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POSSIBILITY OF USING EXPANDED PERLITE AS TEXTURISING AGGREGATE IN LIGHTWEIGHT POLYMER PLASTERS – IMPACT ON THERMAL AND MECHANICAL PROPERTIES OF COATING

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ABSTRACT

The final form of an external wall is made of many layers of materials. Each of them is important from the point of view of its properties. This work focusses on the possibility of modifying the thermal insulation properties of the finishing layer of the facade, the polymer plaster. To reduce the heat conduction coefficient, the standard marble texture aggregate was replaced with a light filler, expanded perlite. It is a highly porous material obtained due to the expansion process of natural volcanic rock. However, its use in building materials is associated with many complications resulting from its low mechanical properties and high water absorption. In this work, the appropriate selection of light fillers allowed the thermal conductivity coefficient to be reduced to as low as 0.125 W/mK. This value is six times lower than the reference sample. This was also accompanied by changes in the coating's impact resistance and adhesion to the substrate. The addition of expanded perlite significantly contributed to the deterioration of these parameters. Therefore, the amount of expanded perlite in the plaster recipe requires optimization to a level that maintains the necessary functional properties of the coating.

KEYWORDS: polymer plaster, lightweight fillers, expanded perlite, thermal insulation materials

INTRODUCTION

Facade coatings are an important element of every building. They play an important function in protecting building materials from external factors, transporting moisture, and are the last layer of the ETICS (External Thermal Insulation Composite System) pour-free insulation system. Due to the small thickness of the layer (1-2 mm), its role in thermal insulation is often ignored. However, considering rising energy prices and the emphasis on sustainable construction, this approach must change. By

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achieving extremely low values of the thermal conductivity coefficient, even with thin layers of material, the difference can be noticeable.

A popular type of facade coating is polymer plasters. They exceed the properties of mineral materials in terms of their strength and resistance to external conditions, as well as aesthetic values. At the same time, they are known for their great possibilities in terms of parameter modification. They contain several fillers with various physical and chemical properties. Fine and textured aggregate should be distinguished. Work [1] already focused on the possibility of using light fillers in the form of glass microspheres as part of the fine filling aggregate, thus achieving significant improvement in the thermal insulation of the coating. The present study is a continuation of considerations regarding the possibility of modifying the composition of the textured aggregate to further improve the thermal insulation properties of the coating.

When introducing a specific lightweight filler into plaster compositions, several factors must be carefully evaluated. They include the physical and functional properties of the filler, economic considerations, and material availability. The type and quantity of filler should be carefully selected to minimize any negative impact on other material properties. Scientific studies have shown promising results regarding the use of lightweight fillers in building materials such as expanded perlite [2,3], expanded glass [4], expanded polystyrene beads [5], and shale [6]. Expanded perlite has been a longstanding focus of interest for researchers in the field of building materials.

Perlite itself is a material of natural origin, a siliceous volcanic rock. Its specific feature is the expansion that it undergoes when heated to a temperature of 900-1200°C. Its volume increases then up to twenty times [7]. As a result of this process, the perlite particles become extremely light owing to their high porosity. This also gives them high thermal insulation properties [8]. Several benefits of the participation of expanded perlite in the matrix of inorganic building materials have been demonstrated. They include improving mass workability [9], reducing shrinkage, lowering the unit density, lowering the thermal conductivity coefficient, improving acoustic insulation, and enhancing fire resistance [10]. Cement producers also indicate that expanded perlite is needed to reduce CO_2 emissions. It partially replaces the limestone and sand used to produce cement. The disadvantages of utilising expanded perlite in building materials include, first, a decrease in mechanical strength. In addition, water absorption grows because of increased porosity [11].

Most of the conducted research is related to mineral building materials. The aim of the study is to determine how the addition of expanded perlite affects the parameters of the polymer plaster. An attempt was also made to determine whether light thermal insulation plaster based on an acrylic binder can meet the requirements for market products.

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CHARACTERISTICS OF SAMPLES AND MATERIALS

This study uses an acrylic resin binder with increased thermal insulation prepared in earlier stages of the project. The fine fill aggregate utilised to produce the mass contained 14.2% glass microspheres by volume. The specification of the mass without texturing aggregates is presented in work [1]. In this study, the work on increasing the thermal insulation of the plaster was continued by introducing expanded perlite into the mass, partially replacing the classic marble aggregate. Table 1 shows the basic characteristics of the texturing aggregates used in this study - expanded perlite and marble aggregate.

Table 1. Characteristics of used materials

	Expanded perlite	**Marble aggregate**
Bulk density [g/cm^3]	0.147	2.85
Granulation [mm]	1.5-2.0	1.0-2.0

Textured aggregate constituted 60% of the plaster mass by volume. The marble aggregate was replaced with expanded perlite in the volume fractions presented in Table 2.

Table 2. Share of expanded perlite in texture fillers

	share of expanded perlite [vol.%]	**share of marble aggregate [vol.%]**
Sample 1	0	100
Sample 2	50	50
Sample 3	75	25
Sample 4	100	0

RESEARCH METHODS

Density

The density of the obtained plaster masses was determined by applying the mass to a mould of known dimensions. The mass was left to dry at room temperature until a constant mass was obtained. After drying, the sample was weighed and the density of the material was calculated based on the knowledge of the mould volume.

Thermal conductivity

Samples to measure the thermal conductivity coefficient were placed in round moulds with a diameter of 60 mm and a height of 10 mm. The samples were applied in three layers, waiting 2 days

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between each layer. After drying, the samples were sanded to obtain a smooth surface. The samples were left to season for 14 days under 50% humidity and a temperature of 20 +/-2°C. The thermal conductivity coefficient of the plaster masses was measured by means of a TA Instruments FOX 50 apparatus. Measurements were carried out for a temperature gradient of 5-15°C.

Impact resistance

The plaster impact resistance test was conducted based on the analysis of hard body impact resistance and puncture resistance. The test material was prepared by applying plaster to a primed polystyrene substrate (according to the intended use of the plaster in the ETICS insulation system). The plaster was then seasoned under normal conditions. The seasoning period was 4 weeks. The test itself was performed using a steel ball weighing 1 kg, which was dropped onto the plaster from two different heights, obtaining impact forces of 3 J and 10 J, respectively. Based on the results, the researched masses could be classified into 3 use categories according to EAD 040083-00-0404. The guidelines are presented in Table 3.

Table 3. Requirements of plaster use categories in terms of impact resistance

Categories	**Recommended application**	**Test results**	
		Hard body impact 3 J	**Hard body impact 10 J**
I	Area directly accessible from ground level and exposed to hard body impact	no perforation	no perforation
II	Area exposed to impact from thrown or kicked objects, but due to its public location and height, the degree of this exposure is limited	no damage	no perforation
III	Area with low probability of being damaged by simple human impact or by thrown or kicked object.	no perforation	-

Adhesion to mineral substrate

The plasters were applied to a primed mineral substrate (concrete slabs) and left to dry. The samples were seasoned for 14 days at 50% humidity and a temperature of 20+/-2°C. After that time, steel discs were glued to the plaster surface with epoxy glue. Then they were torn off using the pull-off technique and the maximum tension force was measured. The measured value was the maximum tension force before sample detachment.

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RESULTS

Density

Expanded perlite is a material characterised by high porosity, and consequently, low volumetric weight. Due to the large differences in the density of perlite and marble aggregate, a reduction in the weight of the entire plaster mass was expected. Figure 1 shows the density values determined for individual samples.

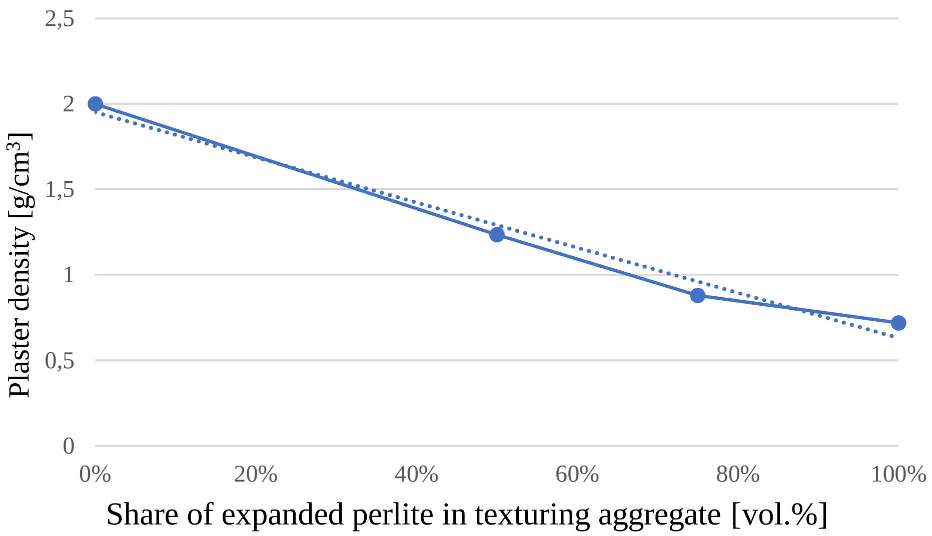

Figure 1. Density results of plaster samples with different expanded perlite contents

The research results confirmed the assumptions. The introduction of a light filler into the plaster mass contributed to a significant reduction in the mass weight. The density of the plaster containing only expanded perlite was more than twice that of the plaster with only marble aggregate. The mass change as a consequence of the filler replacement slightly deviated from the ideal linear relationship.

Thermal conductivity

The addition of a high porosity material contributed to reducing the total weight of the plaster mass. It was expected that the presence of numerous closed air bubbles would also contribute to improving the thermal insulation of the material. The results of the thermal conductivity coefficient measurements are presented in Figure 2.

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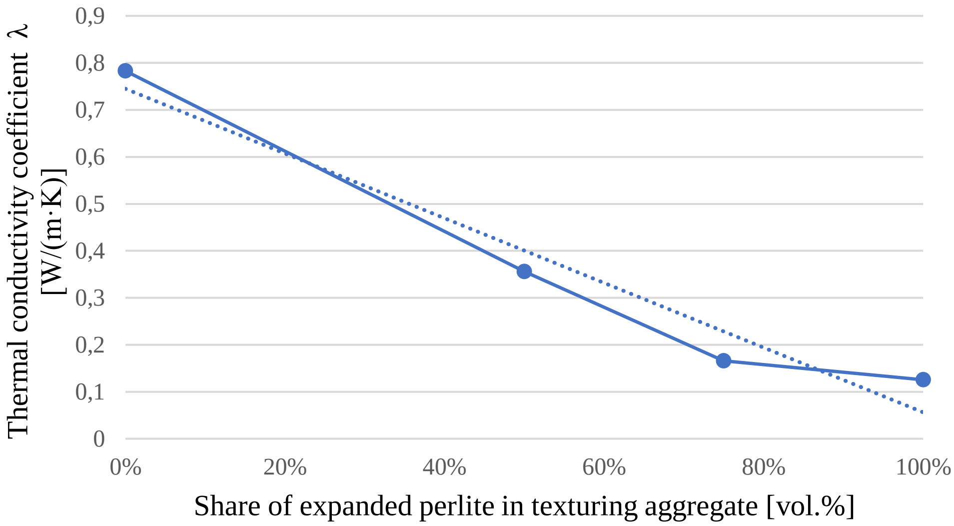

Figure 2. Thermal conductivity coefficient determined for samples with different percentages of expanded perlite

The presented relationship shows the significant impact of the light filler on the thermal insulation properties of the plaster mass. The sample in which perlite constituted 100% of the texture filler had a thermal conductivity coefficient up to six times lower than the sample with the marble aggregate. It should also be noted that as in the case of measurements of the density of the plaster masses, the relationship presented in the graph deviates from the linear relationship. The reason for this phenomenon may be the uncontrolled presence of air bubbles in the plaster binder mass. When a fillers with a large surface area are introduced into the mass, a significant amount of air trapped in the open pores is simultaneously introduced. Depending on the consistency of the mass, some of this air will escape to the surface. The remaining part will remain trapped in the mass. Thus, it may additionally contribute to changing the parameters of the plaster mass.

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Impact resistance

Table 4 displays the results obtained when testing the plaster samples for impact resistance. The results were then related to the impact resistance categories of ETICS.

Table 4. Impact resistance test results

Sample	Type of damage	Hard body impact 3J	Hard body impact 10 J	Impact resistance category
1	diameter of impact [mm]	-	40	I
	presence of cracks	no	yes	
	presence of perforation	no	no	
2	diameter of impact [mm]	22	55	III
	presence of cracks	yes	yes	
	presence of perforation	no	no	
3	diameter of impact [mm]	25	45	III
	presence of cracks	yes	yes	
	presence of perforation	no	yes	
4	diameter of impact [mm]	35	55	III
	presence of cracks	yes	yes	
	presence of perforation	no	yes	

The conducted tests revealed significant differences between the plasters containing perlite as part of the texture aggregate and the reference sample. The initial plaster mass made with standard marble aggregate did not exhibit any damage when tested with the impact force of 3 J. Upon impact of 10 J, it did not penetrate the thermal insulation material either, but cracks appeared to spread out at the point of impact. Such results allow the plaster to be assigned to the most demanding use category, I.

In the case of all the plasters containing the expanded perlite, damage to the coating was already observed in the event of impact with the force of 3 J; cracks appeared on all the samples. With the increasing share of light filler, a larger dent diameter was observed. All the plaster samples containing expanded perlite were destroyed during impact with the force of 10 J. The samples containing 100% and 75% additionally penetrated the thermal insulation material. The diameter of the dents ranged from 45-55 mm. Greater uniformity in the diameter of the dents may be due to the limitation of the diameter of the ball employed during the test. The obtained results allow the conclusion to be made that the light plasters analysed in this study containing an admixture of expanded perlite meet the requirements of category III.

Interesting results were obtained for the sample containing only expanded perlite, for which, in addition to standard coating damage, a loss of structure resulting from crushing of the perlite aggregate

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was observed. This proves the low impact resistance of the filler itself. Photo 1 shows the coating after impact.

Photo 1. Coating damage after hard body impact

Adhesion to mineral substrates

The replacement of the marble aggregate with expanded perlite had a significant impact on the adhesion of the plaster mass to the substrate. Figure 3 presents the average values of the maximum breaking stress. Measurement of each mass was repeated three times.

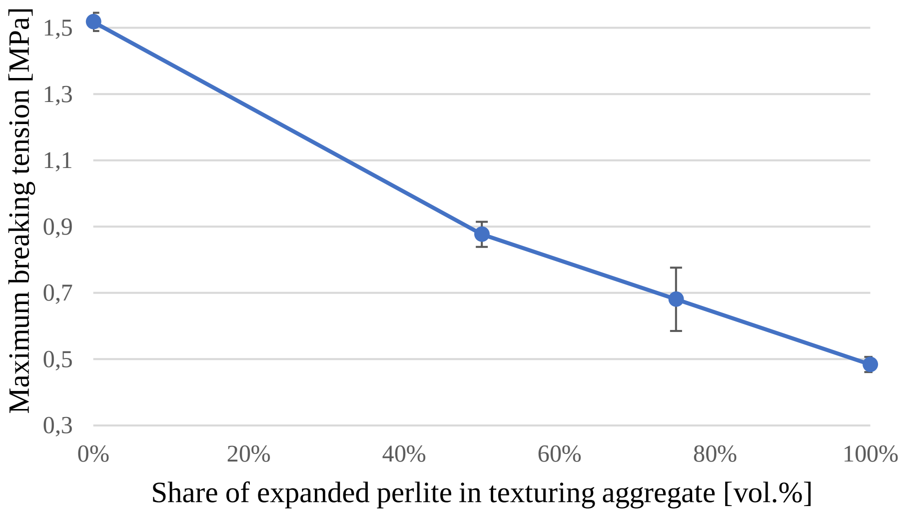

Figure 3. Results of adhesion of samples to mineral substrate depending on content of expanded perlite

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Plaster using only expanded perlite detached from the substrate at a stress three times lower (0.45 MPa) than the plaster with the standard aggregate (1.51 MPa). For the remaining samples, a proportional decrease in adhesion was observed with the increasing amount of expanded perlite admixture. The reasons for this phenomenon can be found in the reduced strength of the investigated fillers. The wettability of the substrate could also have deteriorated significantly as a result of replacing the aggregate with one with a greater surface area (open porosity of perlite). The observed effect could also be an indirect result of the consistency and rheology of the mass, which made it penetrate significantly worse into the porosity of the substrate.

CONCLUSIONS

The research carried out in this study confirmed the effectiveness of the addition of expanded perlite as a filler, which has a positive effect on the thermal insulation properties of the material. Complete replacement of the fracturing aggregate in the plaster contributed to obtaining a coating with a heat conduction coefficient of up to 6 times lower. The accompanying effect was a significant reduction in the weight of the entire plaster mass, which will certainly have a positive impact on aspects related to the application of the mass as an element of the ETICS system.

The results in terms of improving the thermal insulation of polymer plaster are consistent with the results of research on the use of expanded perlite in other types of building materials. Similarly, the influence of expanded perlite on the strength parameters of the plaster was also noticed. Expanded perlite is a material characterised by high brittleness. This study demonstrates that its share in the plaster mass also increases its brittleness and reduces its impact resistance. In addition, when only expanded perlite was used in the mass, damage of the plaster texture was observed following the impact test, even if the coating did not crack. Differences in the adhesion of the coating to the substrate were also observed. Nevertheless, the conducted research did not allow a clear explanation for the cause of this phenomenon to be found.

This work presents expanded perlite as a material with great potential in terms of modifying the thermal insulation properties of facade coatings. When designing materials with high thermal insulation, one should remember about the influence of this filler on other parameters. The topic requires further research into the possibility of subsequent modifications of the composition of the plaster mass in order to minimise the negative impact of expanded perlite on the strength parameters (e.g. selection of a different polymer binder or change of the proportions of the remaining mass components).

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