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THE USE OF PERLITE AS AN INNOVATIVE MATERIAL IN CONSTRUCTIONS

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Abstract: This paper presents a part of a bibliographic study carried out by the authors on the use of innovative materials in constructions, materials that can lead to the increase of the energy efficiency of the constructions, to the increase of their durability, to the reduction of pollution and CO2 emissions, to the protection of the environment, focusing in particular on the non-toxic material, free of organic substances, free of impurities, which does not rot, does not pollute the soil and does not degrade over time even through the action of atmospheric factors, perlite, both granular and expanded, and some of the fields in which it is successfully used in construction.
Keywords: perlite, innovative materials, concrete, plater

1. INTRODUCTION

Lately, in the field of constructions, a series of new innovative materials used in mortars and concretes have appeared, of which expanded and granular perlite are increasingly useful due to their special properties in increasing the thermal resistance of constructions, in environmental protection and in ensuring human health, being a non-toxic material, free of organic substances, free of impurities, which does not rot, does not pollute the soil, does not degrade over time even through the action of atmospheric factors.

2. PROPERTIES OF PERLITE

Perlite is a, chemically stable, ecological and non-degradable material. The raw material is natural pearlitic rock, volcanic rock solidified in water (Figure1) which is crushed, ground and sorted into granulometric fractions [1].

Perlite is an amorphous mineral, originating from volcanic deposits and consisting mainly of aluminosilicate compounds. The mining of perlite presents a low environmental burden, while in recent times. Less than 1% of the world's reserves have been mined for 60 years. In its industrial time process, a significant number of by-products drift and remain unexploited, inducing environmental burden [6].

Perlite is a perfectly dry material, extremely light, with an average density between 200 kg/m^3 and 470 kg/m^3, excellent heat insulator with a thermal conductivity of approximately 0.0495 W/m^{2}K and a 20 cm thick layer of perlite can have a maximum thermal resistance of 5 m^{2}K/W and a maximum transmittance of 0.2 W/m^{2}K. It does not burn and can be used as efficiently and without any risk, both at normal ambient temperatures and in special conditions, at extreme temperatures (between -200º and +850ºC), having fire reaction class A [1].

Expanded perlite is obtained by thermal treatment of pearlitic rock at approximately 1,000ºC, in special ovens. During the manufacturing process, the ground rock flows, in the form of a thread, into a gas flame. At a temperature of approx. 1,000ºC, the phenomenon of expansion occurs instantly, which consists in the sudden increase, by 5-27 times, of the volume of the granules. Because during the expansion process, the swelling of the granules is also accompanied by their partial breaking, this process results in a granulometric distribution between 0-10 mm. In the last stage of production, the expanded perlite is sorted into granulometric fractions, obtaining various granules or even powders.

Figure 1. Natural pearlitic rock [1]

3. VARIOUS USES OF PERLITE

Expanded perlite can be used both in bulk and as light aggregate, in mortars and screeds, in heat-insulating, sound-insulating or vapor-permeable concretes, even in refractory concretes that withstand high temperatures, up to 1100 ºC, if a cement is used suitable [1]. In the following, some of the uses of perlite and expanded perlite in constructions are presented.

3.1. EXPANDED PERLIT AS DRY SUPPORT LAYER FOR FLOORS

The dry expanded perlite support for floors can be composed of a granular bed of expanded perlite covered with perlite OSB boards, being an insulating, completely dry system that constitutes a good support

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for a wide range of floors and which presents a great advantage by reducing the load on the floors, successfully replacing the system consisting of dense screed and extruded polystyrene, being more economical and faster (Figure 2).

Figure 2. Dry support of expanded perlite for floors [1]

Intended for the thermal insulation of tiles on the ground and tiles over an unheated space, this type of support layer is compatible with the underfloor heating system and reduces the influence of the specific thermal bridges of the tiles on the ground and those over unheated spaces.

Among the most important advantages of using this system, we mention the reduction of construction execution time and the reduced impact it has on the environment, since perlite is a natural material and can be reused after the construction is closed [1].

3.2. THERMAL INSULATING PLASTERS WITH EXPANDED PERLITE

To make these heat-insulating plasters (Figure 3), expanded perlite is used, produced in the form of dry powder, pre-dosed.


Figure 3. External heat-insulating plaster with expanded perlite [4]

As favourable characteristics of these interior or exterior plasters, we can exemplify the fact that it is 5-6 times lighter than an ordinary plaster, it is very easy to apply by hand, because after mixing with water it results in an easily workable plastic paste, which can apply in layers between 0.5-5 cm thick, it is a good thermal insulator (it has a thermal conductivity of 0.06 W/m^2K), it ensures a very good vapor diffusion, it falls into the A1 fire reaction class and can also be used for sound insulation [4].

3.3. THERMO-INSULATING STABILIZED PERLITE USED FOR THE INSULATION OF TERRACE AND ABOVE BASEMENT FLOORS

Stabilized heat-insulating perlite, added perlite, is a light product, with a density of 300 Kg/m^3, a dry, two-component, mineral product, packed in bags, used for thermal insulation of constructions and as a light support for hoes. It ensures good thermal and sound insulation, has a very good fire behavior (does not burn, does not emit gases, melts above 1000ºC), falls into the A1 fire reaction class and is easy to apply, the thickness of the layer can vary between 5-50 cm. It is used to insulate the terraces of residential, administrative and social-cultural buildings, in general, to insulate floors over basements or as light support layers for light or dense heat-insulating screeds in which horizontal thermal, electrical and of water. (Figure 4) For commissioning, the manufacturer does not recommend pumping with a hoe or concrete pump with pneumatic transport [1].

Figure 4. Stabilized perlite used for thermal insulation of floors above basements and as a trench support layer. [1]

3.4. GRANULAR PERLITE USED IN CONCRETE

The perlite used in the production of prefabricated concretes, heat-insulating, sound-insulating and vapor-permeable concretes is a granular product (Figure 5), natural and ecological.

Figure 5. Granular perlite used in concrete [1]

It is free of organic substances, with a porous structure, free of impurities, white-grey color, excellent heat-insulating conductivity the thermal value is maximum 0.061 W/m^2K, non-toxic, non-combustible, does not rot, does not pollute the soil, does not degrade over time even through the action of atmospheric factors and, used in bulk, does not allow rodents and insects to live in its mass.

3.5. EXPANDED PERLITE USED IN LIGHTWEIGHT CONCRETES

In the paper *Effect of expanded perlite on the mechanical properties and thermal conductivity of lightweight concrete* [2], authors Ozkan Sengul and team provided data on the effects of expanded perlite on the mechanical properties and thermal conductivity of lightweight concrete.

In the experimental program, a series of mixtures were prepared by partially replacing the natural aggregate with expanded perlite, but keeping the water/cement ratio constant in all mixtures and, as a result, the unit weights of the light concretes in the fresh state varied between 700-2000 kg/m^3 For each mixture/recipe, the mechanical and physical characteristics were determined, namely the compressive strength, modulus of elasticity, water absorption, capillarity and thermal conductivity of the samples.

The results of the tests showed that the compressive strength and the modulus of elasticity decrease with the increase in the perlite content, and the water absorption and the sorption coefficient increase with the increase in the percentage of perlite in the mixtures. It has also been shown that the thermal conductivity is substantially improved with the use of a higher percentage of perlite.

Due to the loss of strength, the concretes produced in this study with more than 20% expanded perlite can be classified as concrete insulation [2].

3.6. EXPANDED PERLITE IN HOLLOW CONCRETE BLOCKS

Lately, in the field of construction, new types of masonry blocks have been tried, some of which were presented by the author Saeed M. Al-Tarbi and his team of researchers, in the scientific article *Development of energy-efficient concrete hollow blocks using perlite, vermiculite, volcanic slag and expanded polystyrene [3].*

The authors made in an experimental program concrete blocks with lightweight materials, using vermiculite, scoria and polystyrene instead of coarse aggregates and perlite as fine aggregates. The blocks were tested for compressive strength and water absorption and thermal conductivity were determined. Comparisons were also made with current masonry on the market, in terms of cost and CO_2 emissions, to assess the ecological impact and long-term viability of the new concrete blocks.

The article aimed to find a sustainable alternative to conventional concrete blocks that can be manufactured on site and explore the potential of using natural and industrial by-products to make greener concrete masonry units that meet industry standards.

The authors' conclusions showed that the newly designed blocks (made with perlite, vermiculite, slag, and polystyrene) satisfied the strength requirement, but only the blocks with perlite and slag can be considered lightweight concrete blocks, while all other types of blocks produced would could be considered medium weight concrete blocks.

From the point of view of thermal conductivities and CO_2 emissions, concrete blocks with slag and perlite were shown to be the best thermal insulators and the least polluting, but perlite and vermiculite blocks, having a high capacity to absorb water, were not recommended for use in regions with very humid climates [3].

3.7. USE OF RAW GROUND PERLITE BY ALKALINE ACTIVATION TO PRODUCE VARIOUS BUILDINGS MATERIALS

The idea of using raw perlite ground by alkaline activation to produce various construction materials, such as plaster, putty and concrete, can achieve advantages both in the economy and in environmental protection, by reducing the consumption of Portland cement.

It is desired to produce cement-free pastes and mortars based on alkaline activation of raw perlite and standard sand.

The authors *Hamza Karakaş a.o*. presented in their work [5] a study on the use of perlite and alkaline activators (NaOH and Na_2SiO_3) as binding materials, as binders, to be able to produce paste and mortar without cement. Their research was also extended to the production of slightly aerated pastes and mortars, using hydrogen peroxide (H_2O_2) as an expansion agent.

Examining the aeration mechanism of the sample, the changes in the values of apparent density, compressive strength and bending strength were determined. At the same time, the thermal properties, thermal conductivity of the paste and aerated mortars were monitored.

Geopolymers in various Water/Perlite and H2O2/Perlite ratios were produced, and their thermal conductivity, apparent density, compressive and flexural strength were contrasted. The experimental finding revealed that adding 0.25% H_2O_2 (by mass of perlite) to the mixtures enabled the production of lightweight pastes and mortars with lower density and lower thermal conductivity coefficient without a significant loss of ultimate strength.

The developed perlite based aerated geopolymer is a eco-friendly and energy efficient solution to buildings.

Based on the results, H_2O_2/Perlite% above 0.5% and water/Perlite% above 45% should be avoided for both paste and mortars.

In order to obtain optimum results in terms of workability, strength, density, and thermal conductivity, it is recommended that the H_2O_2/Perlite ratio for all samples should be 0.25% and the Water/Perlite percentage should be 40%.

4. CONCLUSIONS

Research shows that thermal insulation materials can increase energy efficiency, reduce the negative impact on the environment and be cost-effective through low density, good heat resistance, good thermal conductivity and durability over time.

This paper presents part of a bibliographic study carried out by the authors on the use of innovative materials in construction, focusing on perlite, both granular and expanded, and some of the fields in which it is successfully used in construction.

As an observation, cement-free paste and mortar based only on the alkaline activation of raw perlite proved that they could be used as building materials.

In conclusion, it can be stated that the perlite based aerated geopolymer is a eco-friendly and energy efficient solution to the buildings and the durability of the mixtures decreased with growth the water content in both the paste and the mortar.

The apparent density decreased with the increase of the percentage of, both in paste and mortar and it can be said that cement-free pastes and mortars can be produced in ecological conditions without requiring a large amount of energy and without causing greenhouse gas emissions.

Raw perlite activated by alkali and the produced geopolymer pastes can be used as an alternative binder instead of cement and offers economic and environmental advantages by reducing the consumption of polluting, environmentally unfriendly materials such as Portland Cement.

The lightweight geopolymer pastes and mortars presented by authors have significant flexural and compressive strength and low thermal conductivity.

For future research, it would be interesting to study the behavior of materials obtained by adding steel fibers or composites to the paste and mortar made to increase the air resistance capacity based on perlite geopolymer. At the same time these materials could also be obtained by using some recycled materials to improve the sustainability of newly created products.

The bibliographic study carried out on the currently existing research on the subject pursued, incites the authors to new researches in the field, to the conception of experimental programs through which to study new opportunities for the use of various materials in the creation of innovative materials.

Through future experimental research, we want to create materials with special characteristics, with improved properties compared to the existing ones, sustainable materials, as least polluting as possible, with an important role in increasing the energy efficiency of buildings, in protecting the environment and in ensuring people's health.

Using expanded perlite has many advantages and applications for cement mortars and other building materials.

Expanded perlite is a good alternative to produce cement mortars with high covering capacity. In addition, perlite helps increase water retention, very important thing for regulating water evaporation, especially in summer. Expanded perlite provides warm thin insulation, which is positive in regulating the interior temperature. On the other hand, in a comparison between lightweight and conventional cement mortars, some disadvantages were found, with lightweight materials showing less mechanical resistance and greater water absorption and sportively. The latter could be a problem regarding durability [7].

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