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Green Building in Russia as well as its problems and solutions

The article deals with the issues of environmental ("green") construction in Russia in relation to the tasks of low-rise and individual development. The article describes the history of the formation of the ecological construction market in Russia and abroad, gives a general classification and the main directions of its development. The advantages of green construction, the problems that hinder the rapid development of ecological construction and the stimulating factors of such development are described. The applicable standards of green construction are indicated, both established by the state in the form of normative legal acts, and voluntary, and the advantages of following environmental standards are shown. Practical examples of ecological construction and problems faced by developers in practice are given. The concepts of Passive House, energy-efficient house and non-volatile house are considered in detail, indicating the ways to use the elements of such concepts in the implementation of real construction at the moment, including some practical examples of technical and technological solutions, as well as ways to further improve them. Examples of low-rise buildings currently under construction using standards and principles of ecological construction are given. The Russian standards of green construction are considered in detail, with references to specific regulations and other sources regulating the issues of ecological construction, and the ways of their further development and improvement are indicated. A mathematical model of the order of construction of eco-mobility facilities is proposed, where the capital return indicator is selected as an important criterion, which is determined taking into account the different times of costs for the objects being introduced. Its maximization leads to the choice of such an option, which will be characterized by the largest intermediate volume of input objects, as well as the smallest amount of reduced capital investments, i.e. their more rational dynamics. Thus, this indicator characterizes the efficiency of using capital investments, as well as their return as a result of reducing construction in progress.

Keywords: *ecological construction, passive house, standards of green construction, energy-efficient house, non-volatile house, life cycle cost, practical solutions in green construction, eco-village "Svetlaya Polyana", mathematical model of the priority of ecological construction*

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The level and quality of life largely depend on the sustainable development of housing construction utilizing modern resource-efficient technologies that ensure not only cost reduction, but also the eco-efficiency of construction. While ensuring the satisfaction of the needs of citizens in inexpensive, but high-quality and environmentally friendly housing, the construction complex is at the same time one of the most important points of growth of the country s economy, providing a large share of demand in the real estate market all on itself.

The theory of managing the innovative development of housing construction at the regional level today poses the problem of an economic system organization, that would base off of the commensuration of anthropogenic impact on nature and its resistance to these influences.

1. Development of the eco-building market

The task of gradual transition to the so-called "Green Building", e.g. construction of energy-efficient and environmentally friendly buildings, is becoming urgent. These buildings are to follow several guidelines:

- ensure comfortable living conditions;
- rational use of renewable resources;
- minimization of the negative impact of the facility on the environment during the construction, usage and deconstruction of the building.

State policy pays special attention to increasing certified construction volumes in accordance with the Green Standards requirements. We already have experience in certification according to LEED and BREEAM standards, namely — several unique buildings of Olympic Sochi, a complex of buildings in the Skolkovo innovation center, and etc.

The analysis of the life cycle of buildings made it possible to establish the ratio of the cost of construction and the costs associated with the operation of buildings as 20 to 80 % accordingly. Thus, the reduction of operating costs plays a huge role and the assessment of such costs is one of the base principles of Green Building [1].

Green Building is, first of all, houses aimed at energy efficiency, buildings from natural materials, self-contained energy-independent houses and even houses that generate energy by themselves. They can be classified as follows:

1. Mainstream. The buildings are focused on saving heat and water — they are well insulated, use systems for recovery, collection and use of rainwater and melted snow.

2. Eco High-Tech. These are usually office buildings used by large corporations that use complex waste recycle systems.

3. Autonomous eco-houses — housing focused on complete energy independence achieved through the use of solar and wind energy.

4. Eco-futurism — a trend that is prominently represented by the American architect William McDonough. His ideas imply reuse in the production of buildings that have exhausted their resource, as well as construction from materials that involve

partial or complete dissolution in the soil without causing any damage to nature.

It is obvious that the construction of eco-buildings is more expensive than traditional ones, but in the end, they cut on operational costs. Moreover, the development of technologies, the improvement of architectural and engineering solutions, the appearance on the market of new economical and efficient engineering systems are constantly narrowing this gap. In addition, the use of renewable energy sources is often more profitable already during the construction phase at sites remote from gas and electricity networks. houses built using local building materials are of particular interest. Lastly, taking into account the constant rise in prices for electricity and gas in Russia, "green construction" in the future has no alternative against the background of constantly improving resource saving technologies and the emergence of new engineering solutions that allow more efficient and less expensive use of renewable energy sources.

2. Passive House concept. Solution of practical problems

The concept of Passive House is of great interest, the main feature of which is the next to complete absence of a heating system and extremely low energy consumption. The architectural concept of a passive house is based on the principles of compactness, high-quality and most effective insulation, correct building geometry, zoning, orientation to the cardinal points and the use of recuperation in the ventilation system. A passive house does not require any expenses for maintaining a comfortable temperature at all. Heating is carried out using the energy released by household appliances and people living in the house. In practice, such a system will still need minimal heating, which should be carried out using alternative energy sources, which will also be objectively needed for hot water supply through systems of heat pumps and solar water heaters. Due to them, the issue of air conditioning in the hot season is solved.

The passive house technology provides for a very effective multilayer thermal insulation of all enclosing surfaces, including the floor and ceiling, exclusion of cold bridges, window openings are minimized in area and are manufactured using technological solutions that reduce heat loss — a wide profile, vacuumization of glass units and an increase in their thickness, pasting with special energy-saving films. In addition, to reduce the cost of air cooling, external blinds are used, dissipating the heat of the sun and not letting it inside the house.

The use of energy efficient home technologies paves the way for a non-volatile home — a home that does not need to be connected to external electricity and gas networks. The energy efficiency of the house is such that all of its needs can be met by alternative energy sources. The advantages of such a house can hardly be overestimated:

- the owners of such a house do not depend on changes in gas and electricity prices;
- house upkeep costs cut;
- main power grid independency — fear no blackouts;
- the house selling price is favorably competitive;
- long service life of photovoltaic cells guarantees low system maintenance costs.

The combination of the principle of energy efficient, non-volatile and "smart" home gives its owners undeniable advantages for many years.

The cost of building an energy efficient house is on average 10…15 % higher than the average of an ordinary building, but the recoupment of additional costs, depending on the area of the building, can be from 5 to 10 years. In addition, such a house does not require a boiler room and the organization of water or air heating systems in volume, as is usually done in traditional construction, which means there will be no costs for their operation and repair [2].

In practical terms, the construction of an ideal passive house is constrained by both imperfect technologies and the backwardness of the regulatory framework. Moreover, the construction of partially passive houses seems to be relevant for the near future, using both alternative energy sources, in particular, geothermal energy, and connection to central power supply networks as backup or additional in case of emergencies or abnormal cold weather [3, 4].

An important aspect is the constant improvement of standards, where the main trends should be noted:

- expansion of the categories of objects for which compliance with the standards of green construction and operation will be mandatory;
- development of tools and methodological base for determining indicators previously not used in construction;
- constant tightening of environmental requirements and stimulation of innovations in the field of ecology of construction and operation of buildings;
- involvement of a wide range of scientists, specialists and builders in the formation of standards for Green Building.

The goal of Green Building is to make housing technologies less punishing for the environment, reduce energy consumption, minimize waste and, ultimately, have a beneficial effect on human health, creating a comfortable, safe and environmentally friendly living environment. The technologies used in "green construction" can significantly reduce operating costs, which in itself makes such houses attractive for their future owners, and in addition, it has a beneficial effect on the image of developer companies, allowing them to count not only on the growth of the client base, but also on priority support from public authorities and municipalities [5, 6].

3. Russian system of environmental construction standards

Construction is one of the most conservative industries in the economy. Innovation enters the market and takes hold gradually until it becomes the accepted norm. Environmental certification in construction aims to modernize the construction industry and that is why it sets requirements significantly higher than the current building codes and regulations. The basis for the formation of certification criteria is the principle that about 2 % of buildings on the existing market will be able to reach the highest level, and the main part of certified buildings will make up no more than 25 % of the total construction market. Building performance standards establish targets and objectives to be achieved, and describe methods that can confirm the achievement of targets. The establishment of the Russian system of environmental standards in construction began with the development of criteria for voluntary environmental certification and the creation of a non-profit partnership "Center for Environmental Certification – Green Standards". The certification system is registered in Rosstandart, reg. No. 8470; ROSS RU.I630.04AAD0. The copyright holder is NP "Center for Environmental Certification – Green Standards", the certification body is EcoStandard group. Green Standards is a rating system in which points are awarded for achieving certain levels of compliance. The main goal is to stimulate developers, architects and designers, builders and tenants to introduce resource-saving, energy-efficient technologies, use environmentally friendly building materials that reduce the negative impact of real estate on human health and the world around them. It is possible to certify a projected, constructed and reconstructed building for any purpose, as well as a part of a building.

Today, Russian environmental legislation does not yet fully meet the real needs of economic life. The specifics of the Russian economy, the conditions for the activities of business entities and the lack of legal culture in the field of ecology require certain steps to deepen and clarify the norms that are being formed[1].

The Green Building development movement in Russia is just gaining ground and already has prerequisites for successful promotion:

1) the economic crisis requires the introduction of modern eco-technologies as an important factor in obtaining competitive advantages in the real estate market;

2) Russia declared energy efficiency in construction as the main instrument as part of fulfilling its obligations under the Kyoto Protocol;

3) the growth of economic, social and environmental problems in the country is largely caused by inefficient use of resources and outdated technologies.

The requirements of the Green Standards system are aimed at reducing the consumption of energy resources, using renewable and secondary energy resources, rational water use, and reducing harmful environmental impacts during the construction, operation and disposal of buildings, provided that a comfortable human environment is provided. Using the system, GOST R 54964–2012[2] "Environmental requirements for real estate objects" was developed and approved. The standard can be applied at the stages of design, construction, operation and disposal of real estate objects. The standard recommends assessing the sustainability of the habitat and the effectiveness of the implementation of environmental requirements for real estate in accordance with the Green Standards system and the STO NOSTROY standard of Green Construction. Residential and public buildings. The rating system for assessing the sustainability of the habitat". Environmental requirements for real estate objects are defined by a combination of the following categories:

- eco-management;
- infrastructure and quality of the external environment;
- quality of architecture and layout of the facility;
- comfort and ecology of the internal environment;
- quality of sanitary protection and waste disposal;
- rational water use and regulation of storm water;
- energy saving and energy efficiency;
- environmental protection during the construction, operation and disposal of facilities;
- life safety.

Each basic category is represented by a separate group of criteria that define it. Methods for assessing the degree of ensuring environmental requirements for real estate objects, providing for the achievement of recommended indicators and minimum environmental requirements, are carried out in accordance with the rules and procedures established by the Green Standards certification system.

The main obstacles hindering the development of Green Building in Russia are as follows:

- 80 % of respondents consider the increase in costs for the construction of Green Building as excessive and unreasonable;
- differences in the interests of developers, builders, users and building owners;
- lack of public awareness of the benefits of Green Building;
- lack of qualified specialists in the field of Green Building;
- undeveloped market for environmentally friendly materials, lack of suppliers of such materials;
- lack of government support;
- outdated regulatory and legal framework [7, 8].

Despite the above-mentioned constraining factors for the development of green construction in Russia, elements of environmentally efficient residential development are increasingly being used in the practice of creating new housing, especially individual and low-rise housing. As an example of such development, we can consider the eco-village "Svetlaya Polyana" located in the urban district of Domodedovo, Moscow region (Fig. 1). More than two hundred individual residential buildings ranging from 100 to 130 m^2. are located on land plots with an average of 750 m^2. The adjacent territory is represented by forest, the Severka River and agricultural

1 Federal Law No. 7-FZ of January 10, 2002 "On Environmental Protection".

2 GOST R 54964–2012. Environmental requirements for real estate objects.

Fig. 1. Eco-village "Svetlaya Polyana"

land — there are no sources of water or air pollution and do not have a negative impact. There are also no noise sources. The water supply of the village is organized through a common water intake unit supplying the village with water from artesian wells, and household water disposal through individual septic tanks for each household. Storm runoffs are not used in the village.

The houses of the village achieve high energy efficiency due to good insulation of all enclosing structures, including floors and roofs. The wall of the house is built from a 250 mm thick aerated concrete block, glued on the outside with PSB-S-35 foam plastic 100 mm thick, on which the facade plaster is applied. The projects of the houses provide for a relatively small glazing area, and the window blocks themselves are an energy-efficient double-glazed unit. The houses are oriented in such a way that most of the window openings are oriented towards the south. The ventilation system provides air recuperation.

Low heat losses of houses made it possible to abandon the installation of gas or boiler rooms on other types of fuel and use electric convectors to heat the house. Thus, the houses of the village do not pollute the atmosphere with the products of combustion of certain types of fuel.

The development of the village is carried out by eight types of house projects and due to the standardization of each model, where each structural element is calculated in advance and unchanged from house to house, it was possible to avoid the formation of a large amount of waste, which usually accompanies individual residential development.

From the very beginning, the developer chose such a strategy for the development of the village, in which the start of sales of houses does not begin until the completion of the construction of the neighborhoods, including landscaping, which provides an opportunity for comfortable living immediately after purchasing a home and again reduces the harmful impact on the environment.

Widely accessible and usually locally produced environmentally friendly building materials are used in construction.

4. Mathematical model of eco-construction priority

An important factor in increasing the efficiency of capital investments is the establishment of economically feasible terms for the construction of eco-real estate. When choosing the order of construction of buildings and structures of eco-real estate, it is necessary to consider not only the time aspect, but also economic factors, which include, first of all, the efficiency of using capital investments.

The model criterion for determining the timing and priority of the construction of buildings should be the ratio of the total volumes of construction in progress to the total capital investments calculated for all quarters of the construction period of the property. Suppose that the zoned large-scale flow consists of three real estate objects, erected in sequence, as shown in the graph in Fig. 2.

The segments of straight lines represent the construction process of each property, the numbers above these segments are the quarterly volumes of capital investments, and the numbers under the segments are the same volumes reduced to the start date of the construction of the facility. OAB is an integrated schedule of capital investments development, brought to the moment of construction start, and polygon CDEFHB is an integrated schedule of commissioned objects. Let us denote the area of the OAB by F_1, and the area of the polygon CDEFHB by F_2, then the above criterion can be represented as:

$$Z = (F_1 - F_2)/F_1. \quad (1)$$

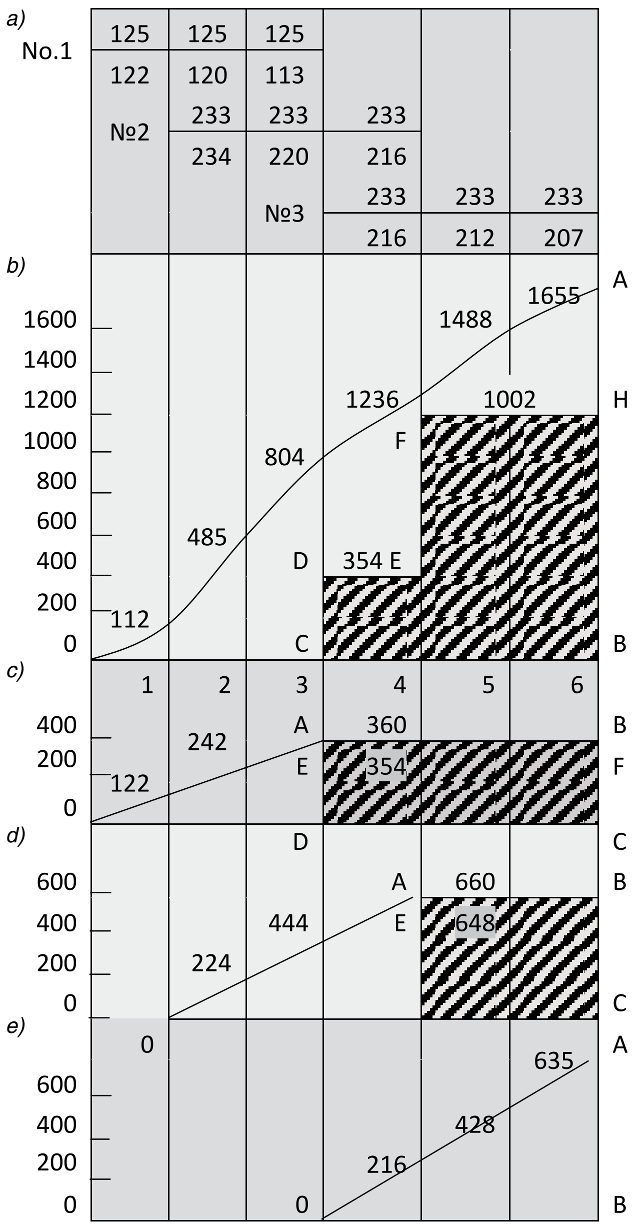

Fig. 2. Graphical interpretation of the model of the construction order of objects included in the zoned consolidated flow

The difference between the areas of $F_1 - F_2$ characterizes the total volume of unfinished construction and it cannot be equal to zero, since the unfinished construction in the form of eco-real estate objects at various stages of construction should be permanent, ensuring the continuous nature of the release of finished products and maintaining a constant front of work. Minimizing the exponent Z in (1) is equivalent to maximizing the simpler exponent Z_k:

$$Z_k = F_2/F_1 \rightarrow \max. \quad (2)$$

The Z_k indicator is the ratio of fixed assets and infrastructure facilities used during construction to the total amount of capital investments used during the construction period. This indicator denotes the share of capital investments utilized during construction, which provides intermediate inputs of funds and capacities and characterizes the return on capital investments diverted for construction.

In Fig. 2, “*c*”, “*d*”, and “*e*” are given for each object included in the zoned consolidated flow, integral schedules for the development and commissioning of funds. The addition of these schedules results in integral schedules for the development of capital investments and the introduction of funds for development in general — “*b*”. Therefore, the capital return indicator can reflect the timing of the start and completion of the construction of eco-real estate, as well as the dynamics of the development of capital investments for each of them.

Let us introduce the following designations: Z_k is capital return indicator; T is the duration of the planning period, quarters (t = 1, 2 ...); N is the required amount of resource when performing work (*i–j*); Φ_i is the cost of funds, thousand rubles, introduced when the *i*-th object is put into operation; t_i^n and t_i^0 are the start and end dates of its construction; t_i is duration of construction of the *i*-th structure in blocks; E_o is the nominal rate of return; T^o is the total term for the completion of eco-development; S_i is the estimated cost of the *i*-th object, thousand rubles; x_i^τ is the volume of capital investments planned for the *i*-th facility in the quarter τ, with the serial number of the beginning of the *i*-th construction. t_i refers to the standard duration of the construction of a property.

To determine F_2 and F_1, it is necessary to analyze all quarters of the planning period and all objects of eco-real estate and infrastructure included in the plan, and for each of them summarize the funds entered at the beginning of the period and quarterly volumes of capital investments starting from the quarter in which the construction of the facility is planned, i.e. from the quarter t, for which $y_i^t = 1$, then (2) takes the form:

$$Z_k = \frac{\sum_{t=1}^{T}\sum_{i=1}^{N} y_i^t \Phi_1 (1+E_o)^{-(t_i^n + t_i)} (T^0 - t_i^0) S_i}{\sum_{t=1}^{T}\sum_{i=1}^{N}\sum_{t=1}^{1} y_i^t x_i^\tau (1+E_0)^{-(ti_i^n + t_i)} (T^0 - t_i^n - \tau)} \to \max. \qquad (3)$$

The resulting expression meets the requirements for the optimality criterion. The capital return indicator is associated with the total duration of the construction of eco-facilities, with the timing of the start and completion of the construction of individual buildings, as well as with the quarterly volumes of capital investments and commissioned funds of each facility; thus, it considers the volume of the planned construction. If it is calculated for different time intervals, then it will express the degree of construction readiness for a particular moment in time. The capital return indicator is determined considering the difference in timing of costs and for the facilities being commissioned. Its maximization will lead to the choice of such an option, which will be characterized by the largest intermediate volume of commissioned objects, as well as the smallest value of the reduced capital investments, i.e. their more rational dynamics. Thus, this indicator characterizes the efficiency of the use of capital investments, as well as their return as a result of the reduction of unfinished construction.

5. Summary

The development pace of Green Building in Russia is constrained by the increased cost of such construction, low awareness of consumers about the benefits in the process of using construction products manufactured in accordance with Green Standards and the backwardness of the regulatory framework [9].

At the same time, progress in the field of new technologies is constantly reducing the difference between the cost of traditional and “green construction”, and the development of modern information technologies, coupled with a constant increase in the level of environmental awareness of the population, makes progress in this area inevitable.

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Экологическое строительство в России. Проблемы и решения

В статье рассматриваются вопросы экологического («зеленого») строительства в России применительно к задачам малоэтажной и индивидуальной застройки. Описана история становления рынка экологического строительства в России и за рубежом, дана общая классификация и основные направления его развития. Описываются преимущества зеленого строительства, проблемы, препятствующие быстрому развитию экологического строительства, и стимулирующие факторы такого развития. Указаны применяемые стандарты зеленого строительства как установленные государством в виде нормативно-правовых актов, так и добровольные, показаны преимущества следованию экологическим стандартам. Приводятся практические примеры экологического строительства и проблемы, с которыми сталкиваются застройщики на практике. Подробно рассматриваются концепции пассивного дома, энергоэффективного дома и энергонезависимого дома с указанием путей использования элементов таких концепций в реализации реального строительства на настоящий момент, в том числе даются некоторые практические примеры технических и технологических решений, а также пути их дальнейшего совершенствования. Приводятся примеры ведущейся в настоящее время малоэтажной застройки с использованием стандартов и принципов экологического строительства. Подробно рассмотрены российские стандарты зеленого строительства со ссылками на конкретные нормативные акты и иные источники, регулирующие вопросы экологического строительства, указываются пути их дальнейшего развития и совершенствования. Предложена математическая модель очередности строительства объектов эконедвижимости, где в качестве важного критерия выбран показатель капиталоотдачи, определяемый с учетом разновременности затрат по вводимым объектам. Его максимизация приводит к выбору такого варианта, который будет характеризоваться наибольшим промежуточным объемом вводимых объектов, а также наименьшей величиной приведенных капитальных вложений, т.е. их более рациональной динамикой. Тем самым этот показатель характеризует эффективность использования капитальных вложений, а также их отдачу в результате сокращения незавершенного строительства.

Ключевые слова: *экологическое строительство, пассивный дом, стандарты зеленого строительства, энергоэффективный дом, энергонезависимый дом, стоимость жизненного цикла, практические решения в «зеленом строительстве», экопоселок «Светлая Поляна», математическая модель очередности экологического строительства*

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