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The Use of Waste Materials in the Construction Industry

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Abstract

Waste materials are a major environmental problem, which is a threat to the environment. It is important to reuse these materials and dispose of them. Waste can be used in the construction industry in two ways: by reusing (reuse components) and recycling (processing waste into raw materials used in the production of building materials). The paper presents my own research using substrates resulting from the processing of waste: foam glass and high-impact polystyrene and the possibility of their use as modifiers composition of basic construction materials. Glass foam is made from glass cullet. It has many advantages, positive effect on the adsorption of sound and workability. Due to the spherical shape and low density it is used as an ultra-light filler. The second addition is High Impact Polystyrene (High Impact Polystyrene - HIPS for short) which is a butadiene rubber modified polystyrene. With the change amount of the rubber mechanical and physical properties of the material are also changed, for example, by increasing the toughness of HIPS. The article presents a critical review of the literature on changes in the composition of traditional building materials on the example of cellular concrete, cement and products of sand - lime. The paper presents my own research and detailed analysis of them. The aim of the study was to determine the impact of additives on the parameters of the physical and mechanical properties and microstructure of the newly created materials compared to their traditional counterparts. The analysis has been subjected to the results of my own research: compressive strength, water absorption, bulk density and construction of structural material. The results are presented in the form of tables and graphs.

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1. Introduction

Mortar is a mixture of a binder with fine grain aggregate and the mixing liquid - it has been used in construction for thousands of years [1]. Thanks to the mechanized production, refined technology and low cost of material, mortars are a popular building material [2]. Mortars are commonly used in traditional form and with additives and admixtures improving their performance. Many modifications and studies of this material shows its new features.

The aim of the study is to determine the effect of selected additives from recycled plastics on physical and mechanical properties of modified cement mortars. Due to their interesting properties, selected additives are: high impact polystyrene regranulate (HIPS) and foamed glass granules.

2. Modification with high impact polystyrene and foamed glass

All High impact polystyrene regranulate is a secondary product [3]. It is a butadiene rubber modified polystyrene (Fig.1a). With the change amount of the rubber, mechanical and physical properties of material are changed – including the increase of the impact strength of HIPS regrind [4]. HIPS is used in many industries, for example: food industry (food packaging), furniture industry (furniture to hospitals), toy industry [5].

Foamed glass (its trade name is poraver) is made from glass cullet (Fig.1b). It has numerous applications, for example it is an ultralight extender, it improves the sound absorption, and its spherical shape has a positive effect on the workability of the mortar [6]. This additive is used for the production of lightweight building blocks - thanks to their porous structure, blocks have excellent thermal insulation, and sound insulation [7].

Fig. 1. (a) high impact polystyrene granulates; (b) foam glass granules.

The literature describes the results of the tests of sand-lime products with the addition of high-impact polystyrene [8]. This additive resulted in a significant increase in compressive strength, which reached almost 50 MPa. Simultaneously, compared to traditional silicate product, adsorption of modified products is reduced.

The preliminary tests of the influence of high impact polystyrene on autoclaved aerated concrete are known [9]. They show that the use of regrind HIPS, contributed to a slight increase in the compressive strength of these products. In the literature there are also attempts to reduce bulk density of the silicate blocks and improve their thermal insulation properties by the use of an additive in the form of foamed glass granules [10]. Despite a decrease in the compressive strength of modified materials, they still fulfil the standard requirements.

3. Methodology

To perform the experiments orthogonal compositional plan type 3k (from k = 2), a full 2-factorial design experiment has been adopted. Rectangular samples were prepared with dimensions 40x40x160 mm. The series of 9 samples have been made, which contain different amount of additives (from 5% to 25% by weight relative to cement), furthermore a single series without additives for comparative purposes. For each of interdependence, six parallel tests have been performed. Samples were taken in the ratio of cement: sand of 1:3, water/cement ratio height is W/C = 0.56. The detailed composition of the samples is presented in Table 1.

Tab.1. The composition of samples.

Ingredients/Number	P1	P2	P3	P4	P5	P6	P7	P8	P9	N
Cement [g]	450	450	450	450	450	450	450	450	450	450
HIPS [g]	22.5	22.5	22.5	67.5	67.5	67.5	112.5	112.5	112.5	-
Foamed glass [g]	22.5	67.5	112.5	22.5	67.5	112.5	22.5	67.5	112.5	-
Sand [g]	1350	1350	1350	1350	1350	1350	1350	1350	1350	1350
Water [g]	252	252	252	252	252	252	252	252	252	252

Properly prepared mortar was placed in three-part forms, and then compacted. The samples were placed in the dark place for 24 hours, after that time they were disassembled and subjected to a water bath where they matured for further 28 days. Thereby a good care of the material was ensured and the bar did not lose water needed to hydrate the cement. Due to the properties of used additives: cellular glass (good thermal and acoustic insulation) and high-impact polystyrene (high impact resistance), tests were carried out for the use of cement mortar as underlay flooring. The samples have been subjected to numerous tests, including: bulk density of fresh and hardened mortar, water absorption, flexural strength and compressive strength.

4. Performed tests and obtained results

4.1. The bulk density

The results of testing the bulk density of the materials showed that with the increase of additive content, the bulk density is decreased. In addition, the impact on the decrease in density is greater for foam glass granulate than for HIPS - which is associated with the difference in the density of additives (Fig.2).

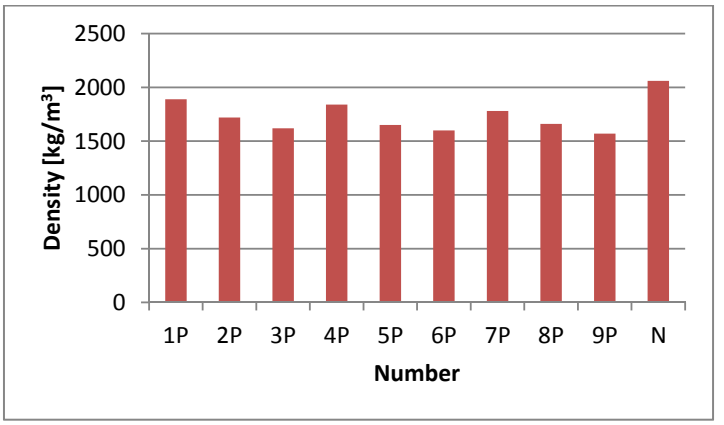

Fig. 2. The results of the density.

4.2. Absorbability

The absorbability is inversely proportional to the bulk density. Glass foam is a lightweight additive, which significantly fills the sample and lowers the weight but increases porosity. A large amount of this supplement prevents particles from being well surrounded by cement paste, and a fresh mortar is relatively "dry". Figure 3 shows that with the increase the amount of additive foam glass, water absorption is also increased.

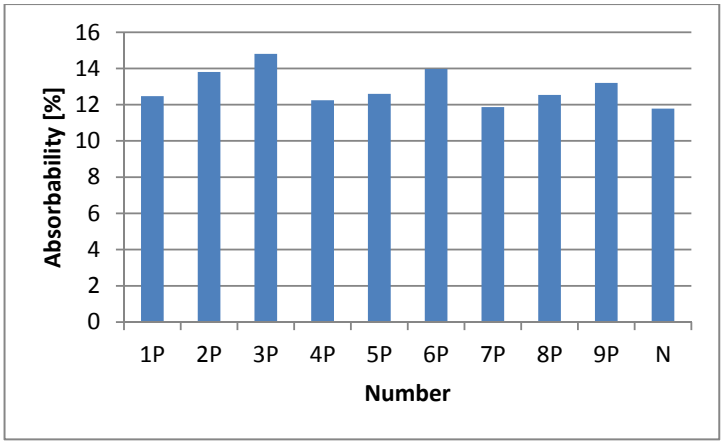

Fig. 3. The results of the water absorption.

4.3. Flexural and compressive strength

In proportion to the growth of density, the compressive strength of hardened mortar increases (Fig.4). However, with the decrease in bulk density, the thermal insulation of materials increases. Analysing the results of bending strength and compressive strength it can be seen that with the increase in the amount of foamed glass, strength decreases, but the regrind HIPS improves the compressive strength up to 15%. This allows to conclude that high-impact polystyrene has a beneficial effect on the studied traits.

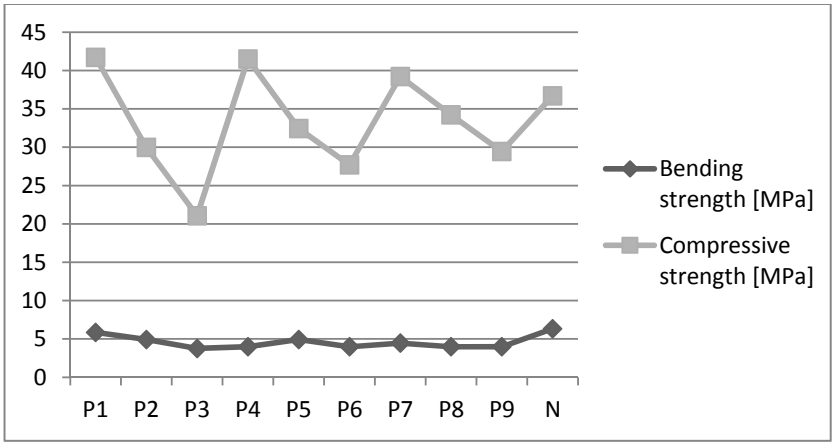

Fig. 4. The results of bending strength and compressive strength.

Based on the study, conclusions about the effect of the additives on the properties of mortars have been drawn. The graph generated by STATISTICA 12.0 software shows that the highest compressive strength can be reached by the samples with high-impact polystyrene content of 90 g (19% based on the weight of cement). A sample of this mixture reaches a strength exceeding 40 MPa (Fig. 5). Despite the differences in the compressive strength (depending on the amount of additives used), all samples reached values higher than the minimum from PN - EN 13813 [11]. In the abovementioned standard the minimum compressive strength is specified as equal to 5 MPa class C5.

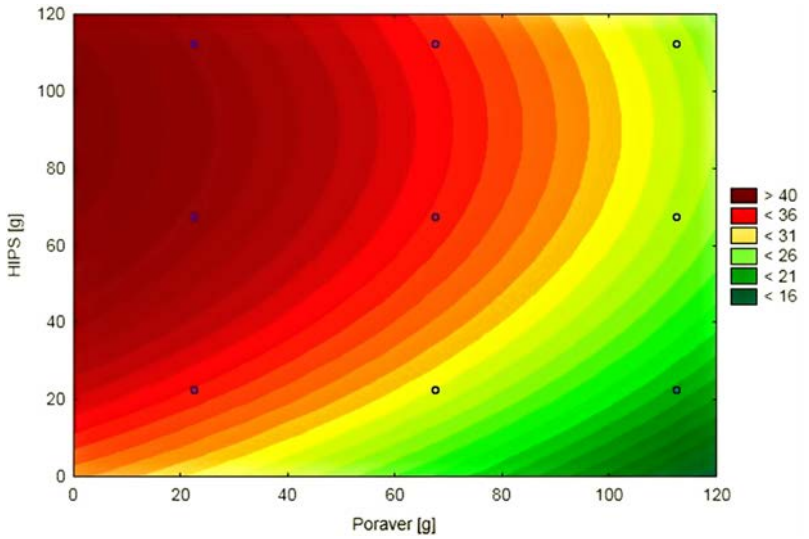

Fig. 5. The dependence of the compressive strength on the number of applied additives.

5. Conclusions

Based on the studies of modified cement mortars, we can assess the effect of the additives on properties such as bulk density, flexural strength, compressive strength and water absorption. As a result of the analysis of the research, the following conclusions can be drawn up:

1. Additives in the form of plastic raw materials have a significant influence on the properties of the cement mortars, which is dependent on the type of additive and the amount thereof.
2. The addition of regrind HIPS improves the compressive strength and does not have a significant impact on the change of absorption.
3. The addition of foamed glass contributes to the absorption of modified products, and simultaneously it reduces the compressive strength of these products.
4. Application of the plastic as an ingredient in cement mortars results in a decrease in bulk density, and consequently, it reduces the weight of the finished component.
5. Using HIPS regrind and foamed glass granulate can be considered as a way of utilization of this waste.

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