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# Improving Tensile Strength and Strength and Resilience of Reinforced Concrete through Pozzolanic Materials

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**Abstract**

So far, there have been many definitions of concrete. According to these definitions, concrete consists of three main materials. These materials include cement materials, water with which cement materials react and become sticky; and fillers that make up a significant volume of concrete. Steel reinforcements reinforce concrete under tension, but they have almost no effect on the Turkish development process. In other words, when the end of the crack reaches the position of the tensile reinforcements, the rate of crack opening increases and also the crack propagation decreases, and then when the crack passes through the reinforcement, the crack development increases at a higher rate. In addition, the presence of reinforcement in certain tensile areas makes the concrete out of homogeneity and homogeneity, and the assumption of concrete homogeneity in analysis methods faces problems. The various advantages of using fibers in concrete, such as increasing bending strength, increasing shear strength, increasing tensile strength, increasing resistance to impact loads, increasing the amount of energy absorption, and increasing cross-sectional resistance against cracking, have caused the use of fibers in strengthening and repairing all kinds of structures. Concrete should be used. The results of the compressive strength test in samples reinforced with 1.5% and 2.5% glass fibers are as follows: The use of glass fibers in this research has reduced the effectiveness of concrete. According to these results, if glass fibers are used, the compressive strength of the samples is greatly reduced. The use of pozzolanic materials has significantly increased the compressive strength of concrete reinforced with glass fibers. Based on this, the highest compressive strength of 7 days and 28 days is related to samples reinforced with 2.5% glass fibers and containing metakaolin. In the samples reinforced with 2.5% glass fibers, with the increase in the amount of metakaolin used from 10% to 15%, the 28-day strength of the samples increased from 53.665 MPa to 56.16 MPa.

**Keywords**: reinforced concrete, strength and resilience, pozzolanic materials, glass fibers.

## Introduction

Due to the thickness and low weight of the parts made of concrete reinforced with glass fibers, it is impossible to use reinforcement in the manufacture of these products. For this purpose, in these conditions, glass fibers are used to improve the behavior of concrete under tensile and bending loads and increase strength. Concrete reinforced with glass fibers can be used to make parts in different shapes and designs. In the past, this concrete has only been used in the production of products with non-instrumental applications in building repairs, sewer linings, tunnel linings, riverbed protective walls, and sound barriers (Zakerhaghighi et al., 2015).

But in recent years, this concrete has been used as a material with the use of acceptable tools in the construction of floors of industrial halls, prefabricated roofs, and telecommunication towers (Norouzian & Gheitarani, 2024). After defining concrete reinforced with glass fibers and examining different methods of producing this concrete, in this chapter, the characteristics of concrete reinforced with glass fibers and the effect of glass fibers on the mechanical properties of this concrete have been studied. Concrete reinforced with glass fibers, composite materials include a mortar of hydraulic cement and fine aggregate, which is reinforced with glass fibers.

This concrete combines the high compressive strength of cement mortar with very high bending and tensile strength due to fiber reinforcement. The amount of fibers used in this concrete, according to the application of this product and its production method, is considered between 1 and 6 percent of the weight of concrete reinforced with glass fibers. Using glass fiber reinforced concrete is not more economical than traditional concrete in all cases; But in places where there is a need to spray concrete on a surface where the use of traditional methods is difficult and time-consuming, or in projects where high execution speed is considered, the cost of using glass fiber reinforced concrete will be lower than traditional concrete (Norouzian & Gheitarani, 2023).

As mentioned, concrete reinforced with glass fibers has a thin cross-section, which causes the weight of this product to be low. This leads to savings in handling operations, storage, transportation, and installation, and as a result, reduces the cost and time of making and operating this concrete compared to traditional concrete. Also, due to the low weight of this concrete, the loads on the building components are reduced and the total costs of the structure are reduced. Products manufactured by glass fiber reinforced concrete are safe, have good chemical resistance, and do not rot or corrode.

GFRC is made of inorganic materials and does not burn. The design of this concrete is such that it can pass the flames and also has a good resistance against fire. However, according to ASTM E119 21 regulations, after 15 minutes, the durability of this concrete against fire depends on the amount of insulation and thermal resistance of its constituent materials. According to what was said, according to the characteristics of this concrete, including resistance to cracking, resistance to thermal stress, and acceptable resistance of this concrete to the attack of harmful chemicals, the useful life of concrete reinforced with glass fibers increases. The cost of repair and restoration of this concrete is minimized (Safaei Mehr, M., 2023). In general, there are two main ways to produce glass fiber-reinforced concrete:

- Premix method
- Spray method
- Premix method

In this method, to produce concrete reinforced with glass fibers, the mortar, and the cut fibers are mixed inside the mixer at the same time (Gheitarani et al., 2024- a). Due to the reduction of concrete performance when glass fibers are used, to produce high-quality pre-mixed concrete, in the first stage, all materials including cement, sand, water, and additives are combined in a mixer until a high-quality and efficient slurry (Kahvand et al., 2015). Produced in the second stage, fibers slowly are added. The length of the glass fibers used in the premix method is between 12 and 25 mm. The maximum amount of fibers that can be used in this method is 3% of the weight of concrete reinforced with glass fibers. Using larger amounts of fibers causes the fibers to become lumpy and reduces the effectiveness of concrete (Sarabi et al., 2023- a).

**Theoretical**

Among the products produced through the premix method are: solar panels, decorative panels, tiles, installation equipment, electrical converter housings, and drainage components. ***Spray method***. To produce concrete reinforced with glass fibers by spray method, in the first stage, cement mortar and sand are transferred into the spray gun through the pump of the device after mixing (Maleki et al., 2024). At the same time, the bundle of uncut fibers is transferred to a winnowing device inside the spray gun. In the last stage, cement mortar, sand, and cut glass fibers are simultaneously sprayed on the desired surface by air pressure from the spray head Concrete production is done layer by layer in the spray method. With each movement of the spray gun, a layer of 4 to 6 mm thickness is poured on the mold, and then each layer is compacted by a wet roller. In general, the spraying method is done manually and mechanized (Khanian et al., 2019).

A- Manual spray method. As the name suggests, this method is strongly influenced by the user. In this method, the user takes the spray gun in such a way that the concrete is sprayed vertically along the form and back and forth on the form. The main use of the manual spray method can be seen in the production of cover panels, facade elements, and ducting (Norouzian & Sarabi, 2023).

B. Mechanized spray method. The mechanized spray method is used to produce flat and shallow sections In this method, the molds are placed on a conveyor and the head of the spray gun moves back and forth on these molds (Samami et al., 2024). This method is used in the production of facade elements, sandwich covers, and sewer linings. In general, the length of the glass fibers used in the spray method is 25 to 40 mm and the amount of glass fibers used in this method is 4 to 6 percent. Processing concrete reinforced with glass fibers. The hydration process of cement at ambient temperature is relatively slow (Norouzian, M. M., 2024).

For this reason, concrete products usually find the possibility to be processed within several weeks after concreting, and in this way, get the required strength and resistance. Products produced by glass fiber reinforced concrete usually have thinner sections and lower w/c than conventional concrete (Karimimansoob et al., 2024- a; GHADARJANI & GHEITARANI, 2013- a). Therefore, if these products are not processed properly before completing the hydration process, they will lose their moisture quickly and will not gain the strength they need. For this purpose, to ensure the complete setting of cement in this concrete, wet curing is done for 7 days. To ensure that the hydration process is complete, the samples are kept moist immediately after production (Ghadarjani et al., 2013- b). Today, several methods are used to achieve this, the main ones being: storage in a humid chamber, sealing the samples in polyethylene bags, and total immersion of the samples in water (Aydin et al., 2020).

The wet processing period can be divided into 3 parts:

**A**- Sample processing before removing from the mold. For this purpose, by placing the samples in a polyethylene cover, the airflow can be minimized throughout the surface of the sample, and finally, the product can retain the maximum possible amount of water.

**B**- Samples are wet-treated for at least 7 days by one of the mentioned methods.

**C**- Sample post-treatment process (for special weather conditions), (Naghibi Iravani et al., 2024- a; Dizaji, A. A. 2024).

This step is done before storing or using the samples. At this stage, the samples must be adapted to the weather conditions of the environment before use. In general, each processing process depends on the product type, production method, and product mixing plan. During the process of concrete reinforced with glass fibers, the resistance and strength of the products are improved from an initial value. Therefore, to avoid applying too much stress to the samples in these conditions, how to remove the samples from the mold, handling, and the main processing process of the samples should be taken into consideration (Aghazadeh et al., 2019).

***Processing with air***. Due to the time-consuming process of wet curing, most of the time this process is not done properly. Therefore, in 1980, research was conducted by the Portland Cement Association to solve the problems caused by the 7-day curing of glass fiber-reinforced concrete. They concluded that the addition of acrylic polymer at the rate of 5% of the total volume of concrete can be a suitable alternative to wet curing. The use of polymer produces a complete membrane around the particles that make up the concrete and thus prevents the moisture in the concrete from escaping. Today, polymer materials are used in the amount of 2 to 10 percent by weight of cement in concrete reinforced with glass fibers (Naghibi Iravani et al., 2024- b).

In this method, after removing the samples from the mold, the produced product can work in the environment. Mechanical properties. The mechanical properties of concrete reinforced with glass fibers include compressive strength, bending strength, tensile strength, modulus of elasticity, strength, impact resistance, and shear strength.

The most important influencing factors on the mechanical properties of GFRC are the amount of fibers used, additives (if used), the ratio of water to cement, the amount of sand and adhesive materials, the length and orientation of fibers, and the methods of processing samples. Compressive strength. According to the research done, usually, the compressive strength of concrete increases only slightly in the presence of glass fibers. In general, glass fibers do not have much effect on the compressive strength of GFRC. According to the research conducted on the behavior of concrete reinforced with glass fibers, it can be seen that the stress-strain diagram of these sections under pressure is linear up to high stresses and similar to the curve obtained from unreinforced concrete.

The presence of fibers has significantly increased the displacement of the samples until the moment of rupture. Regarding the influencing factors on the compressive strength, the method of processing the samples is very important (Ghourchi, M. et al., 2018). If the concrete is not processed well following the mentioned contents, it leads to a direct reduction of all the properties related to cement mortar, the most important of which is the compressive strength of concrete. According to the research, the orientation of the glass fibers in the concrete affects the compressive strength. Fibers parallel to the pressure direction create fracture planes, as a result of which the compressive strength is reduced by about 70%. Tensile strength. In this part, most of the incoming loads are borne by the mortar before the first crack occurs. The highest tensile stress in this area is called bending point (BOP), (Karimimansoob et al., 2024- b).

Moving away from the crack surface, the incoming loads are transferred from the mortar surface to the fibers and from the fibers to the mortar. In this case, small cracks are formed on the concrete surface. As the loading increases, the cracks become larger and the mortar loses its bearing capacity. In this condition, glass fibers present in concrete increase the amount of stress until reaching the maximum tensile strength of concrete (UTS).

By breaking the fibers at both ends of the cracks, without increasing the load, the displacement of the samples increases and finally the concrete is destroyed. In the pre-mix method, due to the lower percentage of glass fibers compared to the spray method and the impossibility of proper distribution of fibers on the concrete surface, the tensile strength of the samples is greatly reduced. In this situation, the distance between the BOP and UTS points is very small, and most of the time these two values occur at the same point (Gheitarani et al, 2024- b). Bending strength The use of glass fibers strongly affects the behavior of concrete under bending.

As a result of the application of bending loads, after creating cracks on the surface of the mortar, the glass fibers bear the loads on the concrete surface, causing a significant increase in the bending strength of concrete reinforced with glass fibers. Impact resistance. Damages caused by impact loads in concrete reinforced with glass fibers are normally inflicted in a specific area. The presence of glass fibers limits the propagation of cracks outside the stressed area (Naghibi Iravani et al., 2024- c).

The Izod device is used to calculate the impact resistance of concrete reinforced with glass fibers. By using this device, the energy required to break the sample is determined by the momentary impact of a standard pendulum on a sample with standard dimensions and measuring the angular rise of the pendulum after the sample breaks. This test is performed on samples with a width of 25-50 mm and a thickness of 6-12 mm (Gheitarany et al., 2013).

***Modulus of elasticity***. Considering the low volume of fibers compared to the volume of concrete, there is not much difference between the modulus of elasticity of concrete reinforced with glass fibers and mortar (Zaker Haghighi et al., 2014). Normally, the modulus of elasticity of concrete reinforced with glass fibers is expressed by the gradient of the linear part of the stress-strain curve of this concrete under tension. According to the mentioned contents, by entering reasonable values in the following equation, it can be shown that the modulus of elasticity of concrete reinforced with glass fibers is not much different compared to the modulus of elasticity of unreinforced concrete (Dizaji et al., 2023).

$$Ec = EfVf + EmVm$$

In this equation, Ec is the modulus of elasticity of concrete reinforced with glass fibers, Ef is the modulus of elasticity of fibers, Em is the modulus of elasticity of mortar, Vf is the volume percentage of fibers, and VM is the volume percentage of mortar, respectively: Fiber length coefficient, fiber shape coefficient, and fiber orientation coefficient (Farrokhirad & Gheitarani, 2024). Types of pozzolans. In general, pozzolans can be divided into the following two categories based on their origin:

A- Natural pozzolans. Some materials are used to produce a pozzolan from the materials available on the ground. Normally, the production process of these materials includes crushing, grinding, separating sizes, and in some cases applying heat for activation. These compounds react with hydrated lime and improve the microstructure of cement paste. The reason for applying the second restriction is that the presence of sulfur in cement mortar increases the possibility of sulfate attack, which results in undesirable and destructive expansion (Gheitarani et al., 2013). Among natural pozzolans, we can mention volcanic ash, calcined clay, metakaolin and zeolite.

B-Synthetic pozzolans. Synthetic pozzolans are materials that are considered by-products in production processes. The main sources of production of these materials are furnaces that produce raw iron, steel, copper, nickel, lead, silicon, and ferrosilicon alloys, and power plants that use coal as fuel. Among the artificial pozzolans, we can mention microsilica, fly ash, and nanosilica (Aghazadeh et al., 2017). The effect of pozzolanic materials on the mechanical properties of concrete:

In general, the use of pozzolanic materials in concrete improves many mechanical properties of concrete. Among the features of concrete containing pozzolan are:

- Reducing the tendency of concrete to water.
- Increasing adhesion and reducing efficiency.

As mentioned, if pozzolanic materials are used, the calcium hydroxide released due to the hydration process turns into calcium silicate hydrate (C-S-H), which increases the adhesion and decreases the efficiency of concrete mixtures .Therefore, to maintain the efficiency of concrete, by increasing the amount of pozzolans, the amount of water used must also be increased or super-lubricant should be used (Sarabi et al., 2023- b).

- Increasing initial and final capture time:
- The time of the initial and final setting increases slightly when using pozzolanic materials.

## Methodology

In this thesis, the effect of using different percentages of glass fibers in samples containing microsilica, metakaolin, and nanosilica has been investigated. Also, the influence of pre-mix and spray methods in making concrete reinforced with glass fibers on the mechanical properties of this concrete has been investigated. Therefore, cubic samples with dimensions of 100*100*100 mm were made to check the compressive strength, and prismatic samples with dimensions of 13*50*350 mm 69 were made to check the bending resistance and strength of the samples.

Concrete reinforced with glass fibers is cement-filled concrete with a relatively low water-to-cement ratio (W/CM). The recommended ratio of water to cement for this concrete is about 0.35-0.33 and the ratio of sand to cement is about 1-0.75. Because the main purpose of this thesis is to compare the effects of pozzolanic materials and glass fibers on the mechanical properties of concrete reinforced with glass fibers in pre-mix and spray methods, in all mixing designs, water ratios It is fixed to cement materials and sand-to-cement materials and is considered equal to 0.35 and 1, respectively.

In the spray method, to prepare the control design, a design was made without the use of fibers and pozzolanic materials. To prepare samples reinforced with 4% fibers (based on the weight of concrete), two mixing designs replacing 10% and 15% weight of cement with metakaolin and two designs replacing 10% and 15% by weight of cement with metakaolin and also two The design was made by replacing 0.75% and 1.5% nano-silica.

In this method, to prepare samples containing 6% fibers, all the mentioned designs were made with 6% glass fibers.

In the spray method, glass fibers were used in the amount of 4% and 6% by weight of concrete, i.e. 88 and 132 kg/m3, respectively, in the construction of the samples.

In the preparation of the samples by the premix method, all the mentioned mixing designs were made in the presence of 1.5% and 2.5% glass fibers.

How to calculate mixing plans

***First step*** - In this step, the amount of glass fibers used for each mixing plan is calculated.

For this purpose, first the amount of fibers in one cubic meter of concrete, and then the weight of the fibers used in the mixing plan is determined.

Fiber% * U (kg/m3) = Wf (1)

$$V_f = \frac{W_f}{G_f \times 1000}$$

U = specific weight of glass fiber reinforced concrete
Wf = weight of fibers in one cubic meter of concrete
$V_f$ = volume of fibers in one cubic meter of concrete
$G_f$ = fiber density

***Second step***- In this step, to calculate the amount of cement used, the volumetric method has been used.

In other words, the volume of cement to make one cubic meter of concrete is obtained from the difference of the ingredients of concrete except cement (Sarabi, M., et al., 2023).

1= Vf +Vw + Vc + Vs +Vmk + Vsf + Vns + Vsup+ A

Considering that the weight of cement materials is the total weight of cement and pozzolanic materials used, as well as the ratios of water to cement and sand to cement, are considered equal to 0.35 and 1 respectively (W/CM) =0.35 and S/CM=1), the weight of cement in the mixing plan is obtained as follows:

As it is known, WCM, which represents the weight of cement materials in one cubic meter of concrete, can be calculated from the equation.

$$WCM = WC + mk \times WCM + sf \quad (2)$$

$$WCM + ns \times WC \quad (3)$$

$$1 - V_f - A = \frac{0.35 \times W_{CM}}{1000} + \frac{(1 - \%pozzolan)W_{CM}}{G_c \times 1000} + \frac{W_{CM}}{1 \times G_s \times 1000} + \frac{\%pozzolan \times W_{CM}}{G_{pozzolan} \times 1000} + \frac{sup \times W_{CM}}{G_{sup} \times 1000} \quad (4)$$

WCM = weight of cement material in one cubic meter of concrete

MK, sf, ns, amounts of metakaolin, micro-silica, nano-silica, and super lubricant according to the weight percentage of cement materials.

A = volume of air

***Step 3*** - Determining the weight of pozzolanic and super-lubricating materials.

Considering that pozzolanic and super-lubricating materials are considered in terms of the weight percentage of cement materials, calculating the weight of these materials, is done as follows:

***Step 4*** - Given that the S/CM ratio is considered to be one in this research, to determine the amount of sand used, the weight of sand should be considered equal to the weight of cement materials used.

***Fifth step*** - The amount of cement used is calculated as follows:

$$WC = WCM - \text{percentage of pozzolanic material} * WCM \quad (5)$$

***The sixth step*** - calculating the weight of water used (Ww)

Ww= 0.35 * WCM

We = weight of water used in one cubic meter of concrete. (6)

How to mix materials and make samples. There are different methods for mixing and making concrete samples .The way of mixing and making concrete samples is effective in the level of efficiency and smoothness of concrete .Due to the sharp reduction of concrete performance in the presence of glass fibers and pozzolanic materials, the method of mixing these materials requires great precision .In this thesis, two methods of spraying and premixing were used to make the samples .For this purpose, how to mix materials and make samples in these two methods will be examined separately.

**Results and Discussion**

Despite the remarkable characteristics of concrete, such as compressive strength, long life, being available and cheap, concrete is a brittle material and performs extremely poorly under bending and tensile loads. With the increase of tensile or bending loads, the cracks produced on the surface of the concrete become larger and eventually cause brittle cracks in the concrete.

The use of steel reinforcement reinforces concrete under tensile loads; however, the use of these reinforcements increases the finished weight of the concrete sections and makes the concrete out of homogeneity. Since concrete sections with low thickness and weight are sometimes needed, it is impossible to use steel reinforcement in the construction of these products. In this situation, glass fibers are used to improve the behavior of concrete under tensile and bending loads. Concrete reinforced with glass fibers can be used to make parts in different shapes and designs.

In the past, this concrete has only been used in the production of products with non-structural applications in building repairs, sewer linings, tunnel linings, riverbed protective walls, and sound barriers. But in recent years, this concrete has shown acceptable results as a material with structural applications. With time, glass fibers show weak points in the concrete environment and affect the mechanical properties of concrete. Therefore, in this research, an attempt has been made to prevent damage to glass fibers over time by using pozzolanic materials such as microsilica, metakaolin, and nanosilica.

A brief overview of the activities carried out in the current research. The purpose of this research is to investigate and compare the effect of different percentages of glass fibers and pozzolanic materials on compressive strength, bending strength, and strength indices of concrete reinforced with glass fibers. Therefore, glass fiber-reinforced samples were made by premixing and spraying.

Based on this, cubic samples with dimensions of 100 x 100 x 100 mm were prepared to check the compressive strength, and prismatic samples with dimensions of 13 x 50 x 350 mm were prepared to check the bending strength and strength of the samples. Because the main purpose of this thesis is to compare the effects of pozzolanic materials and glass fibers on the mechanical properties of concrete reinforced with glass fibers, in all mixing plans, the ratios of water to cement materials (W/ CM) and sand to cement (S/CM) were considered constant and equal to 0.35 and 1, respectively.

To make samples by pre-mix method, in addition to preparing a control design (without fibers and pozzolanic materials), to prepare samples reinforced with 1.5% glass fibers, two mixing designs with 10% replacement and 15% micro-silica, two designs with 10% and 15% replacement of metakaolin, and two designs with replacement of 0.75% and 1.5% nano-silica were made. In this method, to prepare samples containing 2.5% glass fibers, all the designs mentioned were made with 2.5% glass fibers.

In the premix method, glass fibers were used in the amount of 1.5% and 2.5% by weight of concrete, i.e. 33 and 55 kg/m3, respectively, in the construction of the samples. To investigate changes in compressive strength in this method, the samples were tested after 7 and 28 days. To investigate the bending behavior of the samples made by the premix method, the samples were studied three times 7, 28, and 90 days. According to the mentioned materials, a total of 225 concrete samples were made in the premix method.

In the spray method for preparing samples reinforced with 4% fibers, two mixing plans with 10% and 15% replacement of micro silica, two plans with 10% and 15% replacement of metakaolin, and two plans with 0.75% and 5% replacement of 1% nano-silica was made. In this method, to prepare samples containing 6% fibers, all the mentioned designs were made with 6% glass fibers. In the spray method, glass fibers were used in the amount of 4% and 6% by weight of concrete, i.e. 88 and 132 kg/m3, respectively, in the construction of the samples. The samples were made by spray method based on BS-EN 1170-5 standard and using the machine available in the Disman factory.

In the next step, the wash-out test was performed to determine the percentage of glass fibers used on the concrete surface, according to the BS-EN 1170-2 standard, on the fresh phase of concrete. In the spray method, only the bending behavior of the sample was investigated. In this method, to investigate the bending behavior, the samples were tested three times at 7, 28, and 90 days. Also, to check the bending strength, three samples were made from each of the designs made by the spray method.

According to the mentioned contents, in the spray method, a total of 126 concrete samples were subjected to the four-point bending test. After performing compressive strength and four-point bending tests, the obtained results were analyzed using the prepared diagrams. Finally, the role of parameters such as the type and amount of pozzolanic materials, the percentage of glass fibers used, and the production method of concrete reinforced with glass fibers on the compressive strength, bending strength, and strength of the samples were investigated.

## Conclusion

In this section, the influence of glass fibers and pozzolanic materials on each of the characteristics of compressive strength, bending strength, and strength of the samples has been investigated. The reason for the increase in the compressive strength of the samples reinforced with glass fibers due to the use of pozzolanic materials is the filling and pozzolanic properties of these materials. Pozzolanic materials react with calcium hydroxide in concrete and by producing more cement gel, it causes the concrete to become denser, which also increases the compressive strength. The use of nano-silica along with glass fibers in concrete causes a sharp decrease in concrete efficiency.

In this condition, the lowest amount of compressive strength in the samples reinforced with glass fibers corresponds to the samples reinforced with 2.5% glass fibers and 1.5% nano-silica. Arming samples with glass fibers in both premix and spray methods significantly increases the modulus of rupture. According to the obtained results, it is clear that with time from 7 days to 90 days, the modulus of rupture in the samples reinforced with glass fibers in both premix and spray methods, due to the damage caused to the glass fibers in the concrete environment, has decreased.

These materials show that the modulus of rupture of concrete reinforced with glass fibers depends to a large extent on the condition of the glass fibers in the concrete the use of pozzolanic materials has significantly increased the modulus of rupture of concrete reinforced with glass fibers in both premixed and sprayed methods. If pozzolanic materials are used in samples reinforced with glass fibers, the intensity of the decrease in modulus of rupture gradually decreases over time.

The modulus of rupture of the sprayed samples is higher than that of the premixed samples. Because the spray concreting method, is done with the help of air pressure and in the form of spraying, the glass fibers are uniformly dispersed on the surface of the concrete and higher-quality concrete is produced. In this condition, it is possible to use glass fibers with higher percentages than the premix method. In the spray method, the modulus of rupture increases first by increasing the amount of glass fibers; but as the amount of glass fibers continues to increase, the modulus of rupture goes down. According to these results, the improvement of the modulus of rupture compared to the control samples has an increasing trend with an increasing number of glass fibers from 4% to 5.6% and a decreasing trend for values greater than 5.6%. In samples made by the spray method, the highest modulus of rupture is related to samples reinforced with 4.5% glass fibers and 15% metakaolin (Aghazadeh et al., 2018).

In this condition, the lowest modulus of rupture in designs made by the spray method is related to samples reinforced with 1.6% glass fibers and 1.5% nano-silica. By examining the samples after the test, it was observed that the failure occurred in brittle form in the samples without glass fibers; but the failure in samples reinforced with glass fibers has been completely gradual and soft. In this situation, in the samples made by the spray method, the modulus of rupture and displacement of the samples until the moment of failure had much higher values than the samples made by the premix method.

In samples made by the premix method, the maximum bearable load in concrete is approximately the same as the load at the end of the elastic zone (at the moment of the first crack); While the samples made by the spray method still show an increase in load after cracking. According to the obtained results, it can be seen that with time from 7 to 28 days, the specific compressive strength of cement and also the specific compressive strength of the pozzolanic effect have increased. The use of pozzolanic materials such as microsilica and metakaolin has increased the specific strength of cement and the specific resistance of the pozzolanic effect (Gheitarani et al., 2020).

Accordingly, by increasing the use of these materials from 10% to 15%, the contribution of pozzolanic materials to the compressive strength and modulus of rupture of the samples has increased; But if nano-silica is used, with the increase in the amount of use of this material, the contribution of pozzolanic materials to the compressive strength and modulus of rupture of samples containing nanosilica has decreased. As the age of the samples increased from 7 days to 90 days, the specific modulus of rupture of cement decreased; this is even though no specific trend can be seen in the changes of the specific modulus of rupture of the pozzolanic effect over time.

In general, the use of glass fibers in concrete increases the strength of concrete. According to the obtained results, it can be seen that with the increase in the amount of glass fibers, the I10 and I20 indices increase strongly. By examining the obtained results, it can be seen that the values of I5 and I10 indices in the samples containing micro-silica and metakaolin have increased compared to the samples without pozzolanic substances. According to these results, the highest values of the mentioned indices are related to the samples containing metakaolin. In the pre-mix method, it is observed that after 28 days, the final rupture occurs in many mixing designs at a deformation less than the deformation equivalent to 5/10 times the moment of the first crack. This issue occurs more intensively after 90 days (Khanian et al., 2013).

In the samples made by the spray method, with time, the values related to the I20 index have decreased. The damage caused to the glass fibers caused by the alkaline environment of concrete and the cement hydration process has caused the decrease of I20 index values over time. In the spray method, the I20 index has an increasing trend with increasing the amount of glass fibers from 4% to about 5.6% and a decreasing trend for values greater than 5.6%. In this condition, the highest values of the I20 index correspond to samples reinforced with 4.5% glass fibers and containing 15% metakaolin. According to the obtained results, the lowest values of strength indices are related. To samples reinforced with glass fibers and containing nano-silica.

In samples containing nano-silica, with the increase in the use of glass fibers and nanosilica, the reduction of strength indices in samples armed with glass fibers has increased. As the amount of glass fibers increases, after the first crack (LOP), the load increases with a smaller slope. In this situation, in the spray method, due to the amount of glass fibers than the samples made in the premix method, after the first crack (LOP), the load increases with a lower slope. In this condition, the value of MOR exceeds LOP, and endurance increases.

***Suggestions for future research***. To conduct further research, the following suggestions are made. In this research, samples were processed in 20% water. To check the mechanical properties of concrete reinforced with glass fibers, other processing methods such as processing with polymer materials can be used. Because the mechanical properties related to glass fibers change over time; Therefore, it is suggested that to check the durability of concrete reinforced with glass fibers, the mechanical properties of this concrete in intensified conditions such as placing samples in hot water, freezing and thawing cycles, and wet and drying cycles, be studied.

The effect of using glass fibers with different dimensions on the mechanical properties of concrete reinforced with glass fibers should be investigated. The use of different types and lengths of glass fibers can be fruitful to better investigate the role of fiber length on different parameters of bending strength. Considering that in this research, the ratios of water to cement and sand to cement were considered constant. It is suggested that this research be done for different proportions of water to cement and sand to cement. The effect of different percentages of glass fibers and pozzolanic materials on the tensile behavior of concrete reinforced with glass fibers should be investigated as an important factor in the design of this concrete.

**References**

Aghazadeh, M., Karimzadeh, I., & Ganjali, M. R. (2019). Dextran grafted nickel-doped superparamagnetic iron oxide nanoparticles: Electrochemical synthesis and characterization. Journal of Nanostructures, 9 (3), 531-538.

Aghazadeh, M., Karimzadeh, I., Ganjali, M. R., & Malekinezhad, A. (2017). Al3+ doped Fe3O4 nanoparticles: a novel preparation method, structural, magnetic and electrochemical characterizations. International Journal of Electrochemical Science, 12 (9), 8033-8044.

Aghazadeh, M., Karimzadeh, I., Ganjali, M. R., & Maragheh, M. G. (2018). Electrochemical fabrication of praseodymium cations doped iron oxide nanoparticles with enhanced charge storage and magnetic capabilities. Journal of Materials Science: Materials in Electronics, 29, 5163-5172.

Aydin, A. C., Yaman, Z., Ağcakoca, E., Kiliç, M., Maali, M., & Aghazadeh Dizaji, A. (2020). CFRP effect on the buckling behavior of dented cylindrical shells. International Journal of Steel Structures, 20, 425-435.

Dizaji, A. A. . (2024). Dynamic analysis of high-rise residential structures through the cone method. Edelweiss Applied Science and Technology, 8(6), 1895–1914. https://doi.org/10.55214/25768484.v8i6.2355

Dizaji, A. A., Kiliç, M., Maali, M., & Aydin, A. C. (2023). Buckling behaviour of dented short cylindrical shells retrofitted with CFRP. Proceedings of the Institution of Civil Engineers-Structures and Buildings, 176 (1), 62-75.

Farrokhirad, E., & Gheitarani, N. (2024). How Green Wall Imploratory Strategies Can be Facilitated and Optimized through Public Engagement?. European Online Journal of Natural and Social Sciences, 13 (2), pp-128.

GHADARJANI, R., & GHEITARANI, N. (2013). Methods for enhancing public participation in the rehabilitation and renovation of deteriorated housing (case study: Joulan neighborhood in the Hamedan City). a

Ghadarjani, R., Gheitarani, N., & Khanian, M. (2013). Examination of city governorship pattern and citizen participation as a new approach to city management in region 5 of Isfahan municipality using T-test in SPSS. European Online Journal of Natural and Social Sciences, 2 (4), pp-601. b

Gheitarani, N., Arash Sohrabi, S., Naghibi Iravani, S., & Dehghan, S. (2024). Analyzing the Mechanism of the Possible Effect of Place Attachment of Residents of Iranian Neighborhoods in Improving the Level of Quality of Life (Study Example: Joolan Neighborhood in Hamedan City). European Online Journal of Natural and Social Sciences, 13 (1), pp-42. b

Gheitarani, N., El-Sayed, S., Cloutier, S., Budruk, M., Gibbons, L., & Khanian, M. (2020). Investigating the mechanism of place and community impact on quality of life of rural-urban migrants. International Journal of Community Well-Being, 3, 21-38.

Gheitarani, N., Ghadarjani, R., Kahvand, M., & Mehrabadi, S. A. M. (2013). Explaining the effective measures in decreasing the vulnerability of urban area against earthquake using AHP model (case study: Tehran, a metropolis). Journal of Basic and Applied Scientific Research, 3 (8), 675-681.

Gheitarani, N., Norouzian M. M. & Safaei-Mehr, M. (2024). Space Configuration and Identity of Urban Neighborhoods. European Online Journal of Natural and Social Sciences, 13(3), pp-329-347. b

Gheitarani, N., Norouzian, M. M., Safaei-Mehr, M. (2024). Space Configuration and Identity of Urban Neighborhoods. European Online Journal of Natural and Social Sciences, 13 (3), 290-308. a

Gheitarany, N., Mosalsal, A., Rahmani, A., Khanian, M., & Mokhtari, M. (2013). The role of contemporary urban designs in the conflict between vehicle users and pedestrians in Iran cities (case study: Hamedan City). World Applied Sciences Journal, 21 (10), 1546-1551.

Ghourchi, M., Safaeimehr, M., Kazemian, G., & Sadeghi, F. (2018). ASSESSING THE FUNCTION OF NEW SHOPPING CENTERS IN FORMATION OF GLOBALIZATION OF CONSUMPTION (CASE STUDY: MUNICIPAL DISTRICTS 1 AND 2 OF TEHRAN). Вісник Національної академії керівних кадрів культури і мистецтв, (1).

Kahvand, M., Gheitarani, N., Khanian, M. O. J. T. A. B. A., & Ghadarjani, R. A. Z. I. E. H. (2015). Urban solid waste landfill selection by SDSS. Case study: Hamadan. Environment Protection Engineering, 41 (2), 47-56.

Karimimansoob, V., Mahdaviparsa, A., Sadigh Sarabi, M., & Safaei-Mehr, M. (2024). Application of BIM in Energy Conservation in Low-Cost Housing in Case of Study in Dallas Independent School Residential District, Texas. European Online Journal of Natural and Social Sciences, 13 (3), pp-188. a

Karimimansoob, V., Safaei-Mehr, M., Mehdi Norouzian, M., & Gheitarani, N. (2024). Scrutinizing of City Taxes Effects on Final Housing Price in Hamedan. European Online Journal of Natural and Social Sciences, 13(3), pp-235. b

Khanian, M., Bolouhar, B., Gheitarany, N., & Nezhad, S. M. (2013). Studying the causes of vitality in traditional markets of Iran (Case Study: Shoemaking Order of Central Market of Hamadan). World Applied Sciences Journal, 22 (6), 831-835.

Khanian, M., Serpoush, B., & Gheitarani, N. (2019). Balance between place attachment and migration based on subjective adaptive capacity in response to climate change: The case of Famenin County in Western Iran. Climate and Development, 11 (1), 69-82.

Maleki, M., Gheitaran, N., El-Sayed, S., Cloutier, S., & Gaelle Giraud, E. (2024). The development and application of a localised metric for estimating daylighting potential in floor plate. International Journal of Ambient Energy, 45 (1), 2277310.

MM Norouzian, MS Sarabi. (2023). Analyzing the dynamic data of Mashhad metro line 1 tunnel using seismic table. ISAR Journal of Science and Technology. 1 (2), 1-9.

MM Norouzian; N Gheitarani. (2023). The Impact of Commercial Sectors on Environmental Quality: A Case Study of Tabriz's Ecosystem and Financial Landscape. International Journal of Advanced Multidisciplinary Research and Studies, 3 (6), 1553-1559.

MSS Mohammad., Mehdi Norouzian (2023). Analyzing the dynamic data of Mashhad metro line 1 tunnel using seismic table. ISAR Journal of Science and Technology 1 (1), 1-9.

Naghibi Iravani, S., Arash Sohrabi, S., Gheitarani, N., & Dehghan, S. (2024). Spatial Configuration as a Method to Measure the Actual and Potential Ability of Spaces Used by Indoor and Outdoor Users. European Online Journal of Natural and Social Sciences, 13 (2), pp-90. a

Naghibi Iravani, S., Karimimansoob, V., Arash Sohrabi, S., Gheitarani, N., & Dehghan, S. (2024). Applying Fuzzy Logic and Analysis Hierarchy Process (AHP) in the Design of Residential Spaces; Case of Study: Arak City. European Online Journal of Natural and Social Sciences, 13 (2), pp-144.

Naghibi Iravani, S., Sohrabi, S. A., Gheitarani, N., & Dehghan, S. (2024). Providing a Pattern and Planning Method for Footpaths and Sidewalks to Protect Deteriorated and Vulnerable Urban Contexts. European Online Journal of Natural and Social Sciences, 13 (1), pp-1.

Norouzian, M. M. (2024). Investigating the qualitative components of meaning and the role of the endowment tradition in Iranian urban spaces. Edelweiss Applied Science and Technology, 8(6), 477-490. https://doi.org/10.55214/25768484.v8i6.2104.

Norouzian, M. M., & Gheitarani, N. The Impact of Commercial Sectors on Environmental Quality: A Case Study of Tabriz's Ecosystem and Financial Landscape.

Norouzian, M. M., & Gheitarani, N. The mechanism of using the geographic information system in detecting unsafe spaces in the municipal areas of big cities (Investigation of unsafe places in the city of Dallas, Texas, USA)

Norouzian, M. M., & Sarabi, M. S. (2023). Analyzing the dynamic data of Mashhad metro line 1 tunnel using seismic table. ISAR Journal of Science and Technology, 1(2), 1-9.

Norouzian, M. M., Gheitarani, N. (2024). Analysis and Determination of Factors Affecting Flexibility (UR) and Urban Sustainability (US). European Online Journal of Natural and Social Sciences, 13(3), pp-305-329.

Sadigh Sarabi, M., Sohrabi S. A., Dehghan, & Gheitarani, N. (2024). Presenting a Selected Method for the Industrial Use of Roller Concrete through Pavement. European Online Journal of Natural and Social Sciences, 13(3), pp-290-305.

Safaei-Mehr, M. (2024). The Impact of Artificial Intelligence on Gender Equality in the Workplace: An Economic Geography Perspective. European Online Journal of Natural and Social Sciences, 13 (3), 309- 332.

Samami, H., Naghibi Iravani, S., Arash Sohrabi, S., Gheitarani, N., & Dehghan, S. (2024). Evaluation and Optimization of Building Greening Methods in Four Different Climates Using Building Information Modeling (BIM). European Online Journal of Natural and Social Sciences, 13 (1), pp-27.

Sarabi, M. S., Norouzian, M. M., & Karimimansoob, V. (2023). Analyzing and investigating the effects of Naqadeh earthquake aftershocks in West Azerbaijan on the results of probabilistic seismic risk estimation using clustering analysis. ISAR Journal of Science and Technology, 1(1), 38-45. a

Sarabi, M. S., Sohrabi, S. A., Dehghan, S., & Gheitarani, N. Impact on Seismic Risk Analysis of Possible Pulse in Nearby Areas. b

Zaker Haghighi, K., Gheitarani, N., Khanian, M., & Taghadosi, R. (2014). Examination of effects of urban street configuration on the amount of commercial buildings establishment (according to natural movement theory), Case study: Hamedan. European Online Journal of Natural and Social Sciences, 3 (1), pp-20.

Zakerhaghighi, K., Khanian, M., & Gheitarani, N. (2015). Subjective quality of life; assessment of residents of informal settlements in Iran (a case study of Hesar Imam Khomeini, Hamedan). Applied research in quality of life, 10, 419-434.