



Energy-efficient Dry Construction Mixtures Based on Modified Diatomite

Ruslan E. Nurlybayev,^{1,*} Erzhan I. Kuldeyev,¹ Axaya S. Yestemessova,² Zaure N. Altayeva,² Yelzhan S. Orynbekov² and Bakhytzhan K. Sarsenbayev³

Abstract

The article presents data from scientific research work on the development and study of effective dry building mixtures based on modified diatomites. The properties of the mineral filler diatomite were studied, and it was found that its surface becomes more active and has almost 3-4 times higher strength after thermal treatment compared to untreated diatomite reaching 4.28 MPa. It was also established that the optimal addition of low-viscosity cellulose ether (LCE) and redispersible polymer powder (RPP) results in nearly doubling the composite composition's strength and reaching 0.92 MPa. The water retention capacity of the developed compositions was studied using various methods and on different bases, as well as the effect of ambient temperature on this indicator. Thus, with the ratio of lime: diatomite of 1:1, the mixture showed a water retention capacity of 79.6%, a ratio of 1:2 = 80.5%, and a ratio of 1:3 = 88.7%, all three indicators are lower than recommended, according to the regulatory document. With the same ratio of 1:3 and the introduction of special additives LCE + RPP (50:50) in the amount of 0.1%, 0.2% and 0.3%, this value significantly increased to 93%, 96.5% and 96.6%, respectively.

Keywords: Modified diatomite; Dry mixture; Redispersible polymer powder; Cellulose ether.

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1. Introduction

In modern construction practice, increasing attention is being paid to the use of new efficient materials for building, finishing, and repairing buildings and structures, which significantly reduce labor costs on-site and minimize material consumption while simultaneously improving the quality of work performed.^[1-5] Such materials include dry building mixtures (DBM), the production of which has now become a separate dynamically developing area in the construction materials industry. Global and domestic experience in the application of these materials has demonstrated their effectiveness and advantages compared to traditional materials based on sand and cement.^[6,7] Dry building mixtures (DBM) are grouped together by their production based on binders with modifying additives, and in some cases with

granular and reinforcing fillers and pigments. Dry mixture compositions are supplied ready-made and, after mixing with water, are used directly as intended. Constantly improving production technologies, the emergence of new methods and processes allow manufacturing to develop in accordance with the most advanced technologies. Today, dry mixes remain a product of high-tech manufacturing.

The trend in the development of dry building mixtures production technology indicates the influence of two main factors that accelerate and decelerate the development of this production. Dry building mixtures production in Kazakhstan in the near future will continue to increase production volumes associated with the construction of civil and residential buildings, which determines increased demand for dry building mixtures. A relevant factor for the dry mix market is the substitution with competitive local products.

Most dry building mixtures typically include: cement (a universal binder for both exterior and interior work), gypsum (a binder used exclusively for interior work), fine aggregate (mostly sand, graded by particle size), chemical inorganic and organic compounds, and polymer additives. Interestingly, foreign and domestic manufacturers often use cement or gypsum as binding materials. Lime is rarely used as a binder for dry mixes; it is primarily introduced as an enhancing

¹ Institute of Architecture and Civil Engineering, Satbayev University, Satbayev str. 22, Almaty, 050013, Kazakhstan.

² Faculty of Construction Technologies, Infrastructure and Management, International Educational Corporation, Ryskulbekov str. 28, Almaty, 050043, Kazakhstan.

³ Mukhtar Auezov South Kazakhstan University, Tauke Khan ave. 5, Shymkent 160012, Kazakhstan.

*Email: nurlybayev.savenergy@gmail.com (R. E. Nurlybayev)

mineral additive.

From a business perspective, the use of high-quality cement (M400, M500, and higher) is not always justified, especially in cases where the dry mixture's concentration is not designed to withstand high pressure loads. An example of this is gypsum compositions, where the material applied to the surface experiences tensile forces, and the service life of traditional cement-based (or gypsum-based) finishing compositions is largely limited by their low resistance to cracking. In gypsum and decorative compositions, it is preferable to use lower-strength mixtures that are less durable but capable of absorbing tensile forces.

Competitiveness and profitability of production depend on the cost price of the product. Currently, the development of high-quality and cost-effective dry building mixes is crucial for domestic manufacturers of dry building mixes. Reducing the cost of dry mixes can be achieved not only by reducing the content of chemical additives. A promising direction in the production of dry building mixes is the use of binders and fillers based on local materials. Local raw materials are significantly cheaper than imported raw materials from other regions due to lower transportation costs. This creates opportunities for comprehensive utilization of local raw materials while achieving significant economic benefits from the use of dry building mixes, ultimately contributing to cost reduction in construction.

Material costs constitute a significant portion of total expenses, and reducing their price is one of the most important ways to make modern construction more economical.^[8,9] Therefore, a promising direction in the production of dry building mixes is the use of blended binders, modified with finely ground dispersed fillers based on local soft and loose rocks. These binders materials are significantly cheaper than cement, enabling comprehensive development of local raw materials while achieving significant economic benefits from the use of dry mixes in construction.

Accumulated experience has been gained in studying sufficiently pure siliceous rocks (diatomites, tripolites, opoks), their classification has been developed, and their chemical composition, physical, and technical properties are known.^[10-12] According to geological surveys, siliceous rocks in the Aktobe region of the Republic of Kazakhstan are widely distributed. A large part of the surface is covered with Paleogene siliceous deposits, forming numerous diatomaceous deposits. The depth of diatomite occurrence ranges from 0.5 to 30 meters. The thickness of diatomite on the slopes ranges from 7 to 20 meters.

Diatomite is a loose or weakly cemented siliceous sedimentary rock, consisting primarily of the frustules of diatomaceous algae, which are white, gray, or pink in color. In its natural state, diatomites have a high, evenly distributed porosity, reaching 80–85%. The pores are natured and not deep. The chemical composition in its pure form can be expressed by the formula $m\text{SiO}_2 \cdot n\text{H}_2\text{O}$. Silica in diatomites is in an amorphous state and ranges from 78% to 95%. In

addition to silica, diatomites contain small amounts of calcium and magnesium carbonates and some other impurities.

Study of the characteristics of natural diatomite using an electron microscope reveals the presence of quasi-two-dimensional lattices, indicating the nanoscale structure of the investigated material – diatomite. The main part of the rock consists of tiny opaline remains of planktonic diatom algae (about 70%), ranging in size from 0.14 to 0.16 mm, with specimens occasionally reaching sizes up to 0.20–0.22 mm. Diatom frustules exhibit cylindrical, linear (striate), and discoidal forms, with pores up to 200 nm in size.

The free space of diatom algae is filled with colloidal silica. As an impurity, there are short needle-like scales of clay minerals ranging in size from 0.01 to 0.02 mm. According to research, samples taken from the "Zhalpak" deposit belong to biogenic silica-containing rocks, which are represented by remains of organisms building a silica skeleton (sponge spicules, diatom algae frustules, radiolarian skeletons). Comparative analysis also showed that the diatomite from the Aktobe deposit is of higher quality in composition and can be used for the production of lime-diatomite binders, effective low-temperature materials, fillers, *etc.* The analysis and review of the study and research into the potential application of diatomite from the "Zhalpak" deposit show that there are no existing studies on its use in the technology for producing dry construction mixes. Our research group has planned a project for a mini-factory to produce dry construction mix based on diatomite from the "Zhalpak" deposit as part of our scientific research work.

The article discusses modified dry finishing mixes, which consist of a blend of mineral binders, fillers with strictly fixed particle size distribution, and modifying chemical additives. Therefore, the aim of the study is to develop a formulation for dry building mixes using diatomite modified by thermal methods.

The scientific novelty lies in establishing the regularity of diatomite modification by thermal methods, which affects its activity and consequently enhances the strength of the investigated dry mix compositions. The study also identified the influence of low viscosity cellulose ethers and redispersible polymer powder on lime-diatomite compositions regarding key physico-mechanical characteristics such as water retention capacity, compressive strength, tensile strength, and overall structural formation of finishing compositions. The water retention capacity increased by 8.9%, the increase in compressive strength is more than 50%, and the plastic strength changed by 25.5%.

2. Materials and methods

2.1 Materials

The following materials were used to prepare the dry mixture:

1. Slaked lime (fluff) with an activity of 75-88%, produced by the Sastyubinsk plant, true density of 2250 kg/m³, bulk density of 280 kg/m³, and specific surface area of 11000 cm²/g.
2. The diatomite from the Zhalpaksai deposit in Mugalzhaz

district, Aktobe region, has an average bulk density in chunk form of 300–500 kg/m³ and in loose form of 220–350 kg/m³. Its true density is 2000 kg/m³, and its bulk density is 280 kg/m³. The chemical composition of modified diatomite is as follows: SiO₂ – 86.52%; Al₂O₃ – 6.58%; Fe₂O₃ – 3.21%; K₂O – 1.43%; MgO – 0.790%; CaO – 0.238%; TiO₂ – 0.445%; Na₂O – 0.215%; SO₃ – 0.354%; P₂O₅ – 0.0576%; V₂O₅ – 0.0294%; NiO – 1.089%. Thus modified diatomite consists of dispersed particles of silicon dioxide with a developed nanoscale porous structure. Studies of the mineral composition of diatomite show that the main phase consists of minerals such as quartz, montmorillonite, muscovite, and kaolinite (Fig. 1).

3. The following additives were used: - low-viscosity cellulose ether (LCE); - redispersiblepolymer powder (RPP).

2.2 Methods

The compressive strength of the mortar was determined on samples formed as cubes with dimensions of 70.7×70.7×70.7 mm at the ages of 7 days and 28 days. Three samples were prepared for each test period. Detachable molds and a hydraulic press were used for the tests. The mortar mix, with a mobility of more than 5 cm, was placed into the detachable molds without a tray. For this, the mold was set on a brick, which had a moisture content of no more than 2% and water absorption between 10 and 15%. The brick was covered with moistened newspaper. The mold was then filled with the mortar mix with a slight excess and compacted by tamping with a steel rod 25 times in a concentric circle from the center to the edges. The molds filled with the mortar were kept indoors at a temperature of 20±2 °C and a relative humidity of 65% until demolding. After 24 hours from the placement of the mortar mix, the molds were demolded, and the extracted samples continued to be stored in the same room under the

same conditions. Attention should be paid to preventing drafts and avoiding storage of the samples near heating appliances. After 7 days and 28 days, the samples were measured with a caliper with an accuracy of 0.1 mm and placed on a press. For the compression testing of cube samples, a PI-I-A press with automatic control was used. The upper limit of the force (load) measurement range is up to 1000 kN, with a vertical four-column configuration of the loading module. The loading module features an integrated electro-hydraulic control cabinet and an electronic control unit built into its base.

The load on the sample increased continuously at a constant rate of 0.5 MPa per second until failure. The maximum force obtained during the test process was the compressive strength value. The compressive strength limit R for each sample is calculated with an accuracy of up to 0.01 MPa using the formula (1):

$$R = \frac{P}{A} \quad (1)$$

where, P - the breaking load, L; A - the working cross-sectional area of the sample, cm².

The compressive strength limit of the mortar is calculated as the arithmetic mean of the test results from three samples. The tensile strength or shear stress limit of the finishing mixture was determined using a cone plastometer KP-3. The essence of the method lies in determining the depth of cone immersion into the plastic mass under load. The prepared mass was placed into a bowl and leveled with a spatula to be flush with the edges of the bowl. The tip of the cone is brought to the surface of the mass and the indicator was set to zero. A minimum load is applied to the cone, and the rod is gradually loosened while keeping the stopwatch running simultaneously. Reports were made at 10, 20, 30, 45, and 90 seconds, and then at 5 minutes, 30 minutes, and up to 50 minutes. At 5 minutes, the load was increased by 200–300 g, and the depth of cone

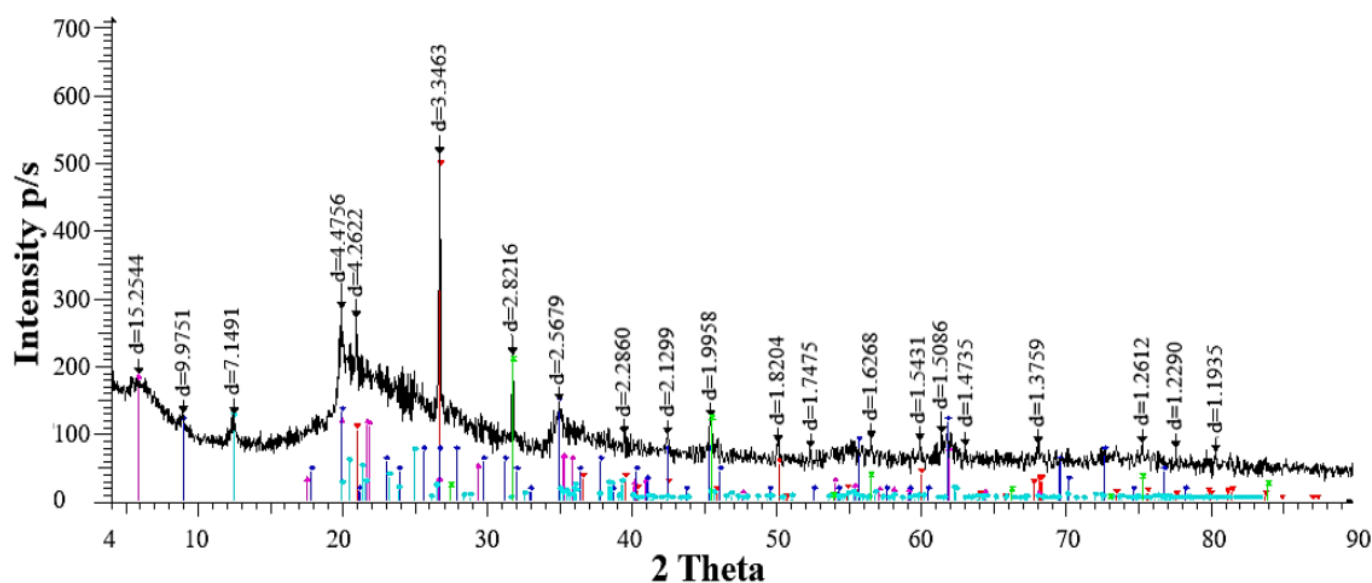


Fig. 1 X-ray phase analysis of diatomaceous raw materials from the "Zhalpak" deposit. Compound Name 1001; Quartz - SiO₂ - 42.9%; Halite - NaCl - 17.9%; Montmorillonite, calcian - (Ca,Na)_{0.3}Al₂(Si,Al)₄O₁₀(OH)₂·xH₂O - 15.6%; Muscovite - H₄K₂(Al,Fe)₆Si₆O₂₄ - 12.8%; Kaolinite - Al₂(Si₂O₅)(OH)₄ - 10.7%.

penetration is again recorded without removing the cone or adjusting the indicator position. Penetrations were repeated up to 5 times.

The drying time of the mortar mix was assessed using a seven-point scale. Drying time is the period during which a certain degree of drying is achieved at a specific layer thickness and under certain drying conditions. For the study, glass plates measuring 90×120 mm, steel plates measuring 70×150 mm, tin plates measuring 70×150 mm, glass balls (Ballotini) with a sieve fraction from 100 to 355 µm, square sheets of printing paper measuring 24×25 mm, free of wood fibers, with a smoothness of 20 to 80 s, a weight per unit area of 60 to 70 g/m², rubber discs with a diameter of 22 mm, a thickness of 4–6 mm, and hardness (Shore A) of (35 ± 5) arbitrary units were used. The research was conducted at 20 ± 2 °C and 65% relative humidity on three samples positioned at least 20 mm away from the edge after natural drying of the applied layer in a horizontal position for 60 seconds. A colored plate was placed with a sheet of paper on it, then a rubber plate is placed on top, and a weight of 20 kg is placed in the middle of the rubber plate. After 60 seconds, the weight, rubber plate, and paper sheet were removed. If the paper sheet does not adhere to the plate with the tested layer, then drying degree 7 is achieved.

The water retention capacity of finishing compositions was determined by testing a layer of mixture 12 mm thick laid on blotting paper. For the test, blotting paper measuring 150×150 mm, a metal ring with an inner diameter of 100 mm, height of 12 mm, and wall thickness of 5 mm, and a glass plate measuring 150×150 mm with a thickness of 5 mm were used. The test procedure is as follows: 10 sheets of blotting paper were weighed with an accuracy of up to 0.1 g, placed on a glass plate, and covered with a gauze pad. A metal ring was placed over them and weighed again. Then, the mortar mix was applied, leveled with the edges, and weighed. After 10 minutes, the metal ring with the mortar is removed, and the wet paper was weighed again with an accuracy of up to 0.1 g. The water retention capacity was calculated using the following formula (2):

$$W = \frac{100 - (m_2 - m_1)}{m_4 - m_3} \cdot 100 \quad (2)$$

where, m_1 - mass of blotting paper before testing, g; m_2 - mass of blotting paper after testing, g; m_3 - mass of the setup without mortar mix, g; m_4 - mass of the setup with mortar mix, g.

Tests were conducted twice for each sample, and the arithmetic mean value was calculated.

For assessing adhesive strength, the stamp pull-off method (normal pull-off) was used. The essence of the method is as follows: a finishing composition is applied to test plates, which then cures for 28 days before conducting tests on them. Six parallel tests were conducted at a temperature of 23 ± 2 °C and relative humidity of 55%. The pull-off force was applied perpendicular to the plane of the plate and increased at a rate not exceeding 1 MPa/s, aiming for failure to occur within an average of 90 seconds on an IR 5057-50 pull-off tester. The IR

5057-50 tensile testing machine is designed for static testing of materials under tension. The maximum load capacity is 50 kN (5 tons). The operation of the machine is based on converting the load applied to the test sample into an analog electrical signal using a strain gauge sensor, which changes proportionally to the applied load. The applied load deforms the test sample, and the machine measures both the magnitude of this load and the corresponding deformation of the sample. The strength during detachment is calculated using the formula (3):

$$R = \frac{F}{A} \quad (3)$$

where, F - tensile strength, L; A - area of the sample, mm².

3. Results and discussion

3.1 Results of experimental research

It is known that the surface of dispersed materials possesses an energetic potential, characterized by the presence of surface energy, and certain processes can occur spontaneously at its active centers. The composition and reactivity of the substance's surface depend on the nature of its formation, particle size, shape, crystalline modification porosity, among other factors.

To enhance the surface activity of diatomite, we decided to conduct its thermal temperatures up to 900 °C.

One of the main indicators of the performance properties of finishing compositions is the compressive strength and the kinetics of their change over time. In this regard, the strength characteristics of compositions based on lime and diatomite, as well as the hardening process of the finishing composition, were studied. Fig. 2 presents experimental data on compressive strength obtained as a result of testing samples measuring 70.7×70.7×70.7 mm at the age of 28 days.

Analysis of the data in Fig. 2 shows that heat treatment of diatomaceous earth at low temperatures (200 °C and 300 °C) does not significantly affect the compressive strength values of the compositions. Increasing the processing temperature to 650 °C increases the strength characteristics to 4.28 MPa. The best performance is achieved when processing diatomaceous rock at a temperature of $t=900-950$ °C, at which the strength was 5.02 MPa. But from the standpoint of saving energy and time, heat treatment of the diatomite filler at $t = 650$ °C was chosen.

Lime and diatomite-based dry construction mixes exhibit slow strength gain under compression, prompting the decision to utilize special additives such as LCE and RPP to regulate the structural formation processes of lime-diatomite compositions.

Based on the obtained modified diatomite, compositions have been developed, the results of which are shown in Table 1.

From the analysis of the data in Table 1 it was revealed that at a ratio of 1:1. 1:2 and 1:3 without special additives, the strength values vary from 0.48 to 0.60 MPa and at a ratio of 1:3 with the use of special additives when introduced 0.1%.

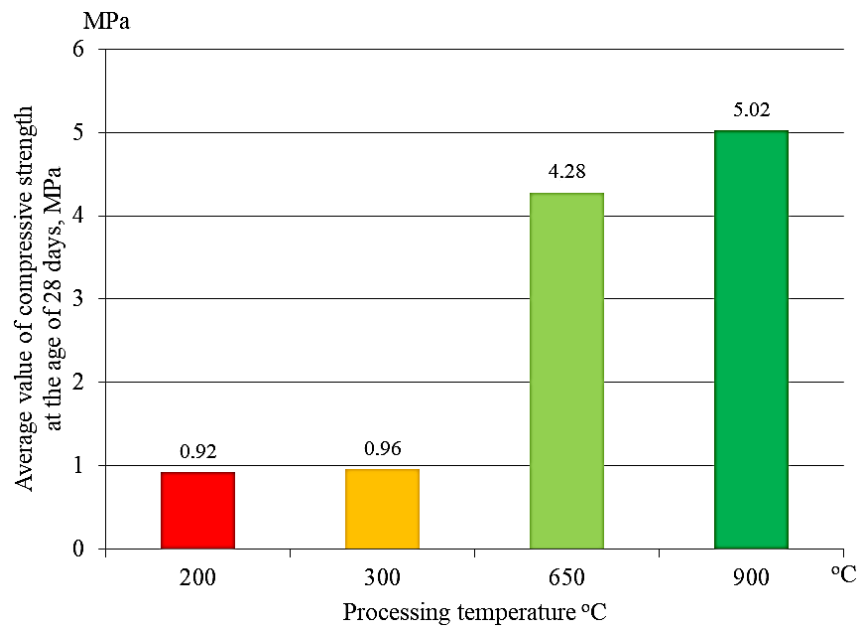


Fig. 2 Compressive strength of compositions depending on the temperature of diatomite processing.

02% and 03% showed strength values from 0.9 to 0.92 MPa.

Figure 3 shows the appearance of the developed lime-diatomite mixture and the entire process from mixing to determining the compressive strength on cube samples measuring 70.7×70.7×70.7 mm.

Dry mixtures based on mineral components are a viscous plastic system, and their quality affects the rheological and technological characteristics. Water-holding capacity allows

you to maintain the mobility of the mixture for a certain period of time.

A moving, smooth mixture well fills all the unevenness of the surface to which it is applied, and slowly releasing water, forms a dense and even finishing layer. The water-holding capacity of the above compositions is shown in Fig. 4.

The results of the compositions on water-holding capacity showed the data that we expected, namely that without the use

Table 1. Compressive strength of the developed compositions.

No compounds	Ratio of lime and diatomite	Additive name	Additive quantity, %	Compressive strength at the age of 28 days, MPa
1	1:1	-	-	0.60
2	1:2	-	-	0.55
3	1:3	-	-	0.48
4	1:3	LCE+RPP	0.1	0.9
5	1:3	(50:50)	0.2	0.92
6	1:3		0.3	0.9

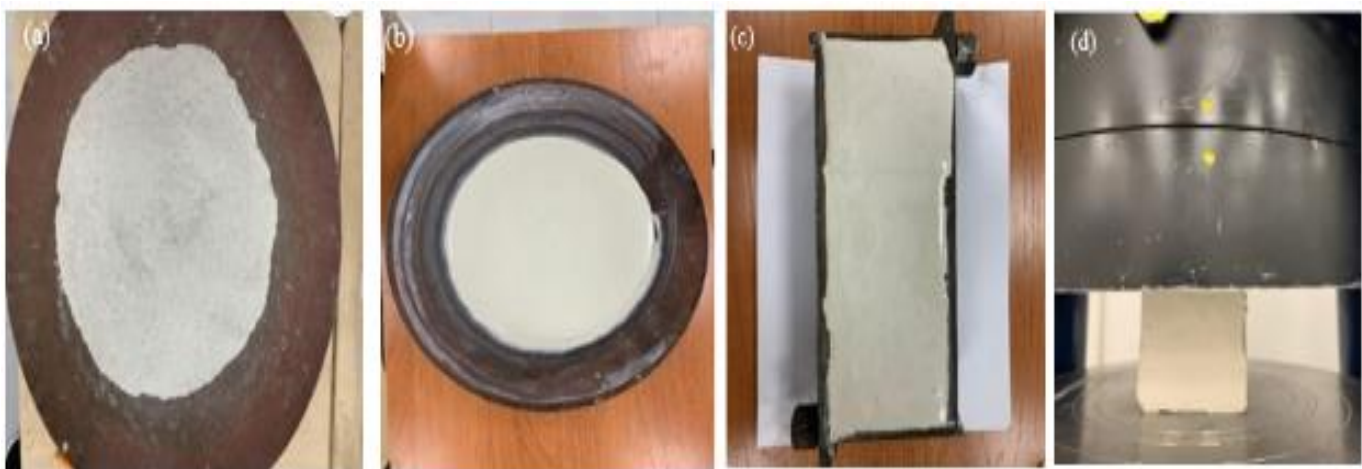


Fig. 3 Appearance of the lime-diatomite mixture: (a) – dry mixture; (b) – mixture mixed with water; (c) – molded cube samples with dimensions 70.7x70.7x70.7 mm; (d) – compressive strength test.

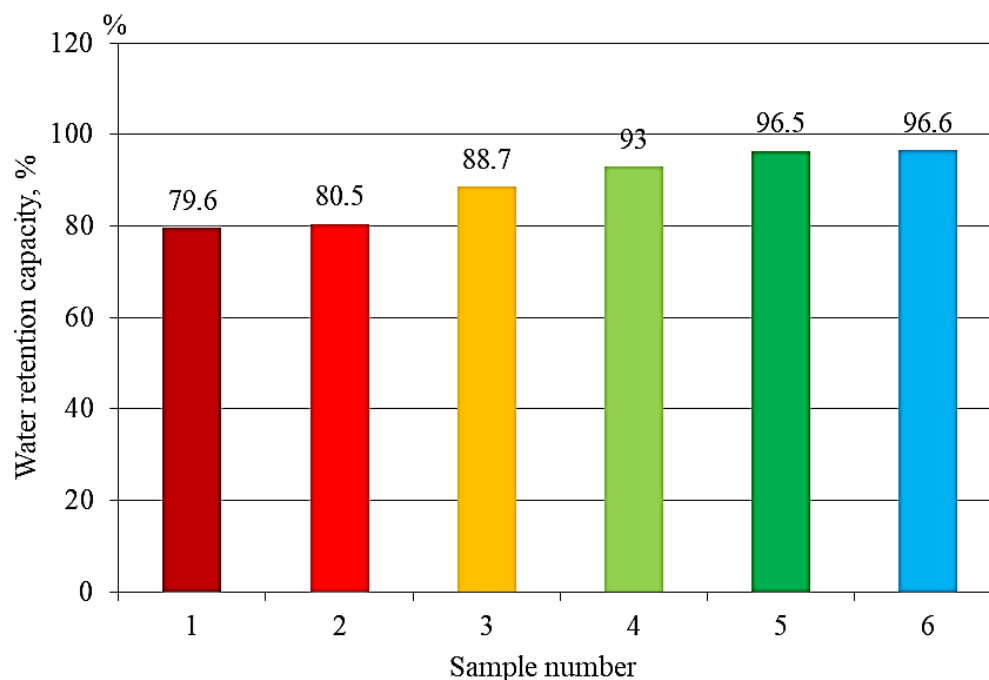


Fig. 4 Water-holding capacity of lime-diatomite compositions.

of special additives regardless of the lime-diatomaceous earth ratio they will be below standard values, and in the presence of special additives this value is normal. The water retention capacity of the studied compositions, shown in Fig. 4, shows that the different ratio of the components of the mixture affects the water retention capacity, but the introduction of special additives for dry mixtures has an even more active effect. So, with the ratio of lime:diatomite 1:1, showed a water retention capacity of 79.6%, a ratio of 1:2 = 80.5%, a ratio of 1:3 = 88.7%, all three indicators are lower than recommended, according to the regulatory document. With the same ratio of 1:3 and the introduction of special additives LCE + RPP (50:50) in the amount of 0.1%, 0.2% and 0.3%, this value significantly changes to 93%, 96.5% and 96.6%, respectively, which is within the limits recommended by the regulatory document and practical necessity for these types of compositions.

In practice, the finishing mixture is applied to a porous substrate rather than filter paper, as described in the method outlined in the regulatory document. Consequently, the indicators will vary, as the amount of adsorbed water differs on materials like bricks, concrete, gypsum, and other porous substrates.

The research results are shown in Table 2 from which we

see that the type of substrate and the thickness of the applied layer have a significant impact on the water-holding capacity of the composition.

Research on the influence of the base and the layer thickness of the developed composition was conducted at thicknesses of 6 mm and 12 mm, as these thicknesses are considered optimal for this type of dry mix.

Reducing the thickness of the applied layer also led to a noticeable decrease in water retention capacity. The water retention value of the composition, regulated and assessed according to the regulatory document, was 88.5% for a layer thickness of 12 mm, and 80.18% for a layer thickness of 6 mm.

Studies have also been carried out to determine the water holding capacity depending on the finished surface. The research results showed that the base type has a significant effect on the water holding capacity. Thus intense absorption of moisture was observed on a brick base, the water-holding capacity of the mixture with a layer thickness of 12 mm was 62.25% and with the same layer thickness on a cement-sand base - 82.18%.

Thus, the water-holding capacity of mixtures applied to highly water-absorbing substrates is significantly lower than the water-holding capacity determined by the method set out in the regulatory document.

Table 2. Water-holding capacity of the mortar mixture depending on the type of coating.

Water-holding capacity		
lime:diatomite 1:3		Same + LCE+ RPP(P/T=2.0)
Thickness of applied coating. mm		Thickness of applied coating. mm
12	6	6
Water holding capacity. %		Water holding capacity. %
88.5	80.18	94.2

The introduction of LCE and RPP into the mixture with a polymerized P/T ratio = 0.2 increases the water-holding capacity of the mixture to 94.2%. A 1:3 lime-diatomite composition without additives has a high-water requirement and low water-holding capacity.

The effectiveness of using LCE and RPP in the composition and their effect on the water-holding capacity of the solution is clearly manifested at elevated ambient temperatures; the results of the study are shown in Fig. 5.

We have found that with an increase in ambient temperature, the water-holding capacity of the composition without LCE and RPP does not meet regulatory requirements, corresponding to readings below 80%. Elevated temperature has little effect on the modified compositions and does not have a significant negative effect on its water-holding capacity.

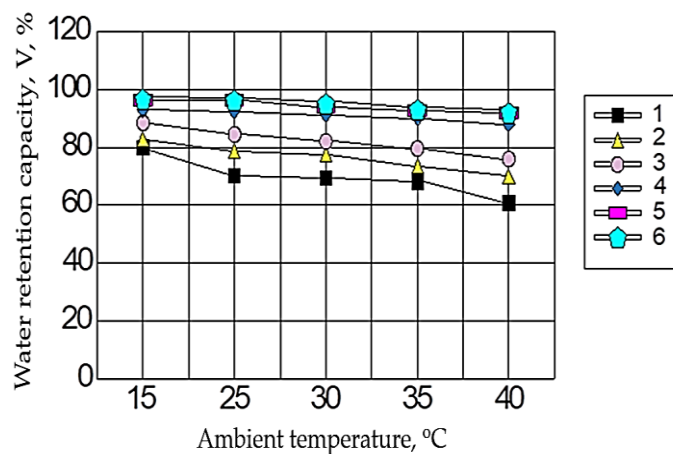


Fig. 5 Dependence of the water-holding capacity of the mortar mixture on the ambient temperature; 1 – composition mixture 1:1; 2 – composition mixture 1:2; 3 – composition mixture 1:3; 4 – composition mixture 1:3 LCE and RPP.

The ability to retain water was also assessed using tensile strength. The studies were carried out on a cement-sand base

with the same ratio of water to solids equal to $W/S = 1.1$ 10 minutes after preparing the mixture.

Experimental data have shown that the water-retaining effect of the LCE and RPP additives prevents the active absorption of moisture from the mixture by the porous base and helps maintain low values of the tensile strength of the compositions (Fig. 6). In addition to the above compositions, we also studied compositions containing LCE and RPP in amounts of 0.01%; 0.02% and 0.03%.

Thus, with the introduction of LCE in quantities up to 0.5% the tensile strength decreased to $t = 0.0067$ MPa (in the control composition $t = 0.0090$ MPa).

Analysis of experimental data shows that with an increase in the solid-water ratio at a constant filler content in the mixture, a natural decrease in tensile strength occurs.

Studying the influence of additives and the modified diatomite itself in the formulations of the compositions made it possible to regulate the drying process of the finishing layer. The studies were carried out on the surface of cement-sand mortar. In order to regulate and determine the drying time of the finishing layer, the additives LCE and RPP were introduced into the mixture recipe. The results obtained are summarized in Table 3.

The orienting effect of additives has been found to significantly improve the drying of finishing coatings. So, when determining the time and degree of drying on a scale of 7 stages, it was found that compositions at 1:1, 1:2 and 1:3 without additives show rapid drying, which is undesirable for compositions of dry building mixtures.

The introduction of from 0.1% to 0.3% of special additives (LCE and RPP) significantly changes the drying time and reaches up to 40 minutes, which confirms the need to modify the compositions of dry mixtures with special additives. And if it is necessary to increase the drying time, it is recommended to increase the consumption of added additives.

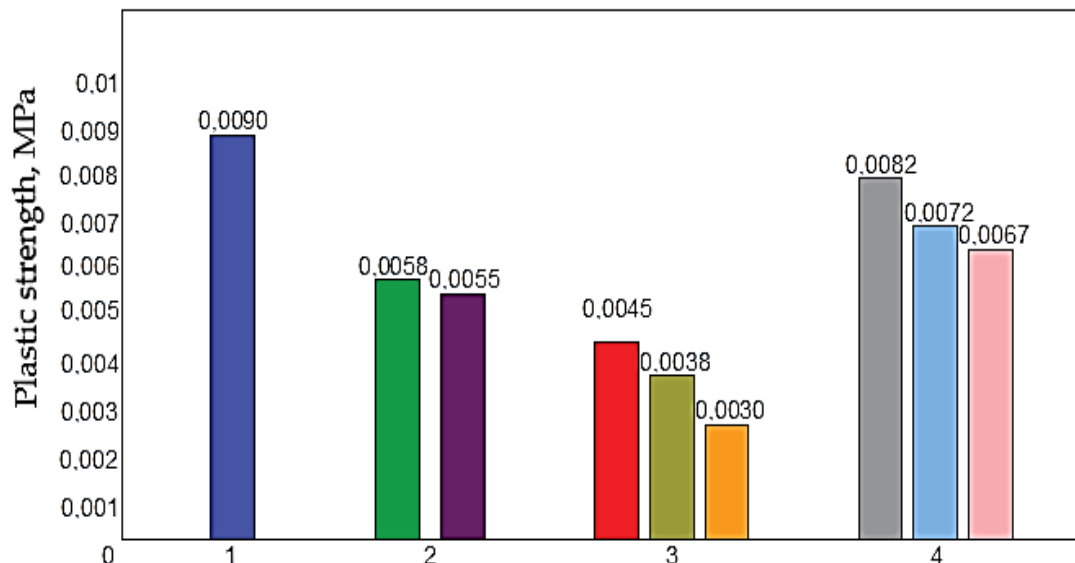


Fig. 6 The influence of additives on the change in tensile strength of lime-diatomite compositions; 1 – lime:diatomite; 2 – same +RPP+LCE (P/T=1.5 и P/T=2.0); 3 – same (0.01%; 0.02%; 0.03%); 4 – same + LCE (0.2%; 0.3%; 0.5%).

Table 3. Data on the degree of drying of compositions based on lime, diatomaceous earth and special additives.

№ compounds	Drying time, min						
	1	2	3	4	5	6	7
1	1	4	6	8	10	14	15
2	1	3	7	10	13	14	17
3	2	6	8	9	14	15	18
4	2	5	8	12	17	20	28
5	3	5	9	11	15	18	30
6	4	7	12	17	24	32	40

Thus, with a reoriented additive content of 0.2% by weight of the dry mixture, the drying time to degree 7 was 30 minutes, and with a content of 0.3% it was 40 minutes. It has been established that the introduction of LCE and RPP additives into the mixture formulation changes the drying process of the finished layer by increasing the drying time of the finishing layer by 50%, depending on the content of the additive.

An important property of finishing coatings is their adhesion to various surfaces. Many other properties of finishing coatings, including durability and protective ability under operating conditions, largely depend on the strength and stability of adhesion.^[13-16]

During the process of structure formation of dry building mixtures, the chemical composition, structure and properties of the material change, changes in macromolecules can occur and their surface is activated and certain stresses are formed in the contact zone. All of the above affects adhesive interactions. Thus, both during the formation of the product and during its operation, the initially established connections can be preserved, destroyed, or supplemented with new ones. The degree of adhesion depends not only on the presence, but also on the number of bonds between the contacting bodies. And accordingly, the number of connections is determined by the area of actual contact between the adhesive and the base.^[17-20] The assessed indicator of the adhesive ability of finishing coatings is the value of adhesive strength. This is an indicator that depends on the formulation of the finished composition, the type and condition of the base, application technology and coating formation conditions.

In this work, the adhesive strength of ready-made lime-diatomite compositions with the surface of cement-sand and brick bases was studied.

The tensile strength was determined using an IR 5057-50

tensile testing machine on beam samples measuring 10×10×50 mm. The strain rate was 1 mm/min. The research results are shown in Table 4.

Analysis of experimental data showed that the control composition has low adhesive and cohesive strength, which amounted to 0.30-0.32 MPa and 0.40 MPa respectively. Of course, this is due to the low moisture-holding capacity of the finished mixture, as well as the very slow development of compressive strength in the early stages of hardening. In this regard the cohesive adhesion properties of lime-diatomite compositions with LCE and RPP additives in amounts of 0.1%, 0.2% and 0.3% were studied.

The highest adhesive strength which is 0.68 MPa for cement-sand mortar and 0.61 MPa for brick base was observed when the composite layer containing the LCE dispersion contains a complete dispersion with a solid polymerized ratio. The presence of polymer additives in the composition of dry mixtures can significantly increase the adhesive ability and improve the cohesive-adhesive interaction of the composition with the base. Increased adhesiveness and peeling strength when modifying dry mixtures with polymer powders is achieved by improving adhesion at the interface with the substrate, as well as the cohesive strength of the solution itself due to the formation of polymer films.^[21-24]

Modification of diatomite and the introduction of LCE and RPP additives into the composition of the dry building mixture led to an increase in the cohesive and adhesive properties of lime-diatomite compositions. In general, it was found that the composite compositions showed higher adhesion based on cement and sand compared to the brick substrate.

4. Conclusions

The results of the conducted research allowed us to formulate

Table 4. Adhesive and cohesive properties of dry building compositions.

№ compounds	Adhesive strength, MPa		Cohesive strength, MPa
	Substrate type (cement-sand mortar)	Substrate type (brick)	
1	0.45	0.42	0.50
2	0.37	0.35	0.44
3	0.32	0.30	0.40
4	0.60	0.55	0.72
5	0.68	0.61	0.80
6	0.63	0.55	0.75

the following main conclusions.

1. A connection has been established between the structure of formation of lime-diatomite composites and the distribution of adsorption centers on the surface of diatomite. In order to increase the surface activity of diatomite, it is proposed to carry out its heat treatment at a temperature of $T = 650\text{ }^{\circ}\text{C}$. It has been established that the largest number of Brønsted and Lewis acid sites is contained on the surface of calcined diatomite at a temperature of $T = 650\text{ }^{\circ}\text{C}$.

2. The reasons for the hardening of lime-diatomite finishing compositions depending on the composition of the dry mixture have been identified. It has been established that the use of thermally activated diatomite increases the compressive strength of the lime-diatomite finishing composition helps to increase the early structural strength and accelerates the processes of hardening of the lime-diatomite compositions.

3. The introduction of LCE and RPP additives into the composition of the dry mixture revealed an increase in the compressive strength of the composite composition by a factor of 2. The optimal content of the additive LCE and RPP was established in the amount of 0.2% by weight of the dry components of the mixture.

4. The water-holding capacity of the developed dry building mixtures based on heat-treated diatomite was determined using methods approved in regulatory documents, which showed result ranging 79.6% to 88.7% for compositions without additives, which is lower than the recommended values and from 93.0% to 96.6% for compositions with additives, as well as the influence of ambient temperature on this characteristic. The water retention capacity of the developed dry construction mixes based on thermally processed diatomite was determined using methods approved in regulatory documents. The results showed a water retention capacity ranging from 79.6% to 88.7% for compositions without additives, which is lower than the recommended values, and from 93.0% to 96.6% for compositions with additives. Research on the effect of ambient temperature on water retention capacity revealed an average decrease of 4.66% for the optimal composition, while for the same lime-to-diatomite ratio of 1:3 without additives, the decrease was up to 14.3%.

5. The water-holding capacity was assessed taking into account the type of substrate and the thickness of the finishing layer. Research results have shown that the type of substrate and the thickness of the applied layer have a significant impact on the water-holding capacity of the composition. Reducing the thickness of the applied layer leads to a decrease in water-holding capacity. The value of the water-holding capacity of the composition with a layer thickness of 12 mm was 88.5% and with a layer thickness of 6 mm – 80.18%. Intense absorption of moisture was observed on a brick base the water-holding capacity of the mixture with a layer thickness of 12 mm was 62.25% and with the same layer thickness on a cement-sand base - 82.18%. Thus, the water-holding capacity of mixtures applied to highly water-absorbing substrates is

significantly lower.

6. A pattern has been identified that affects the rheological and technological properties of dry mixtures depending on the filler and water content. It has been established that with an increase in the amount of diatomite in the mixture, the tensile strength of lime-diatomite compositions decreases.

7. The influence of additives on the degree of drying of the composite layer has been established. It has been established that the introduction of special additives into the mixture extends the drying time of the composite layer. depending on the type and content, by almost 50%.

8. Modification of diatomite and the introduction of LCE and RPP additives into the dry construction mixture led to an increase in the cohesive and adhesive properties of lime-diatomite compositions. In general, it was found that composite compositions showed higher adhesion based on cement and sand compared to a brick substrate, so the highest adhesive strength was 0.68 MPa for cement-sand mortar and 0.61 MPa for a brick base.

The mechanism of structure formation in lime-based building composites modified with nanosized diatomite additives involves the formation of a thermodynamically stable fine-crystalline structure of lime stone through the creation of crystallization centers. These centers consist of the chemical interaction products of nanosized silica particles of diatomite with $\text{Ca}(\text{OH})_2$, as well as their adsorption at the phase boundary, which ensures the blocking of growth and recrystallization of lime crystals. In the presence of modified diatomite, the primary hardening products are hydrate phases that are chemically similar to C-S-H (II), as well as calcite and lime. With the presence of a complex modifying additive (LCE and RPP), a decrease in the amorphous phase and an increase in the crystalline phase are observed, amounting to 24% and 76%, respectively (compared to 28% and 72% in the control sample). Analysis of the phase composition of a sample of lime-diatomite composition indicates the interaction of lime with a modified nanoscale additive of diatomite, as a result, intensive formation of the crystalline phase is observed, which subsequently contributes to improving the operational properties of dry building mixes, while increasing their quality.

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Conflict of Interest

There is no conflict of interest.

Supporting Information

Not applicable.

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