



PROPERTIES OF MAGNESIUM COMPOSITE MATERIALS BASED ON TECHNOGENIC RAW MATERIALS

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ABSTRACT

In the research paper have been developed composites based on magnesium binders. Here were formulated the principle of choosing technogenic materials for composite binders. We investigated the processes of hydration and hardening of composite binders based on iron ore beneficiation. It was revealed that the hydration activity of minerals of technogenic raw materials depends on the structure and ability to hydrolyze in a solution of magnesium chloride. The influence of technogenic aggregates on the formation of composites with various structures is studied. Magnesium composites can effectively realize the unique properties of caustic magnesite, rational use of technogenic materials of various origins.

Keywords: caustic magnesite, technogenic raw materials; magnesium composites.

1. INTRODUCTION

The growing scientific interest in magnesium binders is due to the uniqueness of these materials: the use of salt solutions for mixing; activating ability of caustic magnesite in relation to various substances; high adhesion to any aggregate [1-9].

Magnesium binders are distinguished by simplicity and low energy intensity of production, intensive hardening, high strength parameters [10-16].

The main reasons for the limited use of magnesia binders: small deposits of magnesites; shrinkage and low water resistance of hardened stone.

The deficit of natural magnesites is compensated by the use of dolomite raw materials, natural brucite [17-19], technogenic magnesia materials [20-25]. Developments are continued in order to improve the roasting conditions of raw materials, which affect the activity of magnesium oxide and the properties of solidified astrigent [26-29]. Various additives are introduced, including compounds of phosphorus, silicon, copper, sodium, aluminum, iron, acid to increase the water resistance of magnesia cement [30-39].

An effective solution to the problem of magnesite deficiency is the production of composite binders.

The combination of caustic magnesite with natural and technogenic materials ensures the expansion of the range and increase in the output of magnesium binders [24, 40-44]. Composite binders contain a small amount of caustic magnesite, characterized by increased water resistance [41-50].

This paper is devoted to the study the effect of technogenic materials on the processes of hydration, structure formation and the properties of magnesium composites.

2. THE PRINCIPLE OF SELECTING THE TECHNOGENIC COMPONENT OF MAGNESIA COMPOSITES

We need criteria to assess the suitability of new raw materials. Based on the systematization and analysis of the results of the study properties of various magnesium materials was formulated the principle of selecting the technogenic component of magnesium composites [20, 22, 24, 40-44]. Technogenic materials that are capable of structuring in magnesium compositions are shown in the diagram (Figure-1). The choice of the technogenic component of magnesium composite binders provides for a comprehensive assessment of the composition and structure of the raw material and includes 4 stages (Figure-2).

Most of the man-made materials are latent binders: the hydration activity is low or not appeared. Such materials are activated by various methods (Figure-2).

3. METHODOLOGY

For the preparation of magnesia binders and composites were used following raw materials: caustic magnesite with an MgO content of 85%; water solution $MgCl_2$ with density 1150-1400 kg/m³. The composition of the compounds introduced technogenic materials of various origins: wastes of ore dressing, metallurgical slag, glass battles, sawdust, heat energy waste, former styrofoam packages.

Magnesium composite binders were prepared by co-grinding caustic magnesite and anthropogenic component to a specific surface of 310–330 m²/kg.

Coarse-grained technogenic materials were premixed prior to mixing. Strength properties of binders were determined on samples with dimensions of 20 x 20 x 20 mm, which were formed from a dough of normal density. The properties of the composites were studied on samples with dimensions of 40x40x160 mm. X-ray phase, differential thermal and microscopic methods of analysis were used to study the composition and structure of materials.

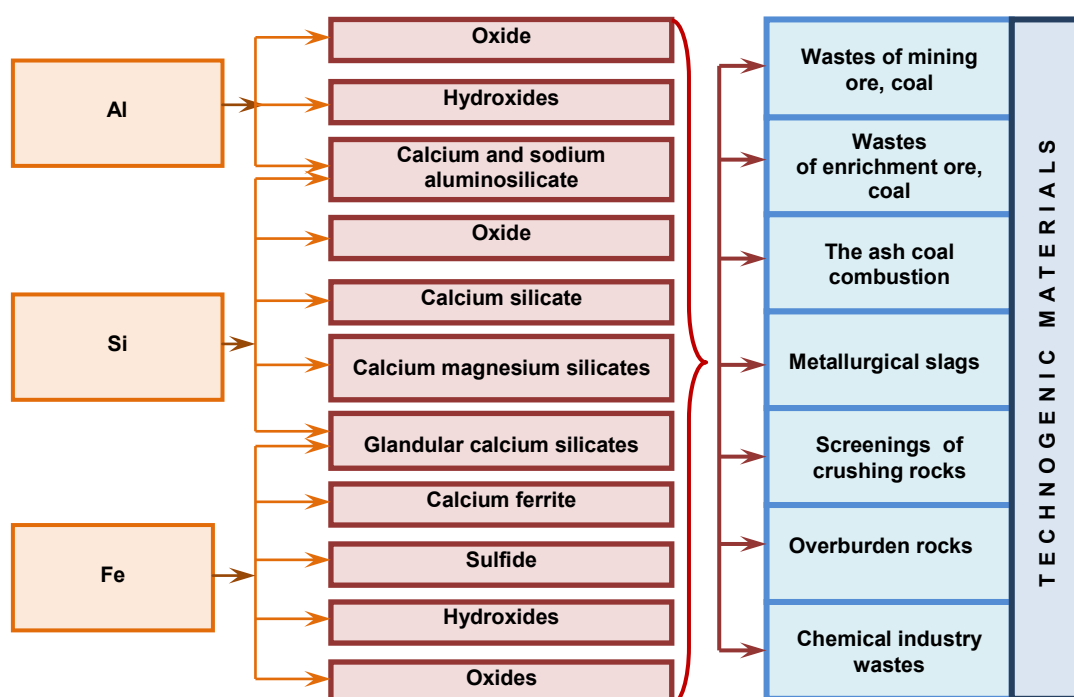


Figure-1. Types of technogenic materials for magnesium compositions.

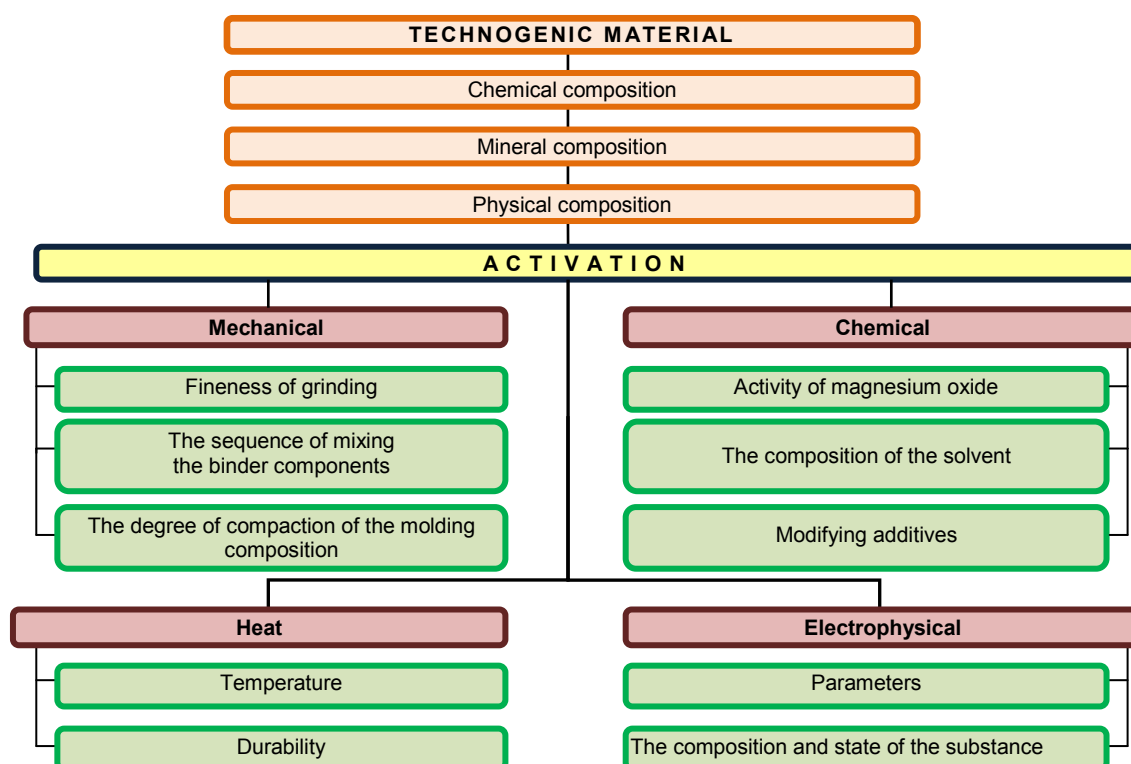


Figure-2. Scheme of evaluation and ways to activate the technogenic component of mixed magnesium binders.

4. MAGNESIUM COMPOSITIONS BASED ON IRON ORE DRESSING WASTE

4.1. Characteristics of iron ore dressing waste

The results of studies on magnesium composite binders with various technogenic components indicate the preferability of using iron ore dressing waste [40, 49].

Composite binders are characterized by high strength, resistance to water. Chemical composition of technogenic material, weight %: SiO_2 - 41; Al_2O_3 - 13; Fe_2O_3 - 16; CaO - 12; MgO - 6; SO_3 -4; R_2O_3 -3; others -2; loss on ignition- 3.



Mineral composition of the technogenic material is formed by silicates of different genesis, %: pyroxenes 20-25; epidote 10-13; feldspars 8-12; chlorites 7-10; scapolite 8-11; grenades 7-12; amphiboles 7-14. Iron ore dressing waste contains 7-11% pyrite, 5-8% calcite. Waste is formed at various stages of magnetic dressing of iron ores of skarn-magnetite origin. Waste of dry magnetic separation is a granular material with a particle size of up to 25 mm. Waste of wet magnetic separation is a finely

dispersed mass of particles with an average size of 0.55 mm.

4.2. Hardening of magnesium composite binders

The results of studies give the evidence of the possibility of containing 10-70% of the technogenic component in magnesium compositions (Table-1). The subsequent restriction of the content caustic magnesite leads to a sharp decrease of the material strength.

Table-1. Influence of the content of the technogenic component on the strength properties of the mixed magnesia binder.

The content of iron ore dressing waste, %	Solution flow rate MgCl_2 , %	Compressive strength, MPa		
		2 days	14 days	28 days
0	43.4	35	53	63
10	40.3	31	56	61
20	38.1	29	47	58
30	36.5	32	52	64
40	34.8	30	46	60
50	32.1	31	49	62
60	28.4	28	47	61
70	25.9	27	48	63
80	24.7	20	37	53
90	23.8	9	17	27

Composite binders with iron ore dressing waste are characterized by delayed hardening, but at the period of 28 days they are not inferior in properties to caustic magnesite. Strength indicators of composite binders depend on the density of the shutter (Figure-3). The influence of the concentration of the MgCl_2 solution is most obvious in the early stages of hardening: the strength values obtained at the extreme values of the concentration of MgCl_2 differ by 7 - 8 times.

To ensure a high rate of hardening magnesium composite binders, a solution of magnesium chloride with a density of 1180 - 1300 kg/m^3 is needed.

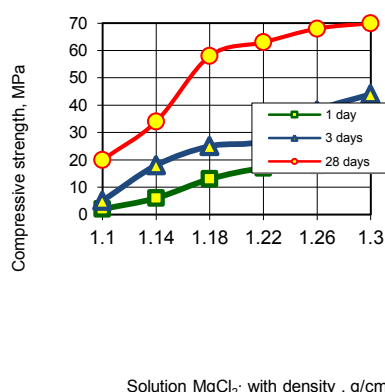


Figure-3. Influence of the density of the preservative on the strength of the composite binder with 50% of technogenic component.

The following features of the hydration magnesia composite binder are revealed during the study. In the compositions, the activity of MgO is increased; the degree of conversion of MgO to hydroxychlorides of magnesium is increased. In solidified composite binders $5\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O}$ (5 - form) predominates, which promotes intensive hardening and high strength of the binder stone. The bulk of $\text{Mg}(\text{OH})_2$ is converted to magnesium hydroxychlorides and hydrates based on natural minerals. In the presence of an anthropogenic component, magnesium hydroxychlorocarbonate $\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 2\text{MgCO}_3 \cdot 6\text{H}_2\text{O}$ is formed. It was found that magnesium hydroxychlorocarbonate is formed with a limited content of MgO in the binder and an increase in the density of the MgCl_2 solution (Figure-4).

The dependence of the formation of pentahydroxychloride $5\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O}$ and magnesium hydroxychlorocarbonate was established.

When using a solution of MgCl_2 with a density of 1240 kg/m^3 and higher, a transition is possible:
 $5\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O} \rightarrow 3\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O} \rightarrow \text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 2\text{MgCO}_3 \cdot 6\text{H}_2\text{O}$.

The intensity of such transformations is due to the increased activity of CO_2 in the presence of MgCl_2 .

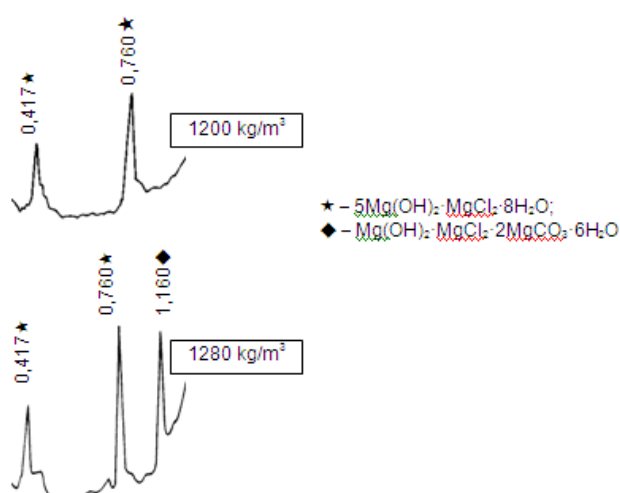
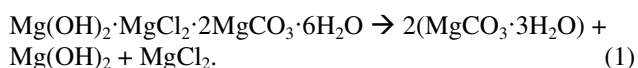


Figure-4. Diffractograms of composite binder with a solution of MgCl_2 of different density (hardening time was 3 days).

With increasing duration of hardening, the content of magnesium hydroxychlorocarbonate in the binder decreases as a result of the reaction:



The phases MgCl_2 and $\text{Mg}(\text{OH})_2$ participate in the formation of an additional amount of magnesium pentahydroxyoxycarbonide and other hydrates.

The possibility of formation and stability of $\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 2\text{MgCO}_3 \cdot 6\text{H}_2\text{O}$ depends on the mineral composition of the technogenic component. The formation of magnesium hydroxychlorocarbonate does not impair the strength properties of the stone; however, the binding potential of the hydrate is not as high as that of magnesium hydroxychlorides.

The microconglomerate structure of the composite binder stone is formed on the basis of a splice of magnesium hydroxychloride crystals and mineral particles of the technogenic component (Figure-5). The formation of amorphous hardly soluble hydrates on the

basis of the technogenic component creates a matrix of the stone and provides its resistance to shrinkage deformations and the action of water.

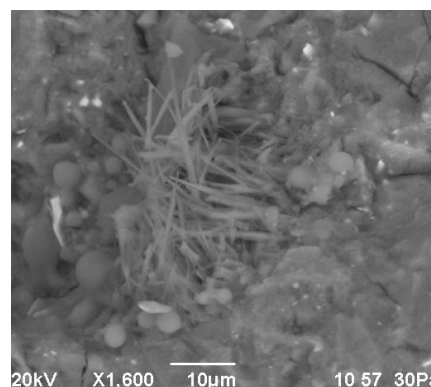


Figure-5. Microstructure of a magnesia composite binder stone.

The hydration and hardening of the magnesium composite binder depends on the mineral composition of the technogenic component.

The activating influence of caustic magnesite with respect to natural silicates is known: diopside, zeolite, tremolite, serpentinite [22, 41]. According to [41], under the action of $\text{Mg}(\text{OH})_2$ and MgCl_2 calcium and magnesium cations emerge from the crystalline lattice of silicates and ion-exchange processes occur. The mineral composition of iron ore dressing is very diverse. The hydration processes in model binders, which contain minerals not studied in the composition of magnesium compositions, have been studied. The choice of minerals for research is due to a wide spread in the composition of technogenic materials.

4.3. Effect of albite on the hardening of magnesium compositions

Albite $\text{Na}(\text{AlSi}_3\text{O}_8)$ is a common feldspar. The strength properties of the model binder depend on the composition of the activating component (Table-2). The hydration properties of the mineral greatly increase in the presence of a solution of MgCl_2 .

Table-2. Strength properties of the composition «caustic magnesite – albite».

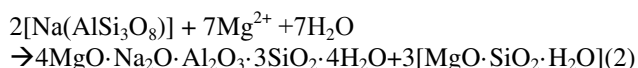
Binder composition, %		Salt solution		Compressive strength, MPa, age, days		
caustic magnesite	albite	composition	density, kg/m^3	1	28	90
35	65	MgCl_2	1220	27	58	61
35	65	MgCl_2	1280	39	74	67
35	65	MgSO_4	1220	11	42	54
100	0	MgCl_2	1220	41	63	57

Under the influence of a solution of magnesium chloride begins the hydrolysis of surface areas of albite grains. Initially, sodium ions transfer to the solution of MgCl_2 , which activate the hydration of the binder.

Hydrosilicates and magnesium hydroaluminosilicates are formed with the participation of hydroxides of silicon, aluminum and magnesium. Alkali appears to be bound by



gel-like hydroaluminosilicates. The following scheme of albite transformations is probable:



The results of the thermal analysis (Figure 6) show that, in addition to magnesium hydroxide (endoeffects at 180 °C, 380 °C, 550 °C), the solidified binder contains: silicon hydroxide (endoeffect at 150 °C), aluminum hydroxide (endoeffects at 280 °C and 550 °C), hydrosilicates magnesium (endoeffect at 150 °C and 550 °C).

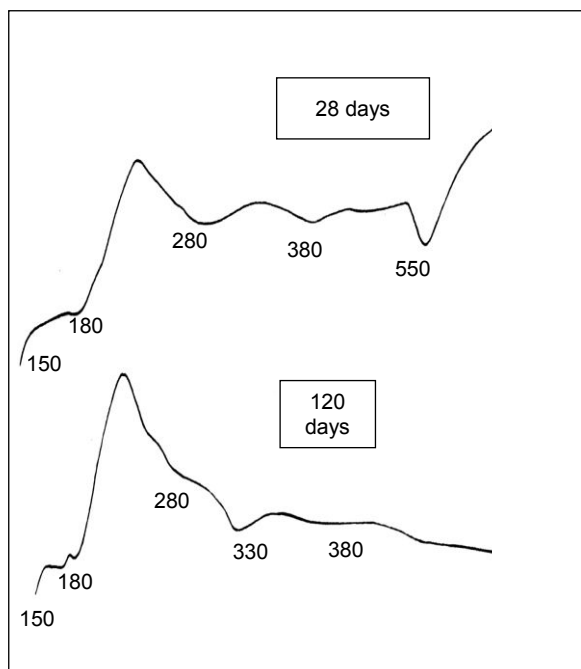


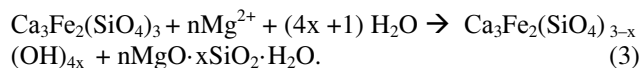
Figure-6. Thermograms of the composition «caustic magnesite - albite».

In the binder of long hardening (120 days), is probable the formation of hydroaluminosilicate compounds bound aluminum hydroxide (endoeffect at 330 °C).

4.4. Effect of andradite on hardening of magnesia compositions

Andradite $\text{Ca}_3\text{Fe}_2[\text{SiO}_4]_3$ - a common mineral of skarn rocks. The compositions with 30 - 60% andradite were studied. Strength values of composite astringents are sensitive to changes in the concentration of magnesium chloride in the early stages of hardening. The maximum strength is ensured by mixing with a solution of MgCl_2 with a density of 1280 kg/m³. The main hydrated phase is $5\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 8\text{H}_2\text{O}$.

Hydrate $\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 2\text{MgCO}_3 \cdot 6\text{H}_2\text{O}$ is formed after 1 day of hardening using a solution of MgCl_2 with a density of 1280 kg/m³. The content of $\text{Mg}(\text{OH})_2 \cdot \text{MgCl}_2 \cdot 2\text{MgCO}_3 \cdot 6\text{H}_2\text{O}$ at the age of 7 days is doubled. The degree of conversion of andradite to hydrates was determined by diffractometric method and amounted to 20-23%. Hydrogens and magnesium hydrosilicates are formed on the basis of andradite. With MgCl_2 the ability of andradite to hydrolyze increases. As a result of substitution of $[\text{SiO}_4]$ на $(\text{OH})_4$, are formed hydrogens of variable composition $\text{Ca}_3\text{Fe}_2[\text{SiO}_4]_{3-x}(\text{OH})_{4x}$. The freed ions $[\text{SiO}_4]$ form $\text{Si}(\text{OH})_4$ silica gel, bind to magnesium hydrosilicates. General scheme of andradite transformation is as follows:



The limited amount and weak crystallization of hydrates based on andradite make it difficult to identify them (Figure-7). Diffraction reflections $d = 0.340$; 0.285 ; 0.206 ; 0.170 nm indicate the presence of $\text{Ca}_3\text{Fe}_2(\text{OH})_{12}$ (a variant of the hydrogranate at $x = 3$).

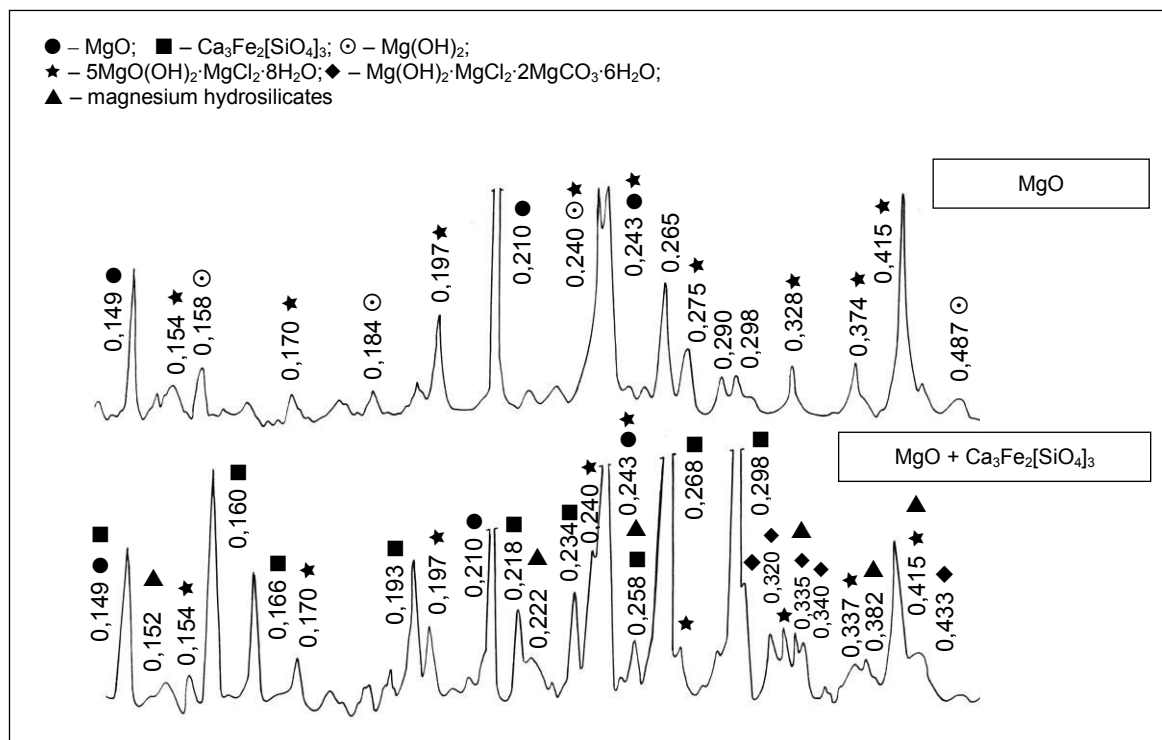


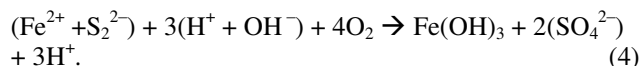
Figure-7. Radiographs of the composition "caustic magnesite - andradite".

Stability of the structure of $\text{Ca}_3\text{Fe}_2(\text{OH})_{12}$ is ensured by the introduction of a small amount of SiO_2 into its lattice. Lines $d = 0.415$; 0.382 ; 0.335 ; 0.258 ; 0.222 ; 0.152 nm indicates the presence of magnesium hydrosilicates (eg, sepiolite).

4.5. Influence of pyrite on hardening of magnesia compositions

Pyrite $\text{Fe}[\text{S}_2]$ is a common sulphide of the earth's crust. We have studied the compositions with different pyrite contents (Table-3). With increasing $\text{Fe}[\text{S}_2]$ concentration, the degree of conversion of MgO to hydrates increases. In the presence of pyrite, hydroxylchlorocarbonate of magnesium is not formed (section 4.2); this is due to the increase in the acidity of the medium.

Under the influence of chlorine ions, oxidation-reduction reactions and hydrolysis of pyrite occur. 40-60% of pyrite is involved in hydration of the binder. The processes of hydrolysis and oxidation of pyrite in MgCl_2 solution are represented by the scheme:

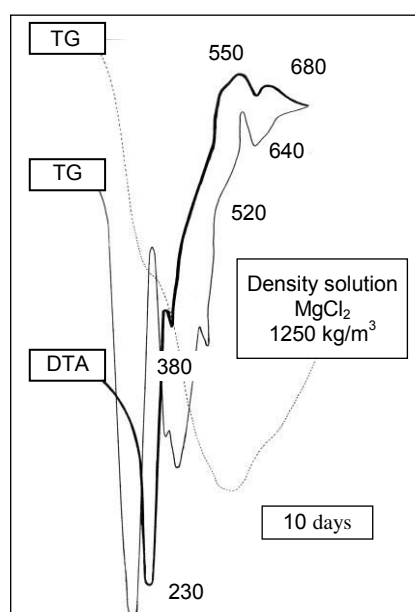
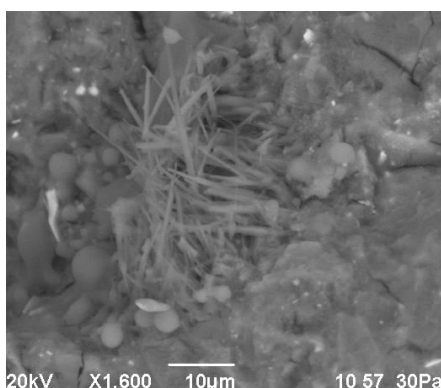


Phase $\text{Fe}(\text{OH})_3$ compacts the structure of the frozen binder. In the presence of sulfate ions, MgO is activated, sulfate hydrates are formed. The decrease in the proportion of magnesium hydroxylchlorides in the stone while maintaining high activity of magnesium oxide is due to the outflow of MgO to the magnesium-ferruginous neoplasms. The exothermic effect at 550°C characterizes the oxidation of pyrite (Figure-8).

The endothermic effect at 640°C indicates the decomposition of magnesium hydroxysulfate and hydrosulfoferrite. The microconglomerate structure of a stone made up of particles of different morphology contributes to the compaction and increase of the stability of the structure to destructive processes (Figure-9). Magnesium pentahydroxyoxochloride is retained in the composition of long-term hardening.

**Table-3.** Properties of the composition «caustic magnesite – pyrite».

The pyrite content, %	The intensity of phase reflections on the diffractogram, op.ed. (age of the stone is 28 days)					Compressive strength, MPa,	
	MgO (0.210 nm)	FeS ₂ (0.163 nm)	Mg(OH) ₂ (0.157 nm)	5 – form (0.197 nm)	3 – form (0.830 nm)	1 day	28 days
0	140	0	14	20	21	55	68
10	126	15	11	16	18	70	65
30	93	43	10	16	16	80	75
50	62	46	8	14	10	59	82
70	22	35	9	11	footprints	67	90
90	0	61	0	footprints	0	11	46

**Figure-8.** Thermograms of the composition «caustic magnesite - pyrite».**Figure-9.** The microstructure of the composition «caustic magnesite - pyrite» (age of hardening is 9 years).

4.6. Analysis of the study results of magnesium composite binders

Combinations of caustic magnesite and iron ore dressing waste allow obtaining compositions which

strength is comparable to magnesia binders. Hydration and hardening of composite astringents depend on the structure, physico-chemical properties and ability of minerals to hydrolyze in $MgCl_2$ solution. The degree of hydration of minerals in magnesium composite astringents is 25 – 60%. Hydration activity of minerals increases in the series: chlorite → actinolite → scapolite → albite → epidote → diopside → andradite → pyrite. The low activity of chlorite and actinolite is due to the peculiarities of the crystallochemical structure of minerals, the increased content of hydrated water in these silicates. The maximum activity is exhibited by composite binders based on the minerals of the island and chain structure. Iron-containing minerals provide an increase in strength and water resistance of composite materials.

The low energy intensity of the magnesium composite astringent is expressed by a 70% reduction in the proportion of the calcining component (caustic magnesite) and the saving of 64 kg of conventional fuel per ton of binder. The ecological advantages of composite binders are the rational utilization of a significant amount of multi-tonnage technogenic materials, reducing the emissions of technological CO_2 by 0.7 kg/kg of binder.

5. MAGNESIUM COMPOSITES OF VARIOUS STRUCTURES

Modern construction requires resource-saving composite materials with specified properties. Magnesium binders are an effective matrix for composite materials due to the high adhesion of caustic magnesite to aggregates of various origins. Here was studied the possibility of obtaining magnesium composites of various structures with the integrated use of technogenic materials.

Molding masses were prepared on the basis of caustic magnesite and composite binders. For the development of composites are used fillers of various structures. The fine-grained aggregate is obtained as a result of crushing and fractionation of the waste of dry magnetic separation of iron ores (Section 4.1). Fibrous aggregate - wood sawdust. Porosized aggregates - aluminosilicate microsphere (waste heat power) and recovered polystyrene pellets (obtained during processing of packaging material). To create composites it is



advisable to use particles with a size of no more than 2.5 mm, which makes it possible to obtain structures of increased homogeneity. The molding mixtures were mixed with a solution of magnesium chloride of density 1240 kg/m³.

5.1. Magnesium composites of dense fine-grained structure

The use of composite binders with an anthropogenic content of up to 30-50% instead of caustic magnesite does not reduce the strength characteristics of composites (Table-4). When using aggregates of large fractions, the strength of composites based on a composite binder is noted to be superior. With an increase in the proportion of aggregate in the molding mass, the sensitivity to the composite binder composition increases.

To maintain high strengths, comparable with the indicators of caustic magnesite, with an increase in the proportion of aggregate, the content of the man-made component in the composite binder should be limited. To optimize the composition of the fractionated technogenic aggregate, the method of mathematical design of the experiment was used.

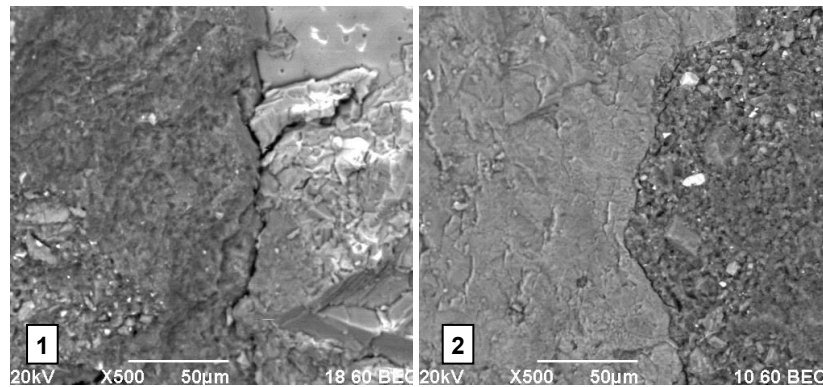
The content of fractions (mm) is optimized, %: «2.5-5.0» 62.5-75.0; «0.63-2.5» 16.7-22.5; «0.14-0.63» 8.3-15.0. The predominance of coarse fraction «2.5 - 5.0» mm with a rational ratio with smaller particles will ensure the formation of a dense structure and increased strength of the magnesia composite (Figure-10). To harden composites of fine-grained structure, it is expedient to pre-treat the filler with a salt preserver.

Table-4. Properties of magnesia composites of dense fine - grained structure.

The content of technogenic component in the binder, %	Fractions of technogenic aggregate, mm	Binder: aggregate	Comosite density, kg/m ³	Compressive strength, MPa
0	2.5 – 1.25	1:1	2299	62
30	2.5 – 1.25	1:1	2424	67
50	2.5 – 1.25	1:1	2484	70
70	2.5 – 1.25	1:1	2504	45
0	1.25 – 0.63	1:1	2260	57
30	1.25 – 0.63	1:1	2441	54
50	1.25 – 0.63	1:1	2469	55
70	1.25 – 0.63	1:1	2468	38
0	1.25 – 0.63	1:1.5	2335	43
30	1.25 – 0.63	1:1.5	2482	42
50	1.25 – 0.63	1:1.5	2355	38
0	0.63 – 0.315	1:1	2135	38
30	0.63 – 0.315	1:1	2285	39
50	0.63 – 0.315	1:1	2303	36
0	0.63 – 0.315	1:1.5	1907	25
30	0.63 – 0.315	1:1.5	2137	27

Primary contact with the magnesium chloride solution releases dust and activates the surface of the aggregate grains; this increases the adhesion of the components and increases the strength of the composite by

15-18%. The results of electron microscopy (Figure-10) indicate a decrease in the defectiveness of contact zones in the microstructure of composites.



1- mixed mixing of all components of the mixture;
 2 - primary contact of the aggregate with a solution of magnesium chloride

Figure-10. Microstructure of fine-grained composites of various preparations.

5.2. Magnesium composites of the combined structure

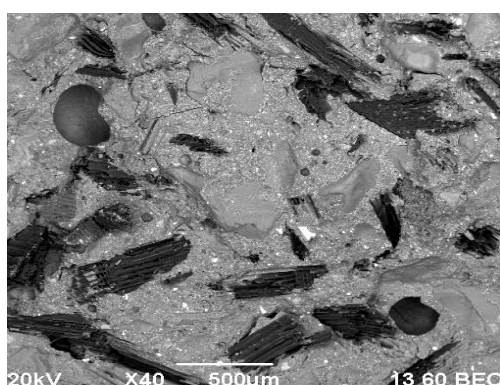
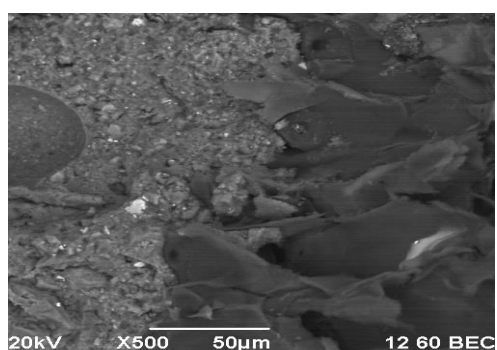
Compositions of a dense composite structure are formed from granular and fibrous particles. The presence of fibers increases the need for a solution of magnesium chloride, contributes to a decrease in density and a reduction in compressive strength (Table-5). In addition, a microsphere was introduced into the mixture-hollow particles with a diameter of 100-250 μm . Due to the high specific surface area of the microsphere, the sedimentation stability of the molding composition increases. The spherical shape and the smooth surface of the microsphere contribute to a reduction in friction and a thixotropic increase in the mobility of the mass. An increase in the microsphere content in excess of 10% leads to a decrease in the strength of the composites. To create a combined structure is important a sequence of combination of the molding mass components. It is expedient to initially mix the granular component with a solution of magnesium

chloride. Then, binder and wood particles are introduced into the mixture. Such a method ensures homogeneity of the structure and an increase in the strength of the composite by 12-15% (Figure-11). The microsphere must be introduced at the final stage of preparation molding mass. In the magnesium compositions of the porous combined structure, the combination «wood sawdust - polystyrene granules» allows to reduce the density of the material by 15-20% while maintaining the strength characteristics

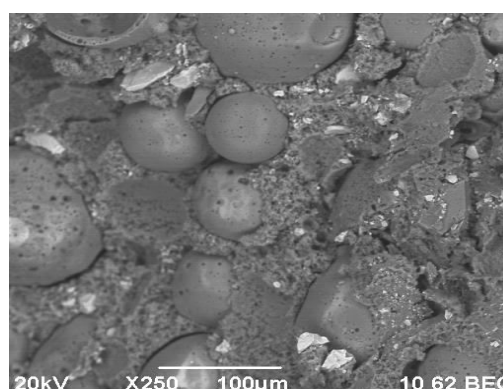
The combination of «microspheres - polystyrene pellets» provides a 10% reduction in material density with an increase in strength indexes by 15-18%. The presence of the microsphere increases the homogeneity of the molding mass, promotes a uniform distribution of the paste of the binder test around the polystyrene pellets (Figure-12).

**Table-5.** Properties of magnesia composites of a dense composite structure.

The content of technogenic component in the binder, %	The content of the granular component, %		Wood sawdust, (content of 20%) fraction, mm	Density, kg/m ³	Compressive strength, MPa
	iron ore beneficiation waste, fraction «0.63-0.14» mm	microsphere			
0	80	—	1.25 – 0.63	1660	46
0	80	—	0.63 – 0.14	1750	46
0	80	—	2.5 – 1.25	1615	50
30	80	—	1.25 – 0.63	1695	43
30	80	—	0.63 – 0.14	1860	45
30	80	—	2.5 – 1.25	1695	51
50	80	—	1.25 – 0.63	1730	35
50	80	—	0.63 – 0.14	1910	38
50	80	—	2.5 – 1.25	1725	39
70	80	—	1.25 – 0.63	1725	30
70	80	—	0.63 – 0.14	1960	34
70	80	—	2.5 – 1.25	1860	38
50	—	5	1.25 – 0.63	1510	31
50	—	5	0.63 – 0.14	1565	33
50	—	5	2.5 – 1.25	1535	35
50	—	10	2.5 – 1.25	1455	37

**Figure-11.** Composite of a dense composite structure with a filler.**Figure-12.** Composite of combined structure with a filler «microsphere - polystyrene granules».

in the integral filler «polystyrene-wood particles-ash microsphere», the choice of a rational method of preparation of the molding mass allows to obtain a combined structure as much as possible «packed» pores of various structures (Figure-13).

**Figure-13.** Composite of combined structure with a filler «expanded polystyrene-wood particles-ash microsphere».

The compositions are characterized by a density of 350 to 650 kg/m³ and a compressive strength of 1 MPa to 7 MPa.



5. 3. Analysis of the results of studies of magnesia composites

Magnesium composites of fine-grained structure are characterized by the complex use of one type of technogenic material: the iron ore dressing waste serves as a component of the composite binder and they are the filler of the composite. Composites minimize the content of caustic magnesite: 25% of the mass of the solid. Composites are recommended for manufacturing of wall blocks, elements of an accomplishment.

Magnesium composites of the combined structure are characterized by a variety of technogenic components. Composites are recommended for the manufacture of wall and thermal insulation blocks.

The analysis of the results of experiments, technological solutions and technical economic calculations allow us to formulate the principles of resource-saving for magnesium composites: maximum realization of the unique properties of the magnesium binder; minimization of the content of the deficient caustic magnesite; integrated use of technogenic materials; activation of raw components in the preparation of molding masses; low power consumption of technological processes.

6. CONCLUSIONS

- Magnesium composites are effective building materials that are characterized by resource-saving at all stages of the life cycle. High activating ability of magnesia binder in relation to various substances allows synthesizing composite astringents on the basis of numerous technogenic materials. The reliable adhesion of magnesia binders to aggregates of various origin ensures the formation of composites of dense and porous structures with the integrated use of technogenic components.
- Within the study was proposed the principle of choice of man-made materials for magnesium composite astringents. The expediency of using technogenic materials is determined by a comprehensive assessment of the chemical and mineral composition, physical properties of the material. The proposed approach of a reasonable choice of man-made raw materials is implemented for iron ore dressing waste.
- It has been established that the hydration ability of the iron ore dressing waste is manifested under the influence of magnesium activation; increases with increasing concentration of salt in the sealant; reaches a maximum level when using a solution of $MgCl_2$ with a density of 1180 - 1280 kg/m³. The limiting content of the technogenic component in the magnesium composite binder is 70%. Here were revealed the features of the hydration of the magnesium composite binder, which consist in increasing the activity of MgO, preferential formation of magnesium pentahydroxychloride; the possibility of forming magnesium hydroxychlorocarbonate.
- Within the study was revealed the activity of minerals of the technogenic component in hydration and formation of magnesium compositions structure. The

expediency of technogenic components with the content of silicates of island structure and ferruginous compounds is substantiated.

- Also the main directions of using magnesium composite astringents in the production of building materials are determined. The expediency of obtaining magnesium composites based on technogenic aggregates of various origins is shown.
- Rational methods of preparation of raw materials are based on the primary contact of components on which the stability of the matrix of composite materials depends. Rational conditions for the formation of the structure of composites provide the maximum realization of the activity of the magnesium binder; provide for the combination of polymodal particles in the aggregate; guarantee the reliability of the adhesion of components in a monolith.

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REFERENCES

- [1] Hu C., Xu B., Ma H., Chen B. and Li Z. 2016. Micromechanical investigation of magnesium oxychloride cements paste. *Construction and Building Materials*. 105: 496-502.
- [2] Beaudoin JJ. and Ramachandran VS. 1975. Strength development in magnesium oxychloride and other cements. *Cement and Concrete Research*. 5: 617-630.
- [3] Ball MC. 1977. Reactions of compounds occurring in Sorel's cement. *Cement and Concrete Research*. 7: 575-583.
- [4] Xia S., Xing P. and Gao S. 1991. Studies on the basic compounds of magnesia cement: the thermal behaviour of magnesium oxychlorides. *Thermochimica Acta*. 183: 349-363.
- [5] Maravelaki-Kalaitzaki P. and Moraitou G. 1999. Sorel's cement mortars: Decay susceptibility and effect on Pentelic marble. *Cement and Concrete Research*. 29: 1929-1935.
- [6] Dehua D. and Chuanmei Z. 1999. The formation mechanism of the hydrate phases in magnesium oxychloride cement. *Cement and Concrete Research*. 29: 1365-1371.
- [7] Li Z. and Chau CK. 2007. Influence of molar ratios on properties of magnesium oxychloride cement. *Cement and Concrete Research*. 37: 866-870.



- [8] Selvamani T., Sinhamahapatra A., Bhattacharjya D. and Mukhopadhyay I. 2011. Rectangular MgO microsheets with strong catalytic activity. *Materials Chemistry and Physics*. 129: 853-861.
- [9] Kandeel AM., El-Mahllawy MS., Hassan HA., Sufe WH. and Zeedan SR. 2012. Effect of type of mixing water and sand on the physico-mechanical properties of magnesia cement masonry units. *HBRC Journal*. 8: 8-13.
- [10] Xu B., Ma H., Hu C., Yang S. and Li Z. 2016. Influence of curing regimes on mechanical properties of magnesium oxychloride cement-based composites. *Construction and Building Materials*. 102(1): 613-619.
- [11] Christensen AN., Norby P. and Hanson JC. 1995. Chemical Reactions in the System $\text{MgO} - \text{MgCl}_2 - \text{H}_2\text{O}$ followed by Time-Resolved Synchrotron X-Ray Powder Diffraction. *Journal of Solid State Chemistry*. 114:556-559.
- [12] Altmaier M., Metz V., Neck V., Müller R. and Fanghänel Th. 2003. Solid-liquid equilibria of $\text{Mg}(\text{OH})_2(\text{cr})$ and $\text{Mg}_2(\text{OH})_3\text{Cl} \cdot 4\text{H}_2\text{O}(\text{cr})$ in the system $\text{Mg}-\text{Na}-\text{H}-\text{OH}-\text{Cl}-\text{H}_2\text{O}$ at 25°C. *Geochimica et Cosmochimica Acta*. 67: 3595-3601.
- [13] Xiong Y., Deng H., Nemer M. and Johnsen S. 2010. Experimental determination of the solubility constant for magnesium chloride hydroxide hydrate ($\text{Mg}_3\text{Cl}(\text{OH})_5 \cdot 4\text{H}_2\text{O}$, phase 5) at room temperature, and its importance to nuclear waste isolation in geological repositories in salt formations. *Geochimica et Cosmochimica Acta*. 74: 4605-4611.
- [14] Zhang T., Cheeseman CR. and Vandeperre LJ. 2011. Development of low pH cement systems forming magnesium silicate hydrate (M-S-H). *Cement and Concrete Research*. 41: 439-442.
- [15] Orlov AA., Chernykh TN., Kramar LYa. and Trofimov BYa. 2011. Energy saving in obtaining magnesia binder for construction purposes. *Construction Materials*. 8: 47-50.
- [16] Mo L., Deng M., Tang M. and Al-Tabbaa A. 2014. MgO expansive cement and concrete in China: Past, present and future. *Cement and Concrete Research*. 57: 1-12.
- [17] Kozlova VK. and Dushevina AM. 2004. Complex use of dolomites of the Taensinsky deposit. *Construction Materials*. 1: 29-31.
- [18] Gu K., Jin F., A.-Tabbaa A. and Shi B. 2014. Activation of ground granulated blast furnace slag by using calcined dolomite. *Construction and Building Materials*. 68: 252-258.
- [19] Liu Z., Wang S., Huang J., Wei Z., Guan B. and Fang J. 2015. Experimental investigation on the properties and microstructure of magnesium oxychloride cement prepared with caustic magnesite and dolomite. *Construction and Building Materials*. 85:247-255.
- [20] Ribeiro DV. and Morelli MR. 2009. Influence of the addition of grinding dust to a magnesium phosphate cement matrix. *Construction and Building Materials*. 23: 3094-3102.
- [21] Hassan SSM, Awwad NS. and Aboterika AHA. 2009. Removal of synthetic reactive dyes from textile wastewater by Sorel's cement. *Journal of Hazardous Materials*. 162: 994-999.
- [22] Zyryanova VN, Berdov GI. and Vereschagin VI. 2009. Magnesium binder based on magnesium chloride brine sludges. *News of Higher Educational Institutions. Building*. 8: 21-25.
- [23] Jianli M., Youcai Z., Jinmei W. and Li W. 2010. Effect of magnesium oxychloride cement on stabilization/solidification of sewage sludge. *Construction and Building Materials*. 24: 79-83.
- [24] Bishimbayev V., Khudyakova T., Werner V. and Gapparova K. 2011. Complex use of mineral and technogenic raw materials for the production of building materials and products. *Industry of Kazakhstan*. 63:71-73.
- [25] Tan Y., Yu H., Li Y., Wu C., Dong J. and Wen J. 2014. Magnesium potassium phosphate cement prepared by the byproduct of magnesium oxide after producing Li_2CO_3 from salt lakes. *Ceramics International*. 40(B): 13543-13551.
- [26] Birchal VSS., Rocha SDF. and Ciminelli VST. 2000. The effect of magnesite calcination conditions on magnesia hydration. *Minerals Engineering*. 13: 1629-1633.
- [27] Kramar LYa. 2007. Influence of impurities on the firing characteristics of high-magnesia rocks for the



- purpose of obtaining a magnesia building binder. Cement and its application. 3-4: 86-89.
- [28] Yan H., Zhang X., Wu J., Wei L. and Liu X. 2008. The use of CTAB to improve the crystallinity and dispersibility of ultrafine magnesium hydroxide by hydrothermal route. Powder Technology. 188: 128-132.
- [29] Sako EY., Braulio MAL. and Pandolfelli V C. 2012. Microstructural evolution of magnesia-based castables containing microsilica. Ceramics International. 38: 6027-6033.
- [30] Lu HP, Wang PL. and Jiang NX.1994. Design of additives for water-resistant magnesium oxychloride cement using pattern recognition. Materials Letters. 20: 217-223.
- [31] Castellar MD., Lorente JC, Traveria A. and Tura JM. 1996. Cracks in Sorel's cement polishing bricks as a result of magnesium oxychloride carbonatation. Cement and Concrete Research. 26: 1199-1202.
- [32] Dehua D. and Chuanmei Z. 1996. The effect of aluminate minerals on the phases in magnesium oxychloride cement. Cement and Concrete Research. 26: 1203-1211.
- [33] Deng D.2003. The mechanism for soluble phosphates to improve the water resistance of magnesium oxychloride cement. Cement and Concrete Research. 33: 1311-1317.
- [34] Li J., Li G. and Yu Y. 2008. The influence of compound additive on magnesium oxychloride cement/urban refuse floor tile. Construction and Building Materials. 22: 521-525.
- [35] Karimi Y. and Monshi A. 2011. Effect of magnesium chloride concentrations on the properties of magnesium oxychloride cement for nano SiC composite purposes. Ceramics International. 37: 2405-2410.
- [36] Salomão R., Milena LM, Wakamatsu MH. and Pandolfelli VC. 2011. Hydrotalcite synthesis via co-precipitation reactions using MgO and Al(OH)₃ precursors. Ceramics International. 37: 3063-3070.
- [37] Tan Y., Liu Y. and Grover L. 2014. Effect of phosphoric acid on the properties of magnesium oxychloride cement as a biomaterial. Cement and Concrete Research. 56: 69-74.
- [38] Xu B., Ma H. and Li Z.2015. Influence of magnesia-to-phosphate molar ratio on microstructures, mechanical properties and thermal conductivity of magnesium potassium phosphate cement paste with large water- to-solid ratio. Cement and Concrete Research. 68: 1-9.
- [39] Li Y., Li Z., Pei H. and Yu H.2016. The influence of FeSO₄ and KH₂PO₄ on the performance of magnesium oxychloride cement. Construction and Building Materials. 10(1): 233-238.
- [40] Miryuk OA.2003. Magnesia compositions of oxychloride hardening. Cement and its application. 4: 38-40.
- [41] Zyryanova VN, Lytkina EV. and Berdov GI. 2010. The influence of mineral fillers on magnesium binders' properties. Technics and technology of silicates. 17: 2-7.
- [42] Chau CK., Chan J. and Li Z. 2009. Influences of fly ash on magnesium oxychloride mortar. Cement and Concrete Composites. 31: 250-254.
- [43] Yildirim K. and Sümer M. 2013. Effects of sodium chloride and magnesium sulfate concentration on the durability of cement mortar with and without fly ash. Composites: Engineering. 52(B): 56-61.
- [44] Li Y., Yu H., Zheng L., Wen J., Wu C. and Tan Y. 2013. Compressive strength of fly ash magnesium oxychloride cement containing granite wastes. Construction and Building Materials. 38: 1-7.
- [45] Yunsong J.2001. Study of the new type of light magnesium cement foamed material. Materials Letters. 50: 28-31.
- [46] Yunsong J.2002. A new type of light magnesium cement foamed material. Materials Letters. 56: 353-356.
- [47] Li G., Yu Y., Li J., Wang Y. and Liu H. 2003. Experimental study on urban refuse/magnesium oxychloride cement compound floor tile. Cement and Concrete Research. 33: 1663-1668.
- [48] Plekhanova TA., Keriene J., Gailius A. and Yakovlev GI. 2007. Structural, physical and mechanical properties of modified wood-magnesia composite. Construction and Building Materials. 21: 1833-1838.



- [49]Miryuk OA. 2011. Features of preparation foam weight for cement less cellular concrete. Technics and technology of silicates. 18: 12-17.
- [50]Zhou X. and Li Z. 2012. Light-weight wood - magnesium oxychloride cement composite building products made by extrusion. Construction and Building Materials. 27: 382-389.