# FIBRE REINFORCED CONCRETE

Plain concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal microcracks are inherently present in the concrete and its poor tensile strength is due to the propagation of such microcracks, eventually leading to brittle fracture of the concrete.

In the past, attempts have been made to impart improvement in tensile properties of concrete members by way of using conventional reinforced steel bars and also by applying restraining techniques. Although both these methods provide tensile strength to the concrete members, they however, do not increase the inherent tensile strength of concrete itself.

In plain concrete and similar brittle materials, structural cracks (micro-cracks) develop even before loading, particularly due to drying shrinkage or other causes of volume change. The width of these initial cracks seldom exceeds a few microns, but their other two dimensions may be of higher magnitude.

When loaded, the micro cracks propagate and open up, and owing to the effect of stress concentration, additional cracks form in places of minor defects. The structural cracks proceed slowly or by tiny jumps because they are retarded by various obstacles, changes of direction in bypassing the more resistant grains in matrix. The development of such microcracks is the main cause of inelastic deformations in concrete.

It has been recognised that the addition of small, closely spaced and uniformly dispersed fibres to concrete would act as crack arrester and would substantially improve its static and dynamic properties. This type of concrete is known as Fibre Reinforced Concrete.

Fibre reinforced concrete can be defined as a composite material consisting of mixtures of cement, mortar or concrete and discontinuous, discrete, uniformly dispersed suitable fibres. Continuous meshes, woven fabrics and long wires or rods are not considered to be discrete fibres.

### Fibres Used

Although every type of fibre has been tried out in cement and concrete, not all of them can be effectively and economically used. Each type of fibre has its characteristic properties and limitations. Some of the fibres that could be used are steel fibres, polypropylene, nylons, asbestos, coir, glass and carbon.

Fibre is a small piece of reinforcing material possessing certain characteristic properties. They can be circular or flat. The fibre is often described by a convenient parameter called “aspect ratio”. The aspect ratio of the fibre is the ratio of its length to its diameter. Typical aspect ratio ranges from 30 to 150.

Steel fibre is one of the most commonly used fibre. Generally, round fibres are used. The diameter may vary from 0.25 to 0.75 mm. The steel fibre is likely to get rusted and lose some of its strengths. But investigations have shown that the rusting of the fibres takes place only at the surface. Use of steel fibre makes significant improvements in flexural, impact and fatigue strength of concrete, It has been extensively used in various types of structures, particularly for overlays of roads, airfield pavements and bridge decks. Thin shells and plates have also been constructed using steel fibres.

Polypropylene and nylon fibres are found to be suitable to increase the impact strength. They possess very high tensile strength, but their low modulus of elasticity and higher elongation do not contribute to the flexural strength.

Asbestos is a mineral fibre and has proved to be most successful of all fibres as it can be mixed with Portland cement. Tensile strength of asbestos varies between 560 to 980 $N/mm^2$. The composite product called asbestos cement has considerably higher flexural strength than the Portland cement paste. For unimportant fibre concrete, organic fibres like coir, jute, canesplits are also used.

Glass fibre is a recent introduction in making fibre concrete. It has very high tensile strength 1020 to 4080 $N/mm^2$. Glass fibre which is originally used in conjunction with cement was found to be effected by alkaline condition of cement. Therefore, alkali-resistant glass fibre by trade name "CEM-FIL" has been developed and used. The alkali resistant fibre reinforced concrete shows considerable improvement in durability when compared to the conventional E-glass fibre.

Carbon fibres perhaps posses very high tensile strength 2110 to 2815 $N/mm^2$ and Young's modulus. It has been reported that cement composite made with carbon fibre as reinforcement will have very high modulus of elasticity and flexural strength. The limited studies have shown good durability. The use of carbon fibres for structures like clading, panels and shells will have promising future.

**Factors Effecting Properties of Fibre Reinforced Concrete**

Fibre reinforced concrete is the composite material containing fibres in the cement matrix in an orderly manner or randomly distributed manner. Its properties would obviously, depend upon the efficient transfer of stress between matrix and the fibres, which is largely dependent on the type of fibre, fibre geometry, fibre content, orientation and distribution of the fibres, mixing and compaction techniques of concrete, and size and shape of the aggregate.

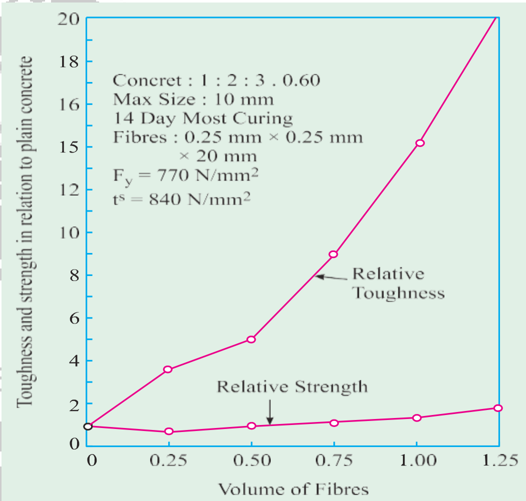
**Relative Fibre Matrix Stiffness**

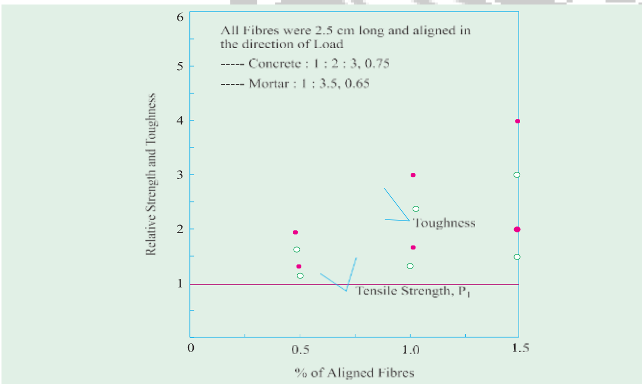
The modulus of elasticity of matrix must be much lower than that of fibre for efficient stress transfer. Low modulus of fibers such as nylons and polypropylene are, therefore, unlikely to give strength improvement, but they help in the absorption of large energy and, therefore, impart greater degree of toughness and resistance to impact. High modulus fibres such as steel, glass and carbon impart strength and stiffness to the composite.

Interfacial bond between the matrix and the fibres also determine the effectiveness of stress transfer, from the matrix to the fibre. A good bond is essential for improving tensile strength of the composite. The interfacial bond could be improved by larger area of contact, improving the frictional properties and degree of gripping and by treating the steel fibres with sodium hydroxide or acetone.

### Volume of Fibres

The strength of the composite largely depends on the quantity of fibres used in it. Fig. 12.5 and Fig. 12.6 show the effect of volume on the toughness and strength. It can be seen from Fig. 12.6 that the increase in the volume of fibres, increase approximately linearly, the tensile strength and toughness of the composite[12.7]. Use of higher percentage of fibre is likely to cause segregation and harshness of concrete and mortar.




### Aspect Ratio of the Fibre

Another important factor which influences the properties and behaviour of the composite is the aspect ratio of the fibre. It has been reported that upto aspect ratio of 75, increase in the aspect ratio increases the ultimate strength of the concrete linearly. Beyond 75, relative strength and toughness is reduced. Table shows the effect of aspect ratio on strength and toughness.

Table: Effect of Aspect Ratio on Strength and Toughness

| *Type of Concrete* | *Aspect Ratio* | *Relative strength* | *Relative toughness* |
|---|---|---|---|
| Plain concrete | 0 | 1.00 | 1.0 |
| with | 25 | 1.50 | 2.0 |
| Randomly | 50 | 1.60 | 8.0 |
| dispersed fibres | 75 | 1.70 | 10.5 |
| | 100 | 1.50 | 8.5 |

**Mixing:**

Mixing of fibre reinforced concrete needs careful conditions to avoid balling of fibres, 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 tendencies. A steel fibre content in excess of 2 per cent by volume and an aspect ratio of more than 100 are difficult to mix. The typical proportions for fibre reinforced concrete is given below:

| | |
|---|---|
| Cement content : | 325 to 550 kg/m$^3$ |
| W/C Ratio : | 0.4 to 0.6 |
| Percentage of sand to total aggregate: | 50 to 100 per cent |
| Maximum Aggregate Size: | 10 mm |
| Air-content: | 6 to 9 per cent |

Fibre content : 0.5 to 2.5 per cent by volume of mix

- Steel - 1 per cent 78 kg/m$^3$
- Glass - 1 per cent 25 kg/m$^3$
- Nylon - 1 per cent 11 kg/m$^3$

**Applications:**

Fibre reinforced concrete is increasingly used on account of the advantages of increased static and dynamic tensile strength, energy absorbing characteristics and better fatigue strength. The uniform dispersion of fibres throughout the concrete provides isotropic properties not common to conventionally reinforced concrete. Fibre reinforced concrete has been tried on overlays of air-field, road pavements, industrial floorings, bridge decks, canal lining, explosive resistant structures, refractory linings etc. The fibre reinforced concrete can also be used for the fabrication of precast products like pipes, boats, beams, stair case steps, wall panels, roof panels, manhole covers etc... Fibre reinforced concrete sometimes called fibrous concrete, is manufactured under the trade name “Wirand Concrete”. After extensive research, the Wirand concrete is used very extensively in United States. Fibre reinforced concrete in also being tried for the manufacture of prefabricated formwork moulds of “U” shape for casting lintels and small beams.