“EFFECT OF HOOKED STEEL FIBRES ON PROPERTIES OF CONCRETE”

A Thesis

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

BACHOLER OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision of

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CERTIFICATE

This is to certify that the work which is being presented in the project title "**EFFECT OF HOOKED STEEL FIBRE ON PROPERTIES OF CONCRETE**" in partial fulfilment of the requirements or the award of the degree of Bachelor of technology in civil engineering and submitted in Civil Engineering Department, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by UTSAV RAJPUT and HIMANSHU JASSAL during a period from July 2016 to May 2017 under supervision of **Mr. Abhilash Shukla** Assistant Professor, Civil Engineering Department, Jaypee University of Information Technology, Waknaghat.

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ABSTRACT

Bond cement is the most widely utilized development material on the planet. The explanation behind its broad utilize is that it gives great workability and can be formed to subterranean insect shape. Standard bond concrete has a low rigidity, restricted flexibility and little imperviousness to splitting. Inside smaller scale splits, prompting fragile disappointment of cement. In this current age, structural building developments have their own basic and strength necessities, each structure has its own proposed reason and henceforth to meet the reason, adjustment in conventional bond concrete has turned out to be required. It has been found that diverse kind of filaments included particular rate to concrete enhances the mechanical properties, solidness and serviceability of the structure. It is currently settled that one of the critical properties of Steel Fiber Reinforced Concrete (SFRC) is its better resistance than breaking and split engendering. In this postulation impact of filaments on quality of cement for M30 review have been considered by shifting the viewpoint proportion of strands in cement. Fiber viewpoint proportion was changed by 50 and 80. Assist the impact of strands on the quality of cement for M30 review has been examined by changing the rate of filaments in the solid. Fiber content shifted by 0%, 0.5%, 1%, 1.5%, 2% and 2.5%.Cubes of size 150x150x150mm to check the compressive quality, light emissions 500x100x100mm for checking flexural quality and chamber of size 100x200mm for checking the split rigidity were threw. All examples were cured for 7 and 28 days before pounding. The aftereffects of fiber strengthened cement for 7 days and 28 days curing with differed angle proportion of fiber were contemplated and it has been found that there is huge quality change in steel fiber fortified cement. Additionally, it has been watched that with the expansion in fiber perspective proportion builds the quality of cement.

LIST OF ABBREVATIONS

SFRC	Steel Fibre Reinforced Concrete
l,b,w,d	Length,Breadth,Width,Depth
OPC	Ordinary Pozolona Cement
CA	Coarse aggregate
FA	Fine aggregates
CTM	Compression testing machine
P	Load applied
L	Length
f_{ck}	Characteristic compressive strength
F_t	Target mean strength
MPa	Mega pascal
w/c	Water Cement ratio
Avg	Average
d	Cross section dimension of specimen
F_{ct}	Tensile Strength
F_b	Flexural Strength
mm	Millimetres
NBD	Non bio degradable

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

Cement is a composite material containing pressure driven bond, water, coarse totals and fine totals. The subsequent material is a stone like structure which is framed by the synthetic response of the concrete and water. The stone like structure is a fragile material which is solid in pressure however feeble in strain. The shortcoming in the solid makes it to break under little loads, at the pressure end. These splits for the most part proliferate to the pressure end of the part lastly, the part breaks. The development of breaks in the solid may likewise happen because of the drying shrinkage. These breaks are essentially small scale splits. These splits increment in size and greatness as the time slips by lastly makes the solid to fizzle. The arrangement of breaks is the primary explanation behind the disappointment of the solid. To build the rigidity of cement many endeavors have been made. One of the fruitful and most regularly utilized strategies is giving steel fortification. Steel bars, nonetheless, strengthen the solid against neighborhood strain as it were. Splits in the strengthened solid individuals broaden uninhibitedly. Therefore requirement for multidirectional and firmly separated steel support emerges which is for all intents and purposes impractical. Fiber support gives the answer for this issue. So to expand the rigidity of cement a procedure of presentation of filaments in cement is being utilized. These strands are consistently disseminated and haphazardly organized. This solid is name as fiber fortified cement. The fundamental purpose behind adding strands to solid blend is to enhance the post splitting reaction of the solid i.e., to enhance its vitality ingestion limit and obvious flexibility, and to give break resistance and split control. Likewise, it keeps up basic honesty and cohesiveness in the material. The underlying investigates joined with a substantial number of follow up research have prompted the advancement of a wide assortment of material plans the fit the meaning of fiber strengthened cement

1.2 FIBRE REINFORCED CONCRETE

Fiber Reinforced Concrete (FRC) is a solid containing stringy material which builds its auxiliary trustworthiness. So we can characterize fiber fortified concrete as a composite material of bond cement or mortar and irregular discrete and consistently scattered strands. Fiber is discrete material having some trademark properties. The fiber material can be anything, yet not all will be compelling and practical. A few strands that are most regularly utilized are:

- Steel
- Glass
- Carbon
- Natural
- NBD

Steel fiber is a standout amongst the most regularly utilized fiber. By and large round strands are utilized. The distance across may fluctuate from 0.25 to 0.75mm. The steel strands here and there get rusted and free its quality. Be that as it may, examinations have demonstrated that filaments get rusted just at the surface. It has high modulus of versatility. Utilization of steel strands makes huge upgrades in flexure, effect and exhaustion quality of cement. It has been utilized as a part of different sorts of structures. Glass fiber is an as of late presented fiber in making fiber concrete. It has high rigidity of 1020 to 4080Mpa. Glass fiber cements are essentially utilized as a part of outside building confronted boards and as design precast cement. This material is great in making shapes before any building and it is less thick than steel. Utilization of carbon fiber is not a created procedure but rather it has a significant quality and modulus of flexibility. Likewise examinations have demonstrated that utilization of carbon filaments makes the solid extremely strong. The review on the carbon filaments is constrained. Principally utilized for cladding reason. Characteristic strands are minimal effort and bounteous. They are non risky and sustainable. A portion of the common strands are bamboo, jute, coconut husk, elephant grass. They can be set in asbestos. It builds durability and flexural quality. It additionally prompts great sturdiness in cement. Transfer of non-biodegradable materials is not kidding issue. It makes ecological issues. Reusing is the best alternative to diminish the waste. These NBD materials are non-destructive, impervious to compound assault, light weight, simple to deal with. NBD materials-fiber plastic, jute plastic, polythene, transfer glass, bond sacks, Studies led up until this point, demonstrated that short and discrete filaments can enhance the basic load limits and effect resistance for non-ferrous strands.

1.3 HISTORY

The utilization of fibres to expand the basic properties of development material is not another procedure. From old circumstances strands were being use in development. In BC, horse hair was utilized to strengthen mortar. Egyptians utilized straw in mud blocks to give extra quality. Asbestos was utilized as a part of cement in mid nineteenth century, to shield it from arrangement of breaks. Yet, in late nineteenth century, because of expanded auxiliary significance, presentation of steel fibres was made, by which the idea of fiber strengthened cement was disregarded for 5-6 decades. Later in 1939 the prologue to steel swapping asbestos was set aside a few minutes. In any case, at that period it was not fruitful. From 1960, there was a improvement in the FRC, basically by presentation of steel strands. From that point forward utilization of various sorts of strands in cement was made. In 1970's standards were created on working of the fiber strengthened cement. Later in 1980's affirmed procedure was created for the utilization of FRC. In the most recent decades, codes in regards to the FRC are being created.

1.4 PROPERTIES OF FIBRE REINFORCED CONCRETE

Properties of cement are influenced by many variables like properties of concrete, fine totals, and coarse totals. Other than this, the fiber strengthened cement is influenced by taking after variables:

TYPE OF FIBRE

A decent fiber is the one which have the accompanying qualities:

- Good attachment with the network.
- Adaptable flexibility modulus (some of the time higher than that of the lattice).
- Compatibility with the cover, which ought not be assaulted or pulverized in the long haul.
- Being adequately short, fine and adaptable to allow blending, transportation and putting.
- Being adequately solid, yet sufficient vigorous to withstand the blending procedure.

ASPECT RATIO

Angle proportion is characterized as the proportion of length to width of the fiber. The estimation of angle proportion changes from 20 to 150. For the most part the expansion in viewpoint proportion expands the quality and durability till the angle proportion of 100. Over that, the quality of solid reduces in perspective of diminished workability and decreased compaction. The length of the fiber utilized is 6mm and measurement of fiber is 0.22mm, viewpoint proportion is 28.

FIBRE QUANTITY

For the most part amount of strands is measured as rate of bond substance. As the volume of fiber increments, there ought to be increment in quality and durability of cement. Concerning strands, there is increment in the quality with the expansion in the fiber content upto a specific rate, after that the quality reductions. We will test for rates of 0, 0.5, 1, 1.5, 2 and 2.5 with the adjustment in l/d proportion.

ORIENTATION OF FIBRE

The introduction of strands assumes a key part in deciding the limit of cement. In RCC the fortifications are set in fancied bearings. Be that as it may, in FRC, the strands will be set in irregular course. The FRC will have most extreme resistance when strands are arranged parallel to the connected load.

1.5 FIBRE MECHANISM

Fiber work with cement using two systems: the dispersing instrument and the split crossing over component. The dividing component requires an extensive number of fibres all around dispersed inside the solid framework to capture any current smaller scale splits that could conceivably extend and make a sound break. For ordinary volume of portions of filaments using little width of strands or small scale filaments or miniaturized scale filaments can guarantee the required no of fibres for smaller scale split capture. The second component named split spanning requires longer straight strands with sufficient cling to the solid. Steel strands are viewed as a prime case of this sort is normally alluded as expansive width filaments or miniaturized scale fibres.

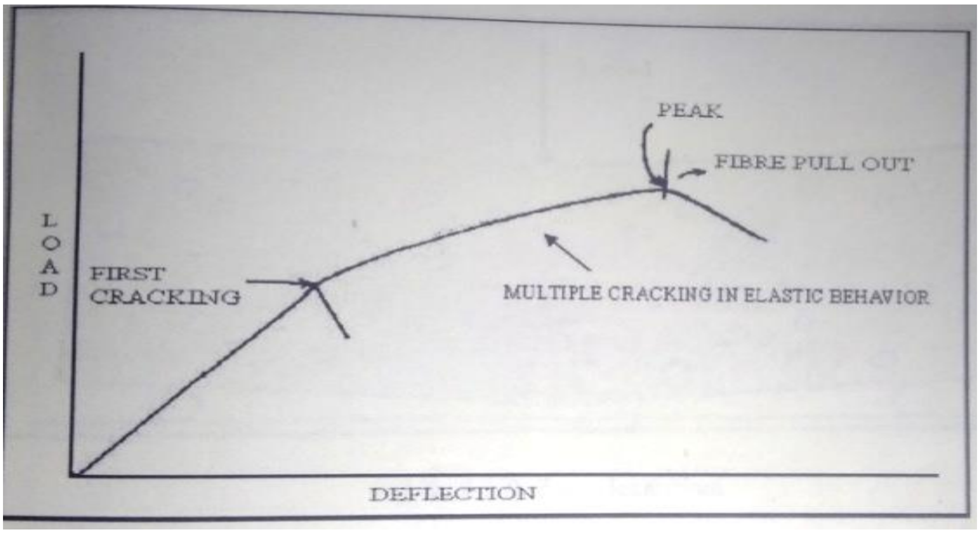

Fig no. 1.1 Fibre mechanism

FIBRE –MATRIX INTERACTION

The ductile splitting strain of bond grid is much lower than the yield or extreme strain of filaments. Thus when a fiber strengthens composite is stacked, the grid will split some time before the fiber can be cracked. The pinnacle anxiety of the solid composite is more prominent than those of the lattice alone amid the inelastic range amongst first and the pinnacle splitting.

BRIDGING ACTION

Pullout resistance of strands (dowel activity) is imperative for productivity. Pullout quality of filaments fundamentally enhances the post breaking elasticity of cement. As a FRC pillar or other auxiliary component is stacked, filaments connect the breaks. Such spanning activity gives the FRC example more prominent extreme elasticity and all the more significantly, bigger durability and better vitality ingestion. An essential advantage of the fiber conduct is material harm resilience. Bayasi and Kaiser (2001) played out a review where harm resilience component is characterized as the proportion of flexural resistance at 2mm greatest break width to extreme flexural limit. At 2% steel fiber volume, harm resilience calculate as per Bayasi and Kaiser was resolved as 93%

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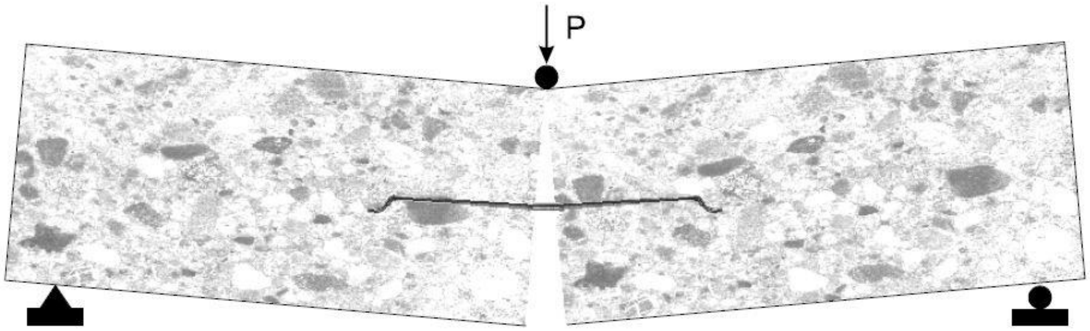

Fig no 1.2 Pullout Mechanism

1.6 WORKABILITY

A deficiency of utilizing strands in cement is lessening in workability. Workability of FRC is influenced by the fiber viewpoint proportion and the volume division and also workability of the plain concrete. As fiber substance builds, workability diminishes. Most analysts point of confinement volume of strands to 4% and angle proportion of 100 to maintain a strategic distance from unworkable blends. Furthermore, a few scientists have restricted the fiber support list (volume of fiber as % * angle proportion) to 1.5 for reasons unknown. To beat the workability issues related with FRC, change of solid blend configuration is suggested. Such adjustments incorporate the utilization of added substances.

1.7 STEEL FIBRE REINFORCED CONCRETE

As indicated by Exodus Egyptians utilized straw to fortify mud blocks. There is proof that asbestos fiber was utilized to fortify dirt posts around 5000 years prior. Prof. Alberto Fava of the University of La Plata in Argentina calls attention to that the hornero is a small feathered creature local to Argentina, Chile, Bolivia and other South American nations; the fowl had been meticulously assembling straw fortified earth settles on tree tops since the appearance of man. In any case, N.V. Bekaert is been viewed as the father of "Fiber Reinforced Concrete".

1.7.1 COMPOSITION OF STEEL FIBRE REINFORCED CONCRETE

The components of SFRC can be explained with help of the figure given below.

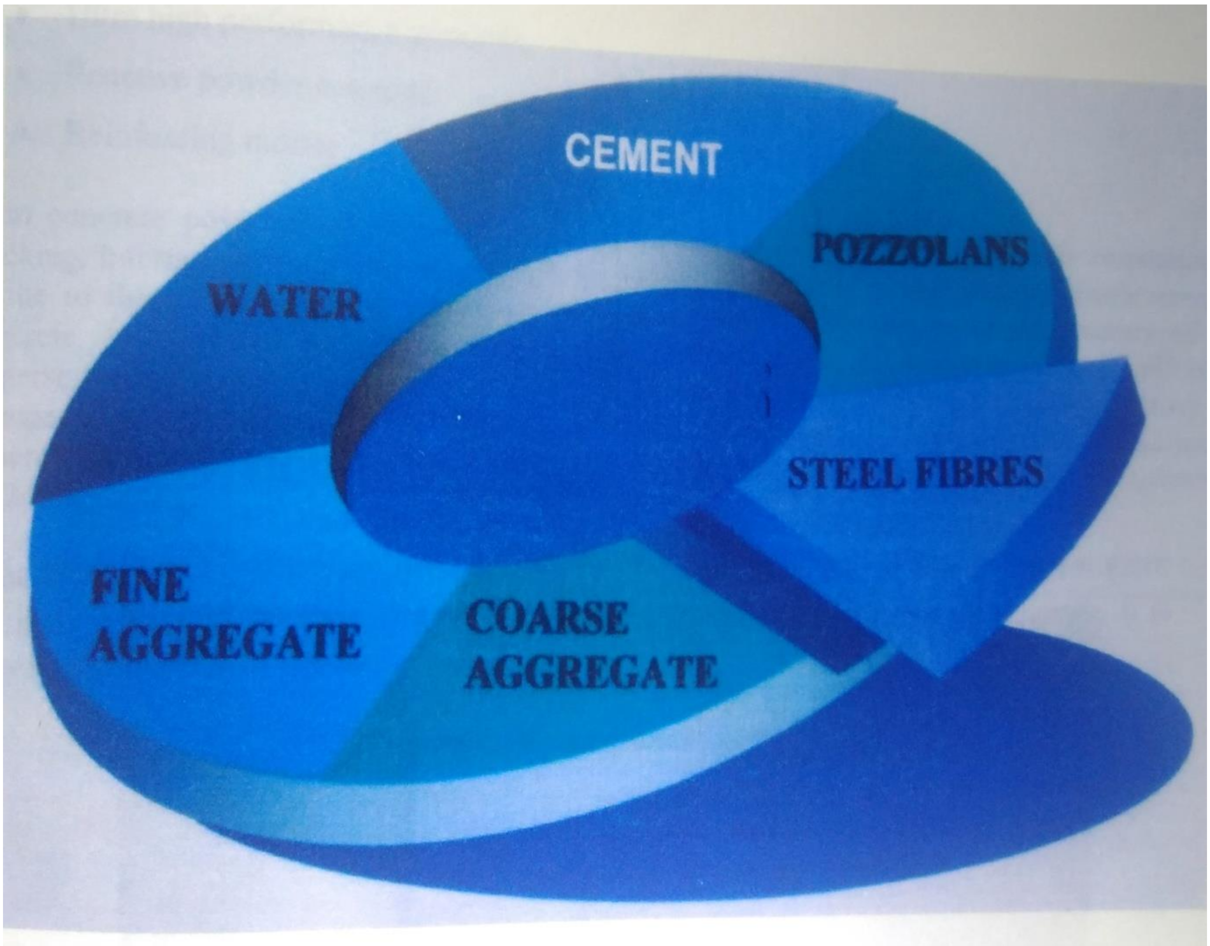

Fig. no. 1.3 Components of steel fibre reinforced concrete

Concrete containing pressure driven bond, water, fine total, coarse total and spasmodic steel filaments is called Steel Fiber Reinforced Concrete. It might likewise contain pozzolans and different admixtures normally utilized with ordinary cement. Filaments of different shapes and sizes created from steel, plastic, glass and regular materials are being utilized. Nonetheless, for most auxiliary and non-basic purposes, steel fiber is usually utilized of the considerable number of strands.

1.7.2 STEEL FIBRES

The hooked end steel fibre used in the experiment is taken from Komatko, Pune Maharashtra. This shape is presumably the most mainstream and effective in the historical backdrop of steel fiber strengthened cement. They can be utilized with any solid blend and high solid thickness. Stack move in the split is great with this fiber shape. In this manner after the presence of the principal split the loss of load-bearing limit happens rapidly yet balances out.

Aspect ratio 50 **Aspect ratio 65** **Aspect ratio 80**

Fig. no. 1.4 Steel Fibres

Hooked steel fibres have the following advantages comparing with the steel bars in the fields:

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

Plain concrete has a low elasticity, high malleability and little imperviousness to breaking. Inner smaller scale breaks are inalienably present in the solid and its poor elasticity is because of the prorogation of such miniaturized scale splits, in the end prompting weak disappointment of the solid. It has been perceived that the expansion of little, firmly divided and consistently scattered strands to the solid would go about as a break arrester and would considerably enhance its compressive and flexural quality properties. This kind of cement is known as fiber reinforced cement concrete. Snared end steel strands are utilized with perspective proportion 80, 50 and 65.

1.8 BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE UNDER CONVENTIONAL LOADINGS

1.8.1 BEHAVIOR OF STEEL FIBRE REINFOECED CONCRETE UNDER DIRECT COMPRESSION

Greatest anxiety a material can manage under squash stacking is known as its compressive quality. The compressive quality of a material that bombs by shattering crack can be characterized inside genuinely limit confines as a freely property. Notwithstanding, the compressive quality of materials that don't break in pressure must be characterized as the measure of stress required to twist the material to a subjective sum. Compressive quality is ascertained by partitioning the most extreme load by the first cross-sectional range of the example pressure test.

1.8.1.1 FOR PLAIN CONCRETE

The anxiety strain bend of cement under uniaxial pressure demonstrates a direct conduct up to around 30% of a definitive quality (fu) on the grounds that under here and now stacking the small scale splits in the move zone stay undisturbed. For worries over this point, the bend demonstrates a continuous increment in the arch up to around 0.75 to 0.95 fu, then it twists pointedly practically ending up noticeably level at the top lastly dives until the example is cracked. Connection between solid execution and degree of breaking from the state of the anxiety strain bend it appears that, for a worry between 30-half of fu, the small scale splits in the move zone demonstrate some augmentation because of stress focus to the tips in any case, no splitting happens in the mortar framework. Until this point split proliferations is thought to be steady as in break lengths quickly achieve their last values if the connected anxiety is held consistent. For a worry between 50-75% of fu progressively the split framework has a tendency to be insecure as the move zone break starts. At the point when the accessible vitality surpasses the required break discharge vitality, the rate of split proliferations will increment and the framework ends up plainly over 75% of fu when finish crack of the test example can happen by connecting of mortar and move zone breaks.

In light of the coveted breaking stages, the conduct of cement can be seen at two levels: Firstly, haphazardly disseminated miniaturized scale splits are shaped or grow under low level of stresses. At the point when elastic anxiety level achieves a particular esteem, these small scale breaks start to confine (strain restriction) and to mix into a full scale split. This full scale break will agate until the anxiety achieves its basic stage. Unfaltering state spreads of this large scale break will bring about strain softening system watched for cement. This general perspective of splitting of solid makes it clear that the principal straight flexible part of stacking up to strain confinement can't be portrayed by crack component watched for cement. This general perspective of breaking of solid makes it clear that the main direct versatile part of stacking up to strain restriction can't be depicted by crack instrument yet can be measured utilizing harm mechanics [Krajcinovic 1984].

1.8.1.2 FOR STEEL FIBRE REINFORCED CONCRETE

Compressive quality is little affected by steel fiber expansion. This quality can likewise be accomplished utilizing silica smoke or fly cinder. In any case, the utilization of steel strands the method of disappointment of high quality cement from a touchy weak one to a more malleable one, again demonstrating the expanded strength of SFRC and its capacity to ingest vitality under element stacking. Compressive quality of SFRC, the fiber sort, volume part and angle proportion assume a vital part in deciding the compressive pliability and vitality retention limit of fiber fortified cement. The material conduct is by and large improved as the volume portion and angle proportion of filaments increments up to limits after which the issues with new blend workability and fiber dispersability begin to harm the solidified material properties. As the expansion in both volume division Vr and perspective proportion l/d prompt change of a similar sort in the compressive conduct of the material, their joined impact has been for the most part examined utilizing the Fiber Reinforcing Index, defined as Vrl/d. The higher the fiber strengthening file, the higher is pliability and vitality ingestion limit of fiber fortified cement. In any case, for high estimations of fiber fortifying record, the issues with workability and fiber disperability of blend have a tendency to fall apart the compressive conduct of the solidified material. Because of their material properties, steel filaments don't at all impacts the quality parameters of cement. Under compressive stacking, when small scale breaking happens as a result of transverse strain powers, steel strands cause split shutting strengths, on one hand. This keeps an eye on an expansion of compressive quality. Then again, porosity increments when steel strands are blended in with the crisp cement. This declines the compressive quality of steel fiber fortified cement. Both impacts in mix tend to counteract each other. The impact of filaments in enhancing the compressive quality of the grid relies on upon whether mortar or cement (having coarse totals) is utilized and on the size of compressive quality. Otter and Naaman [1998] demonstrated that utilization of steel strands in lower quality cements expands their compressive quality altogether contrasted with plain unreinforced frameworks and is straightforwardly identified with volume division of steel filaments utilized.

1.8.2 BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE UNDER FLEXURE

In various examinations, it has been shown that the flexure, shear, torsion, punching, dynamic effect practices of basic components is enhanced by the utilization of SRFC. The constructive outcomes of SFRC on the flexure conduct of the auxiliary components are given as takes after by Craig (1984)

- Increases minute limit and breaking minute
- Increase the pliability
- Increase split control
- Increase inflexibility
- Preserves the auxiliary respectability after bar surpasses a definitive load.

1.8.2.1 FACTORS AFFECTING THE FLEXURE BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE

(a) INFLUENCE OF STEEL FIBRE VOLUME FRACTION

The impact of fiber volume division is appeared in figure. For 90 and 120 kg/m3 fiber content, the post break increment in load is noteworthy. This expansion basically gives the change in flexure quality and stable post split conduct. As appeared, the twisting limit increments as the volume portion increments.

(b) INFLUENCE ON FIBRE LENGTH

The impact of fiber length is exceptionally critical adversary straight strands. Nonetheless, longer strands with higher viewpoint proportions give better execution in both quality increment and vitality assimilation the length of they can be blended, put, compacted and completed appropriately. Since snared end filaments give great safe haven, an expansion in angle proportion of snared strands has less impact as contrasted and steel strands.

(c) INFLUENCE ON FIBRE GEOMETRY

Three diverse fiber geometries, in particular straight filaments, ridged strands, snared end filaments with equivalent length are contemplated on the flexural conduct of Steel Fiber Reinforced Concrete by Gopalaratnam et al. (1991). As indicated by test outcomes, concrete with straight filaments have higher rigidity and post split reaction than other two sorts. The drop after the principal pinnacle is a great deal more articulated for folded and snared end strands. There are various components that impact conduct and quality of SRFC in flexure. They are fiber introduction and fiber shape, fiber bond qualities (fiber misshapening). Additionally, elements that impact the workability of SRFC, for example, w/c proportion, thickness, air content and so forth could likewise impact its quality. A definitive quality in flexure could differ significantly relying on the volume portion of filaments, length and bond attributes of the strands and a definitive quality of the filaments. Contingent on the commitment of these affecting elements, a definitive quality of SRFC could be either littler or bigger than its initially breaking quality.

1.8.2.2 FLEXURAL BEHAVIOUR OF STEEL FIBRE REINFORCED CONCRETE

For the most part, there are three phases of the heap avoidance reaction of SRFC examples tried in flexure. The three phases are:

1. A pretty much straight reaction up to point A. The fortifying system in this bit of the conduct includes an exchange of worry from the lattice to the filaments by interfacial shear. The forced anxiety is shared between the framework and strands until the network splits at what is named as "first breaking quality" or "relative point of confinement".

2. A move non direct bit between point An and the maxi most extreme load limit at point B (expecting the heap at B is bigger than the heap at A). In this part, and in the wake of splitting, the worry in the lattice is logically exchanged to the filaments. With expanding load, the strands have a tendency to step by step haul out from the lattice prompting a non direct load diversion reaction until a definitive load limit at B is come to. This point is named as "pinnacle quality".

3. A post breaking dropping segment taking after the pinnacle quality until finish disappointment of the composite. The heap absconding reaction in this segment of conduct and the degree at which loss of quality is experienced with expanding distortion is a vital sign of the capacity of the fiber composite to retain a lot of vitality before disappointment and is a trademark that recognizes fiber-strengthened cement from plain concrete. This trademark is alluded to as durability. In the Load Deflection Curves of SFRC examples, the non straight part amongst An and B exists, just if an adequate volume division of strands is available. For low volume portion of filaments ($V_f < 0.5\%$), a definitive flexural quality corresponds with the principal breaking quality and the heap avoidance bend plummets quickly after the splitting burden.

1.9 OBJECTIVES

The aim of our project is to use hooked end steel fibres in concrete for improving its properties

- To compare the properties of SFRC with normal concrete
- Our target is to include the steel fibres (snared) to the solid and to concentrate the quality properties of cement with the variety in angle proportion of filaments.
- To study the strength properties of concrete (M30 Grade) for fibre content of 0 & 0.5%, with aspect ratio 50 & 80 at 7 and 28 days.
- To study the strength properties of concrete (M30 Grade) for fibre content of 0, 0.5, 1, 1.5, 2 and 2.5% with aspect ratio 50 at 7 and 28 days.
- The strength properties being studied in our report are as follows:
  1. Compressive strength
  2. Split tensile strength
  3. Flexural strength

CHAPTER 2

REVIEW OF LITERATURE

2.1 Tensile behaviour of high performance hybrid fibre reinforced concrete

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

Summary: The effect of fibres at different volumes of parts in high quality cement has accomplished a decent rigidity. In view of the exploratory examinations did the accompanying conclusions are drawn. It is conceivable to deliver fiber solid composites utilizing steel filaments, with an improved pliable execution contrasted with cement without strands. Fiber consideration of various types expanded compressive quality, in spite of the fact that this expansion was not that critical and could have been acquired with less complex and more efficient strategies like decreasing w/c proportion. Small scale steel filaments ended up being proficient in reinforcing the lattice.

2.2 Performance of steel fibre reinforced concrete

Author: Milind B.Mohod[2]

Summary: Taking after conclusions were drawn from the work did.

1) It is noted that the workability of steel fibre strengthened cement gets lessened as the rate of steel strands increments.

2) Compressive quality continues expanding by increment in steel fiber rate up to the ideal esteem. The ideal estimation of the fiber substance of steel fiber fortified cement was observed to be 1%.

3) The flexural quality of cement continues expanding with increment in fiber content up to ideal esteem. The ideal incentive for flexural quality of steel fiber fortified bond cement was observed to be 0.75%.

4) While testing the example, the plain bond solid examples have demonstrated a commonplace break proliferation design which drove into part of shaft in two piece geometry yet because of expansion of steel filaments in solid splits get stopped which comes about into the flexible disappointment of SRFC.

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

Author: B. Siva Konda Reddy[3]

Summary: The HPC contemplated in this examination program has shown an amazing arrangement of material properties and the conclusions are drawn as takes after:

1) Addition of steel strands to plain cement expanded the compressive and elasticity of cement by 8% and 9% separately.

2) Addition of steel filaments to HPC expanded the imperviousness to chloride particle infiltration.

2.4 Comparative study on steel fibre reinforced cum control concrete under flexure and deflection

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

Summary: The accompanying conclusion can be drawn from the present examinations:

1) It is watched that the flexural quality from steel strands are on higher side from 3% filaments when contrasted with that created from 0%,1% and 2% strands.

2) It is watched that flexural quality increments from 13 to 48.35% through usage of steel strands. What's more, through use of 1% steel filaments flexural quality increments from 13.35 to 23.35%. Through usage of 2% steel strands flexural quality increments from 18.35 to 31.65%. Through usage of 3% steel strands flexural quality increments from 20.8 to 48.35%.

3) The expansion of filaments has altogether upgraded the execution of shaft in flexure. Amid the test it was outwardly watched that the SFRC example has more noteworthy split control as exhibited by decrease in break width and break separating.

4) It is seen amid testing that when example is tried for part elasticity and flexural quality the control solid example has broken into 2 pieces while the SFRC example held the geometric uprightness. It uncovers enhanced pliability of SFRC because of the expansion of steel filaments over control concrete

5) It is watched that for higher rate of steel fiber redirection of pillar is less when contrasted with control shaft.

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

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

Summary: The accompanying conclusions can be drawn:

1) The expansion of steel strands in the solid blend brought about enhanced auxiliary execution measure as far as extreme load conveying limit, split widths, diversion and shape and malleability variable of pillar examples of all the arrangement.

2) The ideal fiber volume rate for all the arrangement was gotten as 1.5%. The further increment in fiber content diminished the heap conveying limit of all examples because of poor compaction of cement on account of balling of filaments.

3) With expansion of steel fibres in solid blend of specimens the presence of first split was postponed. The nearness of steel strands likewise enhanced the post cracking conduct of the examples of all arrangement because of crack arresting process.

2.6 Study of Flexural Strength in Steel Fibre Reinforced Concrete

Author: Patil Shweta, Rupali Kavilkar[6]

Summary:

1) The addition of restricting wire or a steel fiber into the solid altogether builds the flexural quality.

2) At steady rate of fibre=1.5% and by expanding viewpoint proportion of filaments from 40 to 70, it is watched that the flexural quality is expanded from 36.7% to 58.65% when contrasted with plain solid quality.

3) At steady angle proportion 70 and by expanding rate volume of strands from 0.5% to 2.5%, it is watched that the flexural quality is expanded from 29.2% to 119.69% when contrasted with plain concrete.

4) By expansion of restricting wire as a steel fiber to the solid, it is watched that the compressive quality somewhat diminished.

5) The greatest drop in compressive quality (decline of 31.10% when contrasted with plain concrete) is seen with the viewpoint proportion 70 and rate volume of fiber of 1.5%.

2.7 Introduction to steel fibre reinforced concrete on engineering performance of concrete.

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

Summary: The review on presentation of impact of steel filaments can be as yet encouraging as steel fiber fortified cement is utilized for feasible and durable solid structures. Steel strands are generally utilized as a fiber fortified cement and a considerable measure of specialists work conspicuously over it. This survey concentrate attempted to concentrate on the most critical impacts of expansion of steel filaments to the solid blends. The steel filaments are generally utilized strands for fiber fortified cement out of accessible filaments in the market. As indicated by numerous scientists, the expansion of steel strands into cement makes low workable or insufficient workability to the solid, subsequently to take care of this issue; a superplasticizer without influencing different properties of cement might be presented.

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

Author: Nitin Kumar, Sangeeta[8]

Summary: A great deal of audit study has been directed to see the impact of blending steel filaments as fortification material with concrete as parent material. An expansive number of minor and real examining tests were led like compressive, flexural and elasticity with steel filaments blended with cement at different rates. The majority of the survey concentrates exhibited that different mechanical, substance and designing properties like split elasticity, compressive quality, affect quality and flexural quality of cement blended with various rates of steel strands ended up being a decent fortifying material and financially feasible for enhancing the quality and strength attributes of concrete.

2.9 Studies on steel fibre reinforced concrete – a sustainable approach

Author: Vasudev R., Dr. B G Vishnuram[9]

Summary: The variety of direct compressive quality for solid 3D squares was observed to be conflicting with the expansion in rate of filaments. The Splitting rigidity was expanded by 20-22% for solid barrel tests with 0.5% fiber content in M20 and M30 Grade concrete blends. Much research on promptly accessible strands was directed with an extra contribution of cost for the buy of filaments. Yet, these tests were subsequently a genuine case of maintainable advancement as the reusing of scraps from foam shops is done to enhance the conduct of concrete.

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

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Summary: The accompanying conclusions could be drawn from the present examination:

1) By expansion of 0.5%, SF3 Fibers demonstrates most extreme compressive quality.

2) With same volume part, change long of fiber came about almost minor impact on compressive quality of fiber strengthened cement.

3) It was watched that the split elasticity of fiber strengthened cement was subject to length of fiber utilized. By expansion of longer length fiber, the split rigidity increments.

4) By expansion of 0.5%, SF3 strands demonstrates most extreme split elastic over fiber SF1 and SF2.

5) Addition of steel fiber in solid influences the workability of cement. Expansion of 0.5% steel filaments lessened the droop estimation of new concrete. This issue of workability and stream property of cement can be overcome by utilizing appropriate admixtures, for example, Superplasticizers.

CHAPTER 3

EXPERIMENTAL INVESTIGATIONS

3.1 EXPERIMENTAL PROGRAM

To study the interaction of steel fibres (hooked end) with concrete under compression, flexure, split tensile and various other tests were performed in which a number of beams and cylinders were casted. First the strength is measured by varying l/d ratio. After that the experimental program was split into 6 groups. Each group consisted of cubes, cylinders and beams of 15x 15x 15cm, 10x 20cm and 15x 15x 50cm respectively.

- The first group was control concrete with 0% fibre
- The second group consisted of 0.5% of steel fibres, by total volume of concrete.
- The third group consisted of 1% of steel fibres, by total volume of concrete.
- The fourth group consisted of 1.5% of steel fibres, by total volume of concrete.
- The fifth group consisted of 2% of steel fibres, by total volume of concrete.
- The sixth group consisted of 2.5% of steel fibres, by total volume of concrete.

3.2 MATERIALS AND TESTS

3.2.1 CEMENT

Cement goes about as a coupling specialist for materials. Cement is connected in Civil Engineering Industry is created by calcining at high temperature. It is a blend of calcareous, aluminous substances and squashing the clinkers to a fine powder. Bond is the most costly material in cement and it is accessible in various structures. At the point when concrete is blended with water, a concoction response happens therefore of which the bond glue sets and solidifies to a stone mass. Contingent on the substance organization, setting and solidified properties, bond can be comprehensively arranged into two categories:

- Portland Cement
- Special Cement

The cement utilized as a part of this test examination is common Portland bond 53 review. Capacity of concrete requires additional unique care to safeguard its quality and wellness for utilize. To keep its crumbling it is important to shield it from rain, winds and dampness.

Fig. no. 3.1 Cement

Chemical composition of OPC

OXIDES	% CEMENT
CaO	60-67
SiO_2	17-25
Al_2O_3	3-8
Fe_2O_3	0.5-6.0
Na_2O+K_2O	0.1-1.3
MgO	0.1-0.4
SO_3	1.0-3.0

3.2.2 FINE AGGREGATES

Fine aggregates were procured from the JUIT campus itself. Initially observation showed the presence of various impurities and moisture. The impurities were removed by sieve analysis. It had cubical as well as rounded shape with smooth surface appearance. Being cubical, rounded and smooth, it gave good workability. Sieve analysis was done to figure out fineness modulus which came to be 3.14% which is within the limit as per IS 383-1970. The specific gravity was 2.65.

3.2.3 COARSE AGGREGATES

The coarse aggregates were taken from JUIT campus. Initial observations showed the presence of dust particles, leaves. The material whose particles are of size that are retained on IS sieve No. 480 (4.75mm) are termed as coarse aggregate. The extent of coarse aggregates relies on the way of work. The coarse total utilized as a part of this trial examination are of 20mm and beneath sizes, squashed precise fit as a fiddle. The aggregates were clean before utilized as a part of concrete.

3.2.4 WATER

Water to be utilized as a part of the concrete work ought to have the accompanying properties:

- It ought to be free from harmful measure of soils.
- It ought to be free from harmful measure of acids, antacids or other natural and inorganic polluting influences.
- It ought to be free from iron, vegetable matter or some other kind of substances, which are probably going to adversly affect cement or reinforcement
.
- It ought to be free fit for drinking reason.

The elements of water in cement are:

- It wets the surface of totals to build up the coveted attachment between the concrete, sand and totals.
- It readies a plastic blend of the different fixings and bestows the workability to solid with the goal that it can be set effectively.
- It is likewise utilized for the hydration of the solidifying materials with the goal that it can set and solidify amid the time of curing.

3.2.5 FIBRE

The hooked end steel fibre used in the experiment is taken from Komatko, Pune Maharashtra. The shape is presumably the most prevalent and effective in the historical backdrop of steel fiber strengthened cement. Hooked end fibres can be utilized with any solid blend and high solid thickness. Stack move in the split is great with this fiber shape. Along these lines after the presence of the primary split the loss of load-bearing limit happens rapidly yet then settles.

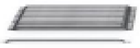
Item Nos.	Length (mm)	Diameter (mm)	Aspect Ratio	Type	Formation	UTS (N/mm2)	Additiona Info	Price exclusive of tax	Brand	Appx. Look
1	60	0.75	80	Single hooked end	Glued	1225	Bright wire	145.0	Bekaert	
2	50	1	50	Single hooked end	Loose	1050	Bright wire	105.0	Beakert	
3	35	0.55	64	Single hooked end	Glued	1345	Bright wire	210.0	Local	

Fig. no. 3.2 Steel Fibres

Micro steel fibres have the following advantaged comparing with the steel bars in the fields:

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

Plain concrete has a low rigidity, high flexibility and little imperviousness to splitting. Interior small scale splits are inalienably present in the solid and its poor rigidity is because of the engendering of such smaller scale breaks, in the long run prompting fragile disappointment of the solid. It has been perceived that the expansion of little, firmly separated and consistently scattered filaments to the solid would go about as a break arrester and would generously enhance its compressive and flexural quality properties. This kind of cement is known as fiber reinforced concrete. Hooked end steel fibres are used with aspect ratio 80, 50 and 64.

3.3 MIXING OF SPECIMEN

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

The sand is laid in a layer of approximately 10cm thick. Then cement is mixed with the sand thoroughly to have a uniform colour. The coarse aggregates are spread on the ground and then the cement-sand mixture is mixed with it to get a uniform matrix. The hooked end steel fibres of desired length are dispersed in the water. The water along with the fibres is added to the mixture and mixed thoroughly to get a uniform mass with required colour and consistency. After the mixing the concrete is poured into the moulds & testing is done after 7 and 28 days.

Fig no 3.3 Hand mixing of specimen

Fig no 3.4 Machine mixing of specimen

3.4 CASTING OF SPECIMENS

For casting the cubes, beams and cylinder specimens, standard cast iron metal moulds of size 150x 150x 150mm for cubes, 100x 100x 500mm for beams, 100x 200mm for cylinders are used. The moulds have been cleaned of tidy particles and connected with mineral oil on all sides before the solid is filled the moulds. Altogether blended cement is filled into the moulds in three equivalent layers of equivalent statures took after by altering. At that point the form is set on the vibrator table for a little timeframe. Overabundance concrete is evacuated with trowel and top surface is done to smooth level.

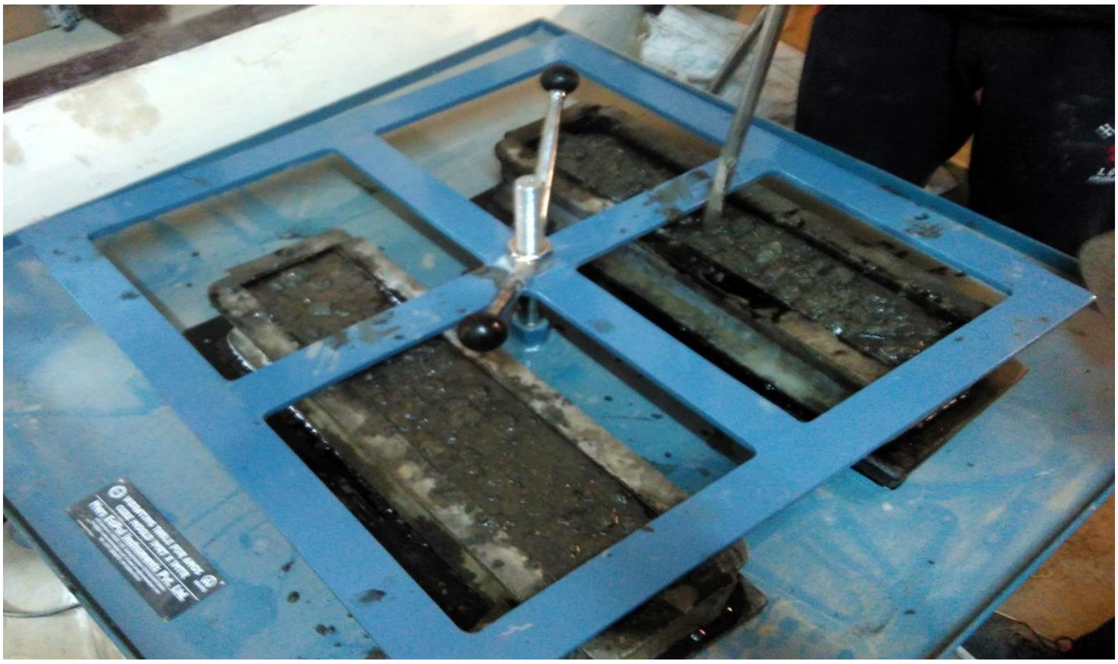


Fig no 3.5 Casting of specimens

3.5 TESTS ON HARDENED CONCRETE

3.5.1 CUBE COMPRESSION TEST

The test was conducted according to IS 516-1959. The cubes of size 150x150x150mm were casted to figure out the compressive strength, Cubes were kept on the bearing surface of CTM, without eccentricity and a constant rate of loading of 550kg/cm^2 per minute was applied till the failure of specimen. The maximum load was noted down and the compressive strength hence calculated.

Concrete compressive strength (f_{ck}) in MPa = P/A

Where,

P= compressive load

A= Area of specimen on which load was applied (150mmx150mmx150mm)

Fig. no. 3.6 Compression test

3.5.2 FLEXURAL TEST

SRFC beams of size 100x100x500mm are tried utilizing flexure testing machine. The example is essentially upheld on two rollers of the machine which are 600mm separated, with a direction of 50mm from each support. The heap should be connected on the shaft from two rollers which are set over the beam with a spacing of 200mm. The load is applied at a constant rate such that the extreme fibre stress increments at 0.7N/mm2/min i.e., the rate of stacking should be 4 KN/min. The heap is expanded till the example comes up short. The most extreme estimation of the heap connected is noted down. The appearance of the fracture faces of specimen and any unique features are examined.

The modulus of rupture is calculated using the formula

$\boldsymbol{\sigma_s = Pl/bd^2}$, where

P= load in Newtons

l= length of span in mm on which the specimen is supported

b= width in mm of the specimen

d= depth in mm of the specimen at the point of failure.

Fig no 3.7 Flexural test on beam

3.5.3 SPLIT TENSILE TEST

SRFC cylinders of dimentions 10cm (diameter) and 20cm (height) are casted, the test is conducted by placing a cylindrical specimen horizontally between the loading planes of compression testing machine, and the load is applied till failure of the cylinder, along the vertical diameter. When the load is applied along the generatrix, an element on the vertical diameter of the cylinder is subjected to a horizontal stress of **2P/πld**, where

P is the compressive load

l is the length

d is the diameter

The fundamental favourable position of this strategy is that a similar kind of example and a similar testing machine is utilized for the pressure test can be utilized for this test. This is the reason this test is picking up ubiquity. The part test is easy to perform and gives more uniform outcomes than the other pressure tests. Quality decided in the spilt elastic test is accepted to be nearer to the genuine rigidity of the concrete, than the modulus of rupture. Split tensile gives about 5-10% higher value than the direct tensile strength.

Fig no 3.8 Split tensile test on cylinder

SOME PRACTICAL DIFFICULTIES ENCOUNTERED

The various practical difficulties encountered can be summarized as below:

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

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

Some of the errors in the observation values may be due to the following reasons:

- Inefficient mixing in the mechanical mixer.
- Increased water content in order to achieve workability.
- Improper curing.
- Improper weighing of the ingredients.
- Improper dispersion of fibres in the specimen.

CHAPTER-4

RESULTS AND DISCUSSIONS

Table no. 4.1.1 Compression test values of M30 grade SFRC for 7 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average compressive strength (in N/mm^2)
0	-	18.4	17.9	18.2	18.15

Table no 4.1.2 Compression test values of M30 grade SFRC for 14 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average compressive strength (in N/mm^2)
0	-	27.5	26.5	27.4	27.15

Table no 4.1.3 Compression test values of M30 grade SFRC for 28 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average compressive strength (in N/mm^2)
0	-	30.8	31.5	31.2	31.15

Table no 4.1.4 Split tensile test values of M30 grade SFRC at 7 days of curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average split tensile strength (in N/mm^2)
0	-	1.81	1.84	1.82	1.83
0.5	50	2.45	2.51	2.49	2.48
0.5	80	3.20	3.27	3.33	3.24

Table no 4.1.5 Split tensile test values of M30 grade SFRC at 28 days of curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average split tensile strength (in N/mm^2)
0	-	3.48	3.45	3.47	3.46
0.5	50	3.78	3.80	3.78	3.79
0.5	80	4.10	4.18	4.13	4.14

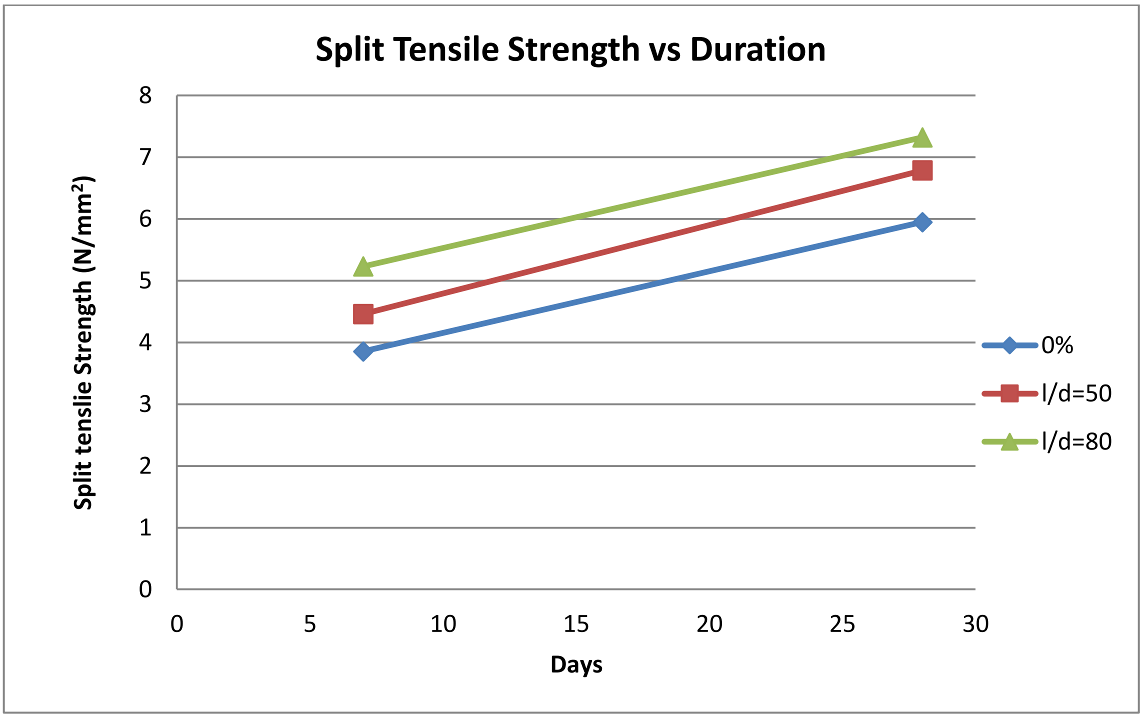


Fig. no. 4.1 Split tensile strength Vs duration

Table no. 4.1.6 Flexural test values of M30 grade SFRC at 7 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm^2)
0	-	3.81	3.9	3.8	3.83
0.5	50	4.42	4.5	4.46	4.46
0.5	80	5.18	5.25	5.2	5.21

Table no. 4.1.7 Flexural test values of M30 grade SFRC at 28 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm^2)
0	-	5.92	5.98	5.96	5.95
0.5	50	6.75	6.82	6.80	6.785
0.5	80	7.23	7.43	7.34	7.32

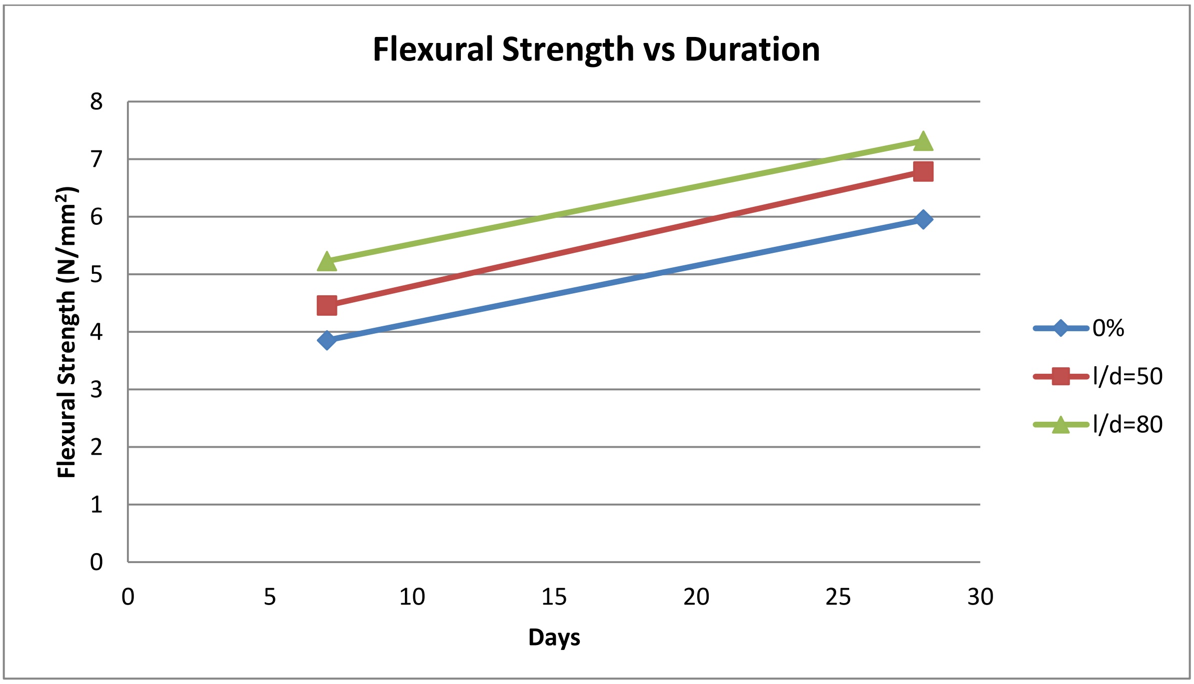


Fig. 4.2 Flexural strength Vs duration

4.2 Comparison of properties of SRFC by varying the percentage of fibres

Table no 4.2.1 Split tensile test values of M30 grade SFRC at 7 days of curing

Percentage of fibres	**Aspect Ratio**	**Trial 1**	**Trial 2**	**Average split tensile strength (in N/mm^2)**
0	-	1.81	1.84	1.83
0.5	50	2.45	2.51	2.48
1	50	2.78	2.82	2.8
1.5	50	2.91	2.96	2.935
2	50	2.84	2.79	2.815
2.5	50	2.78	2.8	2.79

Table no 4.2.2 Split tensile test values of M30 grade SFRC at 28 days of curing

Percentage of fibres	**Aspect Ratio**	**Trial 1**	**Trial 2**	**Average split tensile strength (in N/mm^2)**
0	-	3.48	3.45	3.465
0.5	50	3.78	3.8	3.79
1	50	4.17	4.14	4.155
1.5	50	4.33	4.37	4.35
2	50	4.21	4.19	4.2
2.5	50	3.9	3.94	3.92

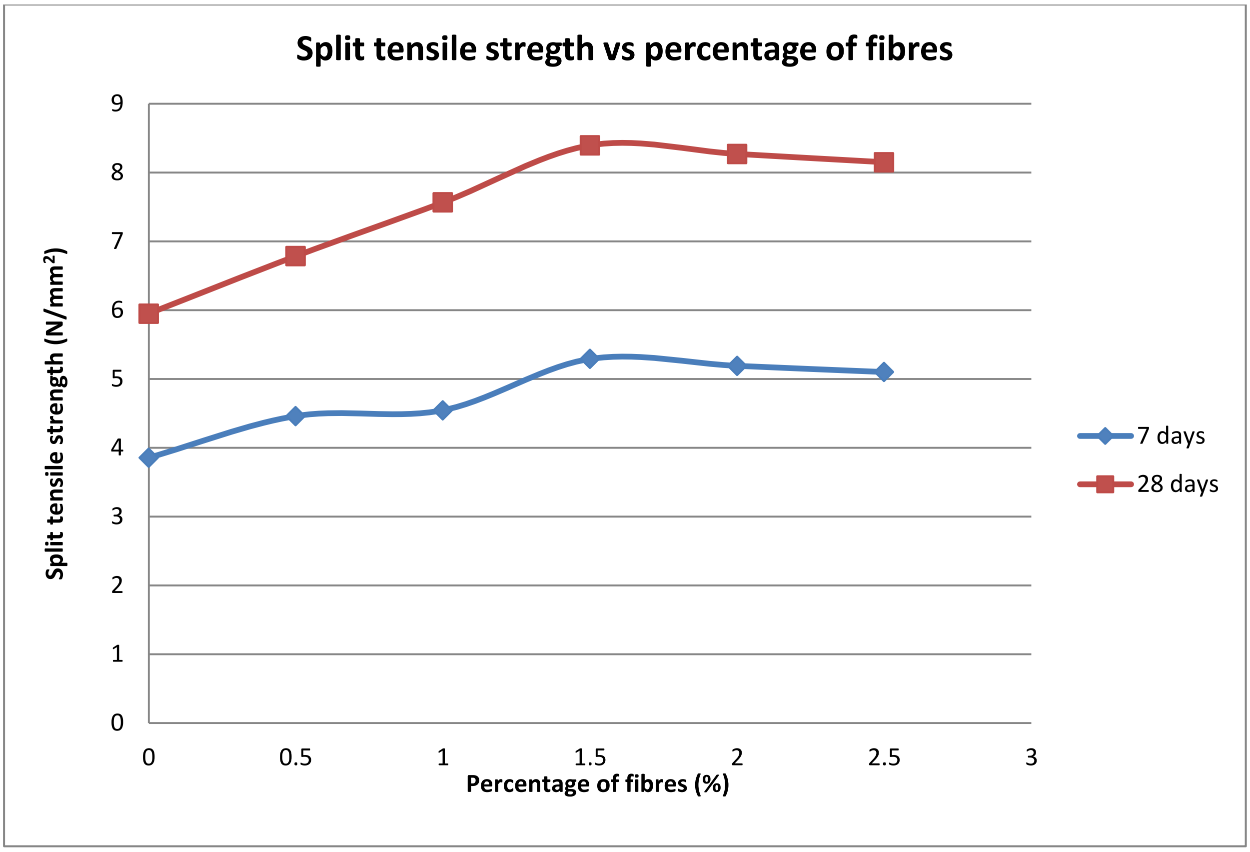


Fig. 4.3 Split tensile strength Vs percentage of fibres

Table no. 4.2.3 Flexural test values of M30 grade SFRC at 7 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm^2)
0	-	3.81	3.9	3.87	3.855
0.5	50	4.42	4.50	4.48	4.46
1	50	4.52	4.57	4.55	4.545
1.5	50	5.27	5.31	5.30	5.29
2	50	5.18	5.2	5.19	5.19
2.5	50	5.11	5.10	5.12	5.11

Table no. 4.2.4 Flexural test values of M30 grade SFRC at 28 days curing

Percentage of fibers	Aspect Ratio	Trial 1	Trial 2	Trial 3	Average modulus of rupture (in N/mm^2)
0	-	5.92	5.98	5.94	5.95
0.5	50	6.75	6.82	6.79	6.785
1	50	7.54	7.59	7.57	7.565
1.5	50	8.41	8.38	8.40	8.395
2	50	8.29	8.25	8.26	8.27
2.5	50	8.13	8.17	8.14	8.15

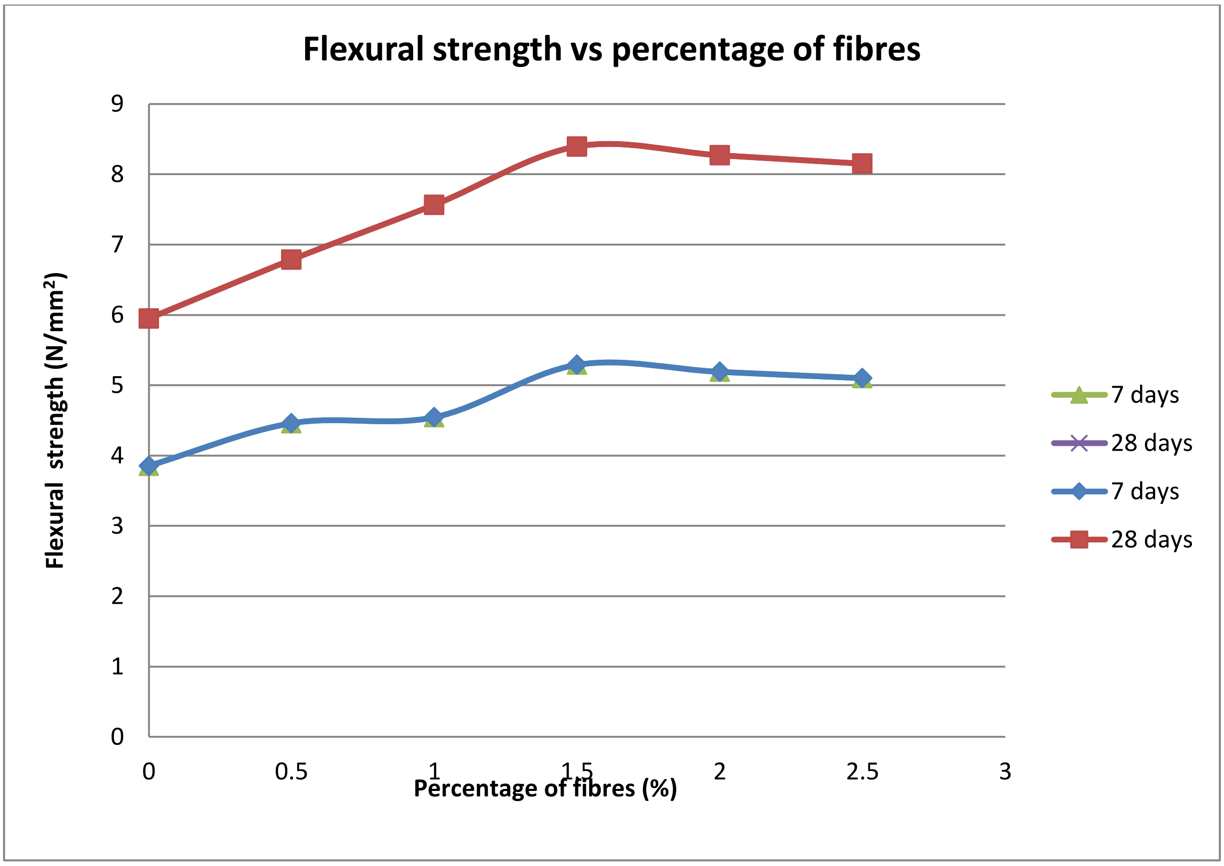


Fig. 4.4 Flexural strength Vs percentage of fibres

4.3 DISCUSSIONS

4.3.1 Split Tesile Strength

The variation in the split tesnile strength with respect to change in the fibre content can be observed. From the results obtained, it is clear that the split tensile strength is maximum when the fibre content is 1.5% of the concrete.the tables below clearly depicts the variation of strength between the plain concrete and fibre reoinforced concrete.

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

Table no.4.3.1.1

Percentage of Steel fibres	SFRC (N/mm^2)	Percentage increase in strength (%)
0	3.465	-
0.5	3.79	9.38
1	4.155	19.90
1.5	4.35	25.54
2	4.2	21.21
2.5	3.92	13.13

From above table it is clear that the Split tensile strength of SFRC with 1.5% fibre has increased by **25.54%** as compared to plain concrete.

4.3.2 Flexural Strength (Modulus of Rupture)

From the results obtained, it is inferred that the most significant increase in the modulus of rupture is obtained by addition of 1.5% of fibres. So comapring the value of modulud of rupture:

Table no.4.3.2.1

Percentage of Steel fibres	SFRC (N/mm^2)	Percentage increase in strength
0	5.95	-
0.5	6.785	14.03
1	7.565	27.14
1.5	8.395	41.10
2	8.27	39.00
2.5	8.15	36.97

From above table it is clear that the Flexural strength of SFRC with 1.5% fibre has increased by **41.10%** as compared to plain concrete.

CONCLUSIONS

- The steel filaments (snared) utilized as a part of this venture has indicated significant change in every one of the properties of solid when contrasted with ordinary cement.
- The steel strands are free from water retention.
- With enhanced comprehension of the connection between fiber attributes and composite or auxiliary execution, the fitting of strands for use in high volume development advertise exists, especially for load conveying basic frameworks and for a few applications particularly in seismic tremor inclined regions. The time is not far that such materials will be utilized as a part of building better and safe development for what's to come.

From the experimental work it was concluded that –
FOR 0.5% FIBRES WITH ASPECT RATIO 50:

- Split tensile strength increased by **9.4%** in 28 days of curing.
- Flexural strength increased by **14.03%** in 28 days of curing.

FOR 0.5% FIBRES WITH ASPECT RATIO 80:

- Split tensile strength increased by **19.5%** in 28 days of curing.
- Flexural strength increased by **23.02%** in 28 days of curing

The optimum percentage of fibres considering the Split tensile and Flexural Strength is **1.5%**.
FOR 1.5% FIBRES WITH ASPECT RATIO 50:

- Split tensile strength increased by **25.54%** in 28 days of curing.
- Flexural strength increased by **41.10%** in 28 days of curing.

SCOPE FOR FURTHER STUDIES

(i) Further review should be possible so as to make sense of the redirections and toughness of cement.

(ii) Further review in the field of leakage properties of steel filaments.

(iii) As the disappointment of SRFC is malleable, future reviews on retrofitting of bewildered and harmed structures can be thought about.

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ANNEXURE A

MIX DESIGN FOR M30 GRADE CONCRETE

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

1	Mass of Cement in Kg/m^3	**380**
2	Mass of water in kg/m^3	**160**
3	Mass of fine aggregates in kg/m^3	**711**
4	Mass of coarse aggregate in kg/m^3	**1283**
5	Water cement ratio	**0.42**

Mix Ratio: 1:2:3.3

ANNEXURE B

TABLE 1 IS 10262:2009

Table 1 Assumed Standard Deviation

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

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

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

TABLE 2 IS 10262:2009

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

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

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

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

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

TABLE 3 IS 10262:2009

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

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

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

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

ANNEXURE C

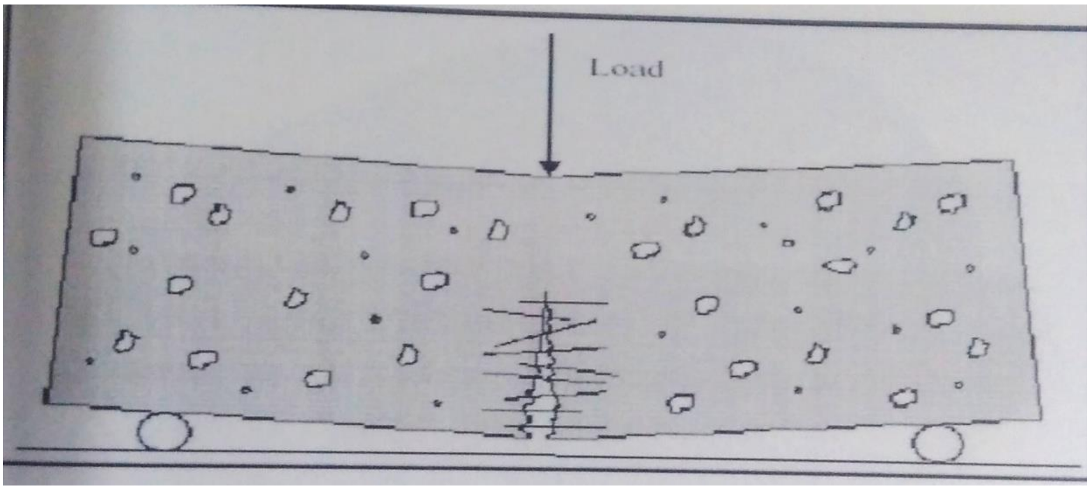
IMAGES TAKEN DURING EXPERIMENTS

Compressive and split tensile strength testing machine

Flexural strength testing machine

Oiling of moulds

Specimen Casted



Fibre pull out mechanism

Split tensile strength test

Fibre distribution a beam sample matrix

REMARKS