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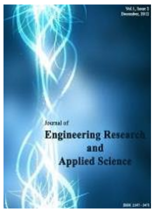

Investigation of effect of fiber type on compressive strength of concrete

G. Calis

Karamanoglu Mehmetbey University, Engineering Faculty, Civil Engineering, Karaman, Turkey.

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Abstract

Fiber reinforced concrete is widely preferred by both the scholars and professionals all over the world. Fiber incorporation aims to develop both mechanical and durability properties of concrete. As some of the fibers such as steel has a rigid structure in nature while other types namely; glass, polypropylene are quire flexible. Inclusion of fiber in a concrete mixture has a direct effect over the concrete matrix. The properties of fiber-matrix combination in fresh state of concrete are dependent upon the amount , type and form of the fiber, matrix constituent and the method of mixing the fiber. In this study impact of various fibers on concrete compressive strength was investigated. 0.5%,1.0%, 1.5%, 2.0% fiber by weight was utilized in the concrete mixtures. The results are promising and successful in terms of compressive strength and compressive strength after frezze and thaw cycles. Durability of concrete is vital for the utilization of concrete as concrete is exposed to the severe environments in various places. Hence, any concrete is required to have certain level of durability. Fiber incorporation is widely preferred practice for purpose of improving those properties.Steel,glass and PVA fiber inclusion contribute the freeze-thaw resistance of concrete mixtures. The fiber type impact is vital and obvious though.

Keywords: glass fiber, PVA Fiber, steel fiber, compressive strength, fiber inforced concrete.

1. Introduction

Even though concrete is one of the most used material and plays significant role in construction industry, it is also known as its brittleness in nature and poor tension in comparison to compressive strength [1].Fiber reinforced cementitious material is the a type of concrete in which fibers are utilized and mixed with other ingredients (aggregate, water, cement) and admixtures.The concept of fiber reinforced concrete originated in 1900 when asbestos was used to reinforce brittle cement. Scholars have focused on fiber reinforced concrete and optimization methods [2–9] for the last decades. The most common fiber reinforcements for structural applications include basalt fiber, steel fibers, glass fibers, synthetic fibers such polyvinyl alcohol (PVA), polypropylene (PP) carbon fibers and natural fibers[10].

However, natural vegetable fibers are not preferred for this purpose in concrete as they cannot develop properties to the limit that shows high strength and / or high resistance to high temperatures [11]. Fiber types can be seen in Fig.1 . Some of fibers such as steel has a rigid structure in nature while other types namely glass, polypropylene are quite flexible. Inclusion of fiber in a concrete mixture has a direct effect over the concrete matrix. The properties of fiber-matrix combination in the fresh state of concrete are depend upon the amount , type and form of the fiber, matrix constituent and the method of mixing the fiber [12]. The workability of concrete is also affected by the fiber existence and proportion of fiber. With the increase of fiber content in concrete mixture slump test results go down. Therefore, it can be deduced that fiber content decreases the workability of concrete mixtures [13,14]. Consequently workability of concrete mixture governs the maximum fiber content . The workability of reinforced concrete is significantly dependent on the type of fiber too.

In the hard state of concrete, with the incorporation of fiber 3 main achievements are aimed. Firstly, it is aimed to improve strength properties (tensile, bending) of concrete. The impact can be either insignificant (less than 10%) or substantial. Secondly, fiber incorporation can improve strain capacity of ductility of the cement matrix. By adding fiber, greater energy absorption capacatiy can be acvhieved on concrete. The increase in ductility and

Corresponding author; gokhancalis@kmu.edu.tr

toughness are generally significant even if the improvement in strength is insignificant [15]. The most recognizable difference of fiber impact in terms of reinforcement of concrete is elastic modulus and creep behavior. Fiber with higher elastic modulus provide better reinforcement to the concrete. However, cost-effectiveness of such incorporation should also be considered.

Fiber reinforced concrete can be seen as a composite material which has its own limitations due to its composition. With the increase of fiber amount in concrete, the workability of high strength concrete decreases. Consequently, in order to deal with such short coming and increase fiber amount in the concrete scholars have developed a new type of fiber reinforced concrete called SIFCON. In SIFCON , the fiber content can be increased up to 12-13% [16]. Spatial networks are created by the fiber all around the aggregates where, fibers perform bonding, and the mortar bears the comparison while providing anchorage to these fibers. Fiber addition to concrete mixture is useful to develop properties of concrete namely compressive strength(CS) and tensile strength(TS) of concrete. The tension stressing capacity is nevertheless multiplied by the inclusion of fiber in the concrete mixture than by its crushing strain. Fibers exist in the concrete do not prevent the microcrack formation in the interfacial transition zone (ITZ). The fibers are not active until the stress levels cause the microcracks to spread into the mortar matrix in the ITZ. Therefore, the first cracking strength value of the concrete with or without randomly dissipated steel fibers (for both the direct tension and flexural strength) is almost identical. Fibers captivate the points where the microcracks tend to extend towards in the ITZ.Consequently, the enlargement of the crack and any further progress of crack in the matrix of concrete is limited. The internal crack occurrence in fiber reinforced concrete is similar to the conventional concrete without fiber. However, the progress of crack from aggregate to the adjoining one through cement mortar matrix is substantially postponed. Fibers are capable of transferring the internal tensile stress induced in the concrete by virtue of the Poisson’s effect and otherwise also, across the cracks developed in the concrete due to o the high tensile strength of fiber and anchorage into the matrix. This results a great enhancement of the ultimate crushing strain of the concrete from the usual value of 0.35% to the value of 0.6%, additionally the ultimate compressive strength of concrete goes upward.

Synthetic fibers on the other hand, do not enable concrete mixtures to create web-structutral system in the hardened concrete due to their elasticity. Therefore, it can be deduced that these fibers are less efficient than steel fibers in terms of improving post-crackin behaviour.This can be considered as the main reason of fiber steel utilization by the scholars all over the world [17]. However recent studies [18–23] indicate that hybrid fiber usage some other fibers along with steel fibers provide better results. It is known that uniform dispersion of fiber in the composite is vitally important for all type of fibers otherwise, the desired results cannot be obtained. Considering the length of fiber is short, not continuous, and are not connected to each/rarely touching eachother in the composite, there is no conductive path for stray. Consequently in case of steel fiber utilized concrete, the corrosion potential decreases. This would result as an improvement in the durability of concrete. Any concrete reinforced with steel fiber is obliged to meet requiremtns determined by certain codes. [17].

While it is widely known that low amounts of fiber additives do not affect the elasticity modulus of concrete, some researchers believe that especially steel fibers affect the elasticity modulus of concrete [24].

Besides effecting mechanical and durability properties of concrete, different types of fiber-reinforcement also affect thickness of plain concrete pavement concrete. 1% fiber inclusion steel, polypropylene and glass have positive impacts on mechanical properties. However, steel fiber has superior effect in increasing compressive strength of the concrete and reducing the thickness of pavement. Similar to compressive strength results, steel fiber results in obtaining higher flexural strength. With the 1% steel fiber (SF) inclusion, the thickness of the pavement reduces 40 mm, from 155 to 105 mm which is asignificant reduce approximately 32%. However, it is determined that glass and polypropylene fiber reinforced concrete are more economical to produce plain concrete pavement with fiber inclusion for the same load carrying capacity [25].

Steel fiber additive increases the compressive strength by 11% in high strength concretes and polyproline increases it by 3%. Based on that study, it is clear that polypropylene increased less than steel fiber. On the other hand, the addition of steel fibers provides 14% increase in tensile strength in high strength concrete, while this increase was determined as 6% with the addition of propylene. As high

strength concrete(HSC) is more brittle than normal strength concrete(NSC), the effect of fiber addition was less in high strength concrete (13).
Even though fiber inclusion can contribute the mechanical and durability properties of concrete, sometimes only one fiber is not sufficient to improve the desired properties. Therefore, hybrid fiber incorporation is also a preferred way [26–28]. In the recent study the carbonation depth of steel fiber reinforced concrete mixtures were investigated. It was observed that fiber incorporation significantly decreases carbonation depth in the concrete. However, when steel fibers are hybridized with barley straws the carbonation depth in concrete decreases even further. Fiber inclusion reduces the interconnection of pores in the concrete. Consequently, carbonation is limited [29].

Steel fibers not only increase the burst resistance but also improve the mechanical properties of concrete at room temperature and high temperature. The anti-splintering dose of steel fibers increases with increasing RPB compressive strength, and the relationship can be expressed as an exponential function [30].

Many researchers have focused on impact of fibers on LWC mechanical behaviors. Recent studies report that compressive strength can be increased by adding SF. Furthermore, flexural strength and splitting tensile increase significantly [34,35] (1). LWC is known with its low shear capacity in comparison to normal weight concrete. However, this shortcoming property can be developed by adding fibers to the concrete specimen. The impact of SF on LWC shear behavior has been reviewed and results show that , SF contributes to development of shear behavior. [37] . 0.5% SF addition increased shear resistance from 50,7 kN to 76,6 kN which is 51% higher than no fiber added concrete. Similarly, when SF addition is 1.0%, the shear resistance enhancement determined to be 68%.

Glass fiber is also preferred fiber to reinforce concrete. It is widely used in non-structural construction element namely; piping, channels and facades. Glass fiber inclusion reduces the weight of the concrete and provides advantage against corrosion in comparison to steel fiber. Glass fiber incorporation can affect the workability of concrete both ways positive and negative. In the recent study 0.03%, 0.06%, 0.1% of glass fiber added concrete mixtures have been investigated. Even though the first mixture shows less slump value than the mixture-0, the other two mixtures show greater slump values [31]. However, compaction factors always increased. In the other study %0.5, %0.7, %0.9, %1.2, %1.5, glass fiber incorporated concrete mixtures have been tested. It was observed that all samples have less workability than sample-0 [32].

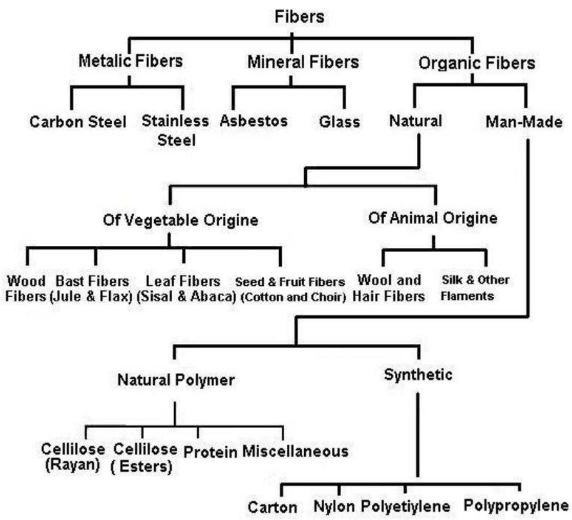

Figure 1: Fiber Types [33].

There is limited number of researches on utilization of glass fiber in LWC. However, recent study [38] reports that LWC, that contains 0.06% glass fiber , shows 7-11% higher compressive strength than 0% glass fiber added LWC. The compressive strength variance increases by higher level of GF addition. Similarly it was proved that [39] with utilization of GF 0.00 to 0.06% , the compressive strength goes up remarkably from 57.85 MPa to 66.01 MPa. Also, it is mentioned that when amount of GF is higher than 0.06%, the increase of compressive strength is insignificant. Splitting tensile on the other hand, has an increase trend with the increase of GF from 0.00% to 1.2%. The increase on splitting tensile is higher than compressive strength.

Polyvinyl alcohol (PVA) is a biodegradable polymer material widely used in biomedicine, packing and reinforced material [40] [41] [42] [43] . PVA fiber come to the front and widely preferred by the scholars due to the high modulus of elasticity which is beneficial for reducing or restricting crack width [44]. PVA fibers are capable of forming strong chemical bond with cement due to containment of hydroxyly group that improves isotropic behavior of material, this strengthens fiber and the cement matrix [45]. On the other hand, such strong bond tends to cause pre-mature fiber rupture therefore, it is undesirable behavior. This undesired situation can be prevented by coating PVA fiber with oil which decreases the strong bond between matrix and the PVA fiber [46]. Unoiled PVA fiber added concrete mixtures show poor compressive and tensile strength performance in comparison to oiled PVA fiber added concrete mixtures. Oiled and unoiled fibers have better performance than mortar though [47]. 2% of PVA incorporation by volume is commonly preferred and leads increase in tensile strength of concrete mixture [46]. Fly ash is preferred to be utilized with PVA fiber in order to develop ductility. However high fly ash incorporation has negative impact on compressive strength and tensile strength [48]. Durability properties of concrete mixtures can be improved with 2% inclusion of PVA fiber by volume [49].

It is a common practice to hybridize steel fibers, PVA, basalt and polyethylene (PE). In the recent study hybridization 1.0 % steel fiber as the main fiber and 0.5% the second fiber (PVA, BF and PE) was investigated. The mixture which has 1.0% steel fiber and 0.5% PVE fiber of PVA fibers added mixture show higher compressive strength, lower density , lower first and ultimate tensile strength [50].

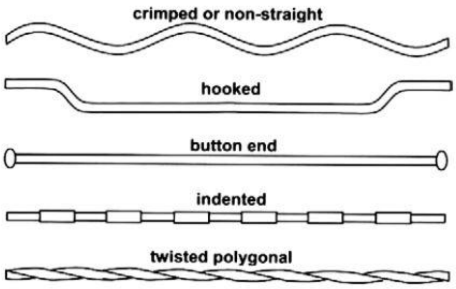

Figure 2. Fiber shapes [10].

In this study it was aimed to determine the impact of various types of fibers on some mechanical properties of concrete. Within the scope of this study compressive strength, and compressive strength after freeze and thaw effect tests were performed on glass, PVA and steel fiber reinforced concrete mixtures. This study is essential to point out the effect of fiber type on the compressive strength of concrete mixtures.

2. Materials and method

In this study fine aggregate (FA) and coarse aggregate (CA) and cement were used in concrete mixtures. No plasticizer was used in the mixtures. 0.5%, 1.0%, 1.5% and 2.0% fiber by weight was used in the mixtures. Concrete mixtures and ingredient by weight can be seen in table.1.

Table 1. Concrete Mixture.

Mixture	Water(kg)	Cement(kg)	FA (kg)	CA (kg)
Sample-0	190	410	620	1130
Sample-1	190	410	610	1120
Sample-2	190	410	610	1110
Sample-3	190	410	600	1120
Sample-4	190	410	590	1120

3. Test results & discussion

Compressive test results can be seen in fig 3. According to the test results, it can be concluded that the highest development in compressive strength is observed on the 2% fiber added concretes. PVA fiber leads the most increase in the concrete mixtures. This also supports the previous studies [6,51,52].

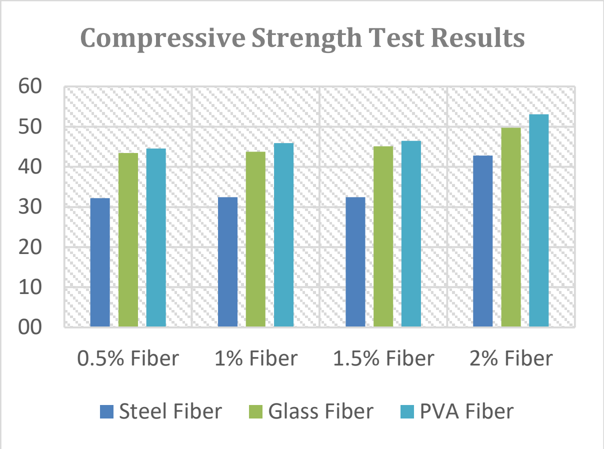

Figure 3: Compressive Strength Test Results.

The increase of glass fiber addition is limited, which is less than expected [32,53]. This can be attributed to the balling effect of glass fiber used in the concrete mixture. At this point it is also important to choose suitable aggregate and cement type as it impacts the water requirement.

Durability of concrete is vital for the utilization of concrete as concrete is exposed to the severe environments in various places. Hence, any concrete is required to have certain level of durability. Fiber incorporation is widely preferred for these reasons [18,54]. It was observed that all the fiber inclusion contributes the freeze-thaw resistance of concrete mixtures. Test results show similar trend with compressive strength which is also expected. These can be summarized as shown below:

- Steel fiber incorporation reduces the compressive strength loss from 16% to 5% by 2% fiber inclusion. It is a linear trend from the beginning, however from 1.5% fiber inclusion to 2.0% fiber inclusion the graph drastically changes.
- PVA fiber inclusion on the other hand reduces compressive strength loss from 16% to 5.44% up to 1.5% fiber addition. Beyond this level, the compressive strength loss determined to be 8%.

Glass incorporation reduces the loss from 16% to 8.48%. Unlike PVA fiber added concrete the reduce trend is linear similar to steel fiber incorporated samples.

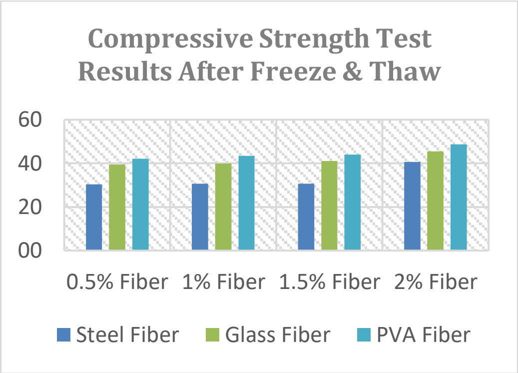

Figure 4. Compressive strength test results after f&t.

4. Conclusion

Fiber utilization is widely common practice all over the world. It is beneficiary for increasing the mechanical and durability properties of concrete and also some of these fibers are produced from waste materials such as plastic, rubber and glass. Hence, fiber incorporation is advantageous in terms of reducing waste and contributes to sustainability as well. Therefore, fiber incorporation can be suggested to improve concrete properties to the professionals. It is vital to determine what kind of environmental effects will exist in the concrete utilization. Furthermore, it should be noted that there is a upper limit for fiber to increase concrete properties. Beyond this limit, the fiber incorporation will not be able to develop the properties as much as desired.

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