EXPERIMENTAL STUDY ON THE BEHAVIOR OF STEEL FIBER REINFORCED CONCRETE

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ABSTRACT

Over the byears, concrete has become considerably more complex. The use of supplementary cementious materials and additives designed to enhance the properties of concrete has grown significantly. The scope of this project is to study experimentally the strength properties of SFRC by adding steel fiber in different proportion (1%, 1.5%, 2%) to concrete. To overcome the deficiency of the conventional concrete, Fiber have been added as secondary reinforcement. Steel fibers are added to concrete in order to overcome the development of micro cracks under applied stress which in turn increase the tensile strength of concrete. The addition of steel fiber in the matrix has many important effects. Most notable among the improved mechanical characteristics of Fiber Reinforced Concrete (FRC) are its superior fracture strength, toughness, impact resistance, flexural strength, resistance to fatigue. Improving fatigue performance is one of the primary reasons for the extensive use of Steel Fiber Reinforced Concrete (SFRC) in pavements, bridge decks, offshore structures and machine foundation, where the composite is subjected to cyclically varying load during its lifetime. The main reasons for adding steel fibers to concrete matrix is to improve the post-cracking response of the concrete,i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control. The initial researches combined with the large volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of Fiber Reiforced Concrete. Steel fiber's tensile strength, modulus of mechanical deformations provide an excellent means of internal mechanical interlock. This provides a user friendly product with increased ductility that can be used in applications of high impact and fatigue loading without the fear of brittle concrete failure. Thus, SFRC exhibits better performance not only under static and quasi-staically applied loads but also under fatigue, impact, and impulsive loading.

INTRODUCTION

1.0 GENERAL

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam or column in a high-rise building. The advantages of using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. The disadvantages of using concrete include poor tensile strength, low strain of fracture and formwork requirement. The major disadvantage is that concrete develops micro cracks during curing. It is the rapid propagation of these micro cracks under applied stress that is responsible for the low tensile strength of the material. Hence fibers are added to concrete to overcome these disadvantages. The addition of fibers in the matrix has many important effects. Most notable among the improved mechanical characteristics of Fiber Reinforced Concrete (FRC) are its superior fracture strength, toughness, impact resistance, flexural strength resistance to fatigue, improving fatigue performance is one of the primary reasons for the extensive use of Steel Fiber Reinforced Concrete (SFRC) in pavements, bridge decks, offshore structures and machine foundation, where the composite is subjected to cyclically varying load during its life time. Today the space shuttle uses fibers in heat shield ties to control the effects of thermal expansion and the human body's strongest and most flexible structures, muscles are made up of fibers. The fact is fibers of almost any description improve the ability of substances to withstand strain.

The inclusion of fibers in concrete is to delay and control the tensile cracking of composite material. Fibers thus transform an inherent unstable tensile crack propagation to a slow controlled crack growth. This crack controlling property of fiber reinforcement delays the initiation of flexural and shears cracking. It imparts extensive post cracking behavior and significantly enhances the ductility and the energy absorption capacity of the composite. Earlier fiber-reinforced concrete was used in pavements and industrial floors. But subsequently, Fiber Reinforced Concrete have wide variety of usages in structures such as, Heavy-duty pavements, Airfields, industrial floor, water retaining and hydraulic structures, parking structure decks, water and waste water treatment plants, pipes, precast roof and wall panels and the techniques of shotcrete application. The lack of corrosion resistance of normal steel fibers could be a disadvantage in exposed concrete situations. The synthetic fibers are uneconomical to medium level people.

2. LITERATURE REVIEW

Kukreja et al (1980) conducted an experiments and reported that, based on the results of three methods such as split tensile test, direct tensile test and flexural test, split tensile strength test was recommended for fibrous concrete. Also increase in tensile strength and post cracking strength, toughness were reported.

Researchers like **Goash et al (1989)** studied tensile strength of SFRC and reported as inclusion of suitable short steel fibers increases the tensile strength of concrete even in low volume fractions, Optimum aspect ratio was found as 80 and the maximum increase in tensile strength was obtained as 33.14% at a fiber content of 0.7% by volume. Also it was reported that cylinder split tensile strength gave more uniform and consistent results than the modulus of rupture test and direct tension test.

Sabapathi and Achyutha (1989) studied the stress – strain characteristics of steel fiber reinforced concrete under compression. Cube compressive strength and Initial Tangent Modulus of Elasticity were obtained and equation for-strain relation was also proposed.

Distribution and orientation of fibers in FRC significantly affect the properties of FRC. Based on this concept, **Paviz Soroushian and Cha-Don Lee (1990)** have carried out some investigation, by counting the number of fibers per unit cross sectional area of SFRC specimen incorporating various volume fractions of different fibers. Theoretical expressions were derived for the number of fibers per cross sectional area in fiber reinforced concrete as a function of volume fraction and length, assuming the cross sectional boundaries as the only factors distributing the 3-D random orientation of fibers. They made comparisons between number of fibers per cross sectional area and the reorientation of fibers in concrete due to vibration.

Ganesan and Ramana Murthy (1190) ascertained the stress- strain behavior of short, confined, reinforced concrete column with and without steel fibers. The steel fibers with volume fraction of 1.5% and aspect ratio of 70 was used. The variable of the study was percentage reinforcement of lateral reinforcement. The strain at peak loads was increased to certain extent.

3. EXPERIMENTAL INVESTIGATION

3.1 MATERIALS USED

Cement : In this experimental investigation O.P.C of 53 grade confirming to IS: 12269- 1987 was used in the preparation of the concrete. Specific gravity 3.15.

Fine aggregate : Locally available River sand conforming to the code IS 383- 1970 is used for this study. Specific gravity 2.74.

Water : Potable water used in this study. Water used for mixing and curing shall be clean and free from oils, acids, alkalis, salt, sugar, organic or other substance that may be deleterious to concrete.

Super plasticizer : In order to increase the strength and also reduce the porosity (impermeability), i.e. to extend the durability and thus the life time of a concrete structure it is of utmost importance to keep the w/c as low as possible using super plasticizer (SP). In our present study CONPLAST SP430(G) super plasticizer from DOLPHIN GEOPOLYMER is used in this study.

Steel fiber : In this study round crimped steel fiber conforming to ASTM A820 with aspect ratio of 100 is used for casting specimens.

SI. No.	Description	Result
1	Length	50 mm
2	Diameter	0.5 mm
3	Aspect Ratio	100
4	Tensile strength	1100 MPa
5	Young's modulus	210 GPa
6	Elongation	15%

Concrete mix of M40 grade was used in the experimental investigation. The mix was designed as per IS 10262-2009 guidelines. The final mix ratio was obtained as 1:1.8:3:0.4(w/c).

Reinforcement details : All the three beams were cast with the following reinforcement details. Two numbers of 10mm diameter rods at bottom and two numbers of 10mm diameter rods at top were provided as main reinforcement. 8mm diameter of stirrups spaced at 100mm center were used as shear reinforcement.

Casting : Concrete was mixed along with steel fibers then concrete was placed uniformly over the length of the standard steel mould in three layers and compacted satisfactory. Demoulding was done after 24 hours and the specimens were cured under water. After 28 days the specimen were removed from the curing tank and taken for testing.

3.2 TESTING OF RC BEAM

The RC beam specimen was placed on the loading frame as shown in figure 5.1. All the beams were tested under two point loading condition. Monotonic load was applied by using screw jack. The applied load is measured using 50 ton proving ring. The observed deflection at mid span was measured by using dial gauge. The beam was loaded up to failure and the values of load at first crack and ultimate failure stage were noted. The cracks were marked by different colours shows clearly the failure pattern of beam.

4. COMPARISON OF STRENGTH PROPERTIES

4.1.1 COMPRESSIVE STRENGTH

The compressive strength of SFRC mixture is 19.4% higher than nominal concrete mix. Result shows that the compressive strength. The variation of compressive strength at 28 days curing for different concrete composition is given in figure.

4.1.2 SPLIT TENSILE STRENGTH

The split tensile strength of SFRC mixture is 22% higher than nominal concrete mix. Result shows that the addition of 1% steel fibers increase the split tensile strength. The variation of split tensile strength at 28 days curing for different concrete composition is given in figure.

4.2 STRUCTURAL BEHAVIOUR

The structural behavior of the beam element is evaluated and results are given in table

PARAMETERS	RC	SFRC	MSFRC
Cracking Load (kN)	22.5	31.5	27.5
Ultimate Load (kN)	49.5	72	63
Ductility Factor	3.76	8.52	4
Energy Absorption capacity (kNmm)	575	800	760
Stiffness (kN/mm)	11.5	37.5	15

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4.2.1 LOAD DEFLECTION BEHAVIOUR

The following Figure shows the Load-deflection behavior of the RC, SFRC and MSFEC beams.

4.2.2 LOAD CARRYING CAPACITY

It is observed from the present investigation that the ultimate load carrying capacity of SFRC beam is 45% higher than the conventional RC beam and the ultimate load carrying capacity of MSFRC beam is 27% higher than the conventional RC beam. The comparison of load carrying capacity of beams under monotonic loading is shown in figure.

4.2.3 DUCTILITY FACTOR

It is observed from the present investigation that the ductility factor of SFRC beams is 127% higher than the conventional RC beam and the ductility factor of MSFRC beams 6.3% higher than the conventional RC beam. The comparison of ductility factor of beams under monotonic loading is shown in figure

4.2.4 STIFFNESS

It is observed from the present investigation that the stiffness of SFRC beam is 3.2 times more than the conventional RC beam and the stiffness of MSFRC beam is 1.3 times higher than the conventional RC beam. The comparison of ductility factor of beams under monotonic loading is shown in figure.

5. CONCLUSIONS

GENERAL

The main reasons for adding steel fibers to concrete matrix is to improve the post-cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility, and to provide crack resistance and crack control. Steel fibre’s tensile strength, modulus of elasticity, stiffness modulus and mechanical deformations provide an excellent means of internal mechanical interlock. This provides a user friendly product with increased ductility that can be used in applications of high impact and fatigue loading without the fear of brittle concrete failure. This phenomenon is particularly advantageous in case of structure located in Earth quake prone areas. The conclusions of the experimental investigation are presented in this chapter.

1. RESEARCH FINDING BASED ON RC AND SFRC BEAM

- The ultimate load carrying capacity of SFRC beam is 45% higher than the conventional RC beam.
- The ductility factor of SFRC beam is 127% higher than the conventional RC beam.
- The energy absorption capacity of SFRC beam is 39% higher than the conventional RC beam.
- The stiffness of SFRC beam is 3.2 times more then the conventional RC beam.

2. RESEARCH FINDING BASED ON RC AND MSFRC BEAM

- The ultimate load carrying capacity of MSFRC beam is 27% higher than the conventional RC beam.
- The ductility factor of MSFRC beam is 6.3% higher than the conventional RC beam.
- The energy absorption capacity of MSFRC beam is 32% higher than the conventional RC beam.
- The stiffness of MSFRC beam is 1.3 times higher than the conventional RC beam.

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