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Experimental Study on Comparison of Hooked-End and Crimped Steel Fibres

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Abstract*— Fibres are generally used as a common engineering material for crack resistance and strengthening of concrete. Their properties and characteristics greatly influence the properties of concrete which has been proved already in many previous researches. Accordingly it has been found that steel fibres give the maximum strength in comparison to glass and polypropylene fibres. In this experimental study, two types of steel fibers namely hooked end and crimped fibers are used. The volume fractions taken are 0.75%, 1.0% and 1.25% and M30 grade concrete is adopted. Cement has been replaced with 25% of Class F flyash. The primary focus is to compare the mechanical properties of concrete using both fibres.
***Keywords* — Ordinary Portland Cement, Hooked end steel fibres, Crimped steel fibre, Flyash**

I. INTRODUCTION

Concrete is the single most widely used construction material on the earth. Being a very flexible material it can be cast to any shape and is suitable for a wide range of structural as well as non-structural applications. The strong points of using concrete include high compressive strength, good fire resistance, high water resistance, low maintenance, and long service life. At the same time there are many drawbacks for concrete which 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 fibres are added to concrete to overcome these disadvantages. The addition of fibres in the matrix has many important effects. Most notable among the improved mechanical characteristics of Fibre Reinforced Concrete (FRC) are its superior fracture strength, toughness, impact resistance, flexural strength, resistance to fatigue etc. Improvement in fatigue performance is infact one of the primary reasons for the extensive use of Steel Fibre Reinforced Concrete (SFRC) in pavements, bridge decks, offshore structures and machine foundation, where the composite is subjected to varying load throughout its lifetime.

II. MANUFACTURING METHOD OF STEEL FIBRES

There are a number of different types of steel fibers with different commercial names. Basically, they are classified depending on the manufacturing methods viz: cut wire (cold drawn), slit sheet, melt extract and mill extract. It can also be classified on the basis of shape and/ or section. Round steel fibres are produced by cutting or chopping wire, typically having diameter of 0.25 to 0.76 mm. Flat steel fibres having cross sections ranging from 0.15 to 0.41mm in thickness by 0.25 to 0.90 mm in width are produced by shearing sheets or by flattening wires. Crimped or deformed steel fibres have been produced both full length and crimped or bent at ends only. Steel fibres are also produced by the melt- extraction process. This method uses wheel that touches a molten metal surface, lifts off liquid metal and rapidly freezes it into fibres which are thrown off centrifugal force. The fibres have an irregular surface and a crescent shaped cross section.

A. Partial Replacement Of Cement With Flyash

Fly ash is a byproduct from burning pulverized coal in electric power generating plants. The mineral impurities in coal (clay, feldspar, quartz, and shale) during combustion fuse in suspension and float out of the combustion chamber with the exhaust gases. As the fused material rises to the top, it cools and then solidifies into spherical glassy particles called fly ash. Fly ash is collected from the exhaust gases by electrostatic precipitators or bag filters. Even though the resulting fine powder resembles Portland cement, chemically it is not similar.

Fly ash is widely used as a supplementary cementitious material (SCM) in the production of portland cement concrete. A supplementary cementitious material, is the one which when used along with portland cement, contributes to the properties of the hardened concrete through hydraulic or pozzolanic activity, or both. A pozzolan is defined as a siliceous or siliceous and aluminous

material that itself does not possess cementitious value, but in finely divided form and in the presence of moisture, reacts with calcium hydroxide at ordinary temperatures to form compounds that possess cementitious properties. The commonly used pozzolans in concrete include fly ash, silica fume, Ground granulated blast furnace slag etc.
The usage of flyash in concrete depends on the purpose of construction. The actual amount used depends on the application, the properties of fly ash, specification limits, and the geographic location and climate as well. Higher levels in the range of 30% to 50% have been used in massive structures such as foundations and dams to keep control over temperature rise. But in the recent times, much higher dosage levels over the range of 40% to 60% are also being used in structural applications, producing concrete with good mechanical properties and durability.

III. EXPERIMENTAL PROGRAM

A. Materials And Properties

The materials used for this experimental study includes natural coarse aggregate, manufactured sand as fine aggregate, cement, superplasticizer, hooked end and crimped steel fibres, water, flyash. Their properties are as follows:

1) Cement: The brand used was "Deccan", with OPC 53 grade. OPC 53 Grade cement is required to conform to BIS specification IS: 12269-1987 with a designed strength for 28 days being a minimum of 53 MPa or 530 kg/cm^2.It was purchased from St. Mary's hollow bricks company, Kothamangalam and it conforms to IS specifications. Properties of the cement are listed in Table 1

TABLE 1 PHYSICAL PROPERTIES OF CEMENT

Name of test	Result
Specific gravity	3.14
Standard consistency	32%
Initial setting time	40 minutes
Final setting time	540 minutes

2) Fine Aggregate: Manufacturer's sand, also known as M-sand has been used for the present investigations and tests were conducted as per IS 2386-1986 (PART I).Specific gravity of fine aggregate is 2.62. The sand was free from clay, silt and chloride content. Fine aggregate are the particles which are used to improve the uniformity and workability in a concrete mix and it also assists the cement paste to hold the aggregate particles in suspension. This improves the plasticity in the mix and prevents the segregation of the aggregate particles.
3) Natural Coarse Aggregate: It constitutes a major portion of concrete. Coarse aggregates of size 20 mm and 12 mm are used. Tests were conducted as per IS 2386 (part III) of 1963.Specific gravity of coarse aggregate is 2.67. Aggregate crushing value was obtained as 30%. As far as possible angular aggregates should be considered. Care should be taken to avoid flaky and elongated aggregates.
4) Water: As per IS 456-2000 recommendations, potable water available in the water supply system was used for casting as well as curing of test specimens. It should have a pH value not less than 6.
5) Flyash: Class F flyash is used(Fig 1). Cement replacement is done with 25 % of flyash. Fly ash is a byproduct of the combustion of pulverized coal in electric power generating plants. It is primarily silicate glass containing silica, alumina, iron, and calcium. Minor constituents are magnesium, sulphur, sodium, potassium, and carbon. This fly ash is pozzolanic in nature, and contains less than 10% lime (CaO).

Fig 1 Class F Flyash

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6) Steel Fibres: Hooked end and Crimped steel fibres are used for the present experimental study (Fig 2 & 3). The Fibres have a length of 30 mm and diameter of 0.5 mm. Aspect ratio is 60.


Fig 2

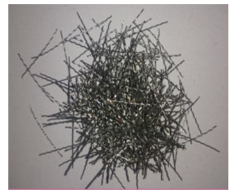
Fig 3

7) Superplasticizer: In this project work, Master Glenium Sky 8233, a product of BASF India Pvt Ltd, an admixture of a new generation based on modified polycarboxylic ether is used. The product has been primarily developed for applications in high performance concrete where the highest durability and performance is required. It is free of chloride & low alkali. It is compatible with all types of cements.

B. Experimental Work

The mix design for M30 grade concrete was done as per IS: 10262(2009).Water-cement ration of 0.43 was adopted. The quantity of materials required per m^3 of concrete is listed out in table 2.

TABLE 2 MATERIALS REQUIRED

Material	Quantity
Cement (kg/m3)	388
Fine aggregate (kg/m3)	670
Coarse aggregate(kg/m3)	1200
Water(*l*/m3)	167
Super plasticizer(*l*/m3)	1.373

IV. TESTS AND RESULTS

A. Compressive Strength

The specimens were casted on 150 x 150 x 150 mm moulds and the testing was done in a compression testing machine as per IS 516(1959). The 28^{th} day and 56^{th} day results are tabulated in table 3. The compressive strength obtained for control mix at 28^{th}day and 56^{th} day are 39.8 and 42.8 respectively. The results for hooked end and crimped fibre reinforced concrete are as given in table 3. (Fig 4)

TABLE 3 COMPRESSIVE STRENGTH

% of fibre	Hooked		Crimped	
	28^{th}day	56^{th}day	28^{th}day	56^{th}day
0.75	42.6	46	33	34.65
1.0	42.91	47.2	34.6	35.98
1.25	44.6	52.6	39.8	42.59

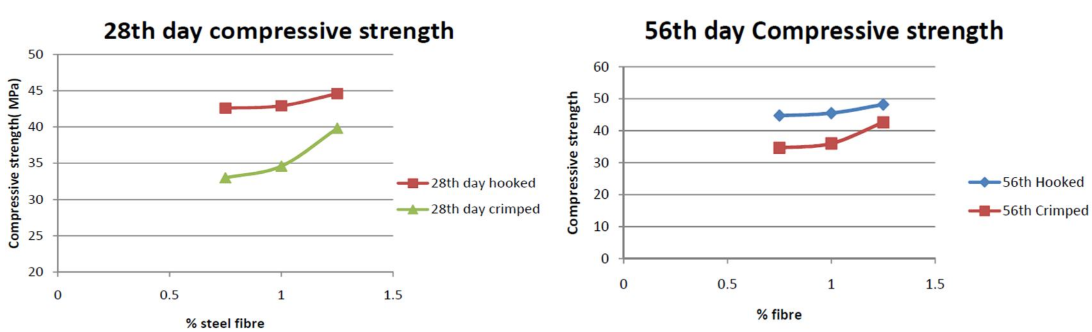

Fig 4: 28^{th}day and 56^{th} day compressive strength

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B. Split Tensile Strength

Split tensile strength test was done on cylinders of 150 x 300 mm cylinders as per IS 5816:1999. It is the indirect test for measuring tensile strength. The 28th day and 56th day test results for split tensile strength are tabulated as follows:

TABLE 4 SPLIT TENSILE STRENGTH

% of fibre	Hooked		Crimped	
	28th day	56th day	28th day	56th day
0.75	3.19	3.51	2.89	3.063
1.0	3.45	4.14	3.183	3.44
1.25	3.48	4.38	2.93	3.135

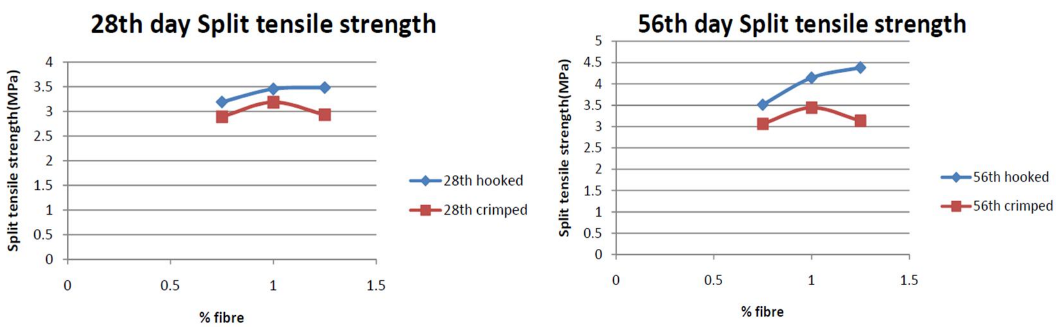

Fig 5: 28th day and 56th day split tensile strength

C. Flexural Strength

It is a measure of unreinforced concrete beam or slab to resist failure in bending. The specimens were tested as per IS 516:1959. 11 X 100 X 500 mm beams are used. The 28th day test results for flexural strength are tabulated as follows:

TABLE 4 FLEXURAL STRENGTH

% of fibre	Hooked	Crimped
0.75	5.33	5.4
1.0	5.6	5.5
1.25	5.92	5.35

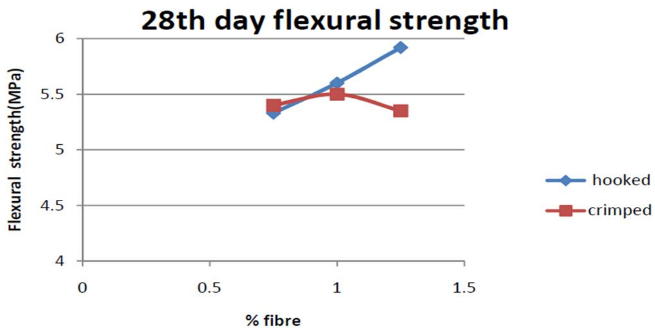

Fig 6: 28th day day flexural strength

Both hooked end and crimped steel fibres improved the mechanical properties significantly. The slight reduction in strength due to the replacement of cement with 25 % of flyash was compensated by the addition of steel fibres. Hooked end steel fibres were found to be better than crimped steel fibres.

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V. CONCLUSION

Based on the experimental studies conducted to determine the mechanical properties of fibre reinforced concrete including both hooked and crimped steel fibres used in percentage ratios 0.75,1 and 1.25 at 25% cement replacement with flyash, the following conclusions were obtained:

After 28thday and 56th day days curing, the compressive strength of hooked fibres increased by 5% with the addition of steel fibres and 1.25% was found to be optimum and crimped fibres showed little effect on compressive strength and 1% was found to be optimum.

The split tensile strength for hooked fibres improved by about 10% and optimum was at 1.25 % and crimped fibres also showed an increase of about 9% till 1% and a gradual decrease after that.

Flexural strength of hooked fibre was maximum at 1.25% and crimped fibre was at 1%.

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