

FIBER REINFORCED CONCRETE – PROPERTIES AND APPLICATIONS IN CONSTRUCTION WORKS

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Annotation: This article describes in detail the types of fiber concrete, their advantages and disadvantages, and the features of their use in building constructions.

Key words: Fibers, Reinforced Concrete, reinforcement, composit, beam, plier, foundation, rebar.

Fiber Reinforced Concrete

Fiber Reinforced Concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibers. Fiber reinforced concrete are of different types and properties with many advantages. Continuous meshes, woven fabrics, and long wires or rods are not considered to be discrete fibers. Fiber is a small piece of reinforcing material possessing certain characteristics properties. They can be circular or flat. The fiber is often described by a convenient parameter called "aspect ratio". The aspect ratio of the fiber is the ratio of its length to its diameter. The typical aspect ratio ranges from 30 to 150. Fiber-reinforced concrete (FRC) is concrete containing fibrous material which increases its structural integrity. It contains short discrete fibers that are uniformly distributed and randomly oriented. Fibers include steel fibers, glass fibers, synthetic fibers, and natural fibers. Within these different fibers, the character of fiber reinforced concrete changes with varying concretes, fiber materials, geometries, distribution, orientation, and densities. Fibre-reinforcement is mainly used in shotcrete, but can also be used in normal concrete. Fiber-reinforced normal concrete is mostly used for on-ground floors and pavements, but can be considered for a wide range of construction parts (beams, pliers, foundations, etc) either alone or with hand-tied rebars Concrete reinforced with fibers (which are usually steel, glass or "plastic" fibers) is less expensive than hand-tied rebar, while still increasing the tensile strength many times. The shape, dimension, and length of fiber is important. A thin and short fiber, for example, short hair-shaped glass fiber, will only be effective the first hours after pouring the concrete (reduces cracking while the concrete is stiffening) but will not increase the concrete tensile strength

Effect of Fibers in Concrete

Fibers are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce the bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally, fibers do not increase the flexural strength of concrete, so it can not replace moment resisting or structural steel reinforcement. Some fibers reduce the strength of concrete. The amount of fibers added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibers) termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fiber length (l) by its diameter (d). Fibers with a non-circular cross-section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fiber is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. An increase in the aspect ratio of the fiber usually segments the flexural strength and toughness of the matrix. However, fibers that are too long tend to "ball" in the mix and create workability problems. Some recent research indicated that using fibers in concrete has a limited effect on the impact resistance of concrete materials. This finding is very important since traditionally people think the ductility increases when concrete reinforced with fibers. The results also pointed out that the microfibres are better in impact resistance compared with the longer fibers.

The necessity of Fiber Reinforced Concrete

1. It increases the tensile strength of the concrete.
2. It reduces the air voids and water voids the inherent porosity of gel.
3. It increases the durability of the concrete.
4. Fibers such as graphite and glass have excellent resistance to creep, while the same is not true for most resins. Therefore, the orientation and volume of fibres have a significant influence on the creep performance of rebars/tendons.
5. Reinforced concrete itself is a composite material, where the reinforcement acts as the strengthening fibre and the concrete as the matrix. It is therefore imperative that the behavior under thermal stresses for the two materials be similar so that the differential deformations of concrete and the reinforcement are minimized.
6. It has been recognized that the 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.

7. 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. Fig 1 and 2 show the effect of volume on the toughness and strength. It can see from Fig 1 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-1: Aspect ratio of the fiber

| Type of concrete | Aspect ratio | Relative strength | Relative toughness |
|------------------|--------------|-------------------|--------------------|
| Plain concrete | 0 | 1 | 1 |
| With | 25 | 1.5 | 2.0 |
| Randomly | 50 | 1.6 | 8.0 |
| Dispersed fibers | 75 | 1.7 | 10.5 |
| | 100 | 1.5 | 8.5 |

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 of randomness, 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

The maximum size of the coarse aggregate should be restricted to 10mm, to avoid an appreciable reduction in the 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.

Different Types of Fiber Reinforced Concrete

Following are the different type of fibers generally used in the construction industries.

1. Steel Fiber Reinforced Concrete
2. Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
3. GFRG Glass Fiber Reinforced Concrete
4. Asbestos Fibers
5. Carbon Fibers
6. Organic Fibers
7. 1. Steel Fiber Reinforced Concrete

A no of steel fiber types are available as reinforcement. Round steel fiber the commonly used type are produced by cutting round wire in to short length. The typical diameter lies in the range of 0.25 to 0.75mm. Steel fibers having a rectangular 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 0.3 to 0.5mm have been 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.

3. GFRG - Glass Fiber Reinforced Concrete

Glass fiber is made up of 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 mats 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 a length of 25mm. The major appliance of glass

fiber has been in reinforcing the cement or mortar matrices used in the production of thin-sheet products.

4. **Asbestos Fibers**

The naturally available inexpensive mineral fiber, asbestos, has been successfully combined with Portland cement paste to form a widely used product called asbestos cement.

5. **Carbon Fibers**

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.

6. **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.

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