Experimental Investigation of the Properties of Glass and Steel Fiber Reinforced Cement Mortar

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ABSTRACT

Plain mortar possess very low tensile strength, limited ductility and little resistance to cracking. Internal micro cracks are inherently present in mortar and its poor tensile strength is due to propagation of such micro cracks. Fibers when added in certain percentage in the mortar improve the strain properties well as crack resistance, ductility, as flexure strength and toughness. In this study crimped steel fibers and glass fibers with length 30 mm were added with three volume fraction (0.25%, 0.5% and 0.75 %.) to improve characteristics of cement mortar. The total samples were casted into cube molds for compressive strength test and prism molds for flexural strength test. The density was studied as physical properties. Total numbers of samples were cured for 3,14 and 28 days in water curing tank before test .The results have shown that the improvement in the properties of mortar, was observed with the increase of the volume fraction of fibers . The fiber type was found to be a key factor affecting the mechanical performance of the material.

Keywords: Cement mortar, glass fiber, steel fiber, compressive strength, flexural strength, volume fraction.

1. Introduction

Cement mortar is characterized by brittle failure, the nearly complete loss of loading capacity, once failure is initiated. This property, which restricts the material's use, can be remedied by the addition of a small quantity of short, randomly distributed fibers (made of glass, steel, synthetic, and natural materials), which can also be used to classify other mortar flaws like low growth resistance, high shrinkage cracking, low durability, etc.[1,4] . Mortar is ideal for a variety of applications. But mortar has some drawbacks, including low tensile strength, brittleness, low post-cracking capacity, low ductility; low impact strength limited fatigue life, inability to accommodate massive deformations [3]. The fragility of plain mortar is caused by the existence of small fissures at the mortar. Fibers can be added to the mixture to reduce the weakness [5]. To boost the mortar's toughness or capacity to resist fracture growth, different kinds of fibers, such as those found in conventional composite materials, have been added to the mix. At the internal micro fractures, the fibers assist to load transfer. Fiber-reinforced mortar is the name given to such a mortar (FRM). Fiber-reinforced mortar is a composite material

made primarily of regular mortar that has been strengthened by fine fibers [6]. The mix becomes more cohesive and less likely to segregate but the workability is significantly reduced by the fibers' interlocking and entanglement with the aggregate particles. The fibers are spread and distributed randomly throughout the mortar during mixing, improving its qualities everywhere. Fibers assist in enhancing ductility performance, fatigue strength, tensile strength, and impact strength [7]

2. Experimental program

2.1 Materials

2.1.1 Cement

The cement utilized in this project is ordinary Portland cement. All cement qualities are validated by reference to IQ.S.5:2019[8]. To prevent any discrepancies between batches, the total quantity was bought and kept in a dry place. The physical parameters of cement are shown in table (1)

Table (1): physical properties of cement

Test	Results	IQ.S. 5:2019 limits
Fitness (cm^2/g)	4678	>2800
Time of setting		
initial(minute)	120	>45
final(hour)	3:50	<10
Compressive strength(N/mm^2)		
2 days	25	>20
28 days	43	>42.5

2.1.2 Sand

The specimens are made from Al-Ekhaider natural sand (Iraq) with a maximum size of (1.18mm). Table (2) depicts the grading of fine aggregate. The analysis shows that the sand grading meets the standards of Iraqi Specification No.45/1984[9].

Table (2): Grading of sand

Mesh Size(mm)	%Passing By Weight	IQ.S. 45/1984 limits
1.18	59.7	55-90
0.60	39.3	53-59
0.30	12.4	8-30
0.15	2.28	0-1
Percentage Of Salt%	0.114	≤0.5

2.1.3 Steel fiber

Steel fibers are one of the most commonly utilized fibers for enhancing strength and fracture control. Crimped fibers with 30mm length were employed in this experiment. In the mortar mixes, three various fiber volume fractions have been used: 0.25%, 0.5%, and 0.75% by mortar volume.

Figure (1): Crimped steel fiber used

2.1.4 Glass fiber

The glass fibers used in mortar suppressed the localization of micro cracks in to macro cracks hence tensile strength increase. It improves durability of mortar by increasing the strength of mortar. Glass fiber with (30) mm length. The amounts used were (0.25%, 0.5%, and 0.75%) by volume of cement

Figure (2): the glass fiber used

2.1.5 Super plasticizer

In accordance with ASTM C494 [10], Glenium 54 was employed to increase workability.

2.1.6 Water

Water is an important ingredient of mortar as it actually participates in the chemical reaction with cement. Throughout the mixing and curing process of the mortar sample, tap water was used.

2.2 Mortar samples preparation

Mixtures of 1:2.75 cement/sand ratios and 0.33 water/cement ratio were prepared for making mortar. Two series of mortars reinforced by fibers were prepared. The first series were reinforced with glass fibers and the second series reinforced with steel fibers. Each series (glass and steel fibers) were reinforced with different percentage (0.25, 0.5and 0.75) % by volume. Table (3) shows the mix design proportions. After the mixing process total

specimens were poured in oily cast iron molds of (50×50×50) mm for compression s test, and 160×40×40 mm prisms steel mold for flexural strength test. When the specimens were solidified they de-molded and cured for 3, 14 and 28 days before tests.

Table (3): Designation of cast

Mix plan	Cement	Sand	Water	Admixture	Steel fiber	Glass fiber
Steel fiber reinforced mortar	1	2.75	0.33	2.5	0	0
	1	2.75	0.33	2.5	0.25	0
	1	2.75	0.33	2.5	0.5	0
	1	2.75	0.33	2.5	0.75	0
Glass fiber reinforced mortar	1	2.75	0.33	2.5	0	0
	1	2.75	0.33	2.5	0	0.25
	1	2.75	0.33	2.5	0	0.5
	1	2.75	0.33	2.5	0	0.75

Figure (3): preparation of specimens.

3. Tests experimental results

Different tests were conducted on the specimens to determine and compare the properties between crimped steel fiber mortar and glass fiber mortar.

3.1 Density

The density was evaluated by drying the samples for 24 hours to confirm that they were dry, and then weighing the dry samples. The density was determined using dividing each sample's dry weight by the sample size.

The specimens with the addition of GF and SF with (0.25, 0.5, and 0.75) volume fraction percentages shown in Figures 4, 5, 6 shows:

- Increasing in density of SFRM when compared with the plain mixture due to the heavy weight of the steel fibers, which leads to increase in density due to the direct proportionality between

weight and density. High steel weight of SF produces heavier specimens and then high density. The higher increasing was with (0.75) vf % [11].

- Decreasing in density of GFRM when compared with the plain mixture. This decreasing resulted from the vacancies that are formed in the mortar structure due to the addition of GF as well as the light weight of GF makes the specimens lighter than control specimens , consequently results in decreasing of density due to the direct proportionality between the weight and density [12] .

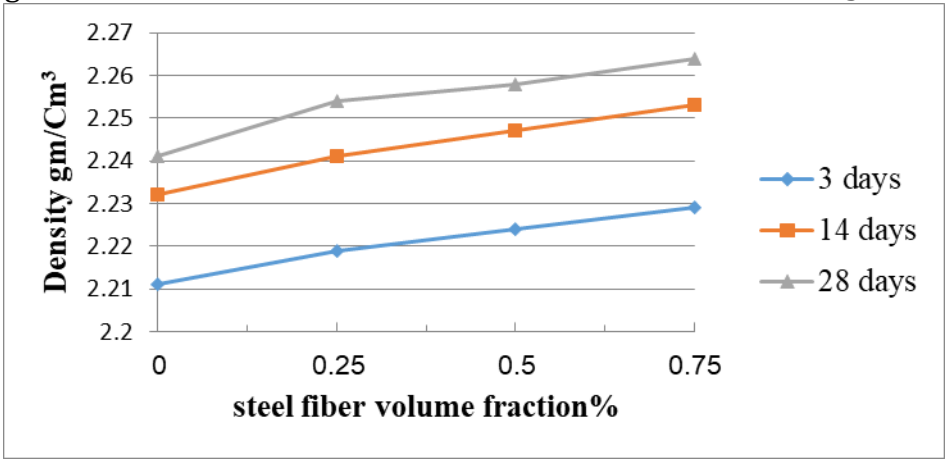

Figure (4): influence of crimped steel fibers on the mortar density

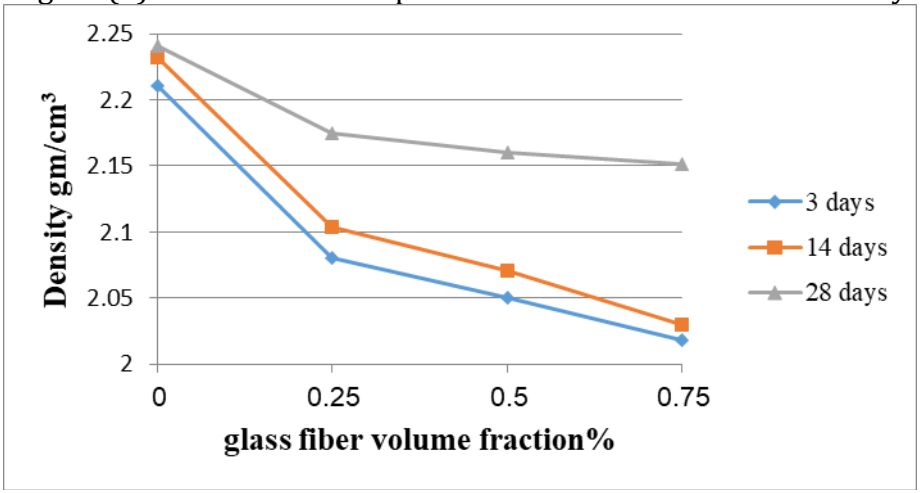

Figure (5): influence of glass fibers on the mortar density

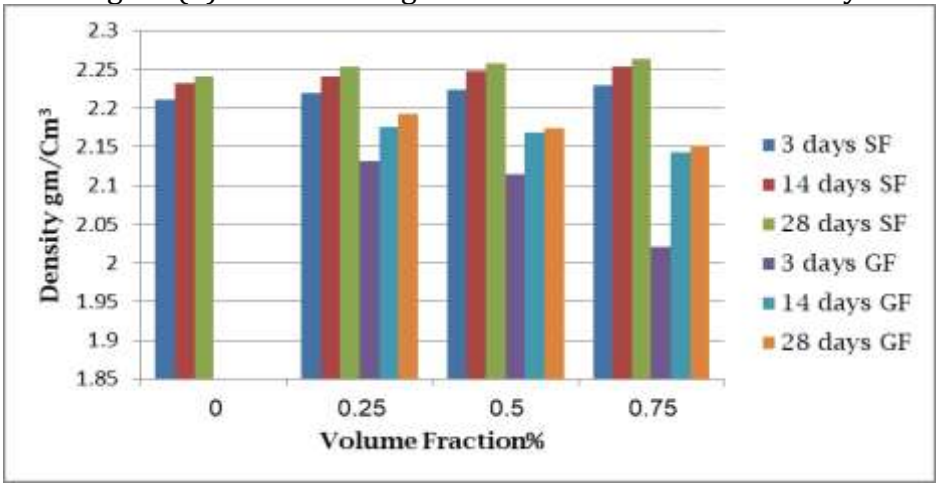

Figure (6): comparison between steel fiber and glass fiber on the mortar density

3.2 Compressive Strength

The compressive strength was determined according to (ASTM C109- 02) [13], using (50mm) cubes. The mortar compressive strength was tested using compression machine of 200KN capacity.

The influence of the fiber types and volume fraction on the compressive strength of the obtained mixtures at 3, 14 and 28 days can be found in figures 7, 8 and 9, for both fiber types, the addition of fibers in the mortar mix at fractions from 0.25% to 0.75%Vf increased the compressive strength, because they are more in number and therefore close to each other and this increases the ability of the mortar to resist more loads. Compared with control specimens. Fibers increased the absorption of energy or improved ductility and the steel fiber produced higher compressive strength. Because steel fiber is stiff and well-bonded, it could better prevent micro - cracks from developing in samples compared with glass fiber [14].

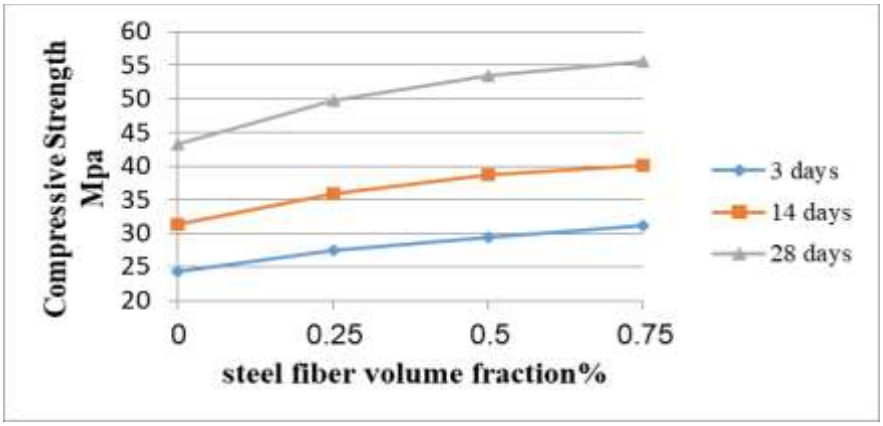

Figure (7): influence of crimped steel fibers on the mortar compressive strength

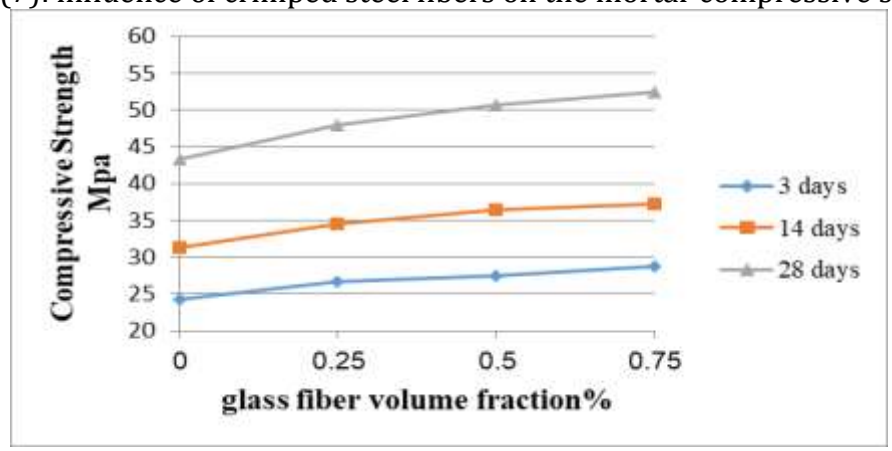

Figure (8): influence of glass fibers on the mortar compressive strength

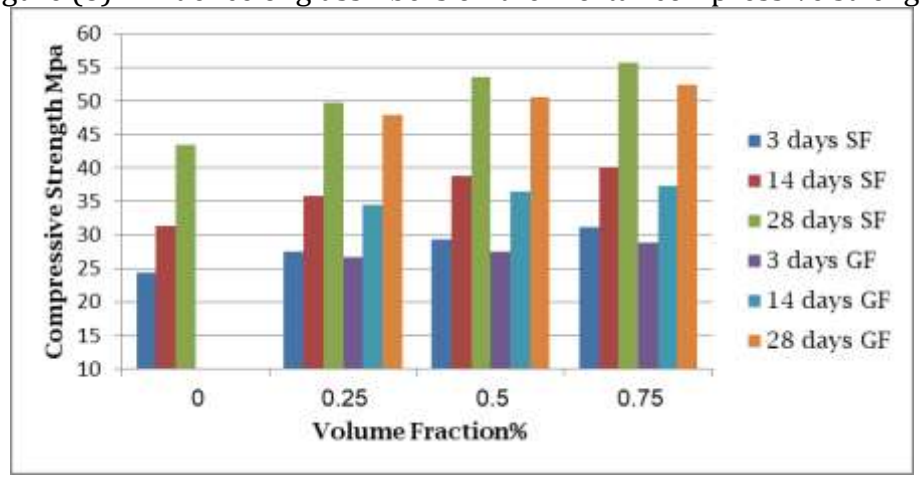

Figure (9): comparison between steel fiber and glass fiber on mortar compressive strength

3.3 Flexural Strength

The flexure strength was determined according to (ASTMC348-08)[15] . Flexural test was carried out on (40x40x160mm). Simply supported prisms with clear span of 100mm, under one point loading by using compression machine.

Relationship between flexural strength and fibers volume fractions (Vf) shown in Figures 10, 11 and 12. Flexural strength increased continuously as Vf increased from 0.25% to 0.75%, the highest value obtained at 0.75% vf for both types. Steel fibers were found to contribute mostly to the strength of FRM; this was because of its high strength and stiffness. It was also able to react with the load quicker than the glass fiber, as seen by the existing of peak load and larger fracture energy at the small deflection. However, in the case of steel fiber, once the load past its peak, most fibers were either pulled out or fractured [16].

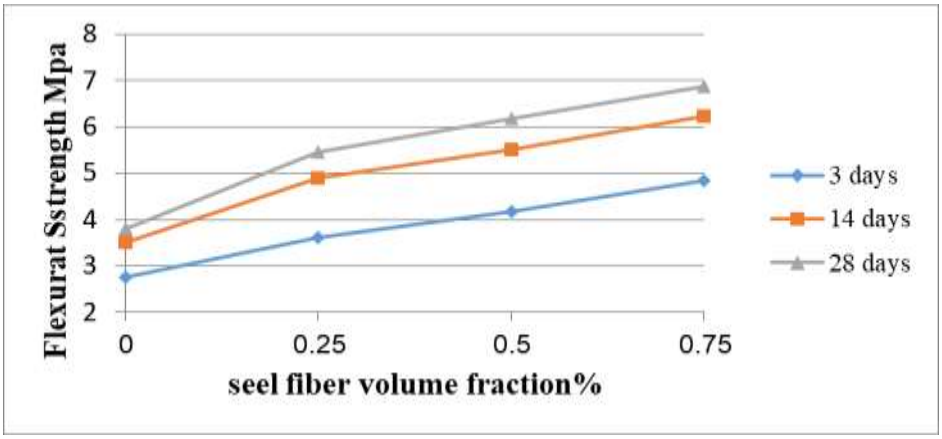

Figure (10): influence of crimped steel fiber on mortar flexural strength

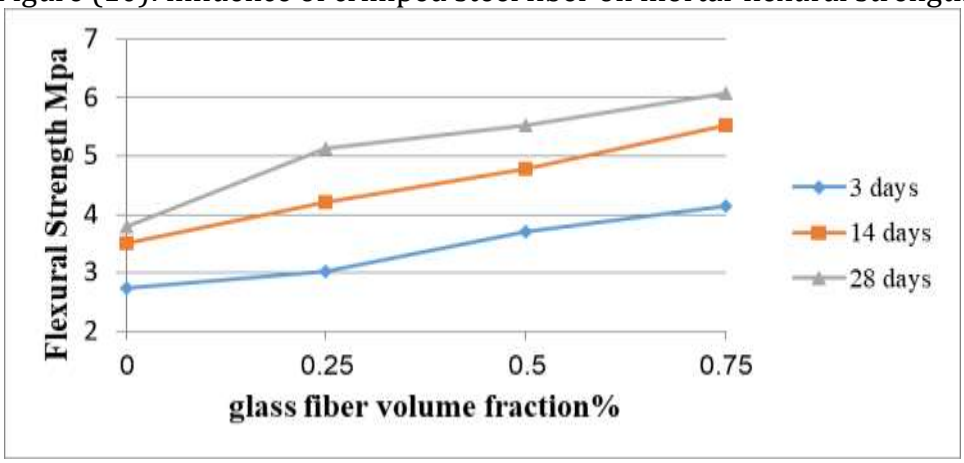

Figure (11): Effect of glass fiber on mortar flexural strength

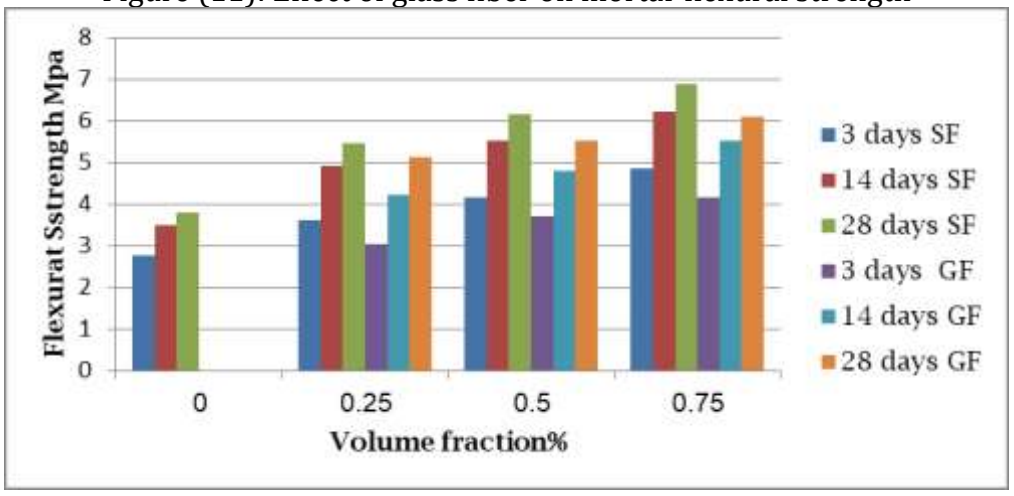

Figure (12): comparison between steel fiber and glass fiber on mortar flexural strength

4. Conclusion

According to the results of the testing in this work, the following conclusions can be dawn:

1. Unit density of mortar is increased with using steel fibers and decrease after adding glass fibers
2. It is found that the compressive strength enhance with increasing of volume fraction of fibers there is a similar trend for the flexural strength.
3. Based on the results obtained, it was found that the flexural and compressive strength maximum at 0.75% crimped fiber content after 28 days of curing.
4. The compressive and flexural strength of the mortar with the addition of fiberglass was lower than that of the mortar with the steel fiber addition.
5. The use of steel and fiberglass in a certain amount can boost the compressive and flexural strength of mortar

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