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Binders for pressed products based on phosphogypsum waste

ABSTRACT

The article is devoted to the issues of obtaining pressed building materials based on dihydrate phosphogypsum. Dihydrate phosphogypsum after mechanical activation in a ball mill acquires the ability to harden in pressed specimens. After activation of dihydrate phosphogypsum in a ball mill and its pressing at a pressure of 30 MPa, the strength of specimens increases by 6...8 times compared to non-activated specimens and reaches 25...30 MPa. There is found the influence of various chemical admixtures on binding properties of activated phosphogypsum and there are shown possibilities of water resistance improvement and increasing of other properties characterizing this material. There is studied an effect of aggregates on the building and technical properties of artificial stone made of phosphogypsum and peculiarities of its structure and change under the influence of different factors.

***Keywords**: dihydrate phosphogypsum, binders, compression, water resistance, strength.*

1. INTRODUCTION

Searching for ways to save resources, save fuel and energy, rational use of industrial waste are the main directions of construction technology development.

Phosphogypsum (PG), formed during the treatment of natural phosphates with sulfuric acid in the production of mineral fertilizers, can be attributed to the largest waste volumes. The main direction of its reprocessing is the production of gypsum binders. The technologies developed for this purpose imply, after preliminary neutralization of PG, its firing and grinding, which requires significant energy consumption and the formation of a large amount of wastewater.

The priority in the development of technologies for non-firing phosphogypsum binders belongs to Academician P.P. Budnikov. In 1924, he established [1] that after grinding with the various additives ($NaHSO_4$, $Na2SO_4$, etc.) and mixing with water, gypsum dihydrate acquires the ability to hardening and, at the same time, achieves significant strength (up 4 MPa in flexural tension strength). Further research showed the possibility of obtaining a non-firing binder by fine grinding it in a ball mill in a dry and wet way without any activating additives [2,3].

A significant disadvantage of the proposed technologies for non-firing gypsum binders is the need for high fineness of grinding. As shown in [3] to obtain gypsum binders with a strength of more than 10 MPa, the passage of gypsum through a sieve with a size of 10,000 holes/cm^2 should be at least 70%.

In [4,5], the possibility of obtaining strong and water-resistant pressed compositions using chemical additives based on urea-formaldehyde resin was experimentally established. The positive role of fillers (zeolite powder, bauxite sludge, acid ash, blast-furnace slag, silica dust, burnt rock) is also noted in the formation of a more dense, durable and water-resistant structure of pressed gypsum stone. There are also various studies showing the possibility of using phosphogypsum in the production of binders and for extruded products [6-10].

Despite the fact that a certain amount of research has been carried out to date, the technology of dihydrate phosphogypsum binder cannot be considered developed. The effect of the composition of dihydrate phosphogypsum has not been established. The features of neutralized phosphogypsum in comparison with original ones have not been studied. The joint influence of factors of compression pressure and dispersion of

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the phosphogypsum binder due to an increase in the grinding duration has not been studied. The influence of additives of various groups on strength and water resistance is poorly studied. The effect of aggregates of different types has not been determined. These questions determined the content of our research.

2. MATERIALS AND RESEARCH METHODS

The studies were carried out with the use of phosphogypsum (PG) from the Rivne JSC "Azot", which is formed during the production of phosphoric acid by the dihydrate method.

The chemical composition of PG is given in Table 1. As can be seen from the data in Table 1, the PG satisfies the requirements of DSTU BV 2.7-1-93 (Ukrainian standard) for an ordinary PG, in accordance with which:

- the content of calcium sulfate must be at least 90%;
- the total content of phosphates (in terms of P_2O_5) is not more than 15%;
- water-soluble phosphates (in terms of P_2O_5) no more than 1.2%;
- the content of fluorides (in terms of fluorine) is not more than 0.4%;
- the content of water-soluble fluorides (in terms of fluorine) is not more than 0.3%;

Table 1. Phosphogypsum chemical composition

Tabela 1. Hemijski sastav fosfogipsa

Legend	Content, % by weight					
	Calcium sulphate $CaSO_4$	Phosphates by P_2O_5	Water-soluble phosphates by P_2O_5	Fluorides	Water-soluble fluorides	Moisture content, %
PG-1	92	1.4	1.1	0.2	0.2	43
PG-2	91	1.1	0.9	0.4	0.15	32
PG-3	90	1.2	1.0	0.1	0.1	29
PG-4	94	1.3	1.1	0.3	0.1	31

To neutralize acidic impurities in PG, ground quicklime was used in the amount of 8.0...8.5% with an activity of 85% by CaO.

To characterize PG, we used specific surface indicators determined by Blaine's air permeability method.

The autohesion of PG particles was determined in a loose bulk state by tearing off a disk with sticky lubricant, the tear-off surface area was 123 mm^2, and the mass of the disk was 3.9 g. The pull-off force was determined from the torsion balance scale with a division value of 1 mg and a measurement limit of 500 mm.

The main construction and technical properties of binders and mortar mixtures based on them were studied using well-known standardized and other proven methods.

To establish the quantitative effects of the individual and joint influence of factors, the search for optimal mortars, mathematical planning of experiments was used in the work. The description of the dependences of the output parameters in the studied factor space was achieved using quadratic polynomial regression equations.

3. EXPERIMENTAL RESULTS AND DISCUSSION

The adhesion force of PG particles should be important in the formation of a structure of a dihydrate phosphogypsum binder.

Therefore, in our work, special experiments were carried out to determine the adhesion force or autohesion of particles [11].

In accordance with theoretical concepts [11], the autohesion of dispersed materials is related to the value of their surface energy:

$$F_A = 2\pi \frac{d_1 \cdot d_2}{d_1 + d_2}\left(\sigma_d - \sigma_s\right) \qquad (1)$$

where F_A is the particle adhesion strength; d_1, d_2 – particle size; σ_d – surface tension of solid particles at the boundary with a dispersed medium; σ_s - the same at the contact boundary of solid particles.

The results of the experiments are shown in Fig. 1. From them it follows that the value of PG autohesion is very significant, being in the range of 15...30 Pa and increasing with the growth of its surface. Neutralization of PG with lime (PGN) leads to some increase in autohesion.

Dihydrate phosphogypsum without special processing has a relatively low ability to hardening in pressed specimens after preliminary or ensuing drying. In Table 2 shows the strength values of specimens-cylinders with a diameter and a height equal to 25 mm, formed on a hydraulic pressing machine, at various pressures. According to these data, higher strength values of the specimens are achieved by neutralizing PG with lime and increasing its specific surface area.

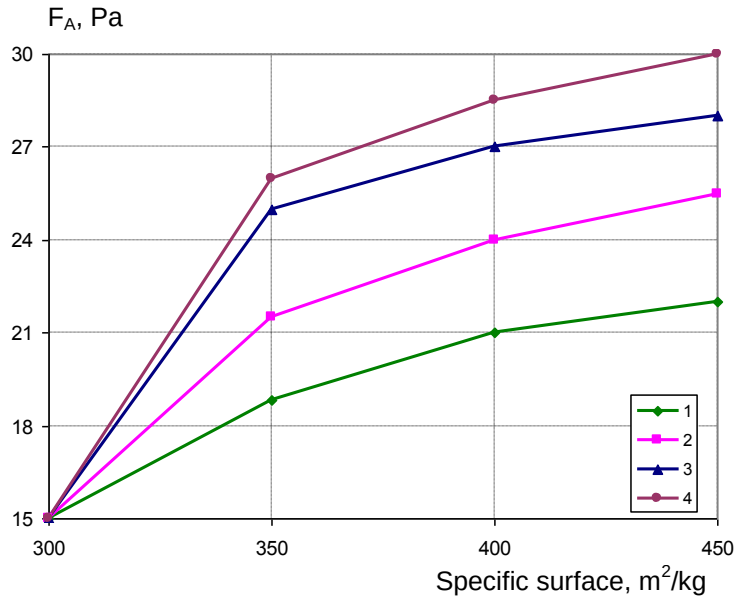

Figure 1. Autohesion of PG particles with different particle sizes 1 – PG-1; 2 – PG-2; 3 – PGN-1; 3 – PGN-2

Slika 1. Autohezija PG čestica sa različitim veličinama čestica 1 – PG-1; 2 – PG-2; 3 – PGN-1; 3 – PGN-2

Table 2. Strength of phosphogypsum after 7 days of hardening

Tabela 2. Čvrstoća fosfogipsa nakon 7 dana očvršćavanja

Legend	Moisture content, %		Compression pressure, MPa	Compressive strength, MPa			
	Original	Residual		Air hardening		After drying	
				3 days	7 days	3 days	7 days
PG-1	43	32.0	5	0.62	0.8	0.86	1.0
		17.2	10	0.7	0.9	1.03	1.2
		12	30	1.2	1.5	1.6	1.9
PG-1	15	14.9	5	0.75	0.9	0.95	1.1
		13.6	10	0.8	0.95	1.12	1.3
		12.2	30	1.7	2.0	2.06	2.4
PGN-1	15	14.6	5	0.78	0.9	1.05	1.2
		13.1	10	0.8	1.1	1.12	1.3
		11.9	30	2.6	3.0	2.8	3.2
PG-2	15	14.8	5	0.8	0.95	1.04	1.2
		13.6	10	0.9	1.2	1.5	1.7
		12.1	30	2.7	3.2	3.1	3.6
PGN-2	15	14.7	5	1.0	1.2	1.3	1.6
		13.2	10	1.1	1.4	1.8	2.2
		11.8	30	2.7	3.3	3.1	3.8

With an increase in the duration of hardening (more than 7 days), the intensity of strength growth of pressed specimens fades. This is confirmed by the analysis of the experimental values of the strength growth coefficient over time. A more noticeable of strength increase up to 180 days is observed for specimens formed of PG neutralized with lime. This can be explained by the carbonization of $Ca(OH)_2$ and the positive effect on the crystallization processes of artificial gypsum stone of the resulting calcium carbonate (Table 3).

In the compression pressure range from 30 to 70 MPa (Fig. 2), the increase in the strength of the specimens is almost proportional to the increase in

pressure. With a further increase in the pressing pressure, the growth of the specimens strength becomes much less noticeable.

Already at a pressure of 10 MPa, residual water is squeezed out and humidity close to optimal is established.

Increasing the compression pressure to 100 MPa (Fig. 2) leads to an increase in strength to 8 MPa of ordinary PG and 9 MPa of neutralized PG (PGN), with a corresponding increase in the density of the specimens.

Table 3. Increasing the strength of non-activated phosphogypsum

Tabela 3. Povećanje snage neaktiviranog fosfogipsa

Legend	Time, days				
	7	28	90	180	360
PG-1	1	1.06	1.08	1.12	1.12
PGN-1	1	1.12	1.15	1.19	1.18
PG-2	1	1.08	1.09	1.11	1.10
PGN-2	1	1.13	1.16	1.20	1.20

Note: Compression pressure is 30 MPa.

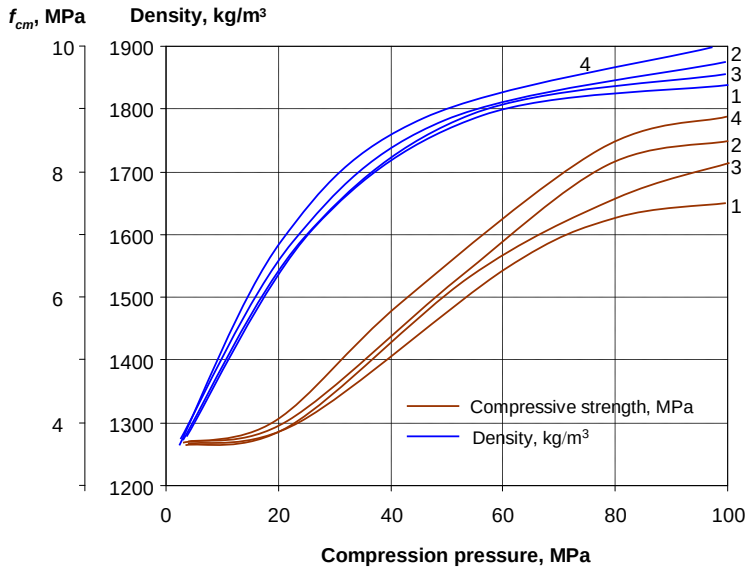

Figure 2. Dependencies of compressive strength and density of phosphogypsum on compression pressure: 1 – PG-1; 2 – PG-2; 3 – PGN-1; 4 – PGN-2

Slika 2. Zavisnosti tlačne čvrstoće i gustine fosfogipsa od pritiska kompresije:1 – PG-1; 2 – PG-2; 3 – PGN-1; 4 – PGN-2

To determine the joint effect of the duration of mechanical activation and compression pressure on the phosphogypsum binder strength, experiments were implemented, algorithmized in accordance with a typical three-level plan for two factors [12]. The planning conditions of experiment are given in Table 4, planning matrix and experimental values – in Table 5. PG grinding was carried out with a mixed cylpebs-ball mill loading with a average ball diameter of 20 mm, the ratio of the mass of grinding bodies to the mass of material is 7.

Table 4. Experiment planning conditions

Tabela 4. Uslovi planiranja eksperimenta

Factors	Variation levels			Variation interval
	-1	0	+1	
Grinding duration, h (X_1)	0	1.5	3	1.5
Compression pressure, MPa, (X_2)	10	20	30	10

Table 5. Planning matrix and experimental results

Tabela 5. Matrica planiranja i eksperimentalni rezultati

No	Coded factors values		Natural values		Compressive strength, f_{cm}, MPa
	X_1	X_2	τ, h	P, MPa	
1	+1	+1	3	30	27.9
2	+1	-1	3	10	8.1
3	-1	+1	0	30	8.8
4	-1	-1	0	10	3.3
5	+1	0	3	20	20.4
6	-1	0	0	20	6.9
7	0	+1	1.5	30	24.1
8	0	-1	1.5	10	6.2
9	0	0	1.5	20	16.0
10	0	0	1.5	20	15.0
11	0	0	1.5	20	17.0

Note: τ - grinding duration, P - compression pressure.

As a result of statistical processing of experimental data, a quadratic regression equation was obtained for the compressive strength of pressed PG specimens after 28 days of air-dry hardening.

$$f_{cm} = 16.2 + 6.2X_1 + 9.3X_2 - 2.76X_1^2 - 1.26X_2^2 + 3.58X_1X_2 \quad (1)$$

An analysis of the strength equation shows that the linear effects of the influence of factors X_1 and X_2 on the PG strength are close. However, due to a significant difference in the values of the quadratic effects (for X_1 it is more than 6 times higher than for X_2), the integral influence of the studied factors is not the same.

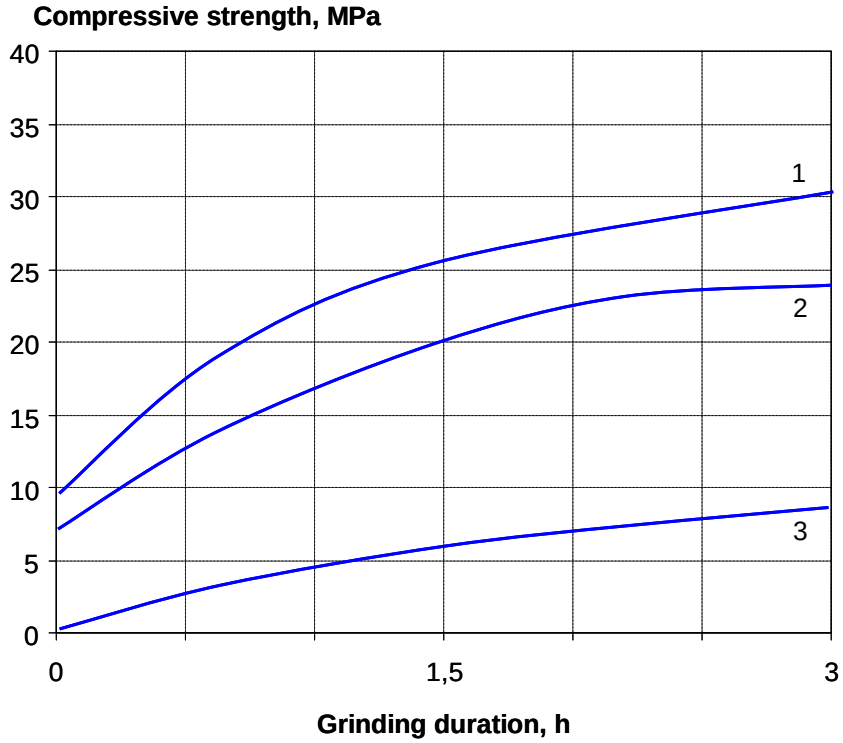

Figure 3. Influence of grinding duration on the dihydrate phosphogypsum binder strength: 1 – compression pressure is 30 MPa; 2 – compression pressure is 20 MPa; 3 – compression pressure is 10 MPa.

Slika 3. Uticaj trajanja mlevenja na čvrstoću veziva dihidrata fosfogipsa: 1 – pritisak kompresije je 30 MPa; 2 – pritisak kompresije je 20 MPa; 3 – pritisak kompresije je 10 MPa.

The greatest effect of the duration of mechanical activation is observed when increasing X_1 in the area from -1 to 0 in the coded values (Fig. 3). At a compression pressure of 30 MPa in this area, the strength increases from 10 to 24 MPa, i.e. more than 2 times. Further increase in X_1 does not cause a significant increase in strength. As follows from Fig. 3 increasing the grinding duration to 3 h leads to an increase of strength from 24 to 32 MPa.

The effect of compression pressure (Fig. 4) is almost linear in the range under study. Equation (1) is characterized by a very significant interaction effect of the factors X_1 and X_2. It shows that the influence of the degree of PG activation depends on the value of the compression pressure.

The influence of chemical admixtures on the properties of dihydrate gypsum and phosphorgypsum binders after the first works in this direction [1, 3, 13], was not considered. At the same time, it should be noted that in these works studied the effect of admixtures on the properties of gypsum binder in specimens of plastic consistency.

The mechanism of the effect of chemical admixtures on the hardening of binders and concretes is most deeply studied in the works by V.B. Ratinov [14-15]. Admixtures were selected (representatives of four classes according to V.B. Ratinov) to study the effect of chemical admixtures on the strength of dihydrate phosphogypsum binders.

Among the admixtures of the first class of electrolytes that change the solubility of binders, the influence of NaCl was studied, as a substance that does not contain ions of the same name with the binder; $CaCl_2$ and Na_2SO_4 as substances containing ions of the same name.

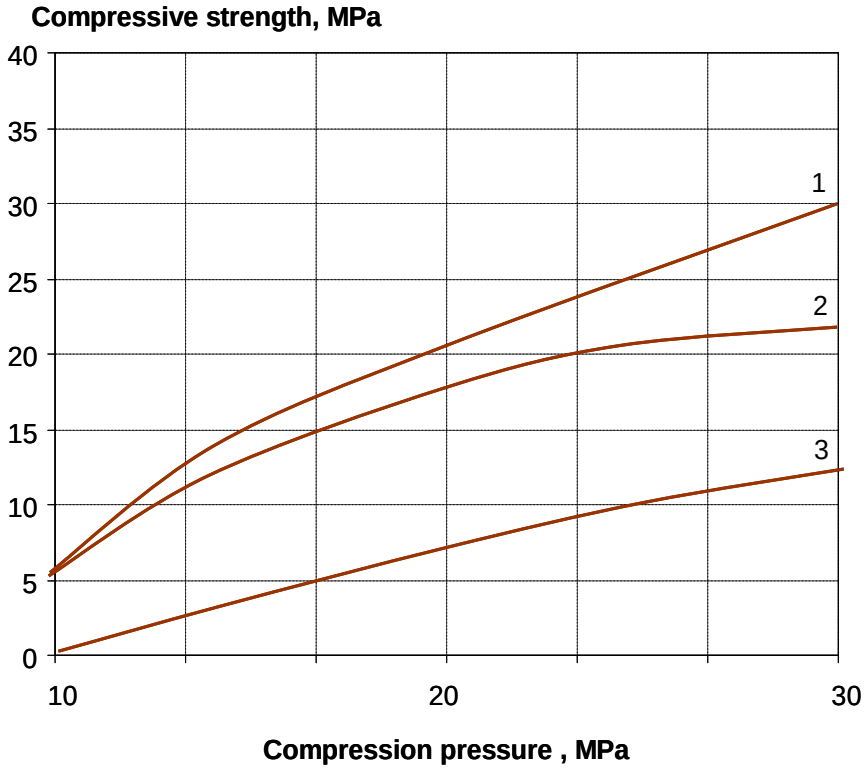

Figure 4. Influence of compression pressure on the dihydrate phosphogypsum binder strength: 1 – grinding duration is 3 h; 2 – grinding duration is 1.5 h; 3 – non-grinding.

Slika 4. Uticaj pritiska kompresije na čvrstoću veziva dihidrata fosfogipsa: 1 – vreme mlevenja je 3 h; 2 – vreme mlevenja je 1,5 h; 3 – bez mlevenja.

The admixture - representative of the second class, reacting with the binder was Na_2CO_3.

The $CaSO_4 \cdot 0.5H_2O$ acted as representatives of class 3 admixtures – crystalline seeds. Representatives of admixtures of the 4th class - organic surfactants, were admixtures: superplasticizer S-3 and hydrophobic organosilicon liquid (HOL). All admixtures were added with the mixing water. The results of the study are shown in Table 6.

An analysis of the experimental data obtained shows that admixtures that increase the strength of dihydrate phosphogypsum binders include admixtures of the 1st class of the second group, that is, those containing ions of the same name with PG, as well as admixtures of the 3rd class - ready-made centers of PG crystallization.

Admixtures-accelerators make it possible to increase both the early and later strength of dihydrate phosphogypsum binders up to 20%, while their optimal concentration is in the range of 1...1.5% by weight of PG. It is characteristic that with an increase in the concentration of admixtures over 1.5%, the accelerating effect of $CaCl_2$ and Na_2CO_3 begins "to fade", and for Na_2SO_4 it changes with the opposite effect - a decrease of strength.

As is known [14], the hardening accelerating effect of the admixtures of the second group of the first class is due to the fact that it sharply increases the probability of the formation of crystal nuclei (α), and the value of α increases more significantly than the supersaturation decreases due to a decrease in the solubility of binders.

The water resistance of dihydrate phosphogypsum binder and compositions based on it is characterized by the water resistance coefficient (WRC). The water resistance coefficient is the ratio of material strength in the water-saturated state to its dry strength. The highest value of the WRC is achieved for PG neutralized with lime.

One of the ways for increasing the water resistance of all gypsum binders, including dihydrate phosphogypsum binders, along with a decrease in pore volume, can be its blockage by poorly soluble and insoluble products. For this purpose, the influence of some inorganic compounds and polymer resins was studied.

Table 6. Effect of chemical admixtures on the strength of dihydrate phosphogypsum binder

Tabela 6. Uticaj hemijskih dodataka na čvrstoću dihidratnog fosfogipsnog veziva

No	Chemical admixtures	Content, % by weight	Compressive strength, f_{cm}, MPa at days		
			1	7	28
1	NaCl	0.5	22.5	27.8	29.6
		1	16.6	19.7	21.4
		1.5	13.5	15.1	17.2
		2	9.8	12.4	13.1
2	$CaCl_2$	0.5	23.4	29.3	32.2
		1	24.5	31.5	34.1
		1.5	25.3	33.4	34.8
		2	26.8	34.1	35.1
3	Na_2SO_4	0.5	24.1	29.9	31.5
		1	24.9	31.4	32.8
		1.5	22.3	26.5	28.9
		2	19.8	24.4	26.7
3	Na_2CO_3	0.5	24.8	30.2	33.4
		1	25.7	31.8	35.8
		1.5	27.4	32.9	35.5
		2	26.3	31.5	35.1
4	$CaSO_4 \cdot 0.5H_2O$	0.5	23.4	28.6	29.1
		1	23.8	28.8	31.4
		1.5	24.1	27.1	30.3
		2	23.3	27.8	28.8
5	S-3	0.5	21.3	25.6	27.1
		1	18.9	22.3	24.5
6	HOL	0.1	20.3	23.3	23.9
		0.2	16.5	18.9	19.5

Among inorganic admixtures, alkali metal silicates show a noticeable effect, which increase WRC to 0.75 (Table 7) without a significant decrease of strength. In this case, the increase of water resistance can be explained by the chemical interaction of alkali metal silicates with calcium sulfate with the formation of a gel-like (silica gel) precipitate, which clogs the pore space of the artificial gypsum stone.

Admixtures of water-soluble carbonates, phosphates, and fluorides are also used, which form the corresponding sparingly soluble compounds with calcium sulfate, which can shield the surface of gypsum grains [16]. These admixtures increase the water resistance of dihydrate phosphogypsum binders, and at the optimum concentration, the mechanical strength of the specimens.

Some increase in the water resistance of dihydrate phosphogypsum binders is also achieved by treating it with hydrophobic organosilicon fluids.

We studied the change in molding properties, strength, water resistance and shrinkage deformations of dihydrate phosphogypsum binders and dihydrate phosphogypsum-cement-ash binders with the adding of quartz and expanded clay sand into their composition. Specimens-cylinders with dimensions d = h = 25 mm were produced by pressing at 30 MPa. Two types of quartz sand were used: very fine (sand fineness modulus (FM) = 1.3) and medium (FM = 2.1); as well as expanded clay (FM = 2.3), the bulk density of which is 800 kg/m^3.

The compressive strength of the specimens immediately after pressing served as a criterion for molding properties. The results of the experiments are given in Table 8.

Table 7. Influence of inorganic admixtures on the strength and water resistance of dihydrate phosphogypsum binders (activation in a ball mill)

Tabela 7. Uticaj neorganskih primesa na čvrstoću i vodootpornost veziva dihidratnog fosfogipsa (aktivacija u kugličnom mlinu)

No	Admixture content, % by weight	Total porosity,%	Compressive strength, f_{cm}, MPa at days			Water resistance coefficient, at days		
			1	7	28	1	7	28
1	Na_2SiO_3 2 4 6	32	 24.6 25.3 25.8	 31.2 33.6 34.1	 34.5 35.1 35.3	 0.63 0.66 0.68	 0.68 0.71 0.73	 0.72 0.75 0.76
2	Na_2CO_3 2 3 4 5	29	 25.9 26.1 27.8 27.6	 31.5 32.3 34.4 34.8	 34.8 35.1 36.2 36.4	 0.61 0.63 0.65 0.67	 0.65 0.68 0.7 0.72	 0.68 0.71 0.72 0.73
3	KF 2 4 5	25	 24.3 24.8 27.6	 29.6 31.3 31.4	 31.3 32.7 32.9	 0.63 0.66 0.68	 0.68 0.69 0.71	 0.7 0.72 0.72
4	Na_2PO_4 2 4 5	19	 25.4 24.8 25.2	 29.8 30.7 30.9	 32.8 33.3 33.4	 0.65 0.67 0.69	 0.69 0.72 0.73	 0.73 0.75 0.75
5	HOL 1 2	14	 23.9 25.2	 28.8 29.2	 31.1 32.7	 0.61 0.65	 0.64 0.69	 0.67 0.71

Table 8. Influence of aggregates on the properties of dihydrate phosphogypsum binders

Tabela 8. Uticaj agregata na svojstva veziva dihidrata fosfogipsa

Binder type	Sand	Mixture composition by volume	Optimal humidity, %	Compressive strength after pressing, MPa
Dihydrate phosphogypsum neutralized	-	-	8	8.5
	quartz (FM =2.1)	1 : 0.5	8	8.1
		1 : 1	7	6.5
		1 : 2	6	4.9
	quartz (FM =1.3)	1 : 0.5	8	8.7
		1 : 1	8	6.8
		1 : 2	9	4.5
	expanded clay (FM =2.3)	1 : 0.5	9	7.1
		1 : 1	10	4.3
		1 : 2	12	2.8
Dihydrate phosphogypsum-cement-ash	-	-	7	7.4
	quartz (FM =2.1)	1 : 0.5	7	7.8
		1 : 1	6	6.1
		1 : 2	7	5.1
	quartz (FM =1.3)	1 : 0.5	8	8.2
		1 : 1	8	6.2
		1 : 2	9	4.8
	expanded clay (FM =2.3)	1 : 0.5	10	6.4
		1 : 1	11	4.3
		1 : 2	12	2.5

The molded specimens were hardened in air-dry conditions. After 1, 7, 28 days and 1 year, their volumetric deformations, compressive strength and water resistance coefficient were determined. All compositions of the studied materials are characterized by insignificant shrinkage deformations, not exceeding 0.01%.

Analysis of the data in Table 9 shows that dihydrate-phosphogypsum binders are more sensitive to a decrease of the aggregate amount. If the adding of one volume part reduces the strength of the binder by 23.5%, then the adding of 2 parts reduces the strength by 42.4%. With a decrease of sand size, there is a tendency for a decrease of strength at an early age, but up to 28 days, the strength is already leveled.

Table 9. Influence of aggregates on strength and water resistance of dihydrate phosphogypsum binders

Tabela 9. Uticaj agregata na čvrstoću i vodootpornost dihidratnog fosfogipsnog veziva

Composition No. according to Table 8	Compressive strength, f_{cm}, MPa at days				Water resistance coefficient, at days			
	1	7	28	1 year	1	7	28	1 year
1	21.5	25.4	27.3	31.6	0.23	0.25	0.27	0.29
2	19.4	21.3	25.6	28.3	0.23	0.27	0.31	0.33
3	15.5	18.4	19.8	19.9	0.25	0.29	0.32	0.35
4	10.3	12.5	14.1	16.1	0.27	0.32	0.34	0.36
5	20.2	22.1	24.8	27.5	0.26	0.28	0.32	0.35
6	17.5	18.6	18.9	19.1	0.28	0.31	0.34	0.37
7	9.8	11.7	14.5	15.5	0.29	0.33	0.35	0.42
8	16.3	18.4	20.9	23.4	0.34	0.37	0.39	0.44
9	10.8	11.9	12.5	14.1	0.36	0.41	0.43	0.47
10	7.4	8.2	8.5	8.7	0.38	0.42	0.45	0.5
11	21.9	26.8	31.5	38.5	0.52	0.61	0.74	0.77
12	22.4	27.5	30.3	36.4	0.42	0.46	0.59	0.63
13	18.8	19.7	23.5	26.1	0.45	0.53	0.57	0.61
14	10.5	15.1	16.4	19.6	0.38	0.41	0.44	0.48
15	21.5	26.8	29.4	35.5	0.49	0.53	0.55	0.58
16	18.1	18.5	22.4	25.5	0.51	0.56	0.59	0.65
17	9.6	14.5	16.0	19.3	0.53	0.59	0.62	0.68
18	18.0	21.3	23.3	24.5	0.52	0.56	0.58	0.65
19	10.6	11.5	12.4	13.1	0.54	0.57	0.61	0.69
20	7.4	8.1	8.5	8.8	0.56	0.61	0.66	0.75

The strength of pressed composites after 1 day is approximately 70...80% of the strength after 28 days, and after 7 days - 80...90%. The strength of the composites after 1 year of curing in air-dry conditions increases by about 10% compared to the strength at the age of 28 days.

The results of the performed studies suggest that one of the areas of application of dihydrate phosphogypsum binders can be the production of wall products. The strength characteristics of dihydrate phosphogypsum binders, their water resistance make it possible to manufacture products for internal walls, partitions that are not systematically moistened.

4. CONCLUSIONS

1. Dihydrate phosphogypsum upon mechanical activation during grinding in a ball mill acquires the ability to hardening in pressed specimens. The values of autohesion of PG particles of different dispersity were experimentally established.

2. The dependences of the strength and density of specimens on the compression pressure have been established. As a result of statistical processing of experimental data, a quadratic regression equation was obtained for the compressive strength of pressed PG specimens. The influence of individual factors on the strength of PG specimens was studied.

3. The influence of chemical admixtures on the properties of dihydrate phosphogypsum binders was considered. Effective means of increasing the water resistance of pressed dihydrate phosphorgypsum are the addition of alkali metal salts (Na_2SiO_3, Na_2CO_3, KF, Na_3PO_4) due to which the water resistance coefficient increases to 0.7...0.75 without a significant decrease of strength.

4. There is established an effect of aggregates of different types on the strength and water resistance coefficient of dihydrate phosphogypsum binders. It was found that the best result is shown by the aggregate in the form of quartz sand with a fineness modulus of 1.3.

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IZVOD

VEZIVA ZA PRESOVANE PROIZVODE NA BAZI OTPADA FOSFOGIPSA

Članak je posvećen pitanjima dobijanja presovanih građevinskih materijala na bazi dihidrata fosfogipsa. Dihidrat fosfogips nakon mehaničke aktivacije u kugličnom mlinu stiče sposobnost stvrdnjavanja u presovanim uzorcima. Nakon aktiviranja dihidrata fosfogipsa u kugličnom mlinu i njegovog presovanja pod pritiskom od 30 MPa, čvrstoća uzoraka se povećava za 6...8 puta u poređenju sa neaktiviranim uzorcima i dostiže 25...30 MPa. Utvrđen je uticaj različitih hemijskih dodataka na vezivna svojstva aktiviranog fosfogipsa i prikazane su mogućnosti poboljšanja vodootpornosti i povećanja drugih svojstava koja karakterišu ovaj materijal. Proučava se uticaj agregata na građevinsko-tehnička svojstva veštačkog kamena od fosfogipsa i osobenosti njegove strukture i promene pod uticajem različitih faktora.

Ključne reči: *dihidrat fosfogips, veziva, kompresija, vodootpornost, čvrstoća.*

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