Development of approaches to technical inspection of "green" buildings

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Abstract. The article is devoted to the consideration of the issues and methodology of the development of the technical survey of the building constructed with the use of "green" technologies. The implementation of investment and construction projects of this kind over the past decade is gaining more and more popularity in our country. This is largely due to several factors, including the need to save energy resources, reduce utility costs, increase the comfort and safety of people living or working in such buildings, and take care of the environment. To date, the greatest interest in the implementation of "green" investment and construction projects is the implementation of office, retail, sports and warehouse facilities. The construction of residential buildings is not yet as popular as in Western countries, but there is a trend towards its development. There are a number of foreign and Russian standards that allow you to certify a building for the assignment of the status of a "green" object. Methods of scoring in the presented standards (BREEAM, LEED and GREEN ZOOM) mainly focused on energy efficiency, safety, comfort, an important environmental aspects of construction, however, almost no technical component and verification algorithms of structural elements of the building. Carrying out a high-quality technical survey is a prerequisite for making a decision on the reconstruction, re-profiling or repair of the object. In conducting these activities should take into account the fact that the engineer needs to spend not just a "classic" technical survey and study taking into account the specific "green" technologies, including to identify design features of the building, to conduct a detailed examination of all utilities, to identify the effectiveness of the functioning and relevance of using specific design elements (if any), to develop arrangements for the repair, conversion or renovation with regard to maintaining or certification. Within the framework of the presented article, the authors identified problems, developed a comprehensive algorithm for conducting a technical survey of a building built with the use of "green" technologies, and gave methodological recommendations.

1 Introduction

Over the past decade, one of the key issues has been the need to limit the use of natural resources due to their significant reduction. In this regard, the task of applying "green"

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standards for the implementation of investment and construction projects is becoming more and more urgent. It is worth noting that this concept has become widespread in the West, while the development of projects in Russia is only gaining momentum. Of course, attempts are being made to improve the regulatory framework on the territory of our country, and some projects are being implemented using such technologies, but the process is quite slow. The implementation of investment and construction projects with the introduction of "green" standards is one of the important and necessary processes for the harmonious development of the country's economy in general and the construction industry in particular. The main task of implementing the concept is to reduce resource consumption through the introduction of new mechanisms and ensure technical and economic feasibility for both developers and end users, ensuring that the negative impact on the external environment is minimized. Real estate objects built with the use of "green" technologies undoubtedly have a positive impact on the quality of life of consumers and its comfort[1-4].

The implementation of investment and construction projects with the use of "green" standards is a complex and multi-level task. There is a lot of literature devoted to the problems of implementing this concept on the territory of the Russian Federation, the problems of regulating the regulatory framework, creating their own standards. However, along with the above, the question of the operation and maintenance of such buildings remains open, and, in particular, the conduct of a technical survey, for example, if it is necessary to carry out repairs or change its technological significance[5-8].

In Russia, the need to implement projects using "green" technologies was first discussed more than 12 years ago, the first buildings certified according to foreign standards BREEAM, LEED appeared in 2012. The dynamics of the introduction of green-certified real estate objects for the period from 2012 to 2020 is shown in Figure 1.

Fig. 1. Number of commissioning of real estate objects certified according to "green" standards.

Studies have shown that the most popular are office buildings built with the use of "green" technologies, in second place – retail real estate and third place is occupied by sports facilities. It is worth noting that residential real estate built using this concept has not yet gained such popularity as in Western countries. First of all, this is due to the high costs of their implementation compared to conventional projects, however, there are already projects that attract the attention of potential buyers. The volume of entering objects by category is shown in Figure 2.

Fig. 2. The volume of commissioning objects by category.

The existing volumes of commissioning of real estate objects suggest that over time there may be a need for re-profiling, and, as a result, re-certification or major repairs, which, according to the laws of the Russian Federation, cannot be carried out without a technical survey. Let's consider what criteria are set for conducting such procedures in the most popular foreign and Russian standards (BREEAM, LEED and GREEN ZOO).

To begin with, we will define the term "technical inspection". This is a process that includes monitoring, testing, analysis and evaluation of structures of buildings and structures in order to determine the operational qualities of structures, the feasibility of repair and reconstruction of buildings and structures, finding out the causes of accidents, predicting the behavior of structures in the future, making a decision on the possibility of repurposing the building. Based on the presented interpretation, we will consider what is said about these processes in the "green" standards [9,10].

1.1 BREEAM

The BREEAM standard developed in England can be used for certification at the design stage of an object, during reconstruction, and for evaluating the possibility of issuing a certificate to an existing object or part of a building. It is a methodology for awarding points for sections that directly or indirectly relate to various criteria for life safety, environmental impact, and comfort[11].

Depending on the stage of the life cycle of the property, there are four types of certification: BREEAM Communities (objects of general design for a large number of buildings), BREEAM New Construction (new construction), BREEAM In-Use (for existing buildings in operation), BREEAM Refurbishment (assessment of repairs for the interior and exterior decoration of buildings). For the present study, the most interesting are the last two types, we will consider them in more detail.

1.2 BREEAM In-Use

The certification process can take from 1 to 6 months, depending on the speed of the customer's submission of supporting documents and the readiness of the object for certification.

At the first stage of the assessment, an initial audit of the documentation is carried out, as well as an inspection of the asset. During the inspection, all systems are photographed, technical documentation, building/land plot plans are analyzed, and residents/employees are interviewed. Then, based on the initial analysis, the rating of the object is predicted, as well as recommendations for its improvement are determined. After the implementation of the measures, the auditor prepares an evidence base together with the customer, on the basis of which an opinion is written to the certifying authority. At the final stage, if everything is successful, a certificate is issued. It is worth noting that the inspection is based only on the visual perception of the appraiser, the analysis of the technical documentation that was issued for the object during construction, and the evaluation of the survey data.

1.3 BREEAM Refurbishment

When conducting certification, the following requirements must be met[12]:

- any evidence must be reliable in terms of its source and applicability;
- any communication records used as evidence must contain clear evidence of the name of the site, the identity and role of the author, the date and identity of the recipient;
- official letters for correspondence must be on the letterhead or letterhead of the organization with the signature;
- the minutes of the meeting should contain the date, venue, and information about the attendees (names, organizations, and roles), as well as the minutes of the meeting and the agreed actions.;
- drawings. All drawings must have the name of the building or site, the phase (if applicable), the name of the drawing, the date, the revision number, and the scale;
- specification. The specification must clearly indicate that it relates to the project being evaluated, and must have a date and revision number. In cases where sections of the specification are provided, the examiner should refer to the extract and, at a minimum, provide the first page of the specification with a detailed description of the project name, revision number, and date;
- the object inspection report should include the name of the building or object, the date, the author, and a summary text to describe in detail what was witnessed, confirming compliance. Photographic evidence can be used to confirm the text in the report;
- during the reconstruction of the building, the integrity, including the continuity of insulation, the prevention of thermal bridges and air leakage paths, is guaranteed by quality through the completion of post-structural tests and inspections. Depending on the type of building or structure, this can be demonstrated by completing a thermographic inspection, as well as a leak test and visual inspection at the appropriate time during the repair. The examination or testing is carried out by a qualified specialist.

In the implementation of this type of certification, the survey is carried out only visually, without the use of special tools that would allow the analysis of building structures.

1.4 LEED

Depending on the type of project, the stage of its implementation (design, construction, operation, etc.), different evaluation schemes are used. According to the standard, new projects can be certified from the beginning of the formation of the technical specifications for the design and buildings that are in operation. Let's consider the most interesting ones for this study [13,14].

1.5 BD + C Building Design and Construction

It is used for new construction or major repairs. Includes requirements that differ depending on the intended purpose of the building.

1.6 ID + C Interior design and construction (design)

It is used for completed interior decoration projects. Includes requirements for commercial buildings that differ depending on the intended purpose of the building.

1.7 O + M Construction work and maintenance

It is used for existing buildings that are undergoing landscaping or are practically not being built. Includes requirements that differ depending on the intended purpose of the building.

Despite the fact that the LEED certification differs from BREEAM by the need to provide calculations, drawings and other technical documentation, it also does not involve the study of the structural elements of the building themselves using specialized equipment.

1.8 GREEN ZOOM

Russian building Certification Standard. As foreign counterparts based on placing ratings on six areas: the location of the built-up area; the sustainability of the territory; energy efficiency; water efficiency; environmentally friendly building and finishing materials; ecology of the indoor environment. Certification is possible for objects that are at the stage of design, implementation or operation. This standard provides for instrumental studies of systems in order to identify compliance with environmental requirements, however, again, it does not involve the study of structures.

Thus, from all of the above, it can be concluded that the existing certification systems do not involve carrying out instrumental methods of inspection of structures, which is a necessary condition when deciding on the possibility of repurposing objects, repairs, etc. This confirms the relevance of the chosen research topic.

2 Materials and Methods

The need for technical expertise of real estate due to numerous factors, among which are:

- the influence of the natural environment, causing physical wear of objects, the presence of defects and damage, reduced reliability of structures;
- the manifestation of man-made factors (accidents, catastrophes, fires, etc.);
- changes in the functional purpose of the object, its obsolescence, increased loads (reconstruction, major repairs, modernization);
- monitoring of the technical condition of objects (scheduled and extraordinary inspections);
- resumption of construction after a long break (objects of unfinished construction);
- the decision of the court or prosecutor's office to conduct a judicial construction and technical expertise;
- determining the market value of the property (purchase and sale transactions, collateral, etc.);
- determining the best and most efficient use of the property, etc[15-17].

The parameters of the technical expertise of real estate objects include the following:

- 1) Materials of design solutions and technical condition of the property:

- scope and types of work on the object;
- cost, expenses, and costs of implementing the project;
- time parameters, including deadlines, duration and reserves of work, stages, phases of the project, as well as the relationship of work;
- resources required for the implementation of the project, including: human or labor, financial, information, logistics, divided into construction materials, machinery, equipment, components and parts, as well as resource constraints;
- the quality of design solutions, the type of resources used, project components, and so on.

2) The appearance of the object as part of the urban environment:

- aesthetic perception of the urban environment, depending on the visual perception of urban spaces, elements of landscaping and the ecological state of the main elements of the urban area;
- compliance of the object with the surrounding development (visual landscape analysis of the planned development)

3) Parameters of operational suitability and reliability of buildings:

- reliable and durable;
- main characteristics and design solution of the object;
- material of load-bearing structures;
- type of foundation and underground structures;
- facility security system;
- organization of heating and air conditioning systems, etc.

4) Assessment of the state of the development area:

- features of the improvement of the territory of the development;
- transport support and ecology of the microdistrict;
- characteristics of the land plot;
- geological features of the base soils;
- hydrological condition of the development area;
- deformation properties and the aggressiveness of the soil of the construction site.

Within the framework of this study, the greatest attention will be paid to conducting a technical survey in order to establish the parameters of the operational suitability and energy efficiency of the building [18,19].

3 Results

Conducting a technical inspection of a building can be divided into three stages: preparatory (obtaining technical specifications, collecting all necessary documentation, drawings), direct inspection, which, in turn, is divided into visual, using instrumental methods, and final (preparing a report, recommendations for eliminating identified defects). This approach is optimal for conducting a technical survey of a "normal" building, however, when conducting an inspection of a building built using "green" technologies, and having passed or planning to pass certification in one of the systems, it is proposed to expand it as follows (Figure 3).

Fig. 3. Number of commissioning of real estate objects certified according to "green" standards.

Taking into account the specific features of the functioning and operation of buildings built with the use of "green" technologies, the authors propose to introduce changes at all stages of the technical survey.

At the *preparatory stage*, it is necessary, in addition to the main documents, to analyze the report on the certification of the building in the international or Russian system in order to conduct a deeper assessment of the object and develop an effective strategy at the final stage. Since this task is essential for further comprehensive analysis, if the customer refuses to provide the requested information from the selected block, the specialist has the right to refuse further cooperation.

The key feature of the *inspection stage* is the introduction of an additional study of specialized equipment, which allows you to classify the building as "green" and identify its functional wear. Since buildings built using this concept often have various technological solutions that reduce the consumption of resources during operation (for example, solar panels, wind cells, etc.), taking into account this parameter is a prerequisite for a comprehensive analysis of the technical condition of the object. If the green roof is used as a technology during the construction of the object, other energy efficiency parameters are taken into account.

At the *final stage*, the authors propose, in addition to the standard procedures typical for the technical inspection of the building, to conduct an additional calculation of the energy efficiency of the object by calculating the compactness coefficient, the building shape coefficient, and the space-planning coefficient.

The *compactness coefficient* can serve as a quantitative estimate for calculating the thermal efficiency of external enclosing structures. The specified parameter is calculated using the following formula:

$$K_k = \frac{S_n}{S_s}, \quad (1)$$

where K_k – the coefficient of compactness,

S_n – the area of external structures,

S_s – the area of a separate section with a similar orientation to the building.

The *building shape coefficient* is an indicator of the energy efficiency of a building, which is calculated using the following formula:

$$K_f = \frac{P_z}{P_k}, \quad (2)$$

where K_f – the coefficient of the building shape,

P_z – the perimeter of the "green" building,

P_k – the perimeter of an equal-sized square.

The *space-planning coefficient* helps to determine how different space-planning solutions affect the relative heat consumption and can be calculated using the formula:

$$K_p = \frac{P \cdot h}{S_p}, \quad (3)$$

where K_p – space-planning coefficient,

P – perimeter of the building,

S_p – floor area.

Based on the above, the energy efficiency of a building in a generalized form can be written as an objective function as follows:

$$E = f(K_k; K_f; K_p), \quad (4)$$

The actual task for the customer is to save the certificate, if it is available, or to purchase it, if it is not available. The first option is most typical for objects in which it is planned to

reconstruct, repurpose or repair the building, the second only for the latter. In this regard, the authors consider it necessary to introduce the item "Development of measures for repair, repurposing or reconstruction based on the requirements of international and Russian standards of "green" construction", since, as described earlier, international and Russian certification systems do not provide for the study of the structural elements of the building, and this is an essential part to ensure the safety and comfort of people living or working at the facility.

4 Conclusions

Based on the results of the study, several conclusions can be drawn:

1. Based on the specifics of buildings built with the use of "green" technologies for the quality of the building survey, it is critically important to train specialists who, first, will have the necessary technical knowledge to conduct it, and secondly, will have a certificate of one of the international or Russian certification systems for the competent study of the possibility and necessary parameters for the repair, reconstruction or conversion of buildings that have already received certificates, taking into account the need for their preservation.

2. An essential condition for the effective development of the building concept is the improvement of calculation standards, and adding a head or to create a new standard that will effectively carry out the calculations of various energy-saving designs that are used in the implementation of "green" construction.

The analysis allows us to conclude that investment and construction projects implemented with the use of "green" technologies are unique and require careful study of all aspects of the technical inspection of the building. The development of this issue is an urgent task both for Russia and on an international scale.

When obtaining certificates of the Russian or international system, great attention is paid to the problem of safety and comfort of housing, which, of course, is an important factor, but it does not take into account the need to conduct not only visual, but also instrumental inspection of structures, including specific ones, to determine their operational properties.

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