Effect of Shape of Steel Fibre on Mechanical Properties of Fibre Reinforced Concrete

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Abstract— Concrete is a composite material composed of coarse aggregate bonded together with fluid cement that hardens over time. Concrete has relatively high compressive strength, than the tensile strength. For this reason it is usually reinforced with materials that are strong in tension. The tensile strength of the concrete can be increased by the addition of the glass fibers, steel fibers, nylon fibers etc.

Fibre reinforced concrete (FRC) is cementing concrete reinforced mixture with more or less randomly distributed small fibres. In the FRC, a numbers of small fibres are dispersed and distributed randomly in the concrete at the time of mixing, and thus improve concrete properties in all directions.

In this project we are aimed to study the effect of shape of steel fibers on mechanical properties of fiber reinforced concrete. For this purpose M30 grade concrete is chosen as the mix. Different shapes of fibers like hooked end, crimped are used in this study as an addition in percentage likes 1%, 2%, 3%, and 4% to the weight of cement. From the test results we came to conclusion that the Mix with crimped shaped fibre shows more resistance to both compressive and split tensile strength than the Mixes with hooked shaped fibre and conventional at an percentage of 2% with the weight of cement. In comparison use of crimped shapes fibre in concrete gives more satisfactory results than the hooked shaped fibre.

Index Terms— Fibre Reinforced Concrete (FRC), Steel Fibers, Mechanical Properties, Compressive Strength, Split Tensile Strength, Fiber Shape, Hooked End Fibers

I. INTRODUCTION

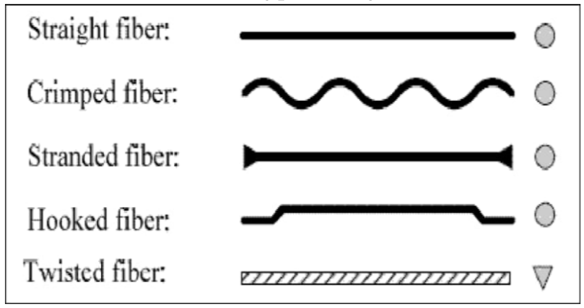
1.1 Introduction:- Fibre reinforced concrete (FRC) is an advanced from of concrete that incorporates fibrous materials to improve its mechanical properties. This fibers help in enhancing the concrete's durability, toughness, and resistance to cracking. Traditional concrete, while strong in compression, is weak in tension and resistant to cracking. The addition of fibers reduces these weaknesses by distributing stress more evenly across the material.

In this fibre reinforced concrete (FRC) should use different types of fibers like,

1. Steel fibre
2. Glass fibre
3. Synthetic fibre
4. Natural fibre

1. Steel fibre:- Made from carbon or stainless steel. Improve tensile strength, toughness, and impact resistance. Commonly used in industrial flooring, pavements, and tunnels.
2. Glass fibre:- Made from alkali-resistant glass. Enhance flexural strength and reduce shrinkage cracks. Used in architectural elements, cladding panels, and decorative structures.
3. Synthetic fibre:- Polypropylene Fibers: Reduce plastic shrinkage cracking and increase durability. Nylon Fibers: Improve impact resistance and abrasion resistance. Polyethylene Fibers: Enhance flexural toughness and reduce permeability.
4. Natural fibre:- Derived from materials like coconut, sisal, jute, hemp, and bamboo. Environmentally friendly and improve toughness. Used in rural and low-cost construction.

In this project we have to investigate on steel fibre reinforced concrete. In this steel fibre reinforced concrete have different types. They are,



II. LITERATURE REVIEW

- Published literature on fiber reinforced concrete first appeared in 1960, and has been increasing significantly since that time reflecting the amount of research and practical application taking place.
- NANNI AND JOHARI (1989) conducted an experiment for pavement construction using steel fiber reinforced concrete (SFRC). The concrete matrix contained flyash, either Class F (used as filler) or Class C (used as a binder). he had presented compression and split tension of laboratory cylinders and filed cores reinforced with different types of steel fiber in various percentsges. It was found that post-cracking characteristics were greatly enhanced by fibers beyond ultimate strength and and also concluded that 19 toughness indexes can be obtained from stress-strain curves in split tension test.
- KAVITAKENE, ET AL, conducted experimental study on behaviour of steel and glass fiber reinforced concrete composites. The study conducted on fiber reinforced concrete with steel fibers of 0% and 0.5% volume fraction and alkali resistant glass fiber containing 0% and 25% by weight of cement of 12mm cut length, compared the results.
- Steel fibers have a marginal effect on compressive strength but improve ductility and energy absorption capacity (Naaman, 1987).
- SFRC exhibits significant improvement in direct tensile and flexural strength compared to plain concrete (Li & Wu, 1992).
- SFRC enhances fracture toughness and prevents sudden brittle failure (Zollo, 1997).
- Steel fibers reduce crack propagation and improve resistance to shrinkage cracking (Grzybowski & Shah, 1990).
- Proper fiber coatings and mix designs mitigate the risk of steel fiber corrosion (Song & Hwang, 2004).
- Hooked, crimped, and twisted fibers provide better anchorage and crack-bridging capabilities (Johnston, 2001).

III. MATERIALS AND METHODOLOGY

3.1.1 ORDINARY PORTLAND CEMENT :-

A cement is a binder, a chemical substance used for construction that sets, hardens, and adheres to other materials to bind them together. Cement is seldom used on its own, but rather to bind sand and gravel together. OPC is manufactured by grinding clinker with a small amount of gypsum.

- In this study, Cement of 53 grade Ordinary Portland Cement was used for the entire work.

Properties:-

- Specific gravity of cement :3.12
- Normal consistency :33%
- Intial setting time of cemet :30min

Fig 3.1 CEMENT

3.1.2 AGGREGATES:-

FINE AGGREGATES

Fine aggregate, commonly referred to as sand, is a crucial component of concrete. It fills the voids between coarse aggregates, improves workability, and enhances the overall strength and durability of concrete.

Locally available natural (river) and confirming to IS specifications was used as a fine aggregate in the concrete mix.

Properties:-

Specific gravity of fine aggregate :2.6

Water obsorption of fine aggregate :1%

Fig 3.2 FINE AGGREGATE

3.1.2.2 COARSE AGGREGATE

- Coarse aggregate refer to irregular and granular materials such as sand, gravel, or crushed stone, and are used for making concrete. In most cases, Coarse is occurring and can be obtained by blasting quarries or crushing them by hand or crushers.
- Coarse aggregate consists of naturally occurring or crushed stones, gravel, or other hard, durable materials, typically retained on a 4.75 mm sieve. It provides bulk to concrete, reducing shrinkage and improving load bearing capacity In our project coarse aggregate of 20mm size is used.

Properties:-

- Specific gravity of coarse aggregate :2.74
- Water obsorption of coarse aggregate :0.5%

Fig 3.3 COARSE AGGREGATES

3.1.2 STEEL FIBERS:-

Steel fibers are commonly used as reinforcement in concrete to improve its tensile strength, crack resistance, and durability.

3.1.3.1 HOOKED FIBRE

- Hooked fibres are a type of steel fibre used in concrete to improve its mechanical properties, particularly toughness, ductility, and crack resistance. These fibres have a hooked or bent end, which enhances their bonding with the concrete matrix and improves load transfer.

Properties of Hooked fibers:-

Nominal dimensions:

- Diameter (D) =0.60mm
- Length (L)=30mm

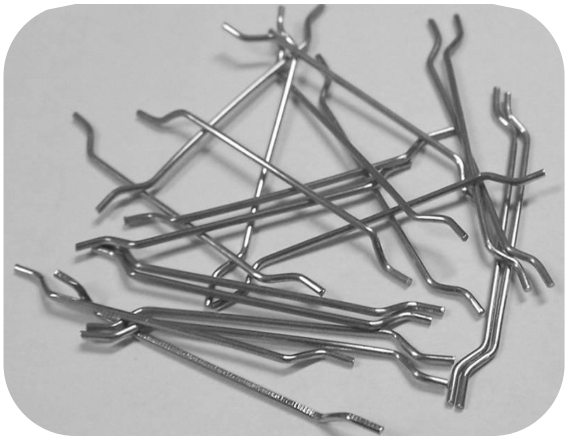


Fig 3.4 HOOKED FIBERS

3.1.3.2 CRIMPED FIBRE

- Crimped fibres are a type of steel fibre used in concrete to enhance its mechanical properties. These fibres have a wavy or zigzag shape, which improves their bonding with the concrete matrix and enhances crack resistance, toughness, and durability.

Properties of Crimped fibers:-

Nominal dimensions:

- Diameter (D) =0.60mm
- Length (L)=30mm

Fig 3.5 CRIMPED FIBRE

3.2 METHODOLOGY:

The experimental Investigation was carried out in different stage.

Stage 1:- Gather the steel fibers based on their physical properties which is used in our project.

Stage 2:- Sample were casted for determination of strength for the conventional concrete.

Stage 3:- Experimental works conducted on steel fibers and mixing different Percentages of fiber for accurate result.
Stage 4:- Mixed steel fibre reinforced concrete should casted in the moulds and the casted specimens should cure upto 7days, 28days for determination of strength of SFRC
Stage 5:- Conducting experimental testing on casted specimens in strength characterstics.
Stage 6:- Comparing the results obtained for different fibers.

LABORATORY TEST CONDUCTED:-
Compressive Strength Test
For cubes were cast to determine 7 days and 28 days compressive strength after curing. The cubes were casted to know the compressive strength of concrete. The size of a cube is as per the IS 10086-1982.

Split Tensile Strength Test
The load was gradually applied on the specimen till the failure of the specimen occurs. The load at which failure of the specimen takes place is noted. The split tensile strength (for) of the concrete was calculated as follow:

$$Fa=2P/((\pi DL))$$

4.4 CONCRETE TESTS
COMPRESSION TEST AND SPLIT TENSILE STRENGTH:
1. Remove the specimen from the water after specified curing time and wipe out excess water from the surface.
2. Leave the specimen in the atmosphere for 24 hours before testing.
3. Place the specimen in the mechine in such a manner that the load shall be applies to the opposite sides of the specimen cast.
4. Align the specimen centrally on the base plate of the machine for a cubic or cylindrical specimen.
5. Rotate the movable portion gently by hand so that it touches the top surface of the specimen.
6. Apply the load gradually without shock and continuously at the rate of 140 kg/cm2 minute till the specimen fails. Increase the load until failure and note the maximum load.

Fig 4.6 Testing of compressive strength.

Fig 4.7 Testing split tensile strength.

CALCULATIONS

Compressive Strength:-
Size of the cube = 15cm×15cm×15cm
Area of the specimen (calculated from the mean size of the specimen)= 225cm2.
Compressive strength = (load in N/Area in mm2)=N/mm2.

Split Tensile Test:-
Size of the specimen = 15cm in diameter and 30cm long
Tensile strength= $2P/\pi DL$= N/mm2.

Tabulate:-

- **Conventional Concrete**

7 days Compressive Strength of conventional concrete,

Specimens	Failure load	Compressive Strength N/mm*2
Cube-1	390	17.5
Cube-2	400	17.78
Cube-3	405	18

7 days Split Tensile Strength of conventional concrete,

Specimens	Failure load	Split Tensile Strength N/mm*2
Cylinder-1	100	1.4
Cylinder-2	110	1.55
Cylinder-3	115	1.62

28 days Compressive Strength of conventional concrete,

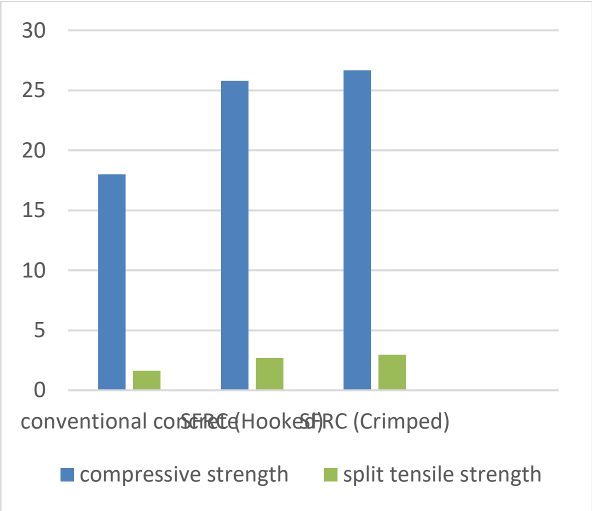
Specimens	Failure load	Compressive Strength N/mm*2
Cube-1	760	33.8
Cube-2	778	34.6
Cube-3	777	34.5

28 days Split Tensile Strength of conventional concrete,

Specimens	Failure load	Split Tensile Strength N/mm*2
Cylinder-1	210	2.97
Cylinder-2	200	2.83
Cylinder-3	205	2.90

Graphical representation:-

- Comparison between conventional concrete, SFRC (Hooked shape) and SFRC (Crimped shape) in compressive strength and split tensile strength of 7 days of curing.



IV CONCLUSION

According to the experimental investigation 7 days of curing,

- optimum compressive strength of conventional concrete is 18N/mm² and split tensile strength of conventional concrete is 1.62N/mm².
- optimum compressive strength of concrete with hooked fibre is 25.78N/mm² and split tensile strength of concrete with hooked fiber is 2.68N/mm².
- optimum compressive strength of concrete with crimped fibre is 26.67N/mm² and split tensile strength of concrete with crimped fibre is 2.97N/mm².

According to the experimental investigation 28 days of curing,

- optimum compressive strength of conventional concrete is 34.6N/mm² and split tensile strength of conventional concrete is 2.97N/mm².
- optimum compressive strength of concrete with hooked fibre is 37.33N/mm² and split tensile strength of concrete with hooked fibre is 3.67N/mm².
- optimum compressive strength of concrete with crimped fibre is 38.22N/mm² and split tensile strength of concrete with crimped fibre is 3.96N/mm².

From the above results steel fibre reinforced concrete is stronger than the conventional concrete.

In the steel fibre reinforced concrete crimped shape fibre should gain more strength than hooked shape fibre at mixing of 2% of mix.

WORKING IMAGES

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