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THE IMPACT OF RECYCLED POLYMERS ON THE FEATURES OF MODIFIED SAND-LIME PRODUCTS

WPŁYW DODATKÓW W POSTACI REGRANULATÓW TWORZYW SZTUCZNYCH NA WŁAŚCIWOŚCI MODYFIKOWANYCH WYROBÓW WAPIENNO--PIASKOWYCH

A b s t r a c t

This paper summarizes the impact of various types of recycled polymers on the basic properties of silicate products. The results of compressive strength test, water absorption and bulk density as well as the structure of the material were analyzed.

Keywords: silicate products, recycled polymers, compressive strength, water absorption, bulk density

S t r e s z c z e n i e

W artykule przedstawiono wpływ różnych rodzajów tworzyw sztucznych pochodzących z recyklingu na podstawowe właściwości wyrobów silikatowych. Przeanalizowano wyniki badań wytrzymałości na ściskanie, nasiąkliwości, gęstości objętościowej oraz budowę strukturalną materiału.

Słowa kluczowe: wyroby silikatowe, recykling tworzyw sztucznych, wytrzymałość na ściskanie, nasiąkliwość, gęstość objętościowa

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1. Introduction

Sand-lime products, called silicates, are one of the most popular building materials used today. They are characterized by high compressive strength (basically between 15 and 25 MPa), good acoustic insulation, high dimensional accuracy and they also have heat absorbing qualities. They are non-combustible, durable, frost resistant, and what is more, cheaper than a ceramic brick. Another important aspect is the fact that traditional silicate products are completely natural. They are obtained by treating a mixture of sand (90%), lime (7%) and water (3%) in reactors, whereby lime slaking takes place. The mixture is then moistened and directed to a presses, where it is formed into bricks or blocks. The whole process takes place in autoclaves, by the direct action of steam at temperatures above 150°C under a pressure of 1.6 MPa, where the silica is combined with the lime to form insoluble calcium silicates. Hydrated calcium silicates arise mainly in the surface of quartz grains, joining sand grains with each other and filling free spaces between grains. The high strength of the products is hereby achieved [1].

Currently silicates enjoy growing interest, not only among investors and contractors, but also among scientists. Thanks to the use of specific additives to the sand-lime mass, shaping certain properties of resulting products is possible. Silicate elements with increased compressive strength may be suitable for building the walls of multi-storey objects and heavily loaded parts of buildings. According to PN-B-03-002:1999 [2], the use of silicates in humid environments with occurring frost (For example: basement walls) is allowed with appropriate protection against moisture. Nonetheless, silicate products are not as willingly used in the performance of underground walls, due to the fear of excessive moisture. By introducing certain modifications in the composition of the sand-lime mass, the absorption of sand-lime products may be reduced. Another direction of scientific research is to reduce the weight of silicate bricks and blocks through the use of lightweight fillers.

Test results of silicate products with basalt aggregate with a grain size of 2–4 mm are known. This addition results in a significant increase in compressive strength (which can reach nearly 50 MPa) with a simultaneous decrease in water absorption compared to the original silicate product. The addition of barium sulfate $BaSO_4$ with a grain size from 0 to 2 mm caused an increase in compressive strength by nearly 60% with an approximate 40% reduction in water absorption. It also has an impact on the silicate micro structure, due to new phases (such as xonotlite, tobermorite and CSH) which occur. Through the introduction of lithium silicate to the sand-lime mass a doubling of the compressive strength and reduction of water absorbtion by 20% were obtained. New chemical compounds are thus created [3]. Attempts to reduce bulk density and improve thermal insulation by adding light foamed glass granulate have also been tested. Despite of decrease in the strength, the product can still satisfy the requirements for silicate products [4, 5]. By introducing low density polystyrene (LDPE) to the silicate mass, products not only have a reduced density, but water absorption is also lower than in case of traditional sand-lime products. Addition of LDPE, however, causes a decrease in the compressive strength silicate elements [6]. An attempt to modify silicates with polymers with a density and hardness greater than LDPE has also been made. Using recycled plastics may provide new opportunities for waste management.

The essence of the study was to determine the effect of selected additives, in the form of recycled polymers on the physical and mechanical properties of modified silicate products.

2. Modification of sand-lime mass

In order to modify the properties of traditional silicate products, various types of recycled polymers, in the form of re granulate and regrind were added to the sand-lime mass. The following table (Table 1) shows the type and amount of additives used in each examined sample.

Table 1

The mass percent of individual additives in the sample.

Sample No.	Mass perecent in the sample [%]		
	HIPS	PP+PE	ABS
1	–	–	–
2	10	–	–
3	20	–	–
4	30	–	–
5	–	10	–
6	–	20	–
7	–	–	20

As can be seen in the table above, three types of polymers were tested: high impact polystyrene HIPS, a mix of polypropylene and polyethylene PP+PE and copolymer of acrylonitrile-butadiene-styrene ABS. The additives were selected on the basis of their properties. The basic criterion for determination of sample composition was to increase compressive strength while limiting water absorption and bulk density.

Sample number 1 contains only sand, lime and water. It was prepared in order to determine the effect of the additive on both the physical and mechanical properties of the modified silicate product.

In the sample denoted by number 2, 10% of sand-lime mass was replaced by white re granulate high impact polystyrene HIPS. In sample number 3 the amount of additive was doubled (to 20%). 30% of weight of sample number 4 which constitutes the same level of polymer as in the previous samples, but this time in the form of regrind – irregular blades. HIPS is a lightweight material with high impact, stiffness and crack resistance. Polystyrene HIPS contains caoutchouc bound physically or chemically. Accordingly to the share of the caoutchouc, physical and mechanical properties of the material vary. Products made of polystyrene HIPS are used, among other things, for making equipment cases, elements of lighting fixtures and packaging for the food industry.

Samples 5 and 6 contain respectively 10 and 20% of colored polypropylene and polyethylene regrind. Polypropylene has a very low water absorbency and permeability. It is characterized by a low density, high corrosion resistance and relatively high surface hardness. It is a thermoplastic material suitable for injection molding, extrusions and for the production of foils and fibers. Polypropylene products retain their shape to a temperature of 150°C. These properties depend largely on molecular weight, degree of polydispersity, tacticity and crystallinity. Polyethylene absorbs very little water, is low density compared to other materials and has a high impact strength even at low temperatures. Its low weight and excellent insulation properties also made it ideal for use as a raw material for the manufacture under water cable, currently used under the English Channel. During World War II polyethylene was used for the construction of lightweight aircraft radars.. Today polyethylene is a popular material used in the production of many everyday items, household products, insulation materials or foils.

In the case of sample number 7, 20% of its weight includes ABS re granulate, a hard material with high impact resistance, which has good insulating properties and is characterized by a high softening temperature. ABS has been used in the production of machinery and equipment housing, interior elements of vehicles, various types of containers, guttering, sanitary and hot water pipe work and elements of furniture [7].

3. Examination methodology and obtained results

The test samples were prepared under laboratory conditions and subjected to autoclaving at temperatures of 203°C and pressure of 1.6 MPa, during which a number of chemical reactions impacted on the properties of final product. The produced samples were subjected to hydrothermal treatments at the Silicate Production Plant in Ludynia. Each test was executed on 6 rectangular samples with dimension of 40 × 40 × 160 mm. The results are presented as the arithmetic mean of all samples.

3.1. Bulk density

Bulk density of the elements was determined mathematically by dividing the sample weight by its volume. The results presented in the chart below (Fig. 1) were averaged. Traditional sand-lime products are produced with bulk density with the range from 1200 to 1700 kg/m^3.

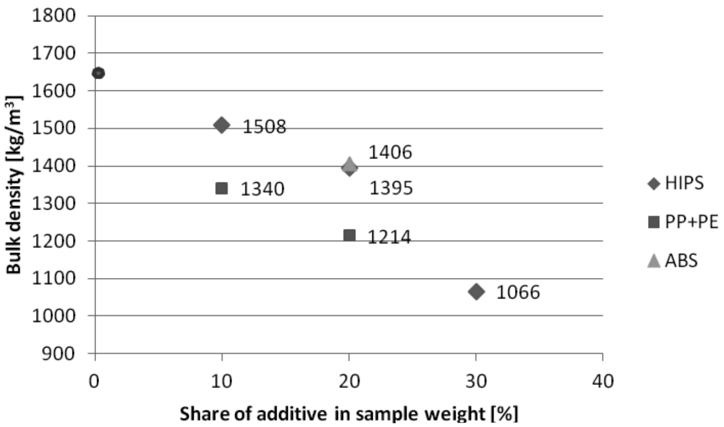

Fig. 1. Bulk density of modified silicate products

It can be seen that all additives caused a decrease in the bulk density of the silicate element, relative to the comparative sample 1. The most noticeable difference can be seen in the case of products modified by polypropylene and polyethylene regrind. This addition to the silicate mass 20% ABS regranulate and the same amount of PP+PE regrind results in a very similar outcome measurement of bulk density of the modified elements.

3.2. Compressive strength

The compressive strength of each sample was determined by subjecting it to the test on the press. In accordance with PN-EN 771-2 [8] declared by a manufacturer value of compressive strength of a silicate masonry unit, which should not be less than 5 MPa. All types of modified silicate samples meet the standard requirements for minimum compressive strength. Compressive strength value of all the samples, except the sample number 7 with ABS, was higher than the compressive strength of the comparative sample.

The highest average compressive strength obtained silicates with the addition of 20% HIPS re granulate, which reached a value greater than 50 MPa, so more than 2.5 times higher than traditional silicate product. After the addition of more of this material, but in the form of regrind, much lower compressive strength was received, but sill higher (by almost 70%) than strength of comparative sample. Samples with the addition of PP+PE mix are characterized by lower strength. These results are presented in the following graph (Fig. 2).

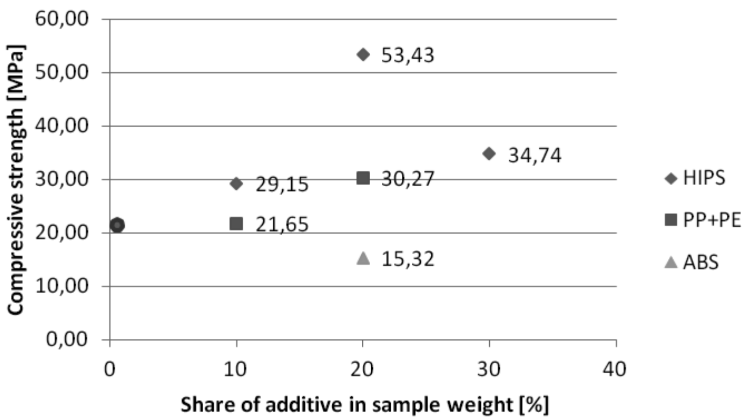

Fig. 2. Compressive strength of modified silicate products

3.3. Water absorption

The chart below (Fig. 3) shows the average results of water absorption of tested silicate samples. All modified sand-lime products are characterized by a significantly reduced water absorption compared to the reference sample.

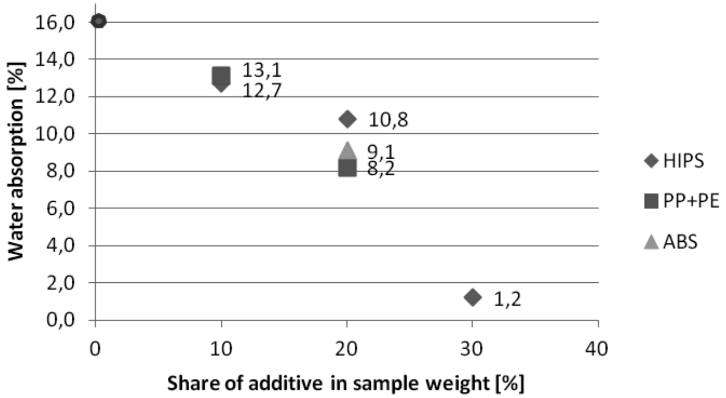

Fig. 3. Water absorption of modified silicate products.

Such a low water absorption of sample number 4, amounting slightly more than 1%, is caused by the addition of a large amount of plastic regrind into the silicate mass, which under the influence of hydrothermal treatment in an autoclave melted down and formed a dense structure.

3.3. Analysis of the structure.

After the hydrothermal treatment of the silicate mass, modified with polymers, a series of chemical reactions and changes in the internal structure took place. Microscopic photos of the samples which had the best results in the compressive strength test are shown below.

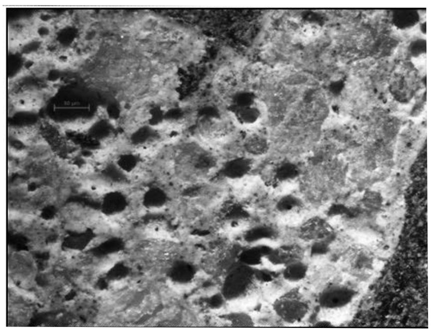

Fig. 4. Picture of the structure of sample 3. 20% HIPS

Figure 4 shows the rather compact structure of the material, with visible air pores. White granules of HIPS under the influence of high temperatures have partially melted and permanently merged with other ingredients. Similary to polystyrenme HIPS, colored flakes of polypropylene and polyethylene have been partially melted during autoclaving. However, in the sample with PP+PE regrind, there are numerous air pockets.

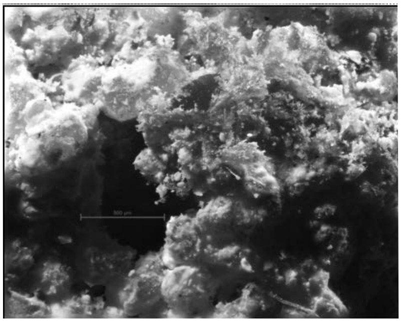

Fig. 5. Picture of the structure of sample 6, 20% PP+PE

4. Conclusions

Based on this research, it is possible to assess the impact of polymers on the properties of modified silicate products, regarding: bulk density, compressive strength and water absorption. The analysis of the study allows to formulate following conclusions:

a) Additives in the form of re granulate and regrind polymers have a significant influence on the properties of silicate products, which is dependent on the type of additive and its amount,
b) HIPS re granulate and mix of PP+PE regrind help to increase compressive strength and reduce the water absorption of silicate products,
c) The addition of ABS re granulate contributes to a large reduction in water absorption but also reduces the compressive strength of sand-lime elements,
d) Introduction to silicate products mentioned above polymers results in decrease in bulk density and therefore decrease in weight of the resulting product.

References

[1] Jasiczak J., *Praca zbiorowa pod kierunkiem prof. dr. hab. inż. Bogusława Stefańczyka, Budownictwo Ogólne, Tom I Materiały i Wyroby Budowlane*, Arkady, Warszawa 2005.

[2] PN-B-03002:1999, Konstrukcje murowe niezbrojone – Projektowanie i obliczanie.

[3] Dachowski R., Stępień A., *The impact of various additiveson the microsrtucture of silicate products*, Procedia Engineering Vol. 21, 2011, 1173-1178.

[4] Jasińska I.,Dachowski R., *Granulat szkła spienionego jako lekki dodatek masy silikatowej, Praca zbiorowa pod redakcją Joanny Bzówki pt. Badania doświadczalne i teoretyczne w budownictwie*, monografia, Wydawnictwo Politechniki Śląskiej, Gliwice 2012.

[5] Dachowski R., Jasińska I., *Wpływ dodatku szkła spienionego na porowatość wyrobów silikatowych*, Archiwum Instytutu Inżynierii Lądowej 2012.

[6] Jasińska I., Nowek M., *Wpływ modyfikacji wyrobów silikatowych dodatkiem w postaci LDPE na ich podstawowe właściwości użytkowe,* Konferencja Młodzi dla Techniki, Wybrane problemy naukowo-badawcze budownictwa i inżynierii środowiska, Płock 2013, 153-158.
[7] Pielichowski J., Puszyński A., *Chemia polimerów*, Wyd. Naukowo-Techniczne Teza, Kraków 2004
[8] PN-EN 771-2 Wymagania dotyczące elementów murowych. Część 2: Elementy murowe silikatowe.