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Enhancing Cement Mortar with Glass Fiber Additives: Effects and Benefits

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Abstract **–** This study aims to investigate the effect of adding glass fiber to cement mortar, a brittle material with low flexural strength, to improve its ductile behavior. Glass fiber has high tensile strength and can prevent cracks in cement mortar. The study examines the workability of cement mortar with different ratios of glass fiber using CEM I 42.5 R cement and CEN Standard Sand, while maintaining a fixed water/cement ratio and constant sand amount. The findings indicate that the workability decreases as the amount of glass fiber increases, especially in samples containing up to 4% of the cement amount.

Keywords – Cement Mortar, Glass Fiber, Workability, Compression And Flexural Strength

1. INTRODUCTION

Adding fibers, specifically glass fiber, to concrete can effectively prevent the expansion and development of cracks in the matrix, resulting in significantly improved flexural strength and durability. This makes it an important method for improving the performance and service life of pavements.

Fenu et al., 2016 [1], examined the dynamic behavior of cement mortars reinforced with both glass and basalt fibers. Ali Ates [2] observed that the performance of concrete reinforced with glass fiber, carbon fiber, and polyethylene fiber was good through three-point bending tests. Fathi et al. 2017 [3] suggested adding glass fiber to concrete to enhance its behavior at various percentages. Glass fiber, as a new artificial inorganic material, has wide sources of raw materials, is easily mass produced, and has low weight, as well as providing heat and sound insulation [4], [5]. Therefore, glass fiber has great potential as a concrete admixture to replace other fibers.

The addition of glass fiber to cement-based mortars can have a significant impact on their mechanical properties, but the exact nature of this effect can depend on several factors, including the ratio of fibers to the cement matrix, the length and strength of the fibers, and the water/cement ratio of the mixture.

Tassew and Lubell reported, the addition of chopped glass fibers to ceramic concrete produced using a phosphate cement binder had little effect on compressive strength and modulus of elasticity, but significantly increased flexural strength and direct shear strength. This was observed in both types of ceramic concrete matrices, one containing sand and the other lightweight expanded clay aggregates, and for fiber volume fractions ranging from 0% to 2%. The study also found that the toughness of the ceramic concrete under compression, flexure, and shear increased with increasing fiber content, while workability decreased. In conclusion, the findings indicate that it is feasible to manufacture glass fiber reinforced ceramic concretes with adequate workability and mechanical characteristics to be utilized in construction components [6].

When added to concrete or cement-based materials in sufficient amounts, fibers such as glass fibers can help to distribute stresses that occur within the material more effectively. Specifically, when cracks develop within the material, the fibers can transmit the stresses in the crack to the surrounding areas of the material where no cracks have occurred, helping to prevent the cracks from propagating further. Glass fibers, in particular, are known for their high degree of hardness and resistance to abrasion, making them suitable for use in concrete applications. They are also relatively flexible, lightweight, and cost-effective, which further adds to their appeal as a reinforcement material. The study aims to investigate the impact of different ratios of glass fiber on workability, rather than the contribution to tensile and compressive strength.

The article, which includes similar studies to be conducted in the continuation of this study, also explores the use of alkali-resistant glass fiber in road pavement concrete to increase its bending strength and wear resistance. It offers accelerated corrosion experiments to determine the corrosion mechanism and property of alkali-resistant glass fiber in cement mortar. The study concluded that alkali-resistant glass fiber reinforced concrete with an optimal mixture amount of 1.0 kg / m3 and the closest packaging method shows great potential for road pavement applications. [7].

2. Materials and Method

2.1 Material

The experimental studies used CEN standard sand as the aggregate and CEM I 42.5/R type Portland cement as the hydraulic binder, which meets the TS EN 197-1 standard [8]. The cement had a specific gravity of 3.1 g/cm^3, a minimum strength of 42.5 MPa, and a fineness value of 3600 cm^2/g. Table 2 provides information on the chemical and physical properties of the cement. The only additive used in the study was fiber.

6 mm and 12 mm glass fibers were used as fiber additives. Properties of glass fiber are given in Table 3.

Table 1 CEN Standard Sand Properties

Sieve Opening (mm)	**Cumulative Remainder (%)**
0,08	99±1
0,16	87±5
0,5	67±5
1	33±5
1,6	7±5
2	0

Table 2 Chemical and Physical Properties [9], [10]

Physical Properties	
Specific Gravity(mg/m^3)	3.11
Fineness Value(cm^2/g)	3600-3900
Initial Set(minute)	150-180
Volume Change(mm)	0.4
3 Day Compressive Strength(MPa)	20-29
7 Day Compressive Strength(MPa)	29-40
28 Day Compressive Strength(MPa)	40-62
Chemical Properties	
SO_3	< %4
MgO	<%1-2
CI	< %0,01
Insoluble Residue	< %5
Loss of Ignition	< %5

Table 3 Properties of Glass Fiber [11]

Fiber	Glass
Fiber Length(mm)	6-12
Fiber Diameter(μm)	13-15
Tensile Strength(MPa)	3400
Density(g/cc)	2.4-2.7
Modulus of Elasticity(GPa)	77
Speciific Gravity(g/cm^3)	2.6

2.2. Method

The experimental setup for the study involved preparing mortar samples with specific dimensions and compositions. The samples were made using 450 grams of cement, 225 grams of water, 1350 grams of sand, and glass fibers of lengths 6mm and 12mm. Four different ratios of fiber were added to the mortar, ranging from 0.5% to 4% of the cement mass, to create fibrous samples. The mixing ratios of the prepared samples are given in Table 4. The samples were then poured into molds and removed one day later. After removal from the molds, the samples were cured in lime-saturated water at a temperature of 20±2^{o}C for 7 days. Finally, compression, bending, spread and water absorption tests were performed on the samples to determine their mechanical properties. One of the batches of mortar included a witness sample that did not contain any fibers. Figure 1 shows the samples after being removed from the molds.

Table 4 Mixing Ratio

Sample No.	Sand (g)	Water (g)	Cement (g)	Glass Fiber (g)
Ref	1350	225	450	0
GF6-0.5	1350	225	450	2,25
GF6-1	1350	225	450	4,5
GF6-2	1350	225	450	9,0
GF6-4	1350	225	450	18,0
GF12-0.5	1350	225	450	2,25
GF12-1	1350	225	450	4,5
GF12-2	1350	225	450	9,0
GF12-4	1350	225	450	18,0

Ref: Reference Sample, GF: Glass Fiber,
6, 12: Fiber Length (mm), 0.5,1,2, 4: Fiber Ratio

Figure 1 Samples After Being Removed From The Molds

3. EXPERIMENT RESULTS

3.1 Spread Test

As the amount of glass fiber added to the mortar increased, the machinability of the mortar decreased. As a result of the spreading test conducted according to TS EN 1015-3[12] standard, it was observed that the spreading amount of mortars decreased as the fiber content increased. While there was not much difference between the results of the test sample containing 0.5% glass fiber and the sample dispersion test, a significant Deceleration in dispersion values was observed in samples containing 2% and 4% glass fiber. The spread test results of the cement samples are given in Table 5, and the test photos are given in Figure 2-3-4-5-6, respectively. The main reason for the decrease in workability is the increase in flocculation in the mortar and the decrease in the consistency of the mortar with the increased fiber content. As the workability decreased, it became more difficult to place the mortar in the mold, and cavities formed in the sample placed in the mold. This reduces its resistance to external influences, causing the mortar to become permeable and the strength of the mortar to decrease.

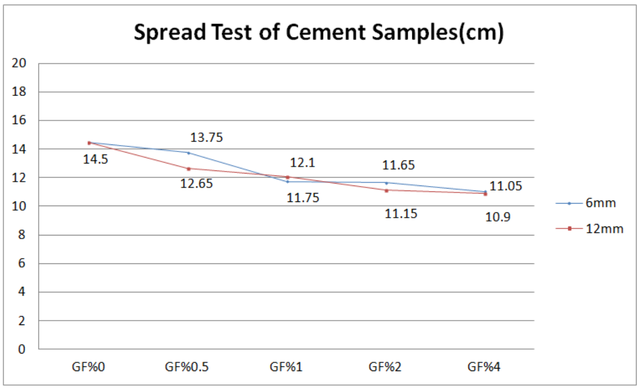

Table 5 Spread Test Results of Cement Samples

Figure 2 Test Sample Spread Test

Figure 3 % 0,5 Glass Fiber Spread Test

Figure 4 % 1 Glass Fiber Spread Test

Figure 5 % 2 Glass Fiber Spread Test

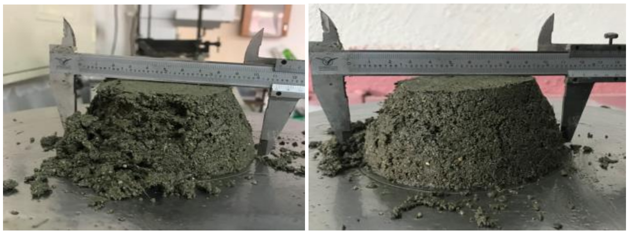

Figure 6 %4 Glass Fiber Spread Test

3.2 Compressive Strength Test

The samples that were cured for 7 days were tested using a press machine manufactured according to TS EN 196-1[13] in Figure 7. The changes in compressive strength of the samples according to fiber size and content, based on the results of the compressive strength tests performed on the samples, are given in Table 6. As can be seen in Table 6, the compressive strength values of GF0.5, GF1, and GF2 samples with 6 mm and 12 mm fiber sizes have increased compared to the reference sample. The maximum compressive strength value was obtained in samples with 1% glass fiber content in both 6 mm and 12 mm sizes. The compressive strength of GF6-1 sample with 1% glass fiber content increased by 12.64% compared to the reference sample, while the compressive strength of GF12-1 sample increased by 10% compared to the reference sample. Similarly, the compressive strength values of GF6-0.5 and GF6-2 samples increased by 8.98% and 9.95%, respectively, compared to the reference sample, while the compressive strength value of GF6-4 sample with 4% glass fiber content decreased by 0.1%. Likewise, the compressive strength values of GF12-0.5 sample increased by 3.66%, while the compressive strength values of GF12-2 and GF12-4 samples decreased by 0.6% and 10.63%, respectively, compared to the reference sample. The decrease in compressive strength is due to the decrease in workability of the mortar and the formation of agglomerates with increasing fiber content. The experimental results showed that increasing the glass fiber content significantly reduces the compressive strength of the concrete. Similarly, Toklu [14] stated in his study that the maximum compressive strength was achieved in samples with 0.3% glass fiber content in 6 mm and 12 mm fiber added mortars, and that further increases in fiber content beyond 0.3% began to decrease the strength.

Figure 7 Press Machine

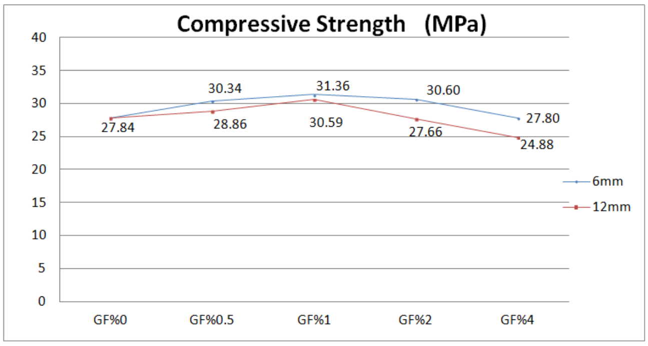

Table 6 Compressive Strength Test Results

3.3 Flexural Tensile Strength Test

The flexural tensile test was performed on specimens whose 7-day curing period was completed, as shown in Figure 8. The change in the strength obtained according to the amount and size of fibers in relation to the flexural tensile strength test results of the specimens is given in Table 7. As seen in the graph, the flexural tensile strength values of GF6-0.5, GF6-2, GF6-4 with 6 mm fiber containing 0.5%, 2%, and 4%, respectively, GF12-0.5, and GF12-1 with 12 mm fiber increased compared to the reference specimen. The maximum increase was in GF6-1 with 6 mm fiber, with a 14.78% increase in flexural tensile strength compared to the reference specimen, and in GF12-1 with 12 mm fiber, with a 6.79% increase compared to the reference specimen. GF6-0.5, GF6-2, GF6-4, and GF12-0.5 specimens also showed an increase of 12.64%, 12.58%, 13.31%, and 3.32%, respectively, compared to the reference specimen. The flexural tensile strengths of GF12-2 and GF12-4 specimens decreased by 3.59% and 9.32%, respectively, compared to the reference specimen. As a result of the experiment, an increase in fiber ratio up to 1% increased the flexural tensile strength in specimens containing 6 and 12 mm fibers, while an increase beyond 1% started to decrease the strength. The increase in fiber amount provided higher strength compared to the reference specimen in specimens containing 6 mm fibers, while in specimens containing 12 mm fibers, it provided less strength compared to the reference specimen after a 1% ratio. The high tensile strength of glass fibers increased the tensile strength of cement mortars. Similarly, Yıldız [15] and Gülan [16] stated in their study that glass fiber additives had a positive effect on flexural tensile strength.

Figure 8 Flexural Tensile Test Machine

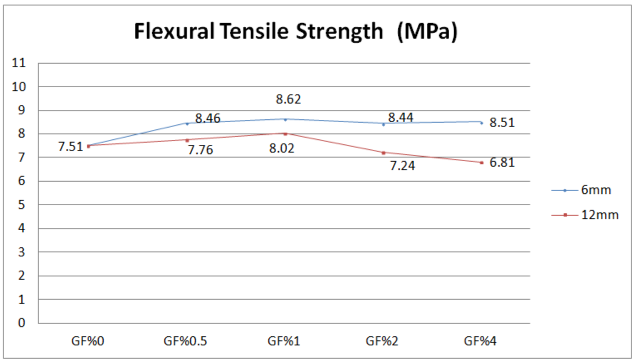

Table 7 Flexural Tensile Strength Test Results

CONCLUSION

The results of the study "Enhancing Cement Mortar with Glass Fiber Additives: Effects and Benefits" are summarized below:

- The workability and spreadability of the mortar mixture decreased with an increase in the amount of glass fiber added. Samples with 18 grams of glass fiber, such as GF6-4 and GF12-4, had very low workability and long mold placement times.

- As the amount of glass fiber increased, the workability of the samples decreased, resulting in voids in the mold and agglomerations in the mortar.

- The addition of glass fiber had a positive effect on the compressive strength of the mortar up to a certain extent. The maximum compressive strength was obtained in GF6-1 samples containing 1% 6 mm fiber and GF12-1 containing 1% 12 mm size fiber, with an increase of 12.64% and 10% compared to the reference sample, respectively.

- The addition of 1% of the fiber amount resulted in maximum bending tensile strength in both dimensions. While the addition of 2% and 4% fiber in the samples containing 6 mm fiber increased the strength compared to the reference sample, the addition of 2% and 4% fiber in the samples containing 12 mm fiber decreased the strength compared to the reference sample.

Overall, the glass fiber additive contributed more to the tensile strength in bending than the compressive strength, as observed in the experiments.

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