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"A Review Report On Characteristics of Mixed Fiber Reinforced Concrete for Structural Applications"

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ABSTRACT- Among the various types of fibers used in the preparation of Fiber Reinforced Concrete (FRC), glass fibers come under the category of non metallic and inorganic type. By making use of Alkali Resistant glass fibers, a very useful FRC composite can be made. This possesses enhanced properties like more tensile strength, energy absorption and corrosion resistance. Researchers all over the world are working on GFRC composites and glass fiber reinforced mortars. Limited amount of work has been done on structural applications of GFRC.

I. INTRODUCTION

1.1 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. One of the undesirable characteristics of the concrete as a brittle material is its low tensile strength, and strain capacity. Therefore it requires reinforcement in order to be used as the most widely construction material. Conventionally, this reinforcement is in the form of continuous steel bars placed in the concrete structure in the appropriate positions to withstand the imposed tensile and shear stresses

1.2 FIBER REINFORCED CONCRETE

The construction material is continuously evolving. The demand for high strength, crack, resistant and lighter concrete resulted in development of fiber reinforced concrete. Fibers that are used are steel, nylon, asbestos, glass, carbon, sisal, jute, coir, polypropylene, kenaf.

1.2.1 History of FRC

The practice of adding certain fibers to construction material dates back to the ancient times. When horse hair, straws were used to strengthen the bricks. In 1911 Porter found that fiber could be used in concrete. Early 1900 saw the use of asbestos fiber. In 1950 fiber reinforced concrete was becoming a field of interest as asbestos being a health risk was discovered. In 1963 Romualdi and Batson published their classic paper on FRC. Since then there was no looking back, glass, steel, polypropylene fiber were used in concrete.

1.2.2 Necessity of FRC

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

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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 un reinforced 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.

1.2.3 Behaviour of Fiber in Concrete

Fibers contribute towards reducing the bleeding in fresh concrete and renders concrete more impermeable in the hardened stage. Contribution of certain percentage of fibers in concrete towards flexural strength is smaller compared to the strength given by the rebars. Most importantly fiber restricts the growth of crack under load thereby arresting ultimate cracking. Non metallic fibers like alkali resistant glass fiber and synthetic fibers provide resistance against chemicals. Reinforcing capacity of fiber is based on length of fiber, diameter of fiber, the percentage of fiber and condition of mixing, orientation of fibers and aspect ratio. Aspect ratio is ratio of length of fiber to its diameter which plays an important role in the process of reinforcement.

1.3 TYPES OF FIBER

There are two methods to categorize fibres according to their modulus of elasticity or their origin. In the view of modulus of elasticity, fibres can be classified into two basic categories, namely, those having a higher elastic modulus than concrete mix (called hard intrusion) and those with lower elastic modulus than the concrete mix (called soft intrusion). Steel, carbon and glass have higher elastic modulus than cement mortar matrix, and polypropylene and vegetable fibres are classified as the low elastic modulus fibres. High elastic modulus fibers simultaneously can improve both flexural and impact resistance; whereas, low elastic modulus fibres can improve the impact resistance of concrete but do not contribute much to its flexural strength. According to the origin of fibres, they are classified in three categories of metallic fibers (such as steel, carbon steel, and stainless steel), mineral fibers (such as asbestos and glass fibers), and organic fibers. Organic fibers can be further divided into natural and man-made fibers. Natural fibers can be classified into vegetable origin or sisal (such as wood fibers and leaf fibers), and animal origin (such as hair fibers and silk). Man-made fibers can also be divided into two groups as natural polymer (such as cellulose and protein fibers), and synthetic fibers (such as nylon and polypropylene). Figure 1 shows the classification of fibers based on this method (James Patrick Maina Mwangi, 1985).

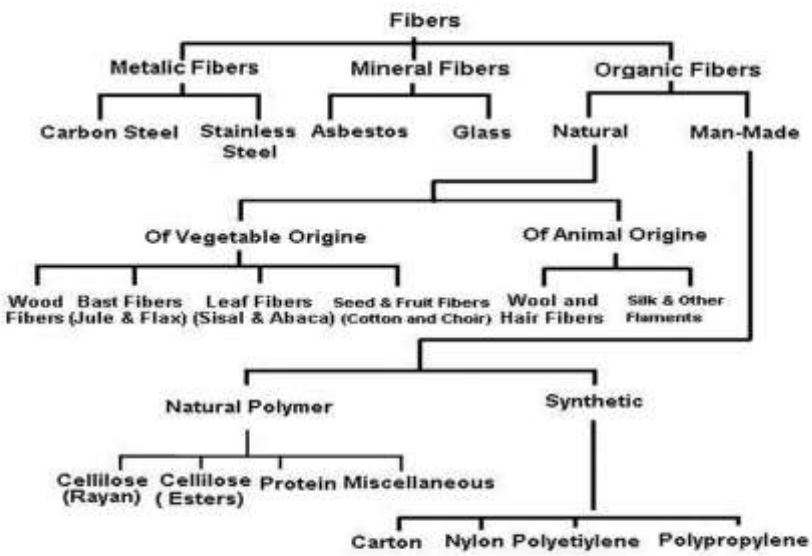

Figure1: Fibers Classification (James Patrick Maina Mwangi, 1985)

1.3.1 Asbestos Fiber

This comes under naturally occurring mineral fiber. Asbestos fiber shows very good resistance to heat, electrical, chemical damage and fire. It has average tensile strength. Hence it became very popular is the late 19th century. Asbestos is a combination of six naturally occurring silicates. They were originally used in building insulation electrical insulation for hot plate curing. More water is required when asbestos fiber is mixed with cement due to high absorption. But later it was discovered that asbestos was carcinogenic in nature, hence very likely to human health that it was totally banned.

1.3.2 Carbon Fiber

Carbon fiber improves the elasticity and gives good tensile strength. They are formed by oxidation of poly-acronitrile fibers. After oxidation thermal pyrolysis is carried out thereby producing carbon fibers. They exhibit high elasticity and give good tensile strength. Rudder of aeroplanes is manufactured using this fiber.

1.3.3 Aramid Fiber

This is synthetic fiber. As name it is aromatic polyamide. Aramid fiber is another reinforcing material that could be used. They are formed by reaction of an amine group and a carboxylic acid halide group. This fiber is commercially known as technora, kevlar, nomex. Kevlar was originally used as composite material for manufacturing the air frame of commercial aeroplane, as they are very light weight and high strength material. In these fibers, chain molecules are all oriented along fiber axis, so high strength chemical bond results in its high strength. This was first discovered by DuPont. They were excellent substitute for asbestos.

1.3.4 Metallic Fibers

They are manufactured by heating the metal until it evaporizes, then depositing it at very high pressure on to polyster film. Metallic fiber is usually aluminized nylon yarn. Metallic fiber is actually a combination of plastic and metal. They can be drawn from steel wool too. The metallic fibers are carbon steel fiber or stainless steel fiber.

1.3.5 Polypropylene, Polyethylene, Nylon Fiber

These show high alkaline resistive and acid resistive property. Polypropylene is a polymer of polyolefin. Polypropylene fiber in the form of fibrillated film fibers show excellent bonding with matrix as the matrix can easily blend into this fibrils thus giving good impact resistance. The nylon and polypropylene have very high tensile strength 561.0 – 867.0N/mm2. They could be used where high energy absorption is required because their high elongation (15-25%) absorbs more energy. The low modulus of this fiber reduces the reinforcing property. They are extensively used in pile shell, non-load bearing corrosion proof member, cladding panels floatation unit, guniting crack inhibitor. It is a very good steel reinforcement substitute in the aspect of transportation and handling purpose in case of precast components because using plastic fiber reduces the size (thinner section are formed) and increases the crack resistance thereby saving material, transportation and erection cost.

1.3.6 Glass Fiber

Glass reinforced cement consists of 4 to 4.5 % by volume of glass fiber mixed into cement or cement sand mortar. This glass reinforced cement mortar is used for fabricating concrete products having section of 3 to 12mm in thickness. Methods of manufacture vary and include spraying, casting, spinning, extruding and pressing. Each technique imparts different characteristics to the end product. Spray deposition constitutes a very appropriate and by far the most developed method of processing. In the simplest form of spray 7 processing, simultaneous sprays of cement sane mortar slurry and chopped glass fiber are deposited from a dual spray gun into, or onto a suitable mould. Mortar slurry is fed to the spray gun from a metering pump unit and it is atomized by compressed air. Glass fiber is fed to a chopper and feeder unit that is mounted on the same gun assembly. The fibers are manufactured from Glass quarry products. The glass quarry products are melted in furnace, and then from the process of bushing, the fiber filaments will be obtained. These are best suited for application as renovating construction material for restoration of old heritage buildings and for architectural applications.

1.3.7 Natural Fiber

Natural fiber are wood fiber consisting of bamboo seed etc., fruit fiber (coir), stem fiber i.e. jute, kenaf, san, flax etc., and leaf fiber like henqueen, sisal, coconut. The cost efficient and energy efficient production of this fiber is a natural advantage. But they have high water absorption, low alkali resistant, are prone to insect and fungal attack and have low elastic modulus making it a deterrent for usage in concrete. Sisal fibers are extracted from agave sisalana leaves. It comprises of pectin, lignin and hemicellulose. They are strong but are prone to alkali attack. Wood fiber or cellulose fiber is the most popularity used natural fiber in concrete. The high modulus of elasticity, tensile strength, and abundance of availability are the major advantage. Wood fiber is extracted from wood by the process called pulping. Wood fiber contains cellulose, hemicellulose and lignin. Lignin reduces the strength of fiber, hence chemical pulping process 8 called kraft or sulphate is used to remove the lignin. The very low alkali resistant property of wood fiber can be improved by using processes that would limit the disintegration of fiber in alkaline environment.

II. LITERATURE REVIEW

Strength properties are the most valuable characteristics of concrete. They have a direct relationship to micro structure of hydrated cement past and concrete. These are directly related to other properties of concrete like elasticity, stress, strain and other construction related activities like forms removal etc. The reinforcement in concrete further enhances these strength properties. Because of the flexibility in methods of fabrication, fiber reinforced concrete can be an economic and useful construction material. The concrete is mostly utilized in the elastic range and there is a need to know the relationship between stress, strain and the elasticity which is the property of concrete. This will provide information on how to control the deformation of the concrete members.

2.1 Elastic Properties of Concrete

K.K. Sideris et. al., (2023) have investigated the relationship between compressive strength, modulus of elasticity of concrete and compressive strength poisson ratio by using cement hydration equation. This equation predicts the final rate of hydration at the age of 15 years of cement used when the hydration ends. The authors have concluded that there always exists a linear relationship between compressive strength-elastic modulus and compressive strength- poisson ratio.

Sander Popovics (2022) reviewed the work conducted by various researchers on the stress strain relationships for concrete. The author has concluded that the testing conditions such as the rate of loading, number of load repetitions, the magnitude of the repeated stresses influence the stress strain diagram of concrete. The curve deviates gradually from straight line due to progressive propagation of internal cracking in the specimen and the aggregate content of concrete influences the curvature of the stress strain curve. Empirical equations can be used to calculate strain and secant modulus of elasticity at ultimate compressive stress.

Sami A Klink (2022) has conducted compression test to measure strains by embedding strain gauge units in the normal weight and light weight concrete cylinders. The elastic modulus of concrete cylinders was considered at their centre. The results showed that the elastic modulus was 55 % higher when compared to the standard test results. Also by empirical formula calculations about 50 % higher actual elastic modulus was obtained. The author has concluded that the actual elastic modulus is a function of its density and compressive strength.

2.2 Impact Strength of Concrete

Yaghoob Farnam et. al.,(2020) have investigated the experimental and numerical effect of high performance fiber reinforced cement composite behaviour at low velocity impact. The authors tested the casted panels by drop projectiles upto an impact at which failure occurs and used LS-DYNA software for modeling. Investigation and behavior by simulating were carried out based on ACI 544 2R. The authors have concluded HPFRC has higher impact resistance than normal concrete and the results obtained from FE analysis based on number of strikes required for failure initiation of the specimen, midpoint deflection, shape of failure pattern are in good agreement with the corresponding experimental results.

V. Bindiganivile, N. Banthia (2019) investigated the fiber matrix bond behavior under impact loading in concrete. Fiber matrix bond strength plays an important role in Impact strength of FRC. High strength fiber matrix results in stiffer bond. The fibers used were three polymeric fiber and one steel fiber. The study revealed that with high bond stiffening with impact loading, steel fibers showed the best peak loads for small inclination compared to aligned load. The study showed that the crack opening displacement associated with peak loading is inversely proportional to loading rate thereby proving the stiffness of fiber matrix bonding. The quasi static and impact rates of loading in case of high strength matrix reduces the strength of the fiber-matrix bond. The study concluded that the fiber, that pull out totally during impact loading is the best suited for high strength matrix.

2.3 Basic Work Conducted on Fiber Reinforced Concrete (FRC)

The use of steel fibers in concrete dates from 1910 to improve the properties of concrete. The main interest in fibrous reinforcement of concrete originates from the work carried out in the early sixties by various researchers.

Romualdi et. al. (2017) studied the mechanism and mechanics of crack arrest properties of steel fibers, tensile strength of uniformly distributed short fiber and the behaviour of reinforced concrete beams. The study concluded that the steel fibers have major influence in enhancing the strength and crack control properties.

Hannant (2016) studied the effect of post cracking ductility on the cement mortar and concrete specimens reinforced with short steel fibers. The flexural strength test resulted in enhanced ductility compared to specimens without fibers.

Naaman and Shah(2016) studied the bond properties of randomly oriented and aligned steel fibers using steel fiber and concluded the fibers have good bonding characteristics and hence improvement in the properties of concrete.

Gopalratnam et. al. (2015) studied the properties of SFRC subjected to impact loading. The results indicated higher energy absorption of the specimen compared to specimens without fiber.

Majumdar (2014) carried out investigations to study the influence of glass fiber reinforcement in cement mortar and concluded that the glass fiber enhances properties of cement mortar.

Shah et. al. (2012) investigated the toughness durability characteristics of glass fiber reinforced concrete and concluded that glass fibers exhibited higher energy absorption leading to a more durable concrete.

N. Banthia et. al. (2011) studied the resistance offered by the hybrid fibers in concrete using steel fiber and polypropylene fiber in the cement matrix. After conducting crack test the authors concluded that polypropylene fiber enhances the efficiency of steel fiber

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