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**Akymbek Abdykalykov**

Doctor of Technical Sciences, Professor  
Kyrgyz State Technical University named after I. Razzakov  
720044, 66 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic  
<https://orcid.org/0009-0006-7260-8738>

**Turatbek Kasymov**

PhD in Technical Sciences, Associate Professor  
International University of Innovation Technologies  
720048, 1/17 Ankara Str., Bishkek, Kyrgyz Republic  
<https://orcid.org/0000-0003-3039-2001>

**Bakytbek Barpiev**

PhD in Physical and Mathematical Sciences, Associate Professor  
Institute of Physics named after Zh. Zheenbaev of the National Academy of Sciences of Kyrgyz Republic  
720071, 265A Chui Ave., Bishkek, Kyrgyz Republic  
<https://orcid.org/0009-0006-0369-2964>

**Taalaibek Bolotov**

PhD in Technical Sciences, Associate Professor  
Kyrgyz State Technical University named after I. Razzakov  
720044, 66 Ch. Aitmatov Ave., Bishkek, Kyrgyz Republic  
<https://orcid.org/0009-0009-9556-8945>

**Nurgul Kudaibergenova**

Senior Researcher  
State Institute of Earthquake Resistant Construction and Engineering Design  
720048, 2 Ch. Valihanov Str., Bishkek, Kyrgyz Republic  
<https://orcid.org/0009-0008-5748-5463>

## **Investigation of the uniform distribution of basalt fibre in a foam concrete mixture**

**Abstract.** This research aimed to study the impact of uniform basalt fibre reinforcement on the mechanical properties of foam concrete, such as compressive strength, bending and frost resistance. A comprehensive methodology was used, which included the preparation and testing of foam concrete mixtures containing basalt fibre, and conducting strength and frost resistance tests using specialised equipment. As a result of the conducted research, it was found that the uniform addition of basalt fibre to the foam concrete composition significantly improves its mechanical properties. The compressive strength of reinforced foam concrete has increased by 30-40% compared to conventional foam concrete, especially noticeable in the early stages of hardening. For example, after 28 days of hardening, the compressive strength of reinforced foam concrete was 2.65 MPa, whereas for the non-reinforced analogue, it reached only 1.8 MPa. In addition, reinforced foam concrete has demonstrated a significant improvement in bending strength. After 28 days of hardening, the bending strength was 1.8 MPa, which is 56% higher compared to conventional foam concrete, which had this indicator

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\*Corresponding author



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of 1.15 MPa. This suggests that basalt fibre effectively prevents the development of microcracks, increasing the overall durability of the material. In addition, in the course of the study, an improvement in the frost resistance of foam concrete reinforced with basalt fibre was revealed. After 30 cycles of freezing and defrosting, reinforced foam concrete showed a lower weight loss of 1.8% compared to conventional foam concrete, in which this figure reached 3.7%. This indicates the high resistance of the material to cyclic climatic influences, which makes it more suitable for use in extreme climatic conditions. Thus, the results obtained confirm a significant improvement in the mechanical properties of reinforced foam concrete, demonstrating that basalt fibre reinforcement makes it a more reliable and durable material for various construction applications

**Keywords:** foam concrete; reinforcement; basalt fibre; cement mortar adhesion; compressive strength; bending strength; frost resistance

## INTRODUCTION

Foam concrete is a lightweight building material that has gained its popularity due to its excellent thermal insulation properties, low weight, and cost-effectiveness. It is a mixture of cement, water, sand, and a special foam generator that forms air bubbles in the solution. Such bubbles help to reduce the density of the material and improve its thermal insulation qualities. Due to these characteristics, foam concrete is used in various industries, and is in demand in construction technologies. However, despite its advantages, foam concrete has certain limitations in terms of strength and durability, which can be improved with reinforcement. The problem is that the uniform distribution of reinforcing fibres, such as basalt fibre, in a foam concrete mixture is a difficult task. Improper fibre distribution can lead to the appearance of local defects, reducing the strength characteristics and durability of the material (Hezentsvei & Bannikov, 2020). This makes it difficult to achieve optimal performance properties of foam concrete and limits its use in more demanding construction projects. In this regard, studies aimed at the investigation of the uniform distribution of basalt fibre in a foam concrete mixture can significantly improve its operational characteristics. Such studies may determine the most effective methods of integrating basalt fibre into foam concrete to minimise problems with uneven distribution and improve the strength and durability of the material. Ultimately, this will help to improve existing foam concrete reinforcement technologies, offering new solutions to improve its quality and expand its applications in construction.

One of the main factors influencing the effectiveness of reinforcement of foam concrete with basalt fibre are the methods of uniform distribution of fibre and its interaction with other components of the mixture (Kutsenko & Kutsenko, 2022). The study by R. Lukpanov *et al.* (2021) noted the influence of mixing methods on the uniformity of foam concrete, emphasising that the use of different mixing methods allows for different degrees of distribution of components in the mixture. O. Gencel *et al.* (2022) focused on assessing the effect of a certain concentration of basalt fibre on the strength and resilience of foam concrete, showing that increasing the fibre content to a certain level significantly improves the mechanical properties of the material. A. Sagyndykov *et al.* (2023) assessed the impact

of basalt fibre on the distribution and structural characteristics of foam concrete, finding that the use of fibre with a certain length and diameter has a noticeable effect on improving compressive strength and crack resistance. Such studies emphasise the need for an integrated approach to the choice of mixing methods, fibre concentration, and its characteristics to ensure maximum efficiency and durability of reinforced foam concrete.

In addition, one of the determining factors of reinforcement of foam concrete with basalt fibre is the quality of interaction of fibre with the matrix of cement mortar. X. Shi *et al.* (2023) reviewed the process of adhesion of basalt fibre to cement mortar, where it was found that pretreatment of fibre with special modifiers significantly improves adhesion to the matrix, contributing to a more uniform distribution and improved mechanical properties of the material. The study by O.Y. Bayraktar *et al.* (2023) analysed the basalt fibre and cement mortar, revealing that optimising the hardening process allows for better properties and structure. M. Khan *et al.* (2022) evaluated the effect of temperature on the fibre integration process, demonstrating that at high temperatures, an increase in the temperature of the mixture can lead to improved fibre distribution, but also requires precise control of conditions to prevent material degradation. Thus, the mentioned studies confirm the importance of investigating the process of interaction of fibre with cement mortar, and the need for further research to fully understand and optimise the technology of reinforcement of foam concrete with basalt fibre.

For the assessment of the effectiveness of basalt fibre in foam concrete, it is important to conduct a comprehensive analysis of the impact on key features of the material, such as compressive strength, bending strength, temperature resistance, and resilience. The study by Q. Fu *et al.* (2022) evaluated changes in the strength of reinforced foam concrete with different concentrations of basalt fibre, showing that the use of fibre improves strength characteristics, providing a significant increase in bending strength. Z. Xue *et al.* (2023) focused on methods for assessing the crack resistance and durability of foam concrete with basalt fibre, finding that basalt fibre reduces the number and width of cracks, contributing to an increase in the durability of the material. In the course of the study, S. Li *et*



al. (2024) analysed basalt fibre’s impact on the qualities of foam concrete, including frost resistance, as a result showing that the uniform distribution of fibre contributes to a better improvement of the studied properties, while uneven distribution can lead to local defects and a decrease in the overall effectiveness of reinforcement. However, despite the results achieved, additional research remains necessary to assess the impact of other mixing methods on the uniformity of fibre distribution and its impact on the long-term performance of foam concrete.

The purpose of this study was to determine the effect of the efficiency of uniform distribution of basalt fibre according to a certain technique on the performance properties of foam concrete. To achieve this goal, tasks were set

that included evaluating the effect of fibre on the mechanical properties of reinforced foam concrete, such as compressive strength, bending strength, and frost resistance, compared with conventional foam concrete.

### MATERIALS AND METHODS

A comprehensive methodology was applied to evaluate the effect of basalt fibre reinforcement of foam concrete on its mechanical and performance properties. First, two mixtures of foam concrete were prepared, which included ordinary foam concrete and foam concrete reinforced with basalt fibre. Portland cement of CEM 1 42.5 N grade produced by Kant Cement Plant (Kyrgyzstan) was utilised for this purpose, which properties are described in Table 1.

**Table 1.** Properties of Portland cement CEM 1 42.5 N

Property	Value
Density, kg/m <sup>3</sup>	3,100
Specific surface area, cm <sup>2</sup> /g	3,500
Beginning of setting, hours	2
End of setting, hours	4
Normal density, %	25

**Source:** developed by the authors

For reinforced foam concrete, basalt fibres manufactured by Aviapromstal (Kyrgyzstan) were added in an

amount of 0.5% of the total volume of the mixture, the characteristics of which are shown in Table 2.

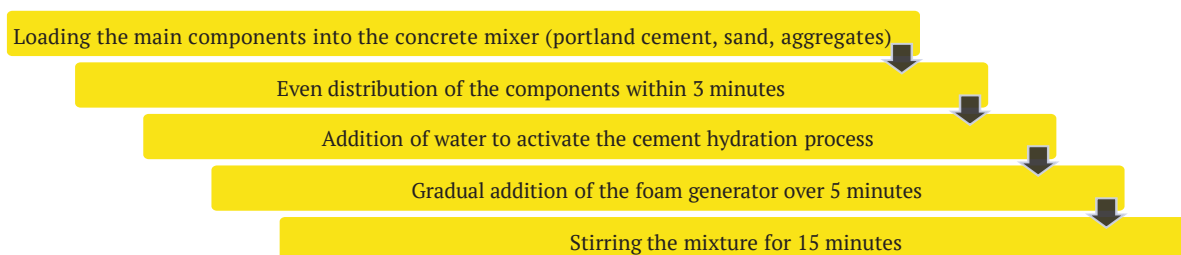
**Table 2.** Characteristics of basalt fibres

Characteristics	Value
Composition	100% basalt
Fibre diameter, µm	13-20
Fibre length, mm	6-12
Density, g/cm <sup>3</sup>	2.63
Tensile strength, MPa	3,000-4,850
Modulus of elasticity, GPa	85-95

**Source:** developed by the authors

For the preparation of foam concrete mixtures, cement and water were added in the amount of 350 and 200 kg/m<sup>3</sup>, respectively. The ratio of cement to water was approximately 0.57. Foam generator PB-2000 (Kyrgyzstan) in the amount of 2 kg/m<sup>3</sup> was used to form a fine-porous structure of foam concrete. Sand, used to increase the density and strength of foam concrete, was added in an amount of 500 kg/m<sup>3</sup>. The density of the sand

was approximately 1,600 kg/m<sup>3</sup>. In addition, during the study, fine gravel of the Gravel-10 brand with a fraction of 5-10 mm was used, which was added in an amount of 150 kg/m<sup>3</sup>. The density of gravel was approximately 1,400 kg/m<sup>3</sup>. All components were thoroughly mixed according to the diagram shown in Figure 1, until a homogeneous mass was achieved using a BM-125 concrete mixer (Kyrgyzstan).



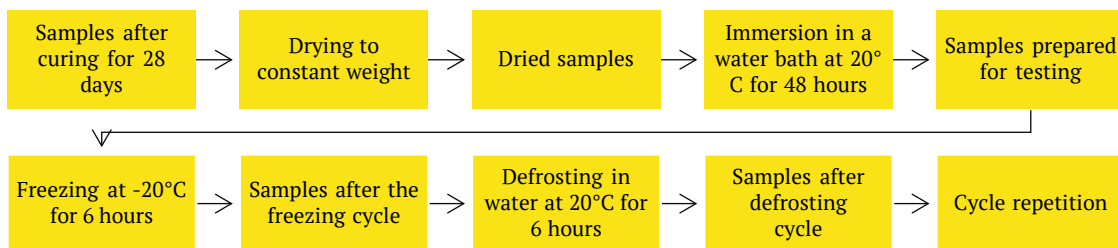
**Figure 1.** Schematic diagram of mixing technology of foam concrete components

**Source:** developed by the authors



After preparing the mixtures, they were poured into moulds to form cubes of 100×100×100 mm and prismatic samples of 100×100×400 mm. After pouring the mixture, the moulds were sealed to avoid the appearance of air bubbles, and left to gain initial strength for 24 hours at a temperature of 20°C. The samples were then removed from the moulds and placed in a water bath at 20°C and 95% humidity until the required age for testing was reached. Compressive strength tests were carried out using a small-sized hydraulic press PGM-1500MG4. The samples were tested for compression after 1, 3, 7, and 28 days of hardening. The test procedure consisted of placing the samples on a pressing table, which was gradually loaded until destruction. The maximum load at which the fracture of the sample oc-

curred was recorded and used to calculate the compressive strength. The MII-100 testing machine was employed to assess the bending strength. The prismatic samples were subjected to loading until destruction, after which the result was recorded. During the tests, the maximum values of bending loads were determined, which allowed calculating the bending strength. Additionally, frost resistance tests were carried out, where the samples were subjected to freezing and defrosting cycles. The tests included measuring weight loss after a certain amount (5, 10, 15, 20, 25, and 30) of cycles of freezing and defrosting, which helped to assess the resistance of foam concrete to frosty conditions. The scheme of frost resistance tests is presented in more detail in Figure 2.



**Figure 2.** Scheme of frost resistance tests

**Source:** developed by the authors

Thus, all the stages of the study helped to obtain a complete understanding of the effect of basalt fibre on the strength and performance characteristics of foam concrete, providing reliable and accurate data for further analysis and application.

## RESULTS

The uniform distribution of basalt fibre in the foam concrete mixture plays a critical role in ensuring optimal mechanical and operational characteristics of the material. Basalt fibre, because of its strong mechanical characteristics and resilience to aggressive media, is used for reinforcing foam concrete, improving its strength, crack resistance, and durability (Kuznetsova & Ivanova, 2023). To achieve the maximum effect from the addition of fibre, it is necessary to ensure its even dispersion across the whole volume of the mixture. This can avoid local concentrations of fibre, which can lead to uneven material properties and potential defects. Basalt fibre is an effective reinforcing component due to its high tensile strength, resistance to corrosion and chemical influences, and heat resistance. When the fibre is evenly distributed in foam concrete, it forms a complex three-dimensional network that effectively prevents the development and spread of cracks in the material. This can significantly improve the various properties of foam concrete, allowing it to withstand heavy loads and impacts without destruction. In addition, the uniform distribution of fibre can help in enhancing the overall structural integrity of the material, increasing its durability and reliability in operation (Amran, 2020).

One of the main parameters used to assess the foamed concrete's mechanical characteristics, and allowing to evaluate the efficiency of uniform distribution of basalt fibre in it, is its compressive strength. This indicator determines the ability of a material to withstand significant compressive loads without breaking or significant deformation. The foam concrete's compressive strength with basalt fibre directly affects its use in building structures where the material is subjected to constant or variable loads (Salami *et al.*, 2022). Compressive strength tests provide important information about the behaviour of foam concrete under load. This determines the maximum load that the material can withstand before the destruction begins. Such data can be used to assess the quality of foam concrete and compliance of its mechanical characteristics with established standards and to help optimise the mixture's composition of foam concrete. By conducting a strength analysis, it becomes possible to adjust and change the proportions of components, add various modifiers, or change production conditions to achieve better material characteristics. This is especially important when developing new grades of foam concrete for specific applications where special properties such as increased strength, lightness or improved thermal insulation are required. In addition, the compressive strength is closely related to other performance characteristics of foam concrete, such as its durability and resistance to external influences. A material with high compressive strength, as a rule, has better resistance to mechanical damage, moisture, and chemicals (Ahmad *et al.*, 2023). This makes it more reliable and durable,





reducing the cost of repair and maintenance of building structures. The results of compressive strength tests con-

ducted with samples of conventional and reinforced foam concrete are shown in Figure 3.

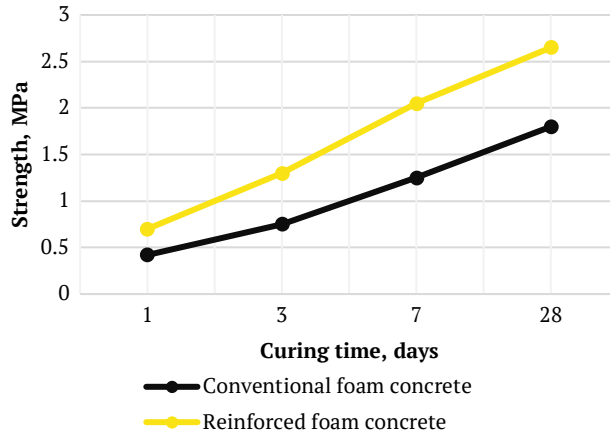


Figure 3. Ultimate compressive strength

Source: developed by the authors

Thus, the results of the tests show that the uniform distribution of basalt fibre in the foam concrete mixture significantly increases the compressive strength of the material at various stages of hardening. After 1 day of hardening, ordinary foam concrete demonstrates a compressive strength of 0.42 MPa, whereas reinforced foam concrete reaches strength of 0.7 MPa. This indicates a significant improvement in strength characteristics due to the addition of basalt fibre. After 3 days of hardening, the compressive strength of ordinary foam concrete increases to 0.75 MPa, and reinforced foam concrete – to 1.3 MPa, confirming a significant improvement in the mechanical properties of foam concrete during reinforcement. After 7 days of hardening, conventional foam concrete reaches a compressive strength of 1.25 MPa,

whereas reinforced foam concrete shows a strength of 2.05 MPa. The uniform distribution of the fibre plays a key role in ensuring these properties, as it contributes to the uniform distribution of stresses throughout the entire volume of the material, preventing local stress concentrations and possible foci of destruction. After 28 days of hardening, conventional foam concrete reaches a compressive strength of 1.8 MPa, while reinforced foam concrete reaches 2.65 MPa. This shows that adding the basalt fibre not only accelerates the strength gain in the early stages, but also provides a long-term enhancement of foam concrete’s mechanical properties. The graph shown in Figure 4 shows the dynamics of the increase in compressive strength when reinforcing foam concrete with basalt fibre.

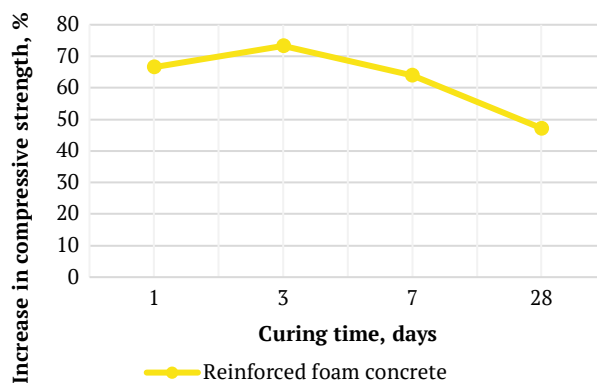


Figure 4. Dynamics of the increase in compressive strength of reinforced foam concrete

Source: developed by the authors

On the first day of hardening, the percentage increase is 66.67%, indicating that reinforcement contributes to the rapid strengthening of the material in the early stages of hardening. This advantage is especially important for structures requiring early formwork removal or

rapid strength gain for further construction work. The 3-day period shows an even more pronounced advantage of reinforced foam concrete, which demonstrates a strength increase of 73.33% compared to conventional foam concrete. Such a significant gain in strength is explained by

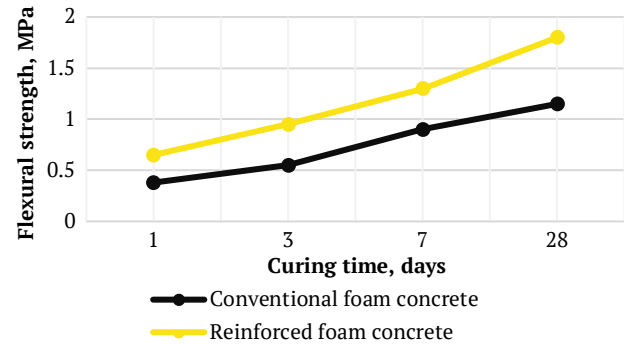


the fact that basalt fibre, evenly distributed throughout the entire volume of the material, forms a mesh structure that efficiently stops the creation and spread of microcracks, thereby increasing the resistance of the material to loads. The percentage increase in strength at the 7-day hardening stage is 64%, which indicates the continued significant influence of basalt fibre on improving the mechanical features of foam concrete. This growth demonstrates that reinforced foam concrete retains its improved characteristics even after some time. In turn, after 28 days, the percentage increase in strength is 47.22%. Although the percentage increase in strength decreases over time, reinforced foam concrete continues to show a significant advantage in compressive strength even at later stages of hardening. One of the main factors contributing to the improvement of compressive strength is the ability of basalt fibre to evenly distribute loads over the entire volume of the material (Yang *et al.*, 2021). As a result, the load is not concentrated in individual areas, but is evenly distributed, which prevents the development of cracks and reduces the likelihood of local damage.

Another factor is that basalt fibre helps to enhance the adhesion between the particles of the cement matrix and aggregates. Since the fibre penetrates into the cement dough and forms strong bonds between its components, this strengthens the material and makes it less susceptible to deformation under the action of compressive forces. Such improved particle-to-particle bonds contribute to a more uniform pressure distribution and an increased ability of the material to withstand high loads, which is especially important for structural elements that experience significant compressive loads (John & Dharmar, 2021). Additionally, it should be emphasised that basalt fibre improves the resistance of foam concrete to internal stress caused by shrinkage and thermal changes. When compressed, internal stresses can lead to cracks, which reduces the strength of the material. Fibre reinforcement helps to neutralise these stresses and reduces the risk of cracking, providing a more stable and reliable structure. This makes reinforced foam concrete more resistant to various operating conditions and increases its durability in construction applications (Yu *et al.*, 2022; Rusho *et al.*, 2024).

Another important characteristic of foam concrete is its flexural strength, which plays a key role in determining its performance properties. Flexural strength characterises the ability of a material to withstand bending forces without breaking and significant deformations. This parameter is especially important for structural elements subject to combined loads, such as floor slabs, wall panels, and other horizontal structures where both vertical and horizontal forces act on the material. It should be noted that increased flexural strength can also assist in enhancing the overall durability of foam concrete. When bending the material, basalt fibre works as microscopic reinforcing rods, taking over part of the load and preventing the development and spread of microcracks. This helps to significantly increase the durability of structures, reduce the need for repairs, and

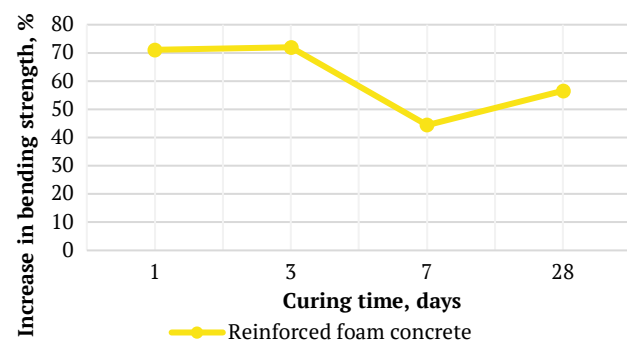
increase the overall reliability of construction sites, making foam concrete with evenly distributed basalt fibre a more effective material for use in construction. The results of bending strength tests conducted with samples of conventional and reinforced foam concrete are shown in Figure 5.



**Figure 5.** Flexural strength test results

**Source:** developed by the authors

The results obtained show that after 1 day of hardening, conventional foam concrete demonstrates a bending strength of 0.38 MPa, whereas reinforced foam concrete reaches a strength of 0.65 MPa. This confirms the noticeable strengthening of the strength properties of the material due to the use of basalt fibre. After 3 days of hardening, the bending strength of ordinary foam concrete is 0.55 MPa, while reinforced foam concrete has values up to 0.95 MPa, which shows an increase in the resistance of the material to bending loads with a uniform distribution of basalt fibre. After 7 days of hardening, conventional foam concrete reaches a bending strength of 0.9 MPa, whereas reinforced foam concrete shows indicators reaching a strength of 1.3 MPa. Ultimately, after 28 days of hardening, conventional foam concrete reaches a bending strength of 1.15 MPa, while reinforced foam concrete reaches 1.8 MPa, demonstrating a continued improvement in mechanical properties over its long service life. The graph shown in Figure 6 shows the dynamics of the increase in bending strength when reinforcing foam concrete with basalt fibre.



**Figure 6.** Dynamics of flexural strength gain of reinforced foam concrete

**Source:** developed by the authors

This graph shows that reinforced foam concrete demonstrates an increase in bending strength by 71.05% compared to conventional foam concrete after 1 day of hardening, which indicates rapid strengthening of the material due to reinforcement in the early stages of hardening. After 3 days, there is also a pronounced advantage of reinforced foam concrete, whose strength gain is 72.73% compared to conventional foam concrete. Such a significant improvement in strength is conditioned by the capacity of basalt fibre to strengthen the connectivity of the foam concrete structure. The percentage increase in strength after 7 days of hardening is 44.44%, which indicates the continued significant influence of basalt fibre on improving the mechanical qualities of foam concrete. Fibre acts as a reinforcing element, distributing loads more evenly and reducing the likelihood of weak points, which helps to increase the overall strength and material's ability to resist bending forces. After 28 days of hardening, the percentage increase in strength is 56.52%. This indicates that, despite the slow-down in strength growth over time, reinforced foam concrete retains a clear advantage in flexural strength even at later stages of hardening.

An important factor is that when bending foam concrete without reinforcement, significant stress concentrations may occur at the sites of microcracks, which can lead to rapid crack development and subsequent destruction of the material. However, when basalt fibre is introduced into the foam concrete, the fibre fibres work as microscopic reinforcements that distribute stresses and prevent the development and spread of microcracks. This, in turn, significantly increases the material's resistance to bending loads (Othman *et al.*, 2020). An additional advantage of the uniform distribution of basalt fibre is the improved adhesion between foam concrete and fibre. When the fibres are evenly distributed throughout the entire volume of the material, each fibre is in close contact with the surrounding foam concrete matrix. This improves the transfer of forces from foam concrete to fibre and vice versa, creating a more durable and uniform structure. As a result, foam concrete with evenly distributed basalt fibre demonstrates higher bending strength compared to non-reinforced foam concrete. In addition, one of the key aspects that allows evaluating the durability and reliability of foam concrete is its frost resistance. This parameter determines the ability of a material to maintain its mechanical properties and structural integrity during multiple cycles of freezing and thawing.

The frost resistance index is especially important for structures that are subject to sudden temperature changes. Low frost resistance can lead to the destruction of the material, deterioration of its strength characteristics and the need for frequent repairs. The foam concrete's resistance to frost demonstrates its ability to withstand cyclical temperature fluctuations without significant loss of strength or cracking. When water freezes in the pores of foam concrete, it expands, which can lead to cracks and disruption of the structure of the material (Zhou & Su, 2023). The results of frost resistance tests conducted

with samples of conventional and reinforced foam concrete are shown in Figure 7.

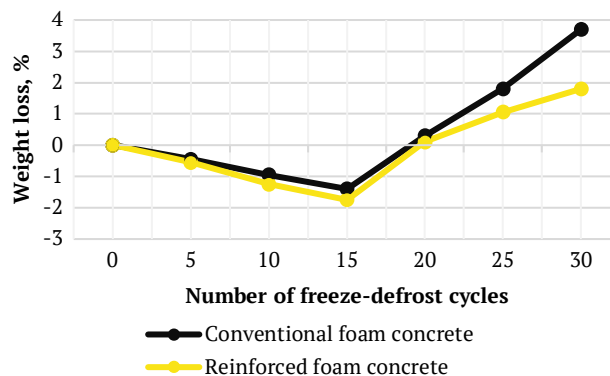


Figure 7. Frost resistance test results  
Source: developed by the authors

These results show how the weight loss of foam concrete differs depending on the number of freezing and defrosting cycles. In the initial stages of testing, up to 5 cycles of freezing and defrosting, both types of foam concrete show negative weight loss values. Ordinary foam concrete loses -0.45%, and reinforced concrete loses -0.55%. Negative values indicate that during this period, both materials, on the contrary, gain weight. This may be due to the fact that moisture in the pores of the material freezes and increases its weight, which indicates the initial stage of moisture accumulation in the foam concrete structure. This situation persists on cycles 10 and 15. Conventional foam concrete shows a weight loss of -0.95% on cycle 10 and -1.4% on cycle 15, while reinforced foam concrete loses -1.25% and -1.75%, respectively. These negative values confirm that at these stages both types of foam concrete continue to gain weight, which may be the result of further accumulation of ice and moisture in their pores. However, reinforced foam concrete demonstrates higher weight gain values, which may indicate its more complex interaction with moisture during the freezing process. After 20 cycles, the weight loss becomes positive. Conventional foam concrete loses 0.3%, while reinforced concrete loses 0.1%. This transition from negative to positive values signals that the initial stages of moisture accumulation are replaced by a stage of its loss. This may be due to the destruction of the structure of the material and the release of accumulated ice, which leads to a loss of weight. Reinforced foam concrete shows less weight loss compared to conventional, which indicates its better behaviour in conditions of frost cycles. At cycles 25 and 30, weight losses increase significantly: conventional foam concrete loses 1.8% at cycle 25 and 3.7% at cycle 30, while reinforced concrete loses 1.05% and 1.8%, respectively. These data confirm that reinforced foam concrete demonstrates lower weight loss at all stages of testing, which emphasises its better frost resistance.

Thus, reinforced foam concrete retains its weight and structural integrity better than conventional, even under prolonged exposure to freezing and defrosting cycles. This



is conditioned by the fact that the basalt fibre used for reinforcement forms a strong mesh structure inside the material, which effectively distributes loads and prevents the development of cracks. Such cracks may result from water freezing and expanding in the pores of foam concrete, which leads to the destruction of the material. Reinforcement prevents the development and expansion of these cracks, thereby reducing the likelihood of weight loss during freezing and defrosting cycles. Moreover, the uniform distribution of basalt fibre enhances the overall strength of the material, which additionally plays a role in its frost resistance. Fibre strengthens the structure of foam concrete, increasing its ability to withstand internal stresses that occur when water freezes inside the material. This helps to prevent damage and deformation, which reduces weight loss during multiple cycles of freezing and defrosting.

## DISCUSSION

A thorough study was conducted of the effect of the basalt fibre mixing technique in a foam concrete mixture with a content of 0.5% of the total volume of the mixture. The main focus was on how the uniform distribution of fibre affects the mechanical qualities of foam concrete. Assessing the impact of the content of basalt fibre in a volume of 0.5%, the study showed that such a number of fibres provides a balance between improving strength and preventing an excessive increase in the viscosity of the mixture, which can make it difficult to process. It was found that the addition of fibre in this concentration leads to an enhancement in the mechanical properties of foam concrete, which makes it more durable and reliable in various climatic conditions. Thus, the uniform distribution of fibre achieved using a special mixing technique confirms the effectiveness of reinforcement of foam concrete with basalt fibre and opens up new opportunities for its use in construction. Y.-F. Li *et al.* (2022) also examined the effectiveness of various concentrations of basalt fibre, as a result revealing that the optimal size and concentration of fibres provides optimal improvement in strength characteristics, while smaller or larger sizes and numbers of fibres lead to a decrease in these effects due to a deterioration in the uniformity of distribution or a rise in the mixture's viscosity. The study by A. Qsymah *et al.* (2023) analysed the durability of reinforced foam concrete under extreme climatic conditions, finally confirming that foam concrete with basalt fibre has the best resistance to temperature and humidity changes. In turn, M. Liu *et al.* (2022) examined the impact of different concentrations of basalt fibre on the microstructure of foam concrete, finding that the optimal concentration of fibre contributed to improving the uniformity of distribution and preventing the development of weak points in the material. Thus, in combination with the findings of the mentioned works, the current study's results emphasise the high efficiency of using basalt fibre at optimal concentrations, which significantly enhances the strength and durability features of foam concrete and expands its potential applications in construction practice.

During the compressive strength tests performed in this study, the characteristics of both conventional foam concrete and foam reinforced with basalt fibre were assessed. For ordinary foam concrete, the compressive strength during the first days of hardening was relatively low, which is typical for this material. At day 1, the compressive strength was 0.42 MPa, which increased to 1.8 MPa after 28 days. In the case of reinforced foam concrete, the results were significantly more impressive. On the first day of hardening, the compressive strength was 0.7 MPa, which is already 66% more than that of conventional foam concrete. The compressive strength of reinforced foam concrete reached 2.65 MPa in 28 days, which is almost 1.5 times higher than that of its non-reinforced counterpart. These results indicate that basalt fibre effectively strengthens foam concrete, increasing its ability to withstand compressive loads. As a result, the reinforcement of foam concrete with basalt fibre significantly expands its possibilities for use in conditions where high strength and durability are required (Sidliarenko, 2023). The study by J. Wang *et al.* (2021) also confirms these findings, showing with their results that the addition of basalt fibre leads to a significant improvement in compressive strength, making the material more suitable for critical structural elements. P.J. Ardhira *et al.* (2023) supplemented these data by discovering during the study that the optimal choice of reinforcing fibres minimises the effect on the viscosity of the mixture and simplifies its processing. H.S. Gökçe *et al.* (2023) revealed that when a certain concentration of various fibres is exceeded, a decrease in compressive strength is observed, which is associated with the formation of excess fibres, which can create local weaknesses in the material. It should be noted that the results of this study, in comparison with the results of the mentioned papers, provide a more detailed understanding of the impact of basalt fibre on the compressive strength of foam concrete, and also emphasise the importance of precise control over the concentration of fibre to achieve maximum performance.

During flexural strength tests, it was discovered that the adding the basalt fibre to foam concrete also significantly improves its characteristics in this indicator. The main test results showed that on the first day of hardening, the bending strength for ordinary foam concrete was 0.38 MPa, while for reinforced foam concrete it reached 0.65 MPa. This represents a 71% increase in bending strength compared to conventional foam concrete, which indicates a significant improvement in resistance to bending loads during the early stages of hardening. After 28 days of hardening, the bending strength of ordinary foam concrete was 1.15 MPa. However, the bending strength of reinforced foam concrete has increased to 1.8 MPa. This is almost 57% more than that of conventional foam concrete, which emphasises the effectiveness of basalt fibre in increasing crack resistance and bending strength. This allows the use of reinforced foam concrete in structures where a combination of high strength and resistance to bending loads is required. D. Falliano *et al.* (2022) studied optimising the





concentration of fibres, as a result, setting the optimal amount of basalt fibre to achieve maximum bending strength. In turn, H. Al-Zubaidi & R. Allouzi (2023) analysed the long-term effects of reinforcement on flexural strength, confirming that basalt fibre retains its effectiveness for a long time, preventing cracks and improving the durability of the material. When comparing the results of this study with the one of the mentioned studies, it should be highlighted that the use of basalt fibre in a concentration of 0.5% shows comparable or even better results in bending strength than in similar studies, which confirms its effectiveness for both early and late stages of foam concrete hardening.

In addition, in the course of this study, a frost resistance test was conducted for ordinary foam concrete and basalt fibre-reinforced foam concrete. In the initial stages of testing, that is, after 5 and 10 cycles, both conventional and reinforced foam concrete showed an increase in weight, indicating water absorption and possibly initial swelling of the material. However, starting from 15 cycles, ordinary foam concrete began to lose weight, which indicates the destruction of the structure and loss of strength under the influence of cyclic freezing and defrosting. The weight loss continued and increased to 3.7% by 30 cycles. Meanwhile, reinforced foam concrete, although it showed a similar trend in the early stages, had significantly better resistance to weight loss. The weight loss of reinforced foam concrete was 1.8% after 30 cycles, which is 2% less than that of conventional foam concrete. These results indicate that basalt fibre enhances the frost resistance of foam concrete, reducing internal damage and improving its ability to maintain structural integrity at extreme temperatures. The study by Y. Guo & H. Yokota (2018) found that under the conditions of freezing and defrosting tests, ordinary foam concrete loses weight much faster, confirming the insufficient resistance of this material to frost-resistant conditions. X. Tan *et al.* (2013) demonstrated that the utilisation of various types of reinforcement, such as polypropylene fibres, improves frost resistance, but not to the same extent as basalt fibre. The results of the study by W. Zhang *et al.* (2016) also confirmed that the addition of steel reinforcing fibres helps to reduce weight loss, but without reaching the level of efficiency observed when using basalt fibre. When evaluating the results obtained and comparing it to the findings of the previous studies, it can be concluded that basalt fibre demonstrates the highest efficiency in improving the frost resistance of foam concrete, providing a significant advantage over other types of reinforcing materials.

Thus, research on improving the properties of foam concrete through reinforcement with various fibres plays a key role in improving its performance and expanding the scope of applications in construction. The analysis of the test results for strength, frost resistance, and other mechanical properties determines the most effective reinforcement methods and identifies the optimal concentrations of additives to achieve the required material qualities. Such research contributes to the development of more

reliable and durable construction solutions, which improve the safety and durability of structures in general.

## CONCLUSIONS

The study found that the uniform reinforcement of foam concrete with basalt fibre has a significant effect on its key mechanical qualities, including compressive strength, bending strength, and frost resistance. Thus, the analysis of compressive strength showed that reinforced foam concrete shows a noticeable improvement compared to conventional foam concrete. At the beginning of hardening, on day 1, the compressive strength of reinforced foam concrete was 0.7 MPa versus 0.42 MPa for the conventional one. This represents an increase of 66% compared to conventional foam concrete. On day 28, the strength of reinforced foam concrete reached 2.65 MPa, which is 47% higher than 1.8 MPa for conventional foam concrete. At all stages of hardening, reinforced foam concrete demonstrated sustained superiority, especially in the early stages, which makes it particularly effective in conditions requiring high compressive strength.

In terms of flexural strength, the results also showed significant improvement. On day 1 of hardening, the bending strength of reinforced foam concrete was 0.65 MPa, which surpasses the standard foam concrete by 71%, which had a strength of 0.38 MPa. On day 28, the bending strength of reinforced foam concrete reached 1.8 MPa, which is 56% higher than 1.15 MPa of conventional foam concrete. These data show that reinforcement is effective both in the early and late stages of hardening, improving bending strength in long-term operation. The frost resistance of reinforced foam concrete is also significantly superior to conventional foam concrete. At the 30<sup>th</sup> test cycle, reinforced foam concrete demonstrated weight loss rates of 1.8%, whereas conventional foam concrete showed 3.7%. This confirms that reinforced foam concrete is more resistant to the effects of freezing and defrosting cycles, which provides it with greater durability and efficiency of use in difficult climatic conditions.

It is worth noting that this study has a limitation in the form of using only one type of basalt fibre during testing, which may not fully reflect all possible variations in the qualities of foam concrete. For further research, the use of various types of fibres and fillers should be considered, including the examination of the impact of these additions on the durability of the material under extreme operating conditions. Another promising area is the investigation of the effect of various additives on the features of reinforced foam concrete, which can improve other performance characteristics such as water resistance and thermal conductivity, expanding the scope of foam concrete in construction.

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## CONFLICT OF INTEREST

None.



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**Акимбек Абдикаликов**

Доктор технічних наук, професор  
Киргизький державний технічний університет ім. І. Раззакова  
720044, просп. Ч. Айтматова, 66, м. Бішкек, Киргизька Республіка  
<https://orcid.org/0009-0006-7260-8738>

**Туратбек Касимов**

Кандидат технічних наук, доцент  
Міжнародний університет інноваційних технологій  
720048, вул. Анкара, 1/17, м. Бішкек, Киргизька Республіка  
<https://orcid.org/0000-0003-3039-2001>

**Бакитбек Барпієв**

Кандидат фізико-математичних наук, доцент  
Інститут фізики ім. Ж. Жеєнбаєва Національної академії наук Киргизької Республіки  
720071, просп. Чуй, 265А, м. Бішкек, Киргизька Республіка  
<https://orcid.org/0009-0006-0369-2964>

**Таалайбек Болотов**

Кандидат технічних наук, доцент  
Киргизький державний технічний університет ім. І. Раззакова  
720044, просп. Ч. Айтматова, 66, м. Бішкек, Киргизька Республіка  
<https://orcid.org/0009-0009-9556-8945>

**Нургул Кудайбергенова**

Старший науковий співробітник  
Державний інститут сейсмостійкого будівництва та інженерного проектування  
720048, вул. Ч. Валіханова, 2, м. Бішкек, Киргизька Республіка  
<https://orcid.org/0009-0008-5748-5463>

## Дослідження рівномірного розподілу базальтової фібри в пінобетонній суміші

**Анотація.** Метою цього дослідження було вивчення впливу рівномірного армування базальтовою фіброю на механічні властивості пінобетону, такі як міцність на стиск, згин і морозостійкість. Було використано комплексну методика, яка включала приготування та випробування пінобетонних сумішей з базальтовою фіброю, а також проведення випробувань на міцність та морозостійкість з використанням спеціалізованого обладнання. В результаті проведених досліджень було встановлено, що рівномірне додавання базальтової фібри до складу пінобетону значно покращує його механічні властивості. Міцність на стиск армованого пінобетону зросла на 30-40 % у порівнянні зі звичайним пінобетоном, що особливо помітно на ранніх стадіях твердіння. Наприклад, після 28 днів твердіння міцність на стиск армованого пінобетону становила 2,65 МПа, тоді як для неармованого аналога вона досягала лише 1,8 МПа. Крім того, армований пінобетон продемонстрував значне поліпшення міцності на вигин. Після 28 днів твердіння міцність на вигин становила 1,8 МПа, що на 56 % вище в порівнянні зі звичайним пінобетоном, у якого цей показник становив 1,15 МПа. Це свідчить про те, що базальтова фібра ефективно запобігає розвитку мікротріщин, підвищуючи загальну довговічність матеріалу. Крім того, в ході дослідження було виявлено поліпшення морозостійкості пінобетону, армованого базальтовою фіброю. Після 30 циклів заморожування і розморожування армований пінобетон показав меншу втрату ваги на 1,8 % в порівнянні зі звичайним пінобетоном, у якого цей показник досяг 3,7 %. Це свідчить про високу стійкість матеріалу до циклічних кліматичних впливів, що робить його більш придатним для використання в екстремальних кліматичних умовах. Таким чином, отримані результати підтверджують значне поліпшення механічних властивостей армованого пінобетону, демонструючи, що армування базальтовою фіброю робить його більш надійним і довговічним матеріалом для різних будівельних застосувань

**Ключові слова:** пінобетон; арматура; базальтове волокно; адгезія цементного розчину; міцність на стиск; міцність на вигин; морозостійкість

