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1. 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 with increased 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.

**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.

**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/m³ 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 offiber. Fibers with end anchorage and Properties and Applications offFiber 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 of Elasticity:

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 10^6 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 year 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.

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 behaviour

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 eliminate 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.

**STEEL FIBER REINFORCED CONCRETE**

- 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.
GLASS REINFORCED CONCRETE

- Glassfiber-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.

![FIG 1.2 GLASS FIBRES](https://simplifiedcivilengineering.home.blog/)

- Very high tensile strength 1020 to 4080 N/mm2.
- Shows comparable improvement indurability to conventional E-glass fiber.

1.3.3 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.

**FIG1.3 SYNTHETIC FIBRES**

**NATURAL FIBRE REINFORCED CONCRETE**

Historically, fiber-reinforced concrete have used natural fibers, such as hay or hair. While these fibers help the concrete's strength they can also make it weaker if too much is used. In addition if the natural fibers are rotting when they are mixed in then the rot can continue while in the concrete. This eventually leads to the concrete crumbling from the inside, which is why natural fibers are no longer used in construction.

**ASBESTOS FIBER REINFORCED CONCRETE**

- ✔️ ✔️ Mineral fiber, most successful of all as it can be mixed with Portland cement.
- ✔️ ✔️ Tensile strength of asbestos varies between 560 to 980 N/mm2.
- ✔️ ✔️ Asbestos cement paste has considerably higher flexural strength than Portland cement paste.
For unimportant concrete work, organic fibers like coir, jute and canesplits are also used.

CARBON FIBER REINFORCED CONCRETE

Posses very high tensile strength 2110 to 2815 N/mm² and Young’s modulus.

Cement composite consisting of carbon fibers show very high modulus of elasticity and flexural strength.
EXPERIMENTAL STUDY:

The materials used and their specifications are as follows

**CEMENT**: Ordinary Portland cement was used and its specific gravity is 3.15*. The brand used was “UltraTech” with P53 grade. The cement was confirming to IS 269-1976.

**FINE AGGREGATE**: River sand was used and tests were conducted as per IS 2386 (PART I). Specific gravity of fine aggregate is 2.65. Water absorption 0.99%. Dry loose bulk density 1502 Kg/m³

**COARSE AGGREGATE**: Crushed granite stone aggregates of maximum size of 20 mm was used. Tests were conducted as per IS 2386
Specific gravity of coarse aggregate is 2.73. Water absorption 0.25%. Dry loose bulk density 1500 Kg/m³

**WATER:** As per IS 456-2000 recommendations, potable water was used for mixing of concrete.

**STEEL FIBRES**

**HOOKED END STEEL FIBRES**

Hooked end steel fibres commercially called as Dramix steel fibres manufactured by Bekaert Corporation were used which had a length of 30 mm and a diameter of 0.55 mm resulting in an aspect ratio of about 55 and conforms to American standard ASTM A820 and Belgium standard 1857. The tensile strength of fibre is in the range of 1100 N/mm².

**CORRUGATED STEEL FIBRES**

Corrugated steel fibres from Stewols & Co were used which had a length of 25 mm and a diameter of 0.45 mm resulting in an aspect ratio of about 55 and conforms to American standard ASTM A820. The tensile strength of fibre is in the range of 1200 N/mm².

**CASTING OF SPECIMENS**

The materials were weighed accurately using a digital the mixture machine and mixed thoroughly for three-minutes. Steel fibres were mechanically sprinkled inside the mixture-machine after thorough mixing of the ingredients of concrete. For preparing the specimen for compressive, tensile, and flexure strength-permanent steel moulds were used.
Fig. Steel fibres used in the experiment
Steel moulds

Wooden moulds were fabricated to cast the test specimens for panel testing. Six wooden moulds were fabricated to facilitate simultaneous casting of test panels. Two different thicknesses were adopted for the panels; the panel sizes adopted were 500×500×50mm and 500×500×100mm.

Before mixing the concrete the moulds were kept ready. The sides and the bottom of the all the mould were properly oiled for easy demoulding. The panel was kept at an angle of 45° and then the concrete was splashed over the panel from a distance of one meter. Then the top surface was given a smooth finish.
Fig. 1.8 Casting by wooden pane

SFRC using hooked fibre

Fig. 1.9 SFRC using corrugated fibre

2.3 CURING OF SPECIMENS
The test specimens were stored in place free from vibration and kept at a temperature of 27°C ± 2°C for 24 hours ± 1/2 hour from the time of addition of water to the dry ingredients. After this period, the specimen were-marked and removed from the moulds and immediately submerged in clean fresh water and kept there until taken out prior to test. The specimens were allowed to become dry before testing. The panels were-cured by dry curing method, i.e. moist gunny bags were covered over the panels.

Fig. 1.10 Use of Admixture

2.4 CUBE COMPRESSION TEST

M25 cube made of steel fiber reinforced concrete is used in compression test.
Fig. 1: Cube before test
Fig. ; Cube after test
REPORT ON FIBER REINFORCED CONCREATE

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Fig; Graphical representation of Compressive Strength of fibre reinforced concrete

Fig; Graphical representation of Tensile Strength of fibre reinforced concrete
CONCLUSION

- The efficient utilisation of fibrous concrete involves improved static and dynamic properties like tensile strength, energy absorbing characteristics, Impact strength and fatigue strength.
- Also provides a isotropic strength properties not common in the conventional concrete.