International Journal of Science and Research (IJSR)
ISSN: 2319-7064
ResearchGate Impact Factor (2018): 0.28 | SJIF (2018): 7.426

Experimental Investigation on Steel Fibre Reinforced Concrete

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Abstract: ***The present aspect of this research is that how we utilize fibres of steel in structural concrete elements for enhancing the concrete's mechanical property. Also the purpose of this research is to determine mechanical properties of concrete and the comparison of these properties with containing and without containing fibres. The experiment is done by using few tests like compressive strength test and flexural strength test. For determine strength in compression and strength in flexure, several test are carried out according to exploration of required investigation. The experimental program included, a total eleven mix batch of concrete which contain steel fibres vary from 0% to 5% by weight of cement with an regular interval of 0.5% by weight of cement. For improvement in mechanical properties of concrete we use hooked type fibre of steel. As we increase the fibre amount, as well as significantly there will occurring a decrement in workability of concrete. i.e. a inverse relation between them.***

Keywords: concrete Steel Fibre, Compressive test, Hooked Steel Fibre, Flexural test, Spliting tensile strength

1. Introduction

We know that concrete has one of unwanted attributes, it is brittle in nature, hence it has low enduringness, and strain capability. Therefore it needs reinforcement so as to be used because the mostly concrete play a vital role as a development material. Generally, reinforcement is done within the sort of bars of steel are placed in a continuous pattern within the concrete structure within the acceptable positions to resist the obligatory tensile stress and shear stress. Fibres, on the alternative hand, are usually short, discontinuous, and at random spread all over the concrete member to supply a complex structure material called fibre reinforced concrete (FRC). Generally steel, jute, glass and polymer fibres are used in these combined structure material in which polymers are natural derivatives. Fibres will manage cracking a lot of effectively because of their tendency to be a lot of closely spaced than typical reinforcing bars. It ought to be tinted that fibre used because the concrete reinforcement isn't a substitute for typical reinforcing bars. In advance concrete technology there are completely separate roles of each fibres and reinforcing bars, and there are a lot of applications where both fibres and reinforcing bars of steel are used. In all the existing fibres for construction purpose we generally used steel fibres, because it is very preferred variety for resisting mandatory properties in composite structures. In initial time, SFs are not able to avoid some index properties such as shrinkage due to plastic and drying phenomenon. After some time many research and investigation done on this and we found that if we add fibres of steel in concrete complex then the results that the toughness in flexure increases, improving ductile nature of concrete before the final failure condition, decreasing crack patterns, enhance a better durability, achieve a better energy absorbing capability. In this paper we give the results of addition of fibres of steel in concrete complex and explore the some mechanical properties and their applications in construction development. Concrete is usually wide construction material on the earth for the reason that it has ability that it may be mould and form. On the other hand concrete has some deficient properties like as low tensile strength, low post cracking capability, brittleness and low ductility, restricted fatigue life, powerless of accommodating giant deformations, Low impact strength. These deficient properties may be enhanced by the employment of SFRC. The fibres are spread and distributed arbitrarily within the concrete throughout combination, and hence concrete property changes uniformly in all directions in concrete complex. The fibre helps to sensational the interior widening cracks, fly ash helps as an admixture for rising up the concrete property. The introduction of the paper ought to make a case for the character of the matter, previous work, purpose, and the contribution of the paper. The content of every section is also provided to know simply regarding the paper.

1.1 Background and Importance of Steel Fibres

Since past days, a lot of endeavour spent up by researcher to know characteristic and behaviour of structures of concrete. The main aim of all the researchers to investigate the properties of concrete such as strength in flexure, strength in compression, strength against shear, ductile nature and certain structural properties with additional steel and alternative matters for enhancing the behaviour of mixed concrete. In ancient time the main aim of using fibres in mixed concrete is to enhancing the brittle behaviour of this. For example, Mesopotamians used straw to reinforce sunbaked bricks. This ancient technology continues to be won't be improve concrete characteristics. Nowadays, fibres are made from totally different materials like steel, glass, carbon, and synthetic material. Each one of these fibres has it specific benefits. However, among all the fibres steel fibre has capability to resist brittle nature when mixed with raw material of concrete. It has been reported [1] that the primary experimental trial to boost concrete characteristics exploitation discontinues steel reinforcing parts, like nails segments, was done in 1910. However, it absolutely was not till 1963 once major experiments were done to boost concrete characteristics employing a real steel fibres. A typical length of steel fibres of 60 mm, and its diameter of 0.75 mm. In order to overcome problems with steel fibres such rusting, researchers have studied other types of fibres. Synthetic fibres (polypropylene and nylon) are number of these fibres. Also in US, that was the first time in whole world that fibres of Polypropylene firstly used in the construction of building resistance against blasting for the organization of united state engineers .Earlier studies showed that these fibres weren't prosperous like steel and glass. However, a better understanding of fibre behaviour, new styles of fibres, and other factors led to successful synthetic fibre.

Ganeshaan N-et-al, performance of fibre steel reinforced concrete for seismic and earthquake resistant " Civil Engg. and construction".

They done a series of tests on compression, which conducted on cube of size "150 mm x 150 mm x 150 mm" and on cylinder of size "150 mm x 300 mm" to hunt static elastic modulus, dynamic modulus of elasticity and compressive strength with and whereas not steel fibres of volume fractions 0%, 0.5%, 1%, 1.5% of 0.5mm diameter of aspect ratio 60 on PPC concrete. If the quantity of steel fibre increases as well as consequently increases concrete's unit weight. If we add steel fibres then there will increase in modulus of elasticity and strength in compression. If we increases silica fume in ordinary concrete then its compressive strength increases. The addition of silicon oxide fume, steel fibres and hydraulic cement as created a robust structural element with better crack resistance, improved ductility and strength behaviour before to loading.

1.2 Composition of Steel Fibre Reinforced Concrete

The components of steel fibre reinforced concrete "SFRC" can be explained with the help of the Figure 1.1. If concrete contains cement, sand that may be a form of fine mixture, coarse sand as per needed characteristics, water in an exceedingly acceptable proportion as per getting ready combine and discontinuous separate steel fibres is named Steel Fibre Reinforced Concrete. It may additionally contain pozzolona and alternative admixtures ordinarily used with typical concrete. Fibres of assorted shapes and sizes made from synthetic material and manmade material like plastic fibre, steel fibre, glass fibre are getting used. However, for most of the structural and non-structural functions, generally fibres of steel are used in all these existing synthetic and manmade fibres.

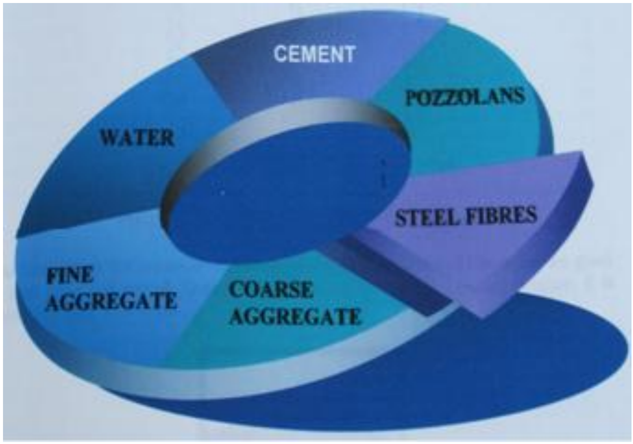

Figure 1.1: Steel Fibre Reinforced Concrete Components

Table 1.1: Physical Properties of Steel Fibres

Sr. No.	Property	Values
1	Diameter	0.75 mm
2	Length of fibre	60 mm
3	Appearance	Bright in clean wire
4	Average aspect ratio	80
6	Deformation	Hooked at both ends
7	Tensile strength	1050 MPa
8	Modulus of Elasticity	200 GPa
9	Specific Gravity	7.8

1.3. Technology for Producing SFRC

SFRC can, in general, be made victimization standard concrete observe, although there are clearly some vital variations. There is a certain basic problem creating issues that in which quantity we introduce fibre volume uniformly to achieve properties as our desire requirement, and also provide a sufficient working ability in recent or fresh concrete to allow proper mixing, batching, transporting, placing, finishing. The hardening characteristics of concrete will increase with addition of steel fibres with applying another aspect ratio, due to this the bond ability enhances between fibre and matrix. Also we take this phenomenon in our mind that with increase in value of aspect ratio fresh concrete's working ability decreases, if decreasing aspect ratio then fresh concrete makes more workable i.e. vice-versa nature. Generally, with increase in length of fibre and amount of fibre according to weight of cement in mix, there is effect occurring in workability of fresh concrete and distribution of fibre uniformly in mixed concrete. Steel fibres have tendency to clumping, so it is a difficult task to achieve homogeneous distribution of steel fibres in a concrete matrix. There are several factor given below due to which Clump and ball nature of fibre occur:

1) Generally, fibres are already clumped with each other they added in matrix, if we apply normal type of mixing then not eliminate these clumps and ball.
2) If we add fibre too quick then it is permit them to distribute in the mixture.
3) If we add amount of fibre in too much quantity.
4) The resultant matrix itself may not sufficient to distribute the fibres.
5) If we add steel fibre as prior to the mixing of other ingredients of concrete, then also due to this they clump to each other.

For avoiding or eliminating the ball and clump nature of steel fibre we adopt some tactics at the time of mixing of concrete. When we use transit mixer, rotating drum mixer for transporting and placing of concrete, the fibres mix in last time to the wet concrete. If we use SFRC then provide a slump value of this 50 to 70 mm greater than normal ordinary concrete.

If we apply a simple screening process in each ingredients of concrete matrix then the tendency to occurring clump and ball in fibres decreases. If we keep 30 to 40 revolutions at mixing speed then we achieve a better distribution of fibres in matrix. If we use fibres at the time of adding fine aggregates then the better distribution of fibre through-out the concrete matrix. The utilization of collated fibres held together by a water-soluble sizing which dissolves during mixing largely eliminates the problem of clumping.

1.4 Scopes and Objectives of Present Work

There are the chief objectives for this research to investigate the utilization of steel fibres in fibre reinforced composite which are made of medium to high concrete capacity.

a) To evaluate the effectiveness of different type of steel fibres according to their geometrical standard such as hooked-end steel fibre.
b) To investigate the strength of composite in compression and flexure.
c) For determine strength in compression and strength in flexure, several test are carried out according to exploration of required investigation. The experimental program included, a total eleven mix batch of concrete which contain steel fibres vary from 0% to 5% by weight of cement with an regular interval of 0.5% by weight of cement. For improvement in mechanical properties of concrete we use hooked type fibre of steel. As we increase the fibre amount, as well as significantly there will occurring a decrement in workability of concrete.
d) The main aim of this research is to determine that at which volume fraction of steel fibre, we achieve the maximum strength in compression and maximum strength in flexure.
e) As what is the variation in ductile behaviour of concrete as per addition of steel fibres, according to their volume fraction by weight of cement.
f) Investigate the pattern and size of crack width as per volumetric fibre content.

2. Mix Design of Concrete

IS methodology of combine designed was used for mix design of M-35 grade of concrete. The quantities of ingredient materials and mix proportions as per design are as under.

Table 2.1: Quantity of Materials per Cubic Meter of Concrete

Material	Proportion by weight	Weight in Kg/m^3
Cement	1	479
F.A.	1.087	521
CAI (20mm) (60%)	1.419	679.98
CAII (10mm) (40%)	0.947	453.33
Water	0.400	191.61

3. Experimental Methodology

3.1 Compressive Strength Test

A cube compression check performed on standard cubes of plain and SFRC of size "100 x 100 x 100mm" after 7days and 28 days of immersed in water of curing plain concrete and SFRC specimens. Results are shown in Table (4.1). The compressive strength of specimen was calculated by the subsequent formula:

$$f_{cu} = \frac{P_c}{A} \quad (1)$$

Where,
P_c = Failure load in compression, KN
A = Loaded area of cube, mm^2
f_{cu} = compressive strength

Expressions for compressive strength in 3rd degree polynomial in terms of V_f are given by the following equations

$$\text{7 Days:} \quad f_{cu} = 0.047\, V_f^{\,3} - 1.143\, V_f^{\,2} + 4.689\, V_f + 29.08 \quad (2)$$

$$\text{28 Days:} \quad f_{cu} = -\,0.068\, V_f^{\,3} + 0.213\, V_f^{\,2} + 0.828\, V_f + 42.77 \quad (3)$$

Vf is Volume Fraction of Fibres (%)

It indicates the best possible amount of fibres which gives best more strength at 28days is 3.0%. The percentage enhance in strength at this amount of fibres over normal plain concrete at 7 and 28 days is 20.68% and 6.150% correspondingly. Cracks take place in microstructure of concrete and fibres cut back the crack development and circulation. After most favourable level, there is fall in compressive strength which indicates air trap in the concrete due to incorporation of higher amount of fibres.

3.2. Flexural strength test

Standard beams of size "100 x 100 x 500mm" were supported symmetrically over a span of 400mm and subjected to two points loading till failure of the specimen. The deflection at the middle of the beam is measured with sensitive dial gauge on UTM.

The flexural strength was determined by the formula:

$$f_{cr} = \frac{P_f\, L}{bh^2} \quad (4)$$

Where,
f_{cr} = Flexural strength, MPa
P_f = Central point through two point loading system, N
L = Span of beam, mm
b = Width of beam, mm
h = Depth of beam, mm

Expressions for flexure strength in third degree polynomial in terms of Vf are obtained

$$\text{7 Days:} \quad f_{cr} = -\,0.0149\ \ V_f^{\,3} + 0.0301\, V_f^{\,2} + 0.27\, V_f + 5.098 \quad (5)$$

$$\text{28 Days:} \quad f_{cr} = -\,0.0262\ \ V_f^{\,3} + 0.245 V_f^{\,2} - 0.3963\, V_f + 6.114 \quad (6)$$

The flexural strength of concrete increases with increase in fibre content upto 4.0% and further decreases when amount of fibre more than 4.0%. The maximum value of flexure strength at 7 days and 28 days are 5.83 and 7.01 correspondingly. Thus, there's improvement in flexural strength of concrete at 7 days from 2.03% to 13.80%, at 28 days from 0.88% to 15.86 %.

4. Conclusions

The present work enables to arrive at the following important conclusions:

1) Workability of concrete reduces as well as fibre content increases.
2) Wet density and dry density at 7 days, 28 days reduces as well as percentage of fibre volume fraction increases.
3) The maximum value of compressive strength is 6.15 at 3.0% of fibre volume fraction and the maximum value of flexural strength is 7.94 at 4.0% of fibre volume fraction.

4) Generally, the acceptable enhancement in assorted strengths is observed with the insertion of steel fibres in normal plain concrete. On the other hand, most gain in strength of concrete is found to rely upon the amount of fibre content. The optimal fibre content to impart highest gain in assorted strengths varies with type of the strength.
5) Ductility of concrete is found to increase with insertion of fibres at high fibre content. The breadth of cracks is found to be a smaller amount in SFRC than that in normally plain cement concrete beam.

5. Applications of SFRCs

Nowadays, SFRC is employed at associate increasing rate in varied applications like the followings

1) Highway and air-field pavements
2) Hydraulic Structures
3) Fibre Shotcrete
4) Refractory Concrete
5) Precast Application
6) Structural Applications

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