Issue No. 2 · 2026
ADVANCED STUDIES
IN ARCHITECTURE AND CIVIL ENGINEERING
(ASACE)

ISSN 3134-8475 (Print)
ISSN 3134-8483 (Online)

UDC 666.913.3
Research article

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DEVELOPMENT AND STRENGTH EVALUATION OF A COMPOSITE ANHYDRITE BINDER BASED ON PHOSPHOGYPSUM

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ABSTRACT

Introduction. Large-scale accumulation of phosphogypsum creates both environmental problems and the need for efficient technologies for its disposal. The development of composite binders based on phosphogypsum can reduce the consumption of natural gypsum raw materials and promote the production of resource-saving building materials. The goal of this study is to study the effect of firing temperature, binder composition, as well as the content and method of administration of lime as an activating additive on increasing the strength of composite anhydrite binder based on phosphogypsum. **Materials and Methods.** The composite mixture containing phosphogypsum, loam and finely ground glass was subjected to heat treatment at temperatures of 700, 800 and 900°C. Hydrated lime was introduced into the fired mixture in amounts of 5, 10, and 15% of the phosphogypsum content. The compressive strength of the samples based on the obtained binder was determined after 7 and 28 days of hardening. X-ray diffraction analysis was used to identify the phase transformations occurring during hydration. **Results and Discussion.** The results showed that the strength of the composite anhydrite binder depends on both the firing temperature and the amount of activator (hydrated lime). The highest strength was obtained at a firing temperature of 700 °C for a composition containing 90% phosphogypsum, 5% loam and 5% glass with the addition of 15% lime. The compressive strength reached 11.8 MPa after 7 days and 25 MPa after 28 days of hardening. An increase in the firing temperature to 800-900°C led to a decrease in strength. X-ray diffraction analysis confirmed the formation of hydrated phases during the hardening process, including gypsum and calcium-containing hydration products. **Conclusions.** The results obtained indicate that phosphogypsum can be effectively used as the main component of a composite anhydrite binder. The proposed composition and processing conditions provide a promising approach to the production of resource-saving binders for dry building mixes and light concrete, while reducing the consumption of natural mineral resources and contributing to the disposal of large-scale industrial waste.

KEYWORDS: phosphogypsum; composite anhydrite binder; anhydrite cement; lime activation; loam; glass cullet; firing temperature; compressive strength; industrial waste disposal.

FOR CITATION:

Ibraimbayeva G.B., Zhilkibayeva A.M., Tashmukhanbetova I.B., Askerov Y.Ye. Development and strength evaluation of a composite anhydrite binder based on phosphogypsum. Advanced Studies in Architecture and Civil Engineering. 2026; 1 (2): 66-78.

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(ASACE)
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1 INTRODUCTION

The rational use of natural resources and environmental protection are currently pressing global issues, as they are key factors in sustainable economic development.

The use of phosphorus-containing waste (phosphogypsum, slag) generated during the production of mineral fertilizers – primarily as a result of processing apatites and phosphorites - represents a promising area in the construction industry, enabling the production of binding materials and road pavements. Many researchers have demonstrated the effectiveness of using phosphate slag and phosphogypsum as fillers in the production of bricks, wall blocks, and stones, as well as additives that reduce density and regulate the firing temperature of construction ceramics [1-5].

The use of industrial waste – including phosphogypsum – as a raw material opens up broad opportunities for conserving resources and energy and reducing material consumption in production. For example, in economically developed countries (the U.S., Japan, and Germany), approximately 20% of the total volume of various binders is made from gypsum, and in Japan, phosphogypsum is fully recycled [6]. Chinese scientists have developed a technology for extracting phosphates from phosphogypsum; in China, up to 50% of phosphogypsum is recycled and actively used in construction [7].

According to statistics, 4-5 metric tons of phosphogypsum are produced per metric ton of phosphoric acid. More than 6 billion metric tons of phosphogypsum have accumulated worldwide. Approximately 200-300 million metric tons are generated annually [8].

Phosphogypsum contains up to 98% dihydrate gypsum and, based on this indicator, is classified as a premium-grade raw material. Furthermore, the high fineness of phosphogypsum allows the crushing and coarse grinding stages to be eliminated from the production process [9].

To date, a number of technologies have been developed for producing construction-grade and high-strength gypsum from phosphogypsum, but not enough of them have been implemented yet. This scientific article presents achievements in one area of phosphogypsum utilization – its incorporation into the production of binders for the construction industry. It outlines possible solutions to problems arising during the processing of phosphogypsum, as well as ways to intensify the processes for producing gypsum binders based on it.

In the construction industry, phosphogypsum can be used in place of natural gypsum in the production of gypsum binders and gypsum-based products, as well as in the cement industry. The use of phosphogypsum is effective in the production of Portland cement, since it not only allows, like natural gypsum, for the adjustment of cement setting times, but also, when added to the raw material mixture, acts as a mineralizer that reduces the clinker burning temperature. Phosphogypsum can be added to construction mixtures and used in brick production. Phosphorus-containing waste is used for soil stabilization and road subgrade construction, thereby increasing the subgrade's strength by 20-40% and reducing dust formation [10]. Nevertheless, phosphogypsum waste is currently used very little.

The feasibility of environmentally safe, large-scale processing of aged phosphogypsum into high-calcination gypsum binders with improved properties (screed gypsum, anhydrite cement) has been established; a technology has been developed for an expanding sulfoaluminate modifier (ESAM) based on phosphogypsum to produce non-shrinking and prestressing mortars and concretes with density grades D300 and D400 [11].

Phosphogypsum binders often cannot compete on cost with binders produced from natural gypsum raw materials. They may offer advantages when phosphogypsum processing plants are located far from natural gypsum deposits, when binder production is organized at a facility that produces phosphoric acid – which solves the problems of transportation

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and wastewater disposal – as well as when the phosphogypsum processing operations are integrated with phosphoric acid production processes and potential consumers are located relatively nearby [12].

To improve the physicochemical properties (neutralization, strength, water resistance) phosphogypsum-based mixtures, other industrial wastes-such as granite and expanded clay dust, as well as chemical wastewater treatment sludge – are incorporated into the composite binder. The physicochemical properties of the wastes were studied: chemical and particle size distributions, the activity coefficient, and the hydraulic activity coefficient of the wastes. This approach to processing several types of waste into composite mixtures forms the basis of waste-free production, making rational use of the full natural potential of mineral resources and addressing numerous issues in the economic, consumer, and environmental sectors [13].

Tens of millions of metric tons of phosphorus-containing waste have accumulated in Kazakhstan, particularly in areas with a chemical industry (Taraz, Shymkent). This accumulation leads to the contamination of soil, water resources, and the atmosphere.

The Zhambyl Region is known for its well-developed chemical industry. There are seven major enterprises operating in the region: “NDFZ” LLP, Branch of “Kazphosphate” LLP – Plant “Mineral Fertilizers”, “Talas Investment Company” LLP, “HIM-Plus” LLP, “Kazakhstan Hydrogen Peroxide” LLP, “Karatau Chemicals” LLP and “Eurochem-Karatau” LLP [14].

Currently, there are two waste dumps in Taraz resulting from ammophos production. The dumps contain over 17 million metric tons of phosphogypsum, and both are completely full [14, 15].



Fig. 1. Phosphogypsum dumps in Taraz

The challenges associated with the use of phosphogypsum are pressing for many reasons:

- for a long time, the issue of phosphogypsum disposal was not given due attention, which led to the accumulation of massive stockpiles of old phosphogypsum;
- transporting phosphogypsum to landfills and storing it there involves significant capital investments and operating costs;
- creating phosphogypsum landfills requires the expropriation of large tracts of land, the resources of which have now been exhausted;
- the storage of phosphogypsum in old tailings piles, even when the pile is properly managed, causes harm to the environment [16].

The authors [16] present the averaged results of chemical analyses of samples of various waste products from the phosphate industry in the Zhambyl Region. Studies have shown that aged phosphogypsum from the

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"KazFosfat" LLP tailings pile is, based on a number of physicochemical characteristics, a more promising raw material for producing gypsum binder than fresh phosphogypsum. The main components are calcium and silicon oxides; most of the waste also contains aluminum and iron oxides. The presence of these oxides characterizes the hydration properties of the raw material components used in the manufacture of binding materials for construction and plays an important role in the technology for producing construction mixtures (Portland cement, alumina cement, glass, fine ceramics, etc.) [17].

2 METHODS AND MATERIALS

The Kazakh Leading Academy of Architecture and Construction has developed an optimal composition for an anhydrite binder based on phosphogypsum produced by "KazFosfat" LLP (Karatau, Zhambyl Region). Aged phosphogypsum from a stockpile was used for the experimental studies.

Analysis and comparison of the chemical and X-ray diffraction compositions of the phosphogypsum revealed the possibility of combining the raw material mixture and approximating the chemical composition of Portland cement. According to XRF and DTA data (Tables 1-2, Figures 2-3), the content of the main component (calcium sulfate dihydrate – $CaSO_4 \cdot 2H_2O$) is 80-82%; the remaining impurities are in the form of P_2O, phosphates, fluorites, and rare earth elements.

Insignificant inclusions of quartz (2%), feldspar (2%), calcite (3%), and hematite (2%) were recorded. The high intensity and sharpness of the main peaks indicate a sufficient degree of crystallinity in the material, confirming its suitability for use as a mineral component in the production of anhydrite binders without additional purification.

Table 1. Chemical Composition of Phosphogypsum from the Karatau Deposit, %

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	F	LOI
1.,2	0.6	1	30	2	0.4	0.2	1.5	0.7	12.5

Table 2. Mineralogical Composition of Phosphogypsum from the Karatau Deposit, %

Quartz	Feldspar	Calcite	Gypsum	Hematite
2	2	3	82	2

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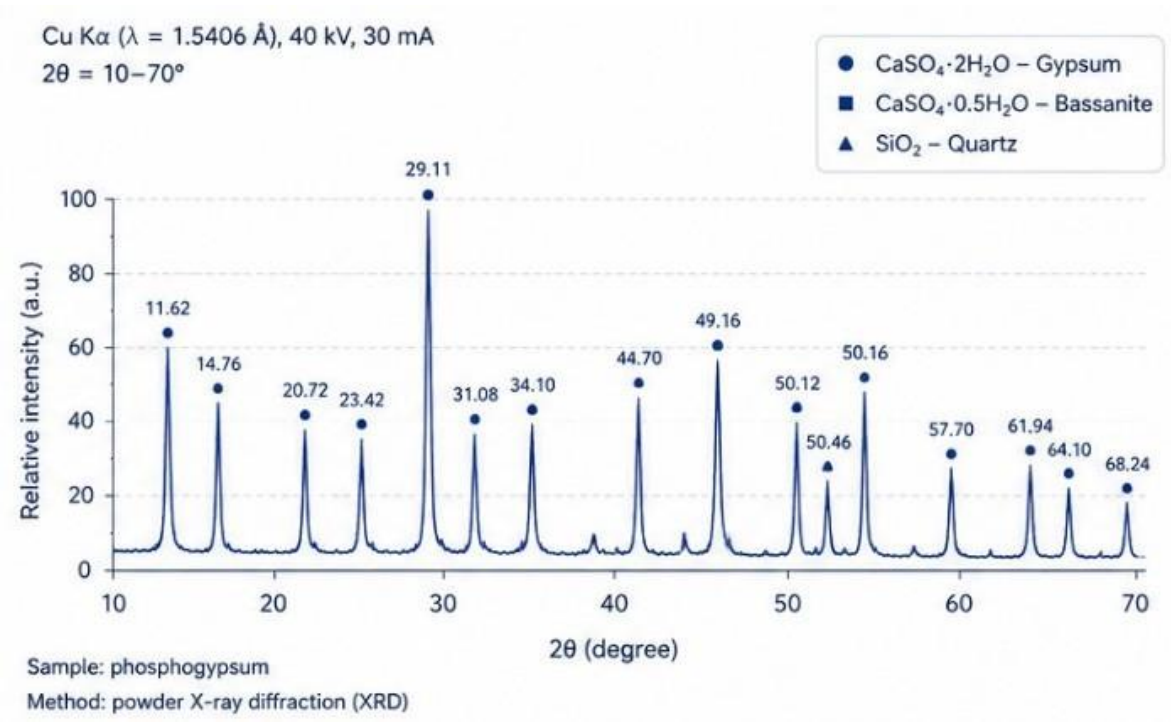


Fig. 2. X-ray Diffraction (XRD) Pattern of Phosphogypsum

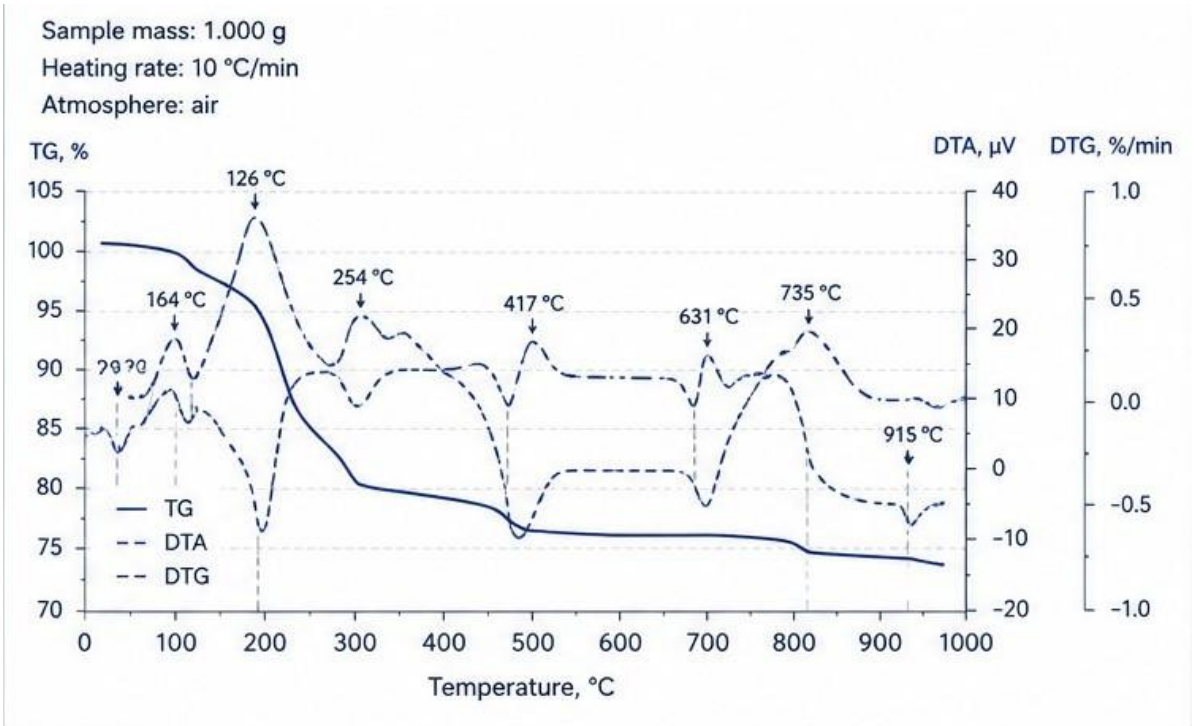


Fig. 3. Derivatogram (TG–DTA–DTG) of Phosphogypsum

Loam from the "Sarykemer" deposit and finely ground glass cullet were used as additives for the production of anhydrite binder, and as a setting accelerator – hydrated lime obtained by moderately calcining limestone from the "Akpandy" deposit, located near the city of Karatau in the Talas District of the Zhambyl Region. The characteristics of the raw materials are provided below.

Loam is used to improve the physical and mechanical properties of anhydrite

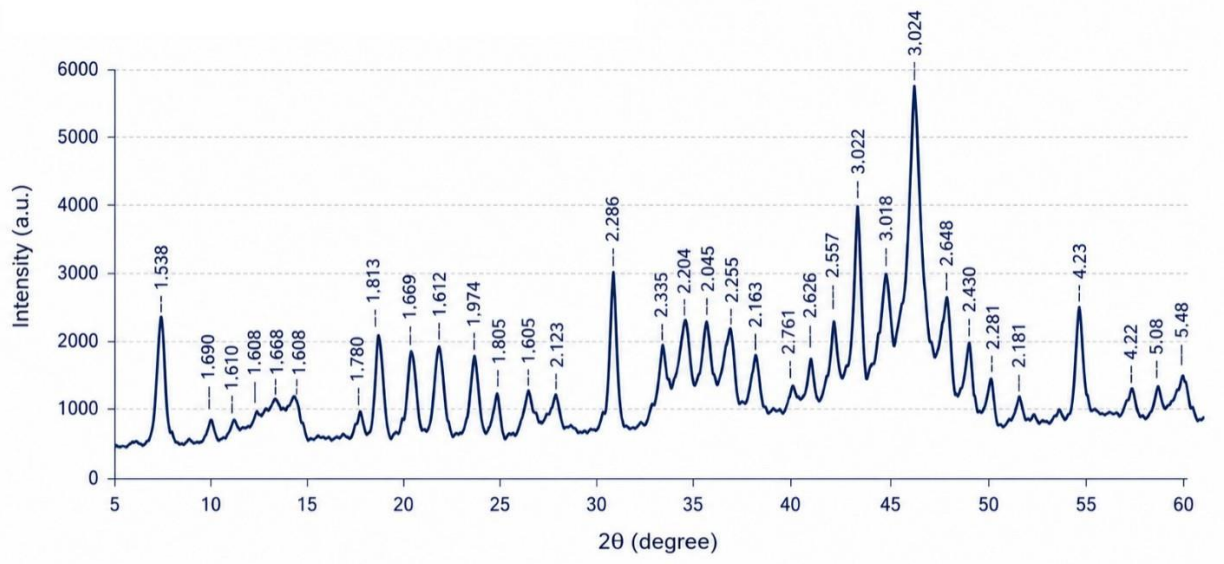
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ISSN 3134-8475 (Print)
ISSN 3134-8483 (Online)

cement. The geological reserves of loam at the extraction site near the village of Sarykemer (Bayzak District, Zhambyl Region) amount to 2,070,943 m3 (according to the subsoil user's local site development project).

Reserve coverage is 10 years. Physical and mechanical properties: average density 1.71 t/m3, plasticity 7-12.4 (average 8.5). The radioactivity level of the deposit does not exceed the safety limits established by the Radiation Safety Standards (RSS).

Table 3. Chemical Composition of Loam from the Sarykemer Deposit, %

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	TiO_2	P_2O_5	MnO_2	SO_3
57.01-52.91	12.73-11.51	4.45	12.46-10.48	2.86	0.55	0.23-0.18	0.93	0.25



Description: XRD pattern of natural loam in the range of 5–60° 2θ (Cu Kα radiation, λ = 1.5406 Å). The numbers above the peaks indicate the corresponding d-spacing values in Å.
Sample: Loam (natural).
Measurement conditions: Cu Kα radiation (λ = 1.5406 Å), 40 kV, 30 mA, 2θ = 5–60°, step size 0.02°, counting time 1 s/step.

Fig. 4. X-ray Diffraction Pattern of Loam

Table 4. Chemical Composition of Limestone from the "Akpandy" Deposit, %

SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	P_2O_5	LOI
0.44-1.0	0.29-0.42	0.1-0.2	53.46-54.61	0.37-0.68	0.02-0.07	0.01-0.027	43.46-43.84

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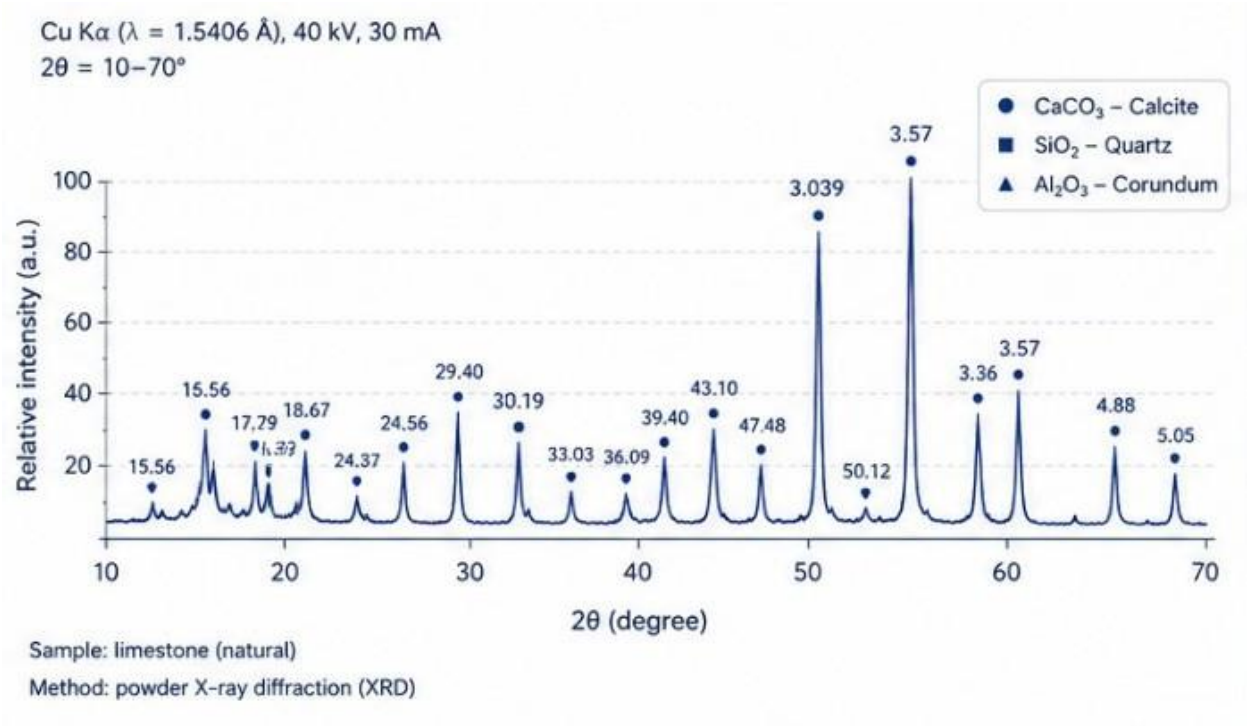


Fig. 5. X-ray Diffraction (XRD) Pattern of Limestone

In the Zhambyl Region, glass waste (broken glass, containers) is collected at specialized recycling centers, which are mainly located in Taraz and district centers (for example, the village of Sarykemer).

An automated DRON-3M diffractometer was used to perform X-ray diffraction analysis. Quantitative phase analysis was performed according to a method based on the dependence of the intensity of diffraction reflection in the material under study compared to standards.

To produce anhydrite cement, the mixture was calcined in a muffle furnace at temperatures ranging from 600 to 900°C.

For physical and mechanical testing, the calcined materials were ground until the residue on a 008 sieve was 8-10%. The water-to-binder ratios used in sample molding were determined based on standard density.

Standard tests of the phosphate anhydrite binder were conducted on a 1:3 mortar mixture (binder:sand, by weight) using 4 × 4 × 16 cm beam specimens after 7 and 28 days of curing. The setting times met the standard requirements for anhydrite cement as specified in GOST 2767.

3 RESULTS AND DISCUSSION

The physical and technical properties of anhydrite binders are determined by the structural transformations that occur during the calcination of phosphogypsum and by changes in phase composition. The fineness of the ground components and the addition of lime also have a significant influence on the properties of anhydrite binders.

Studies were conducted to determine the temperature and duration of heat treatment, as well as to identify the optimal composition of the binder. To this end, the composition of the base for a composite anhydrite binder using phosphogypsum was determined; the phosphogypsum was subjected to heat treatment at temperatures of 700, 800, and 900°C. The firing durations were 35, 30, and 20 minutes, respectively. Exceeding these time intervals or applying a firing temperature higher than 950°C leads to “overfiring” of the material and an irreversible deterioration of its structural and technical properties.

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To systematize the research, the concept of a binder "base" (Table 1) was introduced, consisting of phosphogypsum, clay, and glass.

Table 5. Composition of the base for anhydrite cement made from phosphogypsum

№	Phosphogypsum, %	Clay, %	Crushed glass, %
Firing temperature, 700°C			
1	90	5	5
2	85	10	5
Firing temperature, 800°C			
1	90	5	5
2	85	10	5
Firing temperature, 900°C			
1	90	5	5
2	85	10	5

While determining the optimal firing time, experiments were conducted in parallel to determine the optimal amount of activator additive; for this purpose, the lime was ground in a ball mill for 20-30 minutes.

Initially, the lime was added to ground phosphogypsum, after which the mixture was heat-treated in a muffle furnace. The additive constituted 3-20% of the phosphogypsum mass. Research results showed that mixing lime with phosphogypsum and subjecting them to heat treatment did not yield positive results. Therefore, it was decided to add lime as an activator to a calcined mixture of phosphogypsum, clay, and glass – exceeding 100% of the base mass – in an amount of 5-15% of the phosphogypsum weight.

An analysis of the water demand of the resulting anhydrite cement based on phosphogypsum shows that the normal consistency is 34-40%, the onset of setting is 0.5-2 hours, and the completion of setting is more than 4 hours.

Cubes (2×2×2 cm3) were cast from the resulting anhydrite cement and tested for strength after 7 and 28 days of curing (Tables 6 and 7, Figures 6 and 7).

Table 6. Strength of anhydrite-bound specimens at 7 days

Firing temperature	№ of composition	Strength, MPa		
		Lime – 5%	Lime – 10%	Lime – 15%
700°C	1	7.58	9.5	11.8
	2	3	3	3
800°C	1	5.52	6	7
	2	3.2	0,8	3.2
900°C	1	4.2	5	5.5
	2	0.3	0.3	0.3

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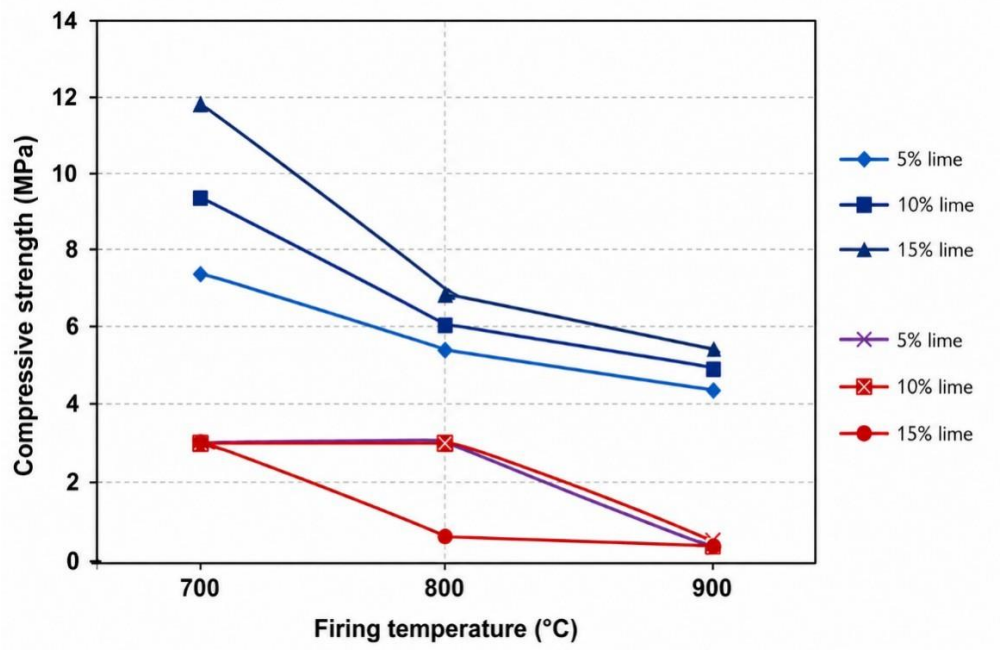


Fig. 6. Effect of Firing Temperature on the Compressive Strength of Samples with Different Binder Compositions after 7 Days of Curing

Table 7. Strength of anhydrite-bound specimens at 28 days

Firing temperature	№ of composition	Strength, MPa		
		Lime – 5%	Lime – 10%	Lime – 15%
700°C	1	15	18.2	25
	2	6.25	4	2.2
800°C	1	10	12.3	13
	2	8.7	5	2
900°C	1	10	8	8
	2	2.2	2.2.	0

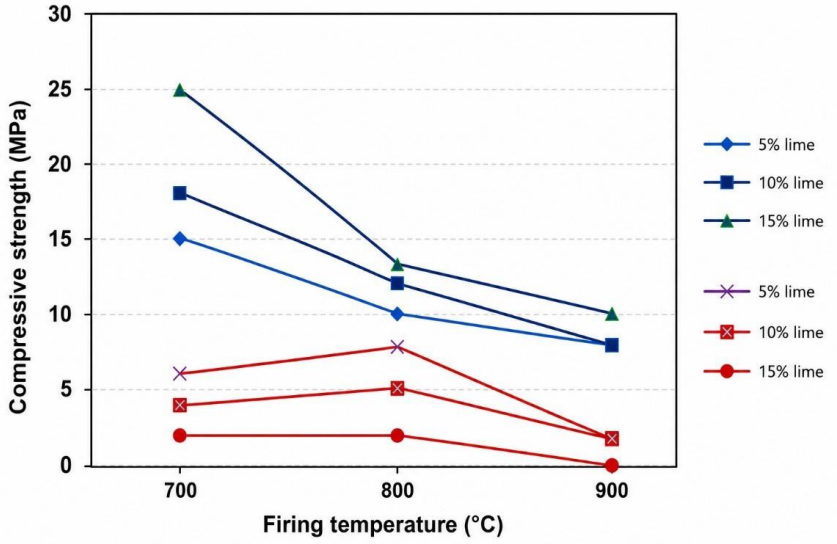


Fig. 7. Effect of Firing Temperature on the Compressive Strength of Samples with Different Binder Compositions after 28 Days of Curing

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Experimental data on the strength of the samples show that the physical and mechanicproperties of the binder depend not only on the calcination temperature but also on the method used to introduce the activating additive. Unlike the co-firing of phosphogypsum with lime, which does not yield positive results at 700°C and 900°C, the addition of lime to an already fired mixture allows for stable strength characteristics to be obtained across the entire temperature range under study.

It has been established that as the heat treatment temperature increases, the strength of the based on phosphogypsum samples decreases. In this case, the optimal firing temperature is 700°C, and the optimal composition is Composition 1 with a 15% lime content, at which the maximum strength of the specimens at 7 days of age averages 11.8 MPa (M100), and at 28 days of age, the strength is 25 MPa (M200).

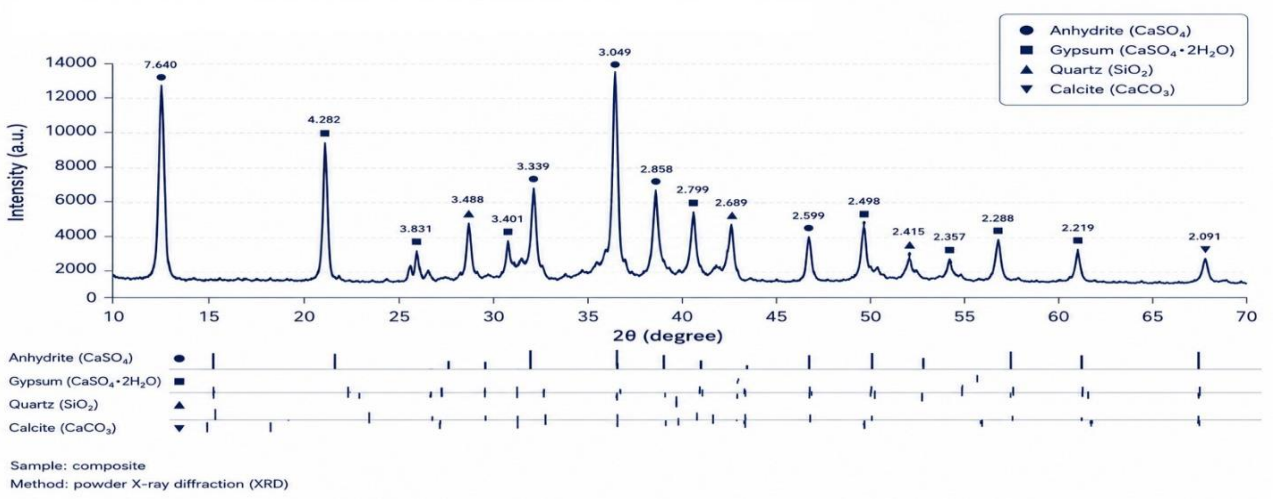


Fig. 8. XRD Pattern of the Composite after 28 Days of Curing

The X-ray diffraction pattern of the hardened products of the composite binder (Formulation No. 1) shows phase changes confirming the occurrence of anhydrite hydration processes. Gypsum peaks (7.640; 4.282; 3.049), as well as calcium sulfoaluminates and hydrosilicates, which ensure the formation of a durable artificial stone.

The decrease in the intensity of the anhydrite peaks compared to the initial calcined product indicates a high degree of its conversion into hydrate phases in the alkaline environment created by the addition of lime.

Thus, the research results demonstrated the possibility of using phosphogypsum to produce an anhydrite binder whose strength is comparable to that of anhydrite cement obtained from natural anhydrite. The phase composition of the hardened products meets the requirements of GOST 2767 for anhydrite binders.

4 CONCLUSION

An analysis of the results obtained leads to the following conclusions:

- by calcining phosphogypsum at a temperature of 700°C and activating it with a high lime content (15%), it is possible to obtain anhydrite with binding properties;
- phosphogypsum from the Karatau deposit is suitable for producing anhydrite cement, which can be recommended for the manufacture of lightweight concrete and dry construction mixes;
- replacing natural gypsum with phosphogypsum and using cullet can reduce the consumption of expensive natural raw materials, address the challenges of disposing of large volumes of industrial waste, conserve resources and energy, and reduce the material

ISSN 3134-8475 (Print)
ISSN 3134-8483 (Online)

intensity of production.

REFERENCES

1. Kravchenko, P.A., Kulikova, O.A., Volgareva, E.A., Kostylev, A.A., and Leshchenko, M.I. Prospects for Research on Phosphogypsum as a Construction Material [Perspectivy issledovaniya fosfogipsa kak materiala dlyia stroitelstva]. Izvestiya PGUPS, 2024/1, pp. 7–21. https://cyberleninka.ru/article/n/perspektivy-issledovaniy-fosfogipsa-kak-materiala-dlya-stroitelstva/viewer (in Russ.)

2. Dovydenko, A.V., and Lunev, A.A. The Use of Phosphogypsum in Road Construction: Potential and Challenges [Perspectivy issledovaniya fosfogipsa kak materiala dlyia stroitelstva: potencial I problemy]. Bulletin of Moscow State University of Civil Engineering, Vol. 18, No.2, 2023. https://cyberleninka.ru/article/n/ispolzovanie-fosfogipsa-v-sfere-dorozhnogo-stroitelstva-potentsial-i-problemy (in Russ.)

3. Abdrahimov, V.Z. The Effect of Phosphorus Slag on the Technical Properties and Phase Composition of Ceramic Bricks [Vliyanie fosfornogo shlaka na tehnicheskie pokazateli I fazovyi sostav keramicheskogo kirpicha]. Proceedings of the Kazan State Architectural and Construction University, 2024, No. 3 (69), pp. 15–26. https://izvestija.kgasu.ru/ru/nomera-zhernala/arkhiv-zhurnala?sod=sod3_2024&idizv=11 (in Russ.)

4. Suleimenov, Zh. T., Moldamuratov, Zh. N., Sagyndykov, A. A., Bayalieva, G. M., Alimbayeva, Zh. B. High-strength wall ceramics based on phosphate slag and bentonite clay. Nanotechnologies in Construction. – 2022. No. 14 (1), pp. 11–17. https://www.proquest.com/openview/e67e5f6cf7af6b931bec4c1aa151740d/1?pq-origsite=gscholar&cbl=2046414

5. Suchkov, D.V. Utilization of Gypsum-Containing Waste from the Mineral Resources Complex. Abstract of the dissertation for the degree of Candidate of Technical Sciences [Utilizaciya gipsosoderzhshih othodov mneeeeeln-syrevigi kompleksa], Higher Attestation Commission of the Russian Federation, Specialty 1.6.21. Geoecology, St. Petersburg, 2024, 24 pp. https://www.dissercat.com/content/utilizatsiya-gipsosoderzhashchikh-otkhodov-mineralno-syrevogo-kompleksa (in Russ.)

6. Ilyin, A.P., Kochetkov, S.P., Bryl, S.V., and Rukhlin, G.V. Problems and Prospects for the Use of Byproducts from the Processing of Natural Phosphates in the Production of Building Materials [Geoekoloicheskaya ocenka vosdeistviya proizvodstva fosfornyh udobrenii na pochvy i rasrirelnost]. Ecology and Construction, No. 4, 2016, pp. 21–29 https://disser.spbu.ru/files/2023/disser_nedbaev.pdf (in Russ.)

7. Nedbaev, I.S., Tsyvkunova, N.V., and Elsukova, E.Yu. A Review of Russian and Global Experience in Addressing Environmental Problems Associated with the Production, Storage, Processing, and Utilization of Phosphogypsum [Obzoe Possiskogo I mirovogo opyta resheniya ekologicheskih problem proizvodstva, hraneniya, pererabotki I ispolzovaniya fosfogipsa]. Bulletin of Eurasian Science. – 2022. – Vol. 14. – No. 4. – https://esj.today/PDF/10NZVN422.pdf (in Russ.)

8. Bakhtina, T.A., Lyubomirsky, N.V., Bakhtin, A.S., Bilenko, G.R., and Tyunyukov, I.A. Development of a Phosphogypsum-Based Binder with Mixed-Type Setting [Razrabotka vyiazhushego veshestva na osnove fosfogipsa, tverdeiushego po smeshannomu tipu]. Bulletin of Moscow State University of Civil Engineering. – Vol. 19. No. 8, 2024, pp. 1301–1316. // https://doi.org/10.22227/1997-0935.2024.8.1301-1316

9. Mtiabaa, Mahmoud. Gypsum binder based on Tunisian phosphogypsum [Gipsovoe viyazhushego na osnove fosfogipsa Tunisa]. Abstract of the dissertation for the degree of Candidate of Technical Sciences in the specialty 05.23.05, Belgorod, 2009, Higher Attestation Commission of

ISSN 3134-8475 (Print)
ISSN 3134-8483 (Online)

the Russian Federation. https://tekhnosfera.com/gipsovoe-vyazhuschee-na-osnove-fosfogipsa-tunisa (in Russ.)

10. Nedbaev, I.S. Geoecological Assessment of the Impact of Phosphate Fertilizer Production on Soils and Vegetation [Geoekologicheskaya ocenka vosdeistviya proizvodstva fosfornyh udobrenii na pochvy I rastitelnost]. Dissertation for the degree of Candidate of Sciences, Saint Petersburg, 2023. https://www.dissercat.com/content/geoekologicheskaya-otsenka-vozdeistviya-proizvodstva-fosfornykh-udobrenii-na-pochvy-i-rastit (in Russ.)

11. Mechay, A.L., Novik, M.V., Baranovskaya, E.I., Sakovich, A.A., and Minakovsky, A.F. Technologies for Processing Phosphogypsum into High-Firing Gypsum Binders and a Sulfoaluminate Modifier for Mortars and Concretes // Construction Science and Technology, 2009/5, pp. 64–69

12. Udalova, E.A., Gabitov, A.I., Shuvaeva, A.R., Nedoseko, I.V., Chernova A.R., Yamilova V.V. Current Status and Future Prospects for the Use of Phosphogypsum in the Production of Binding Materials [Sovremennoe sostoyanie I perspectivnyie vozmojnosti ispolzovaniya fosfogipsa dlyia proizvodstva viyazhushih materialov]. Journal "History of Science and Technology," Section "History and Pedagogy of Natural Sciences," 2016/4, pp. 55–58.

13. Makarevich, N.Y., & Yaglov, V.N. Physicochemical Properties of Additives for the Production of Phosphogypsum-Based Composite Binders [Fiziko-himicheskie svoistva dobavok dliya polucheniya compozicionnyh viyazhushih na osnove fosfogipsa]. Bulletin of Brest State Technical University. 2024. No. 2(134), Construction. https://doi.org/10.36773/1818-1112-2024-134-2-19-23 (in Russ.)

14. Chemical Industry, Landfills, and Air: The Environmental Situation in the Zhambyl Region. KAZINFORM, July 18, 2025. https://www.inform.kz/ru/himprom-otvali-i-vozduh-ekologicheskaya-situatsiya-v-zhambilskoy-oblasti-cf98d7 (in Russ.)

15. Kazfosfat Plant Ready to Supply Farmers with Phosphogypsum at 1 tenge per metric ton // Kazakhstan Agribusiness News, November 12, 2024. https://apk-news.kz/news/item-4628 (in Russ.)

16. Bishimbayev, V.K. Environmental Issues in the Chemical Industry // Proceedings of the National Academy of Sciences of the Republic of Kazakhstan, 2011, No. 1

17. Beisekova, T.I., Shanbaev, M.Zh., Zhandaoletova, F.R. A Study of the Feasibility of Producing Binding Materials from Phosphate Industry Waste. University Proceedings, Section "Geotechnologies. Life Safety," No. 4 (97), 2024, pp. 147–153. https://www.kaznaru.edu.kz/storage/files/229663401567f4ce7e0f1b5213492830_ANNOTATION.pdf

ISSN 3134-8475 (Print)
ISSN 3134-8483 (Online)

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ARTIFICIAL INTELLIGENCE STATEMENT

During the preparation of this manuscript, the authors used [tool name, version] solely for language editing and grammar checking. The authors reviewed and edited the output and take full responsibility for the scientific content, analyses, interpretations and conclusions of the article.

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The article was submitted 5 April 2026; approved after reviewing 5 May 2026; accepted for publication DD June 2026.