Using the Principles of Ecological Design at the Concept Stage of a Construction Project

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Abstract: Using the principles and approaches of ecological design is a good opportunity to improve the environmental performance in construction industry. The most important issue is the use of recycled materials in the construction project. Using the BIM to structure and classify information about the use of recycled materials for construction products and structures, we can determine the level of application of ecological design principles for a facility in the early stages of the life cycle and compare design options for the environmental parameters of the project. Combining BIM technology, ecological design principles and modern construction waste recycling technologies will help improve the environmental performance of construction projects.

1 INTRODUCTION

The principles of ecological design in the context of the main ecological approach were formed in the 70s of the twentieth century. Designer Victor Papanek became the main ideologist and popularizer of the ecological direction in design, his book «Design for the Real World», where he studied in detail the relationship between design and the ecological environment, was published in 1971 (Papanek, 1971).

In scientific research, the principles of ecological design were formed on the basis of several scientific areas, the main of which are design theory and sustainable development, additional - environmental sociology, environmental psychology, environmental ethics, anthropology, bionics and other sciences (Pankina, Zakharova, 2014).

The concept of sustainable development presupposes the coordination of the tasks of social progress, economic development and the solution of environmental problems. The term «sustainable design» is often associated with the ideas of saving resources and energy. Green design also involves the use of environmentally materials, their natural characteristics and features (Pankina, Zakharova, 2017).

The ecological approach in design combines the concepts listed above and implies the creation of products that are compatible with the environment by reducing or completely eliminating the negative environmental impact. The term «ecological design» in modern scientific literature is formulated by the authors as «the direction and paradigm of design, the purpose of which is to harmonize the relationship between society and the environment (natural and anthropogenic), the formation of a worldview, ecological culture, consumer and aesthetic requirements of a person in accordance with the possibilities of nature , ensuring its preservation and minimizing harmful effects at all stages of the life of a design object: production, operation and disposal.» (Pankina, Zakharova, 2017).

2 MANUSCRIPT PREPARATION

This research was based on the principles of ecological design.

Principles of Ecological Design includes (Pankina, Zakharova, 2014):

- ✓ consistency, versatility, multifunctionality and interchangeability;

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- ✓ durability, environmental friendliness of product materials, production processes, consumption and disposal;
- ✓ the ability to reuse an object or its elements;
- ✓ the use of natural materials for products and structures, rationality, simplicity and functionality of the form;
- ✓ efficient consumption of energy resources, rational use of materials.

The tasks of ecological design are aimed at changing the values of society, the formation of an ecological culture and a new culture of consumption, saving resources, using materials and technologies that take into account modern environmental requirements (Pankina, Zakharova, 2017).

An important component of the ecological approach in design is the 3R Initiative (reduce, reuse, recycle). At the same time, methods of reusing materials require a more detailed classification:

- ✓ upcycling - recycling of used materials, which involves a new functional use and increase in value;
- ✓ recycling - recycling of used materials without changing their value;
- ✓ downcycling is the recycling of used materials, which involves reducing their value and new functional use.

The Cradle-to-Cradle concept, developed by Michael Braungart and William McDonough in the early 1990s, implies the continuity of the use of resources and materials. In their book «Cradle to Cradle: Remaking the Way We Make Things», they offer five steps to eco-efficiency. One of the points is the proposal to compile lists of materials used for production (Braungart, McDonough, 2008):

- ✓ materials from the use of which should be abandoned in the first place;
- ✓ problematic substances that currently have nothing to replace;
- ✓ substances that are currently defined as healthy and safe.

All of the listed approaches and principles of ecological design are relevant and important for the construction industry, including the objectives of energy efficiency, the use of renewable energy sources and reasonable resource conservation. At the same time, the problem of disposal of construction waste has the most significant impact on the environment. Therefore, issues related to the recycling and reuse of building materials and structures require special attention.

Also very important is the consistency of implementing the principles of ecological design throughout the life cycle of a construction project, starting from the concept stage.

3 RESULTS

At the initial stage of project life cycle, it is necessary to fix the existing situation and determine the possible level of application of the principles of ecological design. For this task, it is possible to use methods for classifying the reuse of materials (upcycling, recycling and downcycling), as well as methods for structuring materials, according to the concept of eco-performance by Michael Braungart and William McDonough.

The main materials used in the construction of buildings and structures are wood, stone, brick, clay, concrete, metal, glass and plastic. Construction products and structures, as a rule, consist of several basic materials, and can also be treated with various chemical compounds to protect the structure and covered with finishing materials (plaster, mastic, paint, varnish, etc.).

Recycling construction materials involves the use of recycled construction waste. Construction waste includes waste generated in the course of construction and installation work on the demolition, reconstruction, repair or construction of buildings and structures. The major share of construction waste can be reused: metal, wood or plastic products, broken concrete, broken reinforced concrete, broken brick, broken stone and glass. The issues of classification of construction waste and the development of a strategy for their reuse are a priority in the construction research (Gnezdilov, 2018; Sokolov, 2021; Chernaya, 2022).

An example of recycling and reuse of a material is crushed stone from recycled concrete and reinforced concrete. Modern research confirms the possibility of obtaining high-quality secondary crushed stone with the necessary uniform properties that make it possible to use this material for the construction of buildings and structures (Galitskova, 2015; Chulkov, Nazirov, 2018; Popov, Nikulov, 2017).

Information about the possible use of recycled materials for the construction products and structures must be indicated at the initial stage of the project life cycle, using the principles and approaches of environmental design. The Building Information Model (BIM) can become an environment for filling and systematizing information on the environmental indicators of a project. BIM model contains information about the geometric and physical

parameters of the building and its elements, as well as 3D visualization. The BIM model can also contain data on the physical and chemical parameters of materials for construction products and structures.

Today, the BIM model is the most convenient tool for combining building information data. And modern information modeling software products make it possible to add additional tools and parameters created using special programming methods to the BIM model (Shilov, Shilova, 2022; Shilov, Shilova 2021).

In this way we can add information about the possible use of recycled materials for the construction products and structures to the BIM model.

To enter information about the possibility of using recycled materials, we must add the appropriate parameters to the property panel of construction elements, as shown in Figure 1.

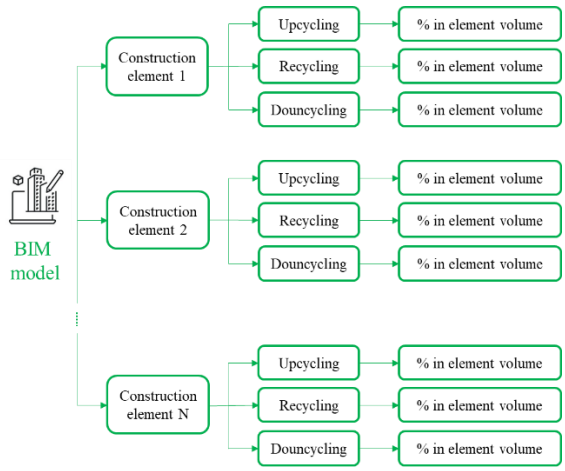

Figure 1: Scheme for determining additional parameters of construction elements in the BIM model.

For example, for the "Wall" element made of reinforced concrete, we can add two additional parameters:

- ✓ the type of recycling (upcycling, recycling or downcycling) used for the materials that make up the structure (rebar and concrete: cement, sand, crushed stone);
- ✓ the percentage of recycled material used in the structure (for example: recycled crushed stone - 5%, downcycling type of recycling).

We can add such parameters for each BIM model element of a construction project, for example, for floors, ceilings, roofs, windows and doors, etc.

After we enter all the necessary information about the use of recycled materials in the BIM model, we will receive a project database on the possibility of using recyclable materials on the construction project.

The next step in applying the principles of ecological design at the initial stage of development of a construction project is the process of analyzing information about the use of recycled materials in the project. To structure project information about the possibility of using recycled materials, we can use the concept of eco-performance of Michael Braungart and William McDonough and make the following lists of products and structures used in the project:

- ✓ products and structures without the use of recycled materials;
- ✓ products and structures that use recycled materials;
- ✓ products and structures made entirely from recycled materials.

The scheme for structuring design information on the possibility of using recycled materials is shown in Figure 2.

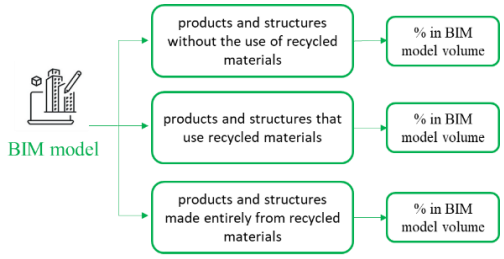

Figure 2: Scheme for structuring design information on the possibility of using recycled materials.

As a result of the above actions, we will get several results at once already at the concept stage of a construction project:

- ✓ a more complete BIM model that contains information about the possibility of using recycled materials for the project;
- ✓ structured information about the use of ecological design principles, including qualitative and quantitative data on construction products and structures that use recycled materials.

In the early stages of the life cycle of a construction project, several options for design solutions are often developed, this is done to compare technical and economic indicators and then select the most effective project option. Today, the environmental performance of the project is becoming even more important than the economic and technical components, so the comparison of project options can also be carried out on ecological parameters.

The analysis of project concept versions in terms of the ecological parameters can be carried out using BIM tools that allow generating reports on specified project indicators. To structure information about the

possibility of using recycled resources in the implementation of the project, we can determine the overall percentage of the use of recycled materials for a certain type of recycling (upcycling, recycling or downcycling), as shown in Figure 3.

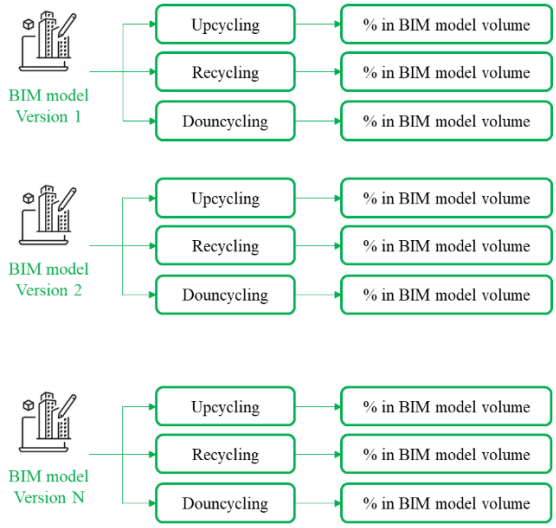

Figure 3: Analysis of project concept versions for ecological indicators using BIM tools.

The use of BIM technology to systematize information about the possibility of using recycled materials in the construction of a facility reflects the main tasks of ecological design associated with the formation of an environmental culture of consumption and the reflection of modern environmental trends in the construction industry.

4 CONCLUSIONS

The result of this study is a series of proposals on how to use the principles of ecological design at the concept stage of a construction project in terms of the use of recycled materials. A convenient technology for structuring and classifying information on the use of recycled materials in the implementation of a construction project is BIM, which allows we to add the necessary parameters to the BIM model. The capabilities of BIM for the analysis and systematization of design information make it possible to determine the level of application of the principles of ecological design for an object at the early stages of its life cycle, as well as to compare options for design solutions according to the ecological parameters of the project.

Accordingly, if we combine BIM technologies, ecological design principles and modern construction waste recycling technologies, we will get a complete project database on the possibility of using recyclable materials at the concept stage of a construction project. This will help to choose a design solution that takes into account the principles of ecological design in the next stages of the development of a construction project.

REFERENCES

Papanek, V., 1971. *The book*, Design for the Real World: human ecologie and social chance.

Pankina, M. V., Zakharova, S. V., 2014. Design principles: from functionalism to ecologization. *In Scientific and methodological electronic journal "Concept"*.

Pankina, M. V., Zakharova, S. V., 2017. The book Ecological design: textbook manual for undergraduate and graduate students, 2nd edition.

Pankina, M.V., Zakharova, S.V., 2014. Principles of Ecological Design. *In Modern problems of science and education.*

Braungart, M.l, McDonough, W., 2008. *The book*, Cradle to Cradle: Remaking the Way We Make Things.

Gnezdilov, M.A., 2018. Pollution of the environment with construction waste. *In a collection of scientific papers of the International Scientific and Practical Conference. Southwestern State University.*

Sokolov, L.I., 2021. Classification and recycling of construction waste. *In Management of the technosphere.*

Chernaya, A.A., 2022. The problem of processing waste from the construction industry. I*n Modern achievements of scientific and technical progress.*

Galitskova, Yu.M., 2015. The results of the study of construction waste. *In International research journal issue.*

Chulkov, V.O., Nazirov, B.Eh., 2018. Recycling of construction and demolition waste during renovation of territories and pavements of large cities. *In Russian Journal of Resources, Conservation and Recycling.*

Popov, M. A. Nikulov, R. N., 2017. The use of construction waste as building resources. *In FUTURE OF SCIENCE-2017: Collection of scientific articles of the 5th International Youth Scientific Conference.*

Shilov, L., Shilova, L., 2022. *The book*, Methodology of Coding Building Information Model Elements at the Stages of the Life Cycle. Lecture Notes in Civil Engineering.

Shilov, L., Shilova L., 2021. To the question of the building information modeling technologies transition to a new development level. *In E3S Web of Conferences.*