BIM-technologies Applied for Designing a Complex Shape of the Building

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Abstract. The purpose of this study is to examine BIM technologies for engineering and design of modern buildings, as well as investigate problems when applying those BIM technologies and suggest the appropriate ways to rectify them. The researchers designed the university building in their study. They took into account current regulations and ergonomic decisions. The design was carried out based on the Building Informational Model (BIM) technologies by the Revit Structure software. There is already information concerning physical and heat-mechanical properties of materials contained in the software. This technology allows one to step up progress on the designer’s work, lets him create a design model of the building not from scratch, as well as sets the properties of its elements. The university information model is a four-storeyed rectangular building deformed on four sides in the form of a concave lens. This research is devoted to the use of building information modelling and BIM technologies for the design of the genuine architectural and construction concept. Although, they had special difficulty with the import of the information model obtained in Revit Structure into a LIRA SAPR computational scheme.

1. Introduction

BIM technology is the process of creating a building information model, highlighting the entire amount of information available about the building at the moment. The complete project is always carried out in 3D-space and represented not only by lines and textures or structures but also by numerous artificial features that have physical characteristics in real life.

With the express aim to predict them, programs for BIM modelling are required. The functions of the computer analysis of the properties and performance data are available. A lot of authors [1,2,3,4,5,6,7,8,9,10,11,12] studied BIM technologies and their application in design. Such authors as G. Acampa [13], M. Khaddaj [14], A. Ginzburg [15], H. A. Gökhan [16], I.V. Lokshina [17], Yujie Lu [18] created information models in their works that were related to the design and construction of facilities, their electric energy systems and infrastructure. A study of F.H. Abanda [19] examines the impact of BIM systems on off-site production and conventional construction methods focused on BIM technological potential to create the facility environment infrastructure and a building master plan. In the paper, A. Vishnivetskaya [20] contemplates the moves aimed at implementing
information modelling in Russia for the construction industry in general and the renovation of housing facilities in particular.

The main aim of the research is to design a modern building, the architectural and planning concept of which meets modern ergonomic requirements, and its load-bearing elements meet the requirements of strength, rigidity and stiffness by using BIM technologies. The building must fit the current standards based on building regulations.

2. Materials and methods
The building project was performed in Revit Structure 2015 software, the training version according to the requirements of the Code of recommended building practice 118.13330.2012 ‘Public constructions’. When constructing the load-bearing frame of a building, the Revit program automatically builds an analytical model of the building in parallel with it. That model consists of the properties of materials that make up the load-bearing elements. This technology is called BIM (Building Information Model) which designs a building information model. Then the model is saved in the common .ifc format for further sending to SAPHIRE 3D software with subsequent analysis in PC LIRA SAPR. SAPHIRE software is a system of parametric 3D modelling of residential and public multi-storeyed buildings and structures at the stages of pre-project design, documenting and obtaining drawings, preparing an analytical model for performing strength computation in LIRA-CAD software.

3. Results and discussion
Due to the long term operation of the university academic buildings and their normal ageing, it appeared necessary to build a new complex of university buildings that meet modern ergonomic requirements. The authors decided to develop a multiple-purpose project of Sholom-Aleichem Priamursky State University.

The authors chose an elliptical-paraboloid shape, which affects the deflected position of the floor slabs for the main building of Sholom-Aleichem Priamursky State University (Fig. 1). The choice depended on the efficiency, ergonomics and suppleness of design decisions.

The designed university building is a building with an inner court and an entrance hall/lobby unit adjacent to it, a gym and four academic buildings (Fig. 2).
Figure 2. View of the master plot plan / general arrangement of the university building.

The central body is a plan of a four-storeyed building of rectangular shape, deformed on four sides in the form of a concave lens. The roof covering of the university building is flat, multi-layered/sandwich with an internal downpipe /drain. The roof covering is separated by a fire barrier at the place of a functional joint. The roof access is provided by two exits from which the walkways open into the ventilation chamber and the cleaning facilities room. The planning pattern of the building is complex and has an individual design according to the demands for higher education institutions.

There is a fresh-air ventilation chamber, a switch board room, a heat point and engineering equipment premises in the basement of the building. There is a lobby unit with a reception area, a wardrobe and a watch standing on the ground floor. In the central body, there is a dining room with a kitchen, a library with a library stack and WC-and-bathroom units. On the first floor, there is a separate gym with workout facilities/fitness rooms and change rooms. In the central body, there is a shift classroom that is placed on the second and third floors, there are also computer classrooms, lecture halls, a student conference hall, departments, bathrooms, showers with locker rooms. The clerical office, archives, a book depository, a reading hall, a medical aid post, a conference room, a department, a dean’s office, a technical department, a special branch and sanitary units are located on the third floor. On the fourth floor, there is a printing office, a personnel branch, a supply manager, vice-rectors’ offices, a rector’s office with the front office, a department of general services, and employment opportunity office, a local student affairs division, a career-broadening program department, a server-based room, an accountants office with a cash department, an international department, security department, extracurricular and scientific research department as well as sanitary units. There is access to the cleaning equipment rooms and ventilation chambers over the roof.

Then, the university building model, designed in Revit Structure, was open in SAPPHIRE 3D, which was 3D software, 2017 and had been saved earlier. The following offers an analytical and finite element model after triangulation of the basic bearing structures of the university building in SAPPHIRE program (Fig. 3).

Based on the physical model transferred from Revit, a computation scheme is produced in SAPPHIRE 3D. Then the building model is transferred from SAPPHIRE software to LIRA SAPR.

When analyzing loads on the bearing elements, they are applied according to Building Regulations 20.13330.2012 ‘Loads and effects/actions’. Depending on the load time, it is necessary to differentiate between permanent and temporary (long, short-term, special) loads.
Figure 3. The university building model in SAPHIRE software: a - analytical, b - finite element model.

The weight of structural parts, including the weight of load-bearing and building envelopes which is 8376.58 tons is considered to be the permanent ones. Short-term loads included occupancy loads, an animal load, overlap of public buildings with full standard values equal to 0.5 t /m²; climatological (snow) loads on the roof, and transmitted ones from the roof to the columns are 0.07 t /m².

The construction of the university building was analyzed in PC LIRA SAPR based on the finite element method. The accounting results are the diagram charts of reinforcement of load-bearing elements (Fig. 4).

Figure 4. Diagram charts of web reinforcement of load-bearing elements in PC LIRA SAPR: a - top slab flange above the gym, b - top slab flange above the ground floor.

For example, in the diagram of web reinforcement of the top slab flange above the gym, the segments highlighted in light yellow are reinforced with elements ranging a rectangle 0 by 1.41 cm² in area. The maximum area values are coloured with dark brown and vary from 7.69 by 10.1 cm². Light yellow fragments characterize the minimum reinforcement values up to 1.41 cm² in the reinforcement chart by the crosswise reinforcement of the top slab flange above the first floor. The maximum area values are presented in dark brown and vary from 12.7 to 15.7 cm². The reinforcement of various load-bearing elements of the university building is selected in a similar manner. Thus, LIRA SAPR software allows one to supplement the building information model with data on the reinforcement of load-bearing reinforced concrete structures.

4. Problems
There was some difficulty with displaying the structure when exporting the model from the Revit Structure program in the universal .ifc format. The problems were solved afterwards in the SAPHIRE 3D; they interfered with further computation in PC LIRA SAPR [21]. Besides, when carrying out the design scheme in SAPHIRE 3D, there is lack of most columns observed that were present at the physical model of the building (Fig. 5).
Figure 5. Model having a design flaw after export to PC SAPPHIRE 3D.

For the missing columns to input into the design diagram, it is necessary to reassign the column material in PC SAPPHIRE 3D for the present. In this case, it will be concrete grade B25. The remaining columns for the physical model are displayed incorrectly schematically as flat surfaces instead of bars. They need to be removed and new columns should be designed for the physical model instead of them after designing new levels. Following the above, the necessity for more correct operation is obvious to perfect the transmission of the analytical model from Revit [22] to SAPPHIRE 3D by supplementing it with the corresponding exporting module.

5. Conclusions
The research performed allows to make the following conclusions:
- The authors designed a modern building using BIM technologies. The architectural and planning concept of it meets modern ergonomic requirements. Moreover, its load-bearing elements meet the requirements of strength, rigidity and stiffness of the construction.
- BIM model contains information about the construction project and can be used at all stages of its life history.
- Using BIM principles, one can visualize a project of any complexity in detail at all stages of its production.
- BIM model allows one to use and correct the same model by all construction participants, viewing it and operating equally in parallel.
- Thanks to BIM technologies, it is possible to reduce the number of errors in the design documentation, so to make the design process more consistent.
- Several software integrated products can be used to design an information model.
- There are integration problems between software products that implement BIM technology.

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