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A Review on Use of Fibers in Concrete

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Abstract - *Fibers are being used as a reinforcing material in concrete since ancient times. They are generally used to control cracking. Also, their inclusion to concrete matrix enhances its strength properties and ductility characteristics. The various types of fibers such as steel, polypropylene, glass, carbon and natural fibers and their effect on properties of concrete are discussed in this research paper. The important factors affecting the fiber selection such as volume, aspect ratio, and orientation are also studied.*

Key Words: **Concrete, Fibers, Strength, Durability, Natural Fibers.**

1. INTRODUCTION

Concrete is the most widely used construction material because its principal components are easily available everywhere, relatively simple production and its wide application to various civil infrastructure works. However, the main drawback of using concrete is its brittleness and susceptibility to crack openings and their propagations, thereby creating many problems in its application. Cracks in a concrete structure leaves a negative impression on the strength, toughness and serviceability of the structures. One of the solutions to this problem is the inclusion of small fibers in the concrete matrix. The concrete containing fibers is also known as Fiber Reinforced Concrete (FRC). In Fiber Reinforced Concrete (FRC), thousands of small fibrous particles are dispersed and distributed randomly in the concrete mixture during mixing, therefore improving its properties in all directions. The fibers act as stress- transfer bridges in concrete and abate the nucleation and also the propagation of cracks in concrete [1]. Moreover, the addition of fibers to concrete modifies its properties both in plastic and hardened state and therefore results into a more sturdy concrete.

The aim of this research is to study the different type of fibers that are being used in concrete matrix and the various factors contributing to the selection of different fibers in concrete.

2. DIFFERENT TYPES OF FIBERS

2.1 Steel Fibers

Steel fibers are a type of metal reinforcement. These steel fibers are relatively short and firmly spaced as compared to the conventional continuous reinforcing bars. They are added to improve the structural properties i.e. tensile strength and flexural strength, and durability. Steel fibers also found to contribute to post-cracking strength due to their crack bridging mechanism and thereby, they help in restraining the cracks in concrete [2]. The research studies carried out by Narayanan and Darwish concluded that addition of steel fibers increases shear strength of the concrete due to their crack- arresting mechanism [3]. Nowadays, steel fibers are being used as main and secondary reinforcement in a number of applications such as highway and air-field pavements, hydraulic structures, refractory concrete, and precast applications [2].

2.2 Polypropylene Fibers

Polypropylene fibers are synthetic fibers and are generally hydrophobic in nature. The research conducted by Alhozaimy et. al found no significant effects of polypropylene fibers on compressive and flexural strengths, while impact resistance and flexural toughness were found to increase in the presence of polypropylene fibers [4]. Toutanji et al. established that the inclusion of polypropylene fibers increases the permeability of conventional concrete but addition of a cementitious material like silica fume can reduce the permeability caused by these fibers [5]. The spalling behaviour of concrete can also be improved by using polypropylene fibers [6]. Therefore, polypropylene fibers have many applications in conventional concrete, self-compacting concretes, high performance concretes, rigid pavements etc.

2.3 Glass Fibers

Glass fibers are inexpensive, lightweight and possess high tensile strength. The use of glass fibers to reinforce cement or concrete is possible due to their high tensile property. But earlier attempts to use glass fibers were not very successful due to their deterioration caused by the alkali particles present in the cement. In 1974, the alkali-resistant glass gibers with addition of zircon oxide ZrO_2 were invented by Majumdar and Ryder [7]. Mirza and Soroushian found that properties of lightweight concrete like flexural strength, ductility, restrained shrinkage cracking and temperature resistance were improved by using alkali resistant glass fibers [8].

2.4 Carbon Fibers

Carbon fibers are expansive in nature, have high modulus of elasticity and their flexural strength is also high. The strength and stiffness of these fibers have been found to be superior even to those steel fibers. The light weight carbon fiber composites combine the qualities of a high tensile

strength with an outstanding fatigue performance [9]. According to Xiao and Wu, the strength and ductility of concrete can be significantly increased by using carbon fiber composite jacketing [10].

2.5 Natural Fibers

In natural fiber reinforced concrete, discontinuous and discrete natural fibers of small diameter are dispersed randomly throughout the concrete matrix while preparing the concrete mix. The density of these fibers is generally low and they possess high specific strength and stiffness. They are advantageous over other synthetic fibers concerning the environment, economy, energy and resource conservation. The most common type of natural fibers used in concrete are jute, coconut and bamboo fibers.

2.5.1 Jute Fibers

The jute fiber is a plant based natural fiber which is mainly composed of cellulose and lignin. The inclusion of jute fiber decreases workability of the concrete matrix but increases the compressive strength of the concrete as reported by Islam and Ahmed [11]. According to Razmi and Mirsayar [12] and Zakaria et al.[13], the incorporation of untreated jute fiber in concrete enhances the compressive strength, tensile strength, flexural strength and also the fracture mechanism of the hardened concrete.

2.5.2 Coconut Fibers

The coconut fiber is also a plant based natural fiber and is extracted from coconut husk. According to their peeled off time from the coconut husks, the fibers may be classified as white and brown fibers [14]. Generally, the brown fibers are used as reinforcing material into the concrete matrix [15]. The strength characteristics such as compressive strength [16], and flexural strength [16,17] were found to increase with the incorporation of these natural fiber in the concrete.

2.5.3 Bamboo Fibers

Bamboo fiber is a cellulosic type of fiber, highly durable, stable, and tough and has strength comparable to the conventional glass fibers [18]. The experimental investigations carried out by Zhang et al. showed that inclusion of bamboo fibers in the concrete enhanced its cubic compressive strength and significantly improved the splitting tensile strength [19]. The incorporation of bamboo fibers in concrete can also reduce concrete's crack-width and deflection, and increase in its beam post-cracking load-carrying capacity [20].

3. FACTORS AFFECTING FIBER SELECTION

3.1 Volume of Fiber

The fiber volume is an important factor influencing the properties of the concrete mix. Higher volume may cause decrease in workability of the concrete mix and lower volume may not fulfill the requirements of the design mix for which fibers are being used in concrete. So, suitable volume of fiber is to be selected for getting the desirable outcomes. Generally, fiber volume up to 2% is used in the concrete mix.

3.2 Aspect Ratio of Fiber

Aspect ratio of fiber is defined as the ratio of length of the fiber to its diameter. Higher the aspect ratio, the more flexible the fiber is. The fibers with lower aspect ratio yield higher compressive strength, a highly energy absorptive material [21].

3.3 Orientation of Fiber

Generally, the fibers are randomly distributed during concrete mixing. However, they can be oriented in the direction of load application and can also be aligned in the direction perpendicular to the load application. However, it is observed that fibers aligned parallel to load offered more tensile strength than the randomly distributed and perpendicularly aligned fibers.

4. CONCLUSIONS

Generally, the plain concrete has a very low tensile strength, limited ductility, and little resistance to cracking. The research studies show that inclusion of small, closely spaced and uniformly distributed fibers to concrete increases its performance as compared to the conventional concrete. These fibers in concrete act as crack-arresters and increases its strength characteristics such as compressive strength, tensile strength. The various fibers that are being used in concrete are steel fibers, polypropylene fibers, glass fibers, carbon fibers, and natural fibers such as jute fibers, coconut fibers and bamboo fibers. The various factors affecting the fiber selection into the concrete matrix are volume, aspect ratio and orientation of fibers. Hence a particular type of fiber or a blend of two or more fibers can be used in concrete mix depending upon the properties required in the concrete structure.

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