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Standards for Green Roofs in Construction Projects

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Introduction. The study seeks to form a structured classification of green roofs essential for systematic development of practices of green architecture and natural urbanism in Russian development. The lack of a holistic approach to typologizing such solutions causes difficulties in designing and implementing environmentally oriented technologies. The system developed by the author covers four major characteristics and a set of sub-elements, which allows for a comprehensive description and differentiation of various types of green roofs. Such a classification can serve as an effective tool for specialists engaged in the field of design, construction and landscaping.

Materials and Methods. In order to look into the topic, a set of theoretical studies has been conducted. Regulatory documents, including GOST and SNiP, as well as international standards LEED and BREEAM, were examined. The works of specialists, practical examples and publications in specialized sources were also analyzed. The study describes an analysis algorithm: the investigation of constructive solutions, environmental characteristics, principles of design and operation. Green roofs are roofing structures with vegetation. Depending on their purpose, they are divided into exploited (for recreation and activities) and non-exploited (environmental functions). The construction of green roofs is regulated by such standards as GOST R 58875-2020, GOST R 54964-2012 and GOST R 58709-2019. These documents define the types of green roofs, requirements for materials, structures, and indoor climate.

Research Results. Throughout the course of the research, a typology was developed includg extensive, intensive and semi-extensive roofs, as well as classifications according to operational, structural, social and environmental criteria. Examples of implementation in international and Russian practice are provided. The classification allows one to account for the human use, placement and level of landscaping of roofs, offering a comprehensive description system.

Discussion and Conclusion. The introduction of green roof standards represents a totally new approach to building lifecycle management, including not only construction, but also environmental improvement, energy conservation, and quality of life, which is a lengthy and controversial process requring time for analysis and adaptation. They contribute to energy efficiency, thermoregulation, improved microclimate, extended roof life, and the creation of new recreational areas. The concept of green roofs is a synthesis of architecture, ecology and technology that can ensure the sustainable development of cities and improve the quality of life. The ultimate aim of this study is to offer a universal tool for typological analysis of green roofs which can be applied domestically to improve the effectiveness of urban planning solutions and sustainable urban environment development.

Keywords: classification of green roofs, types of roofs with landscaping, green roofs, hanging gardens, landscaping of actively used roofs, intensive and extensive landscaping, semi-intensive landscaping

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Оригинальное эмпирическое исследование

Стандарты зеленых крыш в объектах строительства

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Аннотация

Введение. Настоящее исследование направлено на формирование структурированной классификации озелененных кровель, необходимой для системного развития практик зеленой архитектуры и природного урбанизма в условиях российской застройки. Отсутствие целостного подхода к типологизации подобных решений создает сложности при проектировании и внедрении экологически ориентированных технологий. Разрабатываемая авторская система охватывает четыре ключевые характеристики и комплекс подэлементов, что позволяет комплексно описывать и разграничивать различные виды зеленых крыш. Такая классификация может служить эффективным инструментом в работе специалистов, занятых в области проектирования, строительства и благоустройства.

Материалы и методы. С целью раскрытия темы проведен комплекс теоретических исследований. Были изучены нормативные документы, включая ГОСТ и СНиП, а также международные стандарты LEED и BREEAM, проанализированы труды специалистов, практические примеры и публикации в специализированных источниках. В исследовании описан алгоритм анализа: изучение конструктивных решений, экологических характеристик, принципов проектирования и эксплуатации.

Зеленые крыши представляют собой кровельные конструкции с растительностью. В зависимости от назначения они делятся на эксплуатируемые (для отдыха и активностей) и неэксплуатируемые (экологические функции). Строительство зеленых крыш регулируется стандартами, такими как ГОСТ Р 58875-2020, ГОСТ Р 54964-2012 и ГОСТ Р 58709-2019. Эти документы определяют типы зеленых крыш, требования к материалам, конструкции и микроклимату помещений.

Результаты исследования. В процессе исследования разработана типология, включающая экстенсивные, интенсивные и полуэкстенсивные крыши, а также классификации по эксплуатационным, конструктивным, социальным и экологическим критериям. Представлены примеры реализации в международной и российской практике. Классификация позволяет учитывать человеческое использование, размещение и уровень озеленения кровель, предлагая комплексную систему описания.

Обсуждение и заключение. Внедрение стандартов зеленых крыш представляет собой принципиально новый подход к управлению жизненным циклом здания, включая не только строительство, но и улучшение экологичности, энергосбережение и повышение качества жизни, что является процессом длительным и противоречивым, требующим времени для анализа и адаптации. Они способствуют энергоэффективности, терморегуляции, улучшению микроклимата, продлению срока службы кровли и созданию новых рекреационных зон. Концепция зеленых крыш — это синтез архитектуры, экологии и технологий, способный обеспечить устойчивое развитие городов и улучшить качество жизни. Конечная цель данного исследования — предложить универсальный инструмент типологического анализа зеленых крыш, который может быть применен в российской практике для повышения эффективности градостроительных решений и устойчивого развития городской среды.

Ключевые слова: классификация зеленых кровель, виды крыш с озеленением, зеленые кровли, висячие сады, озеленение активно используемых кровель, интенсивное и экстенсивное озеленение, полуинтенсивное озеленение

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Introduction. Modern challenges of urbanization and climate change are exacerbating the need for sustainable solutions for the urban environment. Green roofs are complex systems combining natural elements with engineering structures that can considerably improve the environmental and energy efficiency of buildings.

Despite the active development of technologies and positive international experience, there is no systematic classification of green roofs in domestic practice. Existing studies only look at individual design or functional aspects resulting in a lack of a unified approach in the design, evaluation and implementation of such solutions.

Hence there is a clear gap in the theoretical framework — the lack of a holistic typology of green roofs adapted to the domestic conditions. This stands in the way of adopting of the technology and makes it difficult for processes to be standardized.

The aim of the study is to develop a structured classification of green roofs that accounts for architectural and spatial parameters, functional purpose, landscaping intensity, social accessibility and technical characteristics applicable in the domestic climatic and regulatory conditions.

Materials and Methods. Green roofs are roof structures where vegetation is planted. Depending on their functional purpose, they are divided into exploited (intended for recreation, sports and other activities) and non-exploited (performing mainly environmental functions) ones. Designing such systems requires the use of integrated engineering solutions for improving energy efficiency, sustainability and environmental effectiveness of buildings [1].

As part of the study, a comprehensive theoretical analysis was performed including:

– review of regulatory documentation (including GOST standards, joint venture, international standards LEED, BREEAM);
– study of scientific publications on the design, operation and environmental aspects of green roofs;
– analysis of implemented facilities and standard solutions in different countries.

According to their functional purpose green roofs are classified into:

– exploited (used for recreation, sports, recreation);
– нnon-exploited (perform mainly engineering and environmental functions).

Below are the key technological directions in the construction of green roofs:

1. Layered structure and vegetation cover. The design of the green roof includes a few functional layers: waterproofing, drainage, filtering, substrate and vegetation (Fig. 1). Each uses specialized materials — from modern waterproofing membranes to light, nutritious substrates.

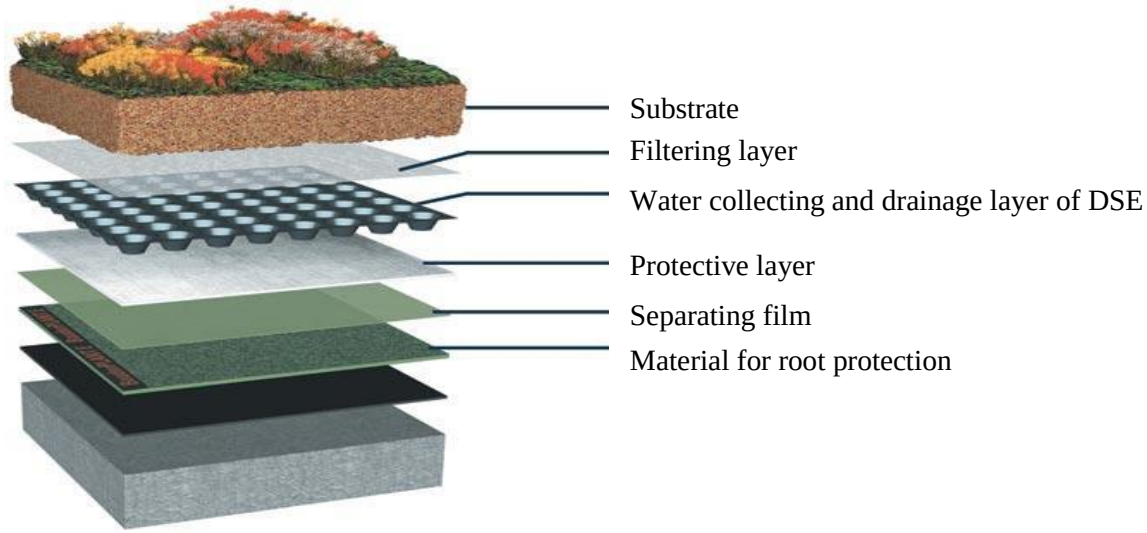

Fig. 1. Scheme of a green roof [1]

2. Water flow management. Effective distribution and use of precipitation is an important task. To this end, rainwater collection, accumulation and reuse systems are used, as well as technologies reducing the risk of moisture retention and damage to the waterproofing layer preventing leakage through roofing structures.

3. Improving energy efficiency. A green roof helps to reduce heat loss and overheating of buildings causing a reduction in air conditioning and heating costs. This is achieved due to the thermal insulation properties of the soil layer and can be complemented by energy—saving solutions, from solar panels to passive ventilation systems.

4. Air purification. Vegetation is involved in filtering pollutants and absorbing carbon dioxide. Particularly resistant plant species are selected that can improve air quality, especially in urban areas.

5. Supporting biodiversity. Green roofs can be adapted for creating microbiotopes. Solutions for attracting beneficial insects, birds and other representatives of fauna are employed.

6. Regulatory regulation. In order for green roof projects to be successfully implemented, it is necessary to comply with current building standards and regulations that define:

– the requirements for the composition of the soil layer, accounting for the stability and viability of plants;
– the parameters of drainage systems ensuring the normal removal of excess moisture;
– safety and structural reliability, including the permissible load on the building's load-bearing elements.

Standards and Regulation

In order to ensure the effectiveness of green roofs, there are standards and regulations that construction companies and architects use in order to create environmentally sustainable facilities [1]:

– soil layers and composition: specific standards regulate the types of soil used on green roofs to ensure not only aesthetic satisfaction, but also maximum vegetation viability.;

– drainage and sanitation: regulation includes drainage systems preventing excessive moisture retention and ensure normal rainwater runoff.;

– security systems: an important aspect is to ensure the safety and stability of green roofs, including weight management and structural integration.

In this country the regulatory regulation of green roofs relies on the following documents:

– GOST R 54964-2012 — establishes general requirements for the improvement of operational roofs;

– GOST R 58709-2019 — contains technical requirements and classification of green roofs;

– GOST R 58875-2020 — "the green standard" which defines the requirements for the environmental sustainability of buildings.

In compliance with the provisions of the GOST R 58709-2019 standard "Green Roofs. General Technical Requirements", the classification of green roofs includes the following main types:

– Garden roofs are those with perennial vegetation that are in need of systematic maintenance;

– Roofs with lawn covering are structures where stable herbaceous plants are planted;

– Roofs with container landscaping are surfaces that are landscaped by placing vegetation in mobile containers.

The standard also provides the requirements for the key components of a green roof (Fig. 2): structural elements (including the bearing capacity of the floor, waterproofing layers, drainage system, thermal insulation materials); used materials (their environmental safety, resistance to moisture, durability); plant communities (permissible species, their agrotechnical characteristics, seasonal sustainability).

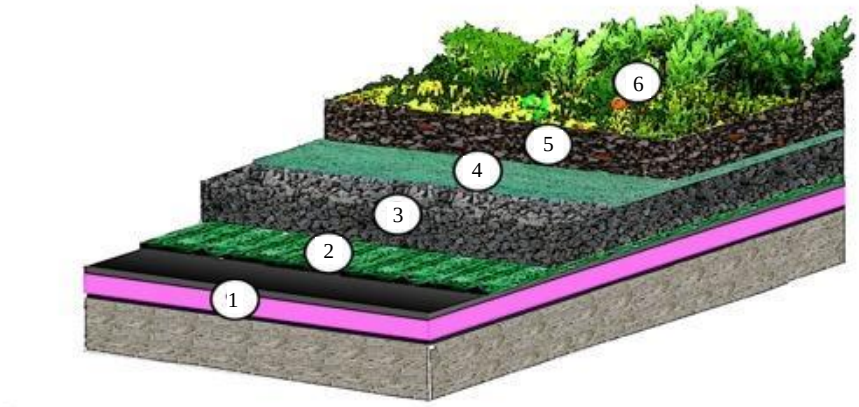

Fig. 2. Constructive solutions of the green roof:
1 — roof surface, waterproofing; 2 — protective and accumulating layers; 3 — drainage; 4 — protection from root germination; 5 — soil layer; 6 — plants [1]

Particular attention in the regulatory framework is paid to ensuring a favorable microclimate inside buildings. Hence according to GOST R 54964-2012, the temperature parameters in residential and public premises should range from 20 to 28°C at a relative humidity of 40 to 60%. Green roofs contribute to the thermoregulation of the interior of the building, reduction of the air temperature in the warmer months and thereby improvement of the microclimatic performance.

Research Results. The history of green roofs goes back a few decades when the technology has witnessed considerable changes. Approaches to standardization and classification of these structures were gradually formed. As a result of the gained experience, a unified typology of green roofs has been developed recognized by the international professional community, particularly by landscape architects.

The most common classification is based on the following criteria:

– load-bearing capacity of the roof;

– thickness and weight of the soil substrate;

– range and requirements for vegetation;

– the possibility and nature of human presence.

According to this typology, there are three major types:

1) extensive roofs — minimal maintenance, thin soil, weather-resistant plants;

2) intensive roofs are complex plantings including shrubs and trees that are in need of maintenance and reinforced construction;

3) semi-extensive roofs are an intermediate option combining elements of the two previous types.

The development of a classification system makes it possible to provide a comprehensive description of the types of green roofs, their purpose, design features and social accessibility.

The classification of green roofs in this study is considered as a systematic approach allowing a description of a complex multilevel structure of elements and their interrelationships. It is based on the interaction of three key components determining the architectural, spatial and functional organization of a green roof: the roof surface, human presence (use) and the vegetation layer. The ratio and degree of involvement of these elements make it possible to identify different types of green roofs as shown in the diagram (Fig. 3) [5].

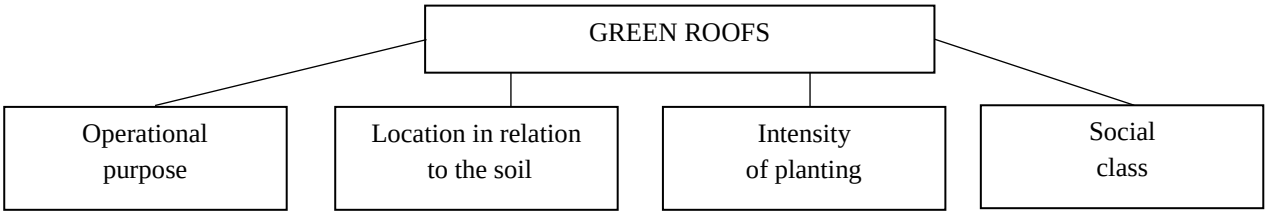

Fig. 3. Classification of green roofs by gender [5]

Deciding whether a person will use the roof for their own purposes is a key point in the natural classification of roofs. This classification includes the first aspect — the division into operational and non-operational roofs (Table 1).

Table 1

Classification according to the degree of exploitation

№	Type of green roofs	Description
1	Operated (without vehicle access)	Recreation areas, playgrounds, landscaped terraces (Fig. 4–7, 15)
2	Operated with the possibility of travel	Parking lots, roofs with walkways and access to equipment (Fig. 5, 9, 10)
3	Partially exploited	Used on separate sections of the roof
4	Unexploited	Perform only environmental and thermal insulation functions

The usable flat green roof offers a wide range of opportunities for recreation, physical development and rehabilitation. If the roof is completely covered with plants and a person is there only for maintenance (e.g., a gardener or a professional), such a roof is considered unused [5].

Depending on which type of green roof is being used, it performs various functions ranging from ecosystem-based (e.g., improving air quality or supporting biodiversity) to functional (e.g., creating space for recreation or sports). Let us consider the advantages of these species in the context of human interaction. Each type of green roof has its own characteristics depending on the specific needs of a building or an area. Operational roofs, e.g., provide additional opportunities for using space making them especially attractive in conditions of a limited urban area. Apart from the environmental and aesthetic advantages, different types of green roofs have functional features that depend on the degree of their operation. E.g., roofs intended for active use can be equipped to accommodate vehicles or install special equipment. It is to be noted that the operation of such roofs (e.g., for parking) is possible only in accordance with the terms of reference regulated by standards and building codes [5].

Green roofs are found on a variety of levels – on the ground, on the balcony, on the pedestrian passing and on the roof of the building, regardless of the number of floors (Table 2).

Table 2

Classification by location relative to ground level

№	Type of positioning	Examples and features
1	Green roofs of buildings	Roofs located on the upper floors of residential, public, and industrial buildings (Fig. 4)
2	Terraced roofs	Roofs located on the upper floors of buildings with terraces or terraced buildings (Fig. 6)
3	Roofs on underground levels	Roofs located on basements and ground floors of buildings, including various levels, above parking lots, shopping malls, and technical floors (Fig. 6, 11, 12)
4	Hanging gardens	Gardens located on various levels of above-ground parts of buildings, special platforms, bridges and overpasses (Fig. 8, 9)

Landscaped exploited roofs and gardens typically belong to different owners – from municipalities and owner associations to private individuals forming their social accessibility (Table 3).

Table 3

Classification by social affiliation (access)

№	Type of social accessibility	Description
1	Public operated roofs	publicly accessible, multifunctional territories with a high recreational load reducing the total area of landscaping and requires the sustainability of the plant assortment used (Fig. 7)
2	Private green roofs and terraces	Penthouses, villas, clubhouses (Fig. 16-17). Plants of different types are used depending on the needs of the owner, the general style, but accounting for the climate, wind load and care options in accordance with design standards.
3	Public green terraces	Operational green terraces of public buildings are designed for recreation and recreation, various types of landscaping provided in special containers and flowerpots. (Fig. 6)
4	Private landscaped terraces	Operational green terraces in private properties decorate historical and modern buildings, enriching the urban environment with a variety of plants and high-quality maintenance. (Fig. 17)

Green roofs and gardens are becoming accessible to both municipalities and homeowners' associations or individuals, which serves as a proof of their social importance. Besides, such roofs have an impact not only on improving the urban environment, but also on tackling environmental problems related to the influence of the technosphere. In one of the studies performed in order to identify the vulnerability of cities, it was found that the biosphere can play a major role in balancing the impact of the technosphere and the economy. E.g., in some European countries, the temperature of traditional roofs in summer can reach as high as 90 °C, while on green roofs it does not go beyond 50 °C, which can dramatically reduce the thermal impact on the environment. Hence the temperature difference between conventional and green roofs can be over 40 ° C, which makes the latter an effective tool in combating overheating of urban areas.

Green roofs can vary significantly — from lawns to planting trees and shrubs. The classification function "greening intensity" allows one to identify a few main categories (Table 4) [9].

Table 4

Classification according to the intensity of landscaping

№	Type of a green roof	Characteristics
1	Hanging gardens	High density, large plants, including trees and shrubs, producing the impression of a garden on a natural landscape (Fig. 8, 9)
2	Celestial oases	They occupy upper floors or flat roofs concentrated in the thick of the urban landscape, with rich plantings of various textures. They are approaching mini-squares and public spaces in scale (Fig. 5)
3	Earthly paradises	They are located on the Earth's surface: on the roofs of underground structures, parking lots, parks, etc. (Fig. 10-12). Landscaping with trees, shrubs and flowers is used to produce the impression of a garden.
4	Sparse landscapes	Green roofs on artificial bases are sparse plantings of lawns, meadows and shrubs (Fig. 11). The key function is recreation, sports, transit traffic. They are particularly relevant for court-yards, business and shopping complexes.
5	Extensive roofs	Flat or curved structures covered with a single layer of lawns, groundcover, or meadow plants. They serve ecological and aesthetic purposes and are not designed for permanent residence (Fig. 13)
6	Water worlds	They are created on artificial grounds to improve the microclimate. Water is the main theme of the project. Ponds, cascades are water elements for a microclimate (Fig. 14)

Fig. 4. Children's playground on the roof on the roof of a multi-storey parking lot. Copenhagen (2018) [8]

Fig. 5. Underground parking roof garden, Baden-Baden (2019) [8]

Fig. 6. Terraced house and green terraces. Arch. Bjarke Ingels Group. Copenhagen (2018) [8]

FIg. 7. Garibaldi Square - green roof in use, Milan (2016) [8]

Fig. 8. Hanging garden. Tsarskoe Selo (18th century, 2017) [8]

Fig .9. Hanging garden above De Sants Metro Station, Barcelona (2022) [8]

Fig. 10. Ground-level park - Zaryadye Park Moscow (2021) [8]

Fig. 11. Lawns of the operational roof of the shopping center on Amsterdam's Museum Square (2013) [8]

Fig. 12. Schouwburgplein Square on the parking roof. Architect West 8. Rotterdam (2013) [8]

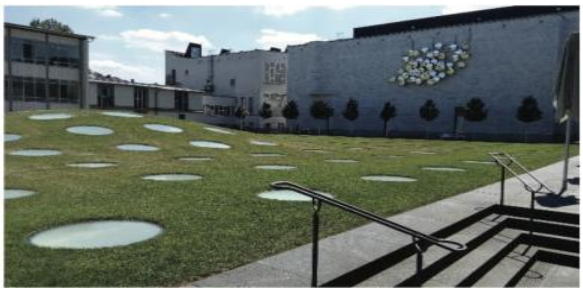

Fig. 13. Green roof of the Museum of Modern Art. Frankfurt am Main (2016) [8]

Fig. 14. Water garden above the parking lot. The Design Museum. Barcelona (2022) [8]

Fig. 15. Operational green roof. Eco-hotel. Normandy (2012) [8]

Fig. 16. Club green roof of the Skolkovo Business School. Moscow (2011) [8]

Fig. 17. Private terraces of the "Vertical Forest" Architect Stefano Bori. Milan (2016) [8]

The benefits of using green roofing (Table 5) are as follows [10]:

- possibility of a dramatic increase in the energy efficiency of buildings leading to a reduction in energy costs and optimization of resource use;
- effective measures in order to combat the urban "heat island" by reducing the temperature in the urban environment;
- noise reduction by means of vegetation in order to absorb sound waves;
- rainwater capture, thereby reducing the burden on the urban sanitation system;
- improving air quality and reducing environmental pollution;
- extending the service life of roofs and reducing the need for them to be replaced;
- creating additional green recreational spaces for public use;
- restoring the biodiversity of urban ecosystems and providing a natural habitat for different animal species [12].

Table 5

Positive effects of using green roofing [11]

Category	Benefit	Owners / investors	Users / tenants	Local community
Economic	Improving the nergy efficiency of a building	√√	√√	√
	Reducing the load on heating, ventilation, and air conditioning systems	√√	√√	○
	Increase in the value of real estate	√√	√	○
	Increasing the service life of a roofing	√√	√√	√
	Improving the efficiency of using solar panels	√√	√√	√
	Reducing the cost of creating and maintaining drainage systems and storm sewers	√√	√√	○
Architectural and urban planning	Increasing the aesthetic appeal of urban development, improving the physical appearance of buildings and structures	√√	√√	√√
	Improving building energy efficiency and environmental friendliness evaluates	√√	√√	√
Environmental	Reducing the „heat island“ effect	○	√√	√√
	Improving the air quality	○	√√	√√
	Carbon sequestration (greenhouse gases)	○	√√	√√
	Stormwater runoff accumulation	○	√√	√√
	Reduction of stormwawter runoff peaks	○	√√	√√
	Reducing urban noise levels	○	√√	√√
	Recreating the natural environment	○	○	√√
	Conservation of biodiversity in urban areas	○	○	√√
Social	Creating new jobs	√√	○	√√
	Creating new functional and public spaces	√√	√√	√√
Social	Citizen involvement in urban/rural development	√	√√	√√
	Opportunity for food production	√	√√	√√

√√ — a great effect
√ — a medium effect
○ — a zero or an almost zero effect

Discussion and Conclusion. The introduction of green roof standards is not merely a new element in construction, but a whole different approach to building lifecycle management. This approach includes not only the construction and

equipping of facilities, but also ensuring environmental sustainability, energy conservation, and improving living standards. However, introducing green roofs into the construction sector is lengthy and ambiguous and also requires time to be optimized and adapted.

The successful and common use of green roofs requires support at the legislative level, as well as a change in the minds of those involved in the construction process who are willing to adapt to new standards and implement environmentally sustainable solutions. From the standpoint of urban planning, the concept of green roofing is an indisputable benefit for developers since it brings together improvement of physical appearance as well as environmental parameters of buildings with effective technologies in order to reduce energy consumption and conserve resources. Therefore green roofing is becoming an innovative solution combining functionality and aesthetics as well as environmental consciousness. Standards and regulation in this context have a key role to play in ensuring sustainability and effectiveness of such systems, making them an essential step to designing more environmentally friendly cities that contribute to public well-being.

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