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ENERGY-SAVING ARCHITECTURE – TRADITION AND MODERNITY

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Abstract

The article presents the issue of energy efficiency in construction, which, although it has already been considered in the past, is nowadays perceived as a priority of modern architecture. The analysis of the subject matter shows the transformation of the design trends and solutions that uses technological possibilities resulting from the development of science, and that energy efficiency has become an important issue today. It is the subject of both scientific considerations and practical activities, the use of which is required also in Poland. The problem can be analysed by assessing the individual stages of the strategy of actions aimed at the improvement of solutions in the field of the energy efficiency of the buildings. On the one hand, computer simulations are applied, and on the other, modern devices in the field of building equipment.

Due to the progressive degradation of the natural environment, its shrinking resources, and the simultaneous increase in energy demand, the issues discussed in the paper are important and urgent. Despite numerous studies on energy efficiency in construction, it should be noted that further development is necessary. Constantly modernized technologies allowing to increase energy efficiency prove that the issue requires continuous updating, and scientific research alone can contribute to the development of a new generation of equipment for facilities that reduce energy consumption and thus are environmentally friendly.

Keywords: energy efficiency, BIM, modelling, modernity, computer simulations, tradition

Streszczenie

Artykuł dotyczy problemu energooszczędności budownictwa, który choć rozpatrywany był już w przeszłości, dziś postrzegany jest jako priorytet współczesnej architektury. Analiza problematyki pokazuje jak na przestrzeni lat zmieniały się tendencje i rozwiązania projektowania wykorzystującego możliwości technologiczne wynikające z rozwoju nauki oraz jak dziś ważnym zagadnieniem stała się efektywność energetyczna. Jest ona tematem zarówno rozważań naukowych jak i działań praktycznych, których stosowanie jest wymagane także w Polsce. Problem można analizować, dokonując oceny poszczególnych etapów strategii działań w zakresie doskonalenia rozwiązań obiektów budowlanych w zakresie ich efektywności energetycznej. Wykorzystuje się przy tym z jednej strony symulacje komputerowe, a z drugiej współczesne urządzenia w zakresie wyposażenia budynków.

Z uwagi na postępującą degradację środowiska przyrodniczego, kurezące się jego zasoby, przy jednoczesnym wzroście zapotrzebowania na energię omawiana problematyka jest ważna i aktualna. Mimo

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licznych badań dotyczących energooszczędności w budownictwie należy zauważyć, że dalszy rozwój jest konieczny. Stale unowocześniane technologie pozwalające na zwiększanie efektywności energetycznej dowodzą, że problematyka wymaga ciągłej aktualizacji, a same badania naukowe mogą przyczynić się do opracowania nowej generacji wyposażenia obiektów, które ograniczą zużycie energii, a tym samym są przyjazne środowisku.

Celem artykułu jest dokonanie oceny dotychczasowych rozwiązań oraz metod badawczych, a także nadanie kierunków dalszych badań. Ich zakres obejmuje krytyczne analizy dotychczasowych rozwiązań.

Słowa kluczowe: energooszczędność, BIM, modelowanie, nowoczesność, symulacje komputerowe, tradycja

1. INTRODUCTION

1.1. GENERAL REMARKS

The desire for energy-saving and rational energy management, which is used throughout the life of the object has already been known in history, although it was taken into account in the design process in various ways and with different results. Currently, it is an important issue because – as J. Biedrońska³ writes – energy saving is an expression of concern for the condition and resources of the natural environment. This tendency is part of the ecological architecture paradigm, which is understood as the architecture that skillfully uses the resources of the natural environment. “An effective way of saving is to directly use the light and thermal energy of the sun and wind in the building, without resorting to mechanical systems. It is a natural way, sometimes also referred to as passive. Its basic advantage is the reduction of energy demand with simultaneous increase of the comfort of using buildings and caring for the natural environment, understood as a series of activities related to reducing the building’s adverse impact on the surroundings”.⁴

On the one hand, the development and progress create the possibility of using new building materials and technologies that allow minimizing heat losses. However, on the other hand, it was the technical progress that led to the robbery management of natural resources and climate change. Such circumstances trigger the need to promote ecological solutions also in the field of architecture or urban design. Especially since the demand for energy is increasing, while the resources obtained from mining raw materials are limited. It is a serious local and global problem and at the same time a challenge for modern architects. It should be noted that almost until the end of the 19th century the energy was mainly produced from burning wood; in the first half of the 20th century, the energy was mainly obtained from coal mining, and today 85% of it is from oil, gas and coal. Nuclear and hydropower energy is obtained to a much lesser extent. Actually, its minute traces (about 1%) are obtained from renewable sources (wind, solar radiation). By promoting pro-environmental solutions, we increase the public awareness of the problems related to the shrinking of the natural resources and thus the growing need to use renewable energy.

The aim of the article is to show that the pursuit of energy-saving in construction, although recognized today as one of the priorities, was already known in the past.

³ Biedrońska J., *Passive solutions in architecture in the context of environmental impact*, Scientific Journals of the Silesian University of Technology, Series: Architecture, 2013, no. 53, p. 39.

⁴ *Ibidem*.

1.2. ENERGY EFFICIENCY – THE TRADITIONAL APPROACH TO THE PROBLEM AND CONTEMPORARY RELEVANCE OF THE SUBJECT

Contemporary urban problems resulting from the progressive degradation of the environment, and shrinking natural resources require measures to minimize the existing threats. One of them is the pursuit of energy efficiency of the buildings while maintaining the intact state of non-renewable resources. Although this aspiration has been present in the past, is still relevant. In fact, today energy efficiency is increasingly desirable and even required.

The perception of architecture and its possibilities significantly changed in the 17th century, when the value of science contribution to the development of technology was noticed. In the 19th century, when the industry grew rapidly, discoveries, technological innovations and all implemented inventions were almost natural. In the period of industrialization and modernism, construction technologies continued to develop until this development was disturbed by the first major energy crisis that occurred in 1974. It was realized then that excessive exploitation of the environment, including fossil fuels, must be controlled and minimized. At that time, restrictions on the heat loss of buildings began to be introduced together with the controlling of the heat transfer coefficients. As a result, the importance of the principles of sustainable began to be appreciated, together with the sustainable design and the pursuit of energy efficiency in buildings, which is part of new design trends, but also – which is not so obvious – a traditional design. Vitruvius himself strictly defined how to locate objects taking into account the directions of the world and the climatic conditions of the place.

He believed that the usefulness of the object is possible with an appropriate layout of its diverse space due to the function of individual rooms. It is possible if the object is aligned according to the cardinal directions. They are also important at the stage of the initial selection of the location of the building itself. Vitruvius considered it important to take into account the local climate, wind direction, ground, selection of building materials, etc. It is therefore clear that from the earliest times people were aware that natural conditions have an impact on the shape of architecture and its energy efficiency. Today, due to the opportunities created by the development of science and technology, this problem is also developed in the context of the use of appropriate technology and materials.

All this means that the discussed issues should be perceived as current and important, allowing improvement of health and environmental conditions in building areas. Moreover, they are also characterised by the economics of solutions at the stage of facility operation.

1.3. TERMS RELATED TO MODERN ENERGY-SAVING AND PARAMETRIC DESIGN – EXPLANATION

Modern energy-saving designing is associated with concepts such as BIM system and integrated design. These concepts are related to supporting practice, which results in architecture with low energy consumption. *Building Information Modeling* BIM system is helpful, as it integrates the data about the object and allows to accurately monitor the various stages of the life of the planned facility. The virtual model created using the discussed technology not only collects three-dimensional data on architecture and construction, but also industry specificity. As noted by A. Górka, K. Bandurski, E. Szczechowiak: “The building model in the BIM standard does not eliminate all obstacles in integrated design, however, it is a common platform for the exchange of data on the building that allows cooperation of all interested

industries at the design, implementation and operation of the building”.⁵ It greatly facilitates the design process, which remains under full control not only of the architect but of all people involved in the investment.

BIM is an appreciated tool of integrated design that creates the possibility of a systemic view of architecture at its various stages, as well as subsequent operation. *Integrated Design Process* distinguishes, among other things, the use of a literary system that enables flexible solutions that allow the architecture to adapt to the changing needs of users. This system provides the use of unusual, often new design methods, with the approval of the investor who has the opportunity to participate in the entire design process. An efficiently progressing development results from the cooperation of all people involved in the investment due to their access to full project documentation.

The first stage of integrated design includes analysis of design assumptions, which are later evaluated in terms of economic profitability. The next three stages are devoted to the development of the project (the initial concept, then the construction project, and then the detailed one). After completion of the design stage and the outcome of the tender for the construction, the planned facility is created and then equipped. Ready for use building is in operation. At the same time, it is possible to prepare the post-built documentation, operational analysis and verification of the design assumptions. The building may undergo reconstruction and, in the final stage of its life, demolition. Therefore, the integrated design includes planned control of the investment at every stage of its implementation and then functioning – life. Taking into account the full life cycle of the building and energy savings, we are able to analyse its efficiency.

1.4. RESEARCH METHODS

The main research method should include the energy efficiency analyses with the possibility of conducting the experiment in real conditions or using computer simulations. They allow to analyse and evaluate a specific issue and a specific application in design practice. However, it should be taken into account that modelling carries the possibility of error. It is all the more likely the more complex the model is. It results directly from the growing difficulty in determining the output parameters, which can lead to a decrease in the accuracy of the results obtained after using a simplified model. Depending on the examined problem we can distinguish different levels of detail of the model. The lowest one is used in the analysis of urban areas, where a specific problem related to buildings is assessed – the power grid, shading resulting from too short a distance between objects, or the degree of heat transferred to the environment at different scales of air pollution.

The medium level of detail concerns a comprehensive analysis of the building – its energy efficiency. For this purpose, a single or multi-zone model is constructed – *Multizone Building Performance Simulation*. When making a general assessment of energy consumption for the entire facility, a one-zone model is constructed, which allows the interior of the entire building to be treated as one zone, the so-called calculation node indicating a consistent temperature. If it is necessary to analyse the interactions between the rooms – the object is treated as a multi-zone model, in which each room is perceived as a separate ventilation area. It can concern one of the rooms in the building, which becomes a separate, one point of calculation. In this

⁵ Górka A., Bandurski K., Szczechowiak E., *Energy-efficient buildings [in:] Innovative challenges of construction technology*, Institute of Building Technology, Warsaw 2017, p. 185.

case, the simulation indicates heat flow inside the building and between the building and the environment using a system of equations in the adopted, relatively short time interval⁶.

The programs used for this simulation are equipped with the pressure model of airflow – *The Airflow Network AFN*. Based on the pressure difference and taking into account the characteristics of the holes and diffusers, it is possible to determine the direction of the airflow and its quantity. The model provides thermal calculations according to the determined algorithm⁷. A simpler way is to treat the airflow as an independent variable. It is also possible to use a model that takes into account calculations over a large period of time (every month)⁸. The heat capacity is then treated as an indicator. Combined programs applicable at various levels of detail are also commonly used.

The last method of simulation is the use of detailed modelling, which is applied for specific devices; it requires the use of specialized engineering and scientific programs (e.g. THERM). It should be noted that computer simulations are not always necessary; sometimes cheaper, more accurate and sufficient way is the analysis in the real environment. There is no doubt, however, that parametric architecture design is becoming increasingly common⁹.

2. ENERGY-SAVING TAKING INTO ACCOUNT THE TRADITIONAL VIEW ON THE ISSUE OF ENERGY EFFICIENCY

2.1. GENERAL CHARACTERISTIC OF THE PROBLEM

The problem of excessive energy consumption is solved nowadays completely different than in the past when it was not possible to use new technologies available today. Optimization of the architectural form, which was fixed in the building tradition, was done by trial and error. Its primary goal was the protection not only against the dangers of insecurity but also against adverse climatic conditions (excessive wind, low temperature, heavy rainfall, etc.). Because it wasn't and still isn't possible to change the climatic conditions, the architects tried to prevent their effects by properly locating the buildings, and shaping their form. The traditional approach is closely related to the defensive nature of architecture, also in the context of protection against harsh climate, which allowed for savings in terms of energy consumption.

The industrial revolution has slightly changed this state of affair. Due to the widespread use of fossil fuels, less attention was paid at that time to the climate, as well as the manner of managing natural resources, which became too expansive in the 19th century. Today, architects and architecture users are learning to cooperate with climate conditions using renewable energy sources; public awareness of problems related to the energy efficiency of buildings is also growing. We are aware that, for the most part, this problem concerns the construction sector. It is assumed that it is responsible for 40% of energy consumption. Transport uses slightly

⁶ *Ibidem*.

⁷ *Ibidem*; Malkawi A. M., Augenbroe G. (eds.), *Advanced Building Simulation*, Spoon Press, New York, London 2004.

⁸ Górka A., Bandurski K., Szczechowiak E., *op. cit.*, p. 185; Passive House Institute, PHPP9 – the Energy balance and Passive House planning tool, https://passivehouse.com/04_phpp/04_phpp.htm (access: 31.07.2017).

⁹ Bonenberg W., Giedrowicz M., Radziszewski K., *Contemporary parametric design in architecture*, Poznan University of Technology, Poznań 2019.

less energy – 30% and industry – 25%. Therefore, restrictions on energy consumption should be sought in construction, which was clearly indicated by the EU Directive, which obliges European Union countries, among others, to reduce the energy consumption of public buildings by December 31, 2018. By December 31, 2020, all newly built buildings are to function as facilities with almost zero energy consumption¹⁰.

2.2. CALCULATED VALUES OF ENERGY DEMAND FOR BUILDINGS

L. Laskowski¹¹ notes that energy-efficient buildings should absorb the least possible energy deposits during operation, but also should be designed so that their construction does not require excessive energy consumption. It is possible when the E index (determining the calculated demand for final energy – heat – for heating the building during the heating season, expressed in the amount of this energy per year per 1 m³ of the volume of the heated part of the building, is lower than the limit E₀ value for residential buildings. It should be assumed that:

$$\begin{aligned}
 E_0 &= 29,0 \text{ kWh}/(\text{m}^3 \cdot \text{year}), \\
 &\text{if } (A/V) \leq 0,20 \text{ m}^{-1} \\
 E_0 &= 26,6 + 12,0 (A/V) \text{ kWh}/(\text{m}^3 \cdot \text{year}), \\
 &\text{if } 0,20 < (A/V) < 0,90 \text{ m}^{-1}, \\
 E_0 &= 37,4 \text{ kWh}/(\text{m}^3 \cdot \text{year}), \\
 &\text{if } 0,90 \text{ m}^{-1} \leq (A/V)
 \end{aligned}$$

where:

A – the sum of the surface areas of all external walls (including windows and balcony doors), roofs, floors on the ground or ceilings over an unheated basement, ceilings over passageways, separating the heated part of the building from the outside air, ground and adjacent unheated rooms, calculated after outer contour [m²],

V – net volume of the heated part of the building, calculated as the gross volume of the building reduced by the volume of separate staircases, lift shafts, as well as external, lift shafts, and external, open parts of the building, such as arcades, balconies, terraces, loggias and galleries [m³]¹². Based on the author's detailed analysis¹³, it can be concluded that the energy efficiency of objects with a given shape and dimensions of their projections and the height measured by the number of storeys (assuming that the height of one storey is 3 m) is affected by the value of the A/V ratio. This value is primarily influenced by the number of floors determining energy demand. The dimensions of the sides and the shape of the projections have less influence. It should be noted that a higher number of floors provide more favourable results due to energy demand. However, even in the case of a two-storey building, the A/V ratio does not exceed 0.90. Therefore it can be assumed that the building's

¹⁰ Directive 2010/31/EU of the European Parliament and of the EU Council of 19 May 2010 on the energy performance of buildings, recast EPBD, <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1573151918639&uri=CELEX:32010L0031> (access: 21.12.2017).

¹¹ Laskowski L., *Thermal protection and energy performance of the building*, Warsaw University of Technology, Warsaw 2008.

¹² *Ibidem*; Kobylarczyk J., *Environmental conditions in the design of residential areas*, Cracow University of Technology, Krakow 2018, p. 185–186.

¹³ *Ibidem*.

final energy demand is below $E_0 = 37.4 \text{ kWh} / (\text{m}^3 \cdot \text{year})$ during the heating period. The value at the indicated building height was usually 0.60 and less.

Analysing the results of research carried out by the National Energy Conservation Agency S.A P. Markiewicz¹⁴ notes that the requirements of the NF15 and NF40 energy standards regarding single-family housing are met with an A/V ratio of 0.70. At $A/V = 0.80$, standards are unlikely to be met.

3. CONCLUSIONS

The issue of energy efficiency, although developed in the past, can be considered as current. It is important in the scientific field, but the effects of research are also used in practice, which is evidenced by numerous projects that provide buildings with energy savings at every stage of their lives. The development of science and technology formulates new standards and requirements which can be met using new technologies unavailable in the past. The topicality of the issues and constantly improved technologies, as well as the research capabilities of energy efficiency make energy-saving as a contemporary aspiration of architects in planning objects for various purposes, fit into the trends of shaping modern architecture. It is manifested in terms of energy consumption savings, with the application of modern building materials and technologies. However, one cannot forget that the defensive nature of historical architecture is the result of, among others, the desire to adapt it to local environmental conditions. Apart from the protective character understood in the context of ensuring security, architecture also defended against difficult meteorological conditions, which favoured the energy efficiency of facilities. Therefore, it has also been applied in the past tradition in which the approach towards local architecture built from local building materials and adapted to the prevailing climatic conditions characteristic for a given location has been firmly rooted. On this basis, it can be concluded that the purpose of the work, including the scope of the problem, has been achieved.

R e f e r e n c e s

- [1] Biedrońska J., *Passive solutions in architecture in the context of environmental impact*, Scientific Journals of the Silesian University of Technology, Series: Architecture, 2013, no. 53.
- [2] Górka A., Bandurski K., Szczechowiak E., *Energy-efficient buildings [in:] Innovative challenges of construction technology*, Institute of Building Technology, Warsaw 2017.
- [3] Malkawi A. M., Augenbroe G. (eds.), *Advanced Building Simulation*, Spoon Press, New York, London 2004.
- [4] Passive House Institute, PHPP9 – the Energy balance and Passive House planning tool, https://passivehouse.com/04_phpp/04_phpp.htm (access: 31.07.2017).
- [5] Bonenberg W., Giedrowicz M., Radziszewski K., *Contemporary parametric design in architecture*, Poznan University of Technology, Poznań 2019.

¹⁴ Markiewicz P., *Integrated energy design, single-family, energy-saving residential buildings*, Cracow University of Technology, Krakow 2017.

- [6] Directive 2010/31/EU of the European Parliament and of the EU Council of 19 May 2010 on the energy performance of buildings, recast EPBD, <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1573151918639&uri=CELEX:32010L0031> (access: 21.12.2017).
- [7] Laskowski L., *Thermal protection and energy performance of the building*, Warsaw University of Technology, Warszawa 2008.
- [8] Kobylarczyk J., *Environmental conditions in the design of residential areas*, Cracow University of Technology, Krakow 2018.
- [9] Markiewicz P., *Integrated energy design, single-family, energy-saving residential buildings*, Cracow University of Technology, Krakow 2017.

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