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State of the Art on Effect of Fibers in Structural Concrete

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Abstract:

Fiber-reinforced concrete has become most widely used material in various construction practices nowadays due to its high ductility and sufficient durability. In this paper the recent advancements in the application of fibers in concrete beams has been studied. Most of the conclusions drawn in this study are arrived by conducting experiments on plain and reinforced concrete beams. Apart from this, an attempt to showcase the recent publications and activities in the area of fibers is also covered. The significance of this paper lies in the collection of research works reported to date regarding the fibers on plain, reinforced concrete beams. The behavior of beams were studied under different loading cases, type and volume fraction of fibers and the various parameters were examined. The result indicates that the addition of fibers will enhance the mechanical properties. This paper also discusses about torsion, fatigue behavior, crack propagation, shear behavior, deformation behavior of the fiber reinforced concrete beam.

Keywords — **Fiber reinforced concrete; steel fiber; fatigue; beams; shear; toughness**

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I. INTRODUCTION

Fiber-reinforced concrete has become most widely used material in various construction practices nowadays due to its high ductility and sufficient durability. In this review paper the recent advancements in the application of fibers in concrete has been studied [1]. The research works on the behavior of plain concrete and reinforced concrete beams with the addition of fibers were summarized in this paper. The outcomes of various researches showed that the addition of fibers will enhance the mechanical properties such as compressive strength, flexural and split tensile strength, toughness, deformation and fatigue characteristics, torsion and shear. The conclusion drawn from all the research works are arrived by conducting experiments and they compared the results with the analytical models to make sure the errors are less [2].

II. EFFECT OF FIBERS ON PROPERTIES OF CONCRETE

A. Compressive strength

The effect of fibers on concrete compressive strength is still under debate as some researchers reported increase in compressive strength and some found out the decrease in compressive strength with addition of fibers[3]. Some researchers even concluded that there will be no significant improvement in compressive strength with the addition of Fibers. The compressive strength of concrete did not show any improvement up to 0.25 % of fiber volume for both basalt fibers and glass fibers, but at 0.25% and for mixes with greater than 0.25 % volume of fibers the compressive strength of concrete increased, the maximum compressive strength obtained for basalt and glass fiber reinforced concrete were 66.6 and
67.6 MPa at 0.5 % and 0.75 % inclusion of fibers respectively, and the compressive strength of plain concrete was 63.4 MPa [4].

B. Splitting tensile strength

Splitting tensile strength cannot give accurate estimation of direct tensile strength due to mixed stress field and different fiber orientation [5], but it is useful as the failure pattern obtained from this test will give us the idea about ductility characteristics of the material [6]. The test results showed that that with the addition of fiber the splitting tensile strength of concrete increased and the highest splitting tensile strength observed for

basalt and glass fibers were 40% and 27% at 1% and .75% fiber inclusion respectively [7]. The increase in splitting tensile strength with addition of fibers is mainly due to bridging action of fibers which restrains the micro crack propagation [8].

C. Flexural Strength

From the test results it was found that with the addition of basalt and glass fibers the flexural strength of concrete increased [9]. The increase was more predominant in case of basalt fibers when compared with glass fibers. In case of glass fibers up to 0.5% fiber inclusion there was improvement in strength but with further increase in fiber content there was no improvement in flexural strength of concrete [10].

D. Toughness (Energy absorption capacity)

The energy absorption capacities of steel fibers increased 121% and 135% with SFs dosages of 30 kg/m^3 and 60 kg/m^3, as compared to plain M20 concrete [11]. Similarly, the toughness of steel fiber reinforced concrete increased 36% and 51% with SFs dosages of 30 kg/m^3 and 60 kg/ m^3, as compared to plain M30[12].

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III. EFFECT OF FIBRES ON PROPERTIES OF BEAMS

A. Mechanical properties:

The researcher focused on comparative study of concrete beams reinforced with different types of fibers available in the market [13] and found out the effects of different steel fiber types on mechanical properties of hardened concrete. The failure characteristics of fibers changed due to addition of fibers. The Dramix long fiber mix with 0.5 % fiber content showed maximum 1st peak load and maximum ultimate load of all other mixes followed by the helix fiber mix of same fiber content [14]. Dramix short fiber mix with 1.5% fiber content by volume showed the maximum ultimate load when compared with other mixes of same fiber content. There was predominant increase in flexural capacities when Dramix fiber mix with short length fibers, they observed that the flexural capacities increased by 120% by varying the fiber content from 0.5 to 1.5 % by volume. They observed increase in toughness values with the addition of fibers, among the 0.5 % fiber content the mix of Dramix long fiber showed the highest toughness value and the mixes of royal fibers showed the least value and among the 1.5 % fiber volume Dramix long fibers showed the highest toughness value [15].

B. Shear strength:

Many studies are going on to find the effect of fibers on shear strength of beam. In this study the researcher carried out the experiments to find out the shear characteristics of fiber reinforced beams and also compared the experimental results with the analytical results obtained from the generated analytical models [16]. The researchers study also focuses on how effectively the fibers can used by potentially replacing with the stirrups and when used in combination (fibers & stirrups) how effectively they improve the shear strength of concrete. The test results showed the increase in compressive strength up to 25 % when fiber volume increased from 0 to 2 % and flexural strength increased by 55 % with increase in fiber volume. Splitting tensile strength increased was doubled with increase in fiber volume [17].

All the beams showed similar linear behavior up to occurrence of first hairline crack, the beams with no shear reinforcement have undergone sudden shear failure immediately after the first crack; in case of beams with only fibers, they continue to resist shear stresses thereby changing the failure mode from shear to flexure type [18]; in case of beam with stirrups but no fibers some spalling occurred at ultimate load but with the inclusion of fibers spalling was eliminated. With increase in fiber content, they observed increase in shear cracking strength and ultimate shear strength [19]. The researcher concluded that with the addition of fibers we can minimize the amount of shear stirrups required.

C. Torsion behavior:

Many researchers are working on torsional behavior of reinforced concrete beams and they found that the effect of longitudinal and transverse reinforcements on torsional capacity and stiffness of beams and found out that the torsional behavior

is linear up to cracking and stiffness value up to cracking is independent of both longitudinal and transverse reinforcement[20]s, but the reinforcements will become effective only after crack initiation providing additional ductility and capacity to the beam. Thus the researchers started to investigate whether they can improve torsional capacity of beams with adding fibers. In case of specimens without fibers the ultimate torque and cracking torque values are same and the torque carried by the section decrease with increase in angle of twist. On the other hand, in case of specimens with fibers the ultimate torque is greater than cracking torque [21]. This change is more apparent in the specimens with 0.6% fiber volume when compared to 0.3% fiber volume. The specimens with 12 mm diameter bars as longitudinal reinforcement gives satisfactory results with 0.3% fiber volume when compared with 8 mm diameter bars as longitudinal reinforcement specimens with same fiber content. The aspect ratio of fibers has no effect on torsional capacity and ductility of beam [22].

D. Deformation behavior:

The researcher tried to find out the deformational behavior of fiber reinforced beams under pure bending. It is found that the under reinforced beams are already ductile in nature and with the addition of fibers it will be even more beneficial in improving the deformation behavior of the beam [23]. The experimental findings showed that there was a decrease in strains, deflections and curvature and increased stiffness altogether contributes to improvement in characteristics of beam. These improvements in characteristics result in less width cracks, lesser deflections and increased flexural rigidity [24]. It was found from the results that the half-depth inclusion of fiber in the tension side is practically as effective as full-depth inclusion of fibers in improvement of deformational characteristics from the beginning to failure, and the fibers will help in maintaining the structural integrity of the beams.

E. Fatigue behavior:

Bridges, runways, marine structures, and railway tracks usually subjected to cyclic loads. Cyclic loads decrease stiffness of structure leading to micro level damage causing fatigue failure. Thus, fatigue is most important criteria in designing those structures [25]. Fatigue of concrete is a advanced process of microcrack initiation and spread leading to macrocracks finally leading to failure. These cyclic loads will degrade the extreme compression fibers of concrete due to redistribution of stresses and as the stress progresses leading to higher tensile stresses to be resisted by reinforcing bars which will leads to fracture. This brittle failure due to stress redistribution suggests that fatigue performance can be improved by increasing steel and also another method is to add fibers to the concrete since these fibers imparts improved mechanical properties to the beam [26].

It was observed that incorporating fibers at 0.4% and 0.8% by volume resulted in stress range reductions of approximately 8% and 16%, respectively, compared to beams without fibers. This reduction in stress range contributed significantly to an increased fatigue life. The stress range of reinforcing steel plays a crucial role in the fatigue performance of beams [27]. Experimental results demonstrated that as the fiber volume increased, the stress range decreased considerably, with reductions of 8% and 16% corresponding to fiber volumes of 0.4% and 0.8%, respectively [28]. Experimental results revealed that fiber-reinforced concrete beams exhibited smaller crack widths compared to beams without fibers. For fiber volumes of 0.4% and 0.8%, the average reduction in crack width was 38% and 46%, respectively [29], relative to non-fiber-reinforced concrete beams. By reducing crack widths, fibers likely minimize the local strain in the reinforcement at the crack locations, which can significantly enhance the fatigue life of the beams [30].

IV. INFERENCE

This paper had reviewed on effect of fibers on reinforced concrete beams. The effect of fibers, different fiber type and different fiber content on mechanical properties of concrete has been summarized. The effective role of fibers on reinforced concrete beams by varying the fiber content, fiber type has been reviewed and summarized. The following inferences were drawn from the study:

1. The Concrete Compressive strength split tensile and flexural strength, toughness and energy absorption characteristics were improved upon addition of fibers.
2. The flexural capacity, ductility and load carrying capacity of beams increased with addition of fibers and at higher fiber contents the effect of length of fiber on properties of concrete will be insignificant.
3. With the addition of fiber reinforcement, we can reduce the amount of shear stirrups required and from the experiments they came up with the optimum combination of 1% of fiber volume and 50-75 % of conventional stirrup reinforcements will give optimum results.
4. The aspect ratio of fibers will have no effect on ductility of the fiber reinforced concrete beams.
5. The deformation characteristics of beam is considerably increased with the addition of fibers. These improvements in characteristics result in less width cracks, lesser deflections and increased flexural rigidity.
6. The fatigue life of the beam is greatly increased with the addition of fibers. Since the fibers will minimizes the crack widths and minimizes the stress rates and local strain taken by the reinforcing steel.

V. RESEARCH NEEDS

There is scope for research in understanding the effective response of fibers in structures under fatigue loading, more experimental research is needed. Also, in recent trends there is much scope for post tensioned beams, thus it becomes a huge scope in finding out the effect of fibers in post tensioned beams and more experimental works are needed.

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