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A study on Fibre Reinforced Concrete with different fibres

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***Abstract*—Increased productivity and improved working environment results in high priority for development of concrete construction over last decades, the astonishing development of fiber-reinforcement technology allowed great achievements in the conception of concrete mixes exhibiting compacting ability. The productivity of fibre reinforced concrete is drastically improved through the elimination of vibration compaction and high workability. This paper emphasizes on behavior of Concrete reinforced with different fibers, properties of fibre reinforced concrete(FRC), its potentiality as a structural material and applicability in construction industry. In fact, the fiber-reinforcement mechanisms can convert the brittle behavior of cement composite into a pseudo ductile behavior up to a crack width that is acceptable under the structural design point of view.**

***Keywords*— FRC, fibre, Aspect Ratio, Orientation, Relative strength, Relative Toughness, Workability**.

I. INTRODUCTION

Fiber Reinforced Concrete(FRC) is composite material consisting mixtures of concrete or cement-mortar withdiscrete, discontinuous, uniformly dispersed suitable fibers, FRC is featured in its fresh state by rheological stability and high flowability. Different types of FRC possess various properties with immense advantages. Fibers are small piece of reinforcing materials with certain characteristics properties either flat or circular. The fiber is often described by a convenient parameter called "aspect ratio". The aspect ratio of fiber can be defined as the ratio of its length to its diameter, typical aspect ratio of FRCrangesfrom 30 to 150.

FRC was deliberately designed to encapsulate all reinforcements only under the influence of gravitational forces, without segregation or bleeding. These advantages make FRC, particularly useful wherever placing is difficult as in complicated work forms or in heavily reinforced concrete members. Through extensive research, it has been derived that FRC possesses higher compressive strength, static flexural strength, impact strength, tensile strength, toughness, increased resistance to wear and tear and higher post-cracking strength (Depending upon the type of fibre used). Maximum size, texture and type of coarse aggregate were the factor effects on flowability of concrete. The flow-ability of FRC decreases with the increase in the maximum size of coarse aggregate. However, mix design methods and testing procedures are still developing. Presence of microcracks at the mortar-aggregate interface causes inherent weakness of plain concrete and can be removed by inclusion of fibres in the mix. Inclusion of fibre reinforcement may take advantage of its high performance in the fresh state to achieve a more uniform dispersion of fibres. The compactness of the FRC matrix due to higher amount of fine and extra-fine particles, may improve interface zone properties, and consequently also the fiber-matrix bond, leading to enhanced post-cracking toughness and energy absorption capacity.

II. DIFFERENT TYPES OF FIBRE USED IN FRC

- ✓ Steel-fibre Reinforced Concrete(SFRC).
- ✓ Polypropylene Fibre-Reinforced Concrete(PFR).
- ✓ Glass-fibre Reinforced Concrete(GFR).
- ✓ Asbestos fibre Reinforced Concrete.
- ✓ Carbon fibre Reinforced Concrete(CFRC).
- ✓ Coconut fibre Reinforced Concrete(Co-FRC).
- ✓ Synthetic fibre Reinforced Concrete.
- ✓ Organic fibre.

1. Steel fiber reinforced concrete(SFRC)

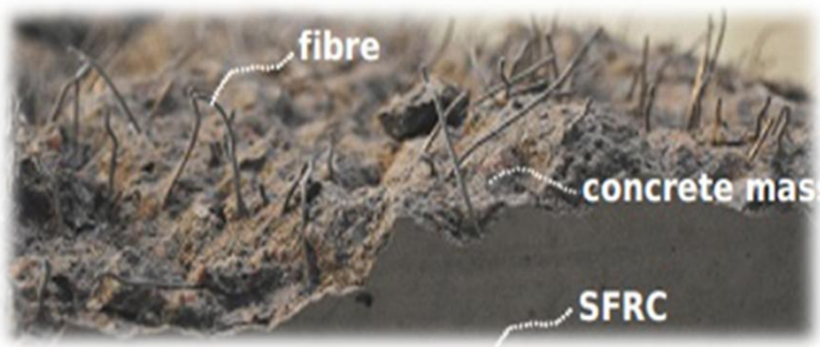

FIG 1: STEEL FIBRE REINFORCED CONCRETE

Concrete possess high compressive strength but is remarkably weak in tension (nearly one-tenth its compressive strength) and as such is usually reinforced with materials that are strong in tension (often steel). Solutions to plain concrete in the form of steel bars reinforcement have existed and been studied long time till now. However, a whole new possibility is open with the use of steel fibres, which have been found improve the properties of plain concrete and cater to various specific applications in structural concrete. Number of steel fiber types is available as reinforcement, but round steel fiber is produced by cutting round wire into short length are used commonly. The typical diameter ranges from 0.20 to 0.70mm while length of steel fibre generally considered is 50mm.Steel fibers of rectangular cross-section (c/s) are produced by silting the sheets about 0.25mm thick. Fiber made from mild steel drawn wire, conforming to **IS: 280-1976** with the diameter of wire varying from 0.3to 0.5mm are practically used in India.
Round steel fibers are produced by cutting or chopping the wire, flat sheet fibers having a typical c/s ranging from 0.15 to 0.41mm in thickness and 0.25 to 0.90mm in width are produced by silting flat sheets. Deformed fiber, which are loosely bounded with water-soluble glue in the form of a bundle are also available. Since individual fibers tend to cluster together, their uniform distribution in the matrix is often difficult. This may be avoided by adding fibers bundles, which separate during the mixing process.

2. Polypropylene fiber reinforced (PFR) concrete

FIG 2: PFR FIBRE

Polypropylene is one of the cheapest & abundantly available polymers, polypropylene fibers are resistant topmost chemical & it would be cementitious matrix which would deteriorate first under aggressive chemical attack. Its melting point is high (about 165 degrees centigrade). So that a working temperature (around 100 degrees centigrade) may be sustained for short periods without detriment to fiber properties. Polypropylene fibers being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly distressed in the mix. Polypropylene short fibers in small volume fractions between 0.5 to 15 commercially used in concrete.
Polypropylene fibre being hydrophobic can be easily mixed as they do not need lengthy contact during mixing and only need to be evenly dispersed in the mix. These are added shortly before the end of mixing the normal constituents.

3. GFRC – glass fiber reinforced concrete

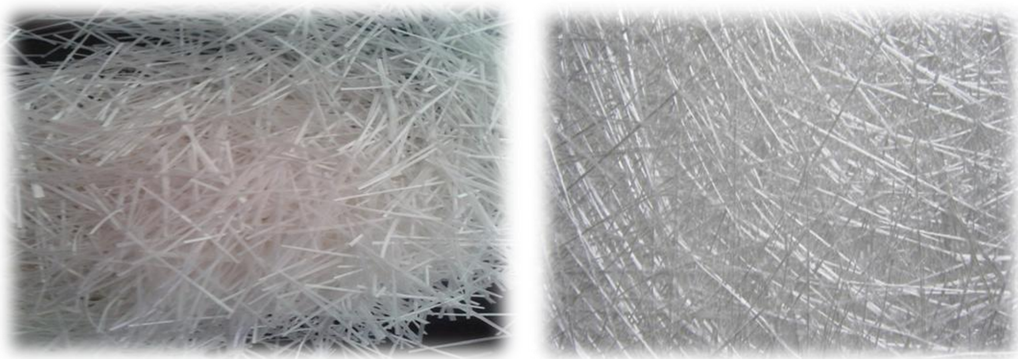

FIG 3: GLASS FIBRE

Glass fiber is made up from 200-400 individual filaments which are lightly bonded to make up a stand. These stands can be chopped into various lengths or combined to make cloth mat or tape. Using the conventional mixing techniques for normal concrete it is not possible to mix more than about 2% (by volume) of fibers of length of 25mm.
The major application of glass fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products. The commonly used verities of glass fibers are e-glass used. In the reinforced of plastics & AR glass E-glass has inadequate resistance to alkalis present in Portland cement whereAR-glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

4. Asbestos fibers

FIG 4: ASBESTOS FIBRE

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement. Asbestos fibers have thermal, mechanical& chemical resistance making them suitable for sheet product pipes, tiles and corrugated roofing elements. Asbestos cement board is approximately two or four times that of unreinforced matrix. However, due to relatively short length (10mm) the fiber has low impact strength. There are health hazards associated with the use of asbestos fibre, it’s use is banned in most of countries. In near future, it is likely that glass fibre-reinforced concrete will replace asbestos completely.

5. Carbon fibers

FIG 5: CARBON FIBRE

Carbon fibers from the most recent & probably the most spectacular addition to the range of fiber available for commercial use. Carbon fiber comes under the very high modulus of elasticity and flexural strength. These are expansive, their strength & stiffness characteristics have been found to be superior even to those of steel. But they are more vulnerable to damage than even glass fiber, and hence are generally treated with resign coating.

5. **Coconut(coir) fibers**

FIG 6: COIR FIBRE

Coconut fibre being low in density reduces the overall weight of the fibre reinforced concrete thus it can be used as a structural light weight concrete. The fiber extracted from the husk of a coconut fruit commonly known as coir fiber, has been traditionally used in tropical regions of Asia, Africa and South America.
The husk consists of Coir fiber and a corky tissue called pith. The husk is immersed in water for 6 - 9 months. This process is called retting. Retting removes some of the dirt and natural enzymes present in the fiber giving it a golden color. The fiber is then extracted by beating it manually using a mallet or by a mechanical extractor machine. This leaves the outer skin of the coconut fruit along with the corky pith. Pith finds large-scale use in horticulture as a growing medium.

7.Organic fibers

Organic fiber such as polypropylene or natural fiber may be chemically more inert than either steel or glass fibers. They are also cheaper, especially if natural. A large volume of vegetable fiber may be used to obtain a multiple cracking composite. The problem of mixing and uniform dispersion may be solved by adding a superplasticizer.
Polypropylene, nylon and other organic fibre due to their low modulus of elasticity are not effective in crack control, and also the organic fibres may decay. However, these fibres improve *impact resistance*.

III. APPLICATION OF VARIOUS FIBRE REINFORCED CONCRETE IN DIFFERENT FIELDS: -

1. Steel fibre reinforced concrete

- Properties such as additional strength in flexure, fatigue, impact and spalling lead to smaller concrete section, improved surface quality and reduced maintenance.
- The main application of steel fibre reinforced concrete are in industrial floors, hydraulic structures, warehouses, ports, highway and airfield pavements is prevalent world over. They are also widely used in underground support infrastructure, particularly shotcrete linings, tunnels linings and ground stabilization.

2. polypropylene fibre reinforced concrete

- **Claddingpanels: -**Reduction in panel thickness may be allowed by inclusion of polypropylene fibres instead of steel mesh reinforcement.
- **Shotcreting: -**Surface coating of polypropylene reinforced-mortar may be provided by Shotcreting using normal equipment. The fibres of about 20mm length enable smooth transport of dry mix through air hoses and nozzles. Water is then added at gun orifice.

  Shotcreting can be advantageously used in wet environments, where polypropylene fibres can eliminate the need for steel (corrodable) mesh on which spray of mortar is required.
- Polypropylene concrete can be advantageously used in energy dissipating blocks.

3. Glass-fibre Reinforced Concrete (GFR)

The glass fibre-reinforced concrete find its application in :-

- Formwork system
- Ducting
- Roofing elements
- Sewer lining
- Swimming pools
- Fire-stop partitioning
- Tanks and drainage elements, etc.

IV. FACTORS AFFECTING PROPERTIES OF FIBER REINFORCED CONCRETE

Fiber reinforced concrete is the composite material containing fibers in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depends upon the efficient transfer of stress between matrix and the fibers. The factors are briefly discussed below:

1. Relative Fiber Matrix Stiffness

The modulus of elasticity of matrix must be much lower than that of fiber for efficient stress transfer. Low modulus of fiber such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but the help in the absorption of large energy and therefore, impart greater degree of toughness and resistance to impart. High modulus fibers such as steel, glass and carbon impart strength and stiffness to the composite. Interfacial bond between the matrix and the fiber also determine the effectiveness of stress transfer, from the matrix to the fiber. A good bond is essential for improving tensile strength of the composite.

2. Volume of Fibers

The strength of the composite largely depends on the quantity of fibers used in it, as it shows the effect of volume on the toughness and strength. It can be observed that the increase in the volume of fibers, increase approximately linearly, the tensile strength and toughness of the composite. Use of higher percentage of fiber is likely to cause segregation and harshness of concrete and mortar.

3. Aspect Ratio of the Fiber

Another important factor which influences the properties and behavior of the composite is the aspect ratio of the fiber. It has been reported that up to aspect ratio of 75, increase on the aspect ratio increases the ultimate concrete linearly. Beyond 75, relative strength and toughness is reduced. Table-1 shows the effect of aspect ratio on strength and toughness.

TABLE I
ASPECT RATIO OF THE FIBER

Type of concrete	Aspect ratio	Relative strength	Relative Toughness
Plain concrete	0	1	1
Randomly	50	1.6	8.0
Dispersed Fibre	100	1.7	10.5

4. Orientation of Fibers

One of the differences between conventional reinforcement and fiber reinforcement is that in conventional reinforcement, bars are oriented in the direction desired while fibers are randomly oriented. To see the effect ofrandomness, mortar specimens reinforced with 0.5% volume of fibers were tested. In one set specimens, fibers were aligned in the direction of the load, in another in the direction perpendicular to that of the load, and in the third randomly distributed.

It was observed that the fibers aligned parallel to the applied load offered more tensile strength and toughness than randomly distributed or perpendicular fibers.

5. Workability and Compaction of Concrete

Incorporation of steel fiber decreases the workability considerably. This situation adversely affects the consolidation of fresh mix. Even prolonged external vibration fails to compact the concrete. The fiber volume at which this situation is reached depends on the length and diameter of the fiber. Another consequence of poor workability is non-uniform distribution of the fibers. Generally, the workability and compaction standard of the mix is improved through increased water/ cement ratio or by the use of some kind of water reducing admixtures.

6. Size of Coarse Aggregate

Maximum size of the coarse aggregate should be restricted to 10mm, to avoid appreciable reduction in strength of the composite. Fibers also in effect, act as aggregate. Although they have a simple geometry, their influence on the properties of fresh concrete is complex. The inter-particle friction between fibers and between fibers and aggregates controls the orientation and distribution of the fibers and consequently the properties of the composite. Friction reducing admixtures and admixtures that improve the cohesiveness of the mix can significantly improve the mix.

7. Mixing

Mixing of fiber reinforced concrete needs careful conditions to avoid balling of fibers, segregation and in general the difficulty of mixing the materials uniformly. Increase in the aspect ratio, volume percentage and size and quantity of coarse aggregate intensify the difficulties and balling tendency. Steel fiber content in excess of 2% by volume and aspect ratio of more than 100 are difficult to mix.

It is important that the fibers are dispersed uniformly throughout the mix; this can be done by the addition of the fibers before the water is added. When mixing in a laboratory mixer, introducing the fibers through a wire mesh basket will help even distribution of fibers. For field use, other suitable methods must be adopted.

V. COMPARATIVE STUDY ON VARIANT FIBRES*: -

*Below mentioned comparative values results from 5 – 10% addition of fibre reinforcement:

TABLE II MECHANICAL PROPERTIES OF VARIOUS FIBRES

Property	SFRC	CFRC	Co-FRC	GFRC
Compressive strength	22.5-30.4 MPa	45-52 MPa	25.5-35.5 MPa	38-43 Mpa
Tensile strength	800-1050 MPa	7.6-9 MPa	80-90 MPa	1550-1700 MPa
Specific Gravity	7.86	3.12	2.6	2.74
Modulus of Elasticity	200 GPa	15.4 GPa	29 GPa	72 GPa
Aspect Ratio	50-100		800	857
Workability	Low	high	Moderate	Nominal
Impact resistance	High	Very Low	Low	Extreme
Flexural strength	15-17.5 MPa	10-12 MPa	7-9 Mpa	4-6 MPa
Toughness index	High	Low	Moderate	Extreme

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VI. CONCLUSION

Following conclusion can be drawn from above literature: -

- It was found that GFRC persist dominating properties over other fibres, even from SFRC.
- As availability of coir fibre is more so it is economical to use coir as fibre as the replacement of glass and steel fibre.
- Addition of small, closely spaced and uniformly dispersed fibers to concrete would act as crack arrester and would substantially improve its static and dynamic properties.
- Workability of the fresh mix is adversely affected by the addition of fibers and further decreases by increasing the fiber volume fraction.
- Other properties such as flexural and tensile strength, ductility, drying shrinkage and toughness of the material is usually benefited by the addition of fibers.
- Fiber reinforcement can be utilized in development of high and ultra-high-performance concrete. But proper execution and competent design are necessary to maintain the performance of fiber reinforced cement-based material.
- GFRC are active replacement of steel reinforcements, being resistant to chemicals and nature’s effect sewer pipe lines can be designed and casted using GFRC.
- When compared to conventional concrete the fiber reinforced concrete is much tougher and has good compressive strength for 7 days and 28 days and the split tensile strength of the GFRC concrete was much better when compared to the conventional concrete and other FRC.

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