

Non-Autoclaved Lightweight Concretes Based on A Nano-Modified Dry Mix for Foam Concrete

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Abstract

In this study, a dry foam concrete mix was nano-modified, and based on it, foam concrete compositions were developed using lightweight porous aggregates—expanded clay gravel, foam glass, and polystyrene granules. It was experimentally determined that the introduction of silica sol in an amount of 0.001% relative to the cement mass resulted in an average increase of 15% in the compressive strength of the foam concrete. The developed foam concretes with porous aggregates are intended for thermal insulation and structural applications, with their average density formed in the range of 300 kg/m³ to 750 kg/m³. Research results showed that these foam concretes have a structural quality coefficient that is 30% or higher compared to foam concretes without aggregates, and they have the potential for effective application in the climatic and construction conditions of Uzbekistan.

Keywords: Dry foam concrete mix, non-autoclaved foam concrete, silica sol (nanomodifier), lightweight porous aggregates, structural quality coefficient.

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1. Introduction

In modern construction practice, the primary wall materials in widespread use include silicate and ceramic bricks and blocks, hollow wall blocks, exterior wall panels for precast reinforced concrete structures, monolithic reinforced concrete walls, small-sized blocks made from foam and aerated concrete, as well as wall blocks made of expanded clay concrete. To achieve the required thermal protection performance, effective thermal insulation layers—such as expanded polystyrene, mineral wool slabs, and other materials—

are additionally applied to exterior wall structures, or the walls are constructed entirely from building materials with low thermal conductivity. Over the last few decades, the use of porous concrete materials in the construction industry has been steadily increasing. This is attributable to the simplicity of their production technology, the availability of raw material resources, and the fact that they are among the most cost-effective wall materials.

Previous studies have proven the effectiveness of a new technological method for preparing foam concrete and its products, which proposes the use of a ready-made dry

mix containing a foaming component. Building on this direction, scientists in the building materials sector of the Republic of Uzbekistan have scientifically substantiated the possibilities of modifying dry mixes with nanoadditives and their technological compatibility with lightweight aggregates. In particular, research conducted from 2018 to 2024 confirmed the high practical efficiency of using cellular concretes based on porous aggregates. The research results showed that incorporating 40–55% porous aggregate into the composition makes it possible to reduce the shrinkage deformations of non-autoclaved foam concrete by 55–65% and significantly lowers its thermal conductivity. It should be specially noted that in recent years, Uzbek scientists have further refined the concept of the combined use of cellular and lightweight concretes. Specifically, the effective use of local raw materials—expanded clay aggregate, metallurgical industry waste, crushed stone, granulated foam glass, and expanded polystyrene granules—has been recommended for the production of foam and aerated concrete. Currently, it is considered appropriate to use porous aggregates with a bulk density not exceeding 500–600 kg/m³ in the production of effective structural and thermal-insulating concretes. Promising aggregates that meet these density requirements include expanded clay aggregate, crushed expanded clay sand, granulated foam glass, and expanded polystyrene. At the same time, the need to develop modern regulatory and technical documentation for certain non-traditional lightweight aggregates, particularly foam glass and composite granules, persists. This indicates the necessity for additional scientific and practical research on the widespread introduction of these materials into the construction industry and underscores the relevance of this field of study.

2. Methods

The following primary materials were used in this study: for preparing dry mixes, Portland cement grade SEM I 42.5B, produced in the Republic of Uzbekistan (in accordance with O'z DSt 31108:2016 / GOST 31108), was used; an industrial foaming agent was used as the

foaming component according to technical specifications; and KZ-TM-30 grade silica fume (microsilica), either based on local raw materials or imported, was used as a modifier.

- Methods for Determining Rheological and Technological Properties:

- The flowability of foam concrete and lightweight concrete mixes was determined by the spread of a Suttard cone in accordance with the requirements of O'zDSt 277-80 "Guidelines for the Production of Articles from Cellular Concrete".

- The average density of foam concrete and lightweight concrete mixes was determined in accordance with O'zDSt 27005:2016 "Lightweight and Cellular Concretes. Rules for Determining Average Density".

- Methods for Determining Physicomechanical Properties:

- The particle size distribution of the dry mix and the modifier was determined using a "NOK-IVA 950" laser analyzer based on the reflected laser beam method.

- The compressive strength of control samples with dimensions of 100×100×100 mm and 150×150×150 mm was tested in accordance with the requirements of O'zDSt 10180:2015 "Concretes. Methods for Determining Strength on Control Samples".

3. Results

Based on experimental results obtained on cement stone, comprehensive studies were conducted on the cement–foaming agent–silica sol multicomponent system. As part of the research, a modified dry mix and the "base" composition of the dry mix were prepared under laboratory conditions by grinding in an SMV-3 type vibratory ball mill using friction and impact-vibration mechanisms (Table 1). The particle size distribution (PSD) was determined using a Horiba LA-950 laser particle analyzer. According to the research results, the specific surface area of the resulting dry mixes was in the range of 450±100 m²/g, and these indicators are shown in Figures 1 and 2.

Table 1

Composition of the dry mix

Dry mix designation	Average density of foam concrete kg/m ³	Quantity of materials per 1 ton of dry mix		
		Cement, kg	Silica sol, kg	Foaming agent, liters
KKK-400-base	400	982	-	8.8
KKK-400-modified	400	982	0.00982	8.8

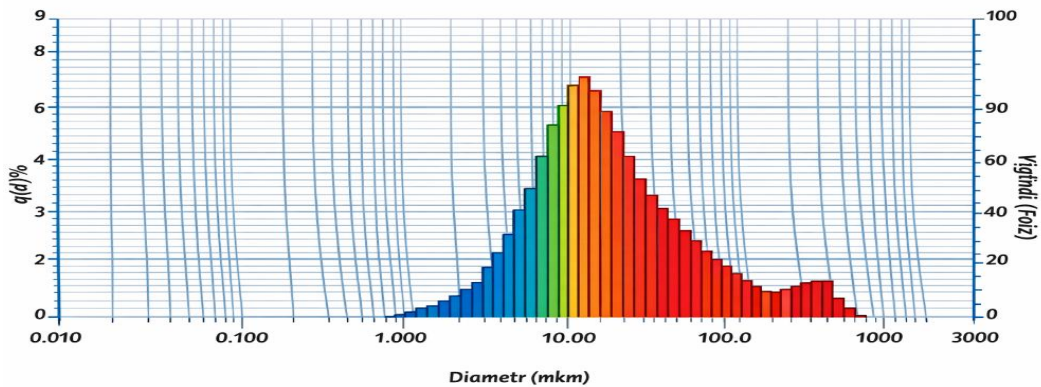


Figure 1. Particle size distribution of the base composition of the dry mix

As can be seen from the data presented in Figure 1, the particle size distribution of the base mix is bimodal in character. The main portion of the particles is located in the 8–30 μm range, constituting 59% of the total volume.

At the same time, it was determined that the minimum particle size is 1.729 μm, and the maximum size is 394.244 μm.

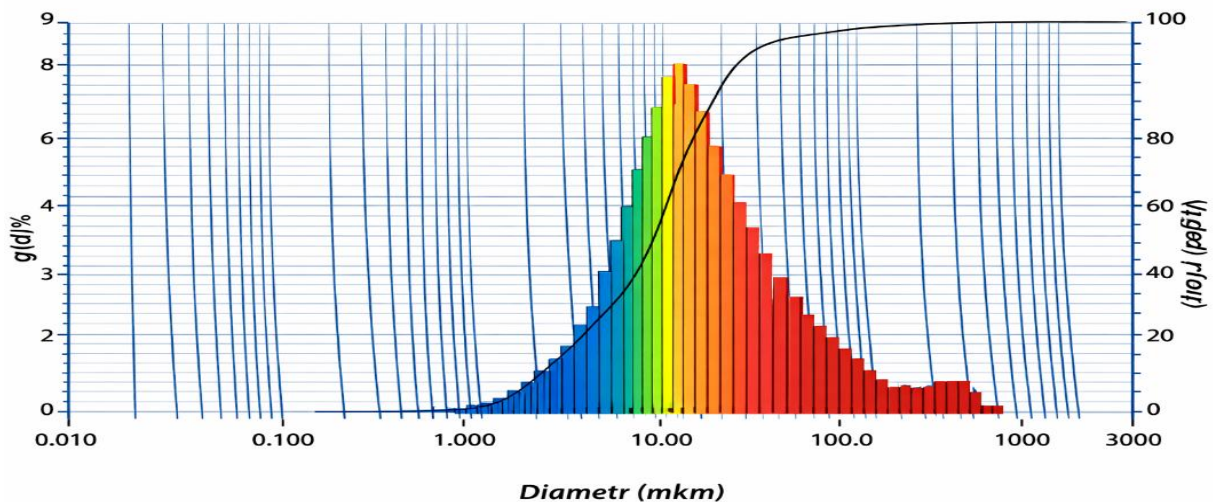


Figure 2. Particle size distribution in the modified dry mix

As can be seen from the results presented in Figure 2, the particle size distribution curve of the modified dry mix has a trimodal character. Specifically, the share of fine fractions with a size of 0.1–5 μm is 34%, particles in the 5–10 μm range are 26%, particles in the 10–20 μm range are 33%, and particles larger than 20 μm are 7%. It

should be noted that the KZ-TM-30 silica sol nanomodifier, introduced into the dry mix at a concentration of 0.001%, did not cause a significant shift of the "left shoulder" of the particle distribution curve towards the nanoparticle region (less than 100 nm). However, the resulting particle size distribution ensures

a rapid increase in the strength of the foam concrete. In particular, particles with a size of 0–5 μm have a decisive influence on the strength formation of foam concrete prepared from the dry mix during the initial hours of

hardening. While particles in the 5–10 μm range significantly affect the strength increase during the 3–7 day period, the 10–20 μm fraction determines the strength indicators at 28 days and beyond (Table 2).

Table 2
Strength of foam concrete made from dry mixes

Material name	Average density, kg/m ³	Compressive strength 28 days, MPa
Foam concrete from dry mix	400	1.5-1.7
Modified foam concrete foam concrete mix	400	1.9-2.0

As can be seen from the results presented in Table 2, modifying the dry mix intended for non-autoclaved foam concrete makes it possible to increase its compressive strength by an average of 15%. These results confirm that the modifiers enhance the activity of the binder system within the dry mix.

As noted above, the use of porous aggregates with a bulk density not exceeding 600 kg/m³ is currently a key consideration in the production of thermal insulation concretes. This requirement is driven by the need to increase energy efficiency and reduce structural loads.

To date, various technological options for lightweight concretes have been developed based on combining porous aggregates with a foamed binder slurry. According to their foaming methods, they can be conditionally divided into three main groups:

1. sand-free concretes foamed using a pre-formed foam;
2. sand or sand-free concretes foamed using gas-forming admixtures;
2. sand-based concretes foamed with air-entraining chemical admixtures.

Within the scope of this research, obtaining lightweight concretes based on dry mixes for non-autoclaved foam concrete belongs to the first group, i.e., the class of sand-free, foam-porous concretes.

An analysis of research dedicated to pore-formation processes shows that the porization of the binder (solution) part of the mixture can be achieved through several technological methods. In particular, the following main methods are distinguished:

1. introducing pre-made technical foam during the mixing process;

2. mixing the cement paste with foam, then combining the resulting porous paste with a porous aggregate;

3. directly adding foaming agents during the mixing process;

4. pre-mixing the foaming agent, water, and binder components, then introducing the porous aggregate.

The common aspect of these methods is that the foam mass and lightweight aggregates are prepared in separate stages. In this process, a significant portion of the foam is observed to break down during the technological cycle, which negatively affects the quality indicators of the finished foam concrete.

Therefore, in the production of foam concrete, it is advisable to carry out the processes of foam formation and mixing with lightweight aggregates simultaneously, in a single technological stage. This requirement is fully met by the technology for preparing lightweight concrete based on dry mixes designed for non-autoclaved foam concrete.

The technology for preparing foam concrete from dry mixes typically requires the use of high-speed mixers with a rotational frequency of 1500 rpm. However, the high-frequency mixing process can lead to the breakdown of the foam mass and the segregation of the lightweight aggregate. Based on the results of experimental studies, it was determined that using a mixer with a blade rotation frequency of 500 rpm is technologically more appropriate for preparing lightweight concrete. The influence of aggregate types on the compressive strength of lightweight concrete made from dry mixes is presented in Table 3. To evaluate the efficiency of lightweight concretes and to compare them with each other, it is advisable to use the coefficient

of structural quality. This indicator makes it possible to reduce the weight of structures while maintaining their strength characteristics. The CSQ is equal to the ratio of

the compressive strength of concrete to its average density, and the values of these indicators are also provided in Table 3.

Table 3
Influence of Aggregate Types on the Strength of Lightweight Concrete

Aggregate Name	Aggregate Fraction, mm	Compressive Strength, MPa	Material Name	Average Density, kg/m ³	Compressive Strength, MPa	CSQ · 10 ⁻³ (R/D), m
Expanded clay gravel	5–10	P100	Lightweight concrete with expanded clay	750	3.11–3.68	4.1–4.9
	10–20	P75		650	2.87–3.45	4.4–5.3
Granulated foam glass	0–2	2.61	Lightweight concrete with granulated foam glass	550	4.6–5.18	8.3–9.4
	0–5	2.26		500	3.91–4.49	7.8–8.98
	7–20	0.79		400	2.3–3.22	5.75–8.05
	5–7	0.78		450	2.53–3.45	5.62–7.6
	1.25–2.5	2.26		500	3.22–3.68	6.44–7.36
	2.5–5	2.03		450	2.53–3.45	5.62–7.6
Expanded polystyrene granules	4–6	–	Lightweight concrete with expanded polystyrene	300	0.92–1.38	3.0–4.6

Table 4 provides the normative values of the structural quality coefficient for lightweight concretes.

Table 4
Normative values of the structural quality coefficient

Material name	Normative document	Normative strength value	SQC · 10 ⁻³ (R/D), m
Expanded clay concrete D700	GOST 25820–2000	Compressive strength class – B2.5–B3.5 (3.27–4.58 MPa)	4.67–6.54
Expanded clay concrete D600	GOST 25820–2000	Compressive strength class – B2.5 (3.27 MPa)	5.45
Expanded clay concrete D500	GOST 25820–2000	Compressive strength class – B1.0–B2.0 (1.45–2.9 MPa)	2.9–5.8
Structural-thermal insulating autoclaved concrete D700	GOST 31359–2007	Compressive strength class – at least B1.5 (2.17 MPa)	3.1

Polystyrene concrete D300–D400	GOST 51263–2012	Compressive strength class – at least B0.5–B0.75 (0.75–1.5 MPa)	1.85–2.75
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An analysis of Tables 2–3 revealed that for all types of lightweight concrete developed, the structural quality coefficient (SQC) was 30% or more higher than the current standard values. This finding confirms the high structural efficiency of the developed compositions. Furthermore, the highest SQC value was recorded in lightweight concrete based on granulated foam glass, which indicates that this aggregate is a promising material for lightweight concretes.

4. Conclusion

Thus, the conducted research has established the high strengthening effect of modifying foam concrete (prepared from dry mixes) with nano-silica, proving the technological and physico-mechanical effectiveness of this approach. It has also been substantiated that using lightweight porous aggregates in foam concrete, including those with ceramic, silicate, and polymer bases, serves to improve structural and thermal performance indicators, justifying their practical application in construction.

References

1. Karimov A.A., Islomov B.S. *Building Materials and Products*. – Tashkent: O'zbekiston, 2018. – 320 p.
2. Rahimov R.R. *Mineral Binders in Construction and Their Properties*. – Tashkent: Fan va texnologiya, 2016. – 280 p.
3. Abdullayev Sh.Sh., Qodirov M.M. *Technology of Lightweight and Porous Concretes*. – Tashkent: Fan, 2015. – 210 p.
4. Kholmatov, U.T. (2017). *Technology for the Production and Application of Foam Concrete*. Tashkent: O'qituvchi. 156 p.
5. Tursunov, B.R., & Rakhmonov, A.N. (2019). *Energy-Efficient Building Materials*. Tashkent: Iqtisodiyot. 240 p.
6. Yuldashev, A.K., & Rasulov, J.X. (2020). *Application of Nanotechnologies in Construction Materials*. Tashkent: Fan va texnologiyalar. 198 p.
7. Saidov, F.M., & Khudoyberdiyev, D.A. (2018). *Composition and Properties of Dry-Mix Mortars*. Tashkent: Texnika nashriyoti. 175 p.
8. O'rozov, K.Sh. (2019). The Influence of Modifying Additives on the Structure and Strength of Foam Concrete. *Qurilish va arxitektura jurnali [Journal of Construction and Architecture]*, (2), 45–49.
9. Khudoynazarov, A.A., & Ismoilov, S.R. (2020). The Use of Nanodispersed Additives in Lightweight Concretes. *O'zbekiston muhandislik jurnali [Engineering Journal of Uzbekistan]*, (3), 33–38.
10. Qodirov, M.M., & Tursunov, B.R. (2018). Physico-Mechanical Properties of Thermal Insulation Concretes. *Qurilish materiallari [Construction Materials] (Tashkent)*, (1), 21–26.
11. Construction Norms of the Republic of Uzbekistan (O'RQMQ). *Lightweight Concretes. Technical Requirements*. (2020). Tashkent.
12. State Standard of the Republic of Uzbekistan (O'zDSt). *Concrete and Reinforced Concrete Products. General Technical Specifications*. Tashkent.