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The Study of Structural Behaviour of Plain Cement Concrete with Special References to Polyamide Fibres Mixes

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Abstract

The various properties of FRC depend on fibre geometry, type, modulus of elasticity, stiffness, aspect ratio, fibre content and fibre orientation. Aggregate size and matrix strength is also an important parameter of fibre reinforced concrete.

To use concrete as a load bearing member it is necessary to increase tensile resistance property of the concrete member. This phenomenon is achieved from hundred year back or more by using primary reinforcement and also by the Application of prestressing. Both of the two methods provide tensile strength to the structural element but do not increase the inherent tensile strength of concrete matrix itself. The overall performance of reinforced concrete composite material is affected then the individual performance of the concrete itself. This led to the search for new material i.e. two phase composite material in which weak concrete matrix is reinforced with strong fibre to produce composite of superior property and high performance. In two phase composite fibrous material, fibres inhibit the deformation of the concrete matrix and import to increase the properties of stiffness and strength. The main purpose of combining organic fibre (polyamide) and inorganic fibres (glass and steel) is to achieve superior properties of plain concrete. In this present investigation the mechanical properties of fibres reinforced concrete is studied by using (steel fibre, glass fibre and polyamide) with different weight fraction of fibres with respect to cement.

Keywords: Steel, Concrete, FRC, Fibre, Aggregate, Polyamides.

Introduction

The mix design of M25 concrete with W/C ratio of 0.42 is taken. Thirteen mixes (13) included one control mix were prepared and tested in the laboratory. The total quantity of fibres mixed in the concrete are in order of 0%, 0.75%, 1.5%, and 2.25% by weight of cement and One mix contains (0.33% of glass fibre+0.33% of steel fibre+0.33% 0f polyamide). The total tested specimens are 239. Admixture such as superplastisizer (water-reducer) namely sikament is also used with the percentage of 1.5% by weight of cement to all the mixes to improve reaction between cement and water and also avoid the concrete from corrosion.

Aim of the Present Study

1. The strength of both fresh and harden state concrete should bedesi rable and according to requirement.
2. Behavior of fibrous concrete should be more thanconventional concr ete and hence fibrous concrete can be used in certain structural members.
3. The effect of fibres on compressive strength of concrete.
4. From present investigation we find the behavior of structural member cast with fibre based concrete.
5. To determine the increase in tensile strength of concrete.
6. Mechanical properties such as flexural strength, compressivestrength and split tensile strength of the fibre reinforced concreteshould be improved by adding fibre into it.

The following properties of the hardened concrete were determined:

1. Compressive strength tests,
2. Split tensile strength tests
3. Flexural strength tests

In this study the cube specimen of size (150mm x 150mm x 150mm) were casted and tested in auto CTM to obtain the compressive strength of FRC.

In addition to this, cylindrical specimens of size (150mm x 300mm) were also prepared to obtain the split tensile strength FRC.

Whereas Beam specimens of size (100mm x 100mm x 500mm) were tested under two point static flexural loading to obtain the flexural strength of FRC.

7 days and 28-day compressive strength test, split tensile strength test and flexural strength tests have been performed in the hardened state of concrete.

This study show mixed fibres provide better properties in controlling cracks and high strengths than single fibre and concrete without fibre. On increasing the percentage of fibres beyond 1.5%, the strength of the concrete matrix decrease due to mat form of fibres or non-uniform distribution of fibres and also decrease due to non-cohesiveness of concrete particle to each other

The idea for which that plain concrete can be strengthened by mixing fibres was first put forward in 1910 by porter. While polypropylene fibre is suitable for improving the impact strength of the concrete, whereas steel fibre is responsible to improve flexural strength and split tensile strength of the plain concrete.

The glass fibre provides greater resistance from propagation and occurrence of early cracks. (Rajagopalan et al. 1974).

Figure: beam Specimen with steel fibre

Glass fibre is also important in those respects but corroded in alkaline environment in the concrete. Sometime in bridges and pavement, flexural fatigue strength is the important parameter and it is designed on the basis of fatigue loading. One more advantage of adding fibres in the concrete gives the higher fatigue strength. Mixing of steel fibre in plain concrete give the formation of concrete composite having improved ductility and high energy absorption capacity composite (stiffness).

However due to inherent property of fibrous concrete-the presence of fibres in concrete can be expected to increase the resistance of conventional reinforced structural member against deflection, cracks and service life of concrete (Chanh 2004).

Quantity of fibres in fibre reinforced concrete is within the limit of 0.5% to 2%. As we increase the percentage beyond 2%, it may reduce the workability of the concrete mix and will give the formation of mat and balling which is difficult to separate by vibration. Whereas higher percentage of fibres are used with special fibre adding technique and different procedure of placement. When fibres reinforced structural member or concrete beams are loaded, the fibre in the concrete will bridge the crack as shown in given Figure 1.1. The bridging action of FRC improves tensile strength and energy absorption capacity as compare to conventional concrete (Yusof et al 2011).

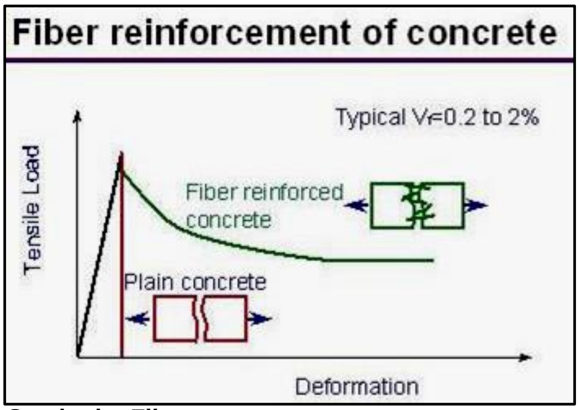
In this study different type of fibres are used for different purpose. One type of fibre is stronger and stiffer while the second type of fibre is flexible and leads to increase toughness and energy absorption capacity of the concrete matrix. One type of fibre is smaller, and it improves the bridges of micro-cracks, and this leads to a higher the tensile strength of the concrete. The second fibre is larger and it decreases the propagation of macro-cracks in concrete and therefore improves the toughness of concrete member.

Properties of Fibres

The following properties of natural and manufactured fibres are as under (Cement and concrete institute):

Steel Fibres

Modern commercially available steel fibres are manufactured from drawn steel wire, by the melt-extraction process or from slit sheet steel which produces fibres that have a crescent-shaped cross section. Typically steel fibres have an equivalent diameters range of 0.15 mm to 0.2 mm and lengths from 7 to 75 mm. Aspect ratios generally range from 20 to 100. The typically content of steel fibre ranges from 0.25% to 2.0% by volume of cement.



Synthetic Fibres

Different fibres types that have been tried in cement concrete matrices include: nylon, acrylic, polyethylene, aramid, carbon, polyester and polypropylene. Currently there are two different synthetic fibre volumes used in application, namely low-volume percentage range from 0.1 to 0.3% by volume of cement and high-volume percentage 0.4 to 0.8% by volume of cement. Most synthetic fibre applications are at the 0.1% by volume. At this level, the strength of the concrete is considered unaffected and the crack control characteristics are sought.

Natural Fibres

Natural fibres materials can be obtained at low cost. Utilization of natural fibres in form of concrete reinforcement is of particular interest to less developed regions where conventional construction materials are not available or are may be expensive.

Natural fibres are divided into two categories:

Unprocessed Natural Fibres

Products made with unprocessed natural fibres such as bamboo, coconut coir, jute, sisal, sugarcane bagasse, wood and vegetable fibres have been tested in number of countries. Problems have been reported with long-term durability of some of these products. To show some increase in mechanical properties, the minimum fibre content is of the order of 3.0% by volume.

Processed Natural Fibres

Wood cellulose is the most frequently used natural fibre. It is most commonly obtained using in the Kraft process. This process involves cooking wood chips in a solution of sodium carbonate, sodium hydroxide and sodium sulphide.

Different grades of wood-cellulose fibre containing more or less of the three main constituents, ligna, cellulose, and hemicellulose can be obtained by bleaching. Cellulose fibre can be produced with tensile strengths up to approximately 2.0 (GPa) from selected grades of wood, and using suitable pulping processes.

Glass Fibres

Glass fibres are available in continuous or chopped lengths. Fibre lengths of up to 35-mm are used in spray applications and 25-mm lengths are used in premix applications. Glass fibre has high tensile strength 2.0 – 4.0 GPa and elastic modulus (70 – 80 GPa). Claims have been made that up to 5% glass fibre by volume has been used successfully in sand-cement mortar without balling. GRC products are used extensively in agriculture, for architectural cladding and components, and for small containers.

Matallic Fibres

The tensile strength and the modulus of elasticity of metallic fibres are 2000 MPa and 140000 MPa respectively. Rough surface area of these fibres result in high performance with regard to bond strength with matrix. Due to high bond strength of metallic fibre with concrete matrix, fibres do not slide from the matrix when micro-cracks appear. At the time of initiation of micro-crack, metallic fibres are immediately tensioned and try to arrest the micro-crack mechanism. Moreover, this fibre is stainless and suitable for use in aggressive environment such as concrete drainage pipe (hameed et al. 2009).

This increase in strength was due to the fibre bridging properties in the concrete. The fibre reinforced concrete was split apart in the tensile strength test and as a result, the load was transferred into the fibres as pull-out behaviour when the concrete crack. The control batch specimens containing no fibres failed suddenly once the concrete cracked.). The fibre reinforced concrete specimens exhibited cracks but did not fully separate This shows that the macro fibre reinforced concrete has the ability to absorb energy in the post-cracking state. (Fig-1.2)

Figure :1.2 Comparison of Fibrous and Non-Fibrous Concrete

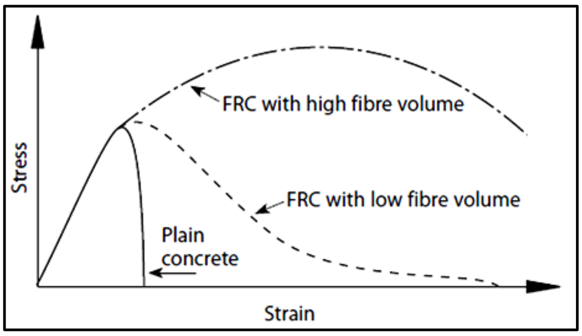


Figure: General Stress-Strain Curves for Fibre-Reinforced Concrete Material (Cement and Concrete Institute)

Fibre Mechanism and Matrix Interaction

Concrete with Fibres work utilizing two mechanisms:

1. Spacing mechanism
2. Crack bridging mechanism.

The spacing mechanism required large number of fibres which are well distributed within concrete matrix to resist any existing micro-crack that could potentially expand and create a sound crack. For typical percentage fractions of fibres, use small diameter fibres or micro fibres can ensure the required number of fibres for micro crack resistance.

The second mechanism called crack bridging requires larger straight fibres with proper bond to concrete. Steel fibres are considered a prime example of this type of fibre that is commonly referred as macro fibres or large diameter fibres. Benefits of using larger steel fibres improve tensile strengths, flexural strength, and compressive strength and, impact resistance ductility, and this was proved by (Bayasi et al 1989).

As shown in Figure 2.3, the tensile cracking strain of cement matrix (less than 1/50 times) very much lower than the ultimate or yield strain of steel fibres. As a result, when a fibre reinforced concrete composite is loaded, the matrix will cracks long before the failure of fibres. (Gebman et al. 2001)

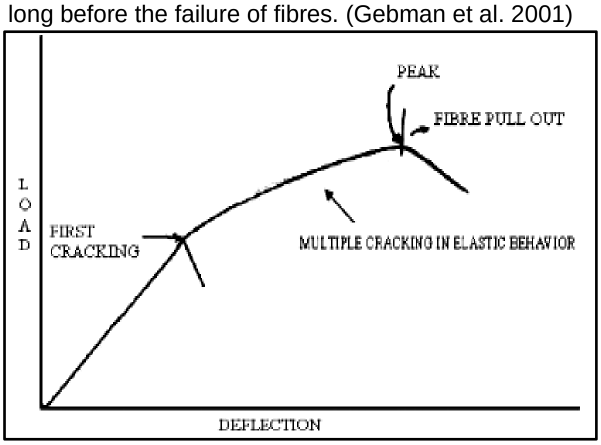


Figure 2.3: Fibre - Matrix Mechanism

Once the matrix is cracked the concrete composite continues to carry increasing tensile stress; the peak stress and strain of the concrete composite are greater than those of the concrete matrix alone and during the inelastic range between first cracking and the peak, multiple cracking of matrix occurs as indicated in given Figure.

Bridging Action of Fibres

Pullout resistance of fibre is important property for efficiency. Pullout strength of fibres significantly increases the post-cracking tensile strength of concrete.as fibre reinforced concrete member or any other structural element is loaded, the fibre bridge the cracks s shown in the Figure 2.4 given below (Gebman et al 2001).

Such type of bridging action provides the fibre specimens with higher ultimate tensile strength and also better energy absorption characteristic and larger toughness. An important benefit of adding fibers in concrete is material damage tolerance.

The damage tolerance factor is defined as a ratio of flexural resistance at maximum crack width of 2mm to ultimate flexural capacity (Bayasi and Kaiser in 2001).

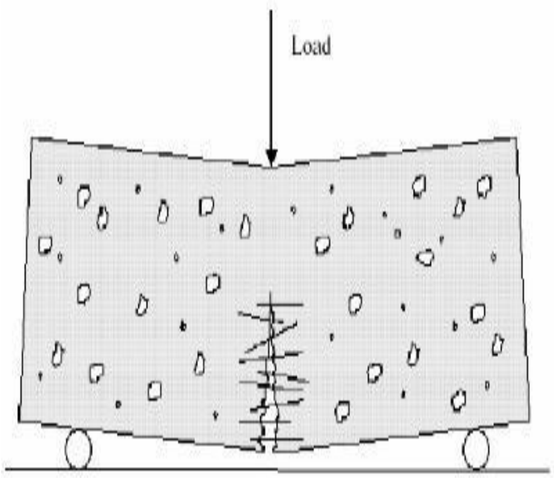


Figure 2.4: Bridging Action

Conclusion

1. Fibers provide a safer working environment.
2. The addition of fiber in concrete convert brittle nature into ductile nature.
3. Flexural strength of concrete is largely affected by adding fibers in concrete almost increase up to 160%.
4. Split tensile strength of glass fiber is very low as compare to normal mix.
5. It should be seen that the compressive strength of steel, glass, and polyamide fiber is almost same.
6. Higher percentages of fibres from 1.5 percentages affect the workability of concrete, and decrease the strength of concrete matrix.
7. 1.50% Dual fibre volume can be taken as the optimum dosage.
8. By using these fiber, maximum strength should be obtained at 1.5 % of fibers.

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