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ANALYSIS OF THE PHYSICAL PROPERTIES OF HYDROPHOBISED LIGHTWEIGHT-AGGREGATE MORTARS

The article is devoted to assessing the effectiveness of hydrophobic and air entraining admixtures based on organ silicon compounds. Mortars with lightweight clay aggregate were the subjects of this investigation. Hydrophobisation of the mass was performed using a hydrophobic admixture and surface hydrophobisation was produced using a methyl silicone resin solution with a high VOC content, a water-based emulsion of methyl silicone resin in potassium hydroxide (KOH) and low molecular alkyl-alkoxy-silane in organic solvents. In this paper, measurements of the basic mechanical and physical parameters were carried out. Compressive strength, flexural strength, density, open porosity, total porosity, absorptivity, capability to diffuse water vapour, frost resistance, sodium sulphate corrosion resistance and the thermal conductivity coefficient were determined. The mortars show high absorptivity of about 26%. Hydrophobisation is ineffective after the period of 14 days - the longer the contact of the preparation with water, the weaker the effectiveness of impregnation becomes. All the samples used in the research demonstrated good resistance to salt crystallization after 15 cycles. Impregnation by the use of mineral waterproofing grout (L2) does not protect to a sufficient degree mortar with lightweight aggregate against damage caused by frost. However, surface hydrophobisation had a considerable impact on the frost-resistant properties of the mortars.

Keywords: hydrophobisation, mortars, physical parameters, thermal conductivity coefficient

ANALIZA WŁAŚCIWOŚCI FIZYCZNYCH HYDROFOBIZOWANYCH LEKKICH ZAPRAW

Artykuł poświęcony jest ocenie skuteczności hydrofobowych i napowietrzających domieszek na bazie związków krzemoorganicznych. Przedmiotem badań były zaprawy z keramzytem. Hydrofobizację w masie wytworzono, stosując domieszki hydrofobowe z kolei hydrofobizację powierzchniową wykonano przy użyciu roztworu żywicy metylo-silikonowej o dużej zawartości ZLO, emulsji na bazie wody z żywicy metylo-silikonowej w wodorotlenku potasu (KOH) i małocząsteczkowego alkilo-alkoksy-silanu w rozpuszczalniku organicznym. W niniejszej pracy przeprowadzono badania podstawowych parametrów mechanicznych i fizycznych. Zostały wykonane następujące badania: wytrzymałość na ściskanie, wytrzymałości na zginanie, gęstość, porowatość otwarta i całkowita, nasiąkliwość, zdolność do dyfuzji pary wodnej, mrozoodporność, odporność na korozję siarczanu sodu, współczynnik przewodności cieplnej. Zaprawy wykazują wysoką nasiąkliwość około 26%. Hydrofobizacja jest nieskuteczna po upływie 14 dni, im dłuższy kontakt materiału z wodą, tym słabsza skuteczność impregnacji. Wszystkie próbki użyte w badaniu wykazały dobrą odporność na krystalizację soli po 15 cyklach. Impregnacja przy użyciu mineralnej zaprawy uszczelniającej (L2) w wystarczającym stopniu nie chroni zaprawy z keramzytem przed uszkodzeniami powodowanymi przez mróz. Hydrofobizacja powierzchniowa miała znaczny wpływ na mrozoodporność zapraw.

Słowa kluczowe: hydrofobizacja, zaprawy, właściwości fizyczne, współczynnik przewodności cieplnej

INTRODUCTION

Lightweight mortar is a mixture of cement or cement-lime with an addition of ingredients that improve thermal insulation. The mortars are created by mixing traditional binders, aggregates, lightweight aggregates (expanded polystyrene granules, expanded perlite, exfoliated vermiculite, lightweight expanded clay aggregate), additives and admixtures. Lightweight expanded clay aggregate may replace sand in mortars. The more the amount of lightweight aggregates instead sand used, the lower the strength parameters of the mortar are. Moreover, the low density of lightweight aggregates reduces the weight of the mortar. The basic advantages of the mortars are as follows: thermal bridges are significantly reduced, high plasticity, stability, vapour permeability, resistance to fungi and algae. The thermal properties of the mortars are affected by the aggregate type and proportion, moisture content, and supplementary cementitious materials [1].

Mortars with lightweight aggregates can be used in sustainable and energy-efficient buildings. Because of that, increased interest in research on mortars with lightweight aggregates, for example: expanded perlite

[2-4], pozzolanic [3], silica fume and fly ash [5], cork granulate [6], recycled polyurethane foam [7], blast furnace slag [8] and pumice [9, 10] has been observed in foreign literature. There have been many studies in literature about the effects of the thermal properties of the aggregate types and proportions on mortars.

Papers [11, 12] present a comprehensive study on the possibility of sewage sludge management in a sintered ceramic material such as a lightweight aggregate. They can be used for wall concrete blocks to reduce the weight of a building with high acoustics and fire resistance [11]. Paper [10] showed that the compressive strength of pumice aggregate mortar was higher than that of Portland cement mortar exposed to freeze-thaw cycles. The use of pumice aggregate provided resistance to sulphate attack. Mortars containing a composite material made of glass fibres dispersed in a resin, usually polyester, had very good physical and mechanical properties. These mortars were characterized by good workability, sufficient compressive strength (at least 5 MPa after 28 days), low specific weight (less than 1100 kg/m^3) and low thermal conductivity (lower than 0.3 $W/m \cdot K$).

In the presented research, expanded clay aggregate (LECA) was used as a lightweight aggregate. Lightweight expanded clay aggregate is produced by firing natural clay, which swells at 1000÷1200°C due to the action of the gases generated inside the mass. LECA has a porous structure enclosed in a hard ceramic coating. Some characteristics of LECA are: fire resistant, moisture impermeable, lightness, thermal insulation with a low conductivity coefficient (as low as 0.097 $W/m \cdot K$), chemically inert, mould and mildew-resistant. LECA granules can be used to produce lightweight concrete or isolation bricks reducing the energy costs in buildings. Air-entraining admixtures are used to produce a more porous structure of the mortars. Added in too-large amounts, admixtures may cause undesired changes in mortar properties, for example strength, absorptivity or water-tightness. Mortars with a high moisture content lose their thermal properties [10]. The pores and capillaries are filled with water containing a variety of ions. When exposed to freezing temperatures, the water in the pores can start freezing and damage the mortar. Furthermore, the salts which are in the water can crystallize in the pores and capillaries causing structure damage. In salted walls the moisture content increases, due to the absorption of moisture from the air. Salt crystallization causes cracks, stains, efflorescence and tarnishes on the material surface. Chemical research works show that one of the most common salts is anhydrous sodium sulphate Na_2SO_4 and hydrated Na_2SO_4 $10H_2O$. At temperatures below 32.4°C, the salt connects with 10 water molecules Na_2SO_4 $10H_2O$. This is related to a fourfold increase in volume and the hydration pressure is about 240 atm. Sodium sulphate has after a few cycles of drying and impregnating causes building materials to disintegrate, even those with high durability and strength as concrete or brick.

In order to decrease the absorptivity of porous mortars, hydrophobisation could be used. The main goal of hydrophobisation is to increase the limit of surface tension between water and the impregnated material so that the difference should be as high as possible [3]. Hydrophobisation changes the wetting angle of the capillaries. This results in the surface repelling water. A thin hydrophobic film lightly coats the capillary walls and does not fill in the entire pore volume. The penetration depth of the hydrophobic preparation depends on the size of the pores and capillaries in the material structure. Moreover the type and concentration of active substance in the preparation is very important. Organosilicon compounds are commonly used for the hydrofobisation of building materials. Silicones are polymers that include any inert, synthetic compound made up of repeating units of siloxane, which is a chain of alternating silicon atoms and oxygen atoms (Si – O – Si), frequently combined with carbon (Si – C – Si) [13]. In research carried out by Frattolillo et al. [14], Formia et al. [15] and Falchi et al. [16], very good effectiveness of the hydrophobic treatment of lightweight mortars was obtained. It was found that the hydrophobic treatment of concrete or mortar prevents against chloride corrosion [17]. One of the most recently proposed techniques is hydrophobic treatment through the use of hydro-repellent products based on alkyl-alkoxy-silanes [14]. For deteriorated materials, and in general for porous surfaces exposed to outdoor elements, reinforcement with epoxy resin has shown to be an effective conservation process [15]. The aim of our other research [18] was to evaluate the feasibility of using hydrophobic preparations based on organosilicon compounds for the protection treatment of lightweight aggregates modified with municipal sewage sludge. The application of different preparations results in differences in the wettability and adhesion properties of lightweight-aggregate-concrete. Organosilicon compounds applied on the subsurface of lightweight concrete reduce the absorption capacity.

In this paper, comparative analysis of the effect of hydrophobic preparations based on organosilicon compounds on the properties of heat insulating mortars with lightweight expanded clay aggregate was carried out. Studies of mortar frost and chemical corrosion durability were conducted.

MATERIALS, SAMPLES AND METHOD

Materials

The composition of the two mixtures of lightweight mortars was prepared. The mortar compositions with lightweight expanded clay aggregate per 1 m^3 are presented in Table 1. The samples were marked with the following symbols: L1 - mortars without a hydrophobic admixture; L2 - mortars with cementitious waterproofing material; L1.1 - L1 mortars which were surface-hydrophobised using a methyl silicone resin

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solution; L1.2 - L1 mortars which were surface-hydrophobised using a water-based emulsion of methyl silicone resin with an addition of organic solvents; L1.3 - L1 mortars which were surface-hydrophobised using low molecular alkyl-alkoxy-silane.

TABLE 1. **Composition of mortars with lightweight expanded clay aggregate**
TABELA 1. **Składniki zapraw z keramzytem**

Material	Symbol unit	L1	L2
Hydrophobic admixture	*Ah* [kg/m³]	-	5.1
Air entraining admixtures	*Aa* [l/m³]	1.2	-
Lightweight expanded clay aggregate 0.0÷2.0 mm	*LECA* [kg/m³]	610	610
Hydrated lime	*Hl* [kg/m³]	130	130
Portland cement CEM I 32.5 R	*Cm* [kg/m³]	170	164.9
Water	*W* [l/m³]	260	260

The hydrated lime complied with the requirements of PN-EN 459-1 and was characterized by an apparent density of 390-410 kg/m^3. The chemical composition of the lime is as follows: CaO - 95.5%, MgO - 0.5%, CO_2 - 2.1%, SO_3 - 0.1%, free water - 1.5%. The Portland cement CEM I 32.5R had the following technical parameters: a specific surface of 3985 cm^2/g, the beginning of binding 75 min, compressive strength after 2 days > 10 MPa, after 28 days > 32.5 MPa, loss on ignition 5.0% by weight of cement, volume stability < 10 mm. CEM I 32.5R was tested according to the Polish standards PN EN 197-1:2002 and PN-B-19707:2003. The properties of the LECA fraction of 0-2 mm used in this investigation are shown in Table 2.

TABLE 2. **Properties of lightweight expanded clay aggregate (LECA)**
TABELA 2. **Właściwości keramzytu**

Parameter	Symbol unit	Lightweight aggregate
Dry particle density	ρ [kg/m³]	2580
Apparent particle density	ρ_{ap} [kg/m³]	790
Apparent density	ρ_a [kg/m³]	510
Water absorption (of mass)	[%M]	14
Porosity	[%]	69
Thermal conductivity coefficient	λ [W/(m·K)]	0.20

In the L1 mixtures a complex plasticiser was used: plasticizing and air-entraining. It delays the setting time and is recommended for mortars and waterproof concrete as well as frost-resistant concrete. The plasticiser is the water salt solution of aliphatic amines and detergents with the density of 1.12÷1.15 g/cm^3 at 20°C. It makes it possible to reduce the water needed for making a mixture by approximately 10%, aerates, improves workability, retards the growth in strength in the initial period and considerably increases the final strength. The admixture was used in the amount of 0.4% by weight of cement.

Mineral waterproofing grout was used in the L2 mixtures. It is a highly cementitious waterproofing admixture for mortars with the following properties: water impermeable, strong adhesion to the substrate, resistant to water and frost, resistant to the effects of mechanical and chemical loads, vapour permeable. The characteristic data of the product are: water requirements - 20 to 21%, working time - 60 minutes, water absorption coefficient w_{24} (determined after 24 hours) < 0.1 kg/(m^2·h$^{0.5}$), water vapour diffusion μ < 200, compressive strength after 28 days - approximately 30 N/mm², tensile bending strength after 28 days - approximately 6 N/mm^2. The L1.1 mixture was hydrophobised using methyl silicone resin. It is a bicarbonate agent used without dilution, suitable for the hydrophobisation of exterior surfaces of walls, cement-lime plasters and porous building materials. The characteristic data of the preparation are: viscosity - 2.846 Pa·s·10^{-3}, surface tension - 24.30 N/m·10^{-3}, density - 0.82 g/cm^3, concentration of the active ingredient 11% [19]. The L1.2 samples were protected with a water-based emulsion of methyl silicone resin with an addition of organic solvents. It is used for water repellent treatment of the external surfaces of walls, cement-lime plasters and porous building materials such as concrete, silica and ceramic bricks, gypsum slabs and as a binder used in paints. The characteristic data of the agent are: dilution with water, colour - milky white, density at 20°C - approximately 1.00 g/ml, resin content - approximately 25%.

Low molecular alkyl-alkoxy-silane in organic solvents was used for the hydrophobisation of the L1.3 samples. It is a hydrophobising impregnation agent for porous, mineral building materials such as fair-faced brick masonry work, sand-lime brick, mineral renders, aerated concrete and light-weight concrete. It can be used for already hydrophobised surfaces. The characteristic data of the preparation are: dynamic viscosity at 20°C - 1.79 Pa·s·10^{-3}, density - 0.80 g/cm^3, siloxane content - approximately 7% by mass.

Sample preparation

Samples with the dimensions 40×40×40 mm were prepared on the basis of EN 196-7:2008. The mortar mixes were prepared in a laboratory in the following order: first the mix - one-third water mixed with LECA. Then cement, lime and admixtures were mixed with the remaining water. The mixture was first mixed for 4 min in a mixer and then placed in a mould in two layers. Each of the layers was properly compacted for 2 min on a jolting table. The top layer was aligned. The samples were cured in a moist atmosphere for 24 hours and then demoulded and marked and stored in a climatic chamber at 23.5°C and relative humidity of 73.5% for 21 days. For the measurements of thermal conductivity the following samples were used: 300×300×50 mm. The samples were demoulded after 72 hours and stored in the climatic chamber with the other samples.

Samples L1.1-1.3 before surface hydrophobisation were dried to a constant mass. The specimens were hydrophobised by immersion in the hydrophobic preparations for 10s. Then, all the samples were seasoned for the period of 7 days in laboratory conditions to start hydrolytic polycondensation.

Methods

Physical properties

According to EN 1936:2006, determination of the bulk density, density and total porosity were performed. In order to perform the test, three samples of mortars without a hydrophobic admixture were prepared with dimensions of 40×40×160 mm. The test was carried out in laboratory conditions at an ambient temperature of 20±2°C. The absorptivity test for mortars was carried out according to PN-EN 13755:2008. Research was conducted on four samples of each mortar (40×40×160 mm). The samples were dried before testing. Measurement of the water absorptivity of mortar by weight was performed after 1 and 14 days. In order to verify whether hydrophobisation not disturbs the diffusion of vapour and gas, vapour permeability tests of the mortars were carried out. After completion of the water absorption examination, the samples were dried with a cloth and left in laboratory conditions at a temperature of 20 ±5°C and a relative humidity of 60 ±5%, to continue the drying process. The measurements were conducted directly after having removed the samples from the container and after 1 and 14 days from commencement of the test. During that time the weight loss was determined, which showed the quantity of water which had evaporated during the process. The percentage of decrease in moisture was referred to as the moisture coefficient.

To determine thermal conductivity coefficient λ, a plate apparatus was used. For that purpose, three plates of each mortar type were prepared. The dimensions of each plate were as follows: 300×300×50 mm. The samples were dried until they reached a constant weight. Research was conducted on the samples when their moisture content was equal to 11÷12%. Only the L1 and L2 mortar without water-repellent surface, which affects the stabilized moisture level stabilized was analysed. Thanks to that, the influence of moisture on thermal conductivity could be established. In order to determine the thermal conductivity coefficient of the mortar, two temperatures were applied: 20°C for a heating plate and 0°C for a cooling plate. The average temperature was 10°C. The operating rules consist in letting a specific heat flow through the sample and measuring the temperatures which occurred at a determined heat flow on the surfaces which let the heat in or out.

Mechanical properties

The flexural strength of the mortars were determined according to EN 1015-11:1999. In this investigation, three rectangular mortar beams each with dimensions of 40×40×160 mm were used. Testing was performed after 28 days of sample curing. The samples were loaded with centrally placed force (3-point bending). The spacing of the supports was 100 mm. The load increase was set at 20 N/s. In this experiment, pieces of test specimens obtained just after the flexural strength test were used as a test specimen. The research was conducted according to EN 1015-11:1999 normative-compressive strength. Evaluation of the concrete grade was elaborated using a Controls compression tester within 3 MN after 28 days of maturation, when the samples gained the average compressive strength.

Frost resistance was determined using the direct method according to EN 12012:2007 and EN 13581:2004. Samples with the dimensions 40×40×160 mm were used. Standard and impregnated mortars with 1-3 preparations were tested for 50 cycles of frosting and thawing (F–T). Then, all the samples were dried to a constant mass and the mass loss was determined.

Resistance to salt crystallization was conducted according to standard EN 12370:2001. Six samples of each batch of mortars were used for the test. The dimensions of the samples were the following: 40×40×160 mm. After drying and weighing, the samples were immersed in a 14% solution of sodium sulphate dehydrate for the period of 2 h. The obtained results are presented in percent as the relative difference of mass in relation to the initial mass of the sample and the number of cycles till destruction, which meant a lack of resistance to salt crystallization.

RESULTS AND DISCUSSION

Physical and mechanical properties

The physical and mechanical properties of the thermal insulating mortars without a water-repellent surface adopted for the examination are shown in Table 3.

TABLE 3. **Physical and mechanical properties of heat-insulating mortars**
TABELA 3. **Fizyczne i mechaniczne właściwości zapraw ciepłochronnych**

Type of mortars/ Descriptive statistics		Apparent density [kg/m^3]	Density [kg/m^3]	Open porosity [%]	Total porosity [%]	Thermal conductivity coefficient - dry state [W/m^{2}K]	Thermal conductivity coefficient - 12% moisture [W/m^{2}K]	Compressive strength [MPa]	Flexural tensile strength [MPa]
L1	Mean	$1.00 \cdot 10^3$	$2.38 \cdot 10^3$	21.80	57.98	0.231	0.321	2.90	0.10
	Standard deviation	0.20	0.34	0.36	1.01	1.02	0.56	0.43	0.21
L2	Mean	$0.90 \cdot 10^3$	$2.36 \cdot 10^3$	20.90	57.63	0.223	0.303	4.00	0.11
	Standard deviation	0.11	0..23	2.12	1.14	1.98	0.44	0.93	0.86

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The cementitious waterproofing admixture causes a decrease in the apparent density and density of the L2 compared to the mortars with air-entraining admixtures (L1).

However, the addition caused an increase in compressive strength of the mortar by 27% for the L2 and an increase in flexural tensile strength by 11%. The thermal conductivity coefficient and open porosity were also smaller for the mortars with the cementitious waterproofing admixture (L2). In the case of the increase in the moisture of the material (in this test 12%), the thermal conductivity increased on average by about 27% for LECA.

The hydrophobisation efficiency specified by the absorptivity and water vapour diffusion ability after 1 and 14 days of the all samples is shown in Figures 1 and 2.

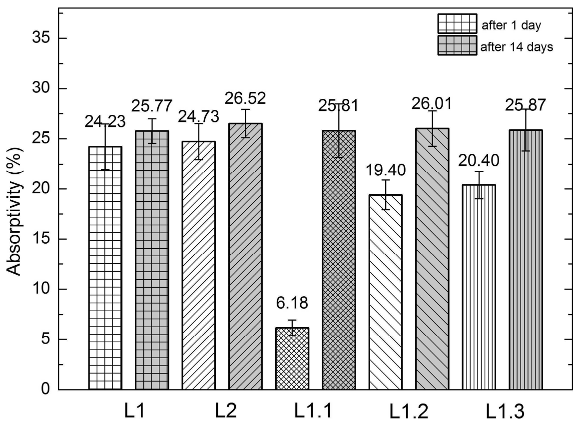

Fig. 1. Absorptivity of tested heat-insulating mortars

Rys. 1. Nasiąkliwość badanych zapraw ciepłochronnych

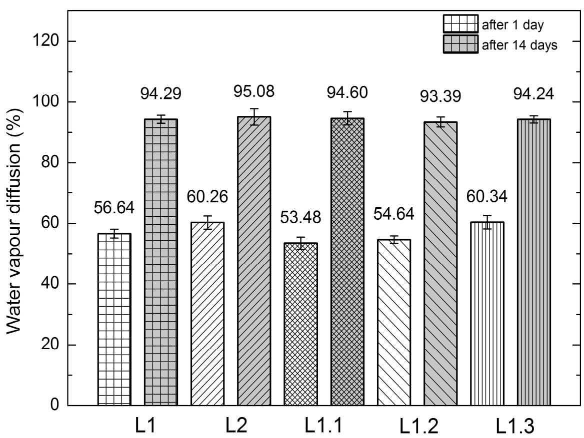

Fig. 2. Water vapour diffusion ability of tested heat-insulating mortars

Rys. 2. Zdolność dyfuzji pary wodnej badanych zapraw ciepłochronnych

In the case where the solid phase material is very light, such as the mortars with the lightweight clay aggregate, then it is normal that the absorption of the mass is larger than the open porosity determined in [%]. In the case of absorptivity bulk, it would be impossible for its value to exceed the open porosity (in Table 3). After 1 day of the study the effectiveness of hydrophobisation was as follows: L1.1 - 74.5%, L1.2 - 20% L1.3 - 15.8%. The best results were obtained by the methyl silicone resin (L1.1). The highest absorption after 14 days of testing was shown by the L2 mortar (26.52%), followed by L1.2 (26.20%), while the lowest absorption was demonstrated by the L1 mortar without an agent (25.77%). After 14 days in water the hydrophobisation treatment of the samples proved to be ineffective.

After the test, the water absorption was determined by the weight percentage decrease in moisture, as a moisture indicator of the mortar before and after hydrophobisation after 1 and 14 days of drying the samples (Fig. 2).

The percentage of decrease in humidity after 14 days for the tested samples (93.4÷95.08%) is roughly at the same level. The water evaporated the fastest from the L2 mortar with the hydrophobic admixture and the slowest from mortar L1.1 with air-entraining admixtures and alkyl-alkoxy-silane. Analysis of the results indicates that surface and weight hydrophobisation do not interfere with the diffusion of water vapour and gases.

The frost resistance of the heat-insulating mortars was referred to as the weight loss after 25 cycles of freezing-thawing. The resistance to salt crystallization of the mortars was defined as the loss of weight after 15 cycles of testing. The test results are shown in Table 4.

TABLE 4. **Average percentage of loss/increase in mass of heat-insulating mortars**

TABELA 4. **Średni procentowy ubytek/przyrost masy zapraw ciepłochronnych**

Type of testing	L1	L2	L1.1	L1.2	L1.3
	Average percentage loss (-)/increase (+) of mass				
Freezing-thawing	−1.6	−15.6	−0.7	−2.4	−7.7
Salt crystallization	0.9	1.5	−1.5	−1.7	−1.8

The hydrophobised mortars are characterized by an insignificant mass change due to freezing and thawing processes in the case of the methyl silicone resin (L1.1). This agent efficiently protected the mortars against frost corrosion. The low molecular alkyl - alkoxy - silanes oligomers in the organic solvents had a negative impact on the condition of the L1.3 samples causing a loss of 7.7%, which is shown in Figure 3. The figure presents the destruction of mortars with LECA after 25 cycles of freezing-thawing.

The first negative effect of varying temperatures appeared as cracks in the samples of mortar L2 after 11 test cycles. After 21 test cycles large mass losses in the L2 samples were observed, while in the L1 and L1.1 samples there were small weight losses and small cracks. After 25 cycles, the sample that showed the lowest frost resistance was the L2 whose weight loss was 15.6%. The aeration admixture resulted in an appropriate structure of the mortars (L1), so that the net capillary pores, which is a natural way to transport liquids inside the mortar was interrupted by equally distributed, very fine spherical air bubbles.

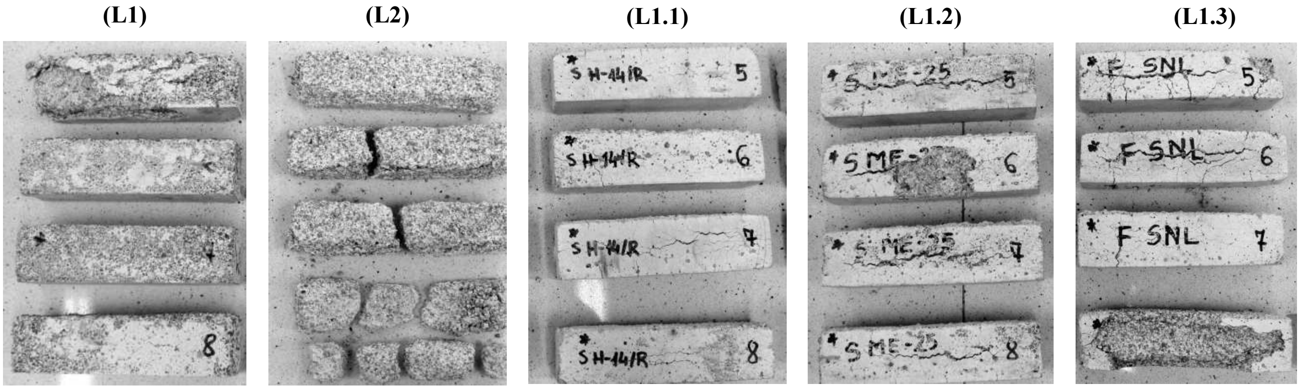

Fig. 3. Samples of heat-insulating mortar with LECA after 25 cycles of freezing - thawing

Rys. 3. Próbki zapraw ciepłochronnych z LECA po 25 cyklach mrożenia - odmrażania

The bubbles are difficult to saturate with water, acting as a buffer for freezing water, which during the change in state increases its volume. The mineral waterproofing grout had a negative impact on the condition of the mortars. The samples with methyl silicone resin (L1.1) are more frost resistant than the remaining samples. The resin with the highest molecular weight filled the open pores of the mortar. The surface is tight enough to effectively protect from frost.

During the salt crystallization test there were no significant changes in the surface of the standard samples (L1, L2). The samples showed very good resistance to the pressure of sodium sulphate crystallization. Figure 4 shows the appearance of the hydrophobic samples after determining the resistance to salt crystallization in the 14% solution of sodium sulphate.

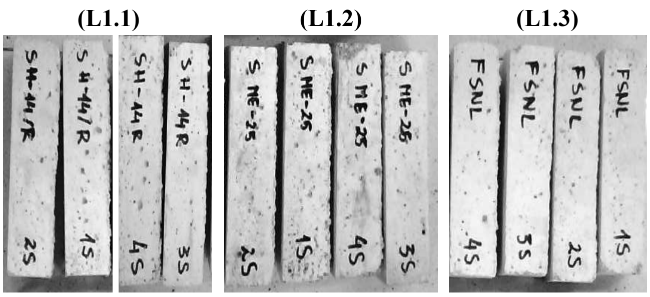

Fig. 4. Hydrophobic samples of heat-insulating mortar after 15 cycles of salt crystallization

Rys. 4. Próbki zhydrofobizowane zapraw ciepłochronnych po 15 cyklach krystalizacji soli

Organosilicon compounds have a negative influence on the chemical resistance of heat-insulating mortar with LECA. The mass loss of non-hydrophobic mortar was 1.7 times lower than L2 with the hydrophobic admixture. The mortars (L2) with the mineral waterproofing group have the highest increase in mass, which proves that crystallized salt is inside the samples.

For the hydrophobic mortars, correlations between the mass loss after frost and salt cycles was established (Fig. 5).

The polynomial relationship in the form of $ax^2 + bx + c$ seems to be the best fit function since the R^2 value is greater than 0.8805. A higher correlation coefficient value indicates that mass loss after F–T cycles has a strong relationship with the mass loss after salt crystallization. There is a clear grouping of the results depending on the type of agent in the mortars. The highest protection against sulphate and frost corrosion of the samples is provided by the methyl silicone resin from among all the investigated agents.

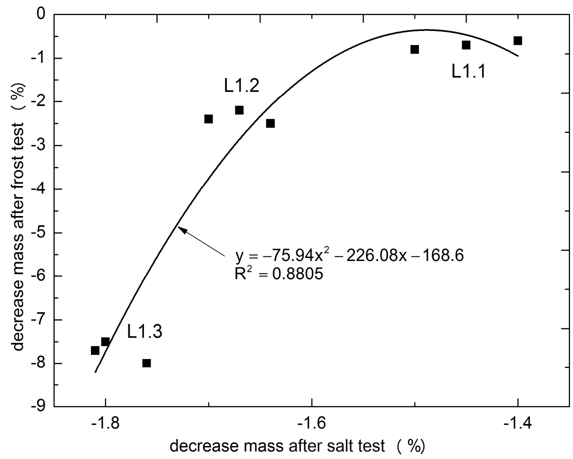

Fig. 5. Relationship between decrease in mass after frost and salt crystallization test

Rys. 5. Zależność pomiędzy ubytkiem masy po teście krystalizacji soli i mrozoodporności

SUMMARY

The article analyses the impact of sodium sulphate and frost corrosion on the state of hydrophobised heat-insulating mortar with the addition of expanded clay aggregate. The hydrophobic agents due to their chemical composition may react with the compounds contained in the impregnated material. The research results are also related to the tightness and porosity characteristics of the heat-insulating mortar structure. One of the significant factors guaranteeing the effectiveness of hydrophobising is the adhesion of the coatings to the material. As a result of water penetration through leaky coating and frost corrosion delamination at the interface between the material and the coating is possible. As analysed in the article, such a situation did not take place, the methyl silicone resin effectively secured the mortar from freezing, which proves its good adhesion to the material.

Based on the conducted study, the following final conclusions can be drawn:

- Hydrophobisation of the mortar mass slightly decreased the porosity of the mortar, and thus in an increase of 27% of its compressive strength. The admixture adversely affected the ability of the hydrophobic mortar - it achieved the opposite effect. As a result of hydrophobising the mass, the mortar samples decreased in density and had improved wettability.
- Despite the hydrophobisation of the surface, water penetrates into the material, but only slowly, and the formulations formed by the coating slow the absorption of water most effectively in the first day in constant contact of the material with water.
- In the case of mortars with LECA, the hydrophobic admixture limits the possibility of crystallized ice to move in the structure of the mortars, causing a reduction in their mass.
- The results of the salt crystallization test of the mortar in the case of mass hydrophobisation note that salt settles on the samples, in the other case, a decrease in the weight of the samples at a comparable level was observed. Hydrophobic and aeration admixtures significantly affect the thermal conductivity and the difference is mainly due to the difference in porosity of the compared materials. Poor protection of the mortar surface is probably due to the short time of saturating the sample in the preparation. The mortars were characterized by high porosity and water absorption, so in order to achieve better efficiency, extending the time of hydrophobisation would be advisable.
- The highest efficiency was obtained for the surface hydrophobised with the methyl silicone resin.

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