Ecological design ideas of large-scale public buildings: review of Russian Botanical Garden greenhouses ecological design

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Abstract. With the rapid development of cities around the world, the concept of ecological design of large-scale public buildings has gradually come to the attention of the public. One of the main problems is the possibility of maintaining a balance between urban development, nature and man, which creates conditions for improving the environment and improving the quality of life of the population. An ecologically comfortable environment is considered today as one of the main prerequisites for the development of a particular territory. This article first gives a brief overview of scientific sources on the design of public buildings in botanical gardens, then discusses the principles of environmental design of large-scale public buildings and, finally, review the ideas of environmental design of greenhouse buildings in Russian botanical gardens from two aspects of form and content. The relevance of the work is ensured by the fact that botanical gardens occupy an important place in any city and it is necessary to understand how to update the garden space, how to respond to the new requirements of society and by what means to attract more visitors. Based on the analysis of various examples, the author notes the existing problems of construction of large-scale public buildings of eco-friendly design in Russian botanical gardens, and also comes to the conclusion that the landscape architecture of Western Europe and the experience of Western engineers in eco-friendly construction has a great influence on the image of modern Russian botanical gardens.

1. Research background

The problem of the relationship between architecture and nature at the turn of the XX - XXI centuries reached a new level due to the development of such branches of science as ecology, bioethics and the growth of the movement for the protection of nature. A turning point in the development of eco-friendly construction was the "Earth Summit" in Rio de Janeiro in 1992, the answer to the questions of which in urban studies was the emergence of the concept of "eco-urbanism". [1]

According to the summit theory, in the development of the city must pay special attention to the harmonious combination of architecture and nature. With the intensive development of urban environment, infrastructure should adapt to the environment and landscape. Russia has successfully implemented many projects based on the concept of ecological urbanization. Botanical gardens are also directly involved, for example, in selecting a range of plants for vertical gardening. Botanical Garden resources are of great significance not only for improving the city's ecological level, but also for building a safe human settlement environment, which directly relates to the physical and mental health of city residents.

The availability of botanical gardens, gradually turned these territories into places of recreation for the urban population. The main architectural and planning centre of any botanical garden is a complex
2. The concept of designing large-scale buildings in the botanical gardens of the world

From the point of view of modern architectural design, a greenhouse is a frame structure made of solid glass or eco-friendly materials, in which a constant temperature, humidity and lighting mode are maintained. The earliest prototypes of greenhouses were wooden or stone buildings with large side windows and opaque roofs that made the lighting uneven. The first greenhouses appeared in the second half of the 16th century in France and were intended only for the winter preservation of heat-loving fruit plants. The first glass greenhouse with stove heating for year-round cultivation of exotic plants was built in the Botanical Garden of Leiden in 1599. Further, greenhouses began to appear everywhere in botanical gardens throughout Europe [3]. Later, greenhouses began to be designed using metal frames and glass walls and roofs, which made it easier to maintain the necessary temperature and humidity. One of the best examples of large-scale public buildings in botanical gardens is the Palm House in Vienna’s Schonbrun Palace Complex, the Habsburg summer residence. Today, the greenhouse is one of the three largest greenhouses in Europe – its length is 128 m, its area is 2,050 sq. m. The framework was based on convex arches made of iron, thanks to the decorative nature and lightness of which, the greenhouse easily fit into the surrounding park.

The prototype of the Vienna Palm House was the Palm House greenhouse at the Royal Botanic Gardens Kew in England. The glass and wrought iron structure embody the design principles developed by John Loudon and Joseph Paxton — the glass is held on a frame of wrought iron arches, held together by horizontal pipes, inside which cables are stretched. The windows are tinted with copper oxide in a greenish colour to protect the plants from overheating. [4-5]

Of the modern greenhouses, it is worth noting the Ecorium project in South Korea, presented at the figure 1. The greenhouse complex was created by the Nicholas Grimshaw architectural company together with Samoo Architects & Engineers on an area of more than 33090 m². The project, which is a glazed dome on a metal frame, is based on the ideas of eco-urbanism, which has reduced the total electricity consumption by 10%.

Figure 1. Ecorium project greenhouses plan

A prime example of the eco-design of large-scale public buildings is the Eden project in Cornwall, in the south-west of England. The greenhouse consists of several geodesic domes on an area of 22,000 m². The domes have a frame of steel pipes forming hexagonal frames with external panels made of eco-friendly ETFE thermoplastic. The panels are fastened around the perimeter and filled with air, thus
forming a large air cushion that protects the greenhouses from heat loss. In addition, the design is organically integrated into the surrounding landscape.

2.1. The principle of sustainable development
The concept of sustainable development emerged as a result of combining three main points of view: economic, social and environmental. It is important that a large-scale public building is not only human-friendly, but also environmentally friendly and cost-effective at all stages: material production, construction, operation and disposal. The building must meet sanitary and environmental standards, be comfortable and functional.

2.2. The principle of energy efficiency
Russia's interest in eco-friendly buildings emerged in 2009 after the president identified reasonable energy consumption as one of the country's most important tasks. An example is the new greenhouse of the Main Botanical Garden named after N. V. Tsitsin (figure 2) - in the course of its operation, it consumes a minimum amount of energy for heating, lighting and other needs. The eco-friendly architecture of the greenhouse allows not only to consciously use natural resources and ensure environmental protection, but also is responsible for improving the standard of living of people and their social responsibility. A notable feature of the greenhouse is the facade, which can be configured to suit the weather conditions; double glass windows can store heat and solar energy, provide up to 50% of the total heat demand of buildings, and maximize the use of natural light. [6]

![Figure 2. Russia Main Botanical Garden greenhouse](image)

In addition, to increase energy efficiency and generate electricity, it is possible to install wind generators with a vertical axis and solar panels on the roofs of buildings. As it was done during the construction of the greenhouse in Pittsburgh, USA.

The greenhouse in Pittsburgh is characterized by an unusual gable roof for this type of building, glazed to reduce heat loss with double-glazed windows. Automatically controlled ventilation windows on the roof allow you to adjust the climate. The southern facade is glazed with single double-glazed windows to create optimal lighting for plants. Inside the greenhouse, ceiling curtains create shade and, if necessary, thermal insulation. Geothermal heat exchangers are used to extract heat or coolness from underground, where the temperature remains stable throughout the year. Plants are heated in the root zone using a system of pipes through which hot water circulates, which reduces the energy consumption for heating the air.
2.3. Local principle

The practical significance of the greenhouse is the harmonious combination of the building with the surrounding space by creating the appearance of the building corresponding to the active form of the relief. The greenhouse as the main structure of the botanical garden maintains a balance between the unlimited creative possibilities of nature, technology and architects [7]. In the ecological design of public buildings in large spaces, according to the terrain and climate, it is integrated with local culture and customs, and building materials are intelligently used to combine modern high-tech technologies with local technologies to form new regional characteristics. In eco-sustainable buildings, there are always aspects that are closely connected with the ethical values of society.

Eco-architecture should be treated equally at the emotional, functional, and social levels. At the functional and social levels, the architecture should be consumer-oriented, user-friendly, adaptable to changes in the needs of users or new owners, and have the potential for anticipated and sudden changes. The emotional level means that the architecture must fit the place. This creates identity and emotionally touches people. The structures of the building must be strong enough to withstand the changes, and the aesthetic qualities must exceed the economic pressure in time.

3. Eco-design of large-scale public buildings in Russian botanical gardens

Modern greenhouses in the botanical gardens of Russia demonstrate the technical possibilities of creating different climatic zones of the planet from the Alpine to the tropics and mangroves, as well as their typical vegetation and rare endangered species. [8]

3.1. Form design

The concept of building greenhouse complexes in Russian botanical gardens is based on the historical architectural style of the country, the natural shape of the terrain and is based on unique scientific discoveries and technologies. Which is fully compatible with the local principle, mentioned before. One of the largest greenhouses in Russia is located in the Main Botanical Garden named after N. V. Tsitsin of the Russian Academy of Sciences in Moscow. The new stock greenhouse of the garden is a multi-section dome metal structure with solid glazing with a height of 33 m. Its modern design satisfies the historical and cultural features of Russian architecture.

In addition, thanks to the chosen dome shape in the greenhouse - there is no shortage of natural light-the sun's rays penetrate from all sides; the air, circulating inside, moves freely, without stagnating in the corners, so that the internal temperature is constant and uniform throughout the entire volume of the greenhouse; the structure is characterized by the highest strength and stability, since it is based on the most stable geometric figure – a pyramid; the exception of the load in winter, when snow can accumulate on the roof.

The second greenhouse under the analysis is the greenhouse of the Peter the Great Botanical Garden in St. Petersburg. In the XIX century, greenhouses in Russia were created in palace ensembles, country residences, and often it was the three-dimensional building. The style of the greenhouse of the Peter the Great Botanical Garden in St. Petersburg is solved by a multi-tiered dome structure, complemented by wrought-iron decorative elements [9]. In addition, the design of the greenhouse is fully consistent with the architectural styles of the time, and the prototype in the design was the greenhouse in the Royal Botanical Gardens Kew in England.
3.2. Content design

In the eco-design of large public buildings, the choice of building materials is particularly important. In the construction of greenhouses of Russian botanical gardens, metal is mainly used – its use reduces the load on the foundation and allows the use of large-area glass. Some 18th-century greenhouses have wooden and stone structures, but they need constant care, antiseptic treatment and antifungal treatment. In the greenhouses of the botanical gardens, electricity costs are accounted for by lighting, forced ventilation, and feeding the circulation pumps. The roof and walls of the greenhouses of the Russian botanical gardens are mainly made up of plastic double-glazed windows, which allows the fullest use of natural sunlight and reduces the cost of electricity during the day. To increase energy efficiency, it is recommended to use energy-efficient lamps - LED, infrared and ultraviolet lamps in combination with mirror, aluminium, foil reflectors – reflectors and a glow regulator. [10]

However, very often, despite their design, the buildings of greenhouses in the botanical gardens of Russia do not meet modern standards of energy efficiency. The source of heat supply is often gas boiler houses. Large heat losses from greenhouses are compensated by additional heat sources - electric air heaters. This solution entails additional energy costs. Another problem is the lack of a high-quality ventilation system, which can lead to condensation on the double-glazed windows and profile surfaces. In addition, to reduce the load on the air conditioning system, it is possible to design the frame of the building in such a way as to maximize the use of load-bearing beams as a system for shading the space inside. As it is done in the Gardens by the Bay project in Singapore. There is also an excellent example of an ecological power plant that runs on biomass and wood waste. The ash obtained after burning is used as fertilizer.

However, the new greenhouse of the Main Botanical Garden in Moscow is an excellent example of energy savings. It was created under a special project with the involvement of leading institutes of the Russian Federation and Finland and is a complex translucent shell of double-glazed windows with energy-saving properties on a metal frame. In the stock greenhouse maintenance, the technology of adiabatic humidification with minimal energy consumption is used to maintain the same level of humidity throughout the year, similar to the climate of a tropical forest.

4. Summary

For the most successful design of large-scale public buildings of eco-friendly design, it should be borne in mind that any project must meet its intended purpose, meet the tasks set, be convenient, comfortable and aesthetically attractive [11]. Meanwhile, in the urban planning aspect, the task arises of choosing not only the optimal location of the building, but also approaches to its organization,
connection with the transport network, on the basis of which, it is possible to identify and systematize the most significant requirements for the design of large-scale public buildings taking into account environmental comfort:

- the building should be harmonious, taking into account the surrounding and existing buildings;
- design should take into account regional and climatic features;
- biopositive (restoration of disturbed flora and fauna on the territory of the city and in the adjacent zone; increase in the intensity of biological processes in the urban environment; increase in biodiversity on the territory of the city);
- to ensure effective interaction between man and space, man and nature;
- provide an opportunity for future transformations.

5. Conclusion

Environmental design of large spatial public buildings should always implement systems thinking, observe the dynamic changes between the topological structure of the relationship between the building and the environment, combine construction technology with organizational function and artistic characteristics, and gradually form a new complex of aesthetic orientation of material, energy and information to guide the progressive development of architectural design. In addition, when choosing eco-design techniques, it is necessary to take into account the natural and climatic features of the region, the urban planning situation, as well as the architectural and planning and spatial characteristics of the projected territories.

This article briefly reviews the ecological design of greenhouses in Russian botanical gardens, as vivid examples of large public spaces. The Russian Botanical Garden has absorbed the classical techniques of landscape architecture of Western Europe and has formed its own national characteristics in the process of its development. Its influence extends to all the republics of the former Soviet Union and other socialist countries, including China.

Despite the existing construction problems, the main of which is the lack of funding, the principles of ecological design of large-scale public buildings are analysed using the example of greenhouses in the botanical gardens of Moscow and St. Petersburg.

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