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EVALUATION OF THE APPLICABILITY OF CLAYDITE-BITUMEN SLABS FOR THE INSTALLATION OF A DRAINAGE LAYER OF GREEN ROOFS FOR BUILDINGS CERTIFIED ACCORDING TO THE SYSTEM LEED

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The article presents the results of a study of the physical and mechanical properties of expanded clay-bitumen material for the drainage layer of green roofs based on expanded clay and waste bitumen roofing chips. The results of assessing the compliance of expanded clay-bitumen material for the drainage layer of green roofs with the criteria of the sections Sustainable Facilities (SS), Energy and Atmosphere (EA), Materials and Resources (MR) and the contribution to obtaining points for certification according to LEED standards are shown.

Keywords: *claydite-bitumen slabs, Physical-mechanical properties, roofing bituminous crumb, LEED certification, LEED requirements, LEED Categories.*

ОЦЕНКА ПРИМЕНИМОСТИ КЕРАМЗИТОБИТУМНЫХ ПЛИТ ДЛЯ УСТРОЙСТВА ДРЕНАЖНОГО СЛОЯ ЗЕЛЕНЫХ КРЫШ ЗДАНИЙ, СЕРТИФИЦИРОВАННЫХ ПО СИСТЕМЕ LEED

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В статье представлены результаты исследования физико-механических свойств керамзито-битумного материала для дренажного слоя зеленых крыш на основе керамзита и отходов битумной кровельной крошки. Показаны результаты оценки соответствия керамзитобитумного материала для дренажного слоя зеленых крыш критериям раздела Устойчивые объекты (СС), Энергия и атмосфера (ЭА), Материалы и ресурсы (МР) и вклад в получение баллов при прохождении сертификации по стандартам LEED.

Ключевые слова: *керамзитобитумные плиты, физико-механические свойства, кровельная битумная крошка, сертификация LEED, требования LEED, категории LEED.*

Introduction. An important element of a green roof is the drainage layer. The purpose of the drainage layer is to remove excess water from the roof. The accumulation of water creates additional weight and also reduces the level of oxygen in the plant base. The choice of drainage depends on factors such as the size of the roof, its slope, the location of the downpipes, the characteristics of the substrate and the planned vegetation. When choosing a drainage system, it is also important to consider logistical and economic factors. The drainage layer is usually installed between the substrate and the waterproof membrane and consists of drainage decks or other drainage material. Drainage layers should prevent the occurrence of the effect of capillarity, i.e., there should be no movement of water through the capillaries to the upper layer. To do this, the layer must have a thickness exceeding the height of the capillary rise of the material. In this case, the smallest pore size in the drainage material should be larger than the largest pore size in the substrate layer. Drainage decks most effectively cope with this task with a limited height of the structure and load. Drainage decks are made of plastic and look like egg cartons. The basic principle of operation is to create a dedicated

space for the free flow of water at some distance from the roof, as well as to raise the substrate above the bumps where water can accumulate. Many drainage decks serve a dual function in that they not only allow excess water to be removed from the plant substrate, but can also retain it within the system. The drainage layer may also consist, for example, of gravel, pumice, expanded clay concrete, brick or foam glass. Regardless of which material is chosen, the most important quality of the drainage material is to prevent the effect of capillarity [1-4].

Materials and Methods. As a material for the drainage layer, it is proposed to use slabs from natural, environmentally friendly raw materials-large-pore expanded claydite-bitumen slabs.

For the manufacture of claydite-bitumen material, roofing bitumen waste from BelRetsikl LLC, claydite fractions from 0,1 to 10 mm from the Claydite Gravel Plant LLC, Novolukoml, were used. Claydite is a material of a cellular structure, expanded during the rapid firing of dark brown clays, which, with significant strength, has a low density and high thermal insulation properties. The bulk density of claydite, which was used in the experiment, was 464 kg / m^3 (Figure 1). Roofing bituminous wastes of BelRetsikl LLC are roofing bituminous crumb (Figure 2). Bituminous crumb contains 39.8% binder (by weight).

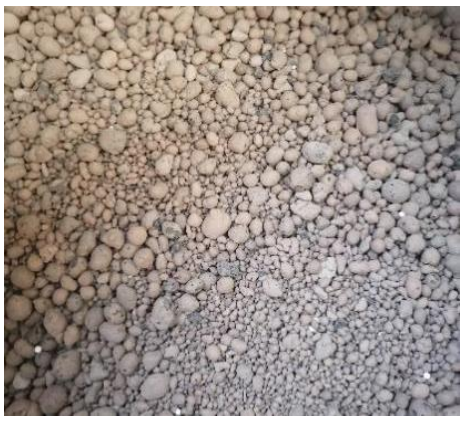

Figure 1. – Claydite with a particle size 0,1-10 mm

Figure 2. – Roofing bituminous crumb

The determination of the compressive strength of claydite-bitumen samples was carried out in accordance with GOST 10180-2012. The compressive strength was determined by testing three specimens-cubes with a rib length of 70 mm. The compressive strength was calculated as the arithmetic mean of the results of three tests. The compressive strength of concrete was determined taking into account the scale factor of 0,9. Compressive strength tests were carried out on hydraulic presses PGM-1000MG4 (Figure 3).

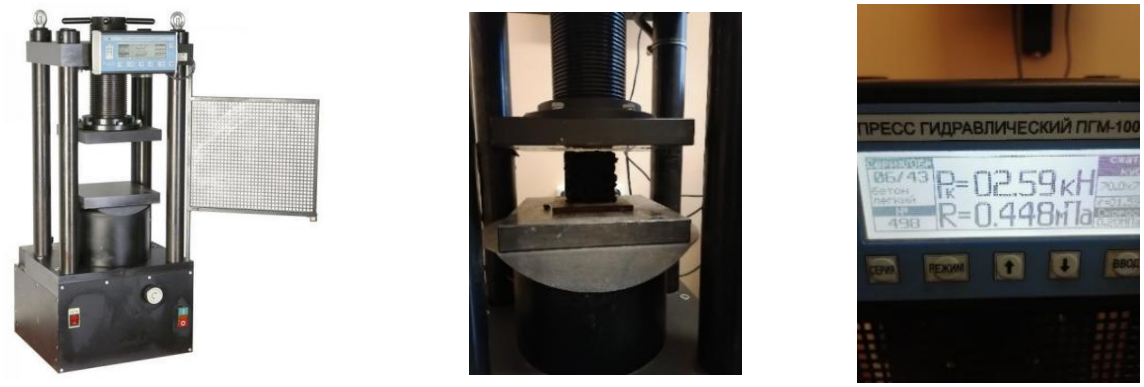

Figure 3. – Hydraulic presses PGM-1000MG4

Results. See Table 1 for raw material mixture composition and test results of claydite-bitumen samples.

Table 1. – Physical-mechanical properties of claydite-bitumen material

Roofing bituminous crumb, kg/m^3	Claydite, kg/m^3	Density, kg/m^3	Compressive strength, MPa	Deformations, mm	Dry thermal conductivity coefficient, W/m°C
139	328	467	0,406	1,71	0,138

After compression test, the original shape of claydite-bitumen sample-cube remains unchanged (Figure 4). This can be explained by the plastic properties of bitumen used as binder. The claydite-bitumen sample-cube has high filtration capacity, and there is no delay in the flow of water through the sample-cube (Figure 5).

Figure 4. – Appearance of sample-cube after strength test

Figure 5. – Filtration capacity of sample-cube

The water absorption of sample-cubes of claydite-bitumen was measured after soaking in water for 24 hours. The kinetics of saturation samples with water is presented in Table 2.

Table 2. – Water absorption kinetics of claydite-bitumen sample-cubes

Mass of dry samples, g	Volume of samples, cm^3	Surface area, cm^2	Mass of samples, g, after being in water, during, h			Water absorption, by weight, % (by volume, %)	Load from slab 7 cm thickness, kH/m^2	
			0,5	2	24		in dry state	in a water-saturated state
160	343	49	175	178	181	13,1 (6,1)	0,326	0,369

Thus, claydite-bitumen slabs have specific advantages for LEED certification of buildings. This is due to the characteristics of the material: compressive strength of 0,406 MPa, a slight increase in load with water absorption of 13,1%, good filtration of the material, and the use of roofing bitumen waste in the composition of the material.

Discussion. This study considers the following standards: LEED 2009 for New Construction and Major Renovation Rating System or 2009 for Core&Shell Development Rating System and LEED Reference Guide for Green Building Design and Construction with its annexes and LEED v4 for New Construction and LEED v4 Reference Guide for Green Building Design and Construction [5-7].

Positive qualities of claydite-bitumen slabs for green building.

1. Energy efficiency. The material has a low coefficient of thermal conductivity, for example, the average density grade D500 has a coefficient of thermal conductivity in a dry state of 0.138 W / m ° C; this allows, in addition to filtering properties, to use the effect of additional insulation of the green roof structure, which has a positive effect on the level of energy efficiency, which is calculated using energy modeling during LEED certification, and also reduces the consumption of energy resources for providing the building.

2. Light weight. The blocks are light in weight with good bearing capacity, which allows:

– simplify roof base structures;
– save on installation;
– reduce labor costs;
– refuse to use heavy lifting equipment;

Consequently

– saving fuel and avoiding exhaust emissions;
– reduce emissions from product transportation.

3. Long life cycle. The material is not subject to the process of decay, aging, shrinkage, destruction over time, durable, does not change its physical and technical characteristics under the influence of external factors, and also provides a long life cycle of a green roof, reduces the need for repair work, as a result - a decrease in the negative environmental impact.

4. Reuse. After the completion of the operational stage of the life cycle, the product can be a secondary raw material: claydite-bitumen products that have lost their consumer properties can be used for further processing. In this case, the newly built object can receive LEED points for the reuse of materials.

5. Green roofs. Thanks to the listed qualities, claydite-bitumen slabs can be used in green roofs. Green roofs are an advantage for LEED certification and will give a building up to two points. Such roofs improve the thermal performance of the building in the summer, create a favorable atmosphere for the recreation of building users and reduce the so-called "heat island effect" during mass use in urban areas.

6. Ensuring security for facility users:

– material to ensure fire safety;
– claydite-bitumen slabs do not contain toxic components and carcinogenic substances, including formaldehyde, phenol, asbestos or any other hazardous ingredients;
– expanded clay concrete slabs are a dielectric.

7. Regionality of materials used. One of the requirements of the LEED standard is the regionality of the building materials used, i.e. extraction of raw materials and direct production should be located within a radius of about 800 km from the construction site of the facility being certified. The purchase of materials produced close to the certified object allows to reduce the negative environmental impact and energy consumption during transportation by reducing the transportation distance. The use of expanded clay bitumen slabs in construction on the territory of Belarus may affect the receipt of additional points in the LEED system for the "regionality" of raw materials and materials.

Table 3 provides information on the requirements of the various categories and LEED credits in which the use of claydite-bitumen slabs can contribute to points.

Table 3. – Contribution of claydite-bitumen slabs to LEED certification points

LEED Categories and Credits	LEED requirements	The contribution of claydite-bitumen slabs to points
Sustainable Sites - Sustainable Sites (SS)		
SS Credit 7.2 Heat island effect - roof (1 point)	Organization of roof gardening for at least 50% of its total area. OR Installing a roof with a high reflectivity coefficient and greening the roof (in a specially calculated proportion).	Claydite-bitumen slabs are a good basis for a green roof, as they have high compressive strength, thermal insulation properties.
Energy and Atmosphere - Energy and Atmosphere (EA)		
EA Mandatory requirement 2 Minimum power consumption	10% (18%) energy bill reduction for new buildings and 5% (14%) for refurbishment compared to the baseline calculated using the method described in Appendix G of ANSI/ASHRAE/IESNA Standard 90.1-2007 for whole building modeling.	Claydite-bitumen slabs are both a structural and heat-insulating material. A low coefficient of thermal conductivity means a high resistance to heat transfer of structures, which reduces energy consumption for heating.
EA Credit 1 Energy optimization (1-19 points)	Improvement in building performance over baseline calculated using the method described in Annex G of ANSI/ASHRAE/IESNA Standard 90.1-2007 for Whole Building Modeling, scoring according to the LEED table.	Helps reduce energy consumption and maximize thermal comfort. The overall result depends on the values of thermal resistance and heat transfer coefficient of all layers of the structure, structural features and design solutions in the aggregate. When arranging structures, it helps to get more points as a result of energy savings over the annual cycle.
Materials & Resources - Materials & Resources (MR)		
MR Credit 2: Construction waste management (1-2 points)	Recycling and/or conservation of non-hazardous construction and demolition waste. The calculation is made by weight or volume (one of the options must be selected). Minimum content of saved and recycled waste: 50% for 1 point, 75% for 2 points.	Waste generated during the installation and adjustment of plates is suitable for grinding and further transfer for processing, use as a raw material for the production of new products.
MR Credit 3: Reuse of materials (1-2 points) (in the long term)	The use of recycled materials, demolition waste and reuse of materials and structures in construction is assessed by LEED if the amount of such materials is not less than 5% (1 point) or not less than 10% (2 points) of the total cost of materials used during construction.	In order to follow the concept of sustainable development and fulfill the goals of "green" building, it is necessary to take into account the life cycle of the building. The use of claydite-bitumen slabs can help to earn additional LEED credits not for the current building under construction, but when using slabs saved during its dismantling or reconstruction, for the green roof of the next building. This is possible due to the fact that the material is not subject to aging, decay, shrinkage, etc. and can be reused.

Ending of Table 3

LEED Categories and Credits	LEED requirements	The contribution of claydite-bitumen slabs to points
MR Credit 5: Regional materials (1-2 points)	Building materials/products (or their components) mined and manufactured within a 500 mile (800 km) radius of the construction site must account for at least 10% (1 point) or 20% (2 points) of the total cost of materials.	The use of claydite-bitumen slabs in construction throughout most of Belarus may result in additional LEED credits for "regionality" of raw materials and materials. In this case, the regional component of the material will be equal to at least 99% of the mass (and, accordingly, of the cost) of the material.
Indoor Environmental Quality (IEQ)		
IEQ Credit 7 / 7.1 Thermal comfort - design (1 point)	The design of the HVAC system and building envelope must be carried out in accordance with the recommendations of the ASHRAE Standard 55-2004, Thermal Comfort Conditions for Human Occupancy. Compliance with section 6.1.1 must be demonstrated.	Claydite-bitumen slabs are one of the elements that regulate the temperature and humidity conditions in the room.
IEQ Credit 10 (Only for schools, 1 point) Mold Prevention	In addition to completing LEED IEQ 3.1, 7.1, and 7.2 credits and designing an air-conditioning system that controls and maintains air humidity below 60%, an "indoor quality maintenance" program must be established that includes measures to prevent mold. The basis for these measures is outlined in Building Air Quality: A Guide for Building Owners and Operators, 402-F-91-102, December 1991, US Environmental Protection Agency.	Claydite-bitumen slabs are not subject to the processes of decay, fungus formation, and are not a favorable environment for the development of mold and microorganisms.

The use of claydite-bitumen slabs can indirectly affect the achievement of 5 to 15 points (depending on the type and version of LEED) and the implementation of the mandatory requirement of the LEED standard for energy efficiency.

Claydite-bitumen slabs are suitable for use in green building projects that are planned to be certified under international certification systems such as the LEED system.

Conclusions. The material for the drainage layer of green roofs, consisting of claydite and roofing bituminous crumb, which is a waste from the repair of rolled roofs, has been studied. It has been established that the claydite-bitumen material has a high filtering ability and has a density of 467 kg/m^3, compressive strength of 0,406 MPa, water absorption by weight of 13,1%, while the load from the plates will be 0,33 kH/m^2 in a dry state and 0,37 kH/m^2 wet.

It has been established that when passing certification according to LEED standards, the use of expanded clay bitumen slabs as a drainage layer in green roof structures can indirectly affect the receipt of 5 to 15 points.

Designing green roof structures based on the applicability of LEED materials will eliminate non-environmental materials in green roof structures, the disposal of which is costly.

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