Principles of biological architecture and green construction certification of modern buildings

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Abstract. This article introduces the main trends in green construction, base principles of biological architecture, and its importance in Europa. The concept of biological architecture is considered as one of the most effective and aesthetic way for modern cities to improve the microclimate is the introduction of green architecture. In a large number of countries around the world, apartment buildings, hotels, offices and government buildings with vertical gardening of facades, decorated with a wide variety of plants. Despite the growing interest in the field of green construction, little research has been done to assess the principles of green systems implementation, especially in construction. This study assesses the factors behind the development of green construction. Green construction is a key to solving global problems and modern way of development urban spaces, many of the principles and practices applied in sustainable architecture, have their roots in antiquity. The improvement and popularization of national green standards in the foreseeable future may significantly affect the housing and communal services.

1 Introduction

Biological architecture revolves around buildings that are designed so as to limit the impact of human activity on the environment. This is an ecological approach to the modern urban spaces, from its design to its construction. Raw materials, heating facilities, waste management and the harmony of the artificial with the natural environment. Many of the principles and practices applied in sustainable biological architecture, have their roots in antiquity. They evolved, however, and came to the measures of the industrial age. This architectural current, in the form we know it today, began at least fifty years earlier, when the world and legislation began to sensitize and become more environmentally friendly. Decreased oxygen levels, not global warming, is the real danger to humanity. Oxygen deficiency causes a weakening of the immune system, which leads to the growth of viral diseases, the accumulation of damaged cells, toxins and early aging. Initially, the human body was adapted to live with 38% oxygen in the air. Therefore, reducing its level by half is very worrying for modern scientists [1–3]. Various ways to achieve zero carbon emissions and CO2 applications and their economic impact are also discussed [4–7].

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Today, our planet is in a state of emergency. It is therefore not possible for experts to rely on the laws adopted in the 70s. Designers, architects, civil engineers, builders and their clients have begun to demand a greener world that balances the damage we have caused to our planet. Over the past ten years, people have become increasingly interested in the environment. This led to the fact that even in the construction sector a fundamentally new method appeared - green organic architecture. We discussed the world examples of such dwellings, which are relatively few, but in themselves they resemble some strange fantasies that fully follow the principles of environmental friendship. Living in such houses allows city dwellers, who crave so much for wildlife, to get at least a little closer to them. This article examines what constitutes a biological architecture, not as one of the new fashion trends, but as a new thought radically for people who decided to abandon the exploitation of nature.

In case of building objects of biological architecture, environmental flexibility is primarily taken into account. The root of the word ecology - «Eco» in Greek means house. Therefore, this method of construction is based on the relationship of housing, House and nature. Following this trend, we believe that a person should fight for the nature. This led to the fact that at the end of the 20th century, avant-garde architecture began to develop. The history of green architecture began relatively recently, when it became clear that the pace of industrialization in construction, which only increased during the last century, began to affect the environment excessively. People began to try to create a home for themselves, taking into account several additional factors - biological, physical and socio-psychological. These conditions led to the introduction of an ecological approach to biological architecture.

As the name suggests, green architecture itself is based on man’s love and respect for nature, and therefore buildings built using similar projects should have minimal impact on the environment. However, in fact, ecological architecture with the help of various visual and material signs of style tries to convey this love. As a result, this led to the construction of original works, which are almost impossible to associate with other styles, since with the forms and lines themselves one can see the real nature. At first glance, such buildings may seem very strange and absurd, as they contain interesting fine lines. However, architects calmly explain this by the fact that nature is very multifaceted, and therefore everything can be created here. But in one of these buildings, they are very similar - they fit so perfectly into the environment that they seem to be creatures of the nature.

Certification of green construction objects based on BREEAM, LEED and DGNB standards. New trends of a green construction and biological architecture - people grow greens, fruits and vegetables, as well as creating an environment for eco-leisure have a positive effect on psychological and physical health. Green building technologies are actively developing in the sustainable greening systems, based on emission-reducing technologies [8–12].

However, in Russia, elements of biological architecture are used less often in multi-storey construction than in the EU countries. The use of green standards is designed to accelerate the transition from traditional to sustainable construction, which would limit the negative impact on nature, and would also ensure safety, favorable conditions for the health and livelihoods of people, as a result of which, a number of advantages can be identified in certification according to green standards.

2 Methodology

In this study, the method of analyzing and comparison of existing methods of greening architectural objects is applied, and an analysis is made of modern Russian and foreign green standards, on the basis of which principles of biological architecture are established. In urban areas, where there is a lack of space for planting trees, shrubs and laying out lawns, the use of climbing plants in vertical gardening plays a huge role. Thanks to such plants, it is possible
at low cost to obtain a high decorative effect in a fairly short period of time. Vertical gardening in the conditions of dense development of high-rise buildings in modern megacities is often the only way to bring green plants closer to the interior. Such plants have high decorative qualities. These qualities include a variety of forms, a bright color of flowers, the presence of dense foliage and even fruits. For example, a plant such as a liana creates various patterns on the facades of buildings and structures due to the intricacies of its branches.

In order to appreciate the full effect of such plants, you need to know that creepers are not a plant species, but a life form. Such plants can be both annual and perennial, ornamental and fruit. Naturally, for the vertical gardening of megacities, perennial species of these plants are used, a feature of which is the colorfulness and picturesqueness of the leaves. In the spring-autumn period, these plants have a rich and dense leaf shape, the flowering of such plants lasts a long time. The vegetation has hanging branches with dense foliage and a tiled surface. The rich abundance of flower colors, the presence of juicy fruits, as well as the lush appearance of such plants, created by a sharp upward movement of elastic stems, creates an undeniable advantage.

2.1 The principle of diversity in vertical greening systems

The most popular plant types of vines in greening systems, at whole, are, for example, Jacqueman's woolly or purple clematis; climbing roses; Chinese wisteria, floribunda rose variety; rooting kampsis; curly honeysuckle Telman. These flowering plants are not inferior to flowering herbaceous plants, shrubs and even trees. And, for example, deciduous liana; lianoid honeysuckle; certain types of grapes, characterized by a special beauty of fruiting. In addition, there is a type of vines that are distinguished by a particularly bright color of leaves in the autumn. Such plants include, for example, Amur grapes, girlish grapes, red bubble. Some types of vines are especially prized for their decorative mosaic foliage. For example, these include Engelman's girlish grapes; girlish grapes or ivy-shaped; tubular kirkazon; vineyard aconite, etc.

For use in vertical greening systems, such types of vines as Engelman's girlish grapes have found wide application; girlish grapes, common ivy; ivy Colchis; climbing hydrangea. These plants have high decorative qualities, thanks to which they are able to easily climb along the walls of houses without special adaptations. But lianas are used not only for vertical gardening. Some creepers have found application in the decorative design of slopes. They are a type of ground cover plant. These include common ivy, Colchis ivy and climbing hydrangea.

It is possible to note the genus of clematis and climbing roses. They tend to have a variety of varieties and species. In addition, they bloom profusely and spectacularly during almost the entire growing season. This is what allows you to create combinations that are distinguished by spectacular flowering over an extended period of time.

As the long-term experience of specialists in the field of urban planning shows, the use of a diverse range of plants to model a successful landscape is completely optional. For ennobling, as well as improving the quality of life for a particular area within the settlement, it is better to use individual types of vines that correspond to these climatic features. At the same time, it is also necessary to take into account the previous experience of using these plants in the field of green urban planning.

Along with this, it is also necessary to note the special value of climbing plants. They conceal not only high decorative qualities, but their main functions in the conditions of vertical gardening are also the decorative design of objects, the masking of individual small structures, the design of playgrounds and recreation areas. But the most important thing is
the creation of special microclimatic conditions, namely, an increase in relative humidity, the creation of shade, and a decrease in the radiation background.

For different types of objects, there are different options for vertical gardening. For example, for residential and public buildings, the method of decorative design is used to increase the artistic and aesthetic appearance of buildings: container technology and modular greening systems [13-15]. The variants of existing vertical greening systems are shown on the Figure 1. Accordingly, this leads to an improvement in microclimatic conditions inside the building itself [16-18]. For special places of rest, maximum shade and isolation are created, for household and special technical structures - camouflage, and for small-sized architectural forms - decorative design.

![Variants of existing vertical greening systems](image)

**Fig. 1.** Variants of existing vertical greening systems: (a) container technology — planting of climbing plants in pots; (b) modular technology — using herbaceous plants.

### 2.2 The principle of diversity in vertical greening systems

The effect of decorating buildings and structures with plants depends on the knowledge of their biological and decorative properties, and especially on how skillfully these properties will be used in connection with the natural environment and local climatic conditions. The composition of such plants is a layout of plant forms into a single harmonious whole. It must be based on strict adherence to biological and harmonious unity in the selection of plants. The selection of the most favorable combinations of plants based on a number of principles: functional, ecological, decorative and systematic. When landscaping buildings and structures with climbing plants, they primarily proceed from functional necessity. Plants embedded in landscaping systems perform the following functions:

- protect the walls of buildings from overheating (densely leafy vines significantly eliminate overheating, and such as grapes, ivy, honeysuckle reduce the intensity of solar radiation by about 50%);
- protect from dust and noise (climbing plants covering the building retain dust, which is then washed away by rain; densely leafy vines such as parthenocissus, coastal grapes, Amur grapes are a good anti-noise screen);
- create a shadow, especially in rooms oriented to the south, southwest and west, or at recreation areas in parks, squares, squares (for this, densely leafy vines with large leaves should be used: Kuanye grapes, Amur, coastal, girlish five-leafed, aristolochia, etc.);
- enrich buildings with oxygen.
Creating a green living laboratory from plants, as close as possible to housing and enriching it with oxygen, is one of the most important functions of plants for biological architecture. This is especially used for large industrial cities or transport routes, where there is clearly a lack of oxygen. In order for landscaping to most fully meet various functional requirements, it is necessary, when choosing plants built into landscaping systems, to take into account their natural properties: growth height, density, foliage density, etc. creepers (fragrant grapes, Amur, girlish five-leafed, Engelman, girlish, pointed F. Veychi). From an ecological point of view, in order to achieve the greatest effect from the design of plants built into landscaping systems, it is necessary to create conditions that best correspond to their biological properties. Plants embedded in landscaping systems are characterized by a different attitude to the external environment. Some of them, such as girlish five-leafed grapes, coastal, Amur, Alpine prince, are unpretentious to soil conditions, tolerate frosty winters and are quite drought-resistant, others are not demanding on soil fertility, but are warm and light-loving.

The selection of plants is significantly influenced by the orientation of buildings, depending on which different conditions are created for the growth and development of plants built into landscaping systems. Conditions with average microclimatic indicators are created near the walls of buildings oriented to the east, northeast and northwest. In buildings of southern and western orientation, an excess of heat and light is created, which causes a deficiency of moisture in the soil, therefore, when landscaping walls of southern and western orientation, light-loving and drought-resistant plants should be used, such as honeysuckle honeysuckle, girlish grapes, coastal, fox, Greek elm, etc. The most unfavorable conditions are created near the walls oriented to the north. In such cases, vines that tolerate shading well should be planted, for example, acute actinidia, Dahurian moon seed, climbing tree pliers, petiolate hydrangea, common ivy, rooting tecoma, etc.).

2.3 The principle of green construction certification systems

Among the most advanced international rating systems, English - BREEAM, American - LEED and German - DGNB should be noted. The press conference held on November 22, 2017 in the Small Hall of the International Multimedia Press Center of MIA Rossiya Segodnya was dedicated to the launch of the first Russian certification for green buildings BREEAM RUS, created on the basis of the leading European environmental rating BREEAM. The BREEAM RUS methodology was developed by the technical committee for standardization 366 of NRU MGSU together with BRE Global during the year. The version of the standard, adapted to Russian conditions, will make it possible to more widely apply one of the most used global standards in the field of green building for residential projects. The construction of the first BREEAM RUS project - a multifunctional apartment complex on Prospekt Mira by the City-XXI Century development group - is the implementation of standards at all stages of the project in order to reduce operating costs, despite the increase in the cost of the project up to 5%, which became the winner of the "Best for life" for eco-design.

Among the advantages of applying this standard in Russia are the use of modern technologies and the transition to a new level of industry development; a flexible approach to the use of national standards, the formation of demand for innovative goods and services in the construction industry, which can become a catalyst for the development of the Russian industry and an incentive for the production of competitive products for use in Russia and export abroad. Another certification system is The Leadership in Energy & Environmental Design (LEED). This is a green building rating system developed in 1998 by the Green Building Council USGBC. More than 7.1 billion m² have been certified under this system, including 5,325 commercial properties and 5,755 private properties. The LEED system
covers almost all types of construction projects: new buildings, existing buildings, commercial interiors, residential buildings and cottages, as well as development projects. The difference between the LEED certification system is the presence of a list of mandatory requirements, failure to comply with which implies the loss of the opportunity to obtain a green certificate. These requirements include: minimum requirements for energy efficiency, including the installation of energy saving systems; reduction of pollution from construction activities; reduction of water consumption, control of air conditioning and microclimate, as well as collection and storage of secondary resources.

The German Sustainable Building Certificate was developed in the mid-2000s by the German Council for Sustainable Buildings (DGNB) in cooperation with the Federal Ministry of Transport, Building and Urban Development (BMVBS). This is the only system in the world that, when assessing the life cycle and conducting an analysis of its cost, is guided by the specifics of the functioning of the building for 50 years. The standard also takes into account economic efficiency, socio-cultural and functional aspects of facilities. DGNB actively engages with the community to promote sustainable development knowledge. The methodology of the DGNB standard makes it possible to equally take into account the indicators of environmental impact and the relative cost of the object. Today, the DGNB Council brings together about 900 members representing the construction and property management sector, including scientific, research and public organizations.

3 Results and conclusions

Biological architecture conducted a series of experiments, many of which were very unsuccessful. However, now there are certain principles of biological architecture that should guide the construction of green buildings. These include:

1) the principle of energy saving is to minimize the need to use thermal energy for heating or cooling.

2) the principle of reducing the volume of new structures implies the use of old buildings or materials from them in new buildings. This principle has been valid for centuries, especially in the Middle Ages, when buildings were built for centuries. However, in the middle of the 20th century, developers began to simply demolish and build everything from scratch, because it was so much easier.

3) the principle of working with the sun offers the use of solar panels in the building as a way to concentrate energy for heating (Figure 2). In addition, in buildings built in the style of green architecture, almost all windows face South.

4) the principle of respect for residents - the building is not just a place to live, but a property in which every inhabitant of the House has a huge role to play in maintaining order.

5) the principle of respect for Place provides for the Eastern philosophy’s view of nature - the unification and fusion of Man and his natural environment. Nature must cease to be only a resource used for the benefit of mankind.

6) the principle of integrity expresses the ideal of eco-architecture. It provides an approach to the construction project in such a way that all of the above principles can be applied.
The Stavros Niarchos Foundation Cultural Center is another successful example of biological architecture (Figure 3). The center was designed by architect Renzo Piano and its construction was funded by the Stavros Niarchos Foundation. The $861 million project was completed in 2016, and was donated to the Greek state in 2017. The project Plans for a big scale donation by the Stavros Niarchos Foundation started in 1998. Initially the foundation planned to make separate donations to the National Library and the National Opera. In 2006 it was decided to build one complex for both organizations and after discussions with the Greek state the area of the former horse racing (Hippodrome) track was chosen. In 2008 the foundation chose Italian architect Renzo Piano to design the complex and in 2012 construction works started. Renzo Piano made the building rising out of the ground like a dislodged piece of the earth’s crust. As a result, an artificial hill is constructed and the roof of both the library and the opera house is emerging from it maintaining the slope. The library is lower and the ‘hill’ concludes with the opera house. The roof of the library will be covered with ground material and planted with indigenous Greek plants.

The competitive analysis of green construction certification systems – BREEAM, LEED and DGNB [19] is shown in Table 1.
### Table 1. The competitive analysis of green construction certification systems.

<table>
<thead>
<tr>
<th>Criteria / Green standard</th>
<th>BREEAM</th>
<th>LEED</th>
<th>DGNB</th>
</tr>
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<tbody>
<tr>
<td>Environmental</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Economic</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Socio-Cultural</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Building Life cycle (50 years)</td>
<td>-</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Functional (Air quality, Innovations)</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Technological</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Location and Transport</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Operational (Material and Resources)</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Energy-efficiency (water-efficiency)</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Adoption (to region, building stage)</td>
<td>+</td>
<td>+</td>
<td>-</td>
</tr>
</tbody>
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The fundamental principles of green building rating systems, important for biological architecture, have been identified and compared. The LEED system covers almost all types of construction projects: new buildings, existing buildings, commercial interiors, residential buildings and cottages, as well as development projects. The difference between the LEED certification system is the mandatory requirements for energy efficiency, control of air conditioning and microclimate, as well as collection and storage of secondary resources. Thus, principles of biological architecture and green building rating systems have been identified and compared. It should be noted that the principles of biological architecture in our country are just being formed and its development requires serious state support, improvement and updating of the regulatory framework in the field of energy saving and environmental protection, taking into account the current practice of green construction.

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