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Research paper

The use of granite dust as an effective filler of concrete mixtures

Grzegorz Prokopski[1], Andriy Huts[2], Vitaliy Marchuk[3]

Abstract: The article presents the results of experimental studies of the influence of granite dust on the properties and durability of concrete. The use of industrial waste – granite dust, in the processing of granite into crushed stone, at the same time allows the rational use of natural resources and solve environmental problems. The possibility of improving the construction and technical properties of concrete filled with granite dust is considered. Experimental-statistical models of technological and physical-mechanical properties of concretes are presented and analyzed, ways of their improvement are shown. The complex of strength properties, water absorption, frost resistance, and durability of such concrete have been studied. The studied concrete are characterized by a more intensive set of strength and obtaining mixtures of "sticky" consistency. Due to the partial replacement of sand by granite dust, the microstructure of the cement matrix is compacted, which is the main reason for reducing porosity and increasing the durability of structures based on the proposed concrete.

Keywords: granite dust, concrete mixture, water absorption, compressive strength, corrosion resistance, frost resistance

[1]Prof., DSc., PhD., Eng., Rzeszów University of Technology, The Faculty of Civil and Environmental Engineering and Architecture, Poznańska 2, 35-084 Rzeszów, Poland, e-mail: grzeprok@prz.edu.pl, ORCID: 0000-0002-3601-897X

[2]MSc., Eng., Rzeszów University of Technology, The Faculty of Civil and Environmental Engineering and Architecture, Poznańska 2, 35-084 Rzeszów, Poland, e-mail: a.huts@prz.edu.pl, ORCID: 0000-0002-4428-8339

[3]PhD., Eng., National University of Water and Environmental Engineering, Institute of Building and Architecture, Chornovola 49, 33-000 Rivne, Ukraine, e-mail: v.v.marchuk@nuwm.edu.ua, ORCID: 0000-0003-0999-0402

1. Introduction

The problem of resource saving in the production of building materials and concrete in particular is determined to a significant degree by the type and characteristics of the used cement and disperse components – fillers, introduced directly into concrete mixes. In terms of energy intensity, the share of cement in concrete is about 70%, so in recent years in modern construction clearly identified a trend towards the use of energy efficient building materials.

The significant growth in the scale of building is due to the need to expand the raw material base for the production of construction materials. Perspective of materials, including technogenic waste, is assessed not only by performance indicators, but also by the prevalence and availability of raw materials.

One of the components of concrete can be dispersed filler of man-made origin. Studies have shown that such materials [1–5] can be successfully used in concrete.

According to research, partial replacement of cement with marble or limestone dust improves rheological properties, as well as the initial strength of mortars and concretes [6, 7]. The use of fly ash instead of a part of cement causes an increase in strength and plastic toughness of concrete [8, 9]. Dobiszewska et al. indicate that the compressive strength of mortars [10] and concrete [11, 12] is increased by the addition of basalt dust.

Test results show that granite filler positively affects the strength properties of mortars [13, 14]. According to [15–17] it follows that the partial replacement of sand in the amount of 25% of granite dust has a positive effect on the compressive strength and flexural strength of concrete, as well as an increase in strength with increasing curing time. Granite dust increases the chemical resistance and durability of concrete.

The use of waste granite dust could become a valuable resource if properly engineered into a successful solution as a partial cement replacement in concrete. Results showed [18] that granitic quarry sludge waste, if ground to sufficient fineness, produces a denser matrix which promoting improvement in resistance to chlorides, without compromising workability and strength. The use of 5% granite dust as cement addition or cement replacement increases the time of corrosion cracking time [19]. Open circuit potential measurements showed [20] that mixes with 20% marble and granite waste dust as cement replacement generally corresponded to higher corrosion potentials (i.e. less probability of active corrosion). Using granite waste dust as partial replacement of cement can be considered an effective way of improving the resistance of concrete mixes to acid attack [21].

It is noted [22, 23] that the main factor in assessing the impact of technogenic fillers on the properties of concrete is the "micro-filler effect". It appears when the volume concentration of finely dispersed filler increases, which leads to a decrease in the porosity of cement stone in the concrete. At a high level of filling after reaching its maximum, there is a decrease in the strength of concrete despite the continuing decline in the porosity of cement stone [22]. Kaprielov [23] supposes that in the mixed system of disperse material with cement it is important that the particles of the former do not isolate the surface of new phases and do not prevent the formation of contacts of accretion between hydrates of crystals. This condition can be achieved by optimizing the volumetric concentration of the dispersed material in the mixed system, taking into account the hydraulic activity of the filler. For the inert filler, the optimal dosage can be a volume comparable to the capillary pores and needed to fill the respective voids and seal the structure.

There is also an opinion [24–27] that the "micro-filler effect" is based on the property of finely dispersed particles to act as crystallization centers, i.e. to accelerate the initial stage of chemical curing. This is explained by the fact that the dispersed dust particles serve as a substrate for crystallization of $Ca(OH)_2$ with pore liquid. As the water content of the compositions increases, the movement of Ca^{2+} and OH^- ions to the surface of the filler particles is facilitated [26], which leads to intensification of the process of formation and growth of $Ca(OH)_2$ crystals.

In the presence of finely dispersed fillers, the contact zone between the cement stone and the aggregate in the concrete is strengthened. This conclusion is made in [27, 28] based on experimental data.

In this way, the use of technogenic waste in the production of building materials is becoming more and more widespread, and the development of technology for the production of concrete using granite dust is actual at the present time. The peculiarity of the studies is obtaining a complex of experimental and statistical models of strength at the age of 3, 7 and 28 days and water absorption of concrete with addition of granite dust, quantitatively characterizing the effect of composition factors (W/C ratio, granite dust content). The study of corrosion- and frost-resistance of concrete filled with granite dust was carried out.

2. Experimental program

2.1. Materials

The research was conducted using the following materials:

- Portland cement CEM I 42.5 N, produced by "Cement Ozarow SA, CRH group", physical and mechanical properties of which comply with PN-EN 197-1:2012 requirements, mineral composition of clinker: C_3S – 64.6%, C_2S – 12.6%, C_3A – 9.4%, C_4AF – 6.9%.
- Granite dust (GD) and coarse aggregate (granite) produced by "Berger BAU Poland", physical and mechanical parameters of GD are given in Table 1. Fig. 1 shows the semi log-

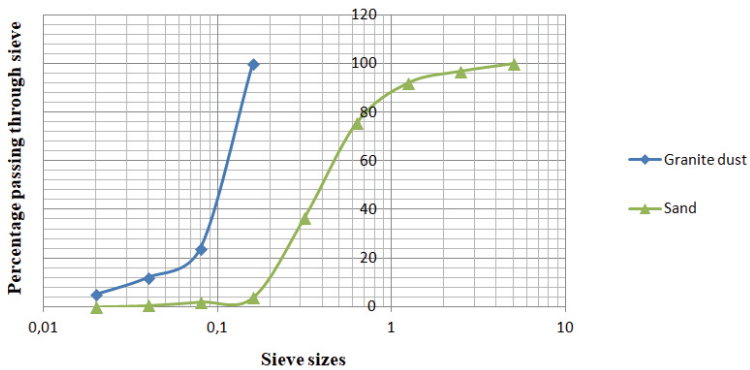

Fig. 1. Particle size distribution of granite dust and sand

arithmic graph of granite dust particle size distribution compared to sand. Coarse aggregate of fractions 6–8 mm, 8–11 mm and 11–16 mm according to PN-EN 12620+A1:2010.

– Quartz sand 0–2 mm, produced by "ZEK Lipie Kruszgeo" according to PN-EN 12620+A1:2010.
– Highly effective superplasticizer based on polycarboxylic esters Muraplast FK59, produced by "MC-Bauchemie Muller GmbH & Co".

Table 1. Physical and mechanical parameters of granite dust

No.	Parameters	Value
1	Specific surface area, m^2/kg (by Blaine method)	240–260
2	Bulk density, kg/m^3	900–920
3	Particle size distribution, % • > 90 µm • 45–90 µm • 32–45 µm • < 32 µm	 4.6 7.3 11.9 76.2
4	Content of clay particles, %	0.2–0.5
5	Humidity, %	0.3–0.5
6	Chemical composition, % • SiO_2 • Al_2O_3 • K_2O • Fe_2O_3 • Na_2O • CaO • TiO_2 • MgO	 64.8 15.6 6.32 6.31 3.08 2.59 0.378 0.325

2.2. Research methods

The choice of experimental methods used in the work was determined by the type of research tasks. The complex of basic construction and technical properties of concrete mixtures and concrete based on granite dust were studied using the methods of current standards.

The studies combined physical-chemical and physical-mechanical research methods. The consistency of concrete mixtures were investigated by cone slump method according to PN-EN 12350-2:2019. The compressive strength was determined in accordance with PN-EN 206+A1:2016, the tests were performed on a device FormTest PRUFSYSTEME type ALPHA 3-3000 S.

Water absorption was determined on 5 cube samples (10 × 10 × 10 cm), which hardened under normal conditions for 28 days by measuring the weight gain of the samples before and after drying according to PN-EN 206+A1:2016.

The microstructure of concrete was studied by means of scanning electron microscopy methods on JSM-5500 LV type microscope (voltage 20 kV, current 20 mA, scanning speed 0.04 s/step, step size 0.013°).

The frost resistance of concrete was tested using the standard method according to PN-88/B-06250 on Toropol K-015 fridge. Freeze-thaw cycles consist of successive freezing of the entire sample in air and unfreezing it in water, and the duration of a complete cycle is at least 6 hours. Freezing is performed in air at $-18 \pm 2°$ and lasts at least 4 hours. Defrosting of samples in water at $+18 \pm 2°$ – time of 2÷4 hours. After the last freeze-thaw cycle, the specimens are weighed and the compressive strength is tested.

Experimental studies, the results of which are given in the work, were performed using mathematical experiment planning (MEP), which allowed to algorithmize the performance of experiments according to the scheme, which is optimal in terms of both the scope of experimental work and statistical requirements [29]. Statistical planning allows to solve the problem of constructing experimental statistical mathematical models in the form of regression equations, which link the initial parameters with the input parameters, various controlled quantitative factors, and then use these models for process analysis, technological calculations and optimization.

Mathematical planning involves selecting the most significant factors and the limits of their variation to determine the initial parameters, as well as conducting experiments on a certain statistically optimal plan (planning matrix), the type of which is determined by the supposed dependence [30]. The regression equations, having a quadratic character, allow tracing individual and general influence of factors on investigated output parameters, to establish necessary and optimum values of factors.

3. Results of research

To determine the properties of concrete filled with granite dust, a series of experiments were implemented, algorithmized according to the two-factor plan of the second order experiment (type B_2) close to the D-optimal [28] in the planning conditions, given in Table 2.

Table 2. Experiment planning conditions

No.	Factors		Levels of variation			Range
	Coded form	Origin form	–1	0	+1	
1	X_1	W/C	0.48	0.54	0.60	0.06
2	X_2	Granite dust, kg/m^3 (GD)	0	100	200	100

The planning matrix, concrete mixtures, and experimental results are given in Table 3.

In the process of research to assess the influence of granite dust on the properties of concrete mixtures and concrete were made standard cube samples ($15 \times 15 \times 15$ cm), which were hardened under normal conditions. A characteristic feature of the experiments was the consistency by cone fall method on constant level S3 (100÷150 mm), which was achieved by introducing the necessary amount of superplasticizer. At all points of matrix, the consumption

Table 3. Experiment planning matrix, concrete mixtures and obtained experimental results

No. point of matrix	Coded values of factors		Natural values of factors		Concrete mixture, kg/m^3			Compressive strength, MPa, at age, days			Water absorption, %
								3	7	28	
	X_1	X_2	W/C	GD kg/m^3	Water	Sand	SP	$f^3_{c,cube}$	$f^7_{c,cube}$	$f^{28}_{c,cube}$	W
1	+1	+1	0.60	200	210	411	1.1	27.3	40.0	47.5	3.80
2	+1	–1	0.60	0	210	608	0.7	18.1	24.0	30.8	5.52
3	–1	+1	0.48	200	168	523	7.0	40.1	53.0	65.6	2.99
4	–1	–1	0.48	0	168	719	6.7	35.2	45.1	60.6	3.52
5	+1	0	0.60	100	210	509	0.7	22.4	29.4	38.7	4.83
6	–1	0	0.48	100	168	621	7.0	38.8	51.0	62.7	3.43
7	0	+1	0.54	200	189	467	3.5	32.8	44.0	54.1	3.51
8	0	–1	0.54	0	189	663	2.1	26.9	36.0	41.8	4.63
9	0	0	0.54	100	189	565	2.8	31.4	41.5	48.3	4.24
10	0	0	0.54	100	189	565	2.8	30.7	39.8	47.8	4.29
11	0	0	0.54	100	189	565	2.8	31.0	40.0	48.0	4.20

of Portland cement was constant and amounted to 350 kg/m^3 of concrete mixture. The content of coarse aggregate (granite stone) was 1260 kg/m^3, the same amount of three fractions of 6÷8 mm, 8÷11 mm and 11÷16 mm. Compressive strength of cube samples were determined at the age of 3, 7 and 28 days, water absorption at the age of 28 days.

Statistical analysis of experimental results allowed to obtain quadratic mathematical models of strength in the form of polynomial regression equations of the investigated parameters ($f^3_{c,cube}$, $f^7_{c,cube}$, $f^{28}_{c,cube}$, W), coded variables (3.1)–(3.4), which are given below. The adequacy of the obtained models is confirmed by the relevant Fisher criteria.

Compressive strength at age of 3 days:

$$f^3_{c,cube} = 30.89 - 7.72 \cdot x_1 + 3.33 \cdot x_2 - 0.05 \cdot x_1^2 - 0.8 \cdot x_2^2 + 1.08 \cdot x_1 x_2 \tag{3.1}$$

Compressive strength at age of 7 days:

$$f^7_{c,cube} = 40.43 - 9.29 \cdot x_1 + 5.32 \cdot x_2 + 0.15 \cdot x_1^2 - 0.05 \cdot x_2^2 + 2.03 \cdot x_1 x_2 \tag{3.2}$$

Compressive strength at age of 28 days:

$$f^{28}_{c,cube} = 47.95 - 12.0 \cdot x_1 + 5.67 \cdot x_2 + 2.91 \cdot x_1^2 + 0.16 \cdot x_2^2 + 2.953 \cdot x_1 x_2 \tag{3.3}$$

Water absorption at age of 28 days:

$$W = 4.24 + 0.7 \cdot x_1 - 0.56 \cdot x_2 - 0.12 \cdot x_1^2 - 0.17 \cdot x_2^2 - 0.3 \cdot x_1 x_2 \tag{3.4}$$

Conversion of concrete mixture composition parameter values into coded form is carried out by the following dependencies:

$$X_2 = \frac{\mathrm{GD} - 100}{100} \tag{3.5}$$

3.1. Compressive strength

Using models (3.1)–(3.4) were constructed graphical dependences of concrete strength (at the age of 3 and 28 days) and water absorption from W/C ratio and the content of granite dust, which are shown in Fig. 2, 3 and 5 respectively.

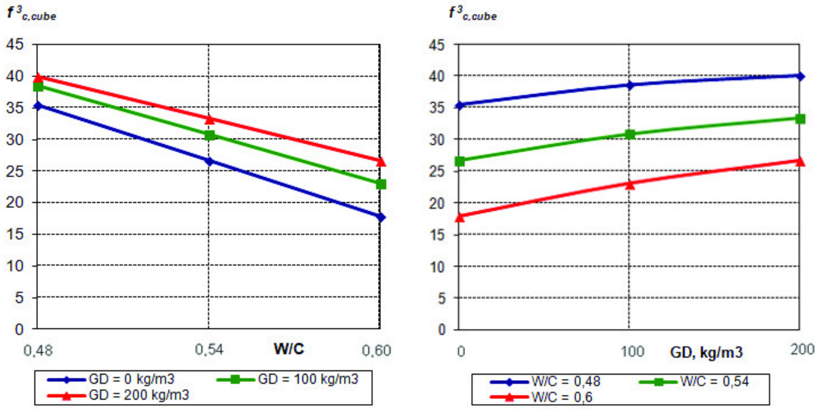

Fig. 2. Graphic dependencies of concrete compressive strength at the age of 3 days with the use of granite dust

Analyzing the obtained experimental-statistical models of compressive strength at the age of 3 days (3.1), it can be noted that an expected more significant factor affecting the early strength is the water-cement ratio (X_1), the increase in which from W/C = 0.48 to W/C = 0.60 leads to a reduction in early strength by 50÷90% depending on the content in concrete of granite dust. The influence of this factor in the selected range of its variation is linear (Fig. 2). Increase in the amount of granite dust (X_2) from GD = 0 kg/m^3 to GD = 200 kg/m^3 accompanies an increase in early strength by 15%, 30% and 50% at W/C = 0.48, 0.54 and 0.60, respectively. This means that in varying ranges with increasing W/C influence of granite dust becomes more significant.

The analysis of the obtained experimentally-statistical model of 28-day compressive strength (3.3) allows to note that W/C ratio is a more significant factor (X_1), the increase of which from W/C = 0.48 to W/C = 0.54 leads to the reduction of strength by 40÷45% in the absence of granite filler in the concrete. Negative impact is slightly reduced by 25÷30% and 18÷22% with an increase in granite dust addition (X_2) from GD = 0 kg to GP = 200 kg/m^3. Increasing the amount of granite dust (X_2) from GD = 0 kg/m^3 to GD = 200 kg/m^3 accompanies an increase in strength by 8÷12% at a minimum level of W/C = 0.48, 28÷32% – at W/C = 0.54, and up to 50% at W/C = 0.60, respectively. In other words, the effect of granite dust addition is more significant at high values of W/C ratio. The influence of this factor in the selected range of its variation is linear (Fig. 3).

When the amount of granite dust increases from GD = 100 kg/m^3 to GD = 200 kg/m^3, the positive impact of dust becomes much less. The effect of interaction of factors can be observed. It is obvious that achieving high strength of concrete is possible with appropriate optimization of mixtures.

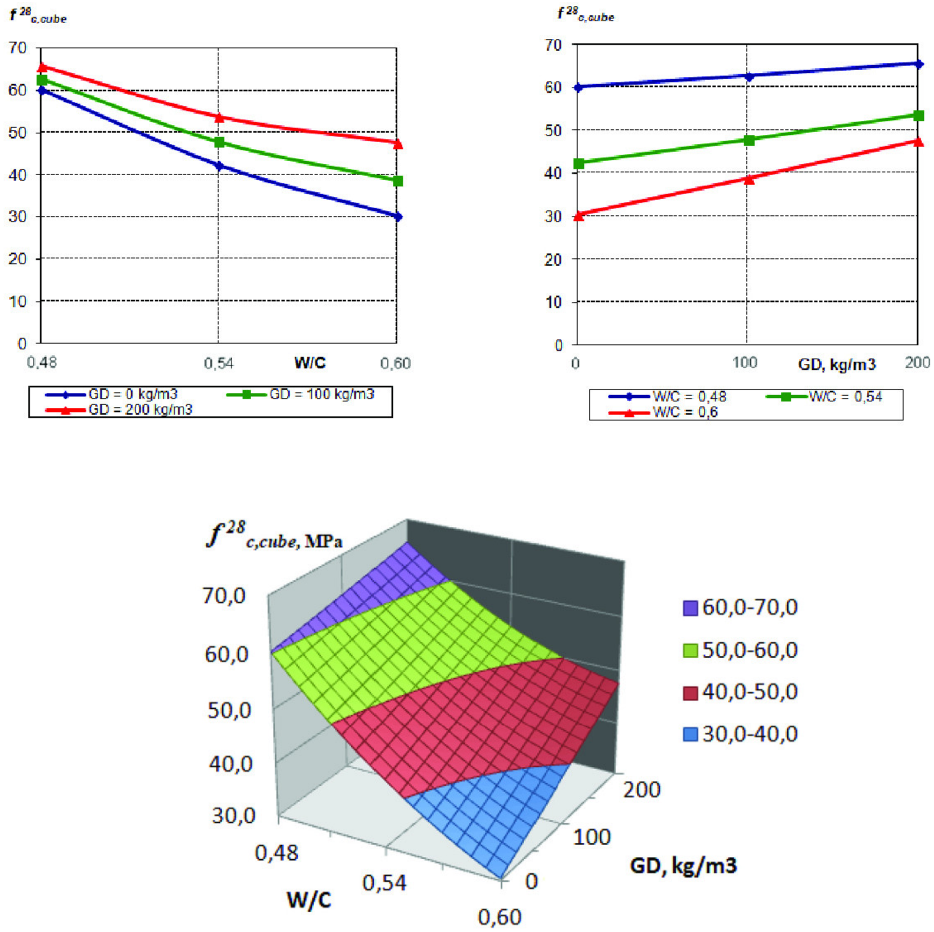

Fig. 3. Graphic dependencies of concrete compressive strength at the age of 28 days with the use of granite dust

3.2. Kinetics of strength change

On the basis of the obtained data (Table 3) the graphical dependences (Fig. 4), which illustrate the kinetics of changes in strength of concrete filled with granite dust at various W/C ratio are constructed.

As can be seen from Fig. 4a, at W/C = 0.60 concrete samples, containing 200 kg/m^3 of granite dust are characterized by higher strength in all periods of hardening (increase by 50÷60%) compared to samples with the use of granite dust 100 kg/m^3 (increase of 20÷25%). In concrete with a low value of W/C = 0.48 (Fig. 4b) in the early periods of hardening (at 3 and 7 days) increase in strength is 11÷18% with a dust content of 200 kg/m^3 and 10-13% with a dust content of 100 kg/m^3. It can be concluded that the granite filler allows to obtain higher strength values at W/C ratio more than 0.5.

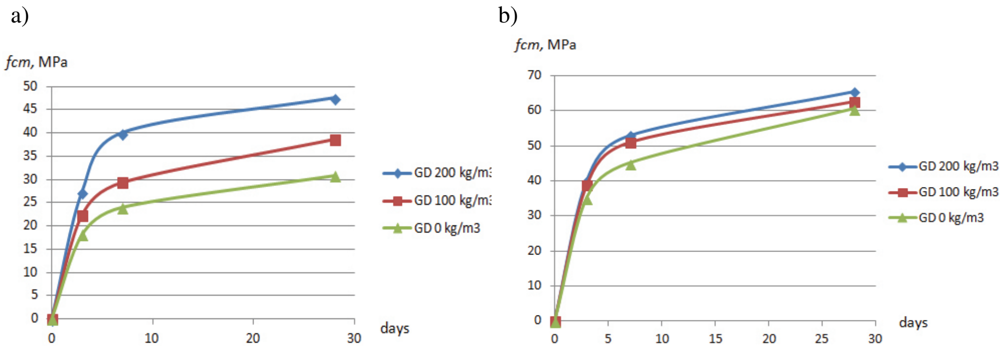

Fig. 4. Kinetics of strength change of concrete filled with granite dust: a) W/C = 0.60; b) W/C = 0.48

3.3. Water absorption

The character of water absorption dependence based on the model (3.4) differs significantly from strength models. It should be noted that the factors have almost the same effect on water absorption. Moreover, the influence of both factors is non-linear, which can be seen both from the corresponding graphical dependence (Fig. 5) and from the quadratic coefficient in regression equation (3.4). A relatively high coefficient of interaction of X_1 and X_2 factors indicates a significant dependence of the influence of each of them on the change and leads to the appearance of ambiguous curves on the graphs (Fig. 5). Addition of granite dust has a significant influence on water absorption of concrete. There is a clearly defined tendency of reducing water absorption with increasing of granite dust. Granite dust in the amount of 100 kg/m^3 leads to a decrease in water absorption at W/C = 0.60 from 5.5% to 4.8%. With a decrease in W/C to 0.54 and 0.48, water absorption also decreases, but the effect becomes

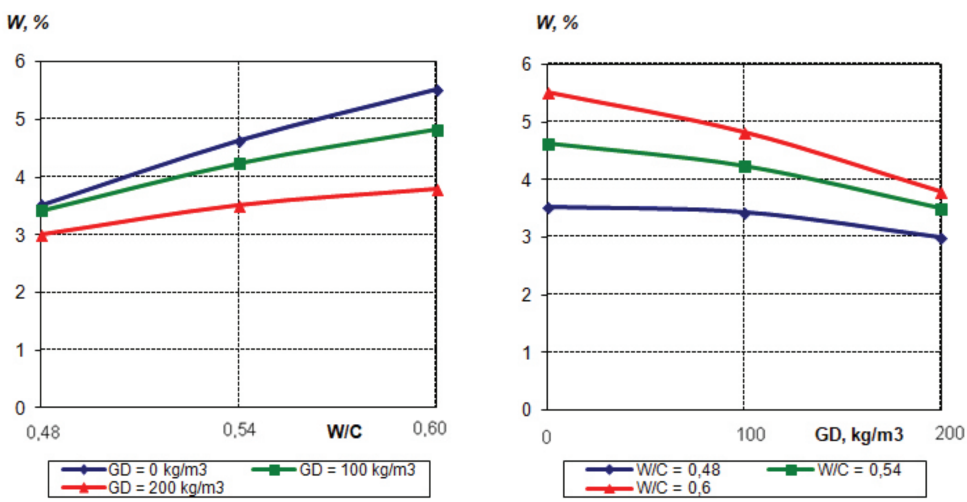

Fig. 5. Concrete water absorption diagram using granite dust

less significant, from 4.6 to 4.2% and from 3.5 to 3.4% with the respective W/C values. Further increase of granite dust content up to 200 kg/m^3 gives a more significant reduction of water absorption from 4.8% to 3.8%, from 4.2% to 3.5% and from 3.4% to 3.0% with respective W/C rations (0.48, 0.54 and 0.60)

3.4. Microstructure

The microstructure of concrete with granite dust was studied by scanning electron microscopy SEM. Selected photos of the microstructure of cement stone with and without granite dust are shown on Fig. 6.

a) b)

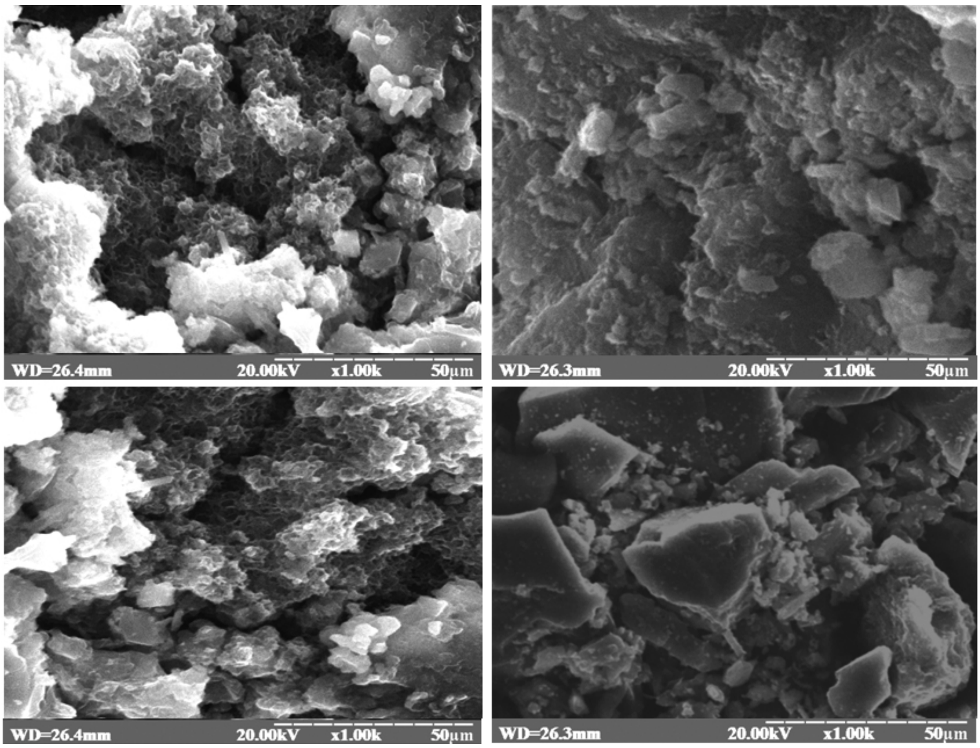

Fig. 6. Microstructure of cement stone without GD (a) and with the use of GD (b), at the age of 28 days

The dominant mineral phases in the studied samples are C–S–H and portlandite. The first of them is found mainly in a small number of needle-shaped crystals. Portlandite, which is the result of hydration of tricalcium silicate (C_3S) and dicalcium silicate (C_2S), forms massive hexagonal crystals, whose aggregates take hexagonal forms. The influence on the microstructure of concrete from the amount of addition of granite dust can be seen from the evaluation of the pore structure (Fig. 6). The addition of granite filler significantly reduces (but does not eliminate) the capillary porosity of the contact zone through a sharp change in the total content of $Ca(OH)_2$.

In addition, the "micro-filler effect", which acts as a center of crystallization, accelerates the initial stage of chemical curing. Hydration products are settled on small particles of dust, and these particles form the center of crystallization

3.5. Durability and corrosion resistance

The effect of aggressive environments is enhanced if the structures are under load. Since the main component for the production of concrete and reinforced concrete structures is cement, its corrosion resistance has a significant impact on the durability of such systems. The corrosion resistance of concrete based on granite dust has been determined on the samples-cubes of size $10 \times 10 \times 10$ mm by changing the compressive strength of samples that hardened 28 days in normal conditions, with their further retention in an aggressive environment. This method allows visual observation of the corrosion cracking process of specimens and, in combination with strength tests, makes it possible to better characterize the behavior of concretes in aggressive environments. Aggressive media were 5% HCl solution, 5% $MgCl_2$ solution and 5% Na_2SO_4 solution, i.e. simulated acid, magnesium and sulfate corrosion.

The criterion for corrosion resistance of concrete is the change in compressive strength:

$$Cr = \frac{f_{cm}^{ae}}{f_{cm}^{w}} \tag{3.6}$$

where: f_{cm}^{ae} – compressive strength of samples stored in an aggressive environment, MPa, f_{cm}^{w} – compressive strength of samples stored in water, MPa.

According to the results of determining the compressive strength of the samples, which were kept in an aggressive environment and in water – the coefficients of corrosion resistance were determined, the results of which are shown in Table 4 and Fig. 7.

Table 4. Corrosion resistance coefficients of concrete with the use of granite dust

Point of matrix	Aggressive agent	Exposure duration, month					
		1	2	3	4	5	6
Mixture of concrete no 1* GD = 200 kg/m^3	HCl	1.0	0.85	0.76	0.68	0.62	0.53
	$MgCl_2$	1.0	0.97	0.9	0.85	0.82	0.80
	Na_2SO_4	1.0	0.96	0.88	0.83	0.78	0.77
Mixture of concrete no 2**, GD = 0 kg/m^3	HCl	0.9	0.81	0.73	0.65	0.60	0.51
	$MgCl_2$	0.99	0.95	0.86	0.82	0.78	0.75
	Na_2SO_4	0.99	0.94	0.85	0.80	0.76	0.72

Note: * – Point 1 according to Table 3, ** – Point 2 according to Table 3.

Concrete based on granite dust have a rather high corrosion resistance to various aggressive environments, including acids. According to the experimental results, it is shown that the corrosion resistance of concrete increases with the addition of granite dust, in particular, the resistance to magnesium corrosion in samples without dust after 90 days is 0.75, while with dust – 0.80. It was noted that when keeping samples with dust in a 5% solution of Na_2SO_4

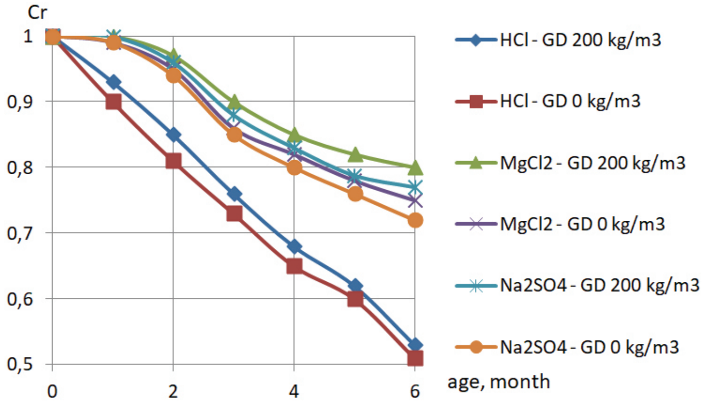

Fig. 7. Coefficients of corrosion resistance of concrete filled with granite dust

coefficient of corrosion resistance of concrete is more than 0.75, in concrete without GD there is a decrease in the coefficient of corrosion resistance to 0.71, but in both cases on the surface of the concrete was observed the appearance of efflorescence. At the same time, in the hydrochloric acid solution, the destruction of the samples both with and without granite dust was more intense – the coefficient *Cr* decreased to 0.53 and 0.5, respectively. The addition of granite dust into the concrete mixture creates the possibility of obtaining concrete that has increased corrosion resistance compared to concrete without a granite filler. This is due to the fact that in the presence of fine filler strengthens the contact zone between the cement stone and aggregate, as well as provides increased density of the concrete contact area and thereby slows down the diffusion of the aggressive agent deep into the sample. Such concrete can be used for hydraulic and road objects exposed to various aggressive environments, as well as building constructions with special requirements.

3.6. Frost resistance

Frost resistance of concrete is largely determined by the nature of its pore structure. Capillary pores are the main defect in the structure of concrete, reducing its frost resistance. Frost resistance of concrete with and without granite dust was determined on 12 samples ($10 \times 10 \times 10$ cm) after 28 days of curing under normal conditions and then 7 additional days in water. Six samples are left in water at $18 \pm 2°$ throughout the test. The second set of samples (6 pcs) were placed into a camera and subjected to freezing.

The test was subjected to 4 series of samples (concrete mixtures according to Table 3, points of matrix number 1–4) with dust content 200 kg/m^3 and without dust at W/C = 0.60 and 0.48. The results are shown in Table 5 and Fig. 8.

The results obtained above on water absorption and microstructure indicate the low open porosity of concrete and explain the possible increase in their frost resistance compared to concrete without granite filler. The critical number of freezing and thawing cycles are given in Table 5. Granite dust, at high values of W/C ratio (above 0.55) contributes to a slight increase

Table 5. The results of frost resistance tests of concrete

No. of matrix point	Granite dust content, kg/m^3	W/C ratio	Frost resistance, cycles, F
1	200	0.60	200
2	0	0.60	150
3	200	0.48	300
4	0	0.48	300

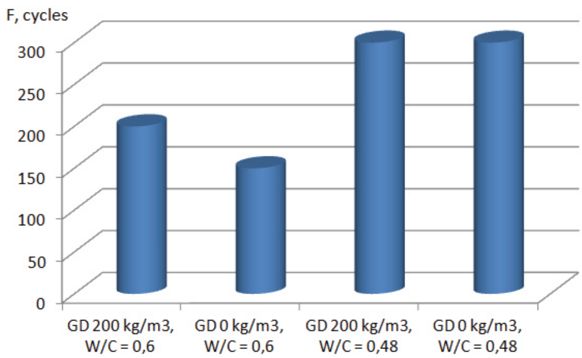

Fig. 8. Frost resistance of concrete

in the frost resistance of concrete compared with samples without granite dust, which is the result of reducing the size of the open capillary pores.

Thus, increasing the frost resistance of concrete using granite dust is crucially related to reducing the size of the capillary pores of concrete, but not their amount.

4. Conclusions

Based on the obtained test results of concrete with the use of granite dust, the following conclusions can be made:

- Addition of granite dust in the amount of 100÷200 kg/m^3 of concrete mixture, allows to increase the strength of concrete during all curing periods.
- At high value of W/C = 0.54÷0.60, the effect of granite dust is more significant compared to W/C = 0.54. It can be noted that the efficiency (increase in strength) of the use of granite dust is observed at higher values of W/C ratio.
- The addition of a dispersed granite filler reduces the total pore volume, average pore diameter and porosity, which provides to low water absorption.
- Microstructure of cement stone with granite dust indicate that the fine particles act as a center of crystallization, i.e. accelerate the initial stage of chemical curing.
- Concrete, which not containing granite dust were somewhat less resistant to the progression of corrosion in all aggressive environments.

– Low W/C and improved parameters of the pore structure of concrete based on granite dust contributes to an increase in their frost resistance. For the tested concrete mixtures the frost resistance is F200–F300.

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Zastosowanie pyłu granitowego jako efektywnego wypełniacza mieszanek betonowych

Słowa kluczowe: pył granitowy, mieszanka betonowa, nasiąkliwość, wytrzymałość na ściskanie, odporność korozyjna, mrozoodporność

Streszczenie:

W artykule przedstawiono wyniki badań doświadczalnych wpływu pyłu granitowego na właściwości i trwałość betonu. Badano betony wykonane z użyciem: cementu portladzkiego CEM I 42,5N, kruszywa grubego granitowego i pyłu granitowego, piasku i superplastyfikatora na bazie estrów polikarboksylowych. Badania eksperymentalne, których wyniki podano w pracy, przeprowadzono z wykorzystaniem matematycznego planowania eksperymentu, co pozwoliło na algorytmizację wykonania eksperymentów według schematu, który jest optymalny zarówno z punktu widzenia zakresu pracy eksperymentalnej, jak i wymagań statystycznych.

Czynnikami zmiennymi był wskaźnik W/C (od 0,48 do 0,60) oraz zawartość pyłu granitowego (od 0 do 200 kg/m^3).

Zwiększenie zawartości pyłu granitowego (PG) od 0 kg/m^3 do 200 kg/m^3 spowodowało wzrost wytrzymałości wczesnej o 15%, 30% i 50% przy W/C, odpowiednio: 0,48, 0,54 i 0,60. W wieku 28 dni wpływ dodatku pyłu granitowego jest bardziej znaczący przy wysokich wartościach stosunku W/C. Wzrost

zawartości pyłu granitowego od 0 kg/m^3 do 200 kg/m^3 spowodował wzrost wytrzymałości odpowiednio o 8–12% przy W/C = 0,48, o 28–32% – przy W/C = 0,54 i do 50% przy W/C = 0,48.

Dodatek pyłu granitowego ma także znaczący wpływ na nasiąkliwość betonu. Zwiększenie zawartości pyłu do 200 kg/m^3 spowodowało znaczne zmniejszenie nasiąkliwości z 4,8% do 3,8%, z 4,2% do 3,5% i z 3,4% do 3,0% przy wskaźnikach W/C, wynoszących odpowiednio 0,48; 0,54 i 0.60, Dodatek pyłu granitowego znacznie ogranicza (ale nie eliminuje) porowatość kapilarną strefy kontaktowej, wskutek gwałtownej zmiany całkowitej zawartości $Ca(OH)_2$. Dodatkowo, efekt "mikrowypełniacza", który działa jak centrum krystalizacji, przyspiesza początkowy etap chemicznego utwardzania. Produkty hydratacji są osadzane na małych cząsteczkach pyłu, które tworzą centra krystalizacji.

Betony z dodatkiem pyłu granitowego charakteryzują się dość dużą odpornością na korozję w różnych środowiskach agresywnych, w tym na działanie kwasów. Na podstawie wyników badań wykazano, że odporność korozyjna betonu wzrasta wraz ze wzrostem dodatku pyłu granitowego. W szczególności odporność na korozję magnezową w próbkach bez pyłu po 90 dniach wynosi 0,75, natomiast z pyłem – 0,8.

Niski współczynnik W/C oraz poprawa parametrów struktury porowej betonów z dodatkiem pyłu granitowego przyczynia się do wzrostu ich mrozoodporności. Dla badanych struktur betonowych mrozoodporność wynosi F200-F300.

Wskutek częściowego zastąpienie piasku pyłem granitowym w mieszance, następuje zagęszczenie mikrostruktury matrycy cementowej, co jest główną przyczyną zmniejszenia porowatości i zwiększenia trwałości konstrukcji wykonanych z tego betonu.

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