Asian Journal of Research in Social Sciences and Humanities
ISSN: 2249-7315 Vol. 11, Issue 12, December 2021 SJIF 2021 = 8.037
A peer reviewed journal

A REVIEW OF LIGHTWEIGHT AGGREGATE CONCRETE FIBER REINFORCEMENT

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DOI: 10.5958/2249-7315.2021.00335.X

ABSTRACT

Despite its numerous benefits, lightweight aggregate concrete (LWAC) has not been extensively utilized in the construction industry due to its greater brittleness and poorer mechanical characteristics when compared to normal weight concrete (NWC) at the same compressive strength. Fibers in LWAC have been proven in studies to be an effective option for resolving such issues. This study examines the effects of fiber addition on the characteristics of several kinds of LWAC. Workability, compressive strength, stress–strain behaviour, tensile strength, modulus of elasticity, and compressive and flexural toughness are some of these characteristics. In general, adding fibers to LWAC, whether in single or hybrid forms, improves mechanical characteristics and increases toughness, ductility, and energy absorption while reducing workability, especially when steel fiber is included in the concrete mixture. The efficacy of fiber in LWAC is greater than NWC when it comes to splitting tensile and flexural strengths.'

KEYWORDS: *Ductility, Fiber, Lightweight Concrete, Mechanical Properties, Toughness.*

1. INTRODUCTION

Concrete is a commonly utilized building material all over the globe. Every year, massive amounts of different kinds of concrete are utilized. Many academics are studying the engineering characteristics of this material as a result of its widespread use[1]. Concrete's enhancing characteristics in both fresh and hardened stages, as well as its durability and environmental effect, are all fascinating study subjects. A fiber as an extra basic ingredient in the concrete mixture is one way to improve certain engineering characteristics of concrete. Asbestos, sisal, and cellulose are examples of natural fibers, whereas glass, steel, carbon, and polymer are examples of manmade fibers. Fibers were first employed to strengthen fragile materials in Egypt about 5000 years ago, when asbestos fiber was utilized to reinforce clay pots[2]. The contemporary development of fiber reinforced concrete in the concrete industry, on the other hand, may have started in the early 1960s. Increased flexural capacity, toughness, post-failure ductility, and crack management are the most advantageous features of fiber-reinforced structures.

Furthermore, fiber reinforcing in concrete has been shown to improve the compressive ductility, toughness, and energy absorption of concrete at an early age[3]. Metallic, polymeric, and natural fibers are the three types of fibers. Steel fiber is the most frequently utilized among the different kinds of fibers for most structural and non-structural applications. Polypropylene (PP), glass, and other fibers come next, although they aren't frequently utilized in structural concrete applications. Economic factors, production facilities, reinforcing effects, and resistance to environmental aggression are all factors that contribute to the increased use of steel fiber. Concrete is fragile, similar to glass, and has a poor tensile strength and shear capacity[4]. Concrete becomes more brittle as its strength increases, making it more prone to breaking. This cracking allows harmful chemicals easy access, resulting in early saturation, freeze–thaw damage, scaling, discoloration, and steel corrosion. Concrete's low breaking propensity during the early stages of hydration and throughout service life is advantageous for constructing a long-lasting construction.

The fracture width and crack spacing in fiber reinforced concrete have been found to decrease, particularly at early ages. Fiber reinforced concrete has a longer service life than concrete without fibers because the fibers prevent fractures from propagating within the concrete[5]. Fiber type and volume fraction have a significant impact on the characteristics of fiber reinforced concrete. Low (1%), moderate (1% to 2%), and high volume fraction (more than 2%) fiber-reinforced composites may be categorized based on their fiber volume fraction. Steel fiber added to concrete in the proportion of 1–1.5 percent by volume has been shown to improve tensile strength by up to 100 percent, flexural strength by up to 150–200 percent, and compressive strength by 10–25 percent. The fiber produces a uniform stress distribution in the concrete, allowing the high strength matrix to be fully used. Steel fibers also enhance the impact strength and toughness of concrete, transforming it from a brittle to a more ductile material. The fracture energy of steel fiber concrete is considerably greater than that of ordinary concrete[6].

The inclusion of steel fibers increases both the compressive strength and the strain corresponding to peak stress. Steel fiber concrete also has a greater maximum compressive strain than ordinary concrete. While it comes to tensile strength, it's been observed that LWAC improves considerably more than NWC when using the same kind and amount of steel fiber. This is owing to the fact that LWAC is more fragile than NWC. Despite the numerous benefits of adding steel fiber to concrete, it does have some drawbacks, including decreased workability of new concrete and the potential to raise the dead load of a composite due to its high specific gravity. Fiber reinforced concrete mixes also take longer to mix and place than ordinary concrete. Concrete buildings are heavy in comparison to the applied load they can support[7]. With the fast growth of extremely tall buildings, large-scale, and long-span concrete structures, structural lightweight concrete (LWAC) with various kinds of LWA has been extensively researched, produced, and utilized in recent years. The use of structural lightweight concrete in the construction industry has a number of benefits, including a high strength-to-weight ratio, reduced dead load for structural design and foundation, reduced risk of earthquake damage to a structure, good tensile strain capacity, superior heat and sound insulation characteristics, low coefficient of thermal expansion, and improved durability[8].

However, certain issues with its technical characteristics have kept it from being extensively utilized in load-bearing structural elements in the building sector. For the same mix percentage and compressive strength, lightweight concrete has a higher brittleness than normal weight concrete (NWC). Furthermore, LWAC has poorer mechanical characteristics than NWC in general. High strength lightweight aggregate concrete (HSLWAC) with a compressive strength of 50–100 MPa has recently been successfully made using a variety of lightweight aggregates that have much superior mechanical characteristics than standard strength LWAC. However, when concrete strength increases, the concrete becomes more brittle in compression and tension, particularly in the case of LWAC[9]. The use of fibers such as steel, polymer, glass, carbon, and composite fibers is one method to address LWAC's brittle texture and poor mechanical characteristics[10].

2. DISCUSSION

The majority of research on fiber reinforced LWACs has concentrated on the use of steel fibers as single or coupled with nonmetallic fibers in LWACs, according to the literature. This paper summarizes prior studies on the effects of fibers on the characteristics of LWAC in both its fresh and hardened states. The workability of concrete is selected in relation to vibration compaction on the job site. Because of the effect of gravity on the slump value in LWAC, the lighter mix produces a lower slump. It has been suggested that a drop of 50–75 mm may be adequate for excellent LWAC workability. The high slump value of LWAC allows the coarse aggregate and heavy mortar to float away from the surface, potentially causing finishing issues. As a result, ACI 213R-87 recommends a maximum drop of 100 mm for LWAC floors to provide a satisfactory surface. Fibers in concrete have a detrimental impact on the workability of freshly laid concrete. The effect of fiber on the fresh characteristics of regular weight self-compacting concrete (SCC) and lightweight self-compacting concrete (SCLC) further demonstrates that fiber inclusion in self-compacting concretes has a significant detrimental impact on the fresh qualities. The amount of workability loss is determined by the kind and content of the fibers utilized. It has been proposed that the quantity of paste rises with increasing cement content, thus increasing the fine aggregate content or utilizing pozzolanic admixtures, in order to provide fiber reinforced concrete with excellent self-compacting properties. In most fiber concrete mixes, a superplasticizer is added to improve workability and reduce the balling effect of fiber. The addition of 1.5 percent super plasticizer by cement weight improved the workability of pumice and expanded clay LWACs reinforced with steel fiber. In their research, the highest volume percentage of fiber was 2%, with a length of 30 mm and an aspect ratio of 60.

Experiments [30] have shown that even with low steel fiber concentration (1%), when the steel fiber percentage exceeds 0.4 percent, a greater dose of superplasticizer is required to maintain proper workability and prevent the concrete mixture from clogging on fibers. Furthermore, when using PP fiber in expanded slate LWAC, the dose of superplasticizer rises as the quantity of fiber in the combination grows. Steel fiber mixes may be improved by increasing the fine aggregate content or adding fluidifying additives in order to provide greater workability. In a research, it was discovered that using fly ash as a cement substitute in NWC compensates for the reduced workability of fiber reinforced concrete. Although fibers like steel and plastic polypropylene reduced the workability of the concrete by 2–8%, the workability remained unchanged when a specific proportion of fly ash (FA) was added to the mix. Like a result, much as with NWC, the use of FA in fiber reinforced LWAC compensates for the loss of workability. In general, modest fiber doses are suggested for fiber reinforced concrete to provide excellent workability. The vibration of such concrete is acceptable for various fiber mixes with a low or even zero slump value.

As a result, the conventional slump test is not always appropriate for determining the workability of fiber reinforced concrete, and other workability test techniques should be employed instead. When fiber reinforced concrete is exposed to vibration compaction, the V–B test is the best of the three standard workability tests, namely slump, V–B, and compacting factor. A V–B duration of 3–10 s is considered sufficient workability for vibration implantation. The inverted slump cone test is another technique for determining the workability of fiber reinforced concrete under vibration. The fiber pumice LWAC workability was assessed using an inverted slump cone. 475 kg/m3, 0.3 percent, 0.7 percent, and 0.56 percent, respectively, for cement content, water to cement ratio, superplasticizer percentage, and weight ratio of coarse lightweight aggregate to natural river sand. Without any fibers, the slump value of this concrete was in the range of 15–20 mm. They utilized end-hooked steel fiber with a length of 35 mm and a diameter of 0.55 mm. Steel fibers with volumes of 0%, 0.5, and 1%, as well as PP fibers with volumes of 0%, 0.2, and 0.4 percent, were utilized separately and in combination. The flow time for all fiber-reinforced mixes was 45–120 seconds in the inverted slump test. The addition of PP fiber has a lower impact on workability. Each steel fiber-containing combination has a substantially poor workability. The use of an air-entraining admixture in addition to a superplasticizer is suggested for improving the workability of steel fiber reinforced LWAC.

Self-compacting concrete has better performance in the fresh condition, which is one of its major features. Despite the fact that adding fibers to concrete lowers its workability, fiber reinforced self-compacting concrete has been found to be possible. Recently, the effective manufacturing of self-compacting LWAC using various kinds of lightweight aggregates was reported in the instance of LWAC. However, the use of fibers in the creation of a cohesive fiber reinforced self-compacting LWAC requires further research. Steel fiber is the most frequent kind of fiber utilized to improve the mechanical characteristics of LWAC. Steel fiber is added to LWAC to enhance its density. This is due to the high specific gravity of this fiber. The results of the tests revealed that a greater steel fiber dose generally resulted in heavier lightweight concrete. Because most general-purpose concrete has a compressive strength of 20 to 40 MPa, obtaining a compressive strength in this range for LWAC is simple and practical in the construction sector. As a result, raising the density is one of the major drawbacks of utilizing steel fiber in LWAC.

This issue should be taken into account by designers, particularly when using a moderate or large volume (>1%) of steel fiber in LWAC. As a result, it is suggested that low fiber content (1 percent by volume or less) steel fiber be used in LWAC, with or without other kinds of fibers that do not substantially influence density (e.g., polypropylene, etc.). The use of mineral admixtures in LWAC, such as silica fume and fly ash, has been suggested as a way to further decrease density. As a result, it is suggested that such additives be included in the LWAC mixture to compensate for the detrimental impact on the density of LWAC caused by adding steel fiber. The studies revealed that a high-strength concrete using 15% silica fume as an addition is 2% lighter than the reference concrete (concrete without silica fume). The density of the concrete was still lighter (approximately 1%) than the reference concrete after adding 1% volume fraction of steel fiber (with an aspect ratio of 80 and density of 7.85 g/cm3), whereas the steel fiber concrete without silica fume had a greater density of about 1%. In addition, using an air-entraining admixture in LWAC mixes may help reduce density while also increasing workability.

Non-metallic fibers are considerably lighter than steel fiber. Carbon and PP fiber, for example, have densities that are about 80% and 88 percent lower than steel fiber, respectively. As a result, instead of utilizing a large volume percentage of steel fiber in structural lightweight aggregate concrete, a low volume fraction of steel fiber combined with a non-metallic fiber (hybrid fiber) is recommended. The test results revealed that a LWAC with 0.5 percent volume fraction of steel fiber (by length (L) of 35 mm and diameter (D) of 0.55 mm) and 0.2 percent of PP fiber (L = 12 mm and D = 0.016 mm) is about 3.2 percent lighter than a LWAC with 0.5 percent steel fiber, while the engineering properties of both fibers reinforced concretes are comparable. The effects of steel and PP fibers on the characteristics of LWAC have been studied among the different kinds of fibers. The steel fiber improves the compressive strength of LWAC, but the increase is not substantial, and the PP fiber has no impact on the compressive strength of LWAC, according to most reports. The compressive strength of steel fiber reinforced concrete is affected by the kind of test specimen used.

He demonstrated that a LWAC supplemented with 0.6 percent volume fraction of a steel produced with sintered fly ash as coarse aggregate performed well. showed three different increases in compressive strength of approximately 3.6 percent for 150-mm cube, 4.7 percent for 100-mm cube, and 7.0 percent for 150 mm 300 mm cylinder mold, indicating that cylinder specimens have higher compressive strength than cubic specimens for the same fiber reinforced concrete. In contrast to this report, for normal weight, normal strength concrete containing fly ash, a significant increase in the compressive strength of the steel fiber reinforced concrete was observed (up to 95%) for the cube specimens, while the same concrete showed a slight increase (up to 13%) for the cylinder specimens.

The impact of steel fiber on LWAC compressive strength is highly dependent on aggregate type. They found that incorporating steel fibers into the matrix of expanded clay LWAC resulted in a 30 percent improvement in compressive strength, while in the case of pumice stone LWAC, the difference in strength was insignificant. They found that when expanded clay (round and regular in shape) is compared to pumice stone LWA (irregular in shape), the surface of the aggregate in contact with the steel fibers reduces. As a result, expanded clay LWAC showed a greater strength. It should be emphasized that when fibers are free of aggregate interference, their efficacy in composites increases. Concrete's flexural strength is proportional to its size.

As the specimen size becomes bigger, it lowers. For materials with a greater brittleness, the size impact is more pronounced. As a result of the fibers increasing the ductility of LWAC, the size effect is anticipated to be reduced for fiber reinforced LWAC. When the flexural strength of HSLWAC was 5.9 MPa for a specimen size of 50 mm (height) 100 mm (width) 200 mm (span), this concrete had 44 percent and 54 percent lower flexural strength than larger specimen sizes of 100 mm 100 mm 400 mm 500 mm and 200 mm 100 mm 800 mm 840 mm, respectively. Steel fiber reinforced concrete, on the other hand, saw a decrease of 18% and 30%, respectively. Fiber reinforced concrete, on the other hand, is considerably less susceptible to the size effect. Carbon fiber (with an average length of 5 mm) in volume fractions of 0.5 percent, 1 percent, and 2 percent improved the flexural strength of a complete pumice LWAC by approximately 13 percent, 32 percent, and 7 percent, respectively, according to the study's findings. It can be observed that adding 2% carbon fiber results in a much smaller improvement in flexural strength than 1%. This may be owing to the lack of adequate fiber dispersion in concrete with large amounts of carbon fiber.

3. CONCLUSION

The addition of fibers to structural lightweight aggregate concrete, especially steel fibers, reduces its workability. The use of a greater dose of superplasticizer and fine aggregate, as well as the use of fly ash in the concrete mixture, is suggested to compensate for the loss of workability. The density of LWAC is increased by steel fiber. Mineral admixtures, air-entraining admixtures, and a low steel fiber content may be used to compensate for the density increase in LWAC. In general, adding steel fiber to LWAC improves its compressive strength. However, if steel fiber accounts for more than 2% of the volume fraction, it may be reduced. Fiber reinforced LWAC, on the other hand, has considerably greater splitting tensile strength than plain LWAC, even at low fiber volume (especially steel fiber). In fiber reinforced LWAC, the use of hooked-end steel fiber as well as cementitious materials results in a greater increase in tensile strength. In LWAC with a larger volume of LWA, the beneficial impact of fiber addition on the splitting tensile strength is more pronounced. The addition of fiber to LWAC also improves its flexural strength. LWAC has a greater increase in flexural strength owing to the addition of fiber than NWC. Steel fiber seems to be considerably more effective than other kinds of fibers in terms of flexural strength. The use of a mix of steel and non-metallic fibers, on the other hand, leads in greater flexural strength than using individual kinds of fibers.

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