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Study of Behaviour of Steel Fiber Reinforced Concrete in Deep Beam for Flexure

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ABSTRACT

In 21st century, government invested most of the money on construction industry to improve the financial condition of our country. So it is the responsibility of civil engineer to improve the new techniques and researches in construction field. Use of deep beam in construction field saves money as well as increase the strength of structure. Reinforced concrete deep beams have very useful structural application such as piles-caps, water tanks and tall buildings. Addition of steel fibers gives good results to both load carrying capacity and increase the flexural strength of the deep beam.Steel fiber is kind of newly developed reinforced material for concrete widely adopted globally now a days, which features good performance in anti-crack, pressure resistance, anti-abrasion bending toughness, affinity with concrete, reinforcement for construction element component and lengthy service life. Thus by using the steel fiber reinforced deep beam with varying percentage of steel fibers increases the first crack load and the ultimate load which gives the high flexural strength to the structure and achieves economy. This paper includes study of behaviour of steel fiber reinforced concrete in deep beam with advantages, disadvantages, proprties of steel fiber etc.

Keywords : Steel Fiber, Beam, Anti-Crack, Pressure Resistance, Anti-Abrasion Bending Toughness, Affinity, Reinforcement

I. INTRODUCTION

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. 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. W+thin these different fibers that 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. Fibre-reinforced normal concrete are 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

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II. DEEP BEAMS CONCEPT

Deep beams are structural elements loaded as simple beams in which a significant amount of the load is carried to the supports by a compression force combining the load and the reaction. As a result, the strain distribution is no longer considered linear, and the shear deformations become significant when compared to pure flexure.

Deep beams are recognized by relatively small values of span to depth ratio. As per code provisions given by bureau of Indian standards a beam shall be considered as deep beam when the ratio of effective span to overall depth ratio is less than 2 for simply supported beam and 2.5 for continuous beam.

Classification of according to span to depth ratio:

- Deep beam (L/D < 1.0)
- Moderate deep beam (1< L/D < 2.5)
- Shallow beam (L/D > 2.5)

III. LITERATURE REVIEW

D.H.Lim,et.al.[1] "Experimental and theoretical investigation on the shear of steel fiber reinforced concrete beam"

In this paper they were investigate the influence of fiber reinforced on the mechanical behaviour of reinforced concrete beam in shear. In this study they were testing three series of reinforced concrete beams having cross section of 100×180 mm and span length of 1300 mm with volume fraction of steel fibers and the contents of shear stirrups. The volume fraction of steel fibers were varied from 0%-2% and ratios of stirrups from from 0%-100% of the required shear reinforcement.

The result of tests shown that the addition of steel fibers increase the compressive strength ,flexural strength .The compressive strength increase by about 25% when fibers were mix into the concrete by upto 2% by volume. Their was 55% increase in flexural strength when fibes content was increase from 0%-2%. Also spliting tensile strength they were test, when 2% fibers was used the spliting tensile strength was more than double .

Giuseppe Tiberti, et.al,[2] "Cracking behavior in reinforced concrete members with steel fibers: A comprehensive experimental study"

Aim of this paper was to investigate the ability of fiber in controlling crack by conducting more than ninety tension tests on R.C. having different size, reinforcing ratios, amount of steel fibers and concrete strength.

They observed that crack spacing reduction of around 30% was seen in sfrc elements with volume fraction of fiber 0.5% and 37% with volume fraction 1%. Increase in reinforcement ratio decreases the mean crack spacing of both SFRC & RC element, but SFRC result more effective in controlling the cracking phenomenon for lower reinforcement ratios.

Xiliang Ning,et.al,[3] "Experimental study and prediction model for flexural behavior of reinforced SCC beam containing steel fibers"

In this paper they were tested Seven full-scale steel fiber reinforced self-consolidating concrete (SFRSCC) beams to study the effects of macro steel fibers on the flexural behavior of reinforced self-consolidating concrete beams. The ultimate load, midspan deflections, steel reinforcement strains, crack width and crack spacing were investigated. Hooked-ended macro steel fiber was added with two different contents (30 or 50 kg/m3, corresponding to a volume fraction of 0.38% and 0.64%, respective All beams having the same dimension of 200 mm * 300 mm *2400 mm, were simply supported with 2100 mm span. The beams were tested under a displacement-controlled procedure by means of a hydraulic servo testing machine having a maximum load capacity of 10,000 kN. The load was applied step by step to the beam at a rate of 20 kN per step with a displacement rate of 0.3 mm/min by the testing machine.

With the incorporation of steel fiber, the number of cracks increased while crack width and spacing decreased. Adding 50 kg/m3 steel fiber in beam with reinforcement ratio 0.76% can perform better than beam with reinforcement ratio 0.96% in terms of yielding and ultimate load. It illustrates that adding 50 kg/m3 steel fiber in reinforced SCC beam can replace reinforcement ratio by about 0.2%. However, the same amount of steel fiber in beam with 0.96% reinforcement ratio cannot achieve yielding and ultimate load similar to the beam with 1.18% reinforcement ratio.

Bensaid Boulekbache,et.al,[4] "Flexural behaviour of steel fibre-reinforced concrete under cyclic loading"
In this paper the main objective of this research is to evaluate simultaneously the influence in the workability, the compressive strength and the flexural behaviour of FRC under cyclic loading. For the experiment of flexural test 150*150*700 mm three beams and to measure the compressive strength three concrete cylinders (110*220 mm) were tested. All specimens were fabricated with concrete of various workability and different compressive strengths (30, 60 and 80 MPa) and reinforced with hooked end steel fibres of aspects ratios of 65 and 80 at contents of 0.5 and 1%.A four-point bending test with notched specimens was conducted using Digital Image Correlation technique.

From the test results, due to the good bond between the fibers and the matrix of concrete the increase in the flexural strength was 242%, 174% and 150% for FRSCC 80-1, FRHSC 80-1 and FROC 80-1 respectively by comparison to plain concrete sample. The results showed that all FRC structural beams under cyclic loading were able to show ample ductility before failure.

IV. EFFECT OF FIBERS IN CONCRETE

Fibres are usually used in concrete to control plastic shrinkage cracking and drying shrinkage cracking. They also lower the permeability of concrete and thus reduce bleeding of water. Some types of fibres produce greater impact, abrasion and shatter resistance in concrete. Generally fibres do not increase the flexural strength of concrete, so it cannot replace moment resisting or structural steel reinforcement. Some fibres reduce the strength of concrete.
The amount of fibres added to a concrete mix is measured as a percentage of the total volume of the composite (concrete and fibres) termed volume fraction (V_f). V_f typically ranges from 0.1 to 3%. Aspect ratio (l/d) is calculated by dividing fibre length (l) by its diameter (d). Fibres with a non-circular cross section use an equivalent diameter for the calculation of aspect ratio. If the modulus of elasticity of the fibre is higher than the matrix (concrete or mortar binder), they help to carry the load by increasing the tensile strength of the material. Increase in the aspect ratio of the fibre usually segments the flexural strength and toughness of the matrix. However, fibres which are too long tend to "ball" in the mix and create workability problems

V. FACTORS AFFECTING PROPERTIES OF FIBER REINFORCED CONCRETE

- **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.

- **Volume of Fibers**
  The strength of the composite largely depends on the quantity of fibers used in it. 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.

- **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.

- **Aspect Ratio of the Fiber**
  Another important factor which influences the properties and behaviour 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 1.1 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
	25	1.5	2.0
With Randomly Dispersed fibers	50	1.6	8.0
	75	1.7	10.5
	100	1.5	8.5

- **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.

- **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.

- **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.

VI. DIFFERENT TYPES OF FIBER REINFORCED CONCRETE

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

- ✓ Steel Fiber Reinforced Concrete
- ✓ Polypropylene Fiber Reinforced (PFR) cement mortar & concrete
- ✓ GFRC Glass Fiber Reinforced Concrete
- ✓ Asbestos Fibers
- ✓ Carbon Fibers
- ✓ Organic Fibers

1) polypropylene fiber reinforced (pfr) cement mortar & concrete

Polypropylene is one of the cheapest & abundantly available polymers polypropylene fibers are resistant to most 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 temp. As (100 degree 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.

2) GFRC – glass fiber reinforced concrete

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 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. 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 where AR-glass has improved alkali resistant characteristics. Sometimes polymers are also added in the mixes to improve some physical properties such as moisture movement.

3) 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. Asbestos fibers here 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 have low impact strength.

4) Carbon fibers

Carbon fibers from the most recent & probability 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.

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 super plasticizer.

steel fibre

Concrete is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This characteristic, which limits the application of the material, can be overcome by the inclusion of a small amount of short randomly distributed fibres (steel, glass, synthetic and natural) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Steel fibre is a kind of newly developed reinforcement material for concrete widely adopted now a day. Steel fibre reinforced concrete （SFRC） has the ability of excellent tensile strength, flexural strength, shock resistance, fatigue resistance, ductility and crack arrest. Therefore, it has been applied abroad in various professional fields of construction, irrigation works and architecture.

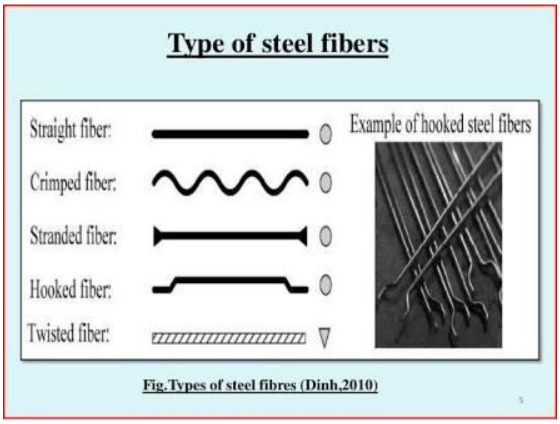

Figure 1. Types of steel fiber

VII. REQUIREMENTS OF GOOD FIBRE

The basic requirement of fibre for improving strength properties are high tensile strength and elastic modulus, adequate extensibility, a good bond at the interface and good stability. The fibre should be capable of withstanding stress for a long period of time.

VIII. ADVANTAGES OF STEEL FIBRE REINFORCED CONCRETE

- ✓ As the fibres are uniformly dispersed all over the member the surface wear characteristics of concrete are considerably improved.
- ✓ SFRC products give more resistance to impact.
- ✓ It improves crack behaviour, makes concrete ductile.
- ✓ It increases tensile strength and improve its durability.
- ✓ steel fibres does not significantly increase compressive strength but it does increase the compressive strain at ultimate load.
- ✓ It reduce maintenance cost.
- ✓ It increase life of structure.

IX. DISADVANTAGES OF STEEL FIBRE REINFORCED CONCRETE

- ✓ Steel fibres are being costlier at present, FRC becomes very expensive compared to R.C.C. in terms of materials only.
- ✓ Steel fibre will not float on the surface of properly finish slab, however rain damaged slabs allow both aggregate and fibres to be exposed and will present as aesthetically poor.
- ✓ It affects the workability of concrete.

X. PROPERTIES OF CONCRETE IMPROVED BY STEEL FIBRES

- **Compressive strength**

  Compressive strength is little influenced by steel fibre addition. Increase in compressive strength ranging from 0 to 15 percent for up to 1.5% volume of fibres is observed. It is mainly controlled by the concrete matrix design. If higher compressive strengths are required, then the addition of silica fume or an appropriate combination of silica fume and other admixtures can be useful.

- **Tensile resistance**
  Fibres aligned in the direction of the tensile stress may bring about very large increases in direct tensile strength, as high as 133% for 5% of smooth, straight steel fibres. However, for more or less randomly distributed fibres, the increase in strength is much smaller, ranging from as little as no increase in some instances to perhaps 60%, with many investigations indicating intermediate values.
- **Flexural strength**
  Elements incorporating steel fibres have higher flexural stiffness (reduced deflections) and smaller crack widths when subjected to service loads. The improvements in flexural strength resulting from steel fibre reinforcement are not large enough to give steel fibres the potential to fully substitute continuous bars in flexural reinforced elements. Increase in flexural strength is ranging from 0 to 20 percent up to 1.5 percent by volume of fibres. Optimum conditions in flexural elements may be achieved through the use of steel fibres together with conventional steel bars.
- **Toughness**
  Toughness was recognized very early in the development of fibre reinforced concrete as the characteristic property that above all others most clearly distinguishes it from concrete without fibres. Under impact conditions, toughness can be qualitatively demonstrated simply by trying to break through a thin section with a manually operated hammer. For example, a thin fibre reinforced mortar flower pot withstands multiple hammer blows over a period of time before a hole is punched at the point of impact. Even then, the rest of the pot retains its structural integrity. In contrast, a similar pot made of mortar without fibres fractures into several pieces after a single hammer blow, totally losing its structural integrity as a pot.
  Under slow flexure conditions, toughness can be qualitatively demonstrated by observing the behaviour of simply supported beams loaded in bending. A concrete beam containing fibres suffers damage by gradual development of single or multiple cracks with increase in deflection, but retains some degree of structural integrity and post crack strength even when deformed to a considerable deflection. In contrast a similar beam without fibres fails suddenly at a small deflection by separation into two pieces, totally losing its structural integrity as a beam.
  The toughness index for plain concrete is equal to 1 because all plain concrete beams fail immediately after the first crack. The toughness indices for FRC vary greatly depending on the position of the crack, the type of fibre, aspect ratio, the volume fraction of the fibre and the distribution of the fibres.
- **Fatigue**
  In composites, crack initiation and propagation produce simultaneous growth of cracks that may (a) extend through the matrix (b) be stopped at a fibre or (c) propagate along a fibre matrix interface. Cracks are initiated by factors such as debonding , voids or fibre discontinuity. The cracks propagation results in cracks joining each other to the extent that matrix is unable to perform its basic function of transferring the load from one fibre to the next in fibre composites. The fracture surface of a matrix usually shows evidence of a complex assortment of fibre failure and fibre pull-out.
- **Creep and Shrinkage**
  Concrete shrinks when it is subjected to a drying environment. The extent of the shrinkage depends on many factors including the properties of the materials, temperature and relative humidity of the environment, the age when concrete is subjected to drying environment and the size of the concrete mass. If concrete is restrained from shrinkage, then tensile stresses develop and the concrete may crack. Shrinkage cracking is one of the more common causes of

cracking for walls, slabs and pavements. One of the methods to reduce the adverse effects of shrinkage cracking is reinforcing the concrete with short randomly distributed steel fibres. Since concrete is almost always restrained, the tendency for cracking is common. Steel fibres have three roles in such situations. They allow multiple cracking to occur, they allow tensile stresses to be transferred across cracks and stress transfer can occur for a long time permitting healing of the cracks.

- **Corrosion**

  When using steel fibres in concrete, attention has to be given to the question of corrosion of the fibres. As the steel volume locally is very small when fibres are used, only limited expansion forces develop due to the corrosion and normally no spalling occurs. Steel fibres in the immediate surface layer rapidly corrode to the depth of surface carbonation, which might however give aesthetical defects in the form of rust coloured surfaces. The loss of contribution to the strength of a corroded fibre has also to be considered. In most applications low carbon, plain steel fibres are used. Steel fibres are less susceptible to corrosion than conventional reinforcing as they are electrically discontinuous.

- **Permeability**

  They reduce the permeability of concrete and thus reduce bleeding of water.

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