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TECHNOLOGICAL FACTORS AFFECTING THE QUALITY OF NON-AUTOCCLAVED CEMENT FOAM CONCRETE

Soy Vladimir Mikhailovich, Doctor of Technical Sciences,
Professor,
Tashkent State Transport University (TSTU), Tashkent,
Uzbekistan.

Jumageldiyev Aziz Olimovich, Master's Student,
Tashkent State Transport University (TSTU), Tashkent,
Uzbekistan.

MAN JIALUN, Master's Student,
Tashkent State Transport University (TSTU), Tashkent,
Uzbekistan.

Abstract: *This paper examines the technological factors affecting the quality of non-autoclaved cement foam concrete. The main production technologies, structural characteristics, physical-mechanical properties, and modern quality improvement challenges are analyzed. Particular attention is paid to the influence of pore structure, admixture compatibility, water demand, and curing conditions on the performance of foam concrete. The role of foaming agents, water-reducing admixtures, accelerators, fly ash, and microsilica in controlling the rheological behavior and structure formation of foam concrete mixtures is discussed. The analysis demonstrates that the quality of non-autoclaved foam concrete depends primarily on the stability of the cement matrix surrounding the pores and the formation of a uniform closed-porosity system. The study confirms that the coordinated use of compatible foaming agents, superplasticizers, and hardening accelerators can reduce water demand, improve pore stability, increase strength, and enhance the overall quality of non-autoclaved foam concrete.*

Keywords: *Non-autoclaved foam concrete, cellular concrete, pore structure, foaming agent, water demand, superplasticizer, microsilica, fly ash, admixture compatibility, density, strength, thermal insulation, shrinkage, cement matrix, quality improvement.*

Technologies of Non-Autoclaved Foam Concrete

Non-autoclaved foam concrete is a cellular concrete in which a porous structure is formed by introducing pre-generated foam or by generating air bubbles directly in a cementitious mixture. Unlike autoclaved aerated concrete, it hardens under normal or heat-moisture curing conditions without high-pressure steam treatment, making it suitable for small-scale and mobile production systems.

The development of foam concrete is associated with the need for lightweight materials for void filling, thermal insulation and structural weight reduction. Research has increasingly focused on the relationship between pore structure and mechanical properties, while energy-efficiency requirements have expanded its application.

Three main production technologies are widely used: the classical two-stage method, dry mineralization and baro-technology. In the classical method, foam is produced separately and mixed with cement slurry, allowing better control of foam quality but requiring additional equipment. The dry mineralization method combines dry mineral components with low-expansion foam, enabling lower-density materials with improved pore stability, although it requires highly compatible cement systems and foaming agents. Baro-technology uses a sealed mixer and compressed air, which after discharge expands to form a more uniform pore structure and denser partitions, but it is technologically more complex.

For small and mobile plants, the one-stage method is the most practical. In this approach, air entrainment and mixing occur simultaneously, and density is controlled by adjusting mixing energy and foaming-agent dosage. Although economically efficient, it requires strict control of admixture compatibility and rheological properties.

Key technological problems include foam instability, mixture settlement, foam generator adjustment and maintenance of stable rheology. Air bubbles must

remain stable during mixing and early hardening; otherwise, both strength and thermal performance are reduced.

The choice of technology depends on target density, equipment availability and production scale. In this study, the one-stage method is considered the most suitable due to its simplicity and direct density control.

A crucial requirement is maintaining a stable relationship between mixture composition and hardened properties. Mixing energy, foam expansion and fresh density must be considered as interdependent parameters. Improper adjustment leads to foam collapse, increased capillary porosity or shrinkage.

Foam concrete quality is mainly determined by the cement matrix surrounding pores. Low density is beneficial only when inter-pore partitions remain dense and durable. Therefore, quality control should focus not only on density reduction but also on forming a stable system of closed pores.

Structure and Physical-Mechanical Properties of Foam Concrete (Condensed)

Foam concrete is a cellular material consisting of a hardened cement matrix with air as the dispersed phase. Its structure is evaluated at two levels: the macrostructure (density, porosity, pore size distribution and morphology) and the solid phase (hydration products, mineral composition and cement matrix interfaces). At densities of 500–700 kg/m³, porosity reaches 74–82%, which significantly improves thermal insulation but reduces load-bearing capacity, making the quality of inter-pore partitions critical for overall performance. The optimal structure is characterized by predominantly closed and uniformly distributed pores with stable partition thickness, since such morphology improves both thermal efficiency and mechanical resistance, whereas connected or irregular pores create stress concentrations and reduce strength even at similar densities.

The physical-mechanical properties of foam concrete are governed not only by average density but mainly by pore structure and matrix quality. Strength depends

on the integrity of inter-pore partitions, while thermal conductivity decreases with reduced density but increases sharply when pores are interconnected or moisture is present. Shrinkage is a major limitation of non-autoclaved foam concrete due to high cement paste content and absence of coarse aggregate, and it is strongly influenced by water content, admixtures, mineral additives and curing conditions. Although empirical strength–density relationships exist, practical performance is primarily controlled by production parameters such as water-to-solid ratio, foaming agent dosage, mixing time and admixture compatibility.

Mineral additions such as fly ash and microsilica can densify the cement matrix and improve hydration, but they also increase water demand, requiring the use of water-reducing admixtures. Therefore, mixture design must balance improved packing density with rheological stability. Foam concrete quality is achieved only when a dense cement matrix is formed around pores, ensuring that low density does not compromise durability. In this context, closed porosity, average density and inter-pore partition strength must be treated as interdependent factors rather than independent variables.

From a technological perspective, foam concrete production operates within a narrow process window. Insufficient density control leads to poor foam distribution and weak structure formation, while excessive instability causes segregation, foam collapse and increased shrinkage. Key control parameters such as fresh density, flow spread, foam stability and setting time provide rapid assessment of mixture behavior. For low water-to-solid ratio systems, coordinated use of water reducers, accelerators and foaming agents is essential. Overall, the final performance of foam concrete is determined by the interaction between mixture composition, pore formation technology and admixture compatibility.

Modern problems of quality improvement

The modern problems of improving the quality of non-autoclaved foam concrete include the compatibility of foaming and water-reducing admixtures, the

stability of foam and foam concrete mass, the absence of controlled heat-curing equipment at some plants, insufficient professional training of production personnel and the lack of detailed technological documentation.

Compatibility of admixtures is a key problem. Foaming agents and water reducers are surface-active substances. They may compete at interfaces, change surface tension and destabilize the foam. In one-stage technology this risk is especially important because all components are introduced into a common mixing system. An admixture that improves the flowability of cement paste may simultaneously reduce foam stability.

Another production problem is the transportation and discharge of foam concrete mixture. Pumping through hoses or prolonged discharge from a mixer may increase density by destroying part of the foam. The difference between the density at the beginning and at the end of discharge can be significant. This leads to uneven product quality and makes it difficult to obtain reliable thermal-insulating properties.

Curing temperature also influences quality. At low positive temperatures the material may not gain sufficient early strength, and the foam concrete mass may settle before the matrix hardens. Modern accelerators and antifreeze admixtures can partly compensate for this effect, but they must be selected with regard to foam stability and cement hydration.

Technological documentation is needed to reduce production variability. It should contain the sequence of dosing, mixing time, target fresh density, acceptable flow spread, curing regime, demolding time and quality-control procedures. Without such documentation, even a correctly designed composition may not be reproducible in production conditions.

Table 1.1 - Main technological problems and rational solutions

Problem	Manifestation	Rational solution
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Foam instability	Settlement of mixture, rupture of pores, density growth	Selection of compatible foaming agent and plasticizer
High water demand	Lower strength, capillary porosity and shrinkage	Use of a water-reducing admixture and optimization of W/S ratio
Delayed hardening	Insufficient demolding strength	Use of a cement hardening accelerator
Non-uniform structure	Large pores and weak partitions	Control of mixing time and foaming agent concentration
High shrinkage	Cracking and reduced durability	Fly ash, lower W/S ratio, dense matrix and curing control

In relation to quality improvement in non-autoclaved foam concrete, the most important technological task is to maintain a stable connection between the composition of the mixture and the final properties of the hardened material. The parameters admixture compatibility, curing temperature and production documentation must therefore be considered not separately, but as mutually dependent factors. When one factor is changed without correcting the other two, the apparent improvement in workability may be accompanied by loss of foam stability, increased capillary porosity or excessive shrinkage.

The analysis of quality improvement in non-autoclaved foam concrete shows that the quality of non-autoclaved foam concrete is governed by the quality of the cement matrix around the air pores. A low-density structure is useful only when the inter-pore partitions remain dense enough to resist mechanical loading and moisture migration. For this reason, the technological interpretation of admixture

compatibility and curing temperature should always include their influence on both fresh mixture behavior and hardened-state performance.

A practical feature of quality improvement in non-autoclaved foam concrete is the need to operate within a narrow technological window. If admixture compatibility is insufficient, the mixture becomes stiff and does not distribute air uniformly. If it is excessive, segregation, foam collapse or increased drying shrinkage can appear. The role of production documentation is to compensate for these deviations and to make the mixture reproducible under laboratory and production conditions.

Factors Governing Water Demand of Foam Concrete Mixtures

The water demand of foam concrete mixtures is influenced by cement fineness, filler gradation, fly ash morphology, finely dispersed mineral additives, chemical admixtures and required workability. Reducing water demand is a key factor for increasing strength and reducing shrinkage.

Fly ash has a dual effect: spherical particles improve flowability by reducing internal friction, while porous or irregular particles increase water demand due to higher water absorption and surface area. Therefore, its effectiveness depends on particle shape, fineness, mineral composition and unburned carbon content.

Microsilica and other highly dispersed additives improve matrix density but significantly increase water demand, requiring the use of superplasticizers. However, their compatibility with foaming agents must be ensured to avoid foam destabilization.

Plasticizing admixtures modify the water bound in solvation layers around cement particles, improving rheology but potentially delaying hydration. For this reason, hardening accelerators are often required in low-water systems.

The central hypothesis is that combining a modern foaming agent with a water-reducing admixture can lower the water-to-solid ratio while maintaining

workability, and that delayed setting can be compensated by accelerators, resulting in a denser inter-pore cement matrix and improved performance.

Water demand control requires treating cement fineness, fly ash morphology and superplasticizer adsorption as interdependent parameters. Independent variation of these factors may cause foam instability, increased capillary porosity or excessive shrinkage.

Foam concrete quality is mainly governed by the cement matrix surrounding the pores; low density is beneficial only when inter-pore partitions remain dense and durable. Therefore, both fresh mixture behavior and hardened-state performance must be considered simultaneously.

A narrow technological window must be maintained. Insufficient cement fineness leads to poor air distribution, while excessive fineness may cause segregation, foam collapse or shrinkage. Superplasticizer adsorption helps stabilize the system and improve reproducibility.

Production control relies on measurable indicators such as fresh density, flow spread, foam stability and setting time, which provide rapid assessment of mixture quality and predicted pore structure.

Low water-to-solid ratio mixtures are especially sensitive to dosing and mixing variations; therefore, Leadcrete LA40, water reducers and accelerators must be used as a coordinated system rather than separately.

The experimental approach integrates technological and structural parameters to explain not only obtained properties but also the mechanisms of structure formation, highlighting the importance of admixture compatibility and foam formation technology.

Conclusion

The production of high-quality structural-thermal-insulating and thermal-insulating foam concrete remains an urgent task because the material can reduce energy consumption both during manufacture and during building operation.

The optimum structure of foam concrete can be obtained only through technological optimization. The average density is important, but it does not determine quality by itself; pore morphology and the strength of inter-pore partitions are decisive.

The most significant formulation and technological factors are the use of an effective foaming agent, water-reducing admixtures, accelerators of setting and hardening, and technological procedures that ensure stable foam in the cement system.

The theoretical analysis confirms the scientific hypothesis that the combination of Leadcrete LA40 with a compatible water reducer and accelerator can reduce water demand while maintaining the required flowability and can bring the quality of non-autoclaved foam concrete closer to more energy-intensive autoclaved cellular concrete.

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