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METHODS OF TEACHING ARCHITECTURAL ENERGY CONSERVATION IN THE EDUCATIONAL DESIGN

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Abstract. Energy conservation is becoming increasingly more relevant for Ukraine and the world, and architectural education must meet one of the most significant challenges of our time. The article analyzes the existing laws and regulations of our country and points out to the lack of a number of national standards necessary for architectural design. It focuses on the problems of real design and ways to solve them within the framework of architectural training. By expanding the curriculum with specialized subjects, such as "Energy Efficient Architecture", the Institute of Architecture of Lviv Polytechnic National University significantly improves the energy awareness of architects and their responsibility for the energy consumption of the objects they design. The analysis of the basic principles and areas of application of energy-efficient architectural solutions is based on interdisciplinary research. This is the basis of the methodology of teaching the discipline with its theoretical and practical components. The paper describes the key aspects of classes on the theory of architectural energy efficiency to students. The practical part involves using instructional design to develop solutions that can be applied in new buildings, as well as in reconstruction, renovation and modernization of objects of different construction periods. Some examples and description of educational projects related to architectural thermal modernization are provided. The resulting information can be applied not only in instructional design but also in future graduation and competition design projects, as well as in students' research works. The outlined prospects for energy conservation in architecture and ways of development of the subject have a significant potential for improving the professional competence of architecture students. Special attention is given to research work aimed to ensure consistency of the content of education with the current state of the economy, energy consumption, achievements of science and technology. By introducing the above means into architectural training, one can expect significant foreseeable energy conservation effects in real, applied design.

Key words: architecture, energy conservation, energy efficiency, public buildings, instructional design, architecture competitions.

1. Introduction

The rapid growth of energy consumption is fraught with the risks of depletion of fossil energy resources. The risks associated with the use of traditional energy make energy conservation and energy efficiency a relevant area of activity for specialists representing different sectors. Although later than many countries, Ukraine got involved in resolving energy efficiency challenges, which are currently treated as a national security issue. A number of laws have been adopted and approximation of national regulations to European ones has been launched: the Law of Ukraine "On Energy Efficiency of Buildings" (2017), "Thermal Insulation of Buildings. DBN V.2.6 and 31: 2016" (2017) [1; 2; 3] and many others.

The global transition to a more environmentally friendly energy use will certainly have an impact on the labor market. In the field of architecture, competence in designing objects with lower energy consumption makes specialists more competitive. In Ukraine, according to expert estimates the cost of heating residential and public buildings makes up about 40 % of total energy consumption [4]. Therefore, the scope of work to be done is unprecedented. In order for the architect's idea to be the engineer's command consistent with the current requirements, one must be able to design the energy efficiency of his object. By introducing the discipline "Energy-Efficient Architecture" into the curriculum, we have significantly improved the energy awareness of architects and their responsibility for the energy consumption of their designed objects. This is exactly what we had in mind more than a decade ago when developing this subject for students of the specialty "Architecture and Urban Planning" at the Institute of Architecture of Lviv Polytechnic National University [5]. In this article, we will share our positive experience and methods of teaching architectural energy conservation.

2. Literature review

Representatives and heads of leading architectural institutions have repeatedly raised the issue of the quality of architectural education and improving the level of training [6; 7]. The study of the theory of architectural energy conservation and energy efficiency is based on foreign experience as well as on significant domestic endeavors [8; 9; 10]. Today, practicing architects have access to a large number of calculation platforms, simulation programs, and various software for calculating and determining energy efficiency. A lot of attention is given to their analysis and ranking in terms of the level of complexity of tasks [11, 12]. However, in real-life work, this toolkit is applied to its full capacity. The problem should be solved during the instructional design stage, where elementary applied calculations give an idea of physical processes and their interaction, as well as make it possible to predict and assess design solutions.

The aim of the article: to construct a methodology and to monitor the results of the instructional design of energy efficiency in design of architectural thermal modernization of existing buildings.

3. Basic Theory Part

The organization of instructional design is outdated as regards accounting for energy saving architectural measures. This is not only due to the fact that during their studies architecture students (specialists and masters) perform 10-11 (or even up to 15, if the work load is large) architectural projects before carrying out their graduation design project or master's qualification work. The problem lies elsewhere. The Institute of Architecture in Lviv, as well as other architectural higher educational institutions of Ukraine have a discontinuous approach to specialized instructional design. There is no comprehensive semester design project with equal regard to the issue of energy conservation. By integrating such a discipline in the curricula, the following problems can be solved: mastering the basic methods of architectural energy conservation, getting acquainted with thermophysical processes, making elementary calculations and learning to construct simulation models. The teaching methodology combines theoretical and practical parts.

The main student training areas in the theoretical part include:

– informing about the national and global energy situation,

– awareness and knowledge of the contemporary domestic regulatory framework,

– ability to apply regulatory requirements in practice;

– familiarization with the main thermophysical processes;

– ways to design taking into account a potential tightening of requirements in view of the harmonization of Ukrainian regulations with the relevant international or European legislation;

– informing about international good practices and the most successful cases of famous architects.

The teaching methodology primarily focuses on performing energy efficiency projects that combine theoretical knowledge and practical skills. This methodological approach allows us to start from the general

standpoint of energy efficiency and energy conservation through learning to make calculations to energy-efficient architectural solutions.

The practical part is based on the professional competence of 4-year bachelor's degree and 1-year master's degree architecture students within their specialty. They carry out a "Design of an Energy-Efficient Single-Family Residential House" or a calculation work "Architectural Thermal Modernization of a Public Building". The latter mostly focuses on solutions that can be applied in reconstruction, renovation and modernization of objects of different periods of construction.

Stages of practical work include:

– selection of climate indicators;

– field survey of objects;

– elucidation of the architectural or historical value of the object;

– analysis of planning, compositional, and shape-forming solutions from the point of view of energy conservation;

– detection of defects in structures and materials

– measurement and study of the values of microclimatic parameters by temperature zones,

– compiling a list of energy saving measures,

– calculation of transmission heat losses,

– selection of the most effective solutions based on calculations,

– customizing these solutions for the existing building,

– submission of the design project with the subsequent visualization of project solutions.

Next, we will describe a number of calculation works made within the discipline.

4. Results and Discussion

According to legislation, new buildings should be designed in conformity with at least class C requirements. The use of energy conservation techniques for them is clear-cut [1]. However, their integration into already existing facilities (which must undergo "certification of energy efficiency of a building"), including validation of the energy efficiency of solutions, requires much more multidisciplinary research and special educational, scientific, engineering and practical studies. Students could choose from a range of buildings and complexes of different designation: "home school", "kindergarten", and "parents' house". This principle of selecting survey and design objects greatly motivated the authors since they could appreciate the practical value of the proposed measures and, thus, manifested greater responsibility in making decisions and calculations.

The practical application of the methods of teaching architectural thermal modernization will be considered based on the design projects of public buildings and complexes. Most of the projects refer to buildings of educational institutions of the 1970–80s with typical design. It is reasonable to assume that the insights and calculations of architectural thermal modernization measures could also be typical and used in the future for such buildings in different regions of Ukraine. A total of 106 projects have been carried out for 82 buildings in the city of Lviv.

Along with architectural design solutions, the projects offer a number of planning, compositional and shape-forming solutions, taking into account the features of each object. Thus, they implied remodeling, adding extensions and superstructures in the form of auxiliary and training premises, glazed rooms, recreation facilities and greenhouses, for which energy efficiency calculations were also made.

Let us discuss some projects that differ significantly in approaches to execution. Thus, the project of architectural thermal modernization of the building of school No. 99 in Lviv implies reducing transmission heat losses by 60 % due to a number of proposed solutions (Fig. 1).

The project of thermal modernization of the orphanage in Tadzhytska Street in the city of Lviv includes a list of measures to reduce transmission heat loss by 64 % (Fig. 2). It should be noted that most of the projects and calculations had been made before the requirements for thermal insulation of fencing structures were tightened in 2013 and new state building codes were adopted. This means that current energy conservation indicators will now be much higher.

Fig. 1. Project of architectural thermal modernization of the building of school № 99 in the city of Lviv.
Authors: Khomandyak M., Klapchuk Yu., supervised by Shuldan L. O., Associate Professor, Ph.D (from the author's archive)

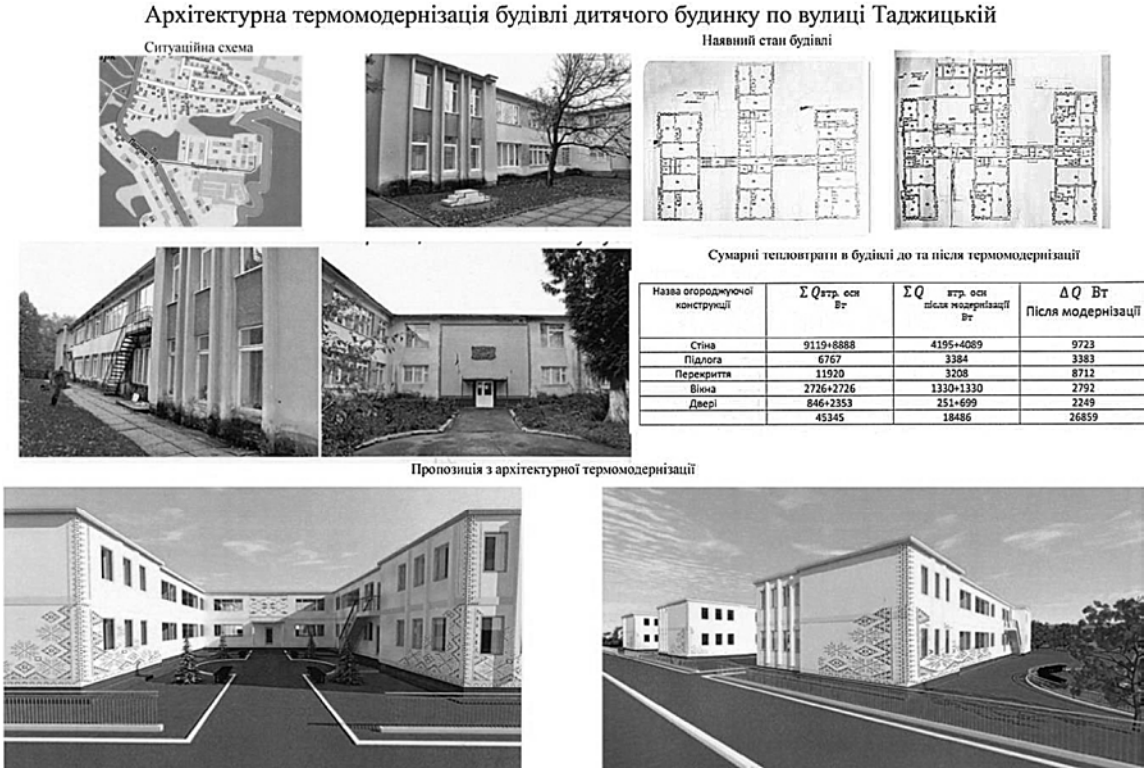

Fig. 2. Educational project of architectural thermal modernization of the orphanage in Tadzhytska Street in the city of Lviv.
Supervised by: Shuldan L.O., authors: Henda K., Labushevskyi O., Shapovalov E. (from the author's archive)

The techniques for historic buildings were chosen from a wide range of energy conservation measures based on both their maximum efficiency as well as the principle of respect for the architectural image of buildings in the historic area of the city. The measures were developed and calculations were made after a study of the history of the educational institution, its architectural or historical value, survey of the condition of its structures and fittings, observance of the values of microclimatic parameters and revision of the functional feasibility of the current planning pattern. During the examination, flaws and defects were detected, destruction and leak spots were found, necessary remodeling was specified, etc. As a result, it was proposed to carry out measures of thermal renovation of separate parts and fragments of fencing structures together with sanitation and restoration works. The calculation of facade insulation was of a training and hypothetical nature. An example of such research can be the project of thermal modernization of the building of school No. 87 in Lviv (**Fig.** 3). Energy savings with regard to transmission heat loss amount to 58.9 %.

Fig. 3. Project of architectural thermal modernization of the building of school № 87 in the city of Lviv.
Authors: Myndio V. M., Yadlovska O. R., supervised by Shuldan L. O., Associate Professor, Ph.D (from the author's archive)

In real conditions, architects have to take into account and analyze considerably more natural, man-made, anthropogenic factors in the shortest possible time. This encourages the creation and (or) use of relevant databases – climatic, geological, geodesic, statistical, etc. In the analysis of the urban development situation, volumetric, planning and compositional solutions, choice of constructive solutions and materials, analysis of the energy efficiency of this or that option, it is necessary to intensify parametric analysis processes. Contemporary architects are increasingly more often resorting to computer simulation tools in the early stages of designing in search for the most viable solutions for designed objects. To boost energy-efficient architecture in our country, we need national BIM and BEM design standards, approved protocols and principles for verifying digital models. For high-quality energy-efficient design, it is necessary to bring the software in conformity with the state standards and regulatory documents with the support of digital databases of all levels.

However, even today students' experience in using their skills and expertise is implemented in competition projects. For example, they took part in the All-Ukrainian Contest Reset City // Renovation – 2018: Development of Optimal Energy-Efficient Solutions for Reconstruction of Typical Kindergartens and Schools. The competition was announced and organized by the National Union of Architects of Ukraine involving Shuldan L. O., Ph. D, as an expert and jury member. The students also became winners of national screening procedures and participants of the international student contests Designing Multi-Comfort House in Madrid and Dubai of different years, etc.

By stimulating the rapid development of the area of energy efficiency in design, raising awareness of the problems and gradually step by step solving the tasks set with regard to training future specialists, it will be possible to shift the process of the professional training of architects to a higher level.

5. Conclusion and Prospects for Further Research

Energy saving is becoming an increasingly more relevant issue in architectural training. In order for the architect's idea to be the engineer's command consistent with the current requirements, one must be able to design the energy efficiency of his object.

In this regard, the task of architectural education is to develop expertise and ability to improve energy efficiency primarily by architectural means. The theoretical part of the educational discipline "Energy-Efficient Architecture" informs about the modern requirements and principles of energy conservation and gives insights into the relevant fundamental, engineering and technical aspects. The discipline is in line with the scientific specialization of the Department of Architectural Design and Engineering of the Institute of Architecture of Lviv Polytechnic National University – i.e. "Architecture of public and residential buildings, constructions of buildings and structures, quality assessment and monitoring of the architectural environment, issues of energy conservation in the field of architecture". It focuses on instructional design, which in architectural schools should not duplicate energy efficiency measures of other scientific and educational disciplines, concentrating instead on the application of architectural and typological principles of energy conservation based on multidisciplinary research. The ability to apply basic techniques and methods, to make calculations, to make simulation models and to analyze them is put to good use both in instructional design when developing projects of architectural thermal modernization of buildings and in future graduation design projects and students' scientific works.

Research work should ensure the consistency of the content of education with the current state of the economy, use of energy, and achievements of science and technology.

Only by integrating the above-mentioned means into architectural education, can we expect tangible energy saving results in the foreseeable future in real, applied design.

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Шулдан Лариса

МЕТОДИКА ВИКЛАДАННЯ АРХІТЕКТУРНОГО ЕНЕРГОЗБЕРЕЖЕННЯ В НАВЧАЛЬНОМУ ПРОЕКТУВАННІ

Анотація. *Актуальність питань енергозбереження для України та світу невпинно зростає і архітектурна освіта має відповідати одному з найважливіших викликів сучасності. У статті проаналізовано наявні в нашій країні закони й норми, а також відзначено відсутність низки необхідних для архітектурного проектування національних стандартів. Розглянуто проблеми реального проектування та шляхи їх вирішення у підготовці архітекторів. Введення в навчальну програму спеціальних дисциплін, таких як "Енергоощадна архітектура" в інституті архітектури Національного університету "Львівська політехніка", значно підвищує енергетичну свідомість архітекторів та їхню відповідальність за рівень енергоспоживання запроектованих ними об'єктів. Аналіз основних засад та напрямів застосування енергоефективних архітектурних рішень базується на міждисциплінарних дослідженнях. Саме це покладено в основу методики викладання навчальної дисципліни з її теоретичною та практичною складовими. Окреслено основні позиції навчання студентів теорії архітектурного енергозбереження. У практичній частині під час навчального проектування відпрацьовуються рішення, що могли би бути застосовані для нових будівель, в умовах реконструкції, реновації і модернізації об'єктів різного періоду зведення. Наведено деякі приклади і опис навчальних проектів архітектурної термомодернізації. Отримані знання знаходять застосування не лише у навчальному проектуванні, а й у подальшому, в дипломному та конкурсному проектуванні, у наукових роботах студентів. Окреслені перспективи енергозбереження в архітектурі та шляхи розвитку дисципліни, що являють собою значний потенціал для підвищення професійної компетенції студентів-архітекторів. Важлива роль належить науковій діяльності, яка має забезпечувати відповідність змісту освіти, сучасному стану економіки та використання енергії, досягненням науки і техніки. Забезпечивши архітектурну освіту названими вище засобами, можна буде очікувати суттєві результати енергозбереження в найближчому майбутньому в реальному, прикладному проектуванні.*

Ключові слова: *архітектура, енергозбереження, енергоефективність, громадські будівлі, навчальне проектування, архітектурні конкурси.*