The energy-efficient technologies in the educational program of the architectural higher school

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Abstract[1]

The world trend in the modern construction is related to the ecological rational design according to "green" standards and applications of the building information modeling – BIM. For more effective implementation of "green" building in Russia, it is necessary to introduce corresponding thematic in the higher education. Despite the absence of common methods, we developed our practice-oriented approach for teaching students Green BIM technologies and in this article we showed how these technologies are integrated into the educational process. The projects of energy-efficient objects, created by students of University of Architecture and Art and Ural Federal University meeting requirements of "green" standards are presented.

1. Introduction

The Ministry of Natural Resources and Environment of the Russian Federation has developed the strategy for the environmental safety of the Russian Federation for the period up to 2025 and the plan for its implementation [1]. The document determines the level of environmental safety in the territory where lives the most of the Russian population at the present time as unsatisfactory. And over the past decade, according to experts, the situation in this area is not improving.

Russia inherited from the Soviet Union a wasteful system of using natural resources, vast contaminated and degraded territories, and numerous objects that cause environmental damage. Cardinal changes in this situation, improving the quality of life and health of the population require joint action by government bodies, businesses, enterprises, public organizations, and the population.

In 2009, The Russian Green Building Council (RuGBC) was created as a member of the World Green Building Council. It is a not-for-profit industry organisation dedicated to accelerating development and adoption of market-based «green» building (sustainable building) practices [2].

RuGBC conducts the educational and organizational work to disseminate the ideology and technologies of green construction as the most promising way to solve economic, social and environmental problems in our country, to increase the efficiency of using existing resources, and abandon obsolete building materials and technologies. The instruments of «green» design are passive and active house technologies [3], traditional energy-efficient power generation, use of wind and solar energy, heat pumps, energy efficient controlled lighting, water treatment, solid waste processing, etc.

In Russia, the active development of environmental construction begins. Increased interest in this topic is demonstrated by the growth in the number of conferences and forums. Gradually, the introduction in the market of environmentally friendly and energy-efficient technologies and materials is increasing. There is the information about projects implemented using the technology of «green» construction in accordance with the main international certification systems. For example, RuGBC's site shows big number of objects in the Russia certified by international and Russian systems: LEED (USA) – more than 20 buildings in Moscow and Moscow region, St. Petersburg, Tver, Dzerzhinsk, Ulyanovsk, etc., 50 buildings are in the process of the certification, BREEAM (Great Britain) – more than 60 objects, GREEN ZOOM (Russia) – more than 60 objects in various cities of the country. In Ekaterinburg, 3 buildings are certified by GREEN ZOOM.

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Today, the construction industry is experiencing an interesting phase of its development, which is focused on the use of high technology and alternative energy sources. The greatest effect in saving energy resources can be achieved only through a set of measures, beginning with the optimal architectural solutions, taking into account the directional energy impact of the outdoor climate on the building, the use of non-traditional energy, and the use of high technologies for the control all types of engineering equipment of buildings. We need examples of implemented projects, methodologies and regulatory documents that help specialists to introduce these technologies into the construction industry of the 21st century. High-tech buildings and high environmental safety of housing should be a hallmark of modern construction.

An important role should be given to the education system in this process. The educating of an environmental responsibility among the young people through teaching at universities, in particular at architectural and construction departments, methods and means of «green» design based on the BIM – building information modeling (Green BIM) [4] will allow in the future improving the condition of the environment and to pass to an environmentally friendly oriented model of economic development. In this area, at present there are no uniform standards, common approaches to education. Moreover, most universities either absence or are at the initial stage of the introducing Green BIM technologies into the educational process.

For the wide spread of the Green BIM technologies, it is necessary to develop educational standards for teaching in universities. But this process is not fast, therefore an architectural and construction university should find its own forms and methods for the rapid introduction of modern technologies in the educational process.

Realizing all responsibility to future generations, we have introduced the number of practice-oriented methods in teaching students on the direction "The Applied Informatics in the Architecture". These methods are the next: the introduction of the most advanced software tools in the field of building information modeling (BIM) and «green» design in the CAD course; discussions of the best world practices in the field of «green» construction (exemplified by Pritzker and other architectural awards); excursions to objects certified according to «green» standards in our city, and studying energy-efficient facilities in other regions; cooperation with organizations implementing building automation systems "smart house", certification systems in according with green standards, with experts in energy conservation; participation of students in international and Russian competitions often with mixed teams from 2 universities; organization and participation of conferences and round tables with the participation of students on the introduction of advanced technologies in the urban environment.

Further, we will also cite a number of projects performed by students of the Department of the Applied Informatics of the Ural State Architectural and Art University in Green BIM technology and meeting the requirements of the green standards.

Our graduates, who have the most modern knowledge in the field of environmental design and information modeling, organically implement these technologies in the practice of construction of facilities that meet the principles of sustainable development.

2. Green BIM Technologies in the educational program "The Applied Informatics in the Architecture"

2.1. Practical-oriented methods of the teaching

The Department of the Applied Informatics delivers interdisciplinary specialists in the field "The Applied Informatics" with the profile "The Applied Informatics in the Architecture". We teach students IT-technologies, including relevant sections in such disciplines as "Computer-aided design (CAD)", "The Architectural design", "The Urban ecology", "Social and environmental foundations of the architectural design", "Environmental factors in the architecture" "Information technologies and management systems in resource-saving", and others. We have also developed a system that allows us to comprehensively teach the principles of environmental design and information modeling through the following practice-oriented methods.

1. The introduction to the CAD course of modern software tools in the field of the building information modeling (BIM) and the «green» design Green BIM.

In the multidimensional program of CAD discipline, we have included a large number of modern automation tools for the architectural and construction industry. Thus, BIM is the mostly relevant and effective technology and it is the process of creating and control the information about a construction object at all stages of its life cycle [5]. The information modeling allows you to visualize and calculate the future object with the selected materials, have several options with a cost estimate, optimize the constructive part, remove collisions of engineering equipment and architectural solutions; all this ultimately increases the efficiency of the project. Since the project relies on a digital model of the building, it allows performing numerous calculations on its optimization in terms of efficiency in the further operation of the building.

BIM-technologies are realized by means of such software systems as Autodesk Revit, GRAPHISOFT ARCHICAD, Nemetscheck Allplan, Bentley Architecture, Tecla Structure, etc. The most common platform, including in universities, is Autodesk Revit. Mostly in the Revit program, students carry out their projects.

In the Navisworks program, students are introduced to the principles of 4D and 5D-modeling.

Autodesk 3DS Max and AutoCAD packages are also used in the learning process.

Students are able to import 3D models into the Unity 3D and Unreal Engine software environment to organize interactive project management in real time. It is also possible to link with the virtual reality equipment to generate three-dimensional scenes with immersion of the user in an artificial environment. This technology is used as an innovative tool for promoting architectural projects.

To work with the relief and design of infrastructure objects, AutoCAD Civil 3D is used.

The development of project concepts is carried out using the InfraWorks 360 platform in order to improve the efficiency of data exchange and collaboration.

Data bases such as Autodesk's Vault system and CSoft's TDMS system for the cataloging and integration of construction objects and for collective project development were mastered.

2. Discussions of the best world practices in the field of environmental design by the examples of winners of Pritzker and other awards.

For interactive lessons students prepare for discussions the topics including the best world examples of «green» architecture. Thus, the projects of architects who work by the criteria of sustainable development were analyzed. These architects were awarded the Pritzker Prize, which is an analogue of the Nobel Prize in the architecture. They are Glenn Murcutt (Australia), 2002 Prize, Alejandro Aravena (Chile), 2016, the Catalan group: Rafael Aranda, Carme Pigem and Ramon Vilalta in 2017.

It should also be noted the international competition LafargeHolcim Awards, which is held since 2005. The jury evaluates all works according to five main criteria: a holistic, integrated view on the sustainable development, an innovation and ability to replicate simultaneously; Ethical standards and social inclusion; Resource consumption and environmental indicators; Economic feasibility, universality and applicability; Contextual and aesthetic impact of the project.

3. Excursions to the objects certified according to the «green» standards in our city and studying the features of the facilities in other regions.

We have visited the cottage village Ekodolia near Ekaterinburg with students to study the experience of building the house of class A+. The house was realized in accordance with the concept of Active House on the basis of the European experience. The main objective of this project is to find a solution for the modern Russian house that meets the high requirements of resource saving, ecology and quality of habitat. At the same time, the cost of building and operating the house must be in keeping with the capabilities of the people.

4. The cooperation with organizations implementing building automation systems "smart home", the certification systems in according with green standards, with experts on energy-efficient housing construction.

During all the period of education, the department of Applied Informatics regularly invites experts from leading enterprises in the field of energy-efficient housing construction to meet with students, such as the Institute of the Passive House (Moscow), the companies "Teplokrepost" and "D-systems" (Ekaterinburg), the "Bureau of Engineering" (St.-Petersburg) and many others.

5. The organization of conferences and roundtables with the participation of students, the participation scientific conferences on the introduction of advanced technologies in the urban environment.

We organize the participation of students in scientific and practical seminars organized by companies that produce new materials and technologies ("Knauf", "Izover", "Teplit"), in major international exhibitions and conferences in Ekaterinburg ("Innoprom", "Forum 100+", "City Spot"), hold round tables and conferences with the invitation of our graduates.

For example, within the annual exhibition "The Building Complex of the Big Urals" we have organized the round table on the application of BIM and Green BIM technologies in the Urals region: difficulties, effects, prospects; BIM in the education: who teaches and how, what competencies are needed for the employers.

6. The participation of students in international and Russian competitions.

During several years, the students of the department take part in the international competition of the Saint-Gobain company for the design of multi-comfort buildings in different countries.

In the Autodesk international competition our student Alexander Ivlev in 2012 received the main prize in the nomination "Give the shape to the future" with the project of an eco-house controlled by the automatic system "Smart House". In the next section, this project is shown.

2.2. Examples of diploma projects using Green BIM technologies

The graduate projects of students of the Applied Informatics department which demonstrate skills in designing of energy-efficient facilities using Green BIM technologies are shown here. In some cases our diploma projects are related to real objects – industrial, public and apartment buildings.

In the Fig. 1 the futuristic project of an individual apartment house, designed to meet the requirements of environmental friendliness and energy efficiency, designed to accommodate the automation system "Smart House" is demonstrated (author Alexander Ivlev).

Fig 1. 3D-visualization of the "smart" eco-house

The structure of the house is two moving "petals" that open to receive sunlight. Roofs are equipped with solar panels and photosensitive sensors. In the "petals" there are bedrooms and living rooms. The central module of the house is cylindrical; it houses the kitchen, the dining room, etc. The house is also equipped with wind power generators that will allow you to maintain the necessary amount of energy during the night or overcast days for the functioning of the internal systems.

For the least impact on the environment, the house is located on five poles, which also facilitate the placement of the building on slopes and cliffs, which will ensure the stability for the moving structure of the house.

The work of the student was directed to a high-quality visualization of the project and he developed a great video clip in After Effects program on the basis of 3DS Max models both the environment and the interior.

In the diploma work of Nadezhda Klyukina (Fig 2), a multifunctional stadium in Tokyo was designed using energy-saving architectural and construction technologies and energy efficient engineering solutions.

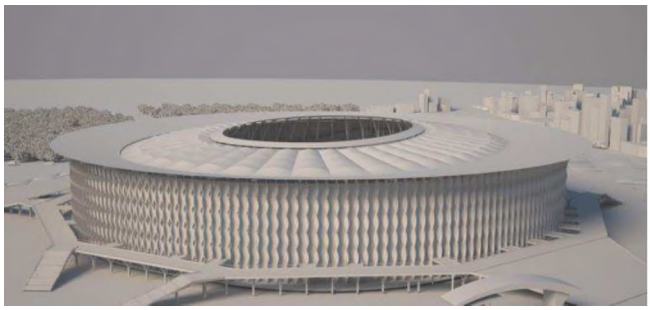

Fig 2. The stadium project in Tokyo

When the stadium was designing, the attention was paid to the environmental optimization and in particular to the Green Goal program, which is being developed by the initiative of FIFA.

In this work, the stadium project has been certified according to the LEED standard.

The architectural solution of the stadium is made using kinetic architecture, in particular, dynamic facades are offered as an alternative to sunscreens with low thermal conductivity, and also a way to organize the active effective ventilation. The facade was modeled in the Autodesk Revit program with the plug-in DYNAMO.

The Autodesk Revit was also used for the information modeling. Along with the digital 3D model for joint development at all stages of the life cycle, the calculation of wind load, the analysis of external flow, the energy audit, the calculation of the heating, ventilation and air conditioning systems was carried out in Revit. Autodesk Green Building Studio software was used to conduct energy modeling and evaluate the energy efficiency of the building.

For more in-depth analysis, the following programs were used: Energy Plus for the analyzing of energy expenditure for heating, cooling, ventilation and lighting; Lighting analysis for Revit – for a more accurate analysis of the illumination of the object in accordance with the LEED standard; Green BIM Engineering uses Autodesk Simulation CFD 2014 to analyze the efficiency of ventilation and air conditioning systems, to develop a passive heating/cooling/ventilation, to study the influence of the shape of the building and obstacles on the external wind load; Flow Design – for modeling air flows.

To calculate the financial model and investment attractiveness of the project, the software product "Alt-Invest" was used to prepare, analyze and optimize investment projects of various industries, scope and focus.

In the diploma work of Maria Sheveleva, the possibilities and advantages of using BIM technologies in the reconstruction of architectural objects are studied using the example of the residential group in Madrid.

Fig 3. The reconstruction of the residential group in Madrid

This project (Fig 3) was presented at the international competition of the Saint Gobain company from a joint team of students of the architectural university and the Ural Federal University.

At present, many large urban centers are very tightly built, so much attention is paid not to the construction of new facilities, but to the improvement and transformation of the already constructed architectural fund. In this case, BIM as a tool can bring great effect.

BIM is especially important for the restoration of historical architecture objects. It is important to model the general condition of the object, as well as the degree of its wear and tear. In this case, it is better to use not

modeling from plans, but scanning of a building with special equipment, since some parameters that may seem insignificant at first glance may turn out to be a destructive factor during reconstruction.

The use of BIM technologies in the reconstruction of buildings is a fairly new and unexplored direction. Usually, the building information model is applied at all stages of design and construction, including operation and demolition. For planning the reconstruction of the BIM model, you can also get all the necessary information.

The advantages of BIM in the process of building reconstruction are as follows:

- The reconstructed object already possesses an architectural form and various systems, from which changes begin. In this case, BIM tools allow you to check automatically the object for various collisions, inconsistencies between old and new subsystems. Specifications are generated automatically; various calculations are performed, including cash estimates.
- The ability to model many reconstruction options, including mixing details of different versions.
- The possibility to develop a modification of the object by stages, for example, dismantling of a part of the building, installation of new architectural forms, installation of new systems and so on.
- Thanks to the information model, it is also possible to efficiently make a partial replacement of engineering systems.
- In the BIM model, you can specify the timing of the reconstruction, lay the time schedules and monitor the current state of the structure.
- Computer experimentation. Since many objects that fall under reconstruction are badly worn, the introduction of innovations in them can be disastrous for them, therefore in BIM programs it is possible to reconstruct various situations, strain calculations. Thanks to this, systems and design solutions are optimized.
- Information modeling is also relevant for seismically unstable areas in the restoration of buildings, since bearing structures are most often only reinforced, and not completely reworked.
- Finally, BIM allows you to design a reconstruction of any age-related building, taking into account new standards for environmental and energy-saving requirements, thanks to which the facility can get a certificate for LEED, GREEN ZOOM, and others.

4. Conclusion (style CSIT-Title2)

Thus, the educational program "Applied Informatics in Architecture" responds to modern requirements and shapes students' knowledge, skills and abilities in the automated design of energy-efficient environmental facilities. In the article the effective modern technology of digital modeling of buildings (BIM and Green BIM) and results of its application in real projects is presented.

- For more widespread application of BIM-technologies, it is necessary to develop educational standards for teaching at universities.
- We have developed the system (6 steps) that allows us to comprehensively teach the principles of environmental design and information modeling through the practice-oriented methods.
- Results of application of BIM-technologies in diploma projects related to real architectural and construction objects in accordance with "green" standards are shown.

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