.

m) Processed Natural Fiber

Wood cellulose is the most frequently used in natural fiber. It is most commonly obtained using the Kraft process this process involves cooking wood chips in a sodium hydroxide sodium carbonate and sodium supplied different grades of wood cellulose fiber containing more or less of the three main constituents cellulose fiber have relatively good mechanical properties compares with many man-made fiber such as polypropylene, polyethylene and acrylic.

1.13 RoleofFibers

The role of fibers is especially to arrest any advancing crack by applying pinching force at the crack tips thus delaying their propagation across the matrix the ultimate cracking strain of the composite is increased to many times greater than that of the unreinforced matrix unlike the convention bars the discrete fibers are dispersed uniformly throughout the matrix hence they can be more beneficial in arresting the growth of any advancing crackIn natural concrete failure will be just after the appearance of first crack at the bottom most layer of specimen it would fail in a very brittle manner and cater strophic there will not be any time lapse between the first crack and collapse where at the failure in fiber reinforced concrete specimen will be very slow the crack which starts from bottom most layer will progress slowly in the upward direction and its growth will be resisted by the bridging fiber at the ultimate stage either the fiber gets pulled out from the matrix or yielding of the fiber occurs this slow process of crack would lead to ductile failure and would give sufficient time between the onset of first flexural crack and ultimate failure still after the complete failure it is very difficult to separate the cracked portion of the specimen.

Romualdi and **Botson**by considering a direct tensile stress field and applying the principle of linear elastic fracture mechanism, show that, the first cracking strength was inversely proportional, to the geometrical spacing of fibers for a given fiber volume content. The reinforcing action by fibers occurs through fiber-matrix interfacial bond stress. Cracks in the matrix will occur through when the composite strain exceeds the cracking strain of the matrix. Since the fibers are stiffer than the matrix i.e., Young's Modulus of the fiber is more than the Young's modulus of the matrix; they deform less and hence exert a pinching force at the **1**aggregate as cracks arrestors in composite. Hence, the cracks are prevented from propagation until the composite ultimate strain is reached. Finally, the failure occurs either by the simultaneous yielding of the fibers and the matrix or by the fiber-matrix interfacial bond failure. The crack controlling property of the fibers has the following three major effects on the behavior of concrete composite.

- Fibers delay the onset of flexural cracking an increase the strain at first crack. The increase in tensile strain being as much as 100%. The ultimate strain may be as large as 20 to 50 times that of Natural concrete.
- The fiber imparts a well-defined post cracking behavior of the compost
- The crack arresting property and consequent increase in the ductility imparts greater energy absorption property to the composite prior to failure. With 2.5% fiber content, the energy absorbing capacity is increased more than 10 times as compared to unreinforced

1.14 Rheology of fiber reinforced concrete

The Rheological properties of the fiber reinforced concrete depend on the size and type of fiber and on the method of production. Since fibers tend to have relatively large water requirement as well as exhibiting a tendency to interlock or ball. In addition, the W/C ratio and ratio of fine to coarse aggregate must be considered, as with conventional concrete. In general, the workability is decreased as the fibers increases, or as the coarse aggregate content increases. It is however, difficult to define a satisfactory method of testing the workability. The mix is considered unworkable when balling of fiber occurs. The aspect ratio of the fiber, cement content and maximum size of aggregate, the addition of a large fiber volume is possible before the occurrence of balling. Apart from difficulties with workability, it is also hard to compare fiber reinforced concrete.

As already stated, fiber reinforced concrete can be defined as a composite material consisting of cement based matrix containing an orderly or randomly distribution of fibers. The fibers act as crack arrestors that restrict the growth of flaws in the matrix, controlling them, enlarging under stress into crack, which is eventually leads to failure, by inhabiting the propagation of cracks originating from internal flaws, considerable improvement in static and dynamic properties can be obtained. Fibers impact the composite quality of crack control, toughness, ductility and impact resistance to the natural concrete. The use of continuous aligned fibers in a cement matrix is fundamentally no different from conventional reinforced or pre stressed concrete, where the large diameter reinforced bars or the smaller diameter pre stressing wire behaves analogous to the continuous aligned fibers. The phenomenon of multiple cracking and composite action in such material have been well established for over century. A more exciting challenge that will find a wider practical application is the use of short, discontinuous fibers that are uniformly distributed in the matrix. It is true that due to random orientation of fibers, not all are equally effective in crack control as well as strengthening and stiffening aspects.

EXPERIMENTAL INVESTIGATION

3.1 EXPERIMENTAL PROGRAM

In order to study the interaction of steel fibers with concrete under compression, split tension. The experimental investigation was taken up on M30 grade of concrete. The investigation was aimed at studying the effect of steel fibers on compressive strength, split tensile strength of M30 grade of concrete to reach the purpose this research, experimental laboratory study was developing on using the materials-53 grade Portland cement, graded coarse aggregate and sand.

The casting work was done in batches for preparing 3 numbers of cubes size 150mm x150mm x 150mm. 3numbers of cylinder of 150mm diameter & 300mm height.

The coarse aggregate used in the casting graded coarse aggregate of this size 20-12.5mm; 12.5-10mm; in the ratio of 60%: 40%:

respectively. The steel fibers were added in the volume fractions of 0%, 0.25%, 0.50%, 0.75%, 1.0% and 1.25%. The details of steel fibers percentage, No. of cubes and cylinders are shown in the following Table No. 3.0.1.

Materials Used:

Concrete is an artificially engineered material made from a mixture of Portland cement, aggregates and water. It is most commonly used construction material in the world. It is strong, cheap and durable the materials used in the present investigation are cement, fine aggregate, coarse aggregate, water and steel fibers.

3.11 Portland cement:

Portland cement is made from heating lime stone and chalk, combined with silicates. Portland cement holds the aggregate together and is available in different grades and colours.The physical properties of the Portland cement used are given in table 3.1(a)

Table 3.1(a): physical properties of cement

S.no	Property	Value
1	Grade	53
2	Fineness	2200
3	Specific gravity	3.00
4	Standard consistency	30.9
5	Initial setting time	30 minutes

3.1.5 Steel fibers: Fibers is a small piece of reinforcing material possessing certain characteristics properties. The fibers are added small amount of tensile strength. Fibers are different types they are plastic, glass and steel fiber etc. Steel fibers are used in the present investigation. The steel fibers have same expansion and contraction as that of concrete.

Steel fibers

3.1.6 Moulds and Equipment:

1. **Cubes**:

The moulds used for concrete cubes are made up of cast iron with dimensions 150mmX 150mm X 150mm for compressive strength.

2. **Cylinders**:

Cast iron moulds are used of size 150 mm diameters X 300mm height for spilt tensile strength.

3. **Compaction**:

Compaction was done by hand using tamping rod the strokes of the rod were distributed in a uniform manner over the cross section of the mould. The concrete was filled in three layers, and for each layer 25 strokes are applied.

4.1 Mix Design:

4.1.1 Mixing

Mix the concrete either by hand or machine

HAND MIXING

(i)Mix the cement and fine aggregate on a water tight none-absorbent platform until the mixture is thoroughly blended and is of uniform color.

(ii)Add the coarse aggregate and mix with cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch

(iii)Add water and mix it until the concrete appears to be homogeneous and of the desired consistency.

SAMPLING

(i)Clean the mounds and apply oil.

(ii) Fill the concrete in the molds in layers approximately 5cm thick.
(iv) Level the top surface and smoothen it with a trowel.

Mix Design for SFRC:

Just as different types of fibers have different characteristics, concrete made with steel Fibers will also have different properties. When developing an SFRC mix design, the fibers type and the application of the concrete must be considered. There must be sufficient quantity of mortar fraction in the concrete to Adhere to the fibers and allow them to flow without tangling together, a phenomenon Called 'balling of fibers'. Cement content is, therefore, usually higher for SFRC than conventional mixes Aggregate shape and content is critical. Coarse aggregates of sizes ranging from 10 mm to 20 mm are commonly used with SFRC.

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Larger aggregate sizes:

Usually require less volume of fibers per cubic meter. SFRC with 10 mm maximum size aggregates typically uses 50 to 75 kg of fibers per cubic meter, while the one with 20mm size uses 40 to 60 kg. It has been demonstrated that the coarse aggregate shape has a significant effect on workability and material properties. Crushed coarse aggregates result in higher strength and tensile strain capacity. Fine aggregates in SFRC mixes typically constitute about 45 to 55 percent of the total aggregate content.

Typical mix proportions for SFRC will be: cement 3.25 to 5.60 kg; water-cement ratio 0.3-0.6; ratio of fine aggregate to total aggregate 0.5-1.0; maximum aggregate size 10mm; air content 6-9%; fibers content 0.5-2.5% by volume of concrete. An appropriate pozzolan may be used as a replacement for a portion of the Portland cement to improve workability further, and reduce heat of hydration and production cost. The use of steel fibers in concrete generally reduces the slump by about 50 mm. To overcome this and to improve workability, it is highly recommended that a super plasticizer be included in the mix. This is especially true for SFRC used for high performance applications. Generally, the ACI Committee Report No. ACI 554 'Guide for Specifying, Mixing, Placing and Finishing Steel Fibers Reinforced Concrete' is followedfor the design of SFRC mixes appropriate to specific applications.

Factors Controlling SFRC

- Aspect ratio, l/d.
- Volume fraction, vf.
- Fiber reinforcing index, RI=l/d x vf.
- Critical length, lmin.
- Balling of fibers.
- Good mix design: more matrix, small aggregate, workable.
- Type of fibers-size, shape, strength, modulus.

Mechanical properties and strength of SFRC:

Relative strength and toughness of the fiber reinforced mortar and concrete. As the percentage of fibers increases, the strength and toughness of fiber concrete increases. The increase in toughness and the effect of aspect ratio. The effect of different types of fibers on the tensile strength is presented. The strain of SFRC corresponding to peak compressive strength increases as the volume fraction of fibers increases. As aspect ratio increases, the compressive strength of SFRC also increases marginally. The load vs deflection of SFRC beam subjected to bending is presented. As the load increases, the deflection also increases. However the area under the load –deflection curve also increases substantially depending the type and amount of fibers added.

Design of M30 grade concrete by ACI method:

Fineness of coarse aggregate =2.40%
Bulk density of coarse aggregate = 1700 kg\m3
Slump required =85 mm

Grade of concrete = M30
Size of aggregate = 20 mm

Step-1:- Target mean strength
Fmin = fmin +ts
=30+1.65*4
=36.6 N/mm2

Step-2:- water cement ratio
Water cement ratio for 36.6 Mpa is 0.37

Step-3:- cement content required:
Slump required =85mm
Aggregate size =20 mm
From table 11.8 water content =200 kg/m3
Water/cement =0.37
Cement = 200/0.37
Weight of cement =540.54 kg/m3

Step-4:- requirement of coarse aggregate
Density = 1710 kg/m3
Size of aggregate = 20 mm, fineness modulus =2.40
From table 11.4, volume =0.66
Weight/volume =density
Weight of coarse aggregate =density *volume = 1710*.66 = 1128.6 kg/m3

Step-5:- requirement of fine aggregate:-
F.A:- density of concrete- weights of (cement+C.A+water)
Size of aggregate= 20mm
Density of concrete =2355 kg/m3 from table 11.9
F.A = 2355-(540.54+1128.6+200)
= 491.86kg/m3

Step-6:- mix proportions:

Cement	F.A	C.A	water
540.54	: 491.86	: 1128.6	: 200
1	**: 0.91**	**: 2.41**	**: 0.37**

M30 Grade:
Mix proportions
C: F.A: C.A: W/C
1: 0.91: 2.41: 0.37

CUBE CALCULATION:
Cube Sizes: 150mm x 150mm x 150mm
Weight of cube = volume x density
=0.15x0.15x0.15x2400
=8.1 kg or 9 kg
Cement= 1x9/1+0.91+2.41+037
= 1.91 or 2.2 kg
F.A = 0.91 X 2.2 =2.002 kg
C.A = 2.41 X 2.2 =5.30 kg
W/C = 0.37 X 2.2 =0.814 kg
0.5 % of steel fibers volume of concrete
Volume of concrete =0.15^3
Volume of steel fibers =$0.5x0.15^3$ /100 =1.68 $x10^{-5}$
Weight of steel fibers = ($0.5 x0.15^3$ /100) x 7850 = 0.132 kg or 132 gm.

3.1.7 Mix proportion:

The investigation was carried on M30 grade of concrete. The mix proportion adapted was 1:0.91:2.41 with w/c ratio 0.37.

3.1.8 Casting:

The total casting was completed with the raw materials. The quantity of fine aggregate mixed with cement. The above mix is transferred in to a big tray and mix with coarse aggregate. Then the quantity of water added to that mix, Then specified % of fibers were sprinkled over the mix and again mixed thoroughly till all the fibers are distributed uniformly in the concrete mix.

The moulds used for casting were oiled and the four sides of the moulds are tightened well. The fresh was smoothly transferred into the mould in three stages and compacted with the help of tamping rod. After casting the top surface of the mould is leveled using trowel. The specimens were demouled after 24 hours of casting. The designation of the specimens were marked with indelible water proof ink and kept under water for curing.

3.1.9 Curing: The specimens cured for 28 days in the curing pond. After the completion of curing period, the specimens were removed from water and kept under the shadow.

3.2. Testing: After the dying of the specimens for 24 hours under shadow the specimens were tested.

3.2.1 Compressive strength:

The cubes specimens were tested on compression testing machine, which is operated by hydraulically. The being surface of the testing machine was wiped off clean and any loose sand or other material removed from the surface of the specimen, whichis to be in contact with compression platens. In the case of cubes the specimens was placed in the machine in such manner that the load was applied to opposite side of the cubes as casted that is not the top and bottom. The axis of the specimen was carefully aligned with the center of the thrust of the spherically scated platen. The load was applied without shock and increased continuously until the resistance of the specimen to the increasing load breaks down and no grater load can be sustained. The maximum load applied to the specimen was recorded.

COMPRESSION TESTING MACHINE

3.2.2 Split tensile strength:

The cylinder specimens were tested on CTM machine. The bearing surface of the testing machine was wiped clean. In case of cylindrical specimen the test was carried outby placing the specimen horizontally between the loading surface of the compression testing machine for the split tensile strength and the axis of the specimen was carefully aligned with the center of thrust of the spherically scated platen. The load was applied without shock andincreased continuously till the specimen break. The maximum load applied to the specimen was recorded.

SPILT TENSILE ST RENGTH

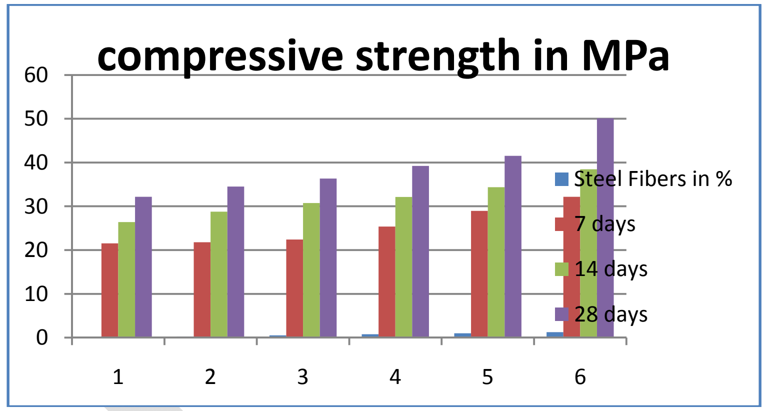
DISCUSSIONS OF TEST RESULTS

EXPERIMENTAL RESULTS ON M30 GRADE OF CONCRETE(28 DAYS):

S.NO	Steel fibers	Compressive strength (MPa)	Split tensile strength (MPa)
1	0.%	32.17	2.73
2	0.25%	34.53	2.95
3	0.50%	36.33	3.33
4	0.75%	39.22	3.82
5	1.0%	41.55	4.5
6	1.25%	50.11	5.67

5.1 COMPRESSION TEST:

Steel Fibers in percentage (%)	Average compressive strength in MPa		
	7 day	14 day	28 day
0%	21.55	26.4	32.17
0.25%	21.78	28.79	34.53
0.5%	22.42	30.75	36.33
0.75%	25.36	32.15	39.22
1.0%	28.94	34.38	41.55
1.25%	32.17	38.47	50.11



5.2 SPLIT TENSILE STRENGTH:

Steel Fibers in percentage (%)	Average split tensile strength in N/mm^2		
	7 day	14 day	28 day
0.0%	1.71	2.15	2.73
0.25%	1.92	2.154	2.95
0.50%	2.085	2.159	3.33
0.75%	2.56	2.78	3.82
1.0%	3.05	3.77	4.5
1.25%	4.25	4.59	5.67

CONCLUSIONS

The following results are inferred based on the experimental results discussed on the previous chapters.

1. Addition of steel fibers to concrete increases the compressive strength of concrete marginally.
2. The addition of steel fibers increases the tensile strength. The tensile strength was found to be maximum with volume fraction of 1%.
3. By the addition of steel fibers the flexure strength was found to decrease marginally.
4. The addition of fibers to concrete significantly increases its toughness and makes the concrete more ductile as observed by the modes of failure of specimens.
5. The stiffness of beams was studied and was found to be maximum for hooked end fibers with 1% volume fraction.
6. The empirical equations developed in this experiment can be used for calculating the

toughness indices or percentage of fibers whichever is required.
7. The ductility of steel fibers reinforced concrete was found to increase with increase in volume fraction of fibers and the maximum increase was observed for hooked fibers with 1%volume fraction.
8. The improvement in the energy absorption capacity of steel fibers reinforced concrete panels with increasing percentage of steel fibers.

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