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# Investigation of the Effect of High-Temperature Glass Fibers and Pozzolanic Materials on Flexural Strength of Concrete by Pre-Mixing and Spraying Method

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**ABSTRACT:** This paper uses glass fibers and pozzolanic materials with different percentages. To investigate the flexural strength and toughness indices of concrete produced by pre-mixing and spraying methods, 15 mixing designs containing different percentages of glass fibers and pozzolanic materials in the pre-mixed method and 14 mixing designs with spraying method have been tested. All mixing schemes were also tested at 350, 650, and 1000 °C, and the results were analyzed by scanning electron microscope (SEM). The use of pozzolanic materials in specimens reinforced with glass fiber improves the modulus of rupture. The modulus of rupture in the presence of heat and the event of a fire is greatly reduced, which is a better performance for controlling this reduction process. Also, the flexural strength of high-temperature samples (1000 °C) can be significantly increased by using metakaolin at different percentages of 10 and 15%.

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## 1- Introduction

Due to the thickness and low weight of the parts made of glass-reinforced concrete, it is impossible to use reinforcement in the manufacture of these products. For this purpose, glass fibers are used to improve the concrete behavior under tensile and flexural loads and to increase the toughness. Glass fiber reinforced concrete can be used to make parts in different shapes and designs. In the past, concrete has only been used in the manufacture of non-structural products for the restoration of buildings, sewer lining, tunnel cover, riverbed, and acoustic barriers. But in recent years, this concrete has been used as an acceptable structural material for the construction of industrial halls, prefabricated roofs, and telecommunication towers [1].

In this study, glass fiber and polypropylene fibers with 1% and 1.5% volume of concrete were used. After fabricating the specimens, it was concluded that by increasing the glass fiber content from 1% to 1.5%, the efficiency of the concrete decreased drastically and the uniform distribution of fibers in the mortar became impossible [2]. Mostofi Nejad *et al.* studied the mechanical properties of glass fiber reinforced concrete with different percentages of fibers and different sand-to-sand ratios. They used four different percentages of glass fibers (0%, 1.5%, 3%, and 4.5%). After examining the compressive strength of the specimens reinforced with glass fibers, they concluded that if 4.5% of the glass fibers was used, the compressive strength would be reduced due to the phenomenon of fibers being shot [3].

## 2- Experimental program

The purpose of this study is to investigate the effect of fibers and adhesives on glass fiber reinforced concrete parameters. In the following, we describe each of the resistance and behavioral components examined in this study. The bending test was performed according to BS-EN1170-5 [4] and ASTM C78 [5] by a four-point bending machine. Usually, the strength of concrete under flexural loading is determined by the bending behavior of beams with simple supports. In addition to the bending test, the below hammer test was also used to calculate the hardness of the concrete. Flexural loading is commonly used to calculate hardness in glass fiber reinforced concrete. In this study, only fine grains (silica sand) were used. It should be noted that to have high-quality concrete, compliance with the requirements of ASTM C33 [6] is required. In this research, Portland cement of Isfahan cement factory was used. The water used in this study is Arak drinking water which is acceptable in quality. In this study, different percentages of micro silica, metakaolin, and nanosilica were used as substitutes for cement in a glass fiber reinforced concrete mixing scheme.

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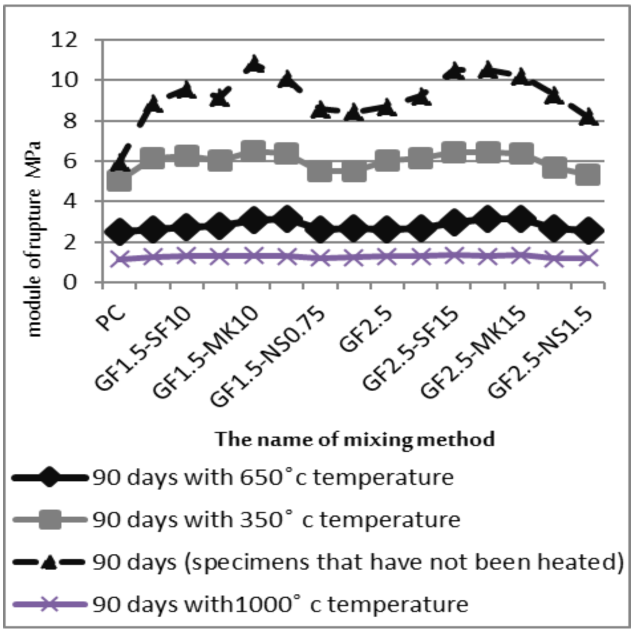


**Fig. 1. Modulus of rupture in all mixing designs made after placing in a thermal furnace to pre-mixed method**

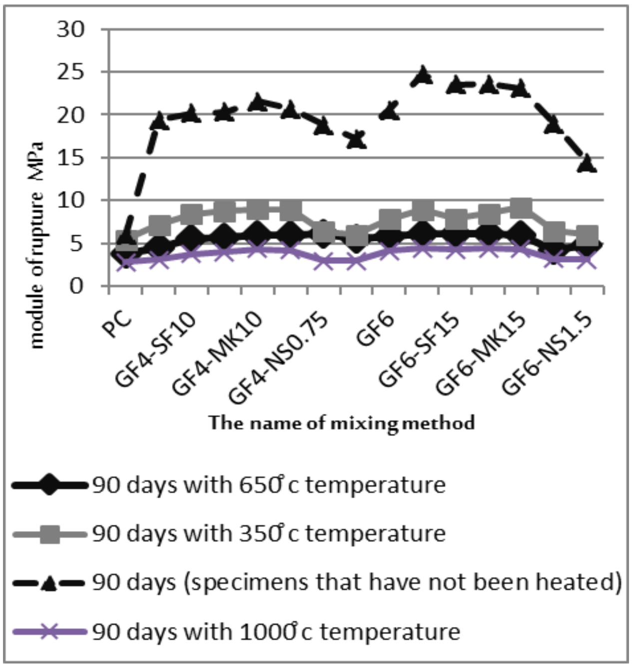


**Fig. 2. Modulus of rupture in all mixing designs made after placing in a thermal furnace to spray method**

The silica used in this research is a product of Iran Ferroalloy Industries Company. The nanosilica used in this research, with the industrial name of Arosil, is a product of Unicom Germany. In this study, the WD 500 super-lubricant manufactured by Arman Chemical Company was used. Two types of glass fibers are used to make concrete in the pre-mixed and spray methods.

## 3- Results and Discussion

According to all internationally accepted standards, the temperature of fires reaches around 1100 degrees Celsius over time. To simulate the fire temperatures, the specimens were placed in a casting furnace. The furnace temperature change cycle was chosen so that the furnace temperature could rise to 200 °C for every 2 hours. This process continued at 800 °C for 5 hours. Then at the end of the fifth hour, the temperature reached 900 degrees Celsius and at the end of the sixth hour, the temperature reached 1000 degrees Celsius. Given the risk of overheating, it was decided to set the maximum temperature at 1000 °C. Also, from each mixing scheme, 5 samples were set on fire. It should be noted that the temperature of the furnace was raised to 350 °C in the first stage and the specimens were placed in the furnace for bending tests. In the second and third stages, the furnace temperature was raised to 650 and 1000 °C, and the bending test results were investigated. Figs. 1 and 2 are plotted to compare the flexural strength of the control specimens made by pre-mixing and spraying methods, with the specimens being placed at 3, 350, 650, and 1000 °C.

## 4- Conclusion

According to Figs. 1 and 2, it can be concluded that generally increasing the temperature significantly decreases the bending strength. This decrease is due to the melting of fibers or the deformation of glass fibers due to the high temperature in the concrete. Also, according to the results obtained at different temperatures, it can be concluded that glass fibers perform well at temperatures up to 350 degrees Celsius, gradually increasing to 650 degrees Celsius and then 1000 degrees Celsius. The SEM image is taken from the tested sample after warm-up confirms this well (Figure 24). In this study, pozzolanic materials such as Microcrystalline, nanosilica, and metakaolin were used to control this decrease in flexural strength and to prevent melting and deformation of fibers in concrete. The results show that in the pre-mixed method, the best performance at 350 °C compared to the control sample for the mixing design was 2.5% glass fiber and 15% metakaolin as well as samples containing 2.5% glass fiber and 15% micro silica, in both the bending strength increased 28.5 percent compared to control sample. Also at 650 °C, it contains samples containing 2.5% fibers and 15% metakaolin with a 25% increase in resistance. On the other hand, at 1000 °C, the samples contained 2.5% glass fiber and 15% metakaolin with an 18% increase in flexural strength.

In the spray method due to the good mixing of cementitious matrix materials, the best performance at 350 °C for mixing design is 6% glass fiber and 15% metakaolin, which increased flexural strength by 68.8% compared to the control. Also at 650 °C, it contains samples containing 6% fibers and 10%

metakaolin with a 61% increase in flexural strength. On the other hand, at 1000 °C, the highest increase was observed for samples containing 6% glass fiber and 10% metakaolin with a 55%

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