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***Olena B. Martynova***, Associate Professor, Candidate of Technical Sciences, Associate Professor, Department of Information Technologies, Faculty of Geodesy, Land Management, and Agricultural Engineering, Odesa State Agrarian University. Odesa, Ukraine.
E-mail: pingu_@ukr.net
ORCID 0000-0001-7324-2543

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## Formation of the Structure and Physical and Mechanical Properties of Non-autoclaved Foam Concrete with an Activated Soluble Component

*Abstract:* This article presents the results of an experimental study on the influence of mechanochemical activation of the mortar component on the physical and mechanical properties of non-autoclaved foam concrete. The relevance of the topic is обусловлена the need to increase the strength and operational reliability of cellular concretes while simultaneously reducing cement consumption and the energy intensity of production. The object of the study is non-autoclaved foam concrete, and the subject is the processes of structure formation and strength development under conditions of mechanochemical activation. The aim of the study is to establish the patterns of influence of combined mechanical and chemical activation on material properties and to determine the possibilities for their regulation. The Box-Behnken plan is applied. The study employed methods of physical experimentation, experimental design (in particular, a multifactor approach), and analysis of the obtained dependencies. The theoretical basis includes the works of domestic and foreign researchers in mechanochemical activation and concrete technology. It has been established that the use of high-speed mixing in combination with chemical accelerating additives ensures a redistribution of structural changes in the solid phase, intensifies cement hydration processes, and promotes the formation of a denser material structure. The obtained results confirm the possibility of a significant increase in the strength of foam concrete up to 325% and controlled regulation of its properties in a wide range, which opens up prospects for effective use of the material in modern construction.

*Keywords:* foam concrete, mechanochemical activation, cement hydration, strength, filler, additives.

### *Abbreviations:*

$Ad$ is admixture,

$AT$ is activation time,

$C$ is cement,

$HMT$ is heat-moisture treatment,
$PC$ is Portland cement.

## Introduction

The industrial production experience of non-autoclaved foam concrete accumulated in recent years has made it possible to identify a number of persistent disadvantages of this material. As before, the issues of strength development and crack resistance remain insufficiently resolved. In the manufacture of products in individual moulds, the deviation of geometrical dimensions from the required indicators becomes a significant technological problem. Due to the non-uniform dimensions of blocks, their installation using adhesive mortars becomes difficult or even impossible. Another disadvantage of block foam concrete is the smoothness of its lateral surfaces, which reduces the adhesion of plaster mortar to the block surface and requires additional costs for the installation of reinforcing meshes. In addition, in the production of non-autoclaved foam concrete on stationary equipment, the slow strength gain reduces mould turnover and consequently increases the cost of products.

At the same time, foam concrete retains a number of unquestionable advantages that justify its further technological development. These include the possibility of production without autoclaving, dimensional stability during pore formation, availability of raw materials, relative simplicity of technology and equipment, low density, and favourable thermal insulation properties. The use of foam concrete is particularly promising in modern monolithic-frame housing construction, where it may serve as an enclosing wall material. However, such application requires the development of technological solutions aimed at improving the physical and mechanical properties of non-autoclaved foam concrete, especially its compressive strength, structural stability and reliability under service conditions.

The relevance of this study is determined by the need to improve the strength and operational performance of non-autoclaved foam concrete while reducing cement consumption, production cost and energy intensity. For non-autoclaved cellular concretes, the problem is especially important because, unlike autoclaved materials, their structure formation occurs under normal or moderately intensified curing conditions. Therefore, the mechanical properties of the final material depend strongly on cement hydration, the stability of the porous structure, the ratio between binder and filler, the use of chemical additives, and the technological method of mixture preparation. Previous studies emphasise that the properties of cellular and foam concretes are governed by multiple factors, including mixture composition, pore structure, rheological behaviour, curing regime and activation of cementitious systems (*Martynov et al., 2021a*; *Martynov et al., 2021b*; *Liew et al., 2021*; *Xiong et al., 2025*).

The research problem lies in the contradiction between the technological and economic advantages of non-autoclaved foam concrete and its insufficient strength characteristics when produced by conventional methods. Increasing cement content may improve strength, but it also increases the cost of the material, raises the water demand of the mixture, intensifies shrinkage processes and may contribute to crack formation. Conversely, replacing part of the cement with filler can reduce cost and shrinkage-related risks, but excessive filler content may reduce strength. Therefore, it is necessary to identify technological methods that can increase the efficiency of Portland cement, accelerate hydration, improve structure formation and compensate for the strength loss associated with partial cement replacement.

One of the promising approaches to solving this problem is mechanochemical activation of the mortar component of foam concrete. This approach combines mechanical activation in a high-speed mixer with the use of chemical hardening accelerators. Mechanical activation can intensify cement hydration, increase the degree of dispersion of the solid phase, promote the formation of cementitious hydrates and improve the distribution of components in the mixture. Chemical activation, in turn, may accelerate strength gain and improve the early structural stability of foam concrete. The combined use of both mechanisms may produce a synergistic effect, making it possible to regulate the structure and properties of non-autoclaved foam concrete more effectively than by either mechanical or chemical activation alone (*Barabash & Harashchenko, 2018*; *Rakhimov et al., 2020*; *Shcherban et al., 2021*).

The scientific novelty of this study consists in the experimental substantiation of the combined influence of filler content, chemical hardening accelerator dosage and activation time of the mortar mixture in a high-speed mixer on the structure formation and strength characteristics of non-autoclaved foam concrete. Unlike approaches that consider these factors separately, the present study analyses their joint effect within a three-factor experimental design. This makes it possible to evaluate not only the individual influence of each technological factor, but also their interaction and synergistic contribution to strength development.

The object of the study is non-autoclaved foam concrete intended for use as a lightweight wall and enclosing material in building construction.

The subject of the study is the formation of the structure and physical and mechanical properties of non-autoclaved foam concrete under conditions of mechanochemical activation of the mortar component.

The study aims to improve the strength properties of non-autoclaved foam concrete by changing the character and mechanical properties of the solid phase through activation of the mortar component and by determining the influence of recipe-technological factors on the final material properties.

To achieve this purpose, the following research tasks are set:

- to analyse the main technological disadvantages of non-autoclaved foam concrete that limit its wider use as a wall material;
- to determine the influence of filler content in the cement–filler mixture on the strength characteristics of foam concrete;
- to evaluate the effect of the “Plastidor” chemical hardening accelerator on cement hydration and strength development;
- to determine the influence of activation time of the mortar mixture in a high-speed mixer on the physical and mechanical properties of foam concrete;
- to identify the combined effect of mechanical and chemical activation on the structure formation of non-autoclaved foam concrete;
- to assess the influence of curing conditions, including normal-humidity curing, natural curing and heat-moisture treatment, on strength gain;
- to establish the possibility of reducing Portland cement consumption by introducing filler without reducing the required strength indicators;

- to determine whether activated non-autoclaved foam concrete can reach performance characteristics comparable with those of autoclaved cellular concretes.

The methodological basis of the study is a three-factor experiment carried out using mathematical methods of experimental design. The experiment was implemented according to a standard Box–Behnken design of type B-3. The selected variable factors are the content of filler in the mixture with cement, the content of a chemical hardening accelerator as a percentage of cement mass by dry substance, and the activation time of the mortar mixture in the reactor of a high-speed mixer. This design makes it possible to compare different technological routes for producing foam concrete and to analyse the combined influence of recipe and technological parameters.

The theoretical significance of the study lies in developing scientific understanding of structure formation in non-autoclaved foam concrete under conditions of mechanochemical activation. The research clarifies the role of Portland cement hydration intensity, filler content, chemical acceleration and mechanical activation in the formation of the solid phase and in the development of strength. It also contributes to the broader theory of cellular concrete technology by showing how the properties of non-autoclaved foam concrete may be controlled through coordinated regulation of mixture composition and technological activation.

The practical significance of the study is connected with the possibility of producing non-autoclaved foam concrete with improved strength and reduced cost. The proposed technological approach allows part of expensive Portland cement to be replaced with filler while maintaining or increasing the required strength indicators through activation of the mortar component. This may improve the economic efficiency of production, increase mould turnover, reduce the energy intensity of manufacturing and expand the field of application of foam concrete from thermal insulation material to structural and thermal-insulating wall material. In practical construction, such material may be used in monolithic-frame housing construction and in low-rise buildings as an enclosing or wall material.

*Thus*, the present study addresses an important technological problem in the production of non-autoclaved foam concrete: how to improve strength and structural reliability without increasing cement consumption and production complexity. The proposed combination of chemical acceleration and mechanical activation offers a promising route for controlled regulation of the structure and physical and mechanical properties of foam concrete, making the material more competitive for modern construction applications.

## Methods

To achieve the aim, a three-factor experiment was carried out using mathematical methods of experimental design. The experiment was conducted according to the standard Box–Behnken design of type B-3.

The selection of variable factors, as well as the levels of their variation, was based on a priori information. From the wide range of mix-design and technological factors affecting the quality of foam concrete, factors were selected which, on the one hand, influence the kinetics of plastic strength development and the final strength of foam concrete and, on the other hand, increase the efficiency of the binder by accelerating and increasing the degree of cement hydration.

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The following factors were selected:

X1—the content of filler in the mixture with cement, expressed as fractions of a unit, (C);

X2—the content of the admixture accelerating cement hardening, expressed as a percentage of cement mass by dry substance, (A);

X3—the activation time of the mortar mixture in the reactor of a high-speed mixer, (T), s.

The following assumptions were used when selecting the factors and assigning the variation levels.

Factor X1 is the content of filler in the mixture with cement. It is known that an increase in the amount of binder increases the strength of porous composite building materials. However, in cellular concretes, the content of solid components, including the binder, is limited by the need to ensure the required average density of the material. On the other hand, the binder, as a component of the raw mixture, is the most expensive constituent, and its contribution to the cost of the material is the most significant. Another argument in favour of limiting cement consumption is explained by the specific nature of non-autoclaved foam concrete.

The process of setting and hardening of non-autoclaved foam concrete is accompanied by significant volume changes, which ultimately lead to crack formation and a decrease in its physical and mechanical properties. The main sources of volume changes are the chemical reactions of cement hydration, namely contraction shrinkage, and moisture shrinkage. Both types of volume change are directly related to cement consumption. As cement consumption increases and cement hydration proceeds, the amount of hydration products increases; their volume is smaller than the volume of the initial reactants, which is the cause of contraction. On the other hand, as the amount of cement increases, the quantity of cement gel also increases. Subsequently, after the loss of moisture, shrinkage cracks occur. Increased initial mixing-water content contributes to the growth of shrinkage deformations due to moisture loss in the material. The amount of mixing water is also directly related to cement consumption, since cement is the component of the raw mixture with the highest water demand. To reduce cement consumption, a certain amount of filler was introduced into the raw mixture according to the experimental design. At the upper level of factor X1, the filler content was limited to 30% of the mass of solid components. This is due to the fact that, as previous experiments have shown, increasing the filler content above 30% in the dry components of foam concrete with an average density of 600 kg/m³ leads to a significant decrease in strength.

Factor X2 is the content of the chemical hardening-accelerating admixture. Modern composite building materials cannot be imagined without the use of chemical admixtures. Chemical admixtures are introduced to impart the required properties to construction mortars and, in finished materials, to enhance functional performance and reduce the energy intensity of the production process.

The selection of chemical admixtures is usually made according to the following criteria: achievement of the required effect, availability, cost, and compliance with sanitary and hygienic requirements.

A wide range of plasticising admixtures affecting the characteristics of concretes is known

(*Pashkevych et al., 2021*).

In the experiment, the cement-hardening accelerator admixture "Plastidor", produced by "Doronyk Ukraine", Kyiv, Ukraine, was used.

Acceleration of strength gain is a highly relevant problem for foam concrete. The need to use a mortar mixture with increased water–cement ratio values, caused by the technological features of production, as well as the influence of foaming agents on the cement hydration process, substantially slows down the hardening time of foam concrete, which negatively affects the productivity of technological lines.

Factor X3 is the activation time of the mortar mixture in a high-speed mixer.

The selection of factors and their variation intervals was made in such a way as to enable comparison of different methods of foam concrete production. The first point of the experimental design, in which all factors are at the lower level of variation, was adopted as the control point. Movement along the axis of factor X1 makes it possible to determine the influence of filler quantity on the properties of foam concrete. Movement along the axis of factor X2 or X3 makes it possible to determine the degree of influence of activation methods, conventionally referred to as chemical or mechanical activation, on changes in the properties of foam concrete. At other points of the mix-design and technological field, the combined influence of the experimentally adopted variable factors, that is, mechanochemical activation, is manifested.

The constant factors were as follows: density of the foam concrete mixture—760 ± 10 g/l; spread diameter of the mortar according to the Suttard viscometer—270 ± 10 mm.

Thus, the specific feature of the experimental design is that its results make it possible to analyse and compare different technologies for obtaining foam concrete.

The physical and mechanical properties, as well as the deformative characteristics of cellular concretes, are largely determined by the temperature and humidity conditions of the environment in which the initial structure forms and subsequent strength development takes place (*Liew et al., 2021*).

It is known that the theoretical strength of autoclaved concretes will always be higher than the strength of normally cured cellular concretes at the same degree of hydration and with the same volume and composition of hydration products.

Consequently, one of the tasks of the experiment was to study the influence of curing conditions on foam concrete strength. For this purpose, some of the specimens were stored in a normal curing chamber and tested on the 28th day of storage, corresponding to grade strength; some specimens were stored under natural conditions, that is, ambient environmental conditions. In addition, some specimens were subjected to heat treatment in a sealed chamber equipped with electric heaters, with an isothermal heating temperature of 50°C and a duration of 8 hours. After this, some specimens were tested immediately after heat treatment, while others were placed in a normal curing chamber and tested on the 28th day of curing.

## Literature Review

Many factors influence the characteristics of cellular concretes (*Martynov et al., 2021a*). An important aspect of foam concrete production technology is the formation of stable foam (*Xiong et al., 2025*).

In addition to chemical admixtures, other activation methods are used in building materials technology. Such methods include the activation of both initial raw materials and semi-finished products. All of them are associated with the additional input of energy at particular stages of material production. The type, point of energy input and duration of exposure are determined by the intended purpose, the technological features of production and economic parameters. In building materials technology, thermal, electrical, magnetic, electromagnetic and mechanical effects are the most widely used. Heat treatment of concretes with steam or electricity is used to accelerate strength development (*Zhang et al., 2022*). Electrical heating and steam heating are applied at the stage of activating concrete and mortar mixtures. Methods for controlling material properties through activation of the mixing liquid, namely magnetisation of water, are also known.

However, mechanochemical activation has gained the widest application in the production of building materials. The issue of mechanochemical activation of raw materials is particularly relevant in the technology of porous concretes (*Rakhimov et al., 2020*). This is due to the need to ensure the stability of the porous structure, accelerated development of structural strength and the formation of a sufficient quantity of cementitious hydration products (*Korjakins & Shakhmenko, 2019*). For this purpose, grinding is carried out both for individual raw materials, such as sand grinding, and for the joint grinding of sand with binders in various grinding units, including ball mills, vibration mills, rod mills and jet mills.

A method has also been proposed for using a high-speed mixer for the separate preparation of cement–water compositions, which are subsequently combined with fillers in a conventional concrete mixer (*Barabash & Harashchenko, 2018*; *Xia et al., 2020*; *Shcherban et al., 2021*). Methods for activating the binder or mortar component in high-speed mixers are also known. With this method, the degree of hydration of binders increases, which leads to accelerated growth of structural strength and an increase in grade strength. This method was used in the experiment. The mortar mixture was activated in a laboratory high-speed mixer developed by I. V. Barabash.

## Results

Table 1 presents the results for the strength of foam concrete cured under normal-humidity conditions for 28 days, corresponding to grade strength, in MPa, as well as the relative strength of foam concrete under different curing conditions, expressed as a percentage of the grade strength.

The analysis of changes in the strength characteristics of non-autoclaved foam concrete was carried out with reference to the base composition, which was cured under normal-humidity conditions for 28 days, corresponding to grade strength (*Martynov et al., 2021a*). In accordance with the requirements of DSTU B V.2.7-45:96 "Building Materials. Cellular Concretes. Technical Specifications", the minimum permissible strength of non-autoclaved foam concrete with an average dry density of 600 kg/m³ is 1.5 MPa, while the maximum is 2.5 MPa.

Figure 1 shows the strength isosurfaces of foam concrete. At the control point of the experiment, where all variable factors are at the lower level of variation, a strength of 1.4 MPa was recorded, which is lower than the standard values. It should be noted that in this case the material was produced solely on the basis of cement, without the use of filler. This, on the one hand, leads to an increase in cost and, on the other hand, causes a number of negative effects described earlier.

Thus, achieving the required physical and mechanical indicators of foam concrete is possible only under conditions of intensification of Portland cement hydration processes.

The graphs show that the greatest increase in strength, up to 325%, occurs at the maximum admixture content of 3%, a cement content of 100%, and a mortar activation time in the high-speed mixer within the range of 20–30 s. These graphs clearly demonstrate the synergistic effects of the mutual influence of the factors. Thus, in foam concrete produced without the introduction of the "Plastidor" admixture, strength increases in direct proportion to mortar activation time according to a linear relationship. The introduction and subsequent increase in filler content in the mortar mixture have an insignificant effect on changes in strength. The activation of the mortar in a high-speed mixer leads to an increase in strength of more than 150% compared with the control composition.

The introduction of the "Plastidor" admixture leads to a transformation in the character of the dependencies and changes them from linear to parabolic, which also indicates a significant interaction between factors X2 and X3. At the same time, the strength of the foam concrete also increases considerably. Even in the region of the factor space with the maximum filler content, the strength of foam concrete increases by 125–200% compared with the control composition.

## Discussion

The results of this study address a persistent technological problem in the production of non-autoclaved foam concrete: the need to improve the quality characteristics of the material while simultaneously reducing production cost and simplifying the manufacturing process. Non-autoclaved foam concrete is traditionally known primarily as a thermal insulation material; however, an increase in its strength may allow it to be transferred into the category of structural and thermal-insulating materials. This, in turn, can expand the field of its application as a wall material in low-rise construction and monolithic-frame housing systems.

The main conclusion drawn from the analysis of foam concrete strength development is that it is not possible to obtain non-autoclaved Portland cement-based foam concrete with standardised strength indicators without using intensifiers that increase the rate and degree of cement hydration. The "Plastidor" admixture and the activation of the mortar component of foam concrete in a high-speed mixer proved to be highly effective intensifiers of Portland cement hardening. Their effectiveness increases further when they are used jointly, that is, under conditions of mechanochemical activation. In addition, the use of mechanochemical activation of the mortar component makes it possible to introduce up to 30% or more filler instead of expensive Portland cement, thereby reducing the cost of production.

The experimental results confirm that the strength of non-autoclaved foam concrete is governed not by a single technological factor, but by the combined effect of mix composition, chemical acceleration, mechanical activation and curing conditions. The strength range obtained in the recipe-technological field of the experiment demonstrates that the material can be deliberately regulated within a broad interval. The fact that strength increased by up to 325% in comparison with the control point indicates that mechanochemical activation does not merely improve one isolated property, but changes the overall process of structure formation in the foam concrete matrix.

The observed effect can be explained by the intensification of cement hydration and by changes in the solid phase of the material. Mechanical activation in a high-speed mixer increases the dispersion and reactivity of the cementitious system, improves contact between cement particles and water, and promotes more uniform distribution of the components. Chemical acceleration additionally stimulates hydration reactions and accelerates the formation of cementitious hydration products. As a result, the foam concrete structure becomes denser and more mechanically stable, while the porous system remains sufficiently preserved for the material to retain the functional advantages of cellular concrete. This interpretation is consistent with studies that emphasise the importance of mechanochemical activation for the hydration and structure formation of cement-based materials (*Rakhimov et al., 2020*; *Barabash & Harashchenko, 2018*; *Shcherban et al., 2021*).

A particularly important finding is the synergistic interaction between the chemical admixture and mechanical activation. When the "Plastidor" admixture was not used, the increase in strength was mainly proportional to the activation time of the mortar mixture. However, the introduction of the admixture changed the character of the dependence from linear to parabolic, which indicates a more complex interaction between the factors. This means that the maximum effect cannot be obtained simply by increasing the duration of mechanical activation or the amount of chemical additive separately. Instead, the technological optimum should be sought in the combined field of factor interaction, where the content of filler, admixture dosage and activation time are balanced.

The results also show that the use of filler may be technologically and economically justified if it is combined with activation of the mortar component. Under conventional conditions, an increase in filler content can lead to a reduction in strength because part of the Portland cement is replaced by a less reactive component. However, mechanochemical activation compensates for this effect by increasing the efficiency of the binder and improving the formation of hydration products. Even at the maximum filler content, the strength of foam concrete increased by 125–200% in comparison with the control composition. This confirms that filler should not be viewed only as a cost-reducing component, but also as an element of the structure-forming system, provided that the binder phase is properly activated.

From a technological point of view, these findings are significant because Portland cement is the most expensive and most shrinkage-sensitive component of the mixture. Excessive cement consumption increases material cost, water demand, contraction shrinkage and the risk of crack formation. Therefore, the possibility of replacing part of the cement with filler while maintaining or increasing strength is important for both economic and durability considerations. The results suggest that mechanochemical activation may provide a practical route for reducing cement consumption without compromising the required physical and mechanical properties of non-autoclaved foam concrete.

The study also confirms the importance of curing conditions for the strength development of non-autoclaved foam concrete. The most favourable conditions for strength gain were normal-humidity conditions with an ambient temperature of 20 ± 2°C and humidity of 98%. This result is theoretically consistent with the hydration mechanism of Portland cement and with the specific nature of cellular concrete structure formation. Since the pore structure and cement matrix develop simultaneously, insufficient humidity or unfavourable thermal conditions may disturb hydration, increase shrinkage and reduce final strength. At the same time, heat treatment may accelerate early hardening, but it does not necessarily provide the same structural quality as normal-humidity curing over the full 28-day period.

The comparison with autoclaved cellular concretes is also important. Autoclaved materials usually achieve higher and more stable strength because their structure forms under elevated temperature and pressure, leading to the development of specific hydration products. Non-autoclaved foam concrete is technologically simpler and less energy-intensive, but its structure formation is more sensitive to curing conditions and mixture composition. The results of this study show that foam concrete with an activated mortar component may approach autoclaved cellular concretes in terms of physical and mechanical properties. This creates a basis for improving the competitiveness of non-autoclaved foam concrete in modern construction practice.

The findings correspond to the broader research context in which the properties of cellular concretes are understood as the result of the interaction between pore structure, binder hydration, rheological behaviour and curing environment (*Martynov et al., 2021a*; *Liew et al., 2021*; *Xiong et al., 2025*). Stable foam formation is necessary but insufficient for obtaining high-quality foam concrete. The porous structure must be supported by a sufficiently strong cementitious matrix, especially during the early stages of hardening. Therefore, the activation of the mortar component should be considered not only as a method for increasing compressive strength, but also as a means of stabilising the entire structure-forming process.

The practical implications of the study are substantial. The proposed approach can increase mould turnover in stationary production because accelerated strength gain reduces the time required before demoulding and further handling. It can also reduce the cost of products through partial replacement of Portland cement with filler. In addition, the ability to produce stronger non-autoclaved foam concrete may expand its use from purely insulating applications to enclosing and wall elements in low-rise and monolithic-frame construction. This is especially relevant for construction systems where low density, thermal insulation, ease of production and sufficient strength must be combined in one material.

At the same time, the results should be interpreted with several limitations in mind. The study focuses on a specific density range, a specific hardening accelerator and a particular laboratory high-speed mixing method. Therefore, the obtained dependencies should not be mechanically transferred to all types of foam concrete without additional verification. The experiment also primarily evaluates strength characteristics, while long-term durability, shrinkage, crack resistance, thermal conductivity, moisture resistance and pore-size distribution require further investigation. Since foam concrete performance depends strongly on the stability and geometry of the porous structure, future studies should include microstructural analysis in addition to mechanical testing.

Another limitation concerns the industrial scalability of laboratory activation. The laboratory high-speed mixer used in the experiment makes it possible to achieve effective activation of the mortar component, but the transfer of this method to industrial production requires optimisation of equipment parameters, energy consumption, mixing time and process stability. It is also necessary to determine whether the same activation effect can be maintained in larger batches, where mixing intensity, heat generation and component distribution may differ from laboratory conditions.

Further research should therefore focus on several directions. First, it is necessary to establish optimal combinations of filler content, admixture dosage and activation time for different target densities of foam concrete. Secondly, the influence of mechanochemical activation on shrinkage, crack resistance and long-term durability should be studied. Thirdly, the pore structure of activated foam concrete should be analysed using microstructural methods in order to connect strength development with pore distribution and matrix density. Fourthly, the economic and energy efficiency of the proposed technology should be assessed under industrial conditions.

Overall, the study demonstrates that mechanochemical activation is an effective technological approach for regulating the structure and physical and mechanical properties of non-autoclaved foam concrete. The combined use of a chemical hardening accelerator and activation of the mortar component in a high-speed mixer intensifies cement hydration, increases strength, allows partial replacement of Portland cement with filler and improves the technological potential of the material. These results support the conclusion that activated non-autoclaved foam concrete can be considered a promising structural and thermal-insulating material for modern construction.

**Conclusion**

The three-factor experiment carried out using mechanochemical activation made it possible to determine effective ways of substantially increasing the strength of non-autoclaved foam concrete while simultaneously reducing the cost of production. The study confirms that the physical and mechanical properties of foam concrete can be purposefully regulated through the combined influence of filler content, the dosage of a chemical hardening accelerator and the activation time of the mortar component in a high-speed mixer. This indicates that the quality of non-autoclaved foam concrete is determined not only by its composition, but also by the technological conditions under which the cementitious matrix and porous structure are formed.

Within the investigated mix-design and technological field, the strength of foam concrete cured under normal-humidity conditions varied from 1.1 to 4.4 MPa. Depending on the level of the other factors, activation of the mortar mixture led to an increase in strength of up to 325% compared with the control point of the experimental design. This result demonstrates the high efficiency of mechanochemical activation as a method for intensifying Portland cement hydration, improving the structure of the solid phase and increasing the strength potential of non-autoclaved foam concrete.

The results also show that temperature and humidity conditions during curing have a significant influence on the final strength of Portland cement-based non-autoclaved foam concrete. The most favourable conditions for strength development were normal-humidity curing at an ambient temperature of 20 ± 2°C and relative humidity of 98%. These conditions ensure more complete hydration of the binder, reduce the risk of premature moisture loss and create a more stable environment for the formation of the cellular concrete structure. Therefore, curing conditions should be considered one of the key technological parameters in the production of non-autoclaved foam concrete with predictable properties.

Foam concrete with an activated mortar component does not yield to autoclaved cellular concretes in terms of its physical and mechanical properties within the investigated strength range. This confirms the possibility of using activated non-autoclaved foam concrete in monolithic-frame housing construction as a wall material. The proposed technological approach may also expand the application of foam concrete from a predominantly thermal insulation material to a structural and thermal-insulating material suitable for enclosing structures and low-rise construction.

An important practical outcome of the study is the possibility of replacing part of expensive Portland cement with filler without reducing the required strength characteristics. The use of mechanochemical activation compensates for the decrease in binder content by increasing the efficiency of cement hydration and improving the structure-forming processes in the material. This creates technological prerequisites for reducing production cost, increasing mould turnover, lowering the energy intensity of manufacturing and improving the competitiveness of non-autoclaved foam concrete in modern construction.

The theoretical significance of the obtained results lies in clarifying the role of mechanochemical activation in the formation of the structure and strength of non-autoclaved foam concrete. The study shows that the joint action of mechanical activation and a chemical hardening accelerator produces a synergistic effect, which changes the character of strength development and enables more effective control of the material's properties. This contributes to the further development of scientific approaches to the design of cellular concretes with regulated structure and performance characteristics.

At the same time, further research is required to verify the obtained patterns for other density classes, binder systems, filler types and chemical admixtures. It is also necessary to study the influence of mechanochemical activation on shrinkage, crack resistance, thermal conductivity, water resistance, durability and pore structure. Additional microstructural analysis and industrial-scale testing would make it possible to confirm the technological stability of the proposed approach and to develop practical recommendations for its implementation in production.

Overall, the study demonstrates that mechanochemical activation of the mortar component is an effective method for improving the strength and technological efficiency of non-autoclaved foam concrete. The obtained results provide a scientific and practical basis for producing stronger, more cost-effective and more widely applicable foam concrete for modern construction, particularly where a combination of low density, thermal efficiency and sufficient mechanical strength is required.

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**Conflict of Interest**

The author declares that there is no conflict of interest.

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## Appendix

Table 1. Experimental design matrix and strength characteristics of foam concrete

| № | Factors | | | Grade strength of foam concrete, MPa | Strength, as a percentage of vintage | | |
|---|---|---|---|---|---|---|---|
| | $X_1$ | $X_2$ | $X_3$ | | After HMT, % of grade strength | 28th day of natural curing, % of grade strength | 28th day after HMT, % of grade strength |
| | F | A | T | | | | |
| 1 | - | - | - | 1,2 | 58 | 83 | 108 |
| 2 | + | - | - | 1,1 | 45 | 73 | 100 |
| 3 | - | + | - | 3,4 | 47 | 62 | 82 |
| 4 | + | + | - | 1,9 | 37 | 47 | 63 |
| 5 | - | - | + | 2,7 | 52 | 81 | 89 |
| 6 | + | - | + | 2,6 | 58 | 69 | 100 |
| 7 | - | + | + | 4,1 | 63 | 80 | 100 |
| 8 | + | + | + | 2,4 | 63 | 75 | 79 |
| 9 | - | 0 | 0 | 3,7 | 62 | 81 | 97 |
| 10 | + | 0 | 0 | 2,7 | 59 | 78 | 111 |
| 11 | 0 | - | 0 | 1,8 | 50 | 72 | 100 |
| 12 | 0 | + | 0 | 2,9 | 48 | 79 | 86 |
| 13 | 0 | 0 | - | 1,7 | 47 | 65 | 76 |
| 14 | 0 | 0 | + | 3,0 | 47 | 80 | 97 |
| 15 | 0 | 0 | 0 | 2,7 | 48 | 74 | 89 |

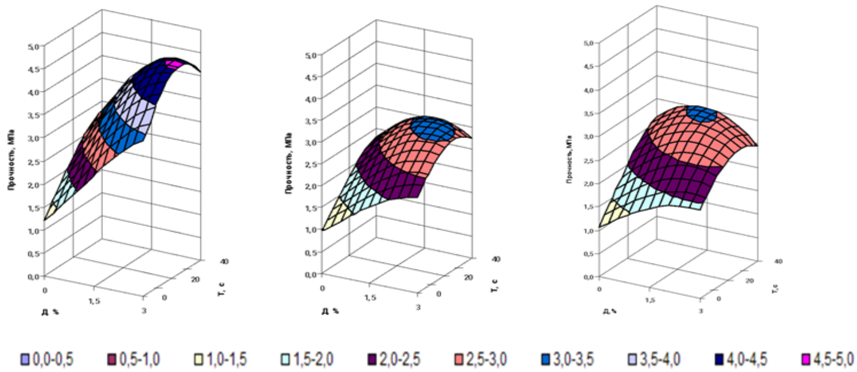


Figure 1. Isosurface strengths of foam concrete with filler content: a—0%; b—15%; c—30%.