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Improving the calculation of the cost of the construction project using BIM technology

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Abstract. In the scientific article the authors summarize the results of theoretical research and practical implementation in the design of residential and public buildings BIM – information modeling technology. The questions of application of digital models for control of financial expenses at all stages of project implementation in construction are considered. An attempt is made to harmonize BIM technology with the Comsol Multiphysics software package. A review of existing studies on this issue in Europe, Asia, the United States and Russia. With the participation of the authors of the article developed a set of specialized families for the system Autodesk Revit, which allow you to perform a comprehensive preliminary study of the construction site of residential buildings. The approach providing increase of efficiency of determination of estimated cost of works on construction of object of construction based on several generalized principles is offered. This innovative approach has been tested in the design of several large construction projects in the Ural region of Russia, implemented in 2017-2019.

1. Introduction

BIM technology (Building information Modeling – building information modeling) involves the construction of one or more virtual building models in digital form. The use of BIM allows with a high degree of reliability to recreate the object itself with all the structures, materials, engineering equipment and processes occurring in it and to debug the main design solutions on the virtual model [1].

The use of models facilitates the design process at all stages, providing more thorough analysis and control. The information model exists throughout the life cycle of the building, and even longer. The information contained in it can be changed, supplemented, replaced, reflecting the current state of the building [2-4]. For the correct operation of the BIM-approach need relevant information sources. Besides static documents (like imagery) need a point of integration between CAD (design), control systems, accounting (e.g. automated complex software 1C), trouble ticket system, email, or regulations of contractors and so on.



In Russia, such scientists and designers as V. V. Talapov, M. S. Panteleeva, V. V. Alenkov, V. Shakhramanyan, V. Sharmanov and others were engaged in the study of BIM technology in relation to the construction and calculation of the cost of construction materials in the project [2-5]. At the state level, adopted a plan for the phased implementation of BIM in the field of industrial and civil construction, approved by the order of the Ministry of construction of the Russian Federation № 926/PR of 29 December 2014.

The world's greatest development in the study of BIM information modeling is currently being celebrated at Brisbane University of technology in Australia, MARA University of technology in Malaysia, as well as at a number of higher education institutions In new Zealand and South Korea [1,6-9]. USA, United Kingdom, Finland, Denmark, Norway, Netherlands, UK, Hong Kong & Singapore are among the countries heading towards significant BIM uptake. In these countries, such an approach as design, construction and operation in one integrated development environment has already been adopted at the state level.

2. Results and discussion

The specialists of "Ural Federal University named after First President of Russia B. N. Yeltsin" together "Institute for planning, architecture and design" (LLC "Inpad") has developed a digital model of the object "Multifunctional building of the Congress centre of the international exhibition centre "Ekaterinburg-EXPO", with the use of BIM. The Congress center, which is being built by Sinara-development, will create the most comfortable conditions both for the organizers of the events and for the audience. In July 2019 The Congress center will become a venue for the global summit of production and industrialization GMIS-2019, which will bring together more than 10 heads of state.

Earlier, based on the results of calculations using BIM tools, an innovative model of strengthening the ground base for five nine-storey residential buildings in the right Bank of the city of Berezniki was developed, which was highly appreciated by the specialists of the Federal Science and High Technology Center and Department of state expertise of Perm region [3]. At the construction site, the creation of a soil mass with the help of soil-cement elements was performed, which was not previously used in the design and construction of buildings in this region.

Technical specifications for the design were set strict requirements for the economic and functional efficiency of the object:

- total area of the building – 41.6 thousand square meter;
- the number of floors to four floors and one basement floor;
- the main multifunctional hall in the basic configuration-4000 seats;
- Concert version of the hall with the organization of the fan zone for 5000 people;
- 15 conference rooms and 26 meeting rooms for public and exhibition forums;
- Catering complexes and restaurant yard;
- short terms of construction and installation works.

According to the design results, the following results were achieved:

- the technical equipment of the multifunctional hall allows to organize not only business events, but also entertainment, theater, Philharmonic concerts at the highest international level, meeting all the specific requirements for the organization of a spectacular space for architectural acoustics, visibility, comfort and safety.
- clarification of the consumption of materials for construction and installation works in the direction of a reasonable reduction;
- elimination of errors in design solutions due to the possibility of checking conflicts at the stage of development of the building model;
- reducing the cost of the object in terms of square meter.

The use of a digital model of the building made it possible to make a refined calculation of the impact of adverse engineering-geological conditions of the construction site.

In the process, the authors investigated the issue of harmonization of BIM technology with the COMSOL Multiphysics software package, which is actively used in the design of energy-saving structures [10].

A sample of stationary heat engineering calculation of 3D-model of the building using this software package is shown below (Figure 1).

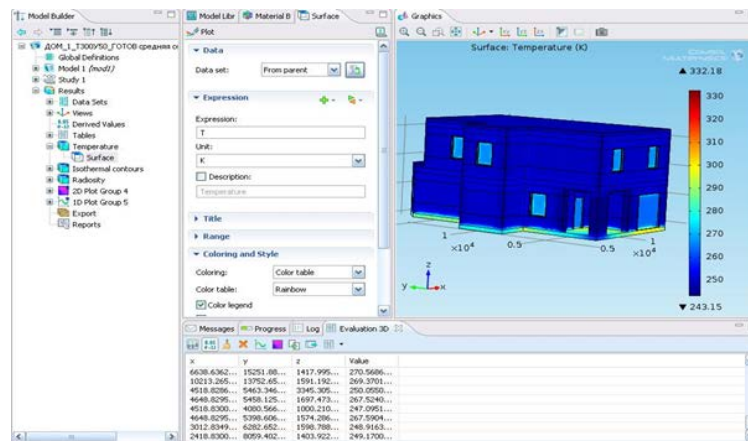


Figure 1. Window with the results of thermal stationary 3D calculation

To solve the PDE, COMSOL Multiphysics uses the finite element method (FEM).

Design and detailed documentation for all design objects is carried out in the licensed Autodesk Revit software package. Elements of the digital model of the building is shown below (Figure 2).

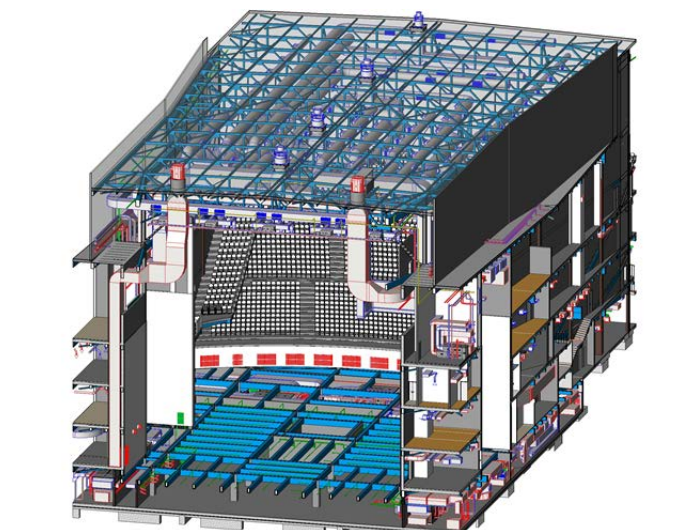


Figure 2. General model of the international exhibition centre building. View in section with internal engineering networks of heating and ventilation.

The task of determining the economic efficiency of the project at the earliest stage of work was a priority in the planning. No less important task is the planning and control of costs at the stage of project implementation. The use of BIM tools, namely, families, including data classified in accordance with the requirements of the customer, allows you to control costs online, at the same time, this work – budgeting and control of financial costs – carried out by specialists of the customer or specially involved organizations. As you know, one of the main advantages of designing using BIM is the ability to calculate the amount of building materials used with high accuracy: with the correct construction of the model, it is possible to extract any set of data originally incorporated into it.

One of the options for the implementation of this possibility for the future calculation of estimates is the use of classifiers.

The classifier is an approach adopted by agreement of the customer and the designer to systematize information about materials and products used for the construction of the facility.

The formulation of the classifier, in the form as it is now offered by the customer, is reduced to coding information for a specific method of calculation (estimate method, resource, per unit volume, etc.). Further processing - creation of sheets with codes in drawings and assignment of information to a specific element, for example (conditionally):

- Wall;
- Brick;
- Design thickness of 250 mm;
- Wire mesh reinforcement;
- On cement-sand mortar M100;
- Fire resistance EI60;
- So forth.

The customer has the possibility of further use of this information. It should be taken into account that the designer (architect, designer, engineer-specialist in engineering networks) there is a significant additional amount of work associated with the correct distribution and sorting of certain building materials within the classifier.

The designer often does not have, and, perhaps, should not have the qualification of an engineer-estimator. The order of definition of these or those parameters of materials, works and elements for determination of cost of works according to the existing estimated standards is often absolutely not obvious. It is also worth considering that at different stages of the project, as a rule, each has its own method of calculating the cost, based on its previous experience.

As a result, designers fill in the parameters of customers (similar, but each has its own requirements), trying to combine them with the internal standards of the organization. Also, they need to take into account the standards of designations, design and use the resources of the program for partial automation. As a result, there is an excessive overflow of information, often duplicating each other in one form or another. Well, the most negative point is the increase in the amount of additional, unpaid work of the employee. As a result, either the quality of work suffers or the term of performance of work is violated.

In order to quickly and effectively check construction estimates, we need a national program to create new regulatory frameworks and their quarterly update. In the United States, for example, thus updated regulatory framework RSMMeans, which can be found for the money anyone [6].

In Russia, the reform of the pricing system and estimated regulation in the construction sector, carried out in 2015-2018, despite a long time period and a significant amount of money spent, has not achieved its goal — the transition to a new pricing model.

In order to facilitate cost estimation and verification of cost estimates using Building information Modeling, a "fair price" principle should be incorporated into the regulatory framework for each type of construction and installation work with reference to a specific region. This will allow, in turn, to conduct tenders for the selection of contractors based on a comparison of the consolidated unit prices, as well as to check the claimed estimated cost [4, 11].

The authors of the article proposed and tested in practice a new approach to calculating the cost of construction of the object using BIM design. At the moment BIM models of objects "Multifunctional building of the Congress center as a part of the international exhibition center "Yekaterinburg-EXPO", Apart-hotel "Belorechensky" in Yekaterinburg, Techno-shopping center JCB, showroom "Mitsubishi Motors Corporation" are prepared.

3. Conclusion

For the design of residential houses, the authors with the participation of specialists of the Institute of design, architecture and design (Inpad LLC) [11] developed a set of specialized families for Autodesk Revit system, which allow to perform a comprehensive preliminary study of the site:

1. Determine the insolation deduction for the building site-the volume, the placement of objects within which will not violate the insolation of the existing building.

2. Place within the boundaries of the land residential sections of different configurations, the main parameters of which (number of storeys, floor area, type of commercial property located on the ground floor) can be dynamically changed.

3. Get a full set of basic technical and economic indicators of the planned development, including the area of the required sites, Parking lots, the calculation of the number of places in preschool institutions and schools.

On the basis of the implemented research results, the authors found that the following approach is the most effective for the correct definition of the economy of the construction object at all stages of design using Building information Modelling project:

1. Calculation of the cost of objects at the stage of the concept and conceptual design is carried out on the basis of integrated performance indicators on the basis of objects of analogues.

2. Exclusion of changes in the type of materials used after the design stage "Preliminary design". At the same time, already at the Project stage, with the proper use of BIM construction technologies, it is possible to obtain the volumes of the main materials used, on the basis of which it is possible to prepare an enlarged estimate.

3. Preparation of estimates based on the volumes obtained from the BIM model, by specialized organizations.

4. Control of expenditure of funds during construction works is possible by agreement of the executed volumes, which are entered in the BIM model by means of automated control, or by employees of the design organization in manual mode.

Thus, Building information Modelling technology has shown the possibility of achieving high speed, volume and quality of design and construction, as well as significant budget savings.

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