The object of the study is the chemical resistance of concrete modified with granite dust and acrylic latex. The materials used in the study were concrete samples with a variable composition of additive components, which were subsequently exposed to an aggressive environment. The problem, which the research is aimed at solving, is the tendency of concrete structures to fail under prolonged exposure to acidic conditions, which significantly reduces their service life. This research aims to address this issue by incorporating modifying additives that improve concrete's resistance to chemical attack. The experimental program involved testing concrete specimens with different concentrations of granite dust (1–4 % by cement mass) and acrylic latex (0.1–0.4 % by water mass) in a 10 % sulfuric acid solution for up to 360 days. Strength loss was assessed at regular intervals, and chemical resistance coefficients were calculated to evaluate durability. Additionally, long-term degradation predictions were made using logarithmic models. The results show that the optimal composition – 4 % granite dust and 0.4 % acrylic latex –significantly improves chemical resistance, with specimens retaining up to 49 % of their initial strength after 100 years of exposure. The enhancement is attributed to the densification effect of granite dust, which reduces permeability, and the hydrophobizing properties of acrylic latex, which minimize acid penetration. Compared to unmodified concrete, the proposed composition demonstrates lower strength loss and higher durability under aggressive conditions. The proposed modified composition offers a reliable solution for extending the service life of reinforced concrete structures exposed to chemical degradation

Keywords: concrete, granite dust, acrylic latex, chemical resistance, bending strength

UDC 691.33:620.193
DOI: 10.15587/1729-4061.2025.323027

ASSESSMENT OF THE CHEMICAL RESISTANCE OF CONCRETE WITH AN ADDITIVE BASED ON GRANITE DUST AND ACRYLIC LATEX

Rauan Lukpanov
Doctor PhD, Associate Professor*
Aliya Altynbekova
Corresponding author
Doctor PhD, Senior Lecturer*
E-mail: kleo-14@mail.ru
Serik Yenkebaev
Doctor PhD, Associate Professor
Department of Construction**
Denis Tsygulyov
Candidate Technical Sciences, Associate Professor
Department of Construction**
Dinara Orazova
Doctor PhD, Associate Professor
Department of Architecture and Civil Engineering***
Zhumabek Omarov
Candidate of Sciences, Associate Professor
Department of Architecture and Design***
Kuanysh Makashev
Doctor PhD, Associate Professor
Department of Architecture and Civil Engineering***
*Department of Architecture and Civil Engineering**
**L.N. Gumilyov Eurasian National University
Satbayev str., 2, Astana, Republic of Kazakhstan, 010008
***Toraighyrov University
Lomov str., 64, Pavlodar, Republic of Kazakhstan, 140008

Received 20.01.2025
Received in revised form 19.03.2025
Accepted date 07.04.2025
Published date 30.04.2025

How to Cite: *Lukpanov, R., Altynbekova, A., Yenkebaev, S., Tsygulyov, D., Orazova, D., Omarov, Z., Makashev, K. (2025). Assessment of the chemical resistance of concrete with an additive based on granite dust and acrylic latex. Eastern-European Journal of Enterprise Technologies, 2 (6 (134)), 44–52. https://doi.org/10.15587/1729-4061.2025.323027*

1. Introduction

The durability of concrete is a crucial factor influencing the long-term performance of civil and industrial structures, particularly those exposed to aggressive environments. Concrete deterioration due to chemical attacks, especially in acidic conditions, is a major challenge in construction engineering. According to [1], exposure to sulfuric acid leads to the leaching of calcium hydroxide, dissolution of calcium-silicate-hydrate (C-S-H) phases, and formation of expansive compounds such as gypsum and ettringite, which weaken the microstructure of concrete, increase porosity, and cause cracking and spalling. This process significantly reduces the service life of reinforced concrete structures, necessitating costly maintenance and repairs. Similarly, [2] highlighted that conventional concrete materials degrade rapidly in aggressive environments without additional protective measures.

Research has demonstrated that aggressive environments affecting concrete can be classified based on various criteria. Research by [3] categorize them by the degree of aggressiveness (non-aggressive, mildly aggressive, moderately aggressive, and highly aggressive), by physical state (gaseous, liquid, or solid), and by chemical composition (organic and inorganic compounds, including sulfates, chlorides, acids, magnesium salts, and alkalis). Additionally, environmental factors such as biological activity play a role in concrete degradation, as metabolic products of bacteria and fungi, fungal hyphae, and plant roots contribute to the deterioration of the cementitious matrix [4].

Highly aggressive environments, such as sulfate-rich soils, seawater, and industrial wastewater, accelerate concrete deterioration. Research by [5] analyzed the effects of sulfate attack, finding that it leads to the formation of expansive compounds like ettringite and gypsum, causing internal stresses and cracking within the concrete. Similarly, chloride ingress promotes steel reinforcement corrosion, significantly reducing the load-bearing capacity of reinforced concrete elements [6]. Additionally, exposure to acidic environments results in the dissolution of alkaline components of concrete, weakening its protective properties and compromising long-term durability. Even fresh water can pose a threat to pozzolanic cement due to calcium hydroxide leaching [7].

Numerous strategies have been explored to enhance the chemical resistance of concrete. Silica fume, fly ash, and metakaolin are known to improve density and reduce permeability, thereby increasing durability in sulfate and chloride-rich environments [8]. Alkali-activated materials (AAMs) have been identified as promising alternatives, exhibiting superior resistance to chemical attacks [9]. However, research by [10] highlight the high production costs and complex handling procedures of AAMs as major barriers to widespread adoption. Additionally, sulfate-resistant cement formulations with low C_3A content have been developed, but they may not always be cost-effective or universally applicable in construction scenarios [11].

One promising alternative is the incorporation of industrial waste byproducts into concrete formulations. Research by [12] investigated granite dust, a byproduct of stone processing industries, and found that it improves density, strength, and resistance to aggressive agents. Moreover, research by [13] studied the influence of polymer-based additives such as acrylic latex, demonstrating their hydrophobizing properties that minimize water absorption and improve resistance to acid attacks. The potential synergy between these two materials – granite dust enhancing density and reducing permeability while acrylic latex provides hydrophobic properties – represents a novel strategy for improving chemical resistance in concrete.

Given the extensive use of concrete in industrial, wastewater treatment, and coastal infrastructure, as well as the economic and environmental challenges posed by its degradation, research on improving its chemical resistance remains highly relevant. The combination of granite dust and acrylic latex as a dual modification strategy has not been extensively explored. Understanding their combined effects on durability, permeability, and long-term strength retention under acidic conditions is essential for the development of more resilient construction materials.

2. Literature review and problem statement

Research by [1] highlights that fiber-reinforced concrete exhibits increased durability due to crack-bridging effects, but its application in highly acidic environments remains limited. Similarly, research by [2] studied the concrete-to-concrete bond performance under aggressive exposure, showing that conventional materials degrade rapidly without additional protective measures.

One of the main threats to concrete durability is sulfate and acid attack. Research by [4] analyzed alkali-activated materials (AAMs) and their resistance to sulfate environments, concluding that these materials outperform ordinary Portland cement (OPC) in sulfate-rich conditions. However, their large-scale implementation is challenging due to cost and production complexities. Research by [11] further investigated geopolymer concrete, which exhibits enhanced resistance in aggressive conditions, but its widespread application is limited by material variability and production inconsistencies.

Several studies have explored the use of industrial byproducts to enhance chemical resistance. Research by [14, 15] evaluated the incorporation of granite sludge in cementitious mortars and found that it improves density and reduces permeability, which enhances durability. Meanwhile, research by [16] examined the influence of polymer latexes on cement-stabilized materials, demonstrating that latex-modified concrete exhibits improved durability, particularly under exposure to road salts and chemicals.

While AAMs and geopolymer concrete exhibit promising chemical resistance, their implementation is hindered by high costs and production difficulties. Fiber reinforcement improves crack resistance but does not significantly alter the chemical stability of the matrix. Additionally, existing studies on granite dust and acrylic latex focus primarily on mechanical properties rather than long-term chemical resistance in highly acidic conditions.

While various additives such as fly ash, silica fume, and metakaolin have been extensively studied for improving chemical resistance, research on granite dust and acrylic latex as a combined additive remains limited. Studies such as [16] suggest that granite-based materials can enhance durability, but their effect on acid resistance in concrete has not been sufficiently investigated. Similarly [15] explored the use of styrene-acrylic emulsion in cement mortars, demonstrating enhanced chloride and sulfate resistance, but did not examine long-term performance under acidic attack.

A major challenge in durability studies is the long-term prediction of concrete performance. Most experimental research is limited to short-term laboratory tests, while long-term degradation models are often based on extrapolated data. Studies such as [12] highlight the need for accurate prediction models to assess the chemical resistance of cement-based composites over extended service periods.

Another critical issue is the cost-effectiveness of proposed solutions. Geopolymer and alkali-activated materials exhibit superior chemical resistance but are often impractical for large-scale application due to high production costs and raw material availability. In contrast, granite dust is an industrial byproduct, making it a low-cost and sustainable alternative for modifying concrete. Acrylic latex, despite being a synthetic polymer, is already widely used in construction materials and can be optimized for economic feasibility.

Another critical issue is the cost-effectiveness of proposed solutions. While AAMs and geopolymer concrete provide superior resistance, their adoption is limited by high production costs and material sourcing constraints. In contrast, granite dust, being an industrial byproduct, represents a low-cost and sustainable alternative. Likewise, acrylic latex is already widely used in construction and can be optimized for economic feasibility.

All this allows to assert that it is expedient to conduct a study on evaluate synergistic effect of the admixtures in terms of improving durability when exposed to aggressive environments.

3. The aim and objectives of the study

The aim of this study is to evaluate the effect of modifying additives granite dust and acrylic latex on the chemical resistance of concrete when exposed to an aggressive environment (10 % sulfuric acid solution). This will make it possible to enhance the durability of concrete structures by improving their resistance to chemical degradation, reducing permeability, and ensuring long-term strength retention.

To achieve this aim, the following objectives were set:

– to conduct experimental tests to determine the chemical resistance of concrete specimens with different additive concentrations under prolonged exposure to an aggressive environment;

– to calculate the chemical resistance coefficient based on residual strength measurements to quantify the effectiveness of the proposed additives;

– to develop predictive models for long-term strength loss and chemical resistance degradation over extended service periods.

4. Materials and methods of research

The object of the study is the chemical resistance of concrete modified with granite dust and acrylic latex. In this study is concrete incorporating the proposed modified additive, which consists of post-distillation stillage (PaB), soapstock (Sp), sodium hydroxide (NaOH), granite dust (Gr), and acrylic latex (Lx).

The main research hypothesis is that the components of the modified additive, specifically granite dust and acrylic latex, influence the chemical resistance of concrete due to their densification effect and hydrophobization.

The chemical resistance tests of concrete specimens were conducted in accordance with GOST P 58896-2020 [17]. The method involves exposing concrete specimens to an aggressive environment followed by measuring their bending strength. A total of five beam specimens of each compared type were tested at control intervals of 30, 60, 90, 180, 270, and 360 days. Each type of specimen had 30 beam specimens in total. The tests were performed in aggressive environments represented by an aqueous 10 % sulfuric acid solution (hereafter referred to as the aggressive environment). The pH value was monitored every 30 days while the specimens were kept in glass containers. The assessment of chemical resistance was carried out according to GOST P 58895-2020 [18].

The chemical resistance coefficient was determined by measuring the residual bending strength relative to the initial (reference) specimen, following GOST P 58896-2020 [17]. The prediction of chemical resistance degradation during prolonged concrete exposure to aggressive environments (10 % sulfuric acid solution) was based on the measured strength losses and calculated chemical resistance coefficients in accordance with GOST P 58896-2020 [17]. The determination of chemical resistance is reduced to the calculation of the chemical resistance coefficient decline:

$$\lg k_{GR} = \left(\lg \tau \overline{k_{GR}} - \overline{\lg \tau}\right) - \left(\frac{\sum\left(\lg \overline{k_{GR}} - \lg k_{GRi}\right)\times\left(\lg \overline{\tau_i} - \lg \tau_i\right)}{\sum\left(\lg \overline{\tau_i} - \lg \tau_i\right)^2}\right)\times \lg \tau = a\times b\times \tau_i, \quad (1)$$

where k_{GR} – chemical resistance coefficient, calculated by exponentiating the obtained value;

$\lg \overline{k_{GR}} = \frac{\sum \overline{k_{GRi}}}{n}$ – mean logarithm of the chemical resistance coefficient;

$\lg \bar{\tau} = \frac{\sum \overline{\tau_i}}{n}$ – mean logarithm of the test duration;

$\lg k_{GRi}$ and $\lg \tau_i$ – logarithms of the chemical resistance coefficients and test durations for the i-th series of specimens at intermediate (control) test periods;

n – number of control tests.

The composition of the additive includes post-distillation stillage (PaB), soapstock (Sp), sodium hydroxide (NaOH), granite dust (Gr), and acrylic latex (Lx). However, the key components influencing the change in acidity are granite dust and acrylic latex. Therefore, for simplicity, Table 1 presents variations in the technological composition of concrete beam specimens without specifying the other additive components, whose quantities remained identical across all specimens.

For reference, the proportion of soapstock in all specimens was 8 % by cement mass, sodium hydroxide was 1 % by soapstock mass, and post-distillation stillage was 6 % by water mass. These proportions were determined based on a series of control tests, which were used as reference values for introducing these components into the concrete mixture (e. g., compressive and bending strength, frost resistance).

Table 1

Composition of concrete specimens

Specimen type – contents (%)	The content of the component by mass, g							
	Sand	Gr	Cement	Sp	NaOH	PaB	Water	Lx
Reference	1500	0	500	–	–	–	200	–
Type 1 – Gr1 %	1485	15	500	–	–	–	200	–
Type 2 – Gr2 %	1470	30	500	–	–	–	200	–
Type 3 – Gr3 %	1455	45	500	–	–	–	200	–
Type 4 – Gr4 %	1440	60	500	–	–	–	200	–
Type 5 – Lx0.1 %	1440	60	460	39.6	0.4	12	187.8*	0.2
Type 6 – Lx0.2 %	1440	60	460	39.6	0.4	12	187.6*	0.4
Type 7 – Lx0.3 %	1440	60	460	39.6	0.4	12	187.4*	0.6
Type 8 – Lx0.4 %	1440	60	460	39.6	0.4	12	187.2*	0.8

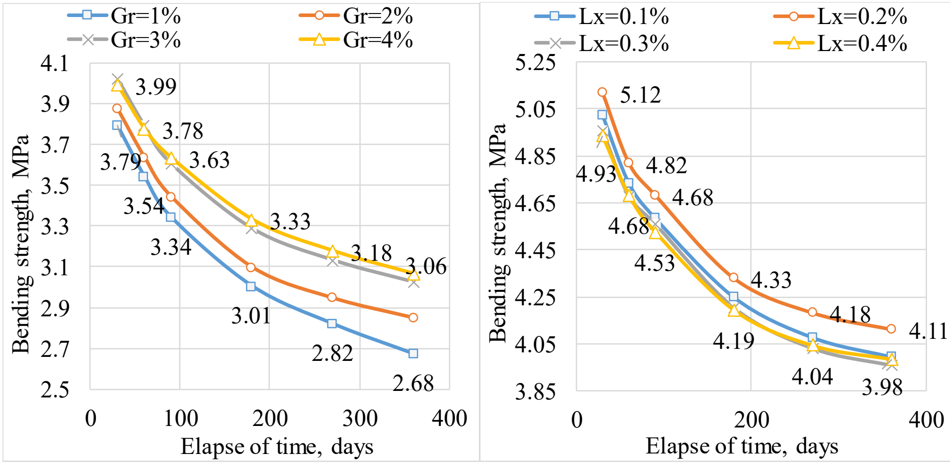
*Note: * – the exact water-cement ratio is adjusted based on normal consistency tests of the cement due to the water-reducing effect of acrylic latex resulting from plasticization.*

Specimens of types 1–4 differ by the inclusion of granite dust (Gr) at 1 %, 2 %, 3 %, and 4 % by the mass of cement in the reference specimen. Specimens of types 5–8 additionally contain acrylic latex (Lx) at 0.1 %, 0.2 %, 0.3 %, and 0.4 % by the mass of water. By default, specimens labeled with the index Lx0.1 % are assumed to contain Gr4 % in their composition.

5. Results of the study of the effect of additives on the chemical resistance of concrete

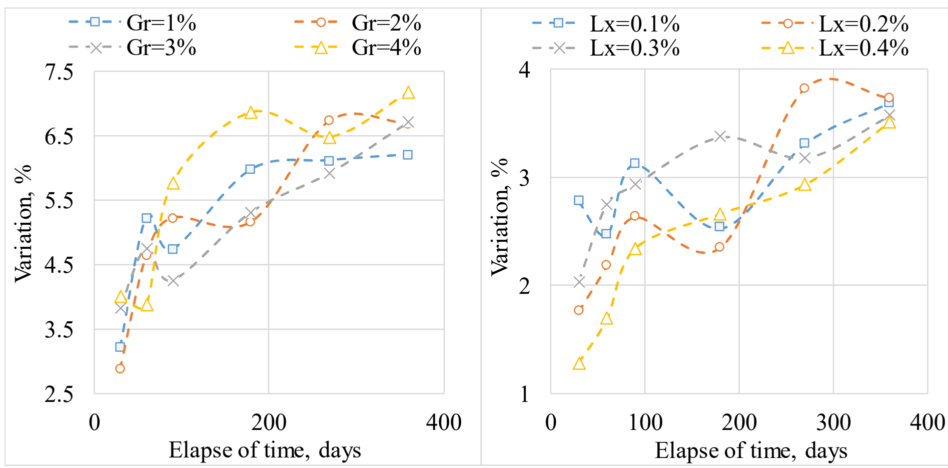
5. 1. Chemical resistance of modified concrete

Fig. 1 illustrates the changes in the strength characteristics of the specimens depending on the duration of exposure. Fig. 1, *a* present the test results for specimens with varying granite dust content, while Fig. 1, *b* shows the results for specimens with different concentrations of acrylic latex.



a *b*

Fig. 1. Bending strength loss over time: *a* — granite dust; *b* — acrylic latex



a *b*

Fig. 2. Variation coefficients of specimens with different compositions: *a* — granite dust; *b* — acrylic latex

According to the strength test results for specimens containing granite dust, the initial strength varies depending on composition. The average values are as follows: Gr1 % – 3.79 MPa, Gr2 % – 3.87 MPa, Gr3 % – 4.02 MPa, and Gr4 % – 3.99 MPa. Thus, bending strength exhibits a peak dependence on additive concentration, with the highest strength observed at a granite content of 3 %. After the maximum exposure period (360 days), strength reduction also varies among different compositions. The percentage decrease relative to the reference specimen is: Gr1 % – 29.5 %, Gr2 % – 26.4 %, Gr3 % – 24.8 %, and Gr4 % – 23.2 %.

A similar pattern is observed in specimens with acrylic latex. The initial strength values for different latex concentrations are: Lx0.1 % – 5.02 MPa, Lx0.2 % – 5.12 MPa, Lx0.3 % – 4.95 MPa, and Lx0.4 % – 4.93 MPa. Strength loss also shows a general decreasing trend with increasing additive concentration, with reductions relative to the reference specimen as follows: Lx0.1 % – 20.5 %, Lx0.2 % – 19.7 %, Lx0.3 % – 20.1 %, and Lx0.4 % – 19.24 %.

5. 2. Chemical resistance coefficients of concrete specimens

Fig. 2 presents the variation coefficients corresponding to each series of tests for specimens of the same composition. Fig. 2, *a* show the variation coefficients for different granite dust compositions, while Fig. 2, *b* displays the variation coefficients for acrylic latex compositions. The data points in the diagrams are conventionally connected by dashed lines to indicate their association with a specific series and to illustrate the trend in data point dispersion over time under aggressive environmental exposure.

The variation coefficients for specimens with granite dust range from 2.9 % to 7.2 %, while those for acrylic latex range from 1.28 % to 3.82 %. These variation coefficients indicate a high convergence of data points, confirming the high reliability of the obtained results.

5. 3. Predicted long-term strength retention

Fig. 3 presents the calculated chemical resistance coefficients. Fig. 3, *a* show the results for different granite dust compositions, while Fig. 3, *b* displays the results for acrylic latex compositions.

The trend of changes in the chemical resistance coefficients follows the same pattern as strength loss (since the calculation formula is linear). However, the diagrams provide a more precise representation of strength variation relative to the reference specimen. This is due to the fact that the initial strength varies across different compositions. Therefore, comparing the reduction in strength should be done relative to the reference specimen rather than using absolute strength values.

The residual strength of specimens with different granite dust concentrations, expressed as a percentage of their initial strength, varies as follows: Gr1 %: from 70 % to 49 %; Gr2 %: from 72 % to 53 %; Gr3 %: from 75 % to 56 %; Gr4 %: from 75 % to 60 %. Similarly, the residual strength of specimens with varying acrylic latex concentrations is as follows: Lx0.1 %: from 85 % to 68 %; Lx0.2 %: from 87 % to 70 %; Lx0.3 %: from 89 % to 71 %; Lx0.4 %: from 92 % to 74 %.

Thus, the transformation of chemical resistance occurs continuously, with each subsequent increase in additive concentration leading to a resistance increase of 31 %, 33 %, 36 %, 40 %, 44 %, and 50 % at 30, 60, 90, 180, 270, and 360 days of exposure, respectively. The diagrams confirm this trend: for instance, the residual strength of type 1 specimens after 30 days (70 %) is lower than that of type 8 specimens after 360 days (74 %).

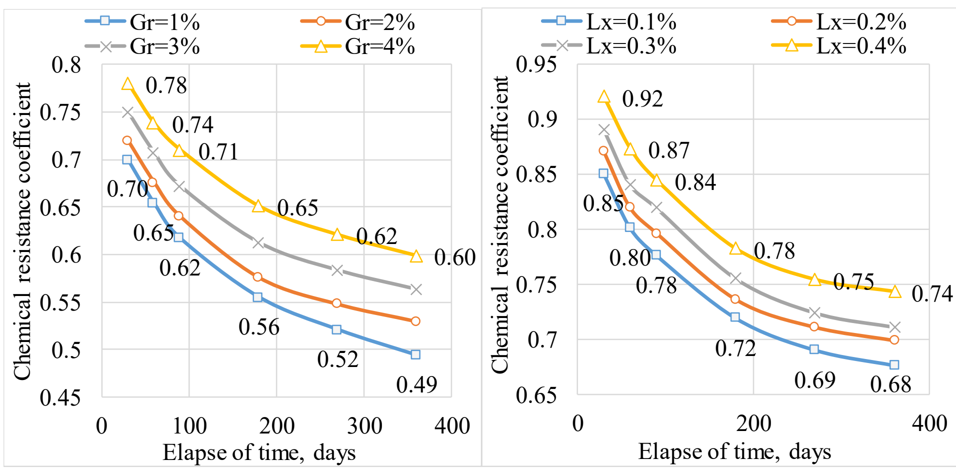
The significant difference between the latex-modified and granite-modified specimens indicates that the hydrophobic effect has a greater influence on the chemical resistance of concrete than the reduction in its permeability.

The following section presents the predicted changes in concrete strength over an extended period under aggressive environmental conditions. Table 2 provides the calculated variable parameters of equation (1), used for predicting long-term changes in the chemical resistance coefficient. These calculations are based on the previously reported laboratory measurements of chemical resistance coefficients, conducted over a 360-day observation period.

Table 3 presents the equations for changes in the chemical resistance coefficient, based on the previously determined variables a and b (from Table 1).

Fig. 4 presents the curves characterizing the predicted changes in the chemical resistance of concrete structures exposed to an aggressive environment over periods of up to 10 and 100 years. Fig. 4, a illustrates the strength loss values relative to the reference specimen, while Fig. 4, b shows the absolute residual strength values. The x-axis represents the serial numbers corresponding to the specimen type, and the y-axis indicates the predicted depletion of their strength characteristics due to exposure to an aggressive environment.

According to the diagrams, for concrete structures of type 1 exposed to aggressive environments, the residual strength of concrete will already decrease to 36 % of its initial value within the first 10 years of service. However, the subsequent reduction in strength occurs at a slower rate. A high intensity of aggressive environmental impact is characteristic of all specimen types during the initial service period, followed by a gradual decrease in intensity over time.



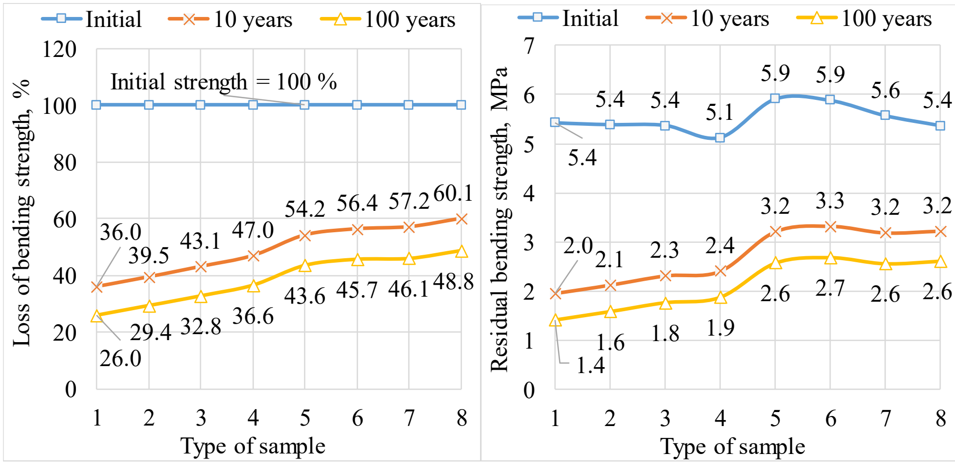
a *b*

Fig. 3. Chemical resistance coefficients of specimens with different compositions: *a* – granite dust; *b* – acrylic latex

Table 2

Parameters of the chemical resistance coefficient variation equation

Calculated parameter	Gr1 %	Gr2 %	Gr3 %	Gr4 %	Lx01 %	Lx02 %	Lx03 %	Lx04 %
$\sum \lg\tau_i$	12.45	12.45	12.45	12.45	12.45	12.45	12.45	12.45
$\sum \lg k_{GRi}$	–1.39	–1.28	–1.14	–1.00	–0.75	–0.68	–0.62	–0.53
$\sum \lg \overline{\tau_i}$	2.08	2.08	2.08	2.08	2.08	2.08	2.08	2.08
$\sum \lg \overline{k_{GRi}}$	–0.23	–0.21	–0.19	–0.17	–0.12	–0.11	–0.10	–0.09
$\sum\left(\lg k_{\overline{GRi}} - \lg k_{GRi}\right)\times\left(\lg\overline{\tau_i} - \lg\tau_i\right)$	–0.12	–0.11	–0.10	–0.09	–0.08	–0.08	–0.08	–0.08
$\sum\left(\lg\overline{r_i} - \lg\tau_i\right)^2$	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
$b = \dfrac{\sum\left(\lg k_{\overline{GRi}} - \lg k_{GRi}\right)\times\left(\lg\overline{\tau_i} - \lg\tau_i\right)}{\sum\left(\lg\overline{\tau_i} - \lg\tau_i\right)^2}$	–0.14	–0.13	–0.12	–0.11	–0.09	–0.09	–0.09	–0.09
$a = \lg\overline{k_{GRi}} - b\cdot\lg\overline{\tau_i}$	0.063	0.053	0.055	0.058	0.071	0.075	0.091	0.099



a *b*

Fig. 4. Chemical resistance coefficients of specimens with different compositions:
a – loss of bending strength; *b* – residual bending strength

Table 3

Equations for changes in the chemical resistance coefficient

Type of specimen	Equation of chemical resistance coefficient
Gr=1 %	$\lg k_{CR}=0.063-0.14\lg\tau$
Gr=2 %	$\lg k_{CR}=0.053-0.13\lg\tau$
Gr=3 %	$\lg k_{CR}=0.055-0.12\lg\tau$
Gr=4 %	$\lg k_{CR}=0.058-0.11\lg\tau$
Lx=0.1 %	$\lg k_{CR}=0.071-0.09\lg\tau$
Lx=0.2 %	$\lg k_{CR}=0.075-0.09\lg\tau$
Lx=0.3 %	$\lg k_{CR}=0.091-0.09\lg\tau$
Lx=0.4 %	$\lg k_{CR}=0.099-0.09\lg\tau$

Nevertheless, the effect of the additive on the absolute strength retention is evident: at the maximum additive concentration (type 8), the residual strength after 10 years of service is 60 %, and after 100 years, it is 49 %. This significantly exceeds the residual strength of type 1 specimens, even after just 10 years of exposure.

6. Discussion of the results of the study of the effect of the additive on the chemical resistance of concrete

The proposed additive composition has not been previously proposed and researched; hence it can be attributed to a novel technological solution. The results obtained in the research can be explained by the mechanisms of interaction of modifying additives – granite dust and acrylic latex with cement matrix, which contribute to the increase of chemical resistance of concrete under conditions of aggressive environment.

During the research, a positive effect of the additive on the chemical resistance of concrete was obtained, which confirms the significance of the study and its practical value. The use of the additive contributes to a noticeable increase in the service life of concrete in aggressive environments. The chemical resistance coefficient of samples using the additive increases to 50 % in relation to ordinary concrete, for a number of reasons described below.

The increase in the chemical resistance of concrete with the addition of granite dust (Fig. 1, *a*, 3, *a*) is primarily due to its compacting effect, which reduces permeability. The fine-grained structure of granite dust promotes the formation of a denser cement matrix, limiting the penetration of aggressive agents. In addition, the pozzolanic properties of granite dust increase the chemical resistance of concrete due to interaction with calcium hydroxide to form secondary phases C-S-H. Maximum strength is achieved at a granite dust concentration of 3 %. With a subsequent increase in concentration, a decrease in strength is observed. This is due to the fact that at a high concentration of granite dust, the amount of silicon oxides becomes greater in relation to the portlandites of the cement binder. The decrease in strength loss with an increase in granite concentration is associated with a change in the density of the samples. That is, with an increase in density, the water permeability of concrete increases, and, consequently, the penetration of an aggressive environment into the concrete structure decreases.

The increase in the chemical resistance of concrete with the addition of acrylic latex (Fig. 1, *b*, 3, *b*) is explained by its hydrophobic properties, which minimize water absorption and limit acid penetration. The latex forms a polymer film on the surface of cement particles and inside microcracks, reducing the connectivity of capillary pores. Maximum strength is achieved with an acrylic latex concentration of 0.2 %. With a subsequent increase in concentration, a decrease in strength is observed. The decrease in strength at high concentrations of acrylic latex can be explained by the increased concentration of the polymer-containing component in the composition of the cement stone. At optimum concentration latex has the function of a micropore filler, while at high concentrations, it replaces the structural components of the cement matrix, which leads to weakening of the load-bearing framework of concrete.

From the graphs in Fig. 2 it can be seen that in both cases the spread of datapoints increases with increasing exposure of the samples to an aggressive environment. This indicates a relatively individual destructive effect of the aggressive environment on a specific sample. However, the spread is not significant, within the permissible values, and may be associated with the existential factor of random structure formation (including the formation of microcracks and micropores) of each specific sample. The latter affects the rate of penetration of the aggressive environment into the sample structure, which has a negative destructive effect when interacting with concrete. It should be noted that the coefficients of variation of samples with the addition of latex are significantly lower than samples with granite, which indicates greater stability of the results of samples with latex. This can be explained by the hydrophobic effect of latex, which compensates for the error in the results of random structuring and the formation of microcracks in the structure of cement stone. That is, acrylic latex envelops the surface of micropores and microcracks, therefore blocking the interaction of an aggressive environment with concrete, thus the penetrating ability of an aggressive environment is a secondary factor.

The predictive models of strength loss (Table 3, Fig. 4) are based on logarithmic approximations obtained from 360-day experimental data. The obtained logarithmic equations are applicable only for evaluating the chemical resistance of concrete compositions. In fact, the influence of the admixture was also observed in the strength loss assessment (Fig. 1), but these calculations are useful for future design of concrete structures based on this composition, as well as for understanding the required design strength reserve for structures, depending on the lifetime of the construction projects. For example, the effect of the admixture on strength changes is evident from the graphs: at maximum admixture concentration (type 8), the residual strength at 10-year service life is 60 % and at 100-year service life is 49 %, which is significantly higher than the strength of Type 1 samples even at 10-year service life.

The results of this research are in agreement with the findings of previous studies on improving chemical resistance with modifying additives. Studies such as [15, 16, 19–23] confirm that permeability reduction and hydrophobization of the cement matrix are effective strategies for improving durability in aggressive environments. Unlike traditional approaches using silica dust or fly ash, this study demonstrates that the combination of granite dust and acrylic latex provides the dual benefits of sealing and hydrophobicity, resulting in superior durability (Figure Unlike alkali-activated concretes, which exhibit high sulfate resistance but are limited in practical application due to the instability of the binder under acidic conditions [6, 10], the proposed modification is compatible with conventional Portland cement-based mixtures, making it more feasible for large-scale implementation.

The proposed technological solution of the additive closes the problematic part of the research on increasing the chemical resistance of concrete, but it has some limitations. One of the limitations of the proposed approach is that the obtained results of strength loss prediction during long-term operation of concrete structures in the conditions of aggressive environment, although they provide valuable data for design, but do not take into account the combination of other negative factors of destructive effects in real conditions, such as temperature fluctuations, mechanical dynamic loading, etc. The results of this approach are not considered. Another potential limitation may be the cost factor associated with acrylic latex. Although its benefits in improving chemical resistance are obvious and the concentration in concrete is very low, a cost-benefit analysis must be performed to determine the economic feasibility of large-scale use.

This research is limited to laboratory-scale experiments conducted under controlled conditions. The findings are specific to concrete compositions with general-purpose Portland cement and may not directly apply to other cement types, such as sulfate-resistant cements. Additionally, the study focuses on chemical resistance in sulfuric acid solutions; further testing in chloride-rich and carbonate environments is needed for comprehensive durability assessment.

Further research will focus on full-scale testing with modeling of real design situations, including changes in temperature, humidity, load factor, etc. From a methodological point of view, for predicting the durability of concrete under various impacts, the use of the finite element method, which allows modeling multifactorial impacts, may be a great potential for promising research. In addition, extending the application to other aggressive environments (e.g., chloride and sulfate exposure) will allow for a more complete evaluation of the proposed additives.

7. Conclusions

1. Experimental assessment of chemical resistance demonstrated that concrete specimens with modifying additives exhibit a lower strength loss after prolonged exposure to an aggressive 10 % sulfuric acid solution. The maximum strength loss for specimens with granite dust varied from 29.5 % (Gr1 %) to 23.2 % (Gr4 %), while for acrylic latex, the reduction ranged from 20.5 % (Lx0.1 %) to 19.24 % (Lx0.4 %). This confirms that increasing the concentration of modifying additives enhances the durability of concrete under chemical attack.

2. The chemical resistance coefficient was determined based on residual strength values. Specimens with granite dust retained 49–60 % of their initial strength, while those with acrylic latex retained 68–74 % over 360 days. The increased resistance is attributed to the densification effect of granite dust, reducing permeability, and the hydrophobizing properties of acrylic latex, minimizing acid penetration. These findings demonstrate that the proposed additives provide a higher resistance level than traditional concrete compositions.

3. Long-term durability predictions indicate that the proposed modified concrete composition retains up to 49 % of its initial strength even after 100 years of exposure to an aggressive environment. Logarithmic models were developed to describe strength degradation trends, confirming that the modification significantly extends the service life of concrete structures. This suggests that the combined use of granite dust and acrylic latex provides a cost-effective and efficient method for improving concrete performance in highly aggressive environments.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

Financing

This research was funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (Gant No. AP19680068).

Data availability

Data will be made available on reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

References

1. Paul, S., van Zijl, G., Šavija, B. (2020). Effect of Fibers on Durability of Concrete: A Practical Review. Materials, 13 (20), 4562. https://doi.org/10.3390/ma13204562
2. Baloch, W. L., Siad, H., Lachemi, M., Sahmaran, M. (2021). A review on the durability of concrete-to-concrete bond in recent rehabilitated structures. Journal of Building Engineering, 44, 103315. https://doi.org/10.1016/j.jobe.2021.103315
3. Zhang, S. P., Zong, L. (2014). Evaluation of Relationship between Water Absorption and Durability of Concrete Materials. Advances in Materials Science and Engineering, 2014, 1–8. https://doi.org/10.1155/2014/650373
4. Zhang, J., Shi, C., Zhang, Z., Ou, Z. (2017). Durability of alkali-activated materials in aggressive environments: A review on recent studies. Construction and Building Materials, 152, 598–613. https://doi.org/10.1016/j.conbuildmat.2017.07.027
5. Mendes, D. D., Mari, J. de J., Singer, M., Barros, G. M., Mello, A. F. (2009). Estudo de revisão dos fatores biológicos, sociais e ambientais associados com o comportamento agressivo. Revista Brasileira de Psiquiatria, 31, S77–S85. https://doi.org/10.1590/s1516-44462009000600006
6. Gu, L., Bennett, T., Visintin, P. (2019). Sulphuric acid exposure of conventional concrete and alkali-activated concrete: Assessment of test methodologies. Construction and Building Materials, 197, 681–692. https://doi.org/10.1016/j.conbuildmat.2018.11.166
7. Zhang, G., Wu, C., Hou, D., Yang, J., Sun, D., Zhang, X. (2021). Effect of environmental pH values on phase composition and microstructure of Portland cement paste under sulfate attack. Composites Part B: Engineering, 216, 108862. https://doi.org/10.1016/j.compositesb.2021.108862
8. Teymouri, M., Behfarnia, K., Shabani, A. (2021). Mix Design Effects on the Durability of Alkali-Activated Slag Concrete in a Hydrochloric Acid Environment. Sustainability, 13 (14), 8096. https://doi.org/10.3390/su13148096
9. Xie, Y., Lin, X., Ji, T., Liang, Y., Pan, W. (2019). Comparison of corrosion resistance mechanism between ordinary Portland concrete and alkali-activated concrete subjected to biogenic sulfuric acid attack. Construction and Building Materials, 228, 117071. https://doi.org/10.1016/j.conbuildmat.2019.117071
10. Koenig, A., Herrmann, A., Overmann, S., Dehn, F. (2017). Resistance of alkali-activated binders to organic acid attack: Assessment of evaluation criteria and damage mechanisms. Construction and Building Materials, 151, 405–413. https://doi.org/10.1016/j.conbuildmat.2017.06.117
11. Gado, R. A. (2022). The feasibility of recycling marble & granite sludge in the polymer-modified cementitious mortars Part A: In polymer-modified cementitious adhesive mortar. Process Safety and Environmental Protection, 159, 978–991. https://doi.org/10.1016/j.psep.2022.01.059
12. Chen, K., Wu, D., Xia, L., Cai, Q., Zhang, Z. (2021). Geopolymer concrete durability subjected to aggressive environments – A review of influence factors and comparison with ordinary Portland cement. Construction and Building Materials, 279, 122496. https://doi.org/10.1016/j.conbuildmat.2021.122496
13. Kapeluszna, E., Kotwica, Ł., Pichór, W., Nocuń-Wczelik, W. (2020). Cement-based composites with waste expanded perlite - Structure, mechanical properties and durability in chloride and sulphate environments. Sustainable Materials and Technologies, 24, e00160. https://doi.org/10.1016/j.susmat.2020.e00160
14. Shojaei Baghini, M., Ismail, A., Karim, M. R., Shokri, F., Firoozi, A. A. (2014). Effect of styrene–butadiene copolymer latex on properties and durability of road base stabilized with Portland cement additive. Construction and Building Materials, 68, 740–749. https://doi.org/10.1016/j.conbuildmat.2014.06.061
15. Li, X., Chu, H., Yao, N., Long, B., Li, W., Jiang, L. (2025). Experimental study of styrene-acrylic emulsion modified mortar with manufactured sand and its performance exposed to combined chloride-sulfate attack. Construction and Building Materials, 458, 139682. https://doi.org/10.1016/j.conbuildmat.2024.139682
16. Veloso Moura, H. R. de C., Pedroti, L. G., Salgado Lopes, M. M., Franco de Carvalho, J. M., Lopes Ribeiro, J. C., Bernardes Dias, J. C. (2023). Influence of biocide and dispersant additives on the performance and durability of building paints produced with granite waste. Construction and Building Materials, 409, 134112. https://doi.org/10.1016/j.conbuildmat.2023.134112
17. Interstate Standard GOST P 58896-2020. Chemically resistant concretes. Test methods.
18. Interstate Standard GOST P 58895-2020. Chemically resistant concretes. Specifications.
19. Lukpanov, R., Dyussembinov, D., Altynbekova, A., Yenkebayev, S., Awwad, T. (2023). Optimal concentration of post-alcohol bard and microsilica in cement-sand mixtures determination. Kompleksnoe Ispol′zovanie Mineral′nogo Syr′â/Complex Use of Mineral Resources/Mineraldik Shikisattardy Keshendi Paidalanu, 330 (3), 92–103. https://doi.org/10.31643/2024/6445.33

20. Lukpanov, R., Dyussembinov, D., Tsygulyov, D., Yenkebayev, S. (2022). Complex modified additive for concrete based on industrial waste. Magazine of Civil Engineering, 115(7), 11507. https://doi.org/10.34910/MCE.115.7
21. Altynbekova, A. D., Lukpanov, R. E., Dyussembinov, D. S., Askerbekova, A. M., Gunasekaran, M. (2023). Effect of a complex modified additive based on post-alcohol bard on the strength behavior of concrete. Kompleksnoe Ispol′zovanie Mineral′nogo Syr′â/Complex Use of Mineral Resources/Mineraldik Shikisattardy Keshendi Paidalanu, 327 (4), 5–14. https://doi.org/10.31643/2023/6445.34
22. Altynbekova, A., Lukpanov, R., Yenkebayev, S., Tsygulyov, D., Nurbayeva, M. (2022). Complex laboratory studies of modified additive influence on concrete physical and mechanical properties. International Journal of GEOMATE, 23 (100), 26–33. https://doi.org/10.21660/2022.100.3641
23. Lukpanov, R., Dyussembinov, D., Zhantlessova, Z., Altynbekova, A., Yenkebayev, S., Orazova, D. (2024). Durability assessment of cellular concrete through strength evaluation under adverse environmental conditions. International Journal of GEOMATE, 27 (124), 16–23. https://doi.org/10.21660/2024.124.4271