Green Roofs: Standardization and Quality Control of Processes in Green Construction

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Abstract. The article considers the problems of standardization and quality control of processes in the construction, improvement of integrated safety of buildings and the implementation of innovative green building technologies, the use of national standards as well as international rating systems for green buildings evaluation. This is one of the priority directions in development of the modern construction. The aim of this study is the analysis of ~~the~~ green roof systems and international standards, which were carried out in the green building industry. The authors have studied traditional and innovative solutions of rational using natural resources and energy, the green roof system with integration of supported solar and wind energy collecting and converting devices and of irrigation system. Some studies provide evidence for the benefits of the modular green roof system in urban green space with microclimate differences. This article presents a new research which advances our knowledge of the economic and environmental services provided by the green roof system. Research reported here also considers the analysis of the Russian and international legislation of the quality control of processes in green construction.

1Introduction

The article considers the problem of standardization and quality control of processes in the construction, improvement of integrated safety of buildings and the implementation of innovative green building technologies, the use of national standards as well as international rating systems for green buildings evaluation. This is one of the priority directions in development of the modern construction.

The aim of this study is analysis of the green roof systems and international standards, that carried out in the green building industry. There are studied traditional and innovative solutions of rational using the natural resources and energy, the green roof system with integration of supported integrated solar and wind energy collecting and converting devices and including irrigation system. Some studies provide evidence for the benefits of the modular green roof system in urban green space with microclimate differences. This article presents new research that advances our knowledge of the economical and environmental services provided by the green roof system. Research reported here also considers the

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analysis of the Russian and international legislation of the quality control the processes in green construction.

2 Experimental section

2.1 Methods to improve green roof installation in different climatic conditions

The main factors that increase the environmental friendliness of green building are following:

1. Energy efficiency and water consumption indicators.
2. Impact of the sunlight interaction on surrounding areas and insolation devices of green buildings.
3. Reduction of construction and demolition waste disposed of in landfills and incineration facilities by recovering, reusing, and recycling materials.
4. Pollution in the atmosphere, the ventilation system indicators.
5. The indicators of greening, healthcare and well-being of the green building areas, including sustainable sites.

Thermal separation, heating and mechanical ventilation circuits depending on zones, uses and orientation, solar thermal and photovoltaic integration on building rooftops are aimed to improve green roof installation in different climatic conditions.

In order to reduce power and water consumption, the various smart devices such as "motion sensors", time and space controlling and using motion effect, plumbing devices and also scheduling systems are used in green building. For the superstructure attics or increasing the quantity of storey of the building, facade is made from one or more of the parties and shifted deep into the outer contour of the building. If there is sufficient surrounding space, trees and gardens are planted to enhance the environmental and aesthetic perception of the green building.

In this research it is equally important to assess the effects of climatic parameters on the green roof system. Mary Semana and Annie Pearcea [1] studied the benefits of green roofs in three different types of climates. They compared the peak flow reduction in two studies from Singapore and Brazil, indoor air temperature and annual energy demand decrease in the studies from Greece and France, and the annual flow volume of storm water reduction in the studies from Canada, Sweden, and USA.

In accordance with world map of climate classification Koppen-Geiger updated "MeteorologischeZeitschrift", the main ones are the equatorial climate, dry, warm temperate, snow and polar climate [2]. Singapore and Rio de Janeiro both have a climate classification of Am /Af (equatorial monsoonal / equatorial fully humid) according to Qin, X. Wu, Y et al. [3] green roof study of storm water management and reduction of urban heat island effect.

In high-density urban areas quickly installed modular green roof system gain success and have a high potential in solving problems such as the lack of urban space, "green" areas. These coatings form a modular living systems on the roofs of large commercial and office buildings and residential buildings [4]. Modular green roof is increasingly dynamic part of ever-growing green building sector. This paper reminds us that research regarding roofing ecosystem provided by the urban landscaping needs to be translated into robust and practical tools for changes in urban planning and management.

Modular green roof system is a technically advanced design solution erection of roofing, as well as innovative technological solutions with a number of functional advantages and the ability to integrate devices that convert solar and wind energy - solar panels, LED-Lamps, microwindturbins as known as wind generators (Figure 1).

Fig. 1. Modular green roof system in urban space

The essence of this innovation solution is in the fact that covering surface on the building roof is covered with special cells - modular trays with vegetation and fixed to the gratings by engagements. Modular trays are equipped with irrigation and drip irrigation systems to create a microclimate zone directly above the roof of the building. While the green roof covering modular device must be observe and control of the green roof installation process. The installation process consist of following steps:

• Correct and consistent installation process of the waterproofing layer and its compliance with the project specification.

• Proper installation of irrigation systems and drip irrigation, and matching their capacities and operating mode with the required parameters in accordance with the provisions of the SRT NOSTROY 2.13.81-2012 "Roofs. The requirements for the device, and the rules of acceptance of control".

• Quality control of works of mounting the roofing and grating.

Preferably, more processes according to the map have to be controlled. It should also be noted that the performance of work report of the roofing system installation must be carried out in the general journal papers or special journals of installation process on the forms, that considered in Russian requirements [5].

To date the most widely accepted standard amongst the leading green roof suppliers is the German FLL standards (For schungsgesellschaftLandschaftsentwicklung Landschaftsbau) – the landscaping and landscape Development Research Society [6]. This standard is generally recognised as the benchmark for green roof installation quality According to the German FLL standard a successful green roof system must basically replicate nature and consist of:

- Protection layer.
- Drainage and filter layers.
- Growing medium.
- Appropriate components for vegetation and irrigation.

The effectiveness of a commercially available green roof system was evaluated in two experiments on the roof of Agriculture building at Southern Illinois University Carbondale. There were twelve green roof modular trays (six 61 cm x 61 cm and six 46 cm x 56 cm), filled to the depth of 5.72 cm with various types of growing medium. Modular trays designed as a randomized complete blocks. These experiments indicated that that the commercially available green roof system with modular trays better than the custom green roofs. The advantages of pre-planting modular trays before green roof "pie" is an more easy

placement on roof structure, improved aesthetics, incentive using in maintenance as well as security procuring.

In this research there is presented modern green roof system, that consists of green roof modular pots with a big variety of configurations (Figure 2).

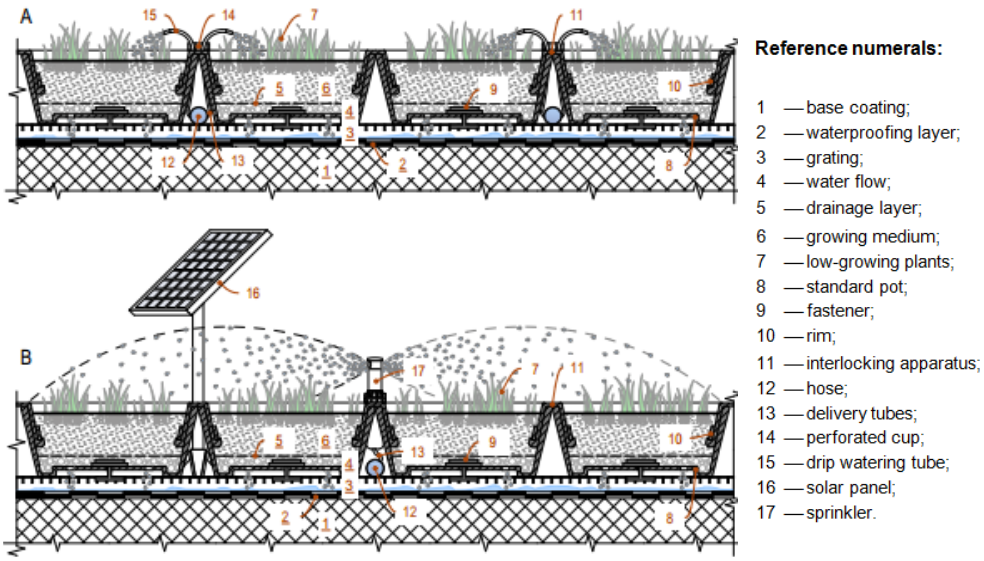

Fig. 2. Schematic views of modular green roof system in section

In conjunction with the Figure 2 the elements of ecologically optimized system are marked with reference numbers, which show a special aspects of method for installing a modular green roof system, comprising the specific steps of roof covering.

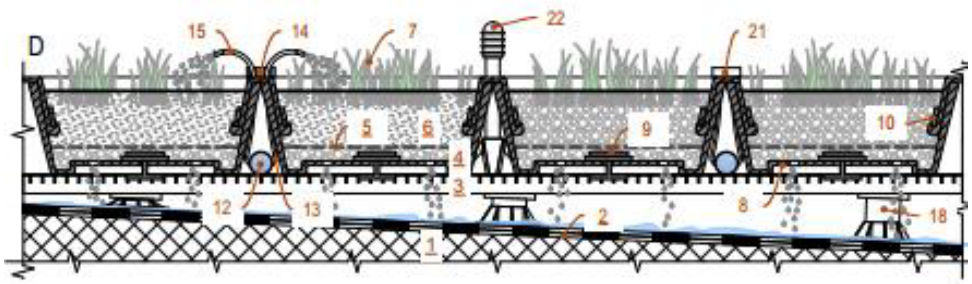

Fig. 3. Schematic view of sloped modular green roof system

Sloped modular green roof system is used adjustable supports to the desired height and construction of communications, network hose for watering. It is also provides quick and easy access to staff to monitoring the status of the waterproofing layer (Figure 3).

Broadly there are great positions of the benefits and improvements of such green roof system. Key advantages are following:

• versatile installation schemes and types of green roof system, improved method for roof covering.

• lightweight, modularity and modern park-like design of green roof modules with reversible interlocking means, that easy and quickly to install, dismounting and maintenance.

• effective water runoff management of green roof systems is provide water supply be special hydroponics system, including automatic watering system, pipes and ducts for water transfer.
• plants diversity and multiplicity of modules comprises different configurations, sizes of diameters and heights that allows to use both intensive and extensive roof greening structures.

The plants are selected according to the specific geographic zone and climate characteristics and green roof type such as extensive, semi-intensive and intensive roofs. And it shows interest in installation of this biggest variants of green roofs and their geographic applicability, which is available in many regions. Also it is important in selecting, that plants affect on the roof's performance and its tolerance to drought, wind, light, shade and pollutants. The low-growing plants may include a wider range of plant species such as Erica carnea "Foxhollow", Erica carnea "Springwood White". The high-growing plants may include a wider range of plant species such as Cryptomeria japonica "Elegans", Cryptomeria japonica "Nana", Cryptomeria japonica "Vilmonaria", Cupressusarizonica "Blue Ice" and others. Alternatively or additionally there can be joined other grasses, herbs and mosses.

2.2 Quality control systems of green buildings in studies of construction process

The appraisal of green building with green roof devices using various methods and standards. In this study versatility techniques are shown in analysis of the interrelationships among systems in green standardization and certification. Standardization in the field of green building is gaining momentum and is successfully operating at the international level. In order to control the quality of constructed facilities around the world there are a number of individual state and interstate systems of standards and ratings. Green roof systems installed on different types of buildings can put on the right track to earning the highest BREEAM, LEED, DGNB and HQE certification ratings [7]. It would be desirable emphasize new HQE system. HQE certification covers the entire lifecycle of a building in studies of construction, renovation and operation process. It adds value to certified projects non-residential buildings, residential buildings and detached houses as well as urban planning and development.

The purpose of HQE certification is to endorse the overall performance of a building and that of the four key areas considered by the certification scheme: energy, environment, health and comfort. The performance levels achieved are stated and endorsed in a certificate issued at the end of the project. They take product and material lifecycles into account. This certification rating system develop its technical schemes that cover all categories of non-residential buildings (logistics, retail outlets, hotels, etc.), the ability to issue certificates worldwide by combining generic criteria, specific criteria, and common indicators, thereby allowing all assets to be compared. Green certification rating systems such as BREEAM, LEED, DGNB and HQE are the most reliable ways to ensure that the high quality nature of a project is recognized.

The one of the famous system is a LEED (Leadership in Energy and Environmental Design). LEED certification system begins with the registration of the project on the USGBC website, it is recommended to work at the design stage of the project.

At the moment there is a preparation for the certification of construction projects for the 2018 FIFA World Cup, in the framework of this program, all 12 new stadiums in Sochi will be certified according to the environmental standards [8].

A similar rating system for new and existing buildings which awards a sustainability rating is BREEAM (Building Research Establishment Environmental Assessment Method).

Launched in 1990 BREEAM involves the widest possible assessment of the building including assessments of the health and wellbeing of the occupants, the environmental impact of the materials used in construction, land using and ecology.

Issuance of a certificate of conformity has been BRE Global - British Institute engaged in the certification of environmental technologies and equipment in the construction, as well as systems and security systems. Throughout the entire project from the design stage to the commissioning of the work involved in the process of the Institute employee, which controls the quality of design and construction process [9].

On the territory of Russian Federation there are few regulations, which controlling the quality of processes, facilities and green construction generally. Such documents has called as standards GOST R 54964-2012 "Conformity assessment. Environmental requirements to the objects of real estate" and national standards STO NOSTROY 2.35.68-2012 "Green Building.residential and public buildings. Taking into account regional peculiarities in the rating system stability assessment of the habitat".

It should be noted, there are separate regulations, which play an important role in the process of constantly changing technologies of construction. Currently Russian systems have not yet formed as unified system of quality control of construction projects, green buildings, like LEED or BREEAM. The Russian government decides to important economic problems and the creation of such systems would entail high costs. This has become necessary to increase the pace of construction of energy efficient buildings, using new methods of green building technologies and advanced quality control systems. It requires the support of investors interested in this and attract the attention of authorities, as well as to contribute to the support of initiatives among the people involved in the development of innovative projects, which aim to develop promising technologies of green building.

In order to control the quality of buildings under construction there are a quantity of individual state and interstate system standards and rankings in the field of green building, which are recognized to ensure the implementation of innovative technologies and innovative solutions in the construction sites.

3 Results section

The quality control and acceptance of green roof installation processes are included in special regulatory codes and industry standards. As stated above green roof system, all aspects of roof requirements that must be different between intensive greening and extensive greening system. The desired aesthetic-ornamental extensive greening system are required a higher degree of installation process than intensive greening system.

A method for modular green roof system installation, comprising the steps of:

- consecutive installation of the waterproofing, drainage and filter layers on the rooftop.
- mounting of adjustable supports on the waterproofing layer.
- side-by-side installation of modular pots on the grating.
- assembling and integration of energy collecting and converting devices such as solar panels, LED-lights, micro wind turbines and irrigation systems.

Green roof construction work quality inspection for this system required inspections for each step of installation process and including:

1. Quality control of green roof construction work is used by qualified inspector of the construction laboratory.

2. Control over observance of the green roof technology of each stages of work in the installing process.

3. Daily quality control report is recorded on a daily basis on follows:

• the date of execution of work;
• conditions of works on separate progrips;
• the results of a systematic monitoring of the quality work.

4. The quality of the device of the each layer. Therefore it is recorded on a act on the hidden work for each layer. The strength of adhesion of waterproofing layer must be not less than 1 kgf / cm2.

5. Discovered during the inspection defects of layers or deviations should be corrected before the start of works of overlying roof layers.

6. Acceptance of the finished roof covering is accompanied overhaul its surface, especially in the trays and places of protruding structures. In some case teas finished flat roof with internal waterdrain checked by filling it with water. The roof testing can be carried out in consultation with the project organization and at air temperature at least + 5 ° C.

7. During the final acceptance of the roof the following documents are required:
• certificates of used materials.
• data of the results of laboratory tests materials;
• report of roofing production work.
• as-built drawings of roof covering.
• acts of intermediate acceptance of the executed works.

The results of inspections must be recorded on the work task inspection form and on the daily quality control report.

4 Discussion section

At the present time there has been 4 Russian LEED-certified and another 40 facilities in the pre-assessment stage, and 10 objects, certified on the BREEAM system.

Office center "Barvikha Luxury Village" is the large complex and Rublevskoeshosse, emphasizes the nature of the International 6 * VIP Business Club. In addition to office space there will be a luxurious lobby and cafe, a business club, restaurants, shops, banks and travel agencies. The project is based on the principles of sustainable construction and energy efficiency. LEED-certified office center "Barvikha" is resource efficient. This building, certified under the LEED v4 rating system, uses less water and energy and reduce greenhouse gas emissions. Ground floor area of 15 000 square meters will be equipped with innovative technologies, which demonstrated the analysis the design of the project, including the following:
• plumbing, sewage conveyance and on-site treatment systems;
• rainwater quantity and quality management systems;
• landscaping, irrigation, and site elements;
• green roofing systems of building.

Thus, the issues of standardization and quality control in the construction of green buildings, introduction of technologies of green building and the use of various green certification rating systems such as BREEAM, LEED, DGNB and HQE standards become essential to modern society because of the need of rational use of natural resources, improving environmental safety of buildings and to reduce the harmful impact on the environment.

Conclusions

Modular green roofs are becoming increasingly important systems of the green building renaissance. Modular green roof constructive system that considered as research object of

study in this article is regarded to the most effective solution of innovative approaches and techniques for green design and construction. Trying to find the optimal system of green roof, this system is to be solved various problems of roof covering by making inexpensive, little expenditure of labor and waste-free green roof assembling based on the principle of building kit. The unique configuration of the system with an unusual combination of architectural and aesthetic design solutions gives a beautiful appearance to the urban areas and also allows to use methods of landscaping on living roof. This innovation green roof solution is appreciated by potential investors because implementing of this system can improve a company's competitiveness, bring great environment benefits and economic profit. While Russian regulations in this field are still missing, existing standards developed in Europe could possibly be used to provide a common basis and further growth of the green roof market. The main aim of this research is to develop cost-effective green technology that can significantly improve building nature-friendly construction, amplify a real-world science enterprise and work in different environmental conditions.

References

1. M.Semaan, A. Pearce, Procedia Engineering, **145**,333-339(2016)
2. M. Kottek, J. Grieser, C. Beck, B. Rudolf, F. Rubel, World map of the Koppen-Geiger climate classification updated "MeteorologischeZeitschrift", **15 (3)**, 259-263 (2006)
3. X. Qin, X. Wu, Y. M. Chiew, Y. Li, British Journal of Environment & Climate Change, **2 (4)**, 410-420 (2012)
4. E. Korol, N. Shushunova, Procedia Engineering, **161**, 1820-1826 (2016)
5. STO NOSTROY 2.13.81-2012, Roofs. The requirements for the device, and the rules of acceptance of control (2012)
6. *ForschungsgesellschaftLandschaftsentwicklungLandschaftsbaue,* Guideline for the Planning, Execution and Upkeep of Green Roof Sites (Release, 2016)
7. URL: http://www.grooflab.com.
8. *Quality in Construction* (Standards and Quality, 61, 2016)
9. URL: http://www.breeam.com.