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Influence of additives and temperature regime on the setting kinetics and strength of foamed concrete

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ABSTRACT
The article presents the results of the development of the physico-mechanical characteristics of fast-setting lightweight concrete. Based on the obtained data, it was concluded that the use of metal cassette molds in foam concrete technology is ineffective. Their turnover can be increased by heating the floor in the workshop and insulating the sides and surfaces of the molds. However, the high cost of energy carriers increases the material's production cost and reduces its competitiveness. At ambient temperatures below 16 °C, it is advisable to use insulated wooden molds, which help retain the heat released during cement hydration. The optimal mold dimensions (1.2 × 1.25 × 0.5 m and 1.2 × 1.25 × 0.6 m) were selected based on cutting technology capabilities. The formation of large monolithic masses is associated with the risk of cracks and even structural rupture due to uneven heat distribution. To maintain the initial mix temperature within 22 – 25 °C, the molding mixture should be prepared using water heated to 30 °C. In insulated wooden molds, the formed material retains a temperature of at least 18 – 20 °C before the onset of hydration. Then, due to the exothermic reaction of cement, the temperature remains stable until demolding. Improvements in natural-setting foam concrete technology have demonstrated the feasibility of introducing a chemically active siliceous component into the mixture. This component binds free $Ca(OH)_2$ released during alite hydration, contributing to long-term strength development. *Research objective* – The development of effective methods to accelerate the early-stage hardening of foamed concrete by studying the influence of electrolyte additives and surfactants on the setting and hardening processes of cement paste. *The novelty of work* lies in establishing patterns in the formation of physical and mechanical properties of foamed concrete with accelerated initial hardening, taking into account its porous structure, and the characteristics of the hardening process.

Keywords: Foam concrete, fast-hardening, lightweight concrete, additives, temperature, ash, waste.

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Introduction

Rapid-hardening foamed concrete is a promising building material that combines low destiny, high thermal insulation properties, and accelerated strength development [[1], [2], [3], [4], [5], [6]].

These characteristics make it highly sought for the construction of enclosing structures, thermal insulation layers, and prefabricated elements [[7], [8], [9], [10], [11]].

This study is dedicated to the analysis of key physical and mechanical characteristics of foamed concrete with accelerated initial hardening, the identification of patterns in their formation, and the development of recommendations for optimizing the composition to improve the strength and thermal insulation properties of the material [[3], [12], [13], [14], [15]]. Special attention is given to the composition of raw materials, porous structure, and the hydration processes of cement stone [[11], [16], [17]].

This study focuses on analyzing the key physical and mechanical characteristics of fast-setting lightweight foam concrete, identifying patterns in their formation, and developing recommendations for optimizing the composition to improve strength and thermal insulation properties [[12], [13], [14], [15]].

Foam concrete production has shown growth trend, and it is widely used for wall construction alongside ceramic bricks, aerated concrete, and hollow blocks made of heavy concrete [[18], [19], [20], [21], [22], [23]]. However, the overall production volume of foam concrete blocks remains significantly lower compared to aerated concrete and ceramic bricks. One of the main limiting factors is the low productivity of foam concrete block production lines due to the turnaround time of the molds. A considerable amount of time is required for foam concrete to gain sufficient strength for demolding [[6], [18], [19], [20], [21], [22]].

The analysis of scientific and technical literature has shown that research on accelerating the hardening of foam concrete is being conducted in two main directions:

- the first involves the setting and hardening time of the cement binder [[23], [24], [25]];

- the second focuses on the use of technological methods and additives directly during the concrete preparation process [[7], [9], [26], [27]].

In concrete technology, including foam concrete, the most commonly used method for accelerating hardening is the introduction of chemical additives. However, unlike heavy concrete, foam concrete has less dense structure and is saturated with water and surfactant molecules from the foaming agents. There are no universal and reliable recommendations for ensuring the accelerated hardening of foam-cement system [[11], [17]]. Conventional additives, such as superplasticizers and calcium chloride, which effectively reduce water demand and speed up hardening in traditional concrete, either do not work in foam concrete or even reduce its strength (as in the case superplasticizers) or fail to produce any significant practical results.

Research objective: The development of effective methods to accelerate the early-stage hardening of foamed concrete by studying the influence of electrolyte additives and surfactants on the setting and hardening processes of cement paste.

The novelty of work lies in establishing patterns in the formation of physical and mechanical properties of foamed concrete with accelerated initial hardening, taking into account its porous structure, and the characteristics of the hardening process.

Experimental part

Materials. In the research, the following raw materials were used:

- portland cements of grade CEM I 32.5N from manufacturers Heidelberg (Ust – Kamenogorsk) and Standard Cement и Standard Cement (Shymkent), produced at cement plants and complying with the requirements of GOST 10178 – 85;

- quartz-feldspar sand from the Kapchagay deposit (Almaty region), with a fineness modulus of 1.48, a silica (SiO_2) content of 37 %, feldspar content of 60.1 %, mica content of 1 %, dust and clay particle content of 1.9 %;

- fly ash from Almaty TPP (thermal power plant), with a SiO_2 content of 88 %;

- synthetic foaming agent FA-2000 (ПВ-2000);

- chemical additives, including sodium nitrate, sodium sulfate, sodium chloride, sodium carbonate, potassium sulfate, potassium chloride, potassium carbonate, potassium nitrate, calcium chloride, and sodium silicate solution. All additives complied with the requirements of the relevant standards.

The study was conducted mainly using standard research methods.

Methods. According to the working hypothesis, the introduction of individual additives was first tested, followed by complex hardening accelerators for concrete. The effectiveness of the additives was initially evaluated using dense cement paste, meaning that the additives were dissolved in mixing water, and the resulting salt solution was mixed with cement until a paste of normal consistency was obtained. The setting time was determined in accordance with GOST 310.10. Standard methods for determining the physical and mechanical properties of binders and concrete were used in the study.

Compressive strength determination according to GOST 25485 – 2019 and GOST 10180 – 2012:

The essence of the method – determination of concrete compressive strength consists in measuring the minimum force that destroys specially prepared control samples of concrete measuring 100 x 100 x 100 mm under static loading at a constant load increase rate, followed by calculating the stress at these forces in accordance with GOST 10180 – 2012.

After placing the sample on the support plates of the testing machine or additional steel plates, the upper plate of the testing machine is aligned with the top surface of the sample so that their planes are fully in contact. The sample is loaded until failure at a constant rate of load increase (0.6 ± 0.2) MPa/s.

The methods of preparing the foamed concrete mixture includes:

- dry mixing: Cement, sand, and ash are mixed for 3 – 5 minutes until a homogeneous dry mixture is obtained;
- foam preparation: Stable foam based on PB-2000 is prepared at a pressure of 0.4 – 0.6 MPa from a 3 – 5 % aqueous solution and air. The expansion ratio is regulated by the component ratio and pressure.
- addition of water and chemicals: Water with additives (0.1 – 5 % of the cement weight) is mixed until homogeneous. The amount of water is calculated based on the workability of the mixture and the water-cement ratio;
- mixing with foam: The liquid solution is added to the dry mix and mixed for 3 – 5 minutes until a uniform mass is obtained;
- casting: The mixture is poured into greased molds without sudden impacts. Light vibration is acceptable.
- curing: Molds are kept at 20 ± 2 °C and humidity ≥ 90 % for 28 days. It is important to maintain high humidity during the first 1-2 days. At low temperatures, heating or accelerators are used.

Main equipment for the experiments:

- laboratory scales (accuracy up to 0.01 g);
- measuring glassware (graduated cylinders, beakers);
- mixer for cement paste preparation;
- consistency meter (Vicat apparatus) for setting time determination;
- laboratory spatula for mixing.

For mixture preparation, the raw materials were dried in a drying oven at a temperature of 100 - 110 °C.

Results and Discussion

According to the working hypothesis, the introduction of individual additives was first tested, followed by complex hardening accelerators for concrete. The effectiveness of the additives was evaluated at the initial stage using dense cement paste. Specifically, the additives were dissolved in mixing water, and the resulting salt solution was mixed with cement until a paste of normal consistency was obtained. The foaming agent was not used in these experiments.

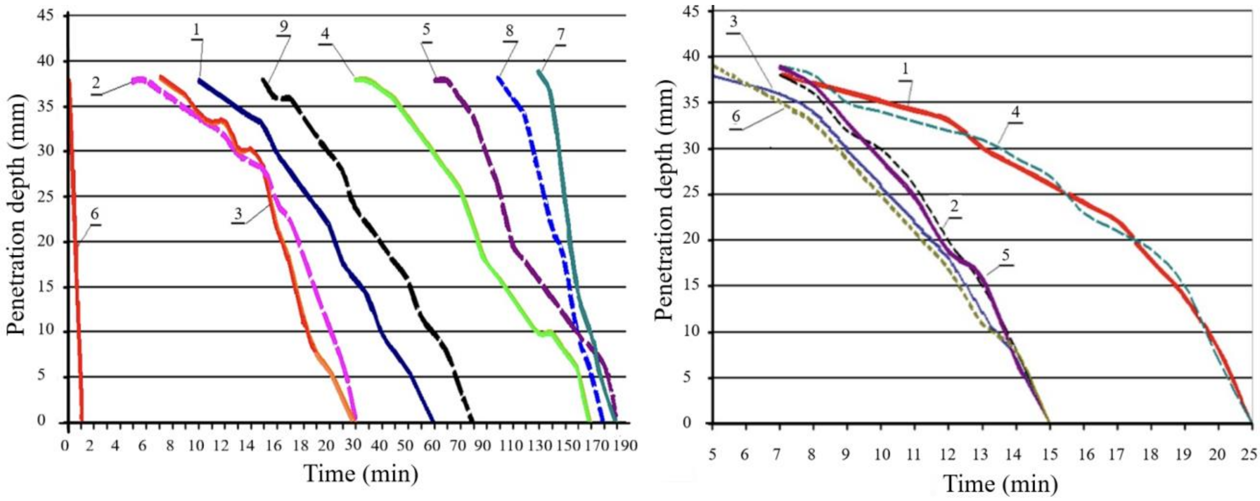
When using portland cement grade CEM I 32.5N in the initial additive – free cement paste, the initial setting time is 2 hours 20 minutes, and the final setting time is 4 hours 20 minutes, which meets the regulatory requirements and indicates a moderate rate of hydration processes at the early stages of hardening.

The test results (Figures 1 a, b) demonstrated the high efficiency of additives containing sulfate ions, as well as sodium and potassium nitrites, in accelerating the setting time of cement paste.

When 1 %, 2 %, and 6 % Na_2SO_4, were introduced, the initial setting time was reduced from 2 hours 20 minutes to 12 minutes, 6 minutes, and 8 minutes, respectively, while the final setting time decreased from 4 hours 20 minutes to 57 minutes, 32 minutes and 22 minutes, respectively. The addition of 1 – 2 % potassium sulfate showed a more moderate effect on setting times compared to the same amount of sodium sulfate, However, at higher K_2SO_4 concentrations, the mixture rapidly thickened and set almost immediately. The effect of $Al_2(SO_4)_3$ was found to be similar to that of potassium sulfate solution when introduced into the cement paste.

Experimental data indicated a moderate effect of sodium, potassium, and calcium chloride salts on cement setting times (Figure 2a). The influence of sodium and potassium nitrites was intermediate between that of sulfate and chlorides (Figure 2a).

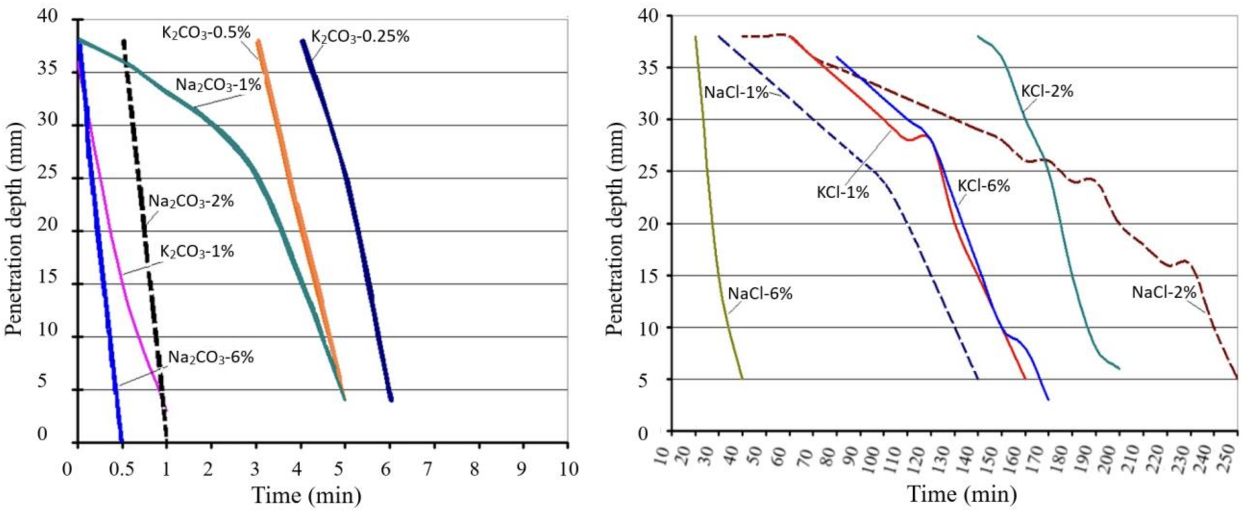
A significant reduction in setting time was observed when potassium carbonates were introduced into the cement (Figure 2b, Table 1). With 0.5 % potassium carbonate (potash) and 1 % sodium carbonate (soda), the setting times were as follows: initial setting - 3 minutes (potash), 1 minute (soda); final setting: 5 minutes (both). Further increases in dosage became impractical, as the cement began to set immediately during mixing with potassium and sodium carbonate salt solutions.



a) b)

a) Additive content: №1 – 3. Na_2SO_4. respectively 1; 2; 6 %. №4 – 6 K_2SO_4 respectively 1; 2; 6 %.
№7-9 $Al_2(SO_4)_3$ respectively 1; 2; 6 %.
b) Additive content: №1 – 3 Na_2NO_2 respectively 1; 2; 6 %.
№4 – 6 K_2NO_2 respectively 1; 2; 6 %; $Al_2(SO_4)$ respectively 1; 2; 6 %.

Figure 1 – Setting times of cement paste with sulfate and nitrite additives



a) b)

Figure 2 – Setting time of cement paste with various additives

Thus, based on the experimental data, the high efficiency of electrolyte additives and the possibility of controlling the setting time of cement binders by adjusting the type and dosage of additives have been established.

Since foam concrete necessarily contains foaming surfaces – active agents (surfactants) that form a dense layer on the surface of hydrating cement particles, thereby slowing down the setting and hardening process, it was important to determine the effect of setting accelerators in the presence of surfactants.

The surfactant dosage in the study was set at 0.25 – 0.5 % of the cement mass, which corresponds to the actual consumption of foaming agents in the production of foam concrete with bulk density of 500 – 1200 kg/m^3. At the initial stage of the experiments, the effect of additives was assessed in dense cement paste, meaning that an electrolyte solution and surfactant were added to the mixing water and stirred with cement until a paste of normal consistency was obtained. Further tests were conducted in accordance with GOST 310.10.

Experimental methods, which data presented in Figure 3 (a, b) – 4 (a, b), have shown that the addition of a foaming agent in combination with most additives does not result in a significant negative effect, such as a prolonged setting time of the cement paste.

Table 1 – Effect of potassium and sodium carbonate additives on cement paste setting time

Additive	Additive content. % by cement mass	Setting time (t – min.)	
		initial	final
With additives	—	2 – 20	4 – 20
Potash (K_2CO_3)	0.25	0 – 0.4	0 – 0.6
Potash (K_2CO_3)	0.5	0 – 0.3	0 – 0.5
Potash (K_2CO_3)	1.0	0 – 0.0	0 – 0.1
Potash (K_2CO_3)	2.0	0 – 0.0	0 – 0.0
Soda (Na_2CO_3)	1.0	0 – 0.1	0 – 0.5
Soda (Na_2CO_3)	2.0	0 – 0.0	0 – 0.1
Soda (Na_2CO_3)	6.0	0 – 0.0	0 – 0.0

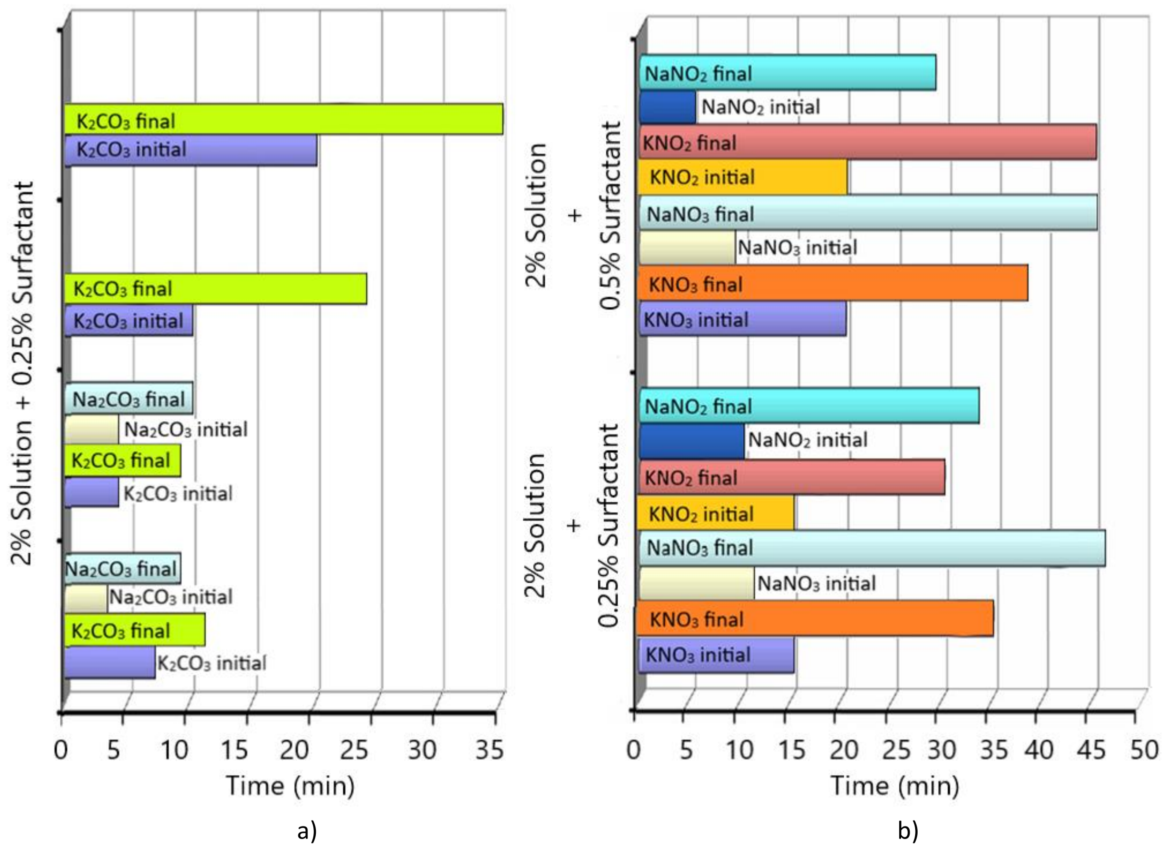


Figure 3 – Setting time of cement paste with nitrate, carbonate additives, and surfactant

When a foaming surfactant was introduced into solutions containing sodium sulfate, sodium and potassium carbonate, sodium nitrite and nitrate, and potassium nitrite and nitrate, the setting times remained relatively short: initial setting time 3 – 20 minutes, final setting time 9 – 46 minutes. However, the setting time increased, when the surfactant was used together with potassium and aluminum sulfate, and potassium, sodium, and calcium chlorides. In this case: initial setting time ranged from 55 minutes to 4 hours, final setting time ranged from 2 hours 50 minutes to 5 hours.

Thus, based on the study results, it was concluded that in dense cement paste, most electrolyte additives in the presence of a foaming surfactant effectively accelerate cement setting. However, in real foam concrete production, the cement paste is in a less dense state. Moreover, the water-to-cement ratio (W/C) in foam concrete is typically higher than the W/C ratio of the same cement paste or cement – silica slurry.

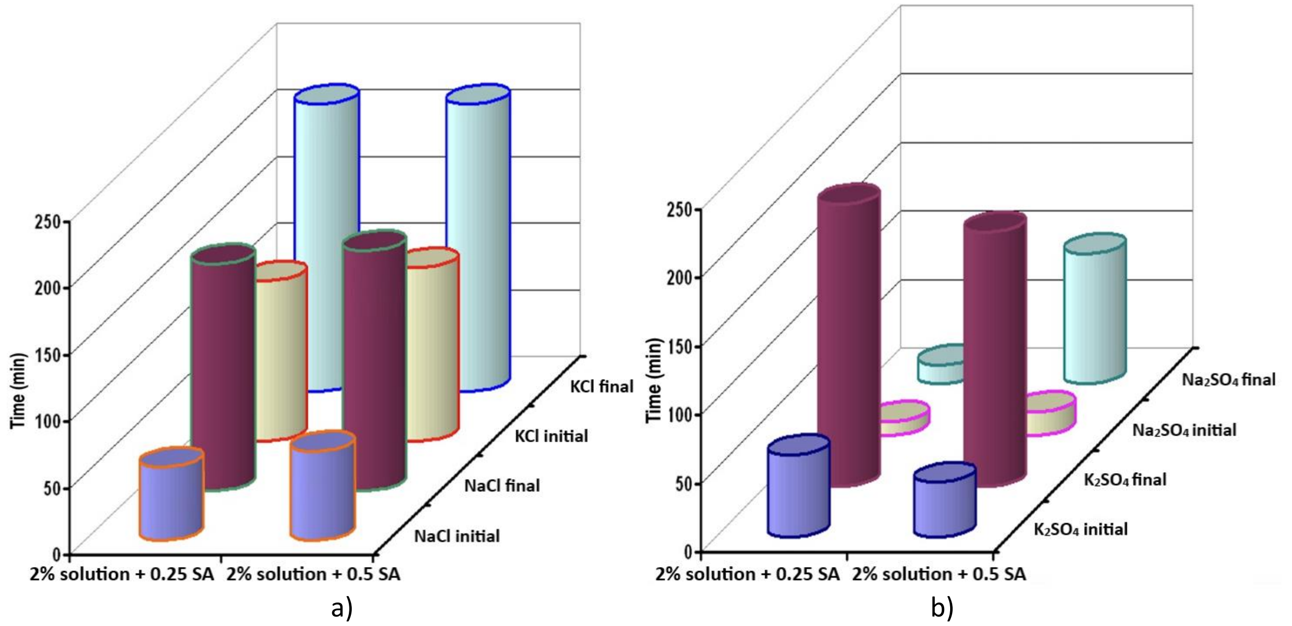


Figure 4 - Setting times of cement paste with chloride, sulfate, and surfactant additives

Therefore, the final assessment of the effectiveness of setting and hardening accelerators can only be made by preparing foamed cement paste and testing the physical properties of the mixture and the physico-mechanical characteristics of the hardened paste.

In the study, the kinetics of strength development of the hardened material and the chemical compatibility of additives with surfactants in an alkaline environment were selected as the controlled parameters to evaluate the effect of additives in production of porous systems. At the same time, the absence of standardized testing method for determining the setting time of foamed cement paste was taken into account.

The experiments revealed the chemical incompatibility of certain foam concrete mixture components during hardening, including sodium carbonate, potassium and sodium nitrites, and potassium and sodium sulfates. This incompatibility manifested as coagulation of the mixture, uncontrolled gas formation, and foam sedimentation. Ultimately leading to the formation of a material with large irregular pores, a loose surface, efflorescence, and low strength. Therefore, this group of additives was excluded from further experiments. When studying the effect of additives on the acceleration of foam concrete hardening, it is crucial from a technological perspective to assess both the setting rate and the hardening rate of the system. Rapid setting is necessary for structural stabilization of the foam concrete during the mixing of the cement-silica slurry with foam and the subsequent shaping of the molded mass. Meanwhile, accelerated hardening ensures the rapid development of early strength, which is essential for demolding the material. At the same time, the final strength of the foam concrete with additives must not be lower than that of foam concrete without additives.

The setting time of foamed cement paste was determined by measuring the temperature change of the foam-cement mixture, while hardening was assessed by testing the strength at different curing ages. The study (Figure 5) established that during foaming of cement paste, the previously observed effects of electrolyte additives on setting time are largely neutralized. The initial heat release from cement hydration, when combined with electrolytes and a foaming agent, begins approximately 2 hours after mixing the binder with an aqueous solution of surfactant and respective salt, while the final setting time occurs within 12 – 14 hours.

To accelerate the setting rate of foamed cementitious mass, a combination of two electrolyte additives along with a surfactant was tested. According to the working hypothesis, CaC_2 was expected to accelerate the hardening of foam concrete, while potassium carbonate (K_2CO_3) would promote rapid setting by reacting with calcium sulfate dihydrate (gypsum), a natural setting retardant in Portland cement.

The results (Figure 5, Table 2) confirmed the validity of this hypothesis and revealed new trends in the hardening kinetics of foam concrete with hardening accelerators (Figure 6).

Foam concrete without additives with a bulk density 600 kg/m^3 reaches demolding strength only after 12 hours. In contrast, with electrolyte additives, the demolding time is reduced by half, and within 24 hours, the strength exceeds that of additive – free foam concrete by more than 1.5 times.

The most significant effect was observed when chloride salts were combined with potassium carbonate (potash) or sodium silicate solution. In this case: foam concrete could be demolded after 2 hours, after 4 – 6 hours, compressive strength reached 0.27 – 0.41 MPa.

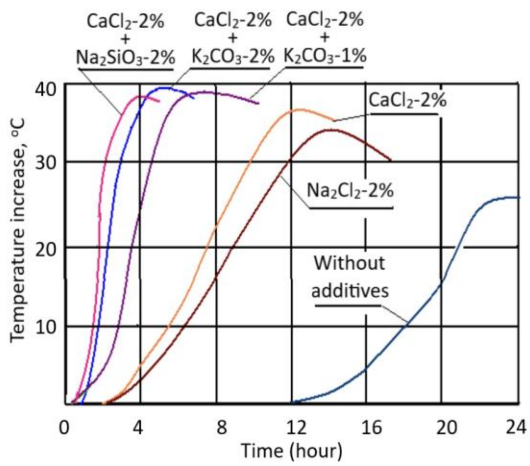


Figure 5 – Temperature change in cement paste with hardening accelerators

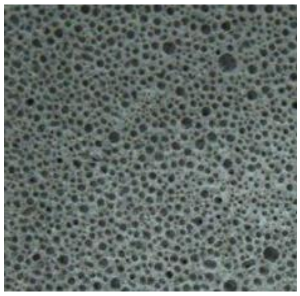


Figure 6 – Structure of foamed concrete

Table 2 – Effect of electrolyte additives on the hardening time of foam concrete with an average density of 600 kg/m^3

Additive		Compressive strength. MPa. After										
Name	Dosage %	2h	4h	6h	8h	12h	24h	2d	3d	7d	14d	28d
—	—	HP	HP	HP	HP	HP	0.13	0.23	0.46	0.62	1.09	1.7
$CaCl_2$	2	HP	HP	HP	HP	0.12	0.21	0.3	0.48	0.74	1.5	2.9
$NaCl_2$	2	HP	HP	HP	HP	0.11	0.18	0.28	0.51	0.98	1.26	2.23
$CaCl_2 + K_2CO_3$	2+1	HP	0.09	0.17	0.18	0.21	0.29	0.42	0.55	0.92	1.4	2.8
$CaCl_2 + K_2CO_3$	2+2	0.13	0.27	0.38	0.41	0.47	0.51	0.55	0.72	1.2	1.6	2.7
$NaCl + K_2CO_3$	2+1	HP	0.06	0.15	0.16	0.19	0.25	0.38	0.57	0.8	1.1	2.7
$NaCl + K_2CO_3$	2+2	0.11	0.28	0.36	0.37	0.42	0.48	0.52	0.66	0.95	1.3	2.6
$CaCl_2 + Na_2SiO_3$	2+2	0.14	0.29	0.41	0.43	0.52	0.55	0.57	0.78	1.34	1.72	3.1
Note – NR – not possible to demold, the sample collapses upon demolding												

After 6 hours, the rate of strength gains significantly slowed down and by 3 days, the compressive strength of all samples (with and without additives) became comparable.

The most noteworthy aspect is the hardening of kinetics between 7 and 28 days.

Calculations based on experimental data (Table 3) indicate that by 7 days heavy concrete reaches 60 % of its design strength, foam concrete (with and without additives) reaches 25 % to 44.4 % of their final strength. Between 7 and 14 days, the strength of heavy concrete increases from 65 % to 80 % (1.23 times), while from 14 to 28 days, it further rises from 80 % to 100 % (1.25 times). In contrast, foam concrete strength increases from 51.7 % to 100 % over the 14 – 28 day period, showing a significantly higher by 1.93 times rate. After 28 days, the strength of foam concrete reaches 1.7 MPa, corresponding to class M15. The addition of individual calcium and sodium chloride salts further optimized the time required to reach final strength.

Table 3 - Strength development kinetics of heavy concrete and foam concrete

Material	**Additive**		**Strength growth. %. Days**				
	Name	**Dosage**	**1**	**3**	**7**	**14**	**28**
Heavy concrete	-	-	-	33	65	80	100
Foam concrete			7.6	27.0	36.5	64.1	100
	$CaCl_2$	2	7.2	16.5	25.5	51.7	100
	$CaCl_2+K_2CO_3$	2+2	18.6	24.8	44.4	59.2	100
	$CaCl_2+Na_2SiO_3$	2+2	17.7	25.1	43.2	55.5	100

Table 4 - Effect of ambient temperature on the strength development of foam concrete with an average density of 600 kg/m^3

Ambient temperature (^{0}C)	**Additive**		**Compressive strength. MPa, after**						
	Name	**Dosage, %**	**0.5 day**	**1 day**	**2 days**	**3 days**	**7 days**	**14 days**	**28 days**
14 – 16	—	—	NR	NR	0.07	0.16	0.35	0.62	1.3
	$CaCl_2$	2	NR	0.09	0.15	0.26	0.42	0.85	2.2
	$CaCl_2 + K_2CO_3$	2+2	0.08	0.32	0.36	0.47	0.84	0.88	2.5
18 – 20	—	—	NR	0.13	0.23	0.46	0.62	1.09	1.7
	$CaCl_2$	2	0.12	0.21	0.3	0.48	0.74	1.5	2.9
	$CaCl_2 + K_2CO_3$	2+2	0.47	0.51	0.55	0.72	1.2	1.6	2.7
23 – 25	—	—	NR	0.11	0.23	0.47	0.67	1.12	1.8
	$CaCl_2$	2	0.13	0.26	0.32	0.49	0.69	1.52	3.0
	$CaCl_2 + K_2CO_3$	2+2	0.18	0.52	0.58	0.75	1.3	1.7	2.8
28 – 30	—	—	NR	0.14	0.25	0.48	0.68	1.11	1.9
	$CaCl_2$	2	0.12	0.23	0.31	0.52	0.70	1.58	2.8
	$CaCl_2 + K_2CO_3$	2+2	0.15	0.49	0.61	0.83	1.4	1.75	2.85

The findings suggest that in foam concrete, the retardation effect of cement hydration persists for up to 7 days, even in the presence of setting accelerators.

After the specified period, the density of the adsorbed layer of surfactant (SA) molecules on the surface of hydrating clinker minerals in cement significantly decreases, leading to accelerated hardening of foam concrete. The reduction in the density of the adsorbed SA layer is caused by a sharp increase in the surface area of hydration products.

One of the disadvantages of natural curing foam concrete technology is the slow strength development at temperatures between + 10 and + 16 °C. These temperatures are most typical during the autumn-spring period in the southern regions of Kazakhstan, while in northern regions, ambient temperatures drop even lower.

As a result, foam concrete production is essentially limited to the summer months.

Since foam concrete is molded in metal forms, the heat generated during cement hydration is rapidly dissipated into the environment due to the high thermal conductivity of steel (λ_{st} = 45 W/(m °C)) through the walls and bottom of the mold. Consequently, foam concrete hardens at ambient temperature. Moreover, nighttime temperatures are typically 5 – 10 °C lower than daytime temperatures, further slowing the hardening process.

Experimental studies (Table 4) revealed a significant decrease in the rate of strength development in foam concrete, both without additives and with electrolyte additives, as the ambient temperature decreased from 8 – 20 °C to 14 – 16 °C.

Foam concrete without additives reached an acceptable strength only after 3 days (Rc = 0.16 MPa), foam concrete with $CaCl_2$ reached 0.26 MPa, foam concrete with $CaCl_2$ combined with potassium carbonate (K_2CO_3) reached 0.47 MPa. At 14 – 16 °C, foam concrete with the optimal additive dosage could be demolded after 12 hours, but it achieved guaranteed strength only after 24 hours of curing.

Conclusions

Based on experimental data, the following comparative and quantitative conclusions can be drawn about the influence of various electrolyte additives and temperature on the setting times and strength characteristics of foamed concrete:

- without additives, the initial setting time of cement paste is 2 h 20 min, final setting – 4h 20 min;

- with 1 % Na_2SO_4, initial setting time is reduced to 12 min, final to 57 min (reduction of more that 4 times);

- with 0.5 % K_2CO_3, initial – 3 minal. Final – 5 min, which shows a 20-fold acceleration.

Compatibility with surfactants:

- with the addition of surfactants, most additives retain the accelerating effect with initial setting from 3 to 20 min, final – 9 to 46 min, but combinations with potassium sulfate and chloride extend the initial setting up to 4 hours, indicating chemical incompatibility.

Demolding strength (after 4-6 h):

- without additives, foamed concrete does not reach the required strength;

- with $CaCl_2$ + K_2CO_3 (2 + 2 %) the strength is 0.27 – 0.41 MPa, allowing the demolding time to be halved.

Strength after 28 days:

- without additives – 1.7 MPa (M15);

- with $CaCl_2$ + Na_2SiO_3 – 3.1 MPa, an increase of 82%.

Temperature regime:

- at 14 – 16°C, foamed concrete without additives reaches 0.16 MPa in 3 days;

- with $CaCl_2$ + K_2CO_3 – strength after 1 day is 0.47 MPa, nearly 3 times faster;

- at 28 – 30 °C, the strength of foamed concrete with additives reaches 2.85 MPa, which is 67 % higher than the base level.

Strength kinetics – by day 7, foamed concrete with additives reach up 44.4 % of the design strength, and by day 28 – 100 % or more.

In comparison, conventional concrete gains from 60 % to 100 % strength during the same period, but foamed concrete with additives shows an almost 2-fold increase in strength gain rate during the 14 – 28 day phase (1.93x).

Conflicts of interest. On behalf of all the authors, the correspondent author declares that there is no conflict of interest.

CRediT author statement: **D. Sartaev, Y. Orynbekov:** Conceptualization, Visualization, Project administration, Funding acquisition; **D. Sartaev, Y. Orynbekov, A. Baisarieva, D. Uxikbayeva:** Methodology, Writing – original draft preparation; **A. Baisarieva, D. Uxikbayeva:** Software; **Y. Orynbekov:** Formal analysis;

All authors have read and agreed to the published version of the manuscript.

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Сартаев Д.Т., Орынбеков Е.С., Байсариева А.М., Уксикбаева Д.А.

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Қабылданды: *25 тамыз 2025*

ТҮЙІНДЕМЕ
Мақалада тез қататын жеңіл бетонның физикалық-механикалық сипаттамаларын әзірлеу нәтижелері ұсынылған. Алынған мәліметтер негізінде көбік бетон технологиясында металл кассета қалыптарын қолданудың тиімсіздігі туралы қорытынды жасалды. Олардың айналымын цехтағы еденді жылыту және қалыптардың бүйірлері мен беттерін оқшаулау арқылы арттыруға болады. Алайда, энергия тасымалдаушылардың құны жоғары болғандықтан материалдың өзіндік құнын арттырады және оның бәсекеге қабілеттілігін төмендетеді. Қоршаған ортаның температурасы 16°С-тан төмен болғанда цемент ылғалданған кезде пайда болатын жылуды сақтауға көмектесетін оқшауланған ағаш қалыптарды қолданған жөн. Кесудің технологиялық мүмкіндіктерін ескере отырып, пішіндердің оңтайлы өлшемдері (1.2 × 1.25 × 0.5 м және 1.2 × 1.25 × 0.6 м) таңдалады. Жылудың біркелкі бөлінбеуіне байланысты ірі монолитті массивтерді қалыптау құрылымның жарылуы және тіпті жыртылу қаупін тудырады. Қоспаның бастапқы температурасын 22 – 25°С диапазонында ұстау үшін қалыптау массасын 30°С дейін қыздырылған суды пайдаланып дайындау керек. Жылытылған ағаш қалыптарда қалыпталған материал ылғалдандыру басталғанға дейін температураны кемінде 18 – 20 °С сақтайды. Содан кейін цементтің экзотермиялық реакциясы арқылы температура қалыптан шыққанға дейін тұрақты болып қалады. Көбік бетонының табиғи қатаю технологиясын жетілдіру қоспаның құрамына химиялық белсенді кремний диоксиді компонентін енгізудің орындылығын көрсетті. Ол алитті ылғалдандырған кезде бөлінетін бос $Ca(OH)_2$ байланыстырады, бұл ұзақ қатаю кезеңінде беріктік жиынтығына ықпал етеді. Зерттеудің мақсаты – Электролиттік қоспалар мен беттік-белсенді заттардың цемент езіндісінің қатаю процестеріне әсерін зерттеу арқылы көбікті бетонның бастапқы кезеңдердегі қатаюын жеделдетудің тиімді тәсілдерін әзірлеу. Жұмыстың жаңалығы – көбік бетонның кеуекті құрылымын, құрамдас бөліктерінің құрамын және қатаю процесінің ерекшеліктерін ескере отырып, жеделдетілген бастапқы қатаю кезеңімен көбік бетонның физикалық-механикалық қасиеттерінің қалыптасу заңдылықтарын анықтау.

Түйін сөздер: Көбік бетон, тез қататын, жеңіл бетон, қоспалар, температура, күл, қалдық.

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Влияние добавок и температурного режима на кинетику схватывания и прочность пенобетона

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АННОТАЦИЯ
Статья представляет результаты разработки физико-механических характеристик быстротвердеющего лёгкого бетона. На основании полученных данных сделан вывод о неэффективности использования металлических кассетных форм в технологии пенобетона. Их оборот можно увеличить за счёт подогрева пола в цехе и изоляции боковин и поверхности форм. Однако высокая стоимость энергоносителей повышает себестоимость материала и снижает его конкурентоспособность. При температуре окружающей среды ниже 16 °C целесообразно использовать утеплённые деревянные формы, которые помогают сохранять тепло, выделяемое при гидратации цемента. Оптимальные размеры форм (1.2 × 1.25 × 0.5 м и 1.2 × 1.25 × 0.6 м) выбраны с учётом технологических возможностей резки. Формование крупных монолитных массивов сопряжено с риском появления трещин и даже разрывов структуры из-за неравномерного распределения тепла. Для поддержания начальной температуры смеси в пределах 22–25 °C формовочную массу следует готовить с использованием воды, подогретой до 30 °C. Затем, за счёт экзотермической реакции цемента, температура остаётся стабильной до момента расформовки. Совершенствование технологии естественного твердения пенобетона показало целесообразность введения в состав смеси химически активного кремнеземистого компонента. Он связывает свободный $Ca(OH)_2$, выделяемый при гидратации алита, что способствует набору прочности на длительных сроках твердения. *Цель исследования* Разработка эффективных способов ускорения твердения пенобетона на ранних этапах путём исследования влияния электролитных добавок и поверхностно-активных веществ на процессы схватывания и твердения цементного теста. *Новизна работы* заключается в установлении закономерностей формирования физико-механических свойств пенобетона с ускоренным сроком начального твердения, с учётом его пористой структуры, состава компонентов и особенностей процесса твердения.

Ключевые слова: пенобетон, быстротвердеющий, легкий бетон, добавки, температура, зола, отход.

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