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EXAMINATION OF SILICATE PRODUCTS IN ORDER TO IMPROVE THERMAL INSULATION

Abstract

The test results of ultimate compressive strength of silicate products containing exclay filler is presented. Silicate products have a high thermal conductivity λ. Their production is the most ecological technology among the manufacturing of wall elements. To improve the thermo-insulating characteristics of silicate products (parallel to preserving their ecologicness), the use of exclay filler is suggested. The tests of ultimate compressive strength were carried out for the wall silicate element (hollowed) with the size of 250x150x220 mm of 15th grade with 10%, 15% and 20% contents of exclay aggregate with 4-10 mm grading. The research helped to calculate the insulation index for the standard (N15) and insulating products.

Keywords: building material, silicate products, external walls, thermal insulation

1. Introduction

Silicate products are building material with a remarkable strength. They are extremely resistant to weather conditions. For this reason they are very popular in Scandinavia, Germany, France, Great Britain, Italy, Spain, Russia and Holland. They have a favourable effect on people and the environment. They are resistant to biological and chemical corrosion and they do not emit any solid or gas substances. Silicate products do not cause ionizing radiation and do not emit any toxic melting products. They have a low radioactive elements content [1-3].

Due to the high insulation index λ, lime-sand products cannot be used as a wall material for constructing one-layered external walls. According to standard requirements, the heat penetration index for one-layered walls amounts to $U< 0.5$ W/m^{2}K, and $U< 0.3$ W/m^{2}K for multilayered ones. It results in making two- or three-layered external walls. To insulate the walls, we commonly use such insulating materials as polystyrene foam or mineral wool. This technology however increases the cost of building the external walls because of the necessity to use the heat insulation.

The aim of the research is to improve the thermal insulation properties of silicate products. We have carried out the preliminary technical and economic analysis of various thermal insulation materials such as polystyrene, mineral wool, perlite, ceramsite, cellulose and others.

The best materials for silicate products are ceramsite and perlite. They are subject to this analysis. In this research we made use of ceramsite aggregate with a granulation of 4-10 mm. It is the most suitable material because of the two reasons:

- the appropriate grain environment of ceramsite aggregate in the external and internal walls, and
- vertically-hollowed silicate elements.

2. Experimental research

For the purpose of the semi-industrial experimental research, we prepared the silica brick elements. They were hollowed, the size of 250 x 150 x 220 mm, and grade 15. After performing the preliminary analysis, we used the ceramsite aggregate. Its granulation was 4-10 mm and 10%, 15% and 20% of its content in product mass. These elements were produced in Silicate Production Plants in Poland, in accordance with appropriate technological norms.

The various production options concerning the lime-sand wall elements were compared on the basis of existing technological and material solutions. Also, additional elements reducing the thermal conductivity ratio l were considered. And the characteristic features of this technological process(es) were taken into the account. To calculate the general effectiveness index of silicate products, including their thermal insulation Kef, we suggest the methodology based on the product of two indices, depending on their weight

$$K_{ef} = (K_{fin} * X) * (K_{\lambda} * (1 - X))$$

K_{ef} – effectiveness index asssociated with using energy-saving silicate products,
K_{fin} – financial ratio concerning the production of silicate products, zł/m^2,
K_{λ} – insulation index λ, W/(mK),
$X \in$ (0; 1) – weight multipliers of particular indices.

The equivalence of the above indices is X = 0.5

First, let us examine a 150 mm thick silicate block. To compare the insulation indices λ, we suggest producing N15 heat-insulating silicate products (150 mm thick) containing 10%, 15%, 20% of the ceramite aggregate (Table 1).

Table 1. The content of additional elements in heat-insulating and standard silicate products

Item	Type of wall silicate elements	Thickness of wall	Additional elements	Granulation	Ceramsite aggregate content
		m	–	mm	%
1.	N 15 (standard)	0.15	–	–	–
2.	N 15 (heat-insulating)	0.15	ceramsite	4-10	10, 15, 20

The formula for calculating the general effectiveness index of silicate products, including their thermal insulation Kef, enabled us to measure the effectiveness of a new heat-insulating silicate product. It was the N15 with a thickness of 150 mm and a 20% content of the ceramsite aggregate. The research helped to calculate the insulation index for the standard (N15) and insulating products. This comparison included the prime costs (material and labour, equipment, energy) of the production of standard and heat-insulating blocks. The effectiveness index for comparable products is presented in the table and on the graph (Fig. 1).

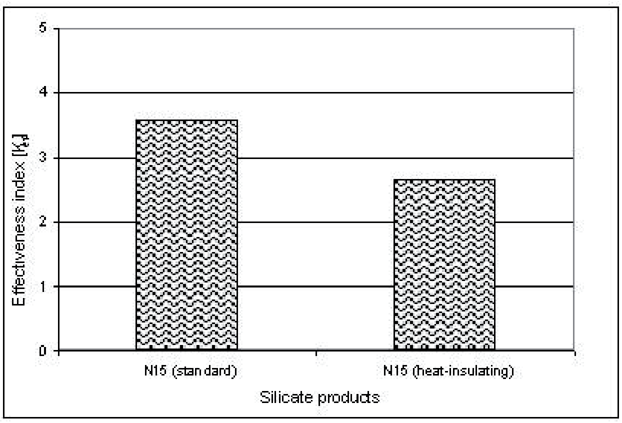

Fig. 1. Effectiveness index, including thermal insulation of silicate products

The average compressive strength of silicate products amounts to 15 MPa. The silicate products have the high insulation index. The thermal insulation for silicate products which are used to build three-layered external walls is ensured by the additional heating layer with a thickness of 10-15 cm. The various proportions of ceramsite improved the insulation index. However, when compared their strength, it brought up the opposite effect. The drop in the strength index went together with the drop in the insulation index λ (Fig. 2).

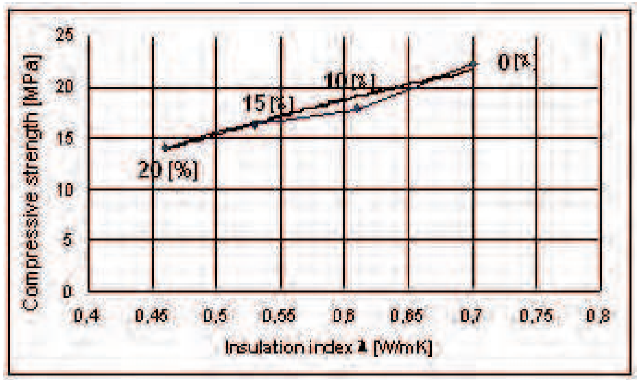

Fig. 2. Compressive strength vs. insulation index

The heat insulation depends predominantly on the density of a material. The products with a high degree of density usually have the high insulation index. This is clearly illustrated in the above figure. We found out, that by adding the ceramsite aggregate of a low bunk density to the content of traditional silicate products, the characteristic value of the insulation index λ was improved.

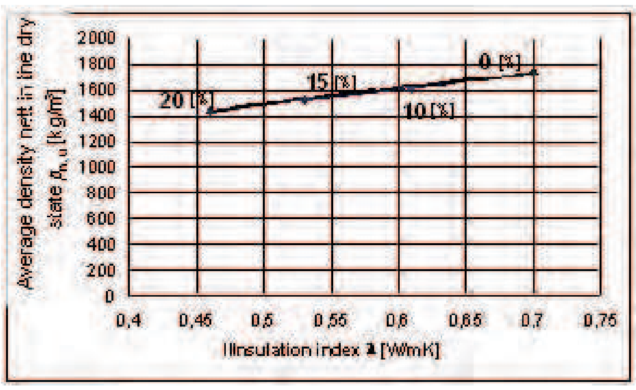

Fig. 3. Density nett in the dry state vs. insulation index

Results of the analyses are presented in the linear regression chart (Fig. 3). It shows that the aggregate has a positive impact on the thermal and moisture properties of the product.

The value of the heat insulation does not depend exclusively on changing the density of products. It also depends on the structure of materials, the type and size of pores and the humidity of elements.

The experiments suggest, that although ceramsite aggregate has a low level of water absorption and absorbability, its slightly worse in comparison with the remaining physical properties. When comparing the results of the capillary pull with the heat insulation index, we came into conclusion that the value of absorption drops along with a simultaneous insulation index growth. However, after exceeding the average insulation value, that is λ = 0.61 W/mK (cw for this value amounts to 15.55%), the two values begin to rise.

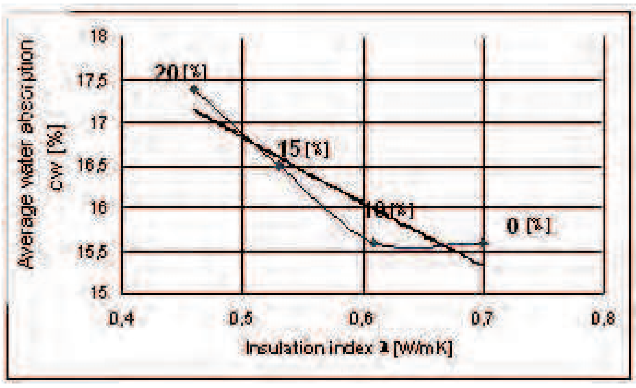

Fig. 4. Water absorption vs. insulation index

3. Conclusions

The following conclusions can be drawn:

1. To improve the thermal insulation of silicate products, we analyzed the following aggregates: ceramsite, perlite, polystyrene foam.
2. As a result of the technical and economic analysis based on numerous criteria we opted for using the ceramsite aggregate.
3. In cersamire aggregate, the drop in the compressive strength index went together with the drop in the insulation index λ.
4. It is necessary to measure the optimal content of the ceramsite aggregate for particular strength requirements of silicate products.
5. The effectiveness index associated with using silicate products, including their thermal insulation for a new heat-insulating and the ceramsite-based silicate, fell 25% in comparison with the standard product of a 20% aggregate content.

References

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BADANIA WYROBÓW SILIKATOWYCH W KIERUNKU POPRAWY IZOLACYJNOŚCI TERMICZNEJ

1. Wstęp

Wyroby silikatowe są materiałem konstrukcyjnym o znacznej wytrzymałości. Charakteryzuje je wysoka odporność na działanie czynników atmosferycznych. Wyroby wapienno-piaskowe nie mogą stanowić materiału ściennego dla wykonawstwa jednowarstwowych murów zewnętrznych, w związku z wysokim współczynnikiem przewodzenia ciepła λ. Zgodnie z wymogami normowymi współczynnik przenikania ciepła dla ścian jednowarstwowych wynosi $U< 0,5$ W/m^{2}K, a dla wielowarstwowych $U< 0,3$ W/m^{2}K.

2. Zakres i metodyka badań

Celem badań jest polepszenie właściwości termoizolacyjnych wyrobów silikatowych. Dokonano wstępnej analizy techniczno-ekonomicznej różnorodnych materiałów termoizolacyjnych, tj. polistyrenu, wełny mineralnej, wełny szklanej, perlitu, keramzytu, celulozy i innych.

Najbardziej korzystnymi okazały się, dla analizowanych wyrobów silikatowych: keramzyt i perlit. Po wstępnej analizie przyjęto w charakterze wypełniacza kruszywo keramzytowe o uziarnieniu 4-10 mm z 10%, 15% i 20% zawartością jego w masie wyrobu. Za bazę wyjściową przyjęto bloczek silikatowy o grubości 150 mm. Dla porównania współczynników przewodzenia ciepła l, zaproponowano produkcję wyrobów silikatowych N15 termoizolacyjnych o grubości 150 mm z zawartością dodatków w postaci kruszywa keramzytowego w ilości 10%, 15% i 20%. Określono także wytrzymałość na ściskanie wyrobów silikatowych oraz średnią gęstość netto w stanie suchym i średnią wartość absorpcji wody.

3. Podsumowanie

Po przeprowadzonych badaniach eksperymentalnych można wyciągnąć następujące wnioski:

1. W celu poprawy izolacyjności termicznej wyrobów silikatowych przeanalizowano następujące wypełniacze: keramzyt, perlit, styropian.
2. Po przeprowadzeniu wielokryterialnej analizy techniczno-ekonomicznej do badań eksperymentalnych wybrano wypełniacz w postaci kruszywa keramzytowego.
3. Zmniejszeniu wytrzymałości na ściskanie towarzyszył jednoczesny spadek współczynnika przewodzenia ciepła λ. Dla konkretnej żądanej klasy wytrzymałości wyrobu silikatowego należy określić optymalną zawartość wypełniacza keramzytowego.
4. Wskaźnik efektywności stosowania wyrobów silikatowych przy uwzględnieniu ich izolacyjności termicznej dla nowowprowadzanego silikatu termoizolacyjnego na bazie wypełniacza keramzytowego został zmniejszony o około 25% w porównaniu z wyrobem N15, przy przyjętej zawartości wypełniacza w ilości 20%.