FIBRE REINFORCED CONCRETE

INTRODUCTION

1.1 GENERAL

Compared to other building materials such as metals and polymers, concrete is significantly more brittle and exhibits a poor tensile strength. Based on fracture toughness values, steel is at least 100 times more resistant to crack growth than concrete. Concrete in service thus cracks easily and this cracking creates easy access routes for deleterious agents resulting in early saturation, freeze-thaw damage, scaling, discoloration and steel corrosion. The concerns with the inferior fracture toughness of concrete are alleviated to a large extent by reinforcing it with fibers of various materials. The resulting material with a random distribution of short, discontinuous fibers is termed fiber reinforced concrete (FRC) and is slowly becoming a well-accepted mainstream construction material. Significant progress has been made in the last thirty years towards understanding the short and long-term performances of fiber reinforced cementitious materials, and this has resulted in a number of novel and innovative applications.

Concrete is one of the most versatile building materials. It can be cast to fit any structural shape from a cylindrical water storage tank to a rectangular beam or column in a high rise building. The advantages of using concrete include high compressive strength, good fire-resistance, high water resistance, low maintenance, and long service life. The disadvantages of using concrete include poor tensile strength, low strain of fracture and formwork requirement. The major disadvantage is that concrete develops micro cracks during curing. It is the rapid propagation of these micro cracks under applied stress that is responsible for the low tensile strength of the material. Hence fibres are added to concrete to overcome these disadvantages. The addition of fibres in the matrix has many important effects. Most notable among the improved mechanical characteristics of Fibre Reinforced Concrete (FRC) are its superior fracture strength, toughness, impact resistance, flexural strength resistance to fatigue, improving fatigue performance is one of the primary reasons for the extensive use of Steel Fibre Reinforced Concrete (SFRC)in pavements, bridge decks, offshore structures and machine foundation, where the composite is subjected to cyclically varying load during its lifetime.

The main reasons for adding steel fibres to concrete matrix is to improve the post cracking response of the concrete, i.e., to improve its energy absorption capacity and apparent ductility and to provide crack resistance and crack control. Also, it helps to maintain structural integrity and cohesiveness in the material. The initial researches combined with the large volume of follow up research have led to the development of a wide variety of material formulations that fit the definition of Fibre Reinforced Concrete. Steel fibre's tensile strength, modulus of elasticity, stiffness modulus and mechanical deformations provide an excellent means of internal mechanical interlock. This provides a user friendly product within creased ductility that can be used in applications of high impact and fatigue loading without the fear of brittle concrete failure. Thus, SFRC exhibits better performance not only under static and quasi-statically applied loads but also under fatigue, impact, and impulsive loading.

1.2 HISTORY OF REINFORCED CONCRETE:

A French gardener by name Joseph Monier first invented the reinforced concrete in the year 1849. If not for this reinforced concrete most of the modern buildings would not have been standing today. Reinforced concrete can be used to produce frames, columns, foundation, beams etc. Reinforcement material used should have excellent bonding characteristic, high tensile strength and good thermal compatibility. Reinforcement requires that there shall be smooth transmission of load from the concrete to the interface between concrete and reinforcement material and then on to reinforcement material. Thus the concrete and the material reinforced shall have the same strain.

1.3 MIXTURE COMPOSITIONS AND PLACING

Mixing of FRC can be accomplished by many methods [2]. The mix should have a uniform dispersion of the fibers in order to prevent segregation or balling of the fibers during mixing. Most balling occurs during the fiber addition process. Increase of aspect ratio, volume percentage of fiber, and size and quantity of coarse aggregate will intensify the balling tendencies and decrease the workability. To coat the large surface area of the fibers with paste, experience indicated that a water cement ratio between 0.4 and 0.6, and minimum cement content of 400 kg/m[3] are required. Compared to conventional concrete, fiber reinforced concrete mixes are generally characterized by higher cement factor, higher fine aggregate content and smaller size coarse aggregate.

A fiber mix generally requires more vibration to consolidate the mix. External vibration is preferable to prevent fiber segregation. Metal trowels, tube floats, and rotating power floats can be used to finish the surface. Mechanical Properties of FRC Addition of fibers to concrete influences its mechanical properties which significantly depend on the type and percentage of fiber. Fibers with end anchorage and Properties and Applications of Fiber Reinforced Concrete. High aspect ratio were found to have improved effectiveness. It was shown that for the same length and diameter, crimped-end fibers can achieve the same properties as straight fibers using 40 percent less fibers[S]. In determining the mechanical properties of FRC, the same equipment and procedure as used for conventional concrete can also be used. Below are cited some properties of FRC determined by different researchers.

Compressive Strength: The presence of fibers may alter the failure mode of cylinders, but the fiber effect will be minor on the improvement of compressive strength values (0 to 15 percent). Modulus ofElasticity : Modulus of elasticity of FRC increases slightly with an increase in the fibers content. It was found that for each 1 percent increase in fiber content by volume there is an increase of 3 percent in the modulus of elasticity.

Flexure: The flexural strength was reported to be increased by 2.5 times using 4 percent fibers.

Toughness: For FRC, toughness is about 10 to 40 times that of plain concrete. **Splitting Tensile Strength:** The presence of 3 percent fiber by volume was reported to increase the splitting tensile strength of mortar about 2.5 times that of the unreinforced one.

Fatigue Strength:

The addition of fibers increases fatigue strength of about 90 percent and 70 percent of the static strength at 2 x 106 cycles for non-reverse and full reversal of loading, respectively.

Impact Resistance:

The impact strength for fibrous concrete is generally 5 to 10 times that of plain concrete depending on the volume of fiber.

Corrosion of Steel Fibers:

A layer exposure of steel fibrous mortar to outdoor weathering in an industrial atmosphere showed no adverse effect on the strength properties. Corrosion was found to be confined only to fibers actually exposed on the surface. Steel fibrous mortar continuously immerse in seawater for 10 years exhibited a 15 percent loss compared to 40 percent strength decrease of plain mortar.

1.4 Structural Behavior of FRC Fibers

combined with reinforcing bars in structural members will be widely used in the future. The following are some of the structural behavior Flexure The use of fibers in reinforced concrete flexure members increases ductility, tensile strength, moment capacity, and stiffness. The fibers improve crack control and preserve post cracking structural integrity of members.

Torsion: The use of fibers eliminates the sudden failure characteristic of plain concrete beams. It increases stiffness, torsional strength, ductility, rotational capacity, and the number of cracks with less crack width.

Shear: Addition of fibers increases shear capacity of reinforced concrete beams up to 100 percent. Addition of randomly distributed fibers increases shear-friction strength, the first crack strength, and ultimate strength.

Column: The increase of fiber content slightly increases the ductility of axially loaded specimen. The use of fibers helps in reducing the explosive type failure for columns.

High Strength Concrete: Fibers increases the ductility of high strength concrete. The use of high strength concrete and steel produces slender members. Fiber addition will help in controlling cracks and deflections.

Cracking and Deflection: Tests have shown that fiber reinforcement effectively controls cracking and deflection, in addition to strength improvement. In conventionally reinforced concrete beams, fiber addition increases stiffness, and reduces deflection.

Necessity: The use of concrete as a structural material is limited to certain extent by deficiencies like brittleness, poor tensile strength and poor resistance to impact strength, fatigue, low ductility and low durability. It is also very much limited to receive dynamic stresses caused due to explosions. The brittleness is compensated in structural member by the introduction of reinforcement (or) pre-stressing steel in the tensile zone. However it does not improve the basic property of concrete. It is merely a method of using two materials for the required performance. The main problem of low tensile strength and the requirements of high strength still remain and it is to be improved by different types of reinforcing materials. Further concrete is also deficient in ductility, resistance to fatigue and impact. The importance of rendering requisite quantities in concrete is increasing with its varied and challenging applications in pre-cast and pre-fabricated building elements. The development in the requisite characteristics of concrete will solve the testing problems of structural engineers by the addition of fibers and admixtures. The role of fibers are essentially to arrest any advancing cracks by applying punching forces at the rack tips, thus delaying their propagation across the matrix. The ultimate cracking strain of the composite is thus increased to many times greater than that of unreinforced matrix. Admixtures like fly ash, silica fume, granulated blast furnace slag and metakaolin can be used for such purposes.

However addition of fibers and mineral admixtures posses certain problems regarding mixing, as fibers tends to form balls and workability tends to decrease during mixing.

2. Synthetic Fiber Reinforced Concrete – Types and Advantages

Concrete undergoes dynamic loading and rigorous environmental conditions. The development of shrinkage cracks in plain cement concrete is a major problem. To overcome this problem sometimes the addition of synthetic fiber to the concrete mix is beneficial. Synthetic Fiber Reinforced Concrete is increasingly being recognized as a favorable substitute for unsustainable inputs. These fibers are made from synthesized polymers of small molecules. The compounds that are used to make these fibers come from raw materials such as petroleum-based chemicals or petrochemicals. These materials are polymerized into a chemical that bonds two adjacent carbon atoms.

Differing chemical compounds are used to produce different types of synthetic fibers. It accounts for about half of all fiber usage, with applications in every field of fiber and textile technology.

2.1 Advantages of Synthetic Fiber Reinforced Concrete

Synthetic Fiber Reinforced Concrete Fiber are more durable than most natural fibers and will readily pick-up different dyes. Also, many synthetic fibers offer consumer-friendly functions such as stretching, waterproofing and stain resistance. Sunlight, moisture, and oils from human skin cause all fibers to break down and wear away. Natural fibers tend to be much more sensitive than synthetic blends. This is mainly because natural products are biodegradable. Natural fibers are susceptible to larval insect infestation; synthetic fibers are not a good food source for fabric-damaging insects. Compared to natural fibers, many synthetic fibers are more water-resistant and stain-resistant. Some of its advantages are;

- Controls and mitigates plastic shrinkage cracking

- Reduces segregation and bleed-water
- Provides three-dimensional reinforcement against micro-cracking
- Increases surface durability
- Reduction of in-place cost versus wire mesh for temperature/shrinkage crack control
- Easily added to concrete mixture at any time before mixing
- Increased durability due to Increased strength of mortar
- No Dampness and leakage
- Improves the abrasion resistance of concrete floors to moving loads.
- Improved impact resistance of floors to point loads

2.2 Different types of Synthetic Fiber Reinforced Concrete and its applications

Various types of fibers that have been tried in concrete include acrylic, aramid, carbon, nylon, polyester, polyethylene and polypropylene. Typically they are categorized as Micro and Macro Synthetic Fiber Reinforced Concrete.

1. **Micro Synthetic Fiber Reinforced Concrete**

Micro fiber concrete with polypropylene fibers are mainly used to reduce plastic shrinkage in fresh concrete. During the hardening process of concrete, dissipation of heat of hydration of concrete coupled with evaporation of water induces tensile stresses. Beyond a threshold limit of these stresses, micro cracks start developing in the concrete. Micro fiber concrete with polypropylene fibers reduces effective the early shrinkage behavior in the first 10 hours of pouring. The reason is that these types of fibers are able to hold back some water and slow down the evaporation process. They also are able to pick up some limited tensile stresses especially in the early age. These types of fibers work better to reduce plastic shrinkage cracks and are often added in addition to the reinforcement of concrete.

Another application of these fibres lies in improving the fire resistance behaviour of concrete structures at very high temperatures. Concrete as such in itself is a good fire-resistant material. Addition of micro fibres in the concrete ensures that as these fibres melt, they create open channels in the concrete pore structure which allows the built up vapours to escape, thereby releasing the internal pressures and preventing the spalling.

2. Macro Synthetic Fiber Reinforced Concrete

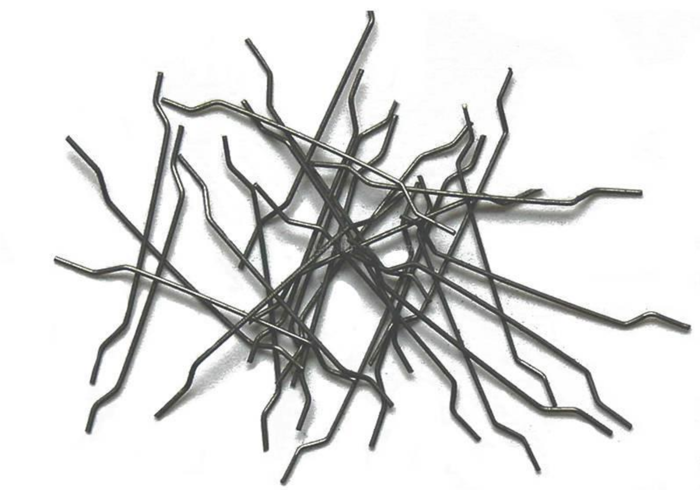
Macro fiber concrete with polypropylene fibers are mainly used in lightly loaded applications where the concrete behavior is calculated as un-cracked concrete just to improve the concrete in terms of their crack behavior and to improve the resistance against the thermal shrinkage process.

The reason that these fibers are mainly used in lightly loaded structures is that in the case of heavily loaded structures, these fibers tend to creep and hence a design in the cracked state under long term loadings does not save the structure in the event of a failure. Macro synthetic fibers do not corrode. Hence in case of macro fibers, no rusty spots appear at the surface. Additionally macro synthetic fibers can be effectively used in applications like temporary linings such as for mines when larger deformations are allowed.

2.3 Types of Fiber Reinforced Concrete:

STEEL FIBER REINFORCED CONCRETE

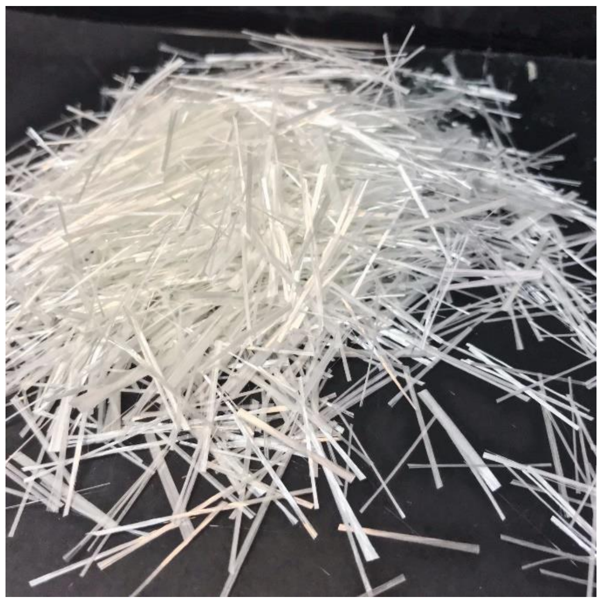
1. **Steel fiber-reinforced concrete** is basically a cheaper and easier to use form of rebar reinforced concrete. Rebar reinforced concrete uses steel bars that are laid within the liquid cement, which requires a great deal of prep work but make for a much stronger concrete. Steel fiber-reinforced concrete uses thin steel wires mixed in with the cement. This imparts the concrete with greater structural strength, reduces cracking and helps protect against extreme cold. Steel fiber is often used in conjunction with rebar or one of the other fiber types.



STEEL FIBERS

2. GLASS REINFORCED CONCRETE

Glass fiber-reinforced concrete uses fiberglass, much like you would find in fiberglass insulation, to reinforce the concrete. The glass fiber helps insulate the concrete in addition to making it stronger. Glass fiber also helps prevent the concrete from cracking over time due to mechanical or thermal stress. In addition, the glass fiber does not interfere with radio signals like the steel fiber reinforcement does.



GLASS FIBRES

3. SYNTHETIC REINFORCED CONCRETE

Synthetic fiber-reinforced concrete uses plastic and nylon fibers to improve the concrete's strength. In addition, the synthetic fibers have a number of benefits over the other fibers. While they are not as strong as steel, they do help improve the cement pumpability by keeping it from sticking in the pipes. The synthetic fibers do not expand in heat or contract in the cold which helps prevent cracking. Finally synthetic fibers help keep the concrete from spalling during impacts or fires.

synthetic fiber

3. Application of Synthetic Fiber Reinforced Concrete

- Floor for industrial, commercial and residential concrete projects
- Footings, foundations, walls and tank applications
- Concrete pipe, vault structures and precast / prestressed beams, PQC Roads, Parking Area, Pavers,
- Tunnels, Canals & All kinds of Plastering Application.

4. Conclusion

Synthetic Fiber Reinforced Concrete has been rapidly growing throughout the building industry since contractors and homeowners started to recognize its many benefits. It is gaining an increasing interest among the concrete community for the reduced construction time and labor costs. Besides cost issues, quality matters are of paramount importance for construction and Synthetic Fiber Reinforced Concrete also fulfills these requirements.

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