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Durability of Glass Fiber Reinforced Mortars

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***Abstract*:** *The reinforcement of construction materials, concretes and mortars, with fibers is a technique that is increasingly used with the aim of improving their mechanical performance. The main objective of this work is to study the effect of incorporating glass fibers at different dosages (0.25, 0.38, 0.5 and 0.75%) on the rheological and mechanical properties of mortar and define the behavior of these mortars in an aggressive environment (Sulfuric acid).*

The study focused on the effect of fibers on the compressive strength and splitting tensile strength of mortars. The evaluation of the durability to sulfuric acid attacks was carried out by measuring the compressive strength and the splitting tensile strength loss.

The obtained results showed that the addition of 0.38% of glass fibers increases the flexural strength. The most resistant mortar to sulfuric attacks is the one with 0.5% of glass fibres.

Keywords: *Glass fibers, Mortar, Sulfuric acid, Mechanical Properties.*

1. Introduction

In modern building practices, the repair and rehabilitation of structures have played an important role. The recent trend is to rehabilitate and reinforce concrete structures or unreinforced masonry by using fibers instead of conventional materials.

Reinforcement of mortars with fibers, homogeneously dispersed, can offer technical solutions for improving mechanical performance as well as limiting and controlling the cracking under mechanical stress. Fibers contribute positively to the durability of cementitious materials by slowing the progression of cracks [1].

Among the fibers most used in the field of construction, we find glass fibers. Their use in mortar has already been the subject of numerous studies [1-7]. However, most of the studies are mainly based on studying the effect of glass fibers on the rheological and mechanical properties of mortars, without going into the aspects of durability, nor addressing their behavior in an aggressive environment. The external attack of the mortar by an aggressive environment is an important and convincing parameter to facilitate the large-scale use of fibers.

The objective of this paper is to study the effect of introducing glass fibers with different proportions and keeping sand, water and cement constant on the mechanical properties and durability of the mortar. This objective is supported by various tests such as workability, flexural strength, compressive strength, weight loss.

2. Materials and Method

2.1. Materials and Mix Proportions

Ordinary Portland cement, silica fume and sand, with a maximum size of 5 mm, were used in this study. Physical properties and chemical compositions of the cement and silica fume used are given in Table 1.

TABLE I : The properties of cement and silica fume.

Component	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	SO_3	K_2O	Na_2O	Specific gravity (g/cm^3)	Blaine (cm^2/g)	LOI
Cement	20.14	3.54	5.53	61.6	1.73	2.29	0.47	0.69	3.1	3500	2.74
Silica fume	95.5	0.79	0.43	0.49	0.86	0.08	0.12	0.28	2.2	2200	1.31

A total of 5 mortar compositions were prepared (see table 3). One without fiber considered as a control mortar. The four other compositions based on glass fibers with four different rates 0.25% - 0.38% - 0.5% and 0.75% by total mortar weight. Water / binder ratio was chosen as 0.55 in the productions. Properties of glass fiber used in mortar production are given in Table 2.

TABLE II : Properties of glass fiber

Length (mm)	*Diameter (µm)*	*Density (g/cm^3)*	*Tensile strength (MPa)*	*Modulus of elasticity (MPa)*
15	14	2.6	3400	77000

TABLE III : Compositions of mortars.

Component (kg/m^3)	CM	GM0.25	GM0.38	GM0.5	GM0.75
Sand	1350	1350	1350	1350	1350
Cement	405	405	405	405	405
Silica fume	45	45	45	45	45
Water	250	250	250	250	250
Glass fiber	-	5.125	7.79	10.25	15.58
w/b	0.55	0.55	0.55	0.55	0.55

The fresh characterization was carried out using mortar workability apparatus according to EN 413-2 standard [8]. All mortars exhibited a firm workability with a flow time greater than 40s. Considering the test results individually, it can be seen that despite the similarities, a slight effect on the consistency can be noticed. Increasing the content of fibers in the mortar mixes resulted in gradual decrease in workability.

2.2. Sample Preparation, Curing and Testing Procedure

The specimens were cast immediately after mortar production and moved to a room at 20°C and 90% RH. After 24 h they were demoulded. The prismatic specimens 4x4x16 cm^3 used to determine the compressive and the flexural strength were stored in water at 20°C until testing at 14, 28 and 50 days. Three specimens were measured per property and age.

2.3. Sulfuric Acid Attack

After demoulding, the specimens were kept in water at a temperature of 20±2°C for 50 days before being subjected to sulfuric acid attack test according to ASTM C267, which is the standard test method for the chemical resistance of mortars, grouts and polymer concrete [9].

The mortar samples were 4×4×16 cm prisms. Six samples were used for each mortar. After 50 days of water curing, three samples remain in water (as a reference medium) and the other three were immersed into 3% sulfuric acid solution. The temperature of the solution was maintained at 22 ± 2°C. Since this phenomenon takes a long time to become aggressive, a procedure was chosen to accelerate the acid attack mechanism based on drying-wetting cycles (2 days at 50° temperature and 2 days in sulfuric acid solutions) for 3 weeks. The solution was renewed every cycle.

At the end of the immersion, the samples were washed smoothly with tap water to eliminate loose components on the surface. Then, they were placed in 50% relative humidity room. After 24 hours, the weight of the samples was measured and recorded. The initial weight of all the specimens was measured in accordance to ASTM C267 prior to the immersion. Compressive and flexural strength test were also performed.

3. Results and Discussion

3.1. Compressive Strength

The compressive strength test results of samples with 0.25, 0.38, 0.5 and 0.75% of glass fibers are presented in Fig 1. The results were compared with the control mortar without fibers.

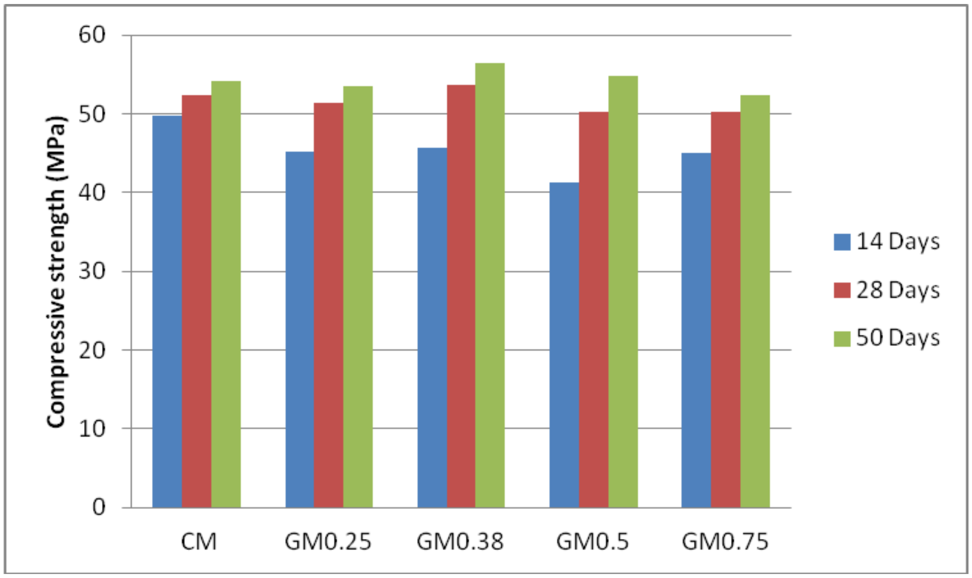

Fig. 1 : Compressive strength of mortars.

The fig 1 shows the compressive strength of mortars with different fiber contents. It can be seen that the optimum compressive strength is obtained with the mortar containing 0.38% of glass fibers and decreases when the fiber content increases to 0.75%.

Glass fibers may prevent fractures in specimens under compressive strength, which explains the enhancement [10]. The fibers are used to bridge micro cracks, thus delaying sample destruction [11].

The slight decrease in compressive strength of GM0.25 and GM0.75 samples can be explained by the poor adhesion with the cement paste. The incorporation of fibers in the cementitious matrix increases porosity, and therefore a decrease in compactness, hence a decrease in compressive strength.

3.2. Flexural Strength

Figure 4 shows the flexural strength test results of mortar with different glass fiber content. It can be seen that the flexural strength of mortar improved up to a certain extent with the incorporation of glass fibers.

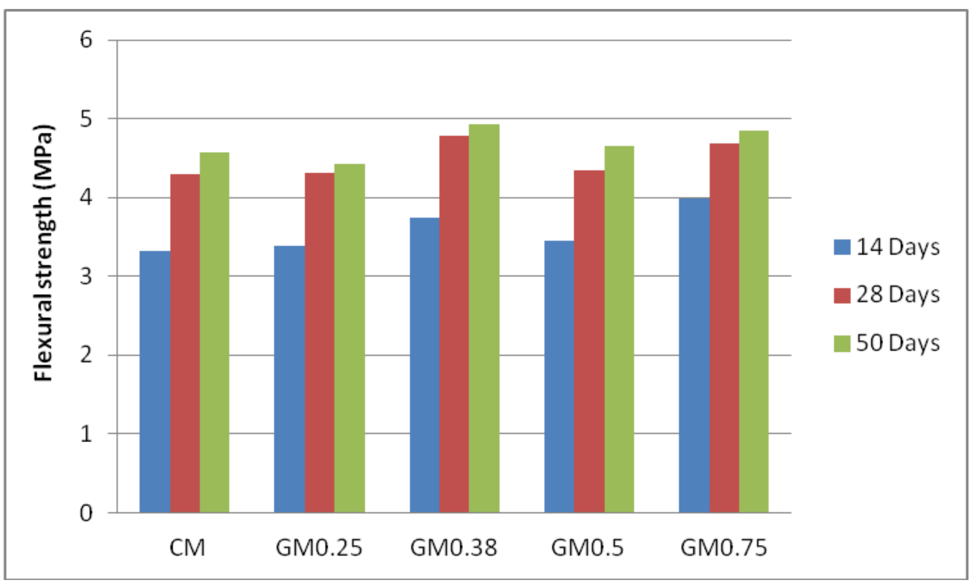

Fig. 2 : Flexural strength of mortars

From fig 2 it was found that the addition of glass fibers in mortars seems to improve their flexural strength. The highest flexural strength values were obtained for samples containing 0.38% of glass fibers with an increase of 7.64% compared to control mortar without fibers at 50 days of hardening. This is due to the bridging effect of the glass fibers. When the matrix cracks, the fibers will resist the load until the interfacial bond between the fibers and the matrix breaks [12]. Thus, the bridging fibers can partly transmit the stress through the crack and improve the flexural performance of samples reinforced using glass fibers [10].

The results show a decrease in the flexural strength for mortars with 0.25% glass fiber content. According to the literature, this can be explained by the flexible nature of glass fibers. The fibers can become entangled during mixing, which leads to poor fibers dispersion and promotes the creation of porosity, in particular poor adhesion with the cementitious matrix which can reduce the overall effectiveness of the reinforcement [13].

3.3. Durability to Sulfuric Acid Attack – Strength Loss

Fig 3 illustrates the flexural strength loss and the compressive strength loss of mortar prisms after exposure to 3% sulphuric acid solution, marked blue and red, respectively. The strength loss was calculated based on the average strength of degraded samples at the end of cycles of drying and wetting with sulfuric acid solution and the average strength of samples hardened in water having the same age.

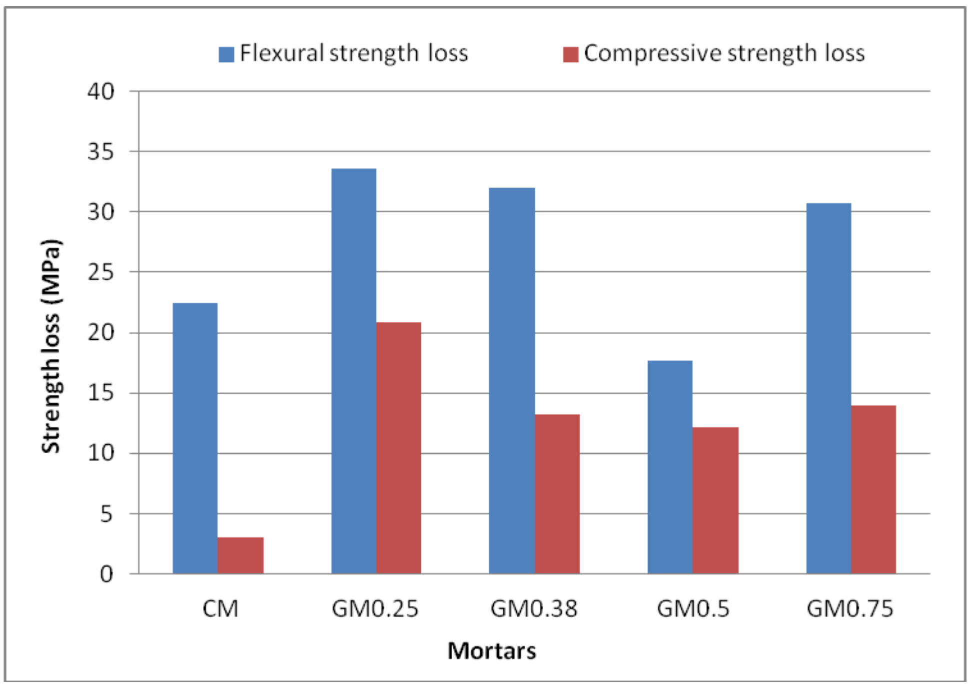

Fig. 3 : Strength loss of mortar samples after exposure to sulphuric acid solution.

From the fig 3 it can be seen that the mechanical performance of all the mortars subjected to acid attack has decreased. This reduction varies from one mortar to another. The control mortar was found to have the lowest compressive strength loss of 2%. This could be attributed to the beneficial combined effect of silica fume in the densification of the porous structure of the mixture and in the evolution of hydration and pozzolanic reactions.

Strength loss was noticed for all glass fiber reinforced mortars even with the use of silica fume. This can be explained by the fact that the incorporation of glass fibers in the cementitious matrix may increases porosity which allow the sulfiric acid solution to penetrate. In the other hand, this loss is due to the chemical reaction between the remaining portlandite and sulfuric acid that involves the formation of gypsum and ettringite which may contribute to the process of expansive deterioration mechanisms [14]. The weakest strength loss for glass fiber reinforced mortars was obtained by GM0.5 mortar.

3.4. Durability to Sulfuric Acid Attack - Weight Loss

The weight loss results of glass fiber reinforced mortars are shown in Fig 4**.** The aggressiveness of sulfuric acid attack is caused by their reaction with the calcium hydroxide of the cement paste, which produces a calcium salt by-product that is highly soluble and easily removed from the paste thereby weakening the structure of mortar samples.

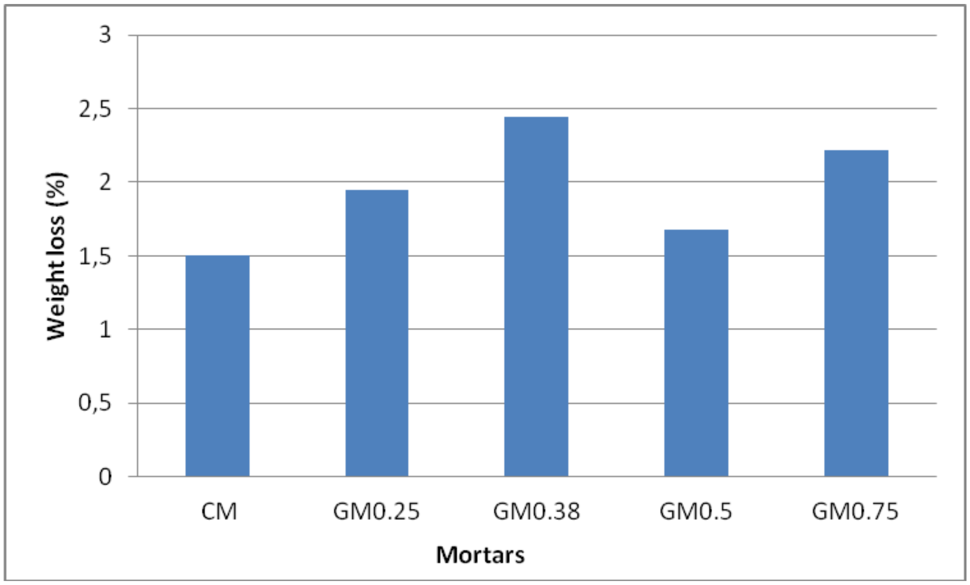

Fig. 4 : Weight loss of mortar samples after exposure to sulfuric acid solution.

Figure 4 shows that, in terms of weight loss, the performance of control mortar is better than that of glass fiber reinforced mortars which is in accordance with the results of compressive strength loss. As for the glass fiber reinforced mortars, mortar with 0.5% of glass fibers is the most resistant to sulfuric acid attack.

4. Conclusion

The aim of this paper is to study the effect of introducing glass fibers with different proportions on the mechanical properties and durability of mortar. This objective is supported by various tests such as workability, flexural strength, compressive strength, weight loss. The following results were obtained:

- The optimum compressive strength is obtained with the mortar containing 0.38% of glass fibers. Glass fibers did not show a significant improvement in compressive strength. However, this does not prevent its use in the field of construction because the results obtained are satisfactory and greater than 50 MPa.
- The flexural strength is positively influenced by the incorporation of glass fibers. The mortar with 0.38% of glass fibers gave the best result.
- The mortar with 0.5% of glass fibers is the most resistant to sulfuric acid attack.

5. References

[1] V. Akyüncü. "Investigation of Mechanical and Permeability Properties of Fiber Mortars". Journal of Sustainable Construction Materials and Technologies, Vol. 6(1), pp. 29-35, March 2021.

https://doi.org/10.29187/jscmt.2021.57

[2] M. Saidi, B. Safi, A. Benmounah and C. Aribi. "Effect of size and stacking of glass fibers on the mechanical properties of the fiber-reinforced-mortars (FRMs)". International Journal of the Physical Sciences, Vol. 6(7), pp. 1569-1582, April 2011.

[3] A. Habib, R. Begum, M. Mydul Alam. "Mechanical Properties of Synthetic Fibers Reinforced Mortars". International Journal of Scientific & Engineering Research, Vol 4(4), pp. 923-927, April 2013.

[4] R.S. Mahdi. "Experimental Study Effect of Using Glass Fiber on Cement Mortar". Journal of Babylon University/Engineering Sciences, Vol. 22(1), pp. 162-181, 2014.

[5] H. Shi, Z. An, R. Gao. "Simulation of mechanical behavior and structural analysis of glass fiber reinforced mortar pipes", Revista Română de Materiale, Romanian Journal of Materials, 50 (2), pp. 198 - 204, 2020.

[6] M. Małek, M. Jackowski, W. Łasica, M. Kadela, M. Wachowski. “Mechanical and Material Properties of Mortar Reinforced with Glass Fiber: An Experimental Study”. Materials, Vol 14, 698, February 2021. https://doi.org/10.3390/ma14030698

[7] J. Ahmad, R.A. González-Lezcano, A. Majdi, N. Ben Kahla, A.F. Deifalla, M.A. El-Shorbagy. “Glass Fibers Reinforced Concrete: Overview on Mechanical, Durability and Microstructure Analysis”. Materials, Vol 15, 5111, July 2022.

https://doi.org/10.3390/ma15155111

[8] EN 413-2. Masonry cement - Part 2: Test methods. European standard, June 2005.

[9] ASTM C267-20. “Standard Test Methods for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings and Polymer Concretes”. ASTM International, 2006.

[10] M. Mastali, A. Dalvand, A. Sattarifard. “The impact resistance and mechanical properties of reinforced self-compacting concrete with recycled glass fibre reinforced polymers”. J. Clean. Prod, Vol 124, pp. 312–324, 2016.

https://doi.org/10.1016/j.jclepro.2016.02.148

[11] M.A. Moghadam, R.A. Izadifard. “Effects of steel and glass fibers on mechanical and durability properties of concrete exposed to high temperatures”. Fire Saf. J. Vol 113, 102978, 2020.

https://doi.org/10.1016/j.firesaf.2020.102978

[12] Atewi, Y.R.; Hasan, M.F.; Güneyisi, E. Fracture and permeability properties of glass fiber reinforced self-compacting concrete with and without nanosilica. Constr. Build. Mater. 2019, 226, 993–1005.

https://doi.org/10.1016/j.conbuildmat.2019.08.029

[13] S.Thomas. P.A. Sreekumar, K. Joseph, G. Unnikrishnan, “A comparative study on mechanical properties of sisal-leaf fibre-reinforced polyester composites prepared by resin transfer and compression moulding techniques”. Compos Sci Technol, Vol 67(3-4), pp. 453-461, 2007.

https://doi.org/10.1016/j.compscitech.2006.08.025

[14] A. Izzat, A.M.M. Al bakri, H. Kamarudin, A.V. Sandu, G.C.M. Ruzaidi, M.T.M. Faheem, L.M. Moga. “Sulfuric acid attack on ordinary Portland cement and geopolymer material”. Revista de Chimie - Bucharest, Vol 64(9), pp. 1011-1014, September 2013.