The Recessed Buildings as a Perspective Direction of ‘Green’ Architecture

S V Ilvitskaya¹, Y V Alexeev², A A Anufriev³

¹Department of Architecture, Federal State Budget Educational Institution of Higher Education “State University of Land Use Planning”, Moscow, Kazakova Str., Building 15., 105064, Russian Federation and department of “Architecture”, Moscow State University of Civil Engineering (MGSU), 26, Yaroslavskoye Shosse, Moscow, 129337, Russian Federation
²Department of “Urban planning”, Moscow State University of Civil Engineering (MGSU), 26, Yaroslavskoye Shosse, Moscow, 129337, Russian Federation
³Department of “Architecture”, Moscow State University of Civil Engineering (MGSU), 26, Yaroslavskoye Shosse, Moscow, 129337, Russian Federation

E-mail: ilvitskaya@mail.ru, alekseev-grado@yandex.ru, anyfriev-aleksey@yandex.ru

Abstract. The article is devoted to the actual problem of preserving and improving the favorable environmental conditions in the urban environment, due to the introduction of the recessed buildings and structures in the architectural-urban planning and construction activity using ‘green’ architecture technologies. Such objects will reduce the load on the ecosystem, energy, improve the quality of the visual environment of the city, and maintain the existing natural landscape along with the flora and fauna while increasing the area of green spaces in urban or rural areas. The characteristic features of the recessed buildings, their advantages and limitations are given. Determined techniques of architectural-figurative solutions of recessed buildings. The principle of harmonious synthesis of ‘green’ technologies and modern achievements in the architecture of the recessed buildings is proposed. Possible solutions to global environmental problems are proposed due to the capabilities of the underlying architecture.

1. Introduction

Environmental pollution, fragile state of the ecosystems, loss of green areas and degradation of the landscape and nature, depletion of renewable and non-renewable energy sources and, in general, ignoring nature, are the result of human activity on the planet over time. The main global environmental issues today are:

- depletion of natural resources and environmental pollution with solid household waste;
- atmospheric pollution and the emergence of the «greenhouse effect» and the degradation and desertification of land;
- pollution of the world’s water resources and the detrimental effect on the flora and fauna.

Due to the fact that our civilization is facing the problem of a global energy crisis, ecological or «green» architecture is becoming increasingly popular and in demand. The task of architects today is to design high-quality, eco-friendly buildings that also have low energy consumption. Currently,
modern buildings (especially residential buildings) are the main sources of energy consumption and pollution, which contributes to unpredictable and catastrophic climate change. The recessed buildings have excellent energy-saving properties in many climatic conditions, including the climate of the central part of the Russian Federation. To ensure constant, comfortable room temperature, ground-based buildings are characterized by a high level of energy consumption for heating and cooling buildings. In contrast, recessed buildings are surrounded by a protective layer of soil. At a depth of two meters in the middle zone in winter and summer, the temperature of the soil is 10-17 ° C, which ensures constant temperatures in the room. However, even with high energy efficiency due to partial penetration into the ground, this type of buildings needs a number of other measures that will reduce energy consumption even more and relate it to green architecture.

Changes in the economy, ecology and psychology of people not only contribute to the emergence of new types of buildings, but also force to revert to traditional construction methods. The principles of green building correspond to buildings partially recessed in the ground. At a depth of two meters in the middle zone in winter and summer, the temperature is 10-17 ° C. In the cold period, the earth gives warmth, in summer – coolness. The need for buried architecture arose in connection with the increased requirements for the heat-shielding properties of walling constructions in Russia and abroad. Surface protection allows not only to significantly reduce energy consumption in normal conditions, but also to reduce the dependence on fuel consumption, especially in severe winter conditions.

One of the main aspects of architectural design and construction of recessed buildings should be called energy savings, which can be obtained in this type of building. The necessary effect of reducing energy costs, provided that the appropriate comfort of living and people’s stay is created, can only be achieved by fulfilling a number of requirements relating to choosing a place for construction, determining the type of building, its placement on the site and orientation, rational planning and design solutions, engineering equipment, landscaping and landscaping site construction. When choosing and determining the location of the recessed building, successfully solved in terms of energy efficiency, it is important to take into account the features that are essential for this type of building — the topography of the site, the geological and hydrogeological conditions, the size of the site and the location of the neighboring buildings. The main requirements for the site are:

- the presence of dry, not prone to erosion, preferably sandy soils;
- low groundwater level;
- presence of relief;
- low relative humidity.

The energy saving effect of recessed buildings is determined by the protective layer of the soil. In the summer, the recessed structures practically do not need air cooling in the rooms, since it is cooled due to the heat return through the walling constructions of the soil dusting. In winter, dusting with soil sharply reduces, compared to ground buildings, heat loss due to the additional thermal resistance of soil dusting.

When choosing basic solutions, it is important to consider the appropriateness of using alternative mechanical systems, such as solar collectors, air conditioning using ice, recovery of heat from wastewater, use of low-grade heat of the Earth through geothermal heat pumps, etc. All alternative energy systems that can be applied to recessed buildings have an impact on design decisions, and often quite significantly. For this reason, a comprehensive, in-depth assessment of such systems when choosing major solutions will allow them to be reasonably included in the design decision.

From an environmental point of view, recessed buildings are interesting not only because they contribute to the conservation of energy resources, but also because they allow the use of buildings that are unsuitable for the placement of above-ground buildings for development. Thus, it creates the possibility of saving urban land at the expense of land considered unsuitable for construction. The sprinkling of buildings with soil and subsequent landscaping can dramatically increase the area of greenery in populated areas, improve the microclimate of buildings and the urban landscape. If the relief is quite picturesque, or if the inhabitants want to have more visual contact with the environment,
then in this case a semi-recessed building on the slope seems more preferable than a ground building on a flat terrain.

Recessed buildings and structures erected with the use of green technologies will significantly reduce environmental pollution in our country, and, subject to certain conditions, will be able to independently satisfy their own needs for energy sources, while not using external power sources. Also in urban conditions, recessed buildings help to restore and preserve the flora and fauna, improve the quality of the surrounding urban environment, i.e. contribute to nature conservation.

In order to solve these problems, it is necessary to develop a theoretical justification for the use of recessed buildings with the use of ‘green’ technologies as a way to improve the environmental situation in the city and the quality of the visual environment, and also to answer a number of questions:

- determination of the functional structure, space-planning decisions and the potential of recessed buildings;
- analysis of the existing experience in the design of recessed buildings and structures;
- analysis of existing experience in ‘green’ architecture;
- analysis of the principles of integrating green technologies into the architecture of recessed buildings in order to ensure energy efficiency;
- to formulate the concept of a modern architectural space of recessed buildings using green technologies.

As a material for the study, a period of time was suggested from the dwellings of the Neolithic era (ca. 9000 years BC) to modern examples of public and residential buildings of the recessed type.

2. Materials and methods
The research methodology is based on the historical, typological and structural-analytical method, going back to the system approach, and consists of several interrelated stages and links, united by a common integrated research concept. The research methodology includes the development of copyright classifications of recessed buildings and creative concepts of the masters of modern landform architecture.

The scientific novelty of the study of recessed buildings contains the main aspects and consists of:

- In establishing the techniques of architectural-figurative solutions of recessed buildings with the use of ‘green’ technologies;
- In identifying the characteristic features of space-planning decisions of recessed buildings using ‘green’ technologies and their development trends;
- Based on the techniques of the recessed architecture, the principle of harmonious synthesis of ‘green’ technologies and modern achievements in the architecture of recessed buildings has been proposed.
- Applying the capabilities of recessed architecture to solving global environmental problems.

The present study is based on theoretical and practical works, in which individual aspects are reflected from different positions.

It is necessary to note the works of A. B. Ponomareva and Yu.L. Vinnikova, dedicated to the main trends and problems of the use of the underground space of large cities and megapolises, a number of works by M A Rogozhnikova, in which the typology and principles of designing a low-rise recessed buildings in the historical and cultural reserves of the European part of Russia are considered.

The patterns of formation of underground and recessed architecture are also set forth in the writings of such authors as Sterling R, Ivanova N A, Dalmatov B I, Bronin V N, Dranovsky A N, Fadeev A B, Mitinsky V M., Barannik S V, Chepelev V T, Zotsenko N L, Vinnikov Yu L, Kharchenko M A, Ponomarev A B, Telichenko V I, Golubev G E, Kelemen J, Vaida Z, Konyukhov D S, Kornilkov M V, Polovov B D, Carmody J, Golani G S, Meijnfelt E, Gelyuk M, Markova E B, Tulakov E S, Kuldashev A T, Ochilov N O, Gritsenko A V.

Many architects and designers were involved in the study of green and energy-saving buildings: Milashechkina O N, Ezhova I K, Selivanova N P, Davis A, Belyaev V S, Ternoy S, Beckle L, Robins
K, Tabunshchikov Y A, Markus T A, Morris E N, Melua A I, Shchipacheva E V, Khokhlova L P, Badin G M, Popova M V, Yashkova T N, Averyanov V K, Podolyan L A, Tyutyunnikov A I, Zaretsky R U, Alekseenko S V.

Methods of assessing the attractiveness presented in the works of authors such as Pomorov S B, Kanteev D V, Kuleshova M E, Likhacheva E A, Timofeeva D A, Zhidkov M P, Peredelsky L V, Korobkin V I, Prikhodchenko O E, Tetior A N were engaged in the study of the ecology and ecosystem of the city.

Questions of the interaction of architecture and nature are investigated in the works of such authors as J E J Ruskin, E Howard, L Sullivan, F L Wright, R Steiner, Burov A K, Lebedev Yu S, Lazarev A I, Temnov V G, Zokoley S V, I Richards, B van Berkel, P Portogizi, C Jenks, D Gans, Z Kaz, S Alain, M Sorkin, B Zevi, M Spix, A Betsky, and other architects and scientific researchers. This study uses the works of Vitruvius, L B Alberti, Michelangelo, L da Vinci, C Darwin, G Greeno, L Caen, H Charun, Z Gideon, C Frempton, D Symonds, Le Corbusier, and A Aalto.

The main provisions of the study of recessed buildings include:

- architectural and spatial types - factors influencing the ‘green’ technologies on the architecture of the recessed buildings;
- principles of rational integration of ‘green’ technologies into the architecture of recessed buildings;
- projected subsurface object in the current historical and architectural environment of the city using modern ‘green’ technologies on the example of the Museum of Nature in the city of Ramenskoye.

‘Green’ architecture (also ecological architecture, ‘green’ building, eco-development, energy-efficient architecture) is an applied section of the architecture, the purpose of which is to reduce the level of consumption of energy and material resources during the entire lifetime of the building and reduce its environmental impact. The term ‘green architecture’ first came from the concept of ‘sustainable architecture’, which arose in the 80s. XX century. The concept of “sustainable development” was proposed by the UN Commission on Environment and Development in 1987.

‘Green’ architecture is created through the interaction of engineering, landscape and architectural solutions and should be considered in their entirety. The key factor of the “green” architecture is that, starting with the germination of the idea, planning, execution, subsequent maintenance and repair, to the point of destruction, is carried out with the help of clean technologies and resources [1].

‘Green’ technologies are innovations based on the principles of sustainable development and reuse of resources. ‘Green’ technologies cover the following areas: general environmental management (waste management, pollution control of water, air, land restoration, etc.); energy production from renewable sources (solar energy, biofuels, etc.), mitigating the effects of climate change, reducing harmful emissions into the atmosphere, improving fuel efficiency, and energy efficiency in buildings and lighting [2].

‘Green’ building standards are systems of criteria and requirements for real estate objects that are designed to regulate a sustainable construction approach and to assess the degree of compliance of buildings with the initial principles. The following international certification systems are applied in Russia: LEED, BREEAM, DGNB, GOST R 54964–2012 “Conformity assessment. Ecological requirements for real estate objects” [3]. Until the end of the 20th century, there was no systematic approach that would allow using the full potential of the building in terms of energy saving and environmental protection. This period can be attributed to the period ‘before the proclamation of the concept of ‘green’ architecture’.

The concept of sustainable development in the Western world was clearly traced for the first time during the energy crisis and the problems of environmental pollution in the 1960s and 1970s. The book Rachel Carson, “Silent Spring”, published in 1962, is considered one of the first attempts to describe that ‘sustainable development’ is inextricably linked with the construction of “green” buildings. In the 1960s and 1970s, the Western world preoccupied with the preservation of natural resources and environmental problems after the next energy crisis. The ideas of maintaining a healthy
lifestyle, protecting and preserving a clean environment have become popular. Unusual houses of a new type appeared in which ecological principles were implemented, alternative energy sources were used. One of the first examples of green architecture in this period can be the ‘House in the Hill’ by architect Arthur Kromb, built in 1974. The building used mainly natural and environmentally friendly materials actively used the natural landscape of the site.

From 1975 to 1993, an understanding of the importance of energy efficiency at the state level was formed, and there was a state support for private initiatives. The goals and objectives of “green” construction were formulated the first BREEAM green building standards were developed. In 1987, the first UN Commission on the Environment was held, where the concept of ‘sustainable development’ was launched, from which the term ‘green architecture’ was first introduced. During this period, namely in 1985, the Residence of Brunsell was built. Architect Obi Bauman tried to fit the building into the natural environment as organically as possible. The house is designed with heat and moisture insulation, provides a stable climate control of the interior, a system of solar collectors has been designed [4].

From 1993 to 1998 the movement at national and intergovernmental levels for mitigating climate change and reducing harmful emissions had a major impact. The collective efforts of the developers formulated and introduced ‘green’ building standards (the emergence of the LEED standard in 1998, the Energy star in 1992). The introduction of computer technology has begun, resulting in the possibility of working with global statistical data, including data on energy consumption. From 1998 to 2005 there is a promotion of innovative approaches in construction and a transition from integrated efficiency to buildings with zero impact and zero emissions. In 1999, the first meeting of the World Green Building Council was held with the participation of 8 countries: the USA, Australia, Spain, the United Kingdom, Japan, the United Arab Emirates, Russia and Canada [5]. In the future, an extended application of the Life Cycle Analysis Method (LCA and LCC) is planned, where at the environmental and economic footprint all costs, risks and feasibility can be calculated from end to beginning, that is, from recycling to the original idea.

Today, there are many areas in the "green" architecture, some of which are:
- Eco-mainstream – European houses, where water and heat are usually saved, the recuperator is turned on. These are houses of ultra-low energy consumption and mass construction in Europe.
- Ecohiotech – pilot projects with complex engineering structures and facades, waste treatment systems, etc.
- Ecoloutek is a kind of green building, where mainly natural materials are used (wood, clay, straw, reed).
- Deepened "green" buildings – buildings that are partially immersed in the ground and comply with the principles of ‘green’ building, are also the most promising direction of the ‘green’ architecture. As you know, the temperature of the soil already at a depth of 5-8 m is constant and does not decrease to negative values even in winter. In the cold period, the earth gives warmth, in summer – coolness. The need for buried architecture arose in connection with the increased requirements for the heat-shielding properties of enclosing structures in Russia and abroad. When choosing the basic solutions for the recessed buildings, it is important to consider the feasibility of using alternative mechanical systems, such as solar panels, air conditioning using ice, recovery of heat from wastewater, the use of low-potential energy.

3. Result

3.1. Features, advantages and limitations of the recessed buildings

The great interest in the recessed buildings, which has arisen recently, can be explained, first of all, by the fact that they expected significant energy savings. In an ordinary ground-based building, a lot of energy is spent unproductively due to losses, as a result of which we ‘warm’ or ‘cool’ the surrounding space. If you reduce the heat transfer from the outside and outside, then to maintain an appropriate microclimate will require less energy. The size of heat loss (or heat gain) for a building depends
mainly on the load on the heating or cooling air supplied to the room, and on the amount of heat loss through the building envelope. In most residential buildings, the volume of air entering the room (natural ventilation) is determined by uncontrolled infiltration through leaks. These heat losses due to infiltration can be significantly reduced or completely eliminated by dusting the structures with earth. In this case, a device of controlled ventilation is possible, and consequently, a device of an efficient heat recovery system is also possible. Heat losses depend on thermal conductivity of enclosing structures. It is a function of the heat transfer coefficient (which can be reduced by arranging additional insulation) and the temperature difference between the outer and inner surface of the wall [6-7].

Above the ground, the temperature difference is determined by the weather conditions of the area. The Earth smooths the amplitude of fluctuations, both daily and annual temperatures. The change in seasonal temperatures affects the ground at a depth of several meters, while the change in air temperature during hours or days has little effect on the temperature of the earth. The graphs show the figures for the state of Minnesota, USA, whose temperature and climate practically coincide with the climate in the central part of Russia. The maximum deviation of daily air temperature was noted at a height of 0.2 m above the ground. This indicates the feasibility of filling the ground with even a layer of 0.2 m.

At a greater depth, only seasonal fluctuations in temperature are noted, and temperature changes are noticeable only after a long time. Thus, for example, for the region of Minnesota - Saint-Paul, the amplitude of fluctuations in the average temperature slowly decreases with increasing depth. At a depth of 5 to 8 m, the temperature almost always corresponds to 10 °C, which is only 3-4 °C higher than the average air temperature in this area and only 10 °C lower than the comfortable temperature in the rooms.

The temperature is set above the average, starting from the summer, when heat is brought to the ground by the water entering the ground, the thermal conductivity of the humid increases.

An essential feature of recessed buildings is that the land can be used as a natural material with high thermal massiveness. Thermal massiveness (that is, the amount of energy required to raise the temperature by 1 °C.) Is expressed in the building's ability to accumulate heat and depends on the density and quantity of building materials. For some time, a building may absorb heat from the air or from direct sunlight. After a period of accumulation of heat, during the night the building gives up thermal energy back to the external environment. In a recessed building, such a process proceeds rather slowly, which makes it possible to keep the house at a comfortable temperature for several hours without heating or cooling. In contrast to this type of building, very little excess heat is accumulated in ordinary ground houses, and when the heat supply runs out, the heat quickly begins to leave the building. One of the most important features of the buried architecture as compared to the above-ground buildings is the ability to save energy, resulting in the reduction of energy consumption for cooling or heating the building. The soil surrounding the recessed building reduces the building’s energy requirements for excessive heating and cooling by reducing heat transfer. In addition, the stable fluctuation of soil temperature creates a constant temperature of the internal environment during the year, which varies from 14 to 18 degrees Celsius. Thus, the premises have a moderate and stable temperature in the summer and winter season [8, 12, 14].

Another feature of the submerged architecture is the preservation of the natural landscape along with the flora and fauna and the increase of green spaces in the city or countryside. Since the roof of the building is covered with earth, most often it is planted with grass or plants, which is an additional green space for the building. The recessed building is perfect for the terrain, where you need to minimize the change of the landscape, keep the picturesque view and ensure a great eye contact with the environment, and where the design of the ground buildings is unacceptable [15, 16].

Another feature is vibration and noise or noise pollution, which have minimal impact on residents in submerged buildings compared to residents of above-ground buildings. The earth protects against sounds of any frequency, which is why the rooms are very quiet.
The cost of maintaining and maintaining the recessed buildings is much less than for the ordinary buildings. The outer shell of the building is surrounded by a mass of land, so parts of the building that are in contact with the ground are protected from various weather conditions, such as rain, frost, wind, hail, and so on. For example, ultraviolet radiations from solar radiation discolor the shell of an ordinary building. As mentioned earlier, the stable fluctuation of the Earth’s temperature is an essential feature, which also leads to a reduction in the cycles of contraction and expansion of building materials, causing thermal cracks to be minimized. The percentage of safety in submerged houses is higher than that of above-ground buildings in such types of natural disasters as lightning strikes, strong winds, storms, and possible earthquake collapses. Since the reinforced structure of this type of building is covered and enclosed with earth, it also creates maximum protection against natural disasters. The construction and structure of the submerged building are superior in quality to an ordinary building. During shocks or the movement of the earth, the recessed buildings also move. At the same time, the ground house collapses. Good flame retardant characteristics are another advantage of the design of the recessed building. The combination of the outer shell of the earth and reinforced concrete gives the building good fire-retardant properties. Another advantage is that such houses are environmentally friendly due to the use of land as a local material. All these advantages can be achieved in different climatic conditions through various combinations of design elements. Thus, the choice of one or another kind of recessed buildings is directly related to the issues of “green” building and sustainable architecture [9 – 11].

Despite its environmental friendliness, energy efficiency and other advantages, the recessed architecture has several disadvantages and limitations. An important limitation of this type of building is that such houses are most often designed for rural areas. Due to its characteristics, submerged buildings are much more difficult to fit into the urban environment than into the countryside. The cost of earthworks during the construction of submerged buildings is higher than that of ordinary buildings and requires additional equipment. Moreover, in recessed buildings much more attention should be paid to wastewater issues as compared to above-ground buildings, which also increases the cost. Recessed buildings need more ventilation than traditional houses, so a well-designed ventilation system is a necessary requirement for recessed buildings. Humidity and the possibility of leakage is another drawback of the buildings of this type, which is why the building needs a reliable sheath made of waterproof materials. The possible lack of a dedicated area for digging out a site for construction is another disadvantage of these buildings.

4. Discussions
1. Architecture of recessed buildings is one of the most ancient directions in “green” architecture, combining traditional and natural energy saving features, as well as the possibility of additional energy saving with the help of modern “green” technologies.
2. Identified as a result of historical analysis, examples of recessed architecture, as well as an assessment of the advantages and limitations of this direction, make it possible to judge about the enormous potential of recessed buildings as a public or residential facility in order to form a single ecological space in an urban or rural environment ‘figure 1’.
3. It is necessary to comprehensively address all issues related to the design and operation of recessed buildings in accordance with the needs of modern society and taking into account the protection of the interests of the future, while preserving the surrounding sustainable natural environment.

Buildings and structures erected with the use of “green” technologies will significantly reduce the environmental pollution of our country, and, subject to certain conditions, will be able to independently satisfy their own needs for energy sources, while not using external power sources. The practical significance of the study lies in the proof of the relevance of “green” technologies (for example, recessed buildings) for the Russian architectural and construction practice. The study can be used in the design and construction of underground residential and public buildings, as well as in the development of educational programs to study the experience of “green” architecture [17-19].

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