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CAPILLARY WATER ABSORPTION PROPERTIES OF CALCIUM STEARATE-COATED PERLITE

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Annotation. In this study, expanded waste perlite particles were coated with calcium stearate ($Ca(C_{17}H_{35}COO)_2$) in different proportions (1–5%) and their water absorption and capillary absorption properties were studied. As a result, the minimum and maximum coating amounts were determined, and the lowest capillary water absorption was recorded. The experiment showed that water absorption was sharply reduced as a result of the $Ca(C_{17}H_{35}COO)_2$ coating. In particular, at a coating level above 3%, perlite practically did not absorb water. The best result was observed at a coating level of 5%, when capillary absorption decreased to 0%. Hydrophobization paves the way for the widespread use of perlite in modern polymer composites and functional materials.

Keywords: perlite, capillary water absorption, sinking, range, deformation and hydrophobicity

Annotatsiya. Ushbu tadqiqotda kengaytirilgan chiqindi perlit zarrachalari turli nisbatlarda (1-5%) kalsiy stearat $Ca(C_{17}H_{35}COO)_2$ bilan qoplandi va ularning suv yutish va kapillyar yutish xususiyatlari o‘rganildi. Natijada qoplamaning minimal va maksimal miqdorlari aniqlanib, kapillyar suv yutishning eng kam miqdori qayd etildi. Tajriba shuni ko‘rsatdiki, $Ca(C_{17}H_{35}COO)_2$ bilan qoplash natijasida suv shimuvchanligi keskin kamaydi. Xususan, qoplama darajasi 3% dan yuqori bo‘lganda perlit deyarli suvni shimmaydi. Eng yaxshi natija 5% qoplama darajasida, kapillyar yutilish 0% gacha kamayganda kuzatildi. Gidrofoblash zamonaviy polimer kompozitlar va funksional materiallarda perlitning keng qo‘llanilishiga yo‘l ochadi.

Kalit so‘zlar: perlit, kapillyar suv yutish, cho‘kish, diapazon, deformatsiya va gidrofoblik

Аннотация. В данном исследовании частицы вспученного перлита были покрыты стеаратом кальция $Ca(C_{17}H_{35}COO)_2$ в различных пропорциях (1-5%), и были изучены их водопоглощающие и капиллярные свойства. В результате были определены минимальное и максимальное количество покрытия, а также зафиксировано наименьшее количество капиллярного водопоглощения. Эксперимент показал, что водопоглощение резко

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снижается в результате покрытия $Ca(C_{17}H_{35}COO)_2$. В частности, перлит практически не поглощает воду, когда уровень покрытия превышает 3%. Наилучший результат наблюдался при уровне покрытия 5%, когда капиллярное поглощение снизилось до 0%. Гидрофобизация открывает путь для широкого использования перлита в современных полимерных композитах и функциональных материалах.

Ключевые слова: перлит, капиллярное водопоглощение, седиментация, диапазон, деформация и гидрофобность

1. INTRODUCTION

Perlite is an acidic volcanic glass that expands at high temperatures to form a porous structure. The lightness, heat and sound absorption properties of expanded perlite (EP) allow it to be widely used in the construction industry. Therefore, it is considered not only as a thermal insulator, but also as an important factor in reducing construction costs. In the scientific literature, many studies have been conducted on the properties of EP-based materials and their use in various construction systems [1;2].

In recent years, research has been conducted to improve the properties of perlite by coating it. Various modifiers, such as $Ca(C_{17}H_{35}COO)_2$, boric acid, aerogels and polymers, have been used to form a coating on the surface of perlite, reducing water absorption and increasing mechanical stability. For example, it has been observed that a concentration of about 2% on the surface of a mineral coated with a $Ca(C_{17}H_{35}COO)_2$ layer enhances the chemical bonding of perlite molecules. Other studies have shown that perlite particles coated with polymers or aerogels have significantly improved water resistance and thermal stability. However, it has also been noted that exceeding the optimal amount of organic and inorganic additives can reduce mechanical strength [3].

Natural fatty acids are up to 10 times cheaper than commonly used water-repellent polymers. A review of the literature shows that so far, there have been almost no studies on coating perlite with $Ca(C_{17}H_{35}COO)_2$ and adding it directly to construction mixtures. Typically, expensive polymers have been used in combination with perlite [4;5].

Perlite, which is widely used as thermal insulation in industrial enterprises, is characterized by its lightweight, porous and high heat-resistant structure. In particular, perlite is used as a thermal insulation coating in coal-fired power plants. However, in practice, perlite is released from the coating of these plants during major or current repairs.

Such perlite released from the plant is in direct contact with the environment. In particular, it absorbs moisture from the air, becomes highly humidified, and at

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the same time mixes with dust particles in the air. As a result, its initial thermal insulation properties decrease sharply, that is, perlite practically loses its functional ability. For this reason, it is no longer considered a useful material, but rather a waste, if not recycled.

Nevertheless, such waste can be reused as a secondary raw material by processing and modifying it on a scientific basis. This not only increases economic efficiency, but also ensures perlitological sustainability by reducing waste.

2. MATERIAL AND METHOD

2.1 Research objects

In this study, waste perlite was obtained from the Uzbekistan GTL enterprise, mechanically processed, i.e. dried, crushed and sieved, the particle size was in the range of 0–1 mm. The particles were manually sieved and cleaned of large mechanical particles. As a result, expanded fine perlite (FP) was classified in the 0–1 mm size fraction. Since this waste perlite was also saturated with moisture in the air, it was thoroughly dried in an oven at a temperature of 180 °C for 60 minutes. The dried perlite particles were coated with $Ca(C_{17}H_{35}COO)_2$ to increase their water resistance.

2.2. Particle coating process

In the experimental process, expanded perlite particles were coated with $Ca(C_{17}H_{35}COO)_2$ in different proportions (1–5%). The main goal was to improve the water-repellent properties by forming a hydrophobic layer on the surface of the particles. The process consisted of several stages, first the mixing vessel was heated to 170 °C, i.e. to the liquidus temperature of $Ca(C_{17}H_{35}COO)_2$, and the set temperature was automatically maintained. Then each sample was placed in the vessel in a percentage ratio, and mixing was started at a speed of 300 rpm. The process was carried out for 15 minutes, and at the end homogeneously coated samples were obtained. They were used for further analysis, including water-repellent tests.

Table-1.

Mass fraction of perlite and calcium Stearate of samples

Samples	Perlite (%)	$Ca(C_{17}H_{35}COO)_2$ (%)
Perlite	100	0
PM-1	99	1
PM-2	98	2
PM-3	97	3
PM-4	96	4
PM-5	95	5

2.2. Water resistance assessment

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The low density of perlite causes it to sink quickly when placed on the surface of water, which indicates its water absorption. Hydrophobic materials, on the contrary, do not sink to the surface of water. Therefore, the degree of sinking of perlite in water is an important indicator in determining its water resistance. In the experiment, coarse and fine perlite aggregates coated with $Ca(C_{17}H_{35}COO)_2$ were placed in colored water in a 100 mL graduated cylinder. Their sinking rate (δGP) and capillary water absorption (βGP) were monitored and stabilized for 20 hours. As a result, the hydrophobic properties of perlite were effectively evaluated.

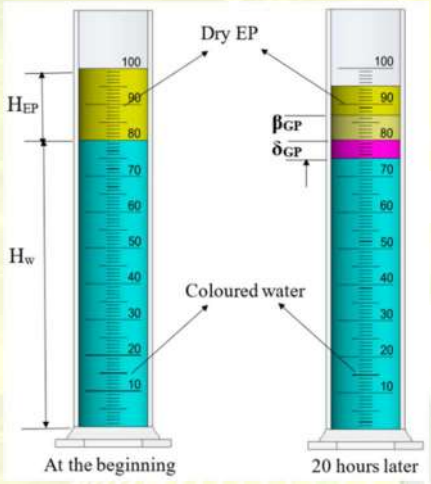


Figure 1. View of the amounts of sedimentation and capillary water absorption

To determine capillary water absorption, 80 mL of water and paint mixture was poured into 100 mL cylinders, and 20 mL of perlite samples were added. Once the process began, time was measured and the degree of immersion and absorption was recorded for all samples.

3. RESULTS AND DISCUSSIONS

3.1. Water resistance of the coated EP

The results of the water-repellent performance of the samples are shown in Figure 2, respectively. The analysis of these figures clearly shows the changes in the capillary water absorption and immersion rates under the influence of different mass percentages of coating. In addition, Figure 3 highlights the dynamic differences in the water absorption and immersion process depending on the coating amount. In particular, the recorded values of immersion, i.e. deformation and capillary water absorption were calculated based on the initial data given in Figure 2 during the 20-hour observation period. In addition, all the graphs presented here represent the results determined based on the experiments that lasted exactly 20 hours. The results show that as the coating amount increased over time, the water permeability of the samples decreased, while the hydrophobic performance increased significantly.

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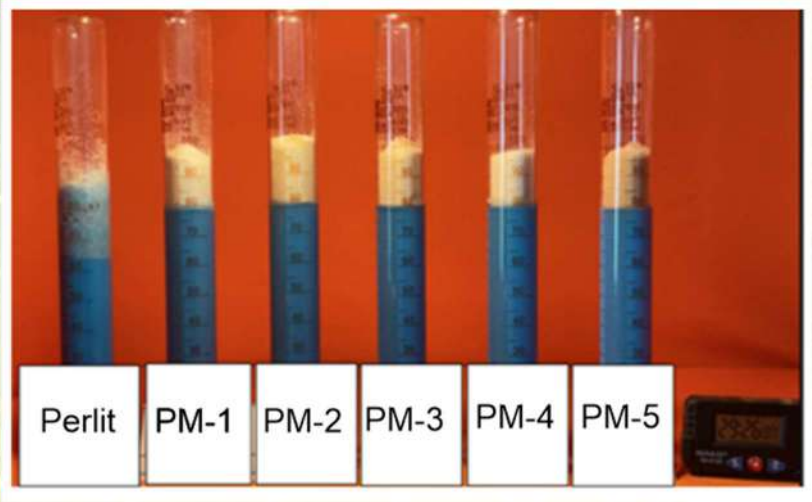


Figure 2. Hydrophobicity performance test of samples

The values were lower for samples PM-1 and PM-2, which were 0.18 mL/cm². These values indicate an increase in the water-repellent efficiency of 83.2% and 91.6%, respectively. Samples PM-3 to PM-5 did not show any deformation at all, meaning they provided 100% hydrophobicity. At the highest coating level, sample PM-5 did not show any deformation at all. This indicates that this sample achieved complete hydrophobicity, meaning 100% water-repellentity.

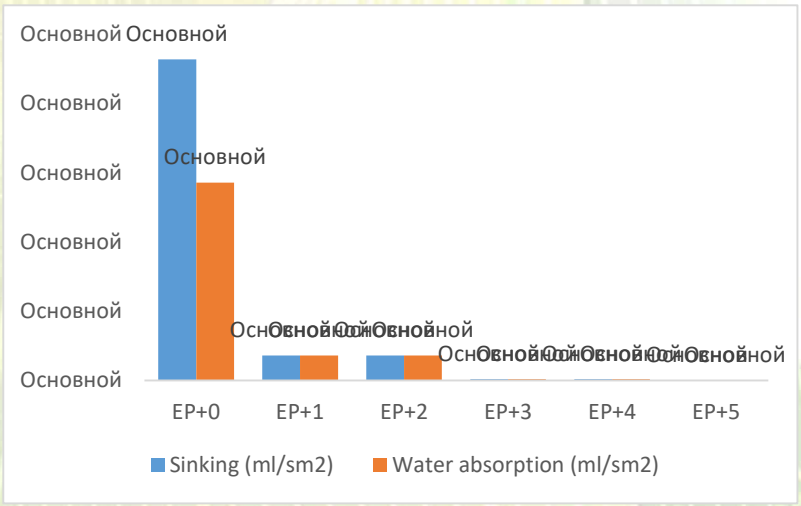


Figure 3. Indicators of dynamic differences in water absorption and immersion

The capillary water absorption values also showed a very close trend to the deformation results. Perlite particles have a low density by nature and have a high water absorption capacity. Therefore, in the uncoated state, both the deformation (δGP) and capillary water absorption (βGP) values were large, namely 2.43 and 1.43. After the coating was applied, these values decreased sharply. This change is explained by the change in the bulk density of perlite particles, i.e., the change in the hydrostatic pressure behavior they generate in water.

3.2. SEM images of uncoated and coated particles

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In order to better understand the microstructural changes, SEM microscopy analyses were performed. SEM images of uncoated expanded perlite particles at 500× and 1000× magnification showed the presence of a large number of open pores on their surface. Such a porous structure creates conditions for rapid penetration of water through capillary channels. In the next step, samples with a coating were analyzed, and it was observed that the pores on their surface were partially blocked, resulting in a smoother and more water-repellent surface. It was also noted that as the amount of perlite and coating increased, the surface of the particles became more evenly coated, and the overall structure became more homogeneous.

a) **b)**

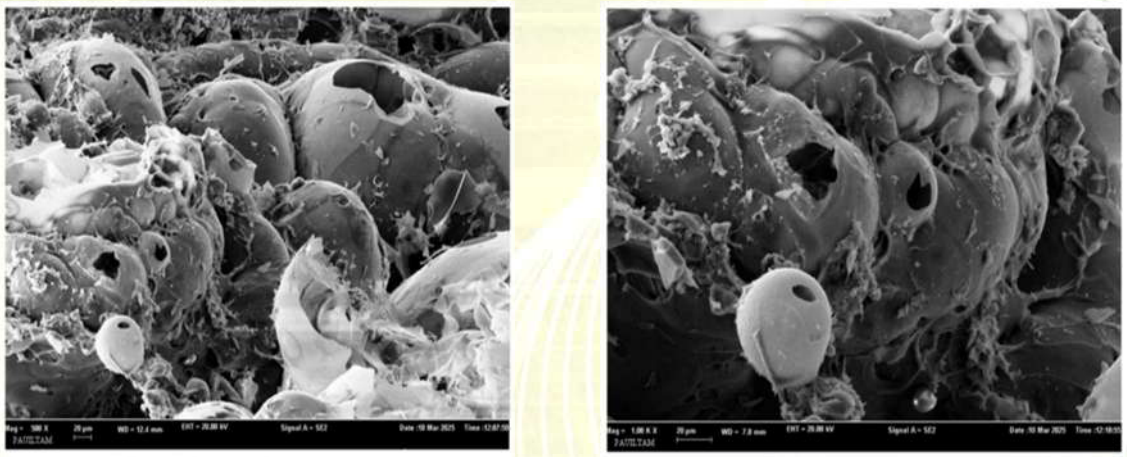


Figure 4. SEM image of uncoated perlite: (a) 500 × and (b) 1000 ×

Uncoated expanded perlite particles after the expansion process acquire a shape close to a sphere and exhibit a high degree of open pore structure (Figure 4). In Figure 4b, layers formed as a result of partial melting are observed on the grain surface, which is inextricably linked to the temperature conditions given during expansion. At the same time, it was also found that the outer shell of the expanded particles is extremely thin and brittle.

a) **b)**

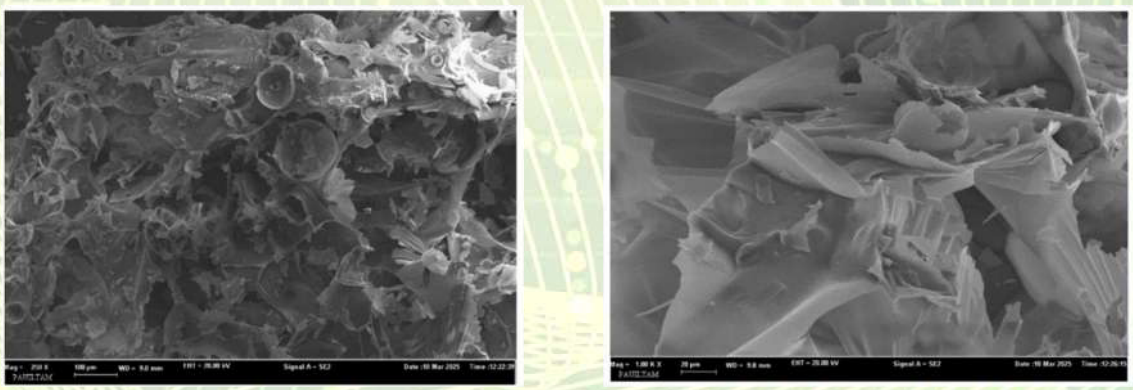


Figure 5. SEM images of perlite coated with 5% $Ca(C_{17}H_{35}COO)_2$: (a) 250 × and (b) 1000 ×

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SEM images of expanded perlite samples after application of 5% $Ca(C_{17}H_{35}COO)_2$ were taken at 250× and 1000× magnification and are presented in Figures 5a and 5b, respectively. After the coating process, it was observed that the initial spherical shape of the particles was partially distorted. This phenomenon indicates, on the one hand, that the brittleness of the material has increased, and on the other hand, that the grain structure has become more open and porous. At the same time, it was found that the coating material was evenly distributed on the particle surfaces, forming a continuous film along the surface. As a result, all surfaces were almost completely coated, as can be clearly seen in the images in Figure 5.

4. CONCLUSION

In this study, the hydrophobic properties of waste perlite obtained from an industrial enterprise and after mechanical processing were analyzed and its recycling possibilities were studied. According to the results, the coating of perlite particles with a high concentration of $Ca(C_{17}H_{35}COO)_2$ (5%) significantly reduced the water permeability by strengthening the hydrophobic layer. SEM analysis showed that the pore structure of perlite particles was partially changed under the influence of the coating, and a dense film was formed on the surface of perlite. This film prevented water absorption and increased the long-term stability of the particles. Thus, the coating of waste perlite with $Ca(C_{17}H_{35}COO)_2$ turns it into a secondary effective raw material. This approach is not only cost-effective, but also opens the way to widespread use in modern polymer composites and functional materials.

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