

Saimaa University of Applied Sciences
Technology, Lappeenranta
Degree Programme in Civil and Construction Engineering

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The applicability of the BIM technology in Russia

Bachelor's Thesis 2016

Abstract

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The applicability of the BIM technology Russia, 146 pages, 11 appendices

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BIM technology is actively developing around the world. Also there is an active extension of using BIM technology in Russian construction industry. However, the level of the development of BIM technology in Russia is still quite low. Due to it, the main purpose of the thesis was to identify the reasons of the low level of BIM technology development in Russia and to determine the applicability of the BIM technology in Russia.

To identify the reasons of the low level of BIM technology development in Russia, the basic information about BIM technology and its development from its occurrence, the basic advantages and disadvantages of using BIM were studied. To determine the applicability of the BIM technology in Russia, the current practical needs of normal Design and Construction Company in Russia with the BIM abilities were compared.

In this thesis, the reasons of the low level of BIM development in Russia were identified. The main problems of BIM practical application in Design and Construction Company in Russia were also identified and recommendations for the further development were given. The ability to meet the current practical needs of normal Design and Construction Company with BIM technology was particular detail analysed and partially confirmed. The thesis could be recommended for companies which are in the beginning of the BIM technology introduction process.

Keywords: BIM, building information modelling, building information model, information modelling, applicability of BIM.

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Terminology

Apple Lisa is a personal computer introduced by Apple Computer Inc. on January 19, 1983 (1).

Building information model (or BIM or BI model) is a digital representation of the physical and functional characteristics of the project (2).

Building information modelling (or BIM or BI modelling) is the process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information (2).

Code of practice (or SP) - standardization document, which contains the rules and general principles of processes to compliance with the technical regulations' requirements (3, chapter 1, paragraph 12).

Computer-aided design (or CAD) is the use of computer systems to aid in the creation, modification, analysis, or optimization of a design (4, p. 3).

Construction Operations Building Information Exchange (or COBie) is an information exchange specification for the life-cycle capture and delivery of information needed by facility managers. COBie can be viewed in design, construction, and maintenance software as well as in simple spreadsheets. This versatility allows COBie to be used all projects regardless of size and technological sophistication (5).

Facility management (or FM) is the integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities (6).

Federal Agency on Technical Regulation and Metrology (or Rosstandart) is a Russian federal executive body providing government services and managing state property in the field of technical regulation and ensuring uniformity of measurements (7).

Finite element method (or FEM) is a numerical technique for solving problems which are described by partial differential equations or can be formulated as functional minimization (8).

Gantt chart is a type of bar-chart that shows both the scheduled and completed work over a period (9).

Industry Foundation Classes (or IFC) is a platform neutral, open file format specification that is not controlled by a single vendor or group of vendors. It is an object-based file format with a data model developed by buildingSMART (10). IFC is the international standard for openBIM and with IFC4 an ISO standard (ISO 16739) (11).

Integrated project delivery (or IPD) is a collaborative alliance of people, systems, business structures and practices into a process that harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction (12).

International Organization for Standardization (or ISO) is an independent, non-governmental international standard-setting body composed of representatives from various national standards organizations (13).

Lira (or «PK LIRA») — multifunctional software package for the design and analysis of building and engineering structures. The implemented method of calculation - FEM (14).

Ministry of Construction Industry, Housing and Utilities Sector (or Ministry) is a government ministry in the Cabinet of Russia (15).

Moscow state expertise (or Mosgoosekspertiza) is an organization authorized to conduct a state examination of the project documentation and results of engineering survey (16).

OmniClass Construction Classification System (or OmniClass or OCCS) is a classification system for the construction industry (17).

Really Universal Computer Aided Production System (or RUCAPS) was a CAD system for architects, and today credited as a forerunner of BIM (18).

SCAD - multifunctional software package for strength analysis of structures. The implemented method of calculation - FEM (19).

Senate Properties is a government owned enterprise under the aegis of the Finnish Ministry of Finance and acts as the government's expert on the working environment and working premises (20).

Sonata was a 3D building design workstation-based system, a product of the early 1990s. (21.)

4D (or the fourth modelling dimension) refers to 3D + time. That is, a model or a modelling workflow is considered to be 4D when the time is added to model objects to allow Construction Scheduling (22).

5D (or the fifth modelling dimension) refers to 4D + cost. That is, a model (or modelling workflow) is considered to be 5D when cost is linked / embedded within BI Models and Model Components. 5D is used for the purposes of generating Cost Estimates and practicing Target Value Design (23).

6D (or the sixth modelling dimension) refers to 4D + project life-cycle management information. This model contains the room elements, such as room name, number, and space type connected with asset information such as manufacturer, model numbers, serial numbers, and any operations and maintenance requirements (24).

1 Introduction

BIM technology is one of the fastest developing technologies worldwide. One of the most powerful reasons for it is the breadth of BIM application possibilities in construction and other industries. BIM is much more than just a new method in the design. It is also a fundamentally different approach to managing, the lifecycle of the buildings or constructions, the man-made environment. BIM is a changed attitude to the buildings and constructions.

For the same reason, BIM is a technology, the implementation of which is extremely difficult and requires the establishment of appropriate premises. Due to it, the introduction of BIM worldwide is uneven. The implementation of BIM technology in Russia goes quite fast, but there are not some important preconditions for the development of the BIM technology. There are also many misconceptions in this area in Russia, which leads to the commission of multiple glaring mistakes in the process of BIM implementation.

In order to structure the development of BIM technology in Russia, determine the vectors of further development, as well as to provide the specific recommendations for the implementation of BIM technology in the companies in Russia, it was decided to write this paper. Due to it, the main purpose of the thesis was to identify the reasons of the low level of BIM technology development in Russia and to determine the applicability of the BIM technology in Russia.

2 Definition of term BIM

BIM is a building information modelling. The uniform definition of the term does not exist, but the following definition captures the essence of BIM:

BIM is a process of the collective creation and use of the information about the construction, forming a reliable basis for all decisions during the life cycle (from the first concept to design, construction, maintenance and demolition). (25.)

According to the Russian standard, information modelling (IM) is the process of creating an information model, which is a collection of data and data correla-

tions, and which describes the real object's properties of interest to the designer and potential or actual user. (26.)

The main objective of BIM in the construction at the moment is the effective support in the implementation of all operational processes throughout the lifecycle of the buildings and structures. (27.)

In practice, the term BIM usually means:

- the process of the creation and use of the coordinated, consistent data base about the project, which allows to visualize the project development and accurately predict the operating characteristics (28)
- the 3D model of a building or other construction object, related to the information data base, where each element of the model has its own properties and additional attributes such as position, strength, price, material, schedule, etc. (29).

According to S. Azhar (30), "a building information model characterizes the geometry, spatial relationships, geographic information, quantities and properties of building elements, cost estimates, material inventories and project schedule. This model can be used to demonstrate the entire building life cycle. A BIM carries all information related to the building, including its physical and functional characteristics and project life cycle information, in a series of "smart objects". For example, an air conditioning unit within a BIM would also contain data about its supplier, operation and maintenance procedures, flow rates and clearance requirements (31)."

Thus, not all 3D models representing a building can be considered as a BIM. For example, a model containing only visual data, but not the attributes of the elements, or model that allows changing the sizes in one view, but does not reflect these changes automatically in the others, are not BIM. (32.)

3 History of BIM development

3.1 Occurrence of the term

Despite of the fact that BIM at this stage of its development is mostly perceived as a new technology, the history of modern BIM is longer than a few years.

The first term, which is now transformed into the BIM, was used in 1974 by Charles Eastman, professor of the Georgia Institute of Technology, as a Building Description System (BDS). The concept of the BIM, described in this article, has not undergone any significant changes to the present day. (33.)

The development of the BIM concept was continuing throughout the world during the 1970s and 1980s of 20th century. The term BDS was used as a Building Product Models (BPM) in the USA, and Product Information Models (PIM) in Europe. Later these terms were united in BIM, which is the most widely used at the moment.

The first term BIM in the sense we understand it now was used in a paper by Simon Ruffle in 1985 (34) and later in a paper by Robert Aish in 1986 (35). Since then, the term BIM gained the popularity among developers and users around the world.

3.2 The first software

The first software products initiating the development of BIM software were steel programs such as RUCAPS and Sonata. These programs were being developed in the 1970s – 1980s. Despite the fact that the programs were not widely known among users due to the high cost of the platforms, they have become an important stage in the development of the BIM technology.

Thus, RUCAPS became the program, which was used to assist in the phased construction of Heathrow Airport's Terminal 3 (36, p. 12). That was the beginning of the development of 4D BIM.

Buildings Description System (BDS) is the first software that successfully created a construction database. The software was created by Charles Eastman.

The database comprised a library of elements, which can be obtained therefrom and inserted into the model. The program used a graphical interface with the possibilities of a perspective view and isometric, option data extraction and sorting. Eastman claimed that BDS is able to reduce the cost of the project up to 50%. The program was written on the PDP-10 (see Figure 1) before personal computers became actively used. (37)



Figure 1. PDP-10 which allowed creating BDS (37)

This program was not generally available. Only some people had a chance to test this tool and it is not known whether any project has been fully implemented with the support of BDS. BDS was, at this stage, only an experiment.

The next software of Charles Eastman - Graphical Language for Interactive Design (GLIDE) - was created in 1977 (see Figure 2). The whole process was fully parameterized. It means that GLIDE had the characteristics of current BIM platforms. It should be noted that generally the authors of these tools were not qualified as architect or designer (37).

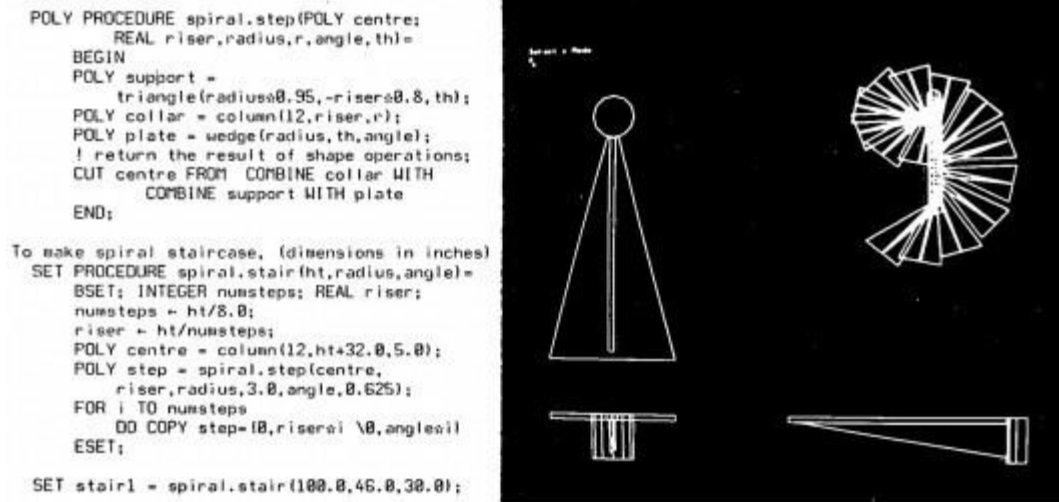


Figure 2. GLIDE. Code on the left forms the stairs to the right (37)

The first BIM software, which was available to work on the PC and became known, was Radar CH¹ (see Figure 3), released by Graphisoft in 1984 to work on the Apple Lisa platform. The feature of the program was a division of 2D and 3D modules. (38.)



Figure 3. The Radar CH interface (37)

¹ Also known as ArchiCAD v.1.1.0

In 1993, the program The Building Design Advisor (BDA), developed at Lawrence Berkeley National Laboratory, became one of the first software that allowed not only to produce the model of the building, but also to carry out an analysis of the design decisions on the basis of the criteria such as, for example, the materials, construction and system geometry used. The multianalysis allowed assessing the efficiency of the different design decisions. (39.)

In 1990 the Finish Company Tekla Oy launched their first X product, Xroad for road planning, followed by Xcity for urban planning. In 1993 the commercial version of the structural steel engineering software Xsteel was completed. And already in 2004 the structural engineering software Tekla Structures based on Xsteel was launched. (40.)

April 5, 2000 Revit Technology Corporation released Revit 1.0, written in C++ for the Microsoft Windows platform, and from 2000 to 2002 released versions 2.0, 3.0, 3.1, 4.0 and 4.1. The aim of the program creating was to create a product that can work with the more complex projects than ArchiCAD can work with. Revit revolutionized the history of the BIM and became the first full 4D BIM software, which allowed simulating the construction process. (41.)

3.3 Collaborated design

Further development of BIM software led to the expansion of BIM software capabilities and scope of possible uses. Thus, in 2004 Tekla Structures has been realized (40), in 2006 – Revit MEP (42), in 2008 - Autodesk Ecotect Analysis (Sustainability) (43) and other programs. This provided most of the construction project participants with the necessary software tools.

There was a natural need for the tool that allows the collaborated work of all participants regardless of their professional field. The first step in this direction was the realization of Revit 6 in 2004 with a function that allows a significant number of the employees working on one integrated model, a form of the collaborative software.

At the moment, with the development of the standards and requirements for BIM programs, capabilities of the collaboration design are expanding. This is

achieved by the revision and redesign of highly specialized software and sometimes by the integration of their tools in the other BIM software.

3.4 Open BIM

Since there was the first convenient opportunity of creating BIM models, the problem of comparing different BIM models made by different specialists appeared. This problem has caused the emergence of the open BIM concept principally driven by neutral IFC file transfer, emerged in the late 1990s.

The idea of open BIM is the ability to free transfer and use of BIM models made for different purposes by different specialists regardless of the tool used to create the native model. (44).

Unlike close BIM, open BIM strategy provides the following benefits:

- Project managers can use a unique set of tools, which consists of the best in their field decisions and optimally solves the design problem.
- Project managers have complete control over the component parts of the project, including on updates independent from each other's software.
- Using a set of solutions reduce risk of data loss, as opposed to working with a merged BIM model (which combines several disciplines, but keeps it in a single file).
- Project managers can abandon complicated setup of BIM-file, sharpened under all kinds of specialties, and use separate models created by independent programs and interconnected.
- As a result, designers get clear BIM, built on open standards, which allows using the data on the entire life cycle of the building (45).

Companies participating the Open BIM program: buildingSMART International, the Nemetschek Group companies, including GRAPHISOFT, Nemetschek Allplan, Nemetschek Vectorworks Inc., Nemetschek Scia, and Tekla (Trimble company group) and Data Design System.

3.5 The modern state of the BIM software market

In recent years, there is rise in popularity of the BIM technology. This is largely due to the scientific and educational papers in the field, high level of the software development and positive experience of the transition to the BIM design of a few countries that gave the high economic results.

At the moment, there are the following trends:

- Increase the number of users in the world, the transition of the individual companies and countries to the BIM modelling
- development and expansion of the software manufacturing companies
- revision and redesign of highly specialized software and the integration of their tools in the other BIM software
- software standardization
- creation of a unified design environment that is independent of the software used
- expansion of the collaborative design tools and capabilities.

After the years of the competition between the different software manufacturers, there are such undoubted leaders as Autodesk, Bentley Systems, Nemetschek Group, GRAITEC and Trimble in the market. Table 1 shows the companies involved in the production of the BIM program, with the highest economic performance in the recent years.

Table 1. Companies with the highest economic performance

Name of the company	Country	Revenue (Millions of EUR)	Name of the main products	Increasing of the revenue
Autodesk	USA	2216,0 (2016) (46)	Autodesk Revit Architecture Autodesk Revit Structure Autodesk Revit MEP	10,12%
		2012,3 (2014) ¹ (46)	Autodesk Navisworks Autodesk Robot Structural Analysis	-1,66%
Bentley Systems	USA	-	Bentley Architectural Bentley Structural Modeler	-
		553,1 (2014) ¹ (47)	Bentley Hevacomp Bentley Facilities	7%
GRAITEC	France	68,7 (2016) (48)	Graytec Advance Design Graytec Advance Workshop	45%
		47,2 (2014) ¹ (49)		26%
Nemetschek Group	Germany	-	Graphisoft ArchiCAD Graphisoft MEP Modeler	-
		218,5 (2014) ¹ (50)	Allplan Architecture Allplan Engineering Allplan BCM Allplan Allfa Solibri Model Checker	26%
Trimble	Finland	_ ²	Tekla Structures Tekla BIMsight	-
		_ ²	Tekla Field3D	-

¹ 2014 was not favorable to the companies, and at the moment (2016) revenue growth of most companies exceeds the presented value

² Revenue from BIM business can not be separated from the total revenue of Trimble Navigation

It is easy to see that all the companies, represented by Table 1, increased their revenue in the recent years. All the companies predict a further increase of the revenue and number of the customers in 2017. Thus, the BIM industry shows strong growth.

4 BIM standards in different countries

For the success of the transition to the BIM design, the support of the industry with the development of the mandatory and optional standards is needed. The greatest interest is the experience of the standards development in the leading in the field of the BIM design countries as such experiences can be replicated by countries, which still do not have their own BIM standards.

4.1 BIM standards in Great Britain

The beginning of the active work on the BIM standards in Great Britain can be considered as 2011, when, in May, the UK government construction strategy was adopted and published.

The task was to go to the obligatory use of the BIM technology in the construction projects with the public funding during the next five years (51). Formally, the mandate for the strategy execution was issued to 1 April 2016, but the goals were actually achieved in 2015.

During these five years, the UK has done a lot of preparatory work on the system revision of all the transition aspects, which was been coordinated by a specially formed BIM Task Group.

A series of the BIM standards and other documents was adopted and published:

- PAS 1192-2:2013 - Specification for information management for the capital/delivery phase of construction projects using building information modelling
- PAS 1192-3:2014 - Specification for information management for the operational phase of assets using building information modelling (BIM)

- BS 1192-4:2014 - Collaborative production of information. Fulfilling employer's information exchange requirements using COBie. Code of practice
- PAS 1192-5:2015 - Specification for security-minded building information modelling, digital built environments and smart asset management (52)
- BUILDING INFORMATION MODEL (BIM) PROTOCOL – identifies the Building Information Models that are required to be produced by members of the Project Team and puts into place specific obligations, liabilities and associated limitations on the use of the models (53)
- Government Soft Landings – regulation of the objects delivery in operation process (for the projects with the public funding) (54)
- Uniclass 2015 - is a unified classification system for the UK industry covering all construction sectors. It contains consistent tables classifying items of all scales from a facility (55)
- BIM Toolkit - the free-to-use NBS BIM Toolkit will benefit both public and private sector construction projects. It provides step-by-step help to define, manage and verify responsibility for information development and delivery at each stage of the asset lifecycle (56).

All of these documents were published online and free to use.

4.2 BIM standards in the United States of America

The beginning of the active work on the BIM standards in the USA can be considered as 1995, when Autodesk Company organized a private alliance of twelve companies to prove the benefits of interoperability — full information exchange — between the many software programs being used in the building industry.

In May 1996 in London the International Alliance for Interoperability (IAI) was established. The IAI established Chapters within individual countries and sometimes by region or language area. An International Council consisting of two representatives from each Chapter was established to coordinate international standards development. On January 11, 2008 the IAI changed its name to buildingSMART to better reflect the nature and goals of the organization. (57.)

At the moment, the buildingSMART alliance, a council of the National Institute of Building Sciences (NIBS) is coordinating the efforts of the facilities industry to implement open BIM standards for the industry (58).

The United States National BIM Standard Version 1, Part 1: Overview, Principles, and Methodologies was released in December 2007 and laid the foundation and provided templates for our future open BIM standards efforts (59).

Since then, the standard has undergone several changes. As a result, in May 2012 the United States National BIM Standard Version 2 was published. Version 2 consisted of reference standards; terms and definitions; information exchange standards (which are built upon the reference standards); and practice guidelines that support users in their implementation of open BIM standards-based deliverables (60).

According to the estimate of the standard by the authors, about 98% of the content of Version 2 still needs improvement and further development (61). It shows how much information the authors would like to add or improve. However, this version of the standard has made a significant contribution to the global standardization of BIM:

- Most vendors support IFC
- COBie used internationally
- Execution plan widely used
- OmniClass growing in use.

The first 3,000 users of the standard were counted by the professionals from more than 70 countries. A few countries, including the UK and South Korea, have used the content of Version 2 as the basis for its own BIM standards. (61.)

The United States National BIM Standard Version 3 was published on 22 July 2015 and. At the time, it is the latest version of the standard. Version 3 covers the entire life cycle of the buildings. According to the Project Committee decision, in the new version of the standard 27 documents were included. The total volume of the standard is 3100 pages of content (62). Version 3, as well as Version 2, has potentially made a significant contribution to the global standardization of BIM.

The United States National BIM Standard Version 3 was published online for free use. (63.)

4.3 BIM standards in Singapore

In July 1993 CORENET¹ project was launched. It was the first step in the history of BIM development in Singapore, which has had an influence on the further development of the industry in the country-state Singapore.

The aim of this project was the implementation of an automated examination of the construction projects provided for obtaining a building permit. The project included a transition from the traditional system of the examination of the drawings and documents to the automated examination of the projects which were made as a BIM. (64.)

To achieve the project objectives, CORENET required certain conditions, such as:

- availability of the efficient BIM software and modelling tools
- proven system of modelling
- standardization of the project requirements
- transfer of the construction industry to the BIM modelling

However, in the beginning of 1990s BIM industry has not been sufficiently developed to comply with these conditions. Thus, CORENET project was too hasty and ambitious, and was doomed to failure.

Since 1999, the state administration of the construction industry in Singapore began to implement by the BCA² (65). This organization is the initiator of the many new ideas in the field of the innovative technologies in construction industry, including BIM.

One of the most important BCA works was the development of The Singapore BIM Guide Version 1, which was published in 2010, and later, reprinted with

¹ Construction and Real Estate Network

² Building and Construction Authority

additions in May 2012 (66). The Singapore BIM Guide included two main sections:

- BIM Specifications
- BIM Modelling and Collaboration Procedures. (67.)

Thus, The Singapore BIM Guide is an information document, defines the roles and responsibilities of the all participants in the BIM project at the different stages of its implementation.

In June 2010 BCA has also organized the \$6 million CPCF¹ to promote BIM industry. The foundation covered the costs of the training, consultancy, purchase of licensed software and other equipment (68). In March 2015 the second \$330 million tranche of the CPCF, designed for three years, was made (69).

At the moment, the existing BIM standard in Singapore is The Singapore BIM Guide Version 2, published in August 2013 and consists of three main sections:

- BIM Deliverables
- BIM Modelling and Collaboration Procedures
- BIM Professionals. (70.)

In addition to The Singapore BIM Guide Version 2, freely available educational materials were developed and published. They are designed to facilitate the transition to the BIM design.

These materials are united in The BIM Essential Guide Series and include:

- BIM Essential Guide for Adoption in Organization
- BIM Essential Guide for C & S Consultants
- BIM Essential Guide for Execution Plan
- BIM Essential Guide for MEP Consultants
- BIM Essential Guide for Architectural Consultants
- BIM Essential Guide for Contractors
- BIM Essential Guide for Collaborative Virtual Design and Construction
- BIM Essential Guide for Building Performance Analysis. (71.)

¹ the Construction Productivity and Capability Fund

These training materials are actually textbooks and templates of the internal regulations for the organizations and professionals.

These factors have allowed the CORENET project to revive. In 2015 the project was put into operation. Since then, according to the requirements of the Government of Singapore, all construction projects, regardless of the ownership and financing, with cross area more than 5 thousand of square meters are examined for permission to build only as a BIM with the help of the official website.

It made the possibility to provide the high-quality and fast transfer of the construction industry from the traditional design to the BIM design. According to the BCA, in 2015 100% of the project organizations transferred to BIM. It significantly improved the efficiency of the construction sector.

4.4 BIM standards in Finland

The process of transferring the construction industry of Finland to the BIM design started in the 1990s. In 2000 the buildingSMART Finland was founded as part of the International Alliance for Interoperability Nordic Chapter. In 2007 BIM is mandatory for all public buildings owned by Senate Properties.

In 2007 Senate Properties launched their first BIM Guidelines 2007 which were developed to the Finnish National BIM Guidelines (COBIM) later (72). These requirements were based on the IFC standards and national guidelines, and consisted of the following parts:

- Volume 1: General part
- Volume 2: Modelling of the starting situation
- Volume 3: Architectural Design
- Volume 4: MEP design
- Volume 5: Structural design
- Volume 6: Quality assurance and merging of models
- Volume 7: Quantity take-off
- Volume 8: Using models for visualization
- Volume 9: Use of models in MEP analysis. (72.)

The work on a new version of these requirements began in 2011. As a result, COBIM¹ 2012 was published March 27, 2012. This version includes 9 parts of BIM Guidelines in 2007, which have been supplemented and renamed in the Series, and 5 new parts:

- Series 10: Energy analysis
- Series 11: Management of a BIM project
- Series 12: Use of models in facility management
- Series 13: Use of models in construction
- Series 14: Use of models in building supervision.

Series from 1 to 13 are translated into English, Estonian and Spanish languages. Series 14 has not been translated from Finnish. All Series were published online and free to use. (73.)

COBIM 2012 is also known as COBIM v1.0. This numbering system has been introduced to facilitate the orientation in the future versions. (73.)

COBIM 2012 is not the BIM standard in the sense we usually understand it. It is mostly the BIM requirements or recommendations that allow the document to be quite receptive to updates or changes. This document includes the minimum requirements for all the participants of the project to provide the implementation of the BIM in accordance with the general rules of the building design. It also ensures the implementation of the BIM benefits.

In projects with any specific requirements, COBIM 2012 should be supplemented and formulated in the contracts between the participants. Thus, a lot of construction companies in Finland issue their own additions to the COBIM.

May 5, 2015 Common InfraBIM Requirements YIV 2015 were published and partially translated into English. These requirements will also include 14 sections, but at the time there are only 12 of them:

1. Data model-based project
2. General modelling requirements
3. Initial data

¹ Common BIM Requirement

4. Model and modelling in different design phases in project
5. Construction models;
 - 5.1. Earth, foundation and rock constructions, pavement and surface constructions
 - 5.2. Preparation instruction for as-planned model for earth works (machine control model)
 - 5.3. Preparation instruction for as-built model for earth works
6. Construction models
 - 6.1. Systems
7. Construction models
 - 7.1. Construction technical components
8. Quality assurance of model
9. Quantity survey, cost management
10. Visualization
11. Asset management
 - 11.1. Modelling requirements for maintenance of the road network
12. Utilization of model in different design phases, construction of infra as well as use and maintenance of infra. (74.)

In addition to COBIM 2012 and Common Infra BIM Requirements YIV 2015, Finland also applies the following standards:

- IFC (Industry Foundation Classes) is the common data structure definition of building information models
- DD (Data Dictionary) is an international nomenclature
- IDM (Information Delivery Manual) is a process description of a specific use case of the models
- MVD (Model View Definition) is a technical description of the process definitions
- BCF (Building Collaboration Format) is the data format to exchange between the different BIM-software, allows the collaboration work on a project by using the XML-file. At the moment, this format is widely used by the programs such as the Tekla Structures, Solibri Model Checker, CADS Planner and the DDS Architecture. (75.)

5 Comparing BIM and CAD

At the moment, there are two main methods of the building design which are widely used worldwide:

- Design using CAD programs ("traditional design")
- Design using BIM programs.

BIM is not a new step of the CAD design development. These methods can be considered independent due to the fundamental differences between their bases.

Thus, CAD design is a computerized and a high quality way to do drawings, which were being done by the hands. The main elements of the CAD drawing are the lines which do not carry information about the object. Additional information is entered into the drawing by using text, tables, specifications and symbols. The fulfilment of the most norms (such as, for example, the condition of strength, stability, insulation, energy efficiency) requires the additional calculations in the appropriate program. Collaborated work of on the drawing is impossible or difficult. The obvious drawback of CAD design is the need to the manufacture of the additional drawings during the construction phase. As well as the need to amend the full set of the documentation in the case of any changes in the project. The final product of the CAD design is a flat drawing.

BIM design is a completely new method to design. Thus, all the elements of the BIM are objects which have their own characteristics, unique attributes and restrictions. There are interrelations between these elements, as well as between the whole model and external data. Using of the elements such as text, symbols, and others is not required, and only provide to simplification the perception of information. The necessary calculations (for example, calculation of energy costs, stability and strength) can be done with using the main BIM software or by side software which have at least one-way communication with the main software. It greatly simplifies and accelerates the design process. The ability of the collaborated design does not only exist, but is also constantly exploding and improving. There is no need to do any additional drawings during the construction phase due to the ability of the fast export of any model view. The updating

of the model information on any model view leads to the automatic updating of all views. The final product of the BIM design is a 3D model with internal and external data.

Table 2 shows the comparison of BIM and CAD in a short form.

Table 2. Comparing the BIM and CAD

Compared features	CAD	BIM
Main element	Line	Object
Information	The information entered by the tables, specifications and symbols	The information carried by the objects
Calculations	The calculations are made in the independent program. The results are entered on the drawing by the hands.	The calculations are made in the main BIM software or in the side software which have at least one-way communication with the main software. The results are usually entered on the drawing automatically.
Ability of the collaborated design	Difficult or impossible	Exists, constantly exploding and improving
Ability of the fast export of any model view (on the paper)	No	Yes
Way of making changes	The changes must be entered in a full set of documentations by the hands	In the case of making changes, all drawings and documents would be automatically updated
Final product of the design	2D drawing	3D model with internal and external data. Drawings can be produced from the 3D model

There is also a difference between the distributions of project costs, which is represented in the MacLeamy Curve (Figure 4).

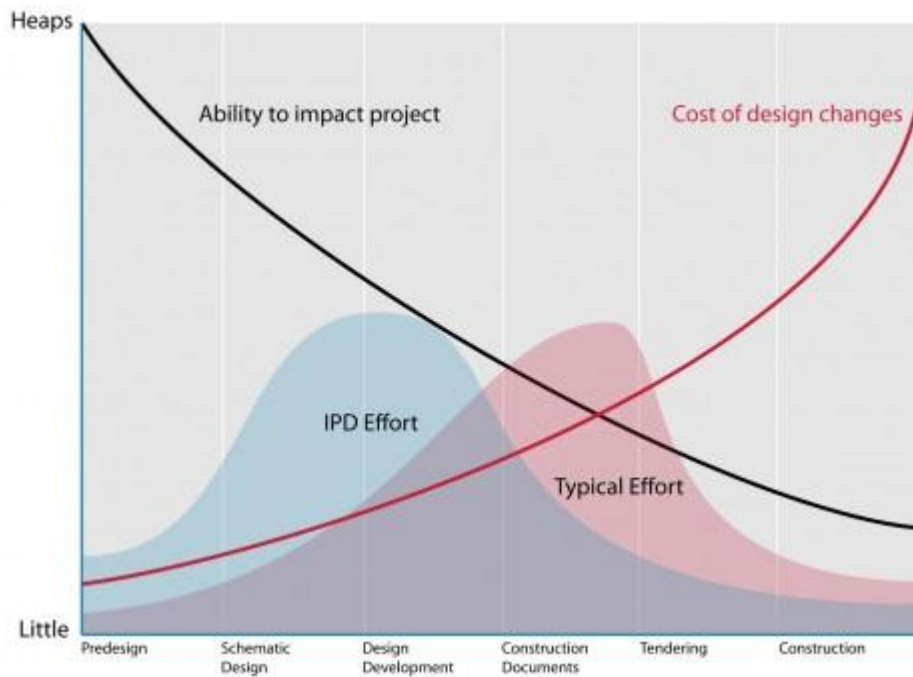


Figure 4. MacLeamy Curve (76)

According to this curve, the maximum of the effort with BIM design is nearer the initial phase of the project, when the cost of changes to the project is minimal.

6 BIM features and benefits

“With BIM (Building Information Modelling) technology, one or more accurate virtual models of a building are constructed digitally. They support design through its phases, allowing better analysis and control than manual processes. When completed, these computer-generated models contain precise geometry and data needed to support the construction, fabrication, and procurement activities through which the building is realized” (36).

These words are the introduction to the Handbook of BIM (36), and reflect the features and benefits which become available with using of BIM technology. The BI model with the correct and error-free design and filling can be used not only during the design phase, but during the other phases of the building life cycle.

However, the potential of BIM technology is not fully used, and also because of the lack of information. In this regard, it is important to make the topic clear with the following paragraphs.

6.1 Centralization of data

6.1.1 Features

At first, the BI model is a database, where the necessary information about the building is not only stored, but also formed and changed during the building life cycle. It is called a merged model. Merged model is a model with geometry and data combined. This would be a model where all the data about the objects – rooms, walls, doors – exist in the model.

This database can include:

- Design, executive and other documentation
- Equipment set-up and pre-launch testing data
- Operation and maintenance data
- Cost of the individual structures and entire object
- Schedule of CIW¹
- Materials and their physical characteristics data
- Data about customers and suppliers
- Other information.

The information contained in the model must be accurate and sufficient to solve the specific problems, and also available to provide all the necessary calculations and analyses. Access to this information should be available to all the project participants who need it.

The inaccuracy, lack or excess of information may lead to design errors. In order to avoid the possible errors or conflicts between the project participants, a lot of countries and companies have developed their own standards and requirements to regulate the level of the BI model information filling.

¹ construction installation works

For example, Figure 5 represents the part of the table from COBIM 2012, “General BIM requirements, Section 2, Appendix 1 (73). This table and the other Sections of COBIM 2012 regulate the level of the BI model information filling and minuteness for each phase of the building life cycle, depending on the initial task.

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Appendix 1: General Purposes of BIM in Different Phases of the Project

ARCHITECTURAL DESIGN	STRUCTURAL DESIGN	MEP DESIGN	
Requirements BIM	Requirements BIM	Requirements BIM	
Space program in a spreadsheet format, requirements of the client and the end-user	Space-specific loads and other structural requirements, if any	MEP requirements for the spaces (indoor climate, lighting, system requirements, etc.)	- Documentation of space requirements and possible other requirements in a structured form
Site BIM			
Site borders, elevations, required joining to the surroundings and to the			- Site use planning - Location of the building(s) on the site
Inventory BIM	Inventory BIM	Inventory BIM	
Spaces and building elements of the existing building(s)	Load-bearing structures, typically included in the architectural BIM	MEP systems to the extent regarded applicable	- Documentation of the starting situation for renovation construction
Spatial Group BIM			
Special case of Spatial BIM. Building masses and principal spatial groups are presented as space objects.			- Investigation and visualization of the building's massing as well as comparison between alternatives - Investment calculation based on scope and massing - Rough energy simulation if applicable
Spatial BIM	Spatial Reservation BIM	Spatial Reservation BIM	
Spaces as space objects, building envelope	Suggestion for structural system, suggestion for basic structure	MEP system service areas, main ducts and flues, as well as pipework, cable racks and other technical systems and spaces presenting significant space requirements	- Design and visualization of alternative spatial design solutions - Scope management - Investment calculation - Energy simulation and, if required, simulation of ambient conditions

Figure 5. General purposes of design disciplines in different BIM projects. Part of the COBIM 2012 (73)

More detailed and strict requirements are included, for example, in Figure 20 of British Standard PAS 1192-2: 2013. (52.)

6.1.2 Benefits

Reducing the number of errors

In practice, a lot of errors committed in the design process, do not depend directly on the professional level of the employees, their expertise and alertness. Perhaps one of the most common causes of the errors is the inability of transmitting all the necessary information accurately, correctly, quickly and timely.

In a real project a large part of the information is transmitted by oral or written communication within company or between the companies. Not every employer is able to correctly understand and present the information. As a result of misunderstanding there are errors. The correction of these errors may require a complete redesign of the project part.

Even if there is no misunderstanding, the relevance of the information is questionable, because the project is constantly developing, the information is corrected and updated, and keeping track of the process is almost impossible.

One of the most effective ways of information transfer is the transfer of project documentation and other documents. Every employee must be able to read the drawings and to receive the information contained in the documents. Keeping track of the documents flow is much easier by taking into account the creation of a common database. However, it takes a clear internal structure (nomenclature) to quickly find the required document.

BIM model in this sense is far ahead of all the databases created independent of the model. Such a database contains all necessary information, does not require an additional time to update it or check its relevance. At the same time it is the most demonstrative type of the database that speeds up the search and work processes.

Reducing the design time

As mentioned above, work with the information flow is a time-consuming and labour-intensive process. At the same time, cases when the designers spend half of their work time on the phone trying to send or receive the necessary information, are not uncommon and can occur in almost any company.

Working with a database as a BIM model, all project participants can save a lot of their work time with reducing of the time to search and perception of information.

Effective interaction with suppliers

Service, equipment and material providers as well as other members of the project, may have an access to information relating to their operation. Thus, the supplier can more fully and accurately assess the scope of work, risks, potential problem areas and their own costs at the stage of signing the contract. Accurate assessment of the supplier's capabilities can reduce the risk of unplanned delays in the progress of the project to a minimum.

Another potential benefit is open access to information for all or a number of potential suppliers. Thus, the customer does not have to look for a contractor itself. A contractor who is interested and able to perform the work will be able to respond to the request and offer their services.

6.2 Visualization

The need for the visualization of the BIM model can occur at the different stages of a project, from the phase of the concept model and ending communication with the end user. It was noted that even those companies that have not transitioned to the BIM technology, visualize the future building for a potential customer or buyer.

Despite of the impressive result of the visualization in modern software, visualization is not the most time-consuming and labour-intensive stage of work with the BIM model.

6.2.1 Features

Concept model

Modern BIM programs have a significant number of tools to allow the quick creation of a concept model. As a rule, there is a need to create multiple versions of this model that are not designed in detail and saturated considerable amount of information. Sometimes these models may contain only information about the overall geometry of the future building, its orientation in the surrounding. An example of such a concept model is made and visualized in the program Graphisoft ArchiCAD by the author and presented in Figure 6.

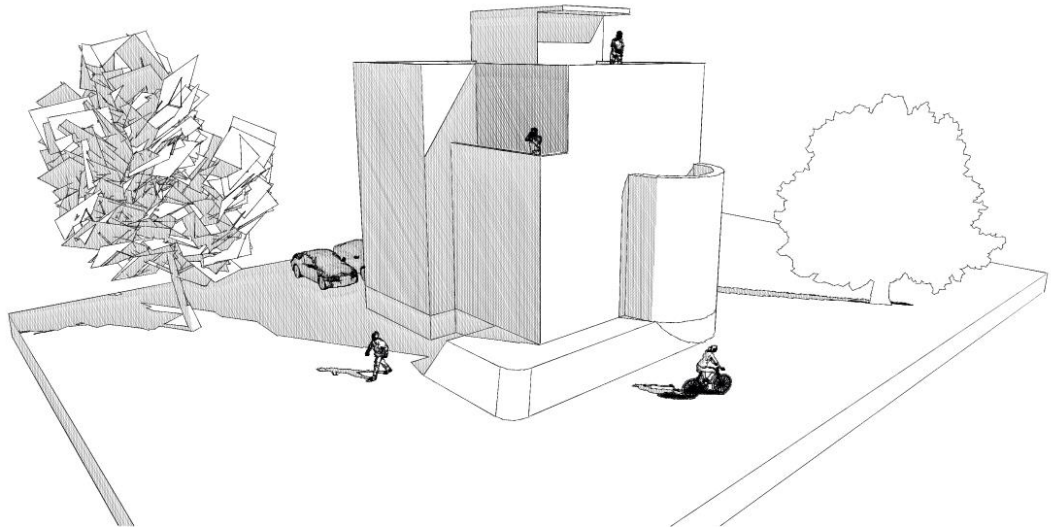


Figure 6. Example of the concept model

Visualization of construction and installation works process

The visualization of the construction and installation works (CIW) progress is also useful. Figure 7 shows an example of the CIW visualization. With this model the supervisor can see how performing the steps of the work at any point in time and volume of work was made during a given period (year, month, week).



Figure 7. Example of the visualization of CIW process (77)

In the case of using BIM at the construction site it is also possible to make a visualization of the future construction work stages in accordance with a sched-

ule. Such a model is transferred to the construction site with a predetermined period of time, where it can be used for ease of the orientation and preparation of the daily or monthly schedule of the construction.

Visualization of the results

The visualization of the end result is required not only to improve the chances of winning the tender, but also to work with the end user, for example, potential buyer of apartments.

Usually, it does not require the information-rich BIM in these cases. Such a model can include only a common geometry, as well as elements in the surrounding area, which are qualitatively and correctly visualized in the form of images or advertisement video. Even in the case of the absence of the full BI model, creating of the architectural model for the visualization takes quite a little time and can be easily done by one person in possession of the necessary skills. Mostly because of this reason there are a lot of companies in Russia which perform the visualization in the BIM programs even if they work in the CAD environment.

Visualization of the operation period

Visualization of the operation period is not common in the case of the preview model absence. However, the following cases can be distinguished when visualization is helpful:

- visualization of the overhaul workflow and result
- visualization of the renovation project workflow and result
- visualization of fire protection of the building and evacuation routes.

Visualization of the building demolition

At the final stage of the life cycle – the stage of outputting the building of operation and its demolition - it is convenient to visualize the process of uninstalling the elements of the building or structure. As in the case of the CIW visualization (paragraph 6.2.2), the demolition project visualization provides a complete and accurate information support of the workflow and the control of the works im-

plementation. It is also possible to obtain the sufficiently precise information on the amount and type of the construction waste.

6.2.2 Benefits

Concept model

These more or less saturated with information models are useful in the initial design phase and during the process of negotiating the future project with the customer or with the participation in the tender. Creating the multiple concept models allows estimating the future result of the design and how it will be fit into the existing town-planning situation. Also it can help to choose the main direction of further development of the project.

Visualization of construction and installation works process

Production policy in the field of the construction industry in many countries including Russia requires a permanent increase of the production rate with a decrease of the construction time.

In this case, the effective control of the actual implementation of CIW is one of the most important factors of the construction project. BIM can be a tool to check the actual performance status of the CIW at the moment and for a certain period.

Modelling the sets of the CIW within the BIM will create an information base, divided into the periods and stages of construction. This database can be conveniently used to assess the timeliness of construction, Statistics and Economic Analysis that is the necessary information to predict results and economic efficiency of the project. (77.)

Visualization of the results

In Russia, more than 679200 equity participation agreements were signed in 2015 (78), not counting the other agreement types, when the user signs the contract with the developer at the time when the building is still not completed or even the construction phase is not started. In some regions of Russia the vol-

ume of the purchase of the apartments under construction is more than 50% of the total.

Thus the qualitatively visualized BIM (see Figure 8) or advertisement video is not only a good way to attract potential buyers, but often the only way for a buyer to get an idea about the product. Such a model is able to greatly enhance the company's competitiveness.



Figure 8. Visualized model of the object of the YIT - Residential Complex Chapaeva, 16, located in Saint Petersburg, Russia (79)

6.3 Design

6.3.1 Features

The possibilities of the BIM programs provide participants of the project with the tools needed at each of the design stages. The performance of the most design tasks is possible with the use of only a few programs that successfully interact with each other.

At the moment, the field of BIM technologies application, standardization of formats and integration of specialized programs is expanding. Construction industry develops to that from beginning to end, regardless of the size and complexity of the project, all the tasks may be performed within a single BI model.

6.3.2 Benefits

Reducing the number of errors

Practice shows that a lot of errors are allowed by the use of irrelevant information. During the design process many decisions with different level of importance are made. A large part of the decisions taken is corrected or changed at least once during the stages of design and construction. The changes also require the updating of the drawings and project documents. The complexity of this process is obvious.

In this regard, one of the main benefits of using BIM at the design stage is reducing the number of errors by automatically updating all related information in the case of any perimeters changed. Since data is stored in a central place in a BIM model any modification to the building design will automatically replicate in each view such as floor plans, sections and elevation. This not only helps in creating the documentation faster but also provides stringent quality assurance by automatic coordination to the different views (80).

BIM is also an excellent tool to check the project if there are any errors or inaccuracies. The reason for that is that this model includes all the independent decisions, individual drawings and elements (merged model). BIM allows coordinating the design drawings and decisions to assure that different building systems do not clash and can actually be constructed in the allowed space. It is called clash detection. (81.)

Finally it should be noted that even the use of BIM technology only as a checking tool brings significant benefits in practice. To do this, an experienced employee performs the model of the designed project and checks it. This approach can improve the quality of projects and reduce errors at the lowest cost.

Reducing the design cost

BIM is an integrated design process. In accordance with the principles of the integrated design process, the maximum intellectual effort is on the stages of development of the concept and schematic design when the cost of change is minimal. This principle is shown by Figure 2.

As a result of the shear of the amount of work, any mistake or any change in the project is much cheaper than in the classical method of designing.

Reducing the design time

The practice of using BIM shows that the positive results are not limited to the shear of the amount of work. There is also the reduction of the overall volume of work. Especially it should be noted that the most of the reduction is on time and energy consuming mechanical work that does not require significant experience of the employees.

After finishing the accurate and informative model, BIM program takes a huge part of the routine duties of the employees, such as, for example, calculating the specifications, changing of the timetable, changing of project documentation. This not only reduces the probability of making mistakes, but also speeds up the production process.

Effective interaction with suppliers

BIM allows quickly and accurately exporting the various elements, which can be sent to the manufacturer of prefabricated elements and structures. This will ensure that such an element will be made in accordance with the project documentation and it will be possible to correctly install it on-site.

6.4 Making the electronic and paper drawings

A unique feature of BIM software is the instant creation of any views: plans, sections, cross-sections or separate unit views etc. The individual characteristics and attributes of all the elements of the model are also allowed for a short time to set up any view and left to display only the required elements of the

model. Using the built-in templates and unique patterns of the company allows the design of project documentation and drawings in the minimum amount of time. Further export of all necessary drawings directly to the printer in the specified format significantly speeds up the process of the documentation design.

6.5 Time scheduling (4D BIM)

6.5.1 Features

In the process of creating the model, it is possible to create the project schedule on the basis of this model. Such a schedule is created by adding the scheduling data to the different elements of the model. The resulting model allows tracking the development of the project step by step and is known as 4D BIM model.

Scheduling data is always connected directly to the elements of the model and may include the information such as:

- date of the start and end of the construction or installation of the element
- development and expansion of the software manufacturing companies
- reserve time for processes that do not lie on the critical path
- relationship of various construction and installation works and their influence on each other
- sequence of the construction and installation works etc.

Creating a 4D BIM model also allows carrying out the visualization of the sequence of the construction and installation works and tracking the results at each of the stages. (82.)

Figure 9 shows an example of the 4D model which was made in Astra Power-project.

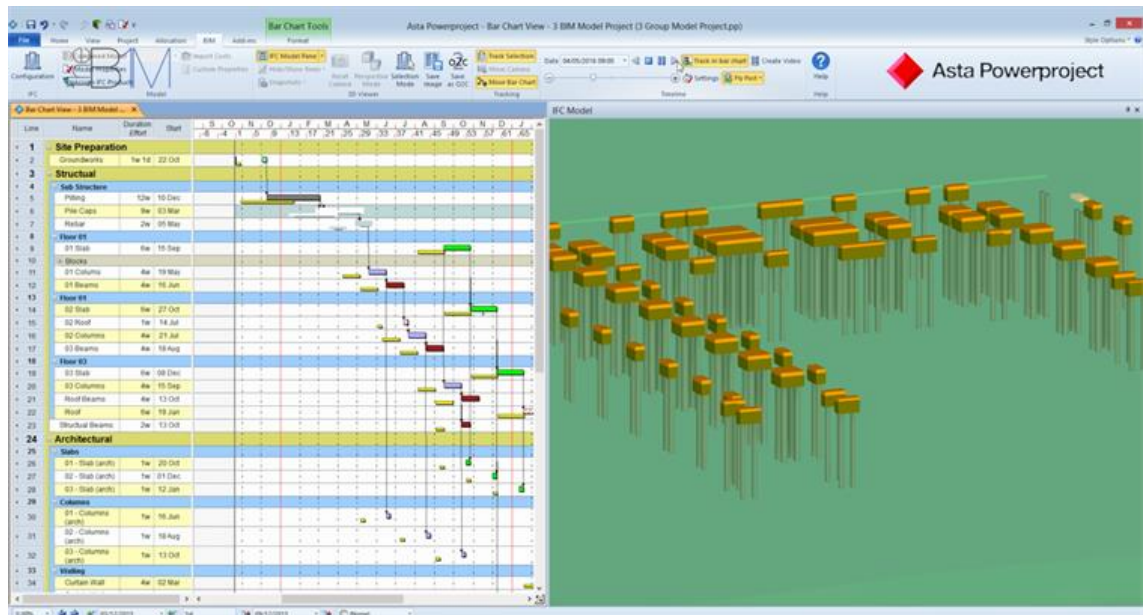


Figure 9. Scheduling data linked to the foundation components of a graphical model was made in Astra Powerproject (82)

6.5.2 Benefits

Changing management

First of all, the use of 4D BIM model is extremely convenient from the point of view of making the operational changes to the project schedule. This possibility also exists in the other programs for scheduling, but the linkage of the project schedule with the model makes it easier and more obvious than, for example, a Gantt chart. 4D BIM information schedule is tied to the specific elements of the model and changes to other characteristics of the element (e.g., increased the setting time of concrete or a changed of the volume of monolithic structure) are reflected immediately in the calendar plan.

Reducing the number of errors

Automatic changes in the schedule, as well as a computerized calculation of the quantities of the materials, allow avoiding the mistakes making in the schedule preparation schedule. Simulation of installation conflicts and design clashes can be performed before the work begins (83).

Increasing the efficiency of the CIW production

Using 4D BIM model at the construction site provides a more efficient, intuitive and logical production process by improving the understanding of the scope of work and sequence of their implementation, and improving the coordination on the site. It also improves the efficiency of monitoring the progress of the construction activities.

6.6 Cost estimation (5D BIM)

6.6.1 Features

Since the 4D BIM model is made, it is possible to create the 5D BIM model by adding the cost information to the elements of the model.

This information can include:

- capital cost of purchasing and installing a component
- running costs associated with it once in use
- anticipated price of renewing it in the future etc. (84.)

The quality and accuracy of the budgeting depends on the accuracy of the information received from the designers and other specialists, and included in the model. The accounting of the cost, which cannot be directly reflected in the model, is also needed. This feature is not new and is not different from the traditional method of creating the estimates. Cost Managers must be experts in their field and carry out the validation of the model execution, if they think that there is a need.

Figure 10 shows an example of the 5D model which was made in Vico Office.

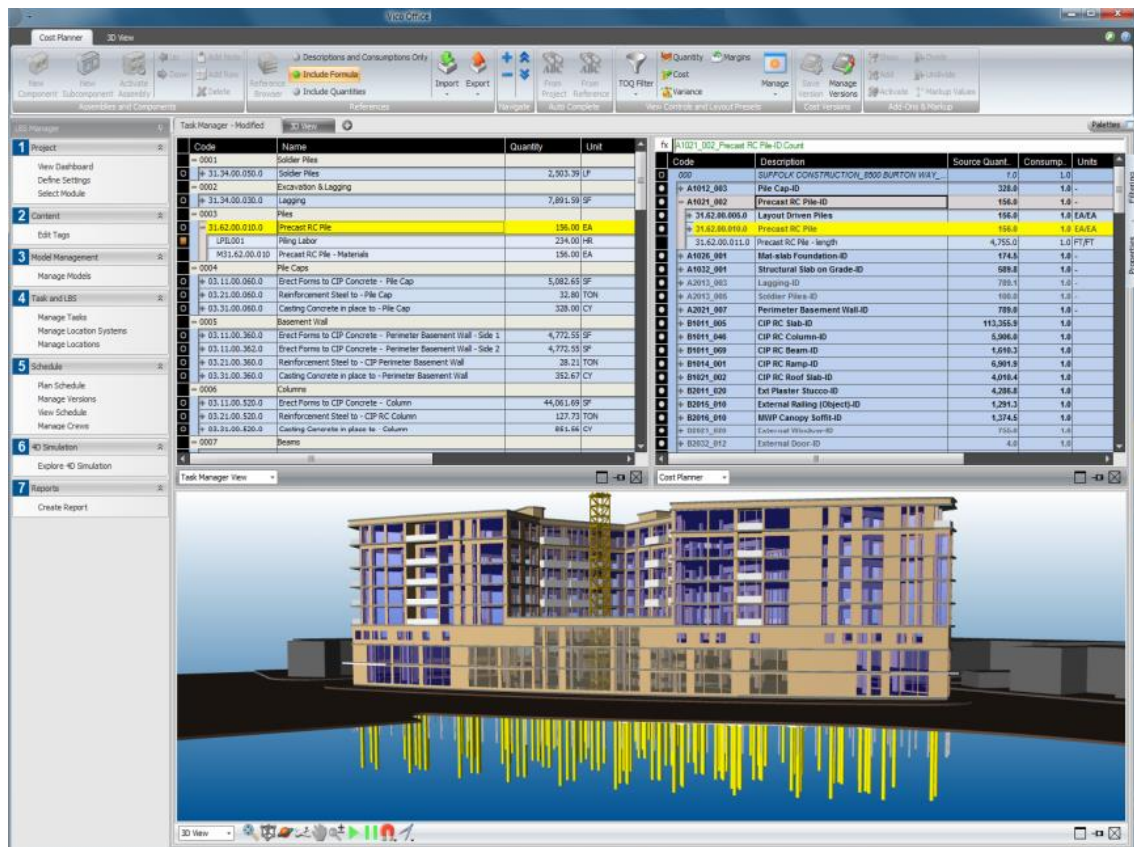


Figure 10. Example of the 5D model which was made in Vico Office (85)

6.6.2 Benefits

Changing management

Since the cost information is the attribute of the specific model elements, any changes of the project (on any view or directly in the cost estimate) will be reflected in the estimate automatically. That means that the estimate will always be not only accurate, but also it will be able to quickly assess the different options and decisions and choose the more economical one. There is no need to correct and recalculate the estimate each time when a change is introduced.

Reducing the number of errors

The errors in the preparation of estimates are often based on the errors in the calculation of materials and the use of irrelevant information. Using 5D BIM model reduces the possibility of the appearance of these two factors that reduces the number of errors in the preparation of estimates.

Reducing the time for preparation of the cost estimate

Using the 5D BIM for estimating Cost Managers can quickly determine the amount and cost of the specific elements of the project, the necessary material costs at every stage of the project and its final cost. Counting can be done automatically, which speeds up the process of budgeting.

Increasing the efficiency of the cost control

The 5D BIM also eases the cost control at every stage of the project and simplifies the compilation of the economic predictions. The ability to track the estimated and actual costs is especially useful in the preparation of the budget or the monthly cost reporting. (84.)

6.7 Facilities Management (6D BIM)

6.7.1 Features

Creating the 6D BIM model is the process of linking of attribute data to support Facilities Management and built asset operation.

This information may include:

- details about the components manufacturer
- details about when the component was installed
- details about necessary maintenance that component requires and when
- details about how to operate the component
- component's optimum level to enhance performance or conserve energy
- component's expected lifespan. (86.)

Thus, the Facilities Management information is the attribute of the specific model elements.

6.7.2 Benefits

Simplification of the decision-making process

The 6D BIM model simplifies the decision-making process during the design and operation of the facility stages. During these stages such a model allows

estimating the impact of the various decisions on the final result and the amount of the costs corresponding to each decision.

Increasing the efficiency of the Facility Management

After transferring the 6D BIM model to the customer, the last one gets the more accurate, interactive database of the information, simplifying the control over the object.

This database contains all the necessary information for maintenance, such as energy efficiency and duration of the lifecycle of the individual components and the entire object. It is possible to obtain the accurate and reliable information about any room any time. It also provides the full information support for the capital repairs, reconstruction and renovation projects. In this model it is possible to save the data about the original object as well as the information about all the changes made to it.

This allows assessing the cost to operate the facility and making the plans for maintenance and capital repairs in advance. This makes it possible to avoid the unexpected costs.

6.8 Simulating

6.8.1 Features

Another feature of the BIM technologies which is not directly related to the process of design and construction is the ability to simulate and analyse the various options for a single project, affected by various factors and solutions. This feature can be used both to determine the most appropriate (for example, eco-efficient, energy-efficient, cost-effective) project, as well as for the research and experimentation in the field of the construction.

In the first case, consideration of the alternative options and scenarios is possible in almost any of the stages of the model. The minuteness of the model and modelling accuracy in this case will depend on the desired accuracy of the results.

In the second case, there is no need to create an accurate model of an existing or projected building (however, if there is one, it can also be used). It can be a computational model of the building that reflects the properties and characteristics required to research. This calculation model is superimposed with some computer effects and analysed the results.

6.8.2 Benefits

Simplification of the decision-making process

The decision-making process at the design and construction stages is often a very difficult process. The reason for this is the large number of parameters that must be considered due to that all elements of the buildings and structures are interconnected.

Using BIM in the decision-making process allows seeing how a decision (for example, changing the appearance of the building, the design loads, the materials used, the change in the cost or time required for installation) will affect all other aspects of the project without significant labour and material costs.

The other way of using BIM is to carry out the simulation and comprehensive analysis of the building performances (such as, for example, energy efficiency and power consumption) throughout its life cycle.

Due to this benefits adjustment and adoption of the most appropriate solutions becomes much easier.

Reducing the operation costs

Reducing the cost of the project is achieved not only by reducing the design and construction costs, but also by reducing the cost of ownership of the building during its operation period. Even if the cost of the building increases, high energy-efficiency allows the project to become economical.

Energy modelling in BIM allows to analyse the design options from the point of view of the volume of their consumption throughout the life cycle and to choose the most cost-effective option, even if the cost of construction of this variant will be

higher. The analysis is possible for one or few of the energy parameters. The comprehensive assessment of the building consumption (water consumption, energy consumption, waste production and materials) is also allowed. (87.)

Increasing the efficiency of the renovation, reconstruction and capital repair projects

BIM technology can be used in the design stage of the renovation, reconstruction and capital repair projects. A comprehensive energy audit in the BIM allows to estimate the most rational and effective field of works for the renovation project. The energy audit also allows comparing the actual energy consumption of the existing building and related costs, and the cost of retrofitting it. The accuracy of the collected data directly affects the accuracy of energy analysis and the choice of the final decision.

This assessment allows achieving the best results at the lowest cost that allows achieving sustainability ratings and certifications in a shorter period of times. (87.)

However, the most part of the software products is aimed at the architects and decisions taken in the early stages of design, rather than the energy engineers or mechanical engineers. Thus, for the qualitative energy analysis it is necessary to use additional and more specialized software.

Another area of using the same BIM tools in the renovation project is Environmental Assessment of the building. Analysis of the eco-efficiency gained popularity with the introduction of systems and ratings such as LEED and systems. These systems aimed at improving the performance of the buildings on the basis of the energy saving, efficient use of the water resources, reducing the carbon dioxide production as well as on the basis of the optimum use of the resources. (88.)

The applicability of BIM in green house projects is a popular area of research. The term Green BIM has become increasingly popular in recent literature, described as a model-based process of generating and managing coordinated and consistent building data during its project lifecycle that enhance building energy-

efficiency performance, and facilitate the accomplishment of established sustainability goals (89).

There is a consensus across the reviewed studies that BIM is still immature for its full adoption in refurbishment projects because of technical, informational and organizational complications (89).

6.9 Collaboration design

6.9.1 Features

At the design stage, there is work on the different parts of a project, for example, constructions, architecture, landscape, water supply and sewerage, electricity and others disciplines. In order to reduce the design time, these sections are usually carried out at the same time. This raises the problem of the unreliability of the information held by the employee. To obtain the reliable information employees need to spend a significant part of the working time. Otherwise the reliable information is not received on time, the work done has to be redone.

The problem of the work coordinating is more visible in the case of the significant number of participating organizations. Especially in the case of the project is also international, design process seriously delayed and the number of errors increases.

Thus the research, prepared for NIST by RTI International and the Logistic Management Institute, estimates the cost of inadequate interoperability in the U.S. capital facilities industry to be \$15.8 billion per year (90).

Project Committee of the National BIM Standard in the United States is considering the BI model as a shared information resource about an object, the basic function of which is to enable the collaboration work. (32.)

In the case of BIM, the model may be used at the same time by all the participants of the project. As a result, each participant of the project has always accurate and up-to-date information on the work of the others.

6.9.2 Benefits

Thinning geographical and language barriers

At the moment, the practice of using the BIM technology proved the possibility of the collaborative implementation of project works by designers, working in different parts of the world. There is a possibility of the work on a single project regardless of preferred software and language used. The use by all the participants of common performance and design standards and overall code systems is simplified interaction.

Thus, the geographical location and language used are no longer an important criterion for choosing a contractor or subcontractor.

Reducing the project costs

The ability to choose the contractor or subcontractor without being tied to a specific geographical location greatly enhances the number of available technologies and materials, as well as increases the number of potential contractors. This allows the customer to achieve the maximum benefit from the project and better economic performance.

At the same time, increased competition leads to the rapid development of the field.

6.10 Creating the physical model (3D printing)

6.10.1 Features

The physical models of the buildings are an inherent part of all building exhibitions and fairs estate. They allow to clearly and without the use of software evaluating the appearance and geometry of the object and the surrounding area.

Earlier a model was made by hand using different materials such as plastic, paper, and plasticine. However, at the moment 3D printing is increasingly used for the manufacture of a building layout.

The most appropriate software to prepare the BI model to print are Revit, 3DMax and Maya. The main appropriate formats are STL, FBX, OBJ, WRL, BLD etc. At the same time the model should meet the following requirements:

- All elements are 3D elements
- All 3D geometry must consist of closed volumes (91).

Figure 11 shows the layout made using 3D printer by The Realization Group.



Figure 11. Layout made using 3D printer (92)

6.10.2 Benefits

Reducing the time and costs

Using BIM to output the model for print using a 3D printer repeatedly accelerates the production process of the building layout reducing the cost in contrast with the traditional way of making the layout.

Appearance of the ability for printing the buildings

The idea, which can develop and become a reality, is the printing of individual assemblies and entire buildings on the 3D printer. For this purpose special construction 3D printers are used. They work on the technology of extrusion and layered fusing. With this technology the formwork is not needed.

The main material which is used in 3D printing is improved cement, for example, cement reinforced with glass fibre. However, other materials, for example, Saltygloo are also used. (93.)

The Saltygloo is made of San Francisco Bay salt and glue. Salty glue is an ideal 3D printing material, one that is strong, waterproof, lightweight, translucent and inexpensive (see Figure 12). (94)



Figure 12. The panels made of Saltygloo by Emerging Objects (94)

In a portfolio of Chinese companies WinSun Decoration Design is almost entirely printed on a 3D printer 1100 m² villa (see Figure 13) and the world's highest 3D printed building - a five-story apartment house (see Figure 14).



Figure 13. Almost entirely printed on a 3D printer 1100 m² villa (95)



Figure 14. The world's highest 3D printed building (96)

The other example is Imatra's start-up company Company FIMAtec (97) (Finland) which began to work with 3D printers in 2014. Fimatec is seeking to 3D print modular apartment buildings. Using the technology which mixes 3D printing with robotic fabrication, Company was able to simultaneously print out the concrete external and internal walls, insulation and reinforcement (see Figure

15). FIMAttec was able to achieve that the printed wall structure meets the European building regulations. (98, 99)



Figure 15. The wall printed on 3D printer by FIMAttec (99)

Rating the possible benefits of 3D printing of the buildings at the moment is impossible. However, the potential defies the imagination.

6.11 Training

On the basis of the standard BIM projects and solutions it is possible to create, for example, the virtual installation instructions for assembling and dismantling of the structures and equipment.

The visualization of escape routes and fire protection of the buildings allows for training actions in cases of emergency.

7 Difficulties in the transition to the BIM design

Despite of the undoubted benefits of the transition from CAD design to the BIM design, this process cannot be called simple. There are a number of disadvantages of the BIM design and difficulties in the transition to a new work method. This should be taken into account in the final decision about the beginning of the transition to the BIM design.

7.1 Software

The transition to BIM does not mean an automatic transfer of the organization to a high-tech, efficient and high quality level of the design. To achieve these results the implementation of the integrated design on the basis of the BIM technology is needed. It requires not only the purchase of licenses of a number of software products, but also the ability of competent and confident use.

Even the fluent use of the software products will not have a significant positive impact without the unified technological chain of production, unified design environment. (100.)

7.2 BIM regulations

The introduction of BIM in the design process leads to a complete change of this process and move from the individual work to collaborative work on a single model. In this situation, the absence of the developed strategy, regulations may introduce an element of uncertainty into the design process.

Regulation of the design organization is a document regulating the cooperation between all participants of the design process, their sequence, including the type and nature of the information transmitted during the different stages.

BIM regulations is a unique document and is individually designed for each organization. The basis for the development of this document are the results of several pilot projects carried out in the course of work over which identified the main issues and difficulties in the transition to BIM. (101.)

7.3 Rationality

Each of the participants in the process of building has his own goals and objectives. They also vary depending on the type, volume and complexity of the project. In this regard, each of the participants should independently evaluate the possibility and rationality of the transition to the BIM design.

For example, often there is no rationality in creating BIM models for simple (temporary building, single-storey parking etc.) and standard (standard school or a residential building) projects.

It should also be noted that the positive effect from the use of BIM technology is not immediate and increases gradually and depends largely on the level of the involvement in the BIM.

Thus, the transition of small and medium-sized organizations to the BIM design can be irrational, and compulsory introduction of the BIM technologies all over the world can lead to the failure of this sector of the construction market and a reduction of competition. (102.)

7.4 Blurring of the boundaries of responsibility

Traditional design workflow is based on the individual work of each participant of the project. In the case of any errors or inaccuracies in the project, it is not difficult to find the person responsible for the error.

Integrated BIM concept involves the simultaneous access to the model for a large number of the employees and their simultaneous operation. This reduces the number of errors initiated by poor transmission of information in the organization, but, at the same time, leads to the blurring of the boundaries of responsibility. Stages of the project are also being less strong; the design work is carried out almost parallel to the various departments, the control points, where the result can be checked, are lost.

As a result, to determine the person responsible for some inaccuracy in the model and to prove the guilt becomes more difficult. Without quality work of BIM coordinator, a blurring of the boundaries of the responsibility can lead to an increase in cost of risk. (30.)

7.5 Technocentricity

One of the factors complicating the transition to a BIM design is the concentration of specialists on the software instead of work culture. This leads to the pop-

ularity of the delusion that BIM design is reduced only to perform the mechanical work, that it is plenty to choose the right tool to solve the problems.

This opinion is dangerous for the development of the construction industry. Mandatory application of the BIM technology could lead to that experienced professionals who have not necessary skills and desire to start to explore BIM, will be unable to compete in the labour market. A core staff of the company will consist of the young professionals, committed serious errors due to lack of the sufficient knowledge and experience. This will lead to the generation gap in the construction industry, the loss of valuable experience. The development of the construction culture will slow down or step back. (103.)

7.6 The absence of a direct transition from BIM design to construction

Except for some examples and projects, the result of the BIM design work anyway is 2D drawings. This phenomenon is typical, for example, for Russia. This condition is common and mandatory for the implementation of the design work.

Thus, a situation arises where the production operations are carried out in the 3D format, but the final stage is not BI model. BIM must be additionally adopted for the presentation in the form of the 2D drawings. This significantly grows the requirements to the level of the work coordination that is necessary for the manufacture of high-quality 2D documentation. (103.)

7.7 Redistribution of the participants costs and responsibilities structure

MacLeamy Curve was given above (see Figure 4). This curve has a number of unaccounted factors. The same factors are usually omitted in the popularizing of the BIM design.

Without disputing the obvious advantages from the introduction of the BIM in general, it should not be forgotten that the participants of the project do not have the same benefit. For example, the efforts in coordination and collaboration, which have previously been the responsibility of the contractors at various levels, now actually passed on to the architects and engineers. (103.)

7.8 Monodisciplinarity of the concept design stage

It is noted that at the moment BIM program is still not well supported to collaboration design on a project in the early stages. Only in the recent years, there has been progress in the conceptual design tools that allow connecting the conceptual model with the results of highly specialized, monodisciplinary analysis. As a result, there are difficulties in analysing the effectiveness of the project options under consideration at the stage of the conceptual design. (103.)

7.9 Changing the structure of earnings

With the introduction of the BIM technology in the design organizations comes the inevitable redistribution of the responsibilities and scope of work. That leads to a redistribution of funds for the salaries of employees in the different sections. For example, the Construction Department was the responsible for creating a design scheme, modelling such a scheme in a special software, calculating and checking it. With the BIM, the main part of this work can be done with the import of the model in the construction program from the architectural model. It means that part of the traditional Construction Department responsibilities is the Architecture Department with the BIM. This reallocation of the responsibilities cannot please everyone.

8 BIM in Russia

8.1 Brief description

Despite of the fact that BIM in Russia is only beginning its development, the situation is gradually changing for the better. The main reasons that lead to promote the use of BIM in Russia are:

- mandatory training of future professionals in the universities the basics of BIM modelling
- assistance of the State in the promotion and popularization of BIM design
- increase the number of international projects, where a foreign company commits the partners to use the BIM technology.

Under the influence of these and other reasons, the management of companies is growing awareness of the fact that the development of BIM is necessary for the further business development. For example, BIM is necessary to enter the international market or to work with large government contracts.

Earlier the BIM introduction in organizations came below, initiated by employees. At the moment (in 2016), the introduction of the BIM comes from the top, and the effectiveness of this approach is much higher.

At the moment (in 2016), the introduction of BIM technology in various sections of the design is on the different levels of implementation. The greatest development BIM has received in the Architecture discipline, where the basic tools of the BIM software are widely used, as well as expanding Russian library of the BIM elements made in accordance with the market characteristics and requirements. Thus, it can be assumed that the implementation of full working BIM projects will not be problematic for the architects.

BIM has not found a wide development in the Construction discipline yet due to the traditional use of such programs as LIRA and SCAD to perform calculations. These programs were not allowing the import from BIM programs for a long time. However, this possibility has appeared in programs, and it should contribute to the promotion of BIM in the Construction Department.

Works of Russian MEP designers in the BIM programs are practically not represented. This can be explained by the lack of the MEP elements library, the creation of which is a time-consuming process, as well as lack of support for software systems traditionally using BIM data exchange formats.

8.2 Assistance of the State

8.2.1 Professionals Initiative

In 2012 there were a number of articles on the subject of promotion and popularization of BIM in Russia, which noted the lack of the State support and supposed that the State would not support BIM in the near future.

Therefore, in January 2013 a separate group of professionals wanting to change the situation established a working group to promote the BIM and IPD at the expense of own funds (104). February 6, 2013, the Group received accreditation in the MAAM¹ (see Figure 16). The work of the Group was supported by the President of the MAAM, chief architect of RAN², National Architect of the USSR, Academic Platonov Y.P.



Figure 16. Preliminary agreement on the accreditation the Group at MAAM reached (January 2013, from left to right: Lazebnyj A.V., Platonov Y.P., Korol M.G.) (107)

¹ MAAM (or IAAM) - International Academy of Architecture in Moscow, Moscow Branch (105)

² RAN (or RAS) - The Russian Academy of Sciences (106)

8.2.2 Plan of the BIM phased introduction

Expansion of the Working Group, joining the ranks of its members, design institutes and large construction holdings, as well as holding numerous conferences and seminars led to appearance of the government's attention to the need to begin work on the implementation of BIM.

On July 4, 2014 an important step by the government was made. At the board meeting of the Presidium of the Presidential Council for Economic Modernisation and Innovative Development (see Figure 17) the plan of the BIM phased introduction was discussed (108). To Ministry of the Russian Federation, Rosstandart, the Expert Council under the Government of the Russian Federation and institutions of the development were ordered to "develop and approve a plan for the phased introduction of BIM in the field of the industrial and civil construction, including enabling the examination of project documentation, prepared by using such technologies" (109).



Figure 17. Board meeting of the Presidium of the Presidential Council for Economic Modernisation and Innovative Development about the innovation development in the construction industry. March 4 (107)

The next step in the implementation of BIM on the state level was made on July 14, 2014. Mosgosexpertiza published new requirements for electronic docu-

ments for the state expertise of the design and estimate documentation. Among them there was the ability to submit to examination BIM model in the * IFC (2x3), 3D*PDF, 3D*DWFx or NWD (Navisworks) formats as an additional document. (108.) On April 27, 2015 this ability is implemented in the Center of the State Examination of St. Petersburg (110).

On December 24, 2014 Mosgosexpertsiza completed the consideration of a first BIM project. The project was developed by Gradproekt. Apart from the standard design documentation set, a comprehensive BI model (see Figure 18) in electronic form was given (111).



Figure 18. BIM of the polyclinic for 550 seats in the New Vatutinki district. The first BIM project which was considered by Mosgosexpertsiza (111)

On December 29, 2014 the Ministry of the Russian Federation adopted the plan of the BIM phased introduction in the field of industrial and civil construction (112).

Among the provisions of the document there are the following provisions:

- development of 23 pilot BIM-projects
- examination of the pilot projects and analysing the results
- development of the BIM-classifier
- adjustment of building codes - for year 2016

- mandatory requirement for the use of BIM in the implementation of the government orders since 2017
- Ministry will make recommendations on the use of BIM technology to the contractors since 2018 (112).

Since the adoption of the Plan of the information modelling technology phased introduction, the response of the construction industry in the use of BIM has significantly increased.

8.2.3 Pilot projects

The implementation of the idea into practice started with the selection of the pilot projects (see Figure 19) implemented with the use of BIM technology on March 17, 2015.

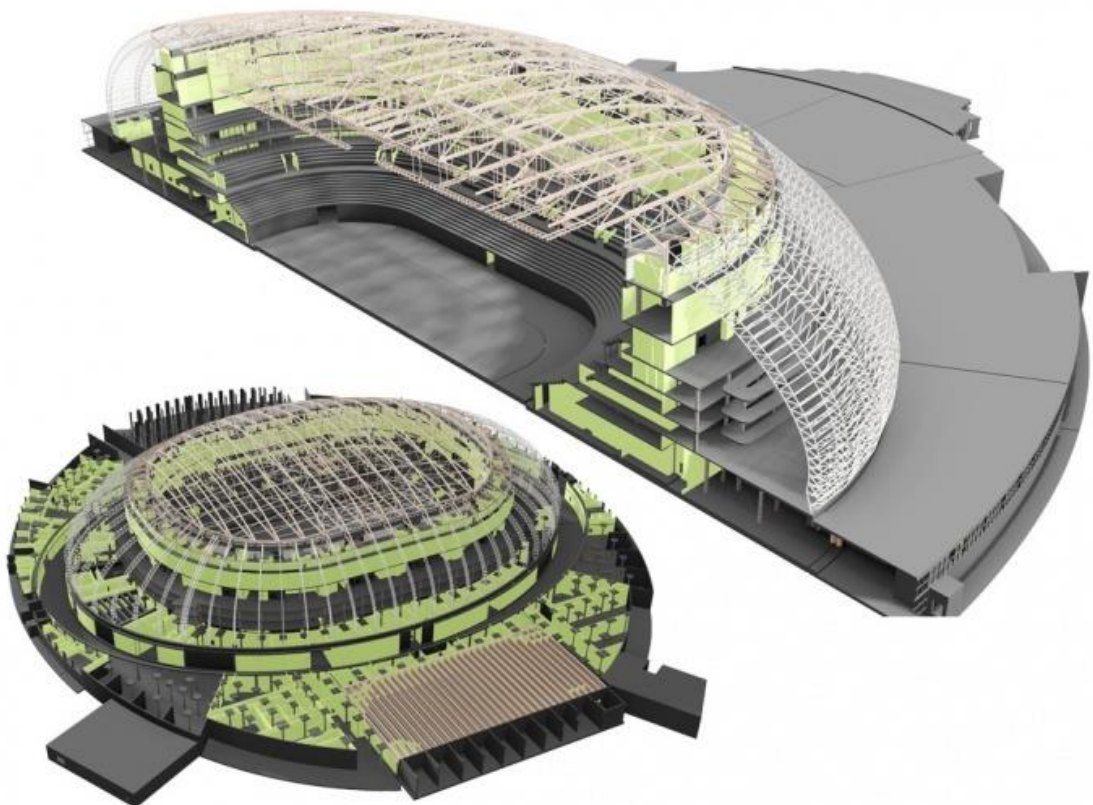


Figure 19. One of the pilot projects. SODIS Lab: Fisht and an ice stadium in Sochi (113)

In November 2015 the examination of the pilot projects has been completed. In December 2015, a report to the Government was made. The report were

marked the following difficulties encountered in the implementation of the action plan:

- decreased the number of pilot projects
- project organizations manually adjusted the project documentation and/or not provided the information model to the examination
- experts are not ready to give suggestions for the pilot project
- experienced participants of the design and other participants of the projects were not included (113).

8.2.4 Further development

As a result of the examination of the pilot projects and analysis of the results, the main problems and challenges of the BIM implementation in the construction industry in Russia were identified.

Thus, on September 2, 2015 Ministry published technical requirements for the development of the classifier construction resources and codification of construction resources, taking into account the estimated price lists. Work on the development of the classifier, including about 70000 items, and codification of construction resources completed in late 2015. (114.)

Stroitelstvo¹ started developing the first version of the national BIM standards in industrial and civil construction based on ISO standards. This decision was taken on August 25, 2015 at the meeting of Technical Committee for Standardization TC 465 Stroitelstvo. Work on the development completed in October 2015. (115.)

The first version of the national BIM standard includes the following documents:

1. Information modelling of the buildings and constructions
 - 1.1. Main provisions
 - 1.2. Requirements for the software and organization of work process
 - 1.3. Requirements for operating documentation of the constructed objects

¹ Research centre Construction

- 1.4. Requirements for the exchange of information at all stages of the life cycle
2. Construction. Model of the construction work data organization
 - 2.1. Structure of the project information management
 - 2.2. Structure of the classification of information
 - 2.3. Structure of object-oriented information (116)

In 2016 RI Stroitelstvo was also involved in the development of the following SP:

1. SP Information Modelling in construction industry. Rules of exchange between the information models of objects and models used in software systems
2. SP Information Modelling in construction industry. Rules for the development of the information model components
3. SP Information Modelling in construction industry. Rules of formation of an information model objects at different stages of the life cycle
4. SP Information Modelling. Rules of the organization of work of production and technical departments (116).

8.2.5 BIM management in public organizations

In July 2016 Mosgosekspertiza officially approved the BIM-manager position. BIM-manager is responsible, among other responsibilities, to train employees of Mosgosekspertiza tools and features of working with BIM-models; the study and implementation of the latest developments in this area; and setting up of existing software for automated examination of the BI models for compliance with all relevant regulatory documents.

At the moment, Mosgosekspertiza issued more than 10 expert reports on the projects performed with the use of BIM. More than 50 experts trained in the program of work with BIM-models employs in Mosgosekspertiza in total. Mosgosekspertiza continues to work in this direction - both in terms of the implementation of BIM directly in the organization of work, as well as in the promotion and development of BIM in the country. (117.)

8.3 Obstacles to the transition to the BIM design in Russia

Despite of the active position of many companies and individual employees, as well as support from the state, at the moment there are several obstacles to the transition to the BIM design in Russia.

8.3.1 Unstable economic situation

The first obstacle is the unstable economic situation in Russia. As a result, construction companies prefer the traditional methods of design due to the confidence in that investing in the new method brings unjustified economic risks.

8.3.2 Lack of regulatory documents

The development of BIM is still hampered by lack of clear support on the part of regulatory documents. Methods of BIM design in Russia have not been worked out yet; the standards have not been developed to an appropriate level. As a result, the participants of the project have no clear understanding of how BIM should be carried out. For the transition to the BIM technologies in the first place the development of the national BIM-standards is necessary.

8.3.3 Lack of system for determining the cost

There is no unified system for determining the cost of the construction resources. There are regional documents, but electronic database needs improvement. In addition, a substantial part the existing documents is outdated and does not contain the information about new technologies. It is not possible to get the information about the cost, its dynamics, new entrants, new materials and technologies.

8.3.4 Lack of the current list of the typical design solutions

There is not the current list of the typical design solutions. The assembly of the model from the elements of the model families, designed on the basis of the standard solutions, is significantly more efficient, allows reducing the time and number of errors. At the moment, the organization carrying out the transition to the BIM creates a new families database from the very beginning. (118.)

8.3.5 Expert organizations require 2D drawings

Despite of the emergence of the possibility of passing the examination with a BIM project, it should be noted that the expert organizations do not conduct examination of BIM projects in the way, which is the most effective. For a positive conclusion of the examination it is required to provide not only a BI model, but also a full set of 2D drawings, which significantly increases the amount of work.

8.3.6 Training system imperfections

Finally, the training system BIM design from developers and educational institutions is beginning to develop. Self-study is still the best way to start to understand BIM process and BIM software.

9 BIM in Company

The conversation about the opportunities, advantages and further development of BIM technology from software vendor point of view, as well as on the methods and problems of implementation of BIM technology at the state level is endless conversation. However, the end user and main driving force of the BIM is the participant of a construction project. One of the main construction project participants is construction organization, which is a main target consumer of BIM software.

For this reason it was decided to research the situation with the implementation and problems of the implementation of BIM technology in the Russian Construction and Design Company.

9.1 Brief description of Company

Company, based on which the practical part of this thesis was written, is a construction company in St. Petersburg, Russia, serving simultaneously as an investor, a customer, a designer, a developer and a general contractor. It provides a full range of construction services with little or no involvement of subcontractors.

The Company was founded in 2001 and since then has put into operation 373 853 m² of living space and 5236 apartments in residential buildings. All houses built and put into operation were built on monolithic technology. (119.)

Thus, the Company is a prime example of a typical design and construction organization in Russia, the main product of which is multistore residential buildings, and its experience can be replicated by many other construction companies.

9.2 Current situation in the Company

9.2.1 Brief description

At the moment, the basic working tools in the Company are AutoCAD (development of drawings), and SCAD (calculation of structures). The use of BIM tools in the Company presented weak and does not go beyond the architectural department and department of realization. The following features can be noticed:

- Architectural models are produced in Revit Architecture. Subsequent rendering is carried out in 3D max. The resulting image after rendering finalized in Photoshop and used to visualize the results of construction stage.
- MEP models are not produced.
- Analytical models for strength calculations are produced in SCAD. Export to SCAD or a similar program for the calculation of structures is also not carried out.
- The possibilities of scheduling, counting materials or automated drawing creation are not used.
- BIM at the construction site is not presented and used.

9.2.2 Hardware

The hardware in Company allows working with BIM technology. Empirically it has been found that collaboration work is also feasible. The Company's management in the near future is ready to allocate the necessary funds for the re-engineering of processes in the organization and transformation of the organi-

zational structure, the purchase of new software licenses, training of employees and the gradual transition to the new standards.

Thus, the necessary technical and material basis for the beginning of the transition to a BIM design was created in Company. The main problems associated with the implementation of the BIM lie in the organizational and economic field.

It can be concluded that the first steps towards the use of BIM can be done at this stage

9.2.3 BIM Maturity Level

According to the model proposed by Mark Brew and Mervyn Richards, the level of maturity of information modelling is evaluated based on the ability to operate and exchange the information in the process of design and construction (see Figure 20). (120.)

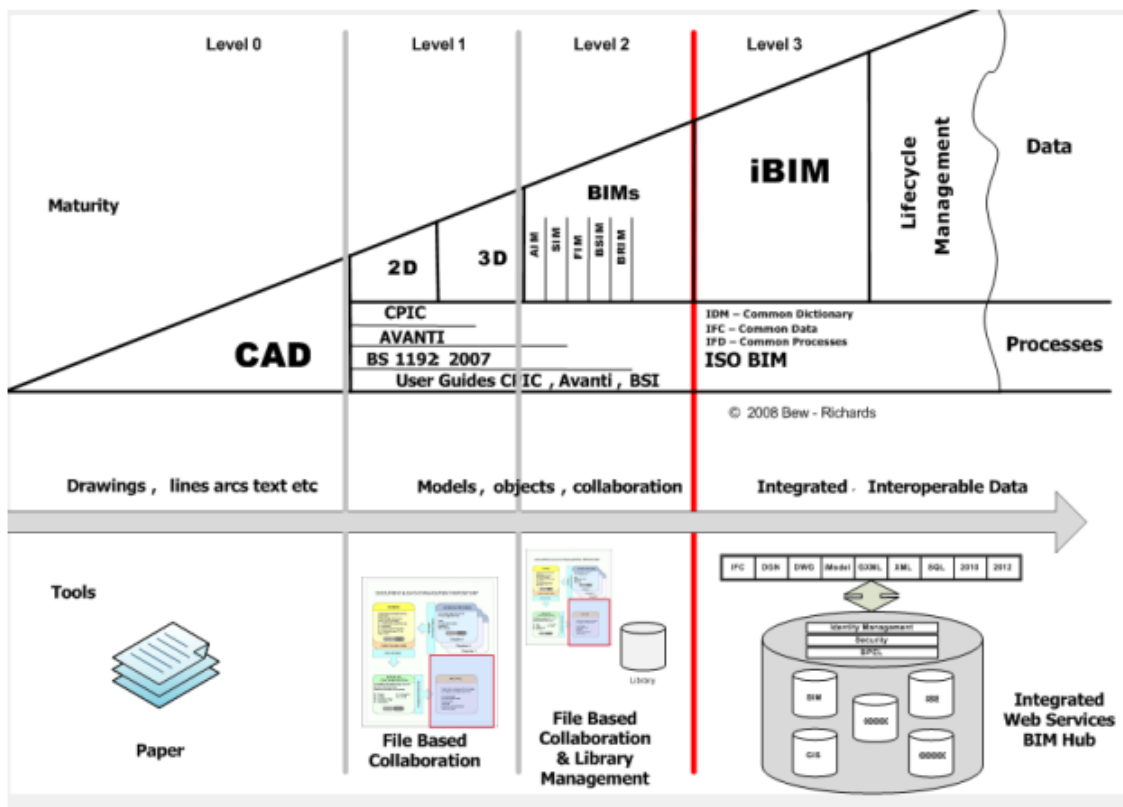


Figure 20. BIM Maturity Levels (120)

“Level Definitions:

Level 0. Unmanaged CAD probably 2D, with paper (or electronic paper) as the most likely data exchange mechanism.

Level 1. Managed CAD in 2 or 3D format using BS1192:2007 with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data managed by standalone finance and cost management packages with no integration.

Level 2. Managed 3D environment held in separate discipline “BIM” tools with attached data. Commercial data managed by an ERP. Integration on the basis of proprietary interfaces or bespoke middle programme data are could be regarded as “pBIM” (proprietary). The approach may utilise 4D and 5D cost elements as well as feed operational systems.

Level 3. Fully open process and data integration enabled by “web services” compliant with the emerging IFC / IFD standards, managed by a collaborative model server. Could be regarded as iBIM or integrated BIM potentially employing concurrent engineering processes” (120).

According to the model, Company at its stage of development is only preparing for the transition to level 1.

9.3 Reasons of non-using BIM

9.3.1 Unstable economic situation

As previously mentioned, within the unstable economic situation in Russia, most of the construction companies prefer the tested and proven methods of production work. New techniques and technologies pay off after a certain time and require additional investment funds, and are subject to certain risks. As a result, the idea of transition to BIM technology is usually not considered during the economic crisis.

9.3.2 Social Factor

A substantial part of the project department staff is over 40 years old. Experienced candidates, which do not require a lot of time for learning the features of work in the Company, are more preferable in employment. As a result, there is a shortage of young staff with the skills to work with BIM.

Employees do not see the need to transition to BIM technology and insufficiently motivated the beginning of learning new methods. There is a risk that many employees of the Company, in the case of oblige them to the learning BIM, will prefer to work in another Company.

9.3.3 Unsuccessful experience

Unsuccessful experience also affects negatively on the implementation of BIM technology. In the recent past, all employees were required to take BIM courses at the expense of the Company to subsequently initiate the transition to BIM technologies. However, due to lack of understanding of BIM technologies' potential and the lack of motivation, courses have not brought essential results and became irrational waste of Company funds.

9.3.4 Distrust

Many employees feel distrust of the new software due to lack of experience of its implementation in the Russian construction industry. An additional distrust is involved by the risk of the possible occurrence of additional problems with the coordination of the project in examination.

9.4 Recommendations

9.4.1 Economic problems

One of the problems standing in the way of the Company development is the lack of funds. To overcome this obstacle requires an economic analysis of the situation. However, even without such analysis results of the introduction of BIM technology could be predicted based on theoretical and experimental research in the field. (121.)

According to such studies, the transition to BIM technology requires re-engineering of the organization's processes costs and costs of the transformation of the organizational structure as well as the purchase of hardware and software. However, on average within 15 months the production volumes of the company reach their former value and continue to grow often reaching twice higher values. According to statistical studies, the average value of investment returns is more than 60% (121).

Thus, investing in the development of the Company in this area is one of the possible ways to increase Company's profits during the economic crisis. In Russia, for example, a lot of construction companies have started their transition to BIM technologies during the economic crisis of 2008-2009.

9.4.2 Social problems

In general, Company's staff consists of highly experienced employees of middle age. Such management policy has both advantages and disadvantages.

Among the advantages are:

- Fast performance, high capacity
- A small number of errors and mistakes
- Independence in decision-making process
- Ability to work in a team
- Ability to work in a critical situation
- Ability to work in accordance with the priorities
- Ability to quickly find a way to solve most problems encountered.

Among the disadvantages are:

- Lack of motivation
- Negative attitude towards changes in ways of working
- Preference is given to traditional tools
- Distrust to new tools
- Inability and/or unwillingness to work in new software.

One possible way of avoiding this system is the gradual recruitment of new young employees possessing skills in the BIM and the ability to learn. As a result, increase the motivation of employees, and the transition to BIM technology became more progressive and logical.

An additional advantage of this solution is rapidly getting younger and enough experienced employees. Since working together with experienced specialists is much more effective for the development of the professional skills, rather than self-studying while working or studying in educational institutions.

Also educational work in this area can affect the motivation of employees. Specialists, who do not have enough knowledge of the BIM, often formed the wrong impression about the possibilities of these technologies. Many employees believe that the use of BIM is possible only for visualization designed project. However, the BIM possibilities are not limited by visualization.

9.4.3 Reorganizing the structure of the project team

Specialists in the field of BIM technology implementation in companies recommend the following structure of the design team:

1. Upper Level - Experts. High experienced employees who have an appropriate level of knowledge and are well versed in the subject matter and design process. Their main tasks are to generate ideas, to define the concepts and basic goals of the project, to monitor the compliance of the work results to the technical requirements and norms, to manage the design process and its results. Experts needed the level of software knowledge which allows them viewing a model. This is very important, because such people tend to be aged and very busy at work, so they have little or no opportunity to deal with the new programs in detail and, especially, to model something.
2. Middle Level - Designer. The task of these employees is to direct creation of an information model. So that they need a good understanding of the issues and a high professional level of software knowledge. Designers in such a structure are the main executors of the project.

3. Lower level - Drawers. Drawers are not directly involved in the process of creating a model and are not making changes to it. Their main tasks are to create model elements and families and to design documentation. In other words, to create, to set and to format design specifications and drawings for the data from the model, as well as to improve to the required level drawings of assemblies and details. Drawers are mainly beginning designers, due to their low experience in the field or low level of software knowledge (122).

Such an organizational structure of the project team is more logical for BIM and simplifies the transition to the new design technology.

9.4.4 Partial transition to BIM

Division of the employees into several teams working on different projects allows for a partial transition to a BIM technology. Partial transition to BIM allows one team to transfer its own project in the BIM environment regardless of other employees and teams.

Employees most interested in the BIM should form such a team. It reduces the impact factor of a lack of motivation. Transferring only one of the company projects in the BIM environment allows minimizing the economic costs and risks.

Completion of the project with a successful result increases the motivation of other employees, and allows company to get the employees with appropriate experience in BIM design. These employees could conduct the further training work.

9.4.5 Implementation of the pilot project

One of the most important steps towards the BIM implementation is the implementation of a pilot BIM project. It allows, for example, to:

- Simplify the process of drawing up company BIM regulations
- Start the creating of BIM element base
- Identify the main vectors and problems of the transfer to BIM technology

- Create a state or a project team that is ready to transition to BIM technology and able to pass of their experience to other employees
- Improve the level of BIM and BIM software knowledges.

9.5 First steps towards the BIM implementation

The implementation of a pilot BIM project, which has been said above, is not only important, but also an inevitable step of the BIM implementation process. The results of the pilot project can largely influence the further development of the company, both in a positive and in a negative sense.

Thus, it is essential that the pilot project has given positive results and not became a disaster for company. For this purpose, along the lines of UK soft landing (Government Soft Landings), and based on the experience of other countries and foreign companies, it is important not only to direct the process of implementing a pilot project, but also a long period of preparation for such a project.

Based on everything that has been said above, it can be concluded that the standard stages of preparation to a pilot project implementation for each company are (order can be selected individually for each company, depending on background):

- Pre-teaching employees the basics of modelling.
Responsibility for this stage, as a rule, entirely rests with the management of the company. Of course, before the start of the pilot project, it could not be known which skills will be useful in the future. However, the basics of modelling will be useful for sure. The success of this phase is mainly based on the desire, willingness and personal responsibility of employees to training, as well as the quality level of courses.
- Assessment of the economic and other risks.
At this stage it is important to predict of company further development in the case of different scenarios realization (perfect scenario, most likely scenario and negative “humiliating failure” scenario). While employees’ efforts should be aimed at the realization of the perfect scenario, compa-

ny should be ready for the realization of the negative scenario, both morally and financially.

- Preliminary assessment of the pilot project difficulties

Difficulties can arise both in the search for contractors and the passage of the construction expertise, and in many other cases. Due to it, researching the information and finding the solutions to potential problems are important. The list of potential problems was set out above.

- Educational works

Before the implementation of the pilot project is necessary to ensure that employees have a more or less reliable information about BIM technology, the possibilities and limits of its applicability to avoid overly negative or, on the contrary, a positive response.

- The reorganization of company structure

Since BIM project is implemented in accordance with completely different scheme than the traditional construction project, the preliminary reorganization of company (or its part in the case of partial transition) structure should be made. The reorganization of company structure allows minimizing the risks and could be recommended due to this reason. In the same time, the preliminary reorganization as well as the partial transition is possible only in the case of company simultaneous work on different projects.

- Purchase and approbation the required software

It is important not only to purchase the required software, but also confidence in its reliability before the start of design the pilot project

- Identification of the company needs and assessment of the possibility their satisfaction with BIM technology

This phase is more or less unique to each of the construction company according to the features of their activities.

A significant part of these steps can be carried out solely on the initiative of the company's relevant specialists. Comprehensive information providing carrying out educational works has been given above. However, the step of identification of the company needs and assessment of the possibility their satisfaction with

BIM technology can be initiated third-party specialist. This will be discussed in more detail below.

10 Assessment of the possibility of Company needs satisfaction with BIM technology

As part of the assessing the possibility of Company needs satisfaction with BIM technology, it was decided to perform a part of the Company project using BIM technology. Such a project is not a BIM pilot project in the conventional sense, but allows conducting the preliminary assessment of the BIM technology possibilities with minimum efforts.

10.1 Initial data about the project

10.1.1 Location

A multistore apartment house with integral and attached premises for public use and integral and attached underground parking is a part of residential complex Pragma City. Pragma City construction site is located in Vyborg district, in the structure Northern planning district of St. Petersburg. The main directions of the Northern planning district are Vyborg highway and Engels prospectus with access to St. Petersburg Ring Road. The construction site is limited by the neighbouring site in the north, 3rd Verkniiy lane and its project continuation in the east, by Zarechnaya Street in the south and by neighbouring site adjacent to Olginskaya road in the west (see Figure 21-22).

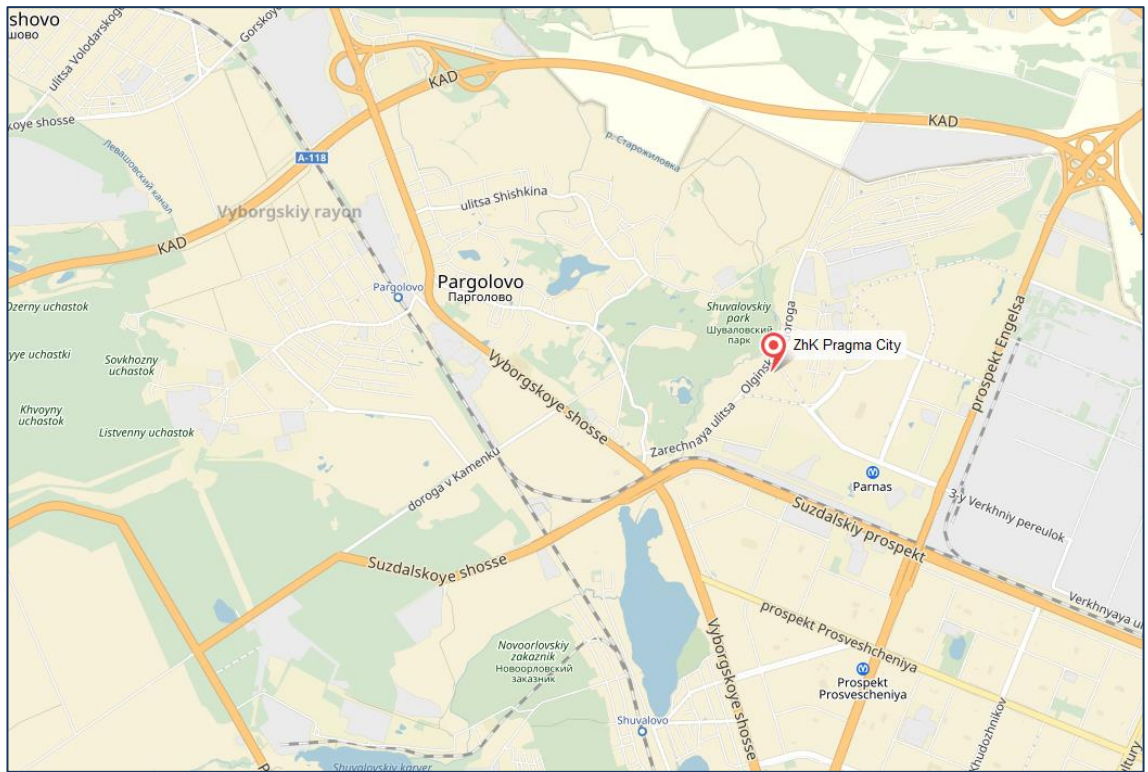


Figure 21. Location of the Pragma City construction site

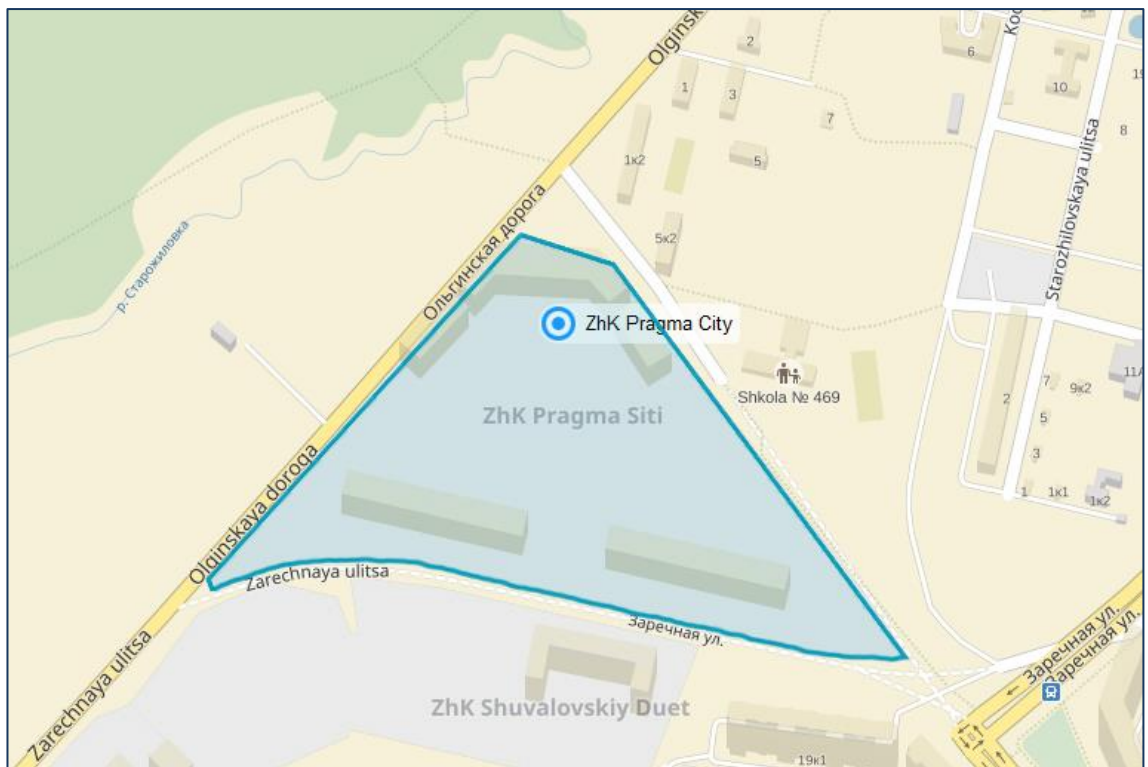


Figure 22. Pragma City construction site boundaries

The master plan is shown in Figure 23.



Figure 23. The master plan of the residential complex (123)

10.1.2 Engineering and economic figures

Some of the engineering and economic figures are presented in Table 3.

Table 3. Engineering and economic figures (123)

Name of the figure	Unit	Quantity
Total area	m ²	24 338
Site area, including:	m ²	13964.8
- Site area of the residential house	m ²	4247.7
Number of sections		7
Number of floors		23, technical attic and basement
Total apartment area including area of balconies and loggias reduced by the reduction coefficient	m ²	51069.4
- Apartment area excluding area of balconies and loggias	m ²	47100
Total area of integral premises for public use of Floor 1 and Floor 2.	m ²	4370
Total area of technological premises	m ²	1061.7
Number of apartments, including:		915
- Studio apartment		236
- 1-roomed flat		212
- 2-roomed flat		213
- 3-roomed flat		254
Estimated number of residents (based on the norm of 30 m ² per 1 person).		1591

10.1.1 Main features and dimensions

The project provided the construction on the site of a 23-storey 7-section residential building with integral and attached premises for public use and integral and attached underground parking. The building has a basement and technical attic.

The maximum building height from the surface of the earth to the highest point is 72.77 m. The difference between the level of passage for the fire engines and level of the lower boundary of a higher opening (window) in the external wall is 67.42 m.

The construction scheme is a cross-wall scheme (123).

10.1.1 External and internal walls

Load-bearing walls and floors are designed of reinforced concrete. Exterior walls are multilayer of two types. Non-loadbearing walls are designed from expanded concrete blocks (D400, B2.5, F25) with outer layer from ceramic facade brick of three colours (light, grey and brown) M400, F75. Load bearing external walls are designed from reinforced concrete with outer layer from ceramic facade brick and thermal insulation from the non-flammable mineral wool ROCKWOOL FACADE BATTS.

Internal non-loadbearing walls and partitions are designed from:

- walls and partitions between the apartments are double walls of fibre foam concrete tongue and groove plates with a thickness of 80 mm, a density of 1200 kg/m^3 with an air gap filled with mineral wool
- walls and partitions between the rooms are single walls of fibre foam concrete tongue and groove plates with a thickness of 80 mm, a density of 1200 kg/m^3 (123).

10.1.2 Floors

Floors from the 2nd (in part) to the 23rd are residential. The height of the residential floors is 3.0 m. The height of Floor 1 is 3.6 m.

Floor 1 and Floor 2 include the integral premises for public use.

The attic in the building is technical; its height is 1.8 m from floor to ceiling (123).

10.1.1 Roof

There is a flat roll roof with traditional design. There are an internal drain and brick parapets with metal railings on the top of the parapet. The height of the roof parapets is 1.2 m. Outputs on the roof are made from unsmokable staircases through the fire doors (123).

10.1.2 Drawings

To perform the BIM, the architectural 2D drawings with facades, floors, roofs and sections were provided.

10.1.1 Current situation

The state of the construction site in September 2016 is shown in Appendix 1.

10.2 Identification of the Company needs

To assess the BIM applicability it was decided to perform BIM (architectural model) in Revit Architecture 2017 and to test the feasibility of some of the BIM features.

The list of features that require evaluation was made on the basis of the Company employees' current needs. This list is provided below:

- the possibility to design
- the possibility to visualize
- the possibility to render in Cloud
- the possibility to export of drawings to AutoCAD 2015
- the possibility to make section and joint drawings
- the possibility of automatic replacement of all identic elements to the others
- the possibility to create a breakdown of floor premises
- the possibility to design and to visualize an apartment interior
- the possibility to count the volume of the materials used
- the possibility to assess the accuracy of calculating the volume of material
- the possibility to create windows used specification
- the possibility of thermal calculations
- the possibility to export an architectural model to Revit Structure and Revit MEP
- the possibility to export a model to the calculation software
- the possibility to export a model to other software for further view on the construction site.

10.3 Results of the assessment

10.3.1 Design

Methods

To assess the possibility of designing modelling of the building from Floor 1 to Floor 23, the technical attic and roof was carried out in Revit Architecture 2017.

The following elements were modelled:

- External and internal walls and partitions (include layers)
- Monolith slabs including attic slab (include layers)
- Roofing (include layers)
- Staircases
- Elevator shafts
- Balconies and loggias
- Openings
- Windows, doors and translucent structures
- Blind area
- Brick parapets with metal railings
- Ventilating shafts
- Outputs on the roof from staircases

Modelling was performed according to the provided architectural drawings. An example of the provided drawings is presented in Appendix 2.

Some results are presented in Appendix 3.

Resume

To perform the modelling of the multi-storey apartment house required to use only the basic tools of the program. There were no special difficulties in carrying out the modelling. The process of modelling has also revealed a number of clashes in the original drawings. Among them:

- Non-compliance the provided drawings of facades and floors to each other (see Figure 24)

- Impossibility of construction of the roof according to the drawings provided, the need to change the design slope value (see Figure 25) and the roof levels (see Figure 26)

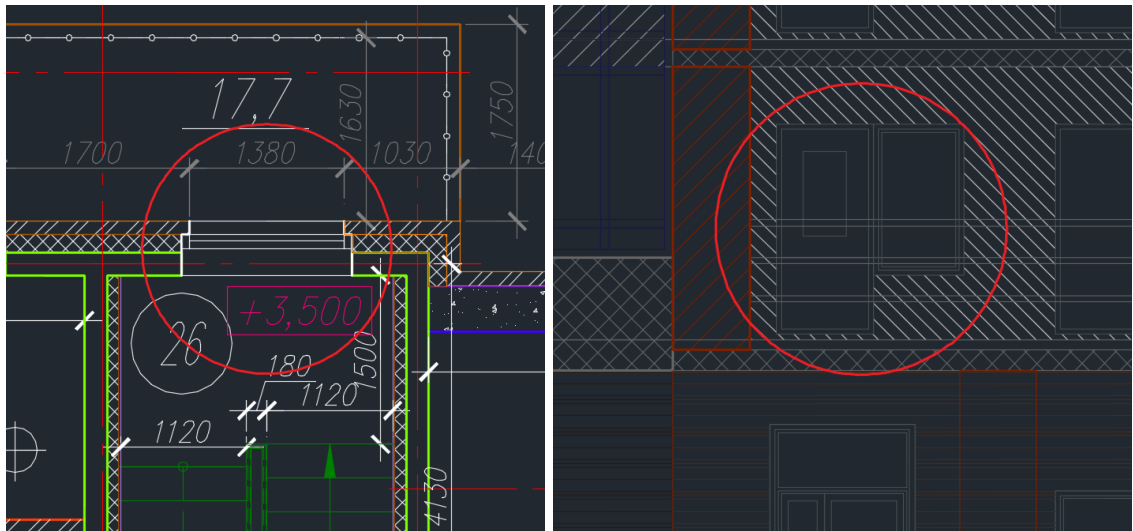


Figure 24. Non-compliance the provided drawings of facades and floors to each other (floor plan from the left side and facade from the right side)

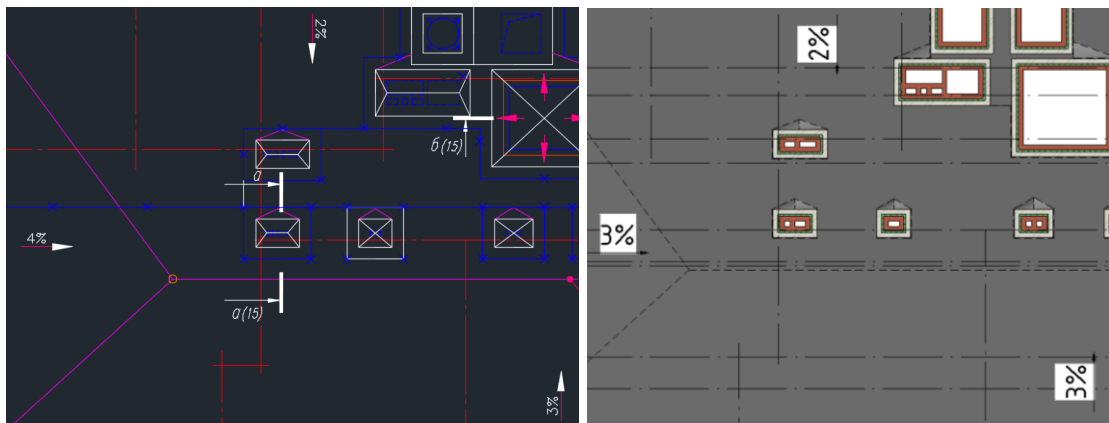


Figure 25. Clash in the design roof slope value (provided roof plan from the left side and model roof plan from the right side)

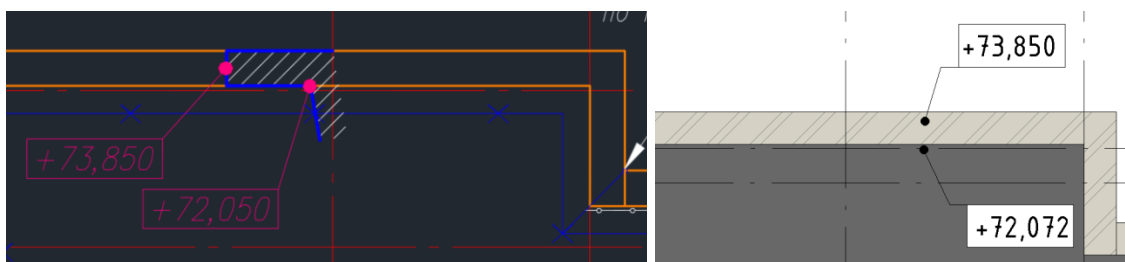


Figure 26. Clash in the design roof levels (provided roof plan from the left side and model roof plan from the right side)

These clashes are not serious, but clearly show the applicability of using the BIM technology as a tool for clash detection.

In general, BIM takes much less time than the preparation of drawings in AutoCAD. During preparation of drawings the reduction in the number of clashes is directly related to the drawing process as well as Revit Architecture 2017 functionality as BIM software were marked. The software allows quickly correcting any mistakes and making changes.

The possibilities of grouping elements (since any element of the group was changes, all elements of the group were also changed) and the establishment of relations between elements (for example, changing the position of the wall influence the associated walls, floor slabs, openings, windows and doors, roofing and blind area positions and shapes according to the nature of their relations) are especially convenient.

10.3.1 Visualization

Methods

As evidence of the possibility of the visualization, the render of Section 7 was made with Revit Architecture 2017 own tools (see Appendix 4). For this Render tool was used.

Resume

In Revit Architecture 2017, as well as in other BIM software, the visualization is possible. With a number of Render tool settings (see Figure 27) the high quality detailed image can be prepared. Using advanced rendering software (such as, for example, 3D Max) allows getting an image with the quality that is indistinguishable from a photograph.

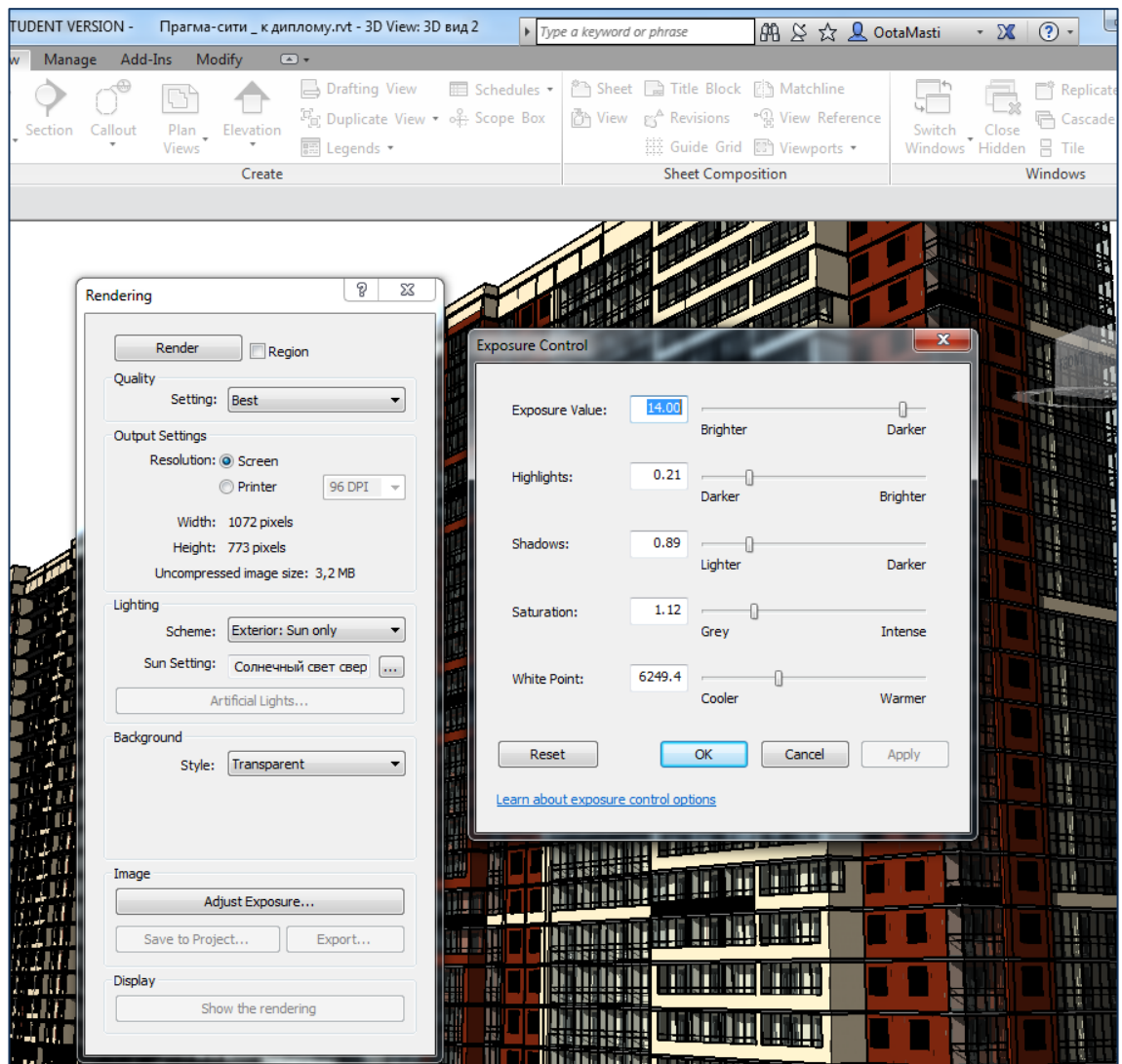


Figure 27. Render tool settings

It should be noted that the process of rendering directly on the computer is time-consuming and requires a good enough hardware. In this regard, Render in Cloud may be recommended to perform quality imaging.

10.3.2 Visualization in Cloud

Methods

To assess the possibility of performing remote visualization (visualization in Cloud), an attempt to visualize the model with Render in Cloud tool (see Figure 28) model was made. However, an unexpected result was received: visualization in Cloud is not possible if the user name or the name of any folder in which

the program was installed has been given in Cyrillic. In this case, Revit Architecture 2017 gives an error message (see Figure 29).

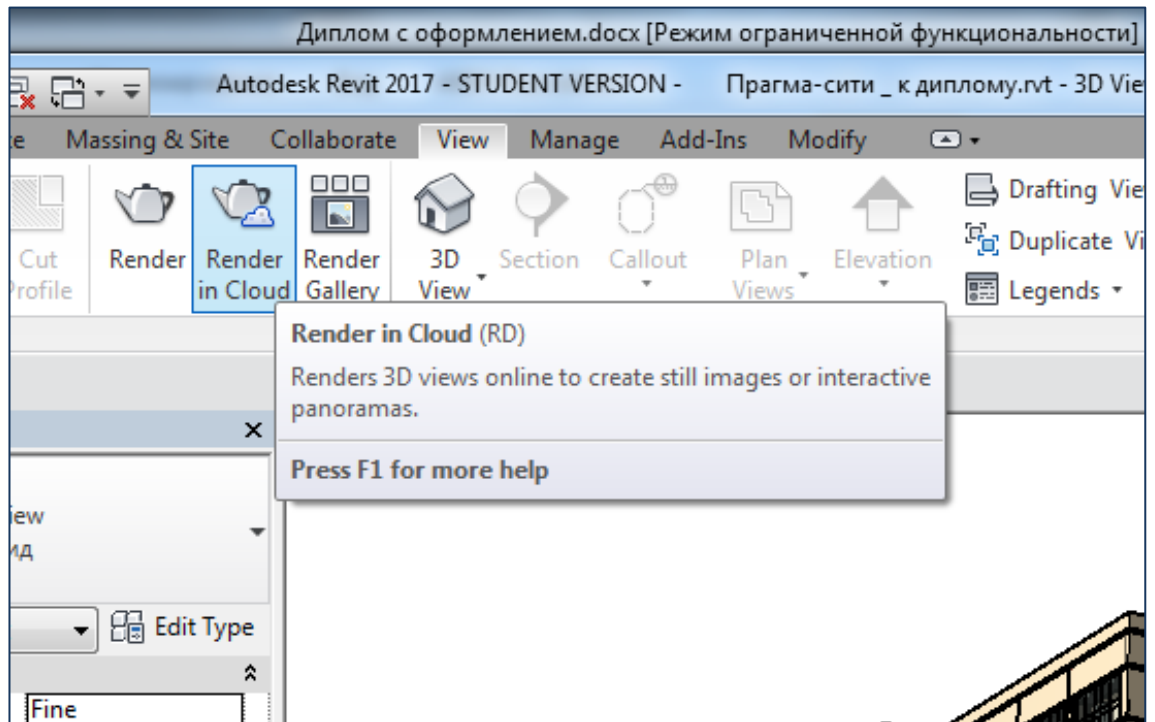


Figure 28. Render in Cloud tool

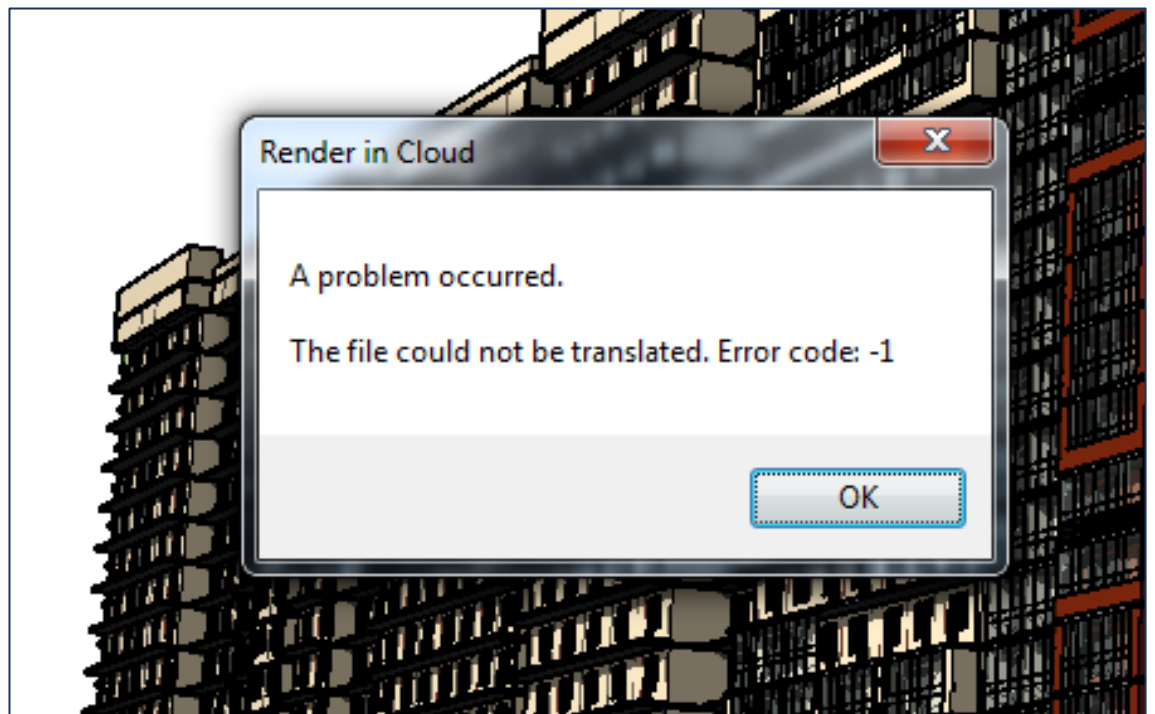


Figure 29. Render in Cloud tool error message

Resume

The possibility to perform the remote visualization could not be and has not been tested. However, such a possibility exists, as evidenced by the existence of Render Gallery (see Figure 30) and user's visualized projects in it (see Figure 31). This gallery contains not only the rendered image, but also the panoramas, stereo pans and insolation calculation projects.

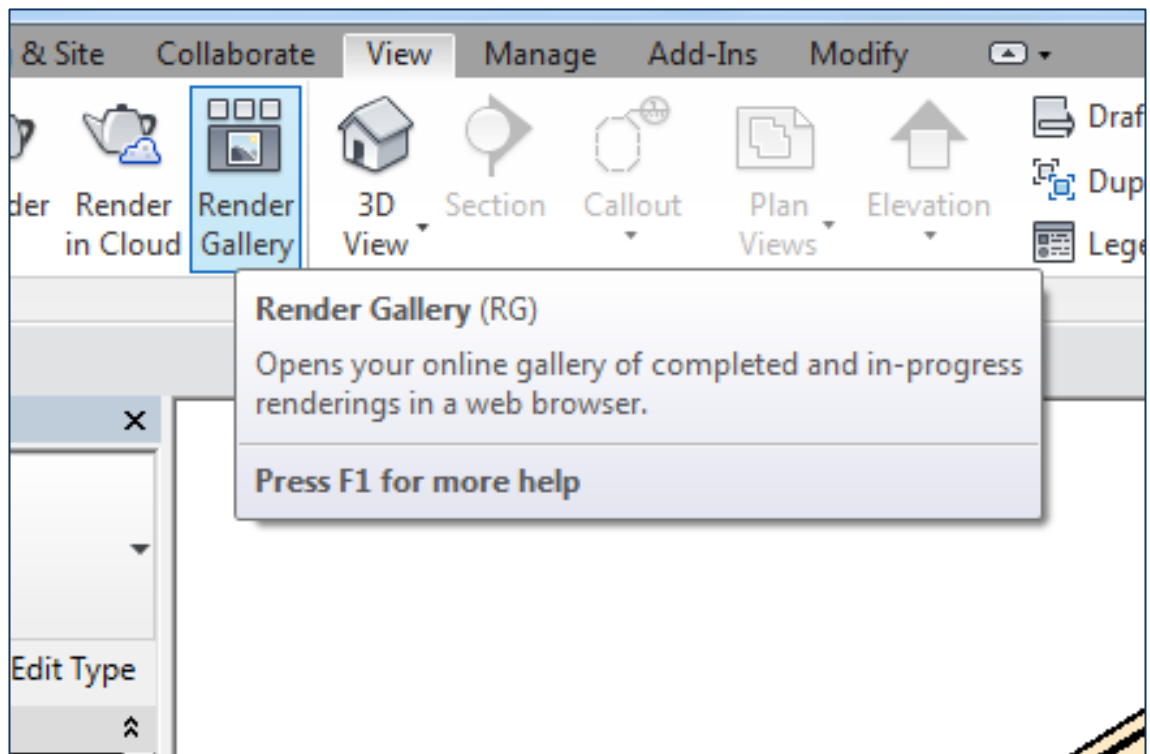


Figure 30. Render Gallery tool

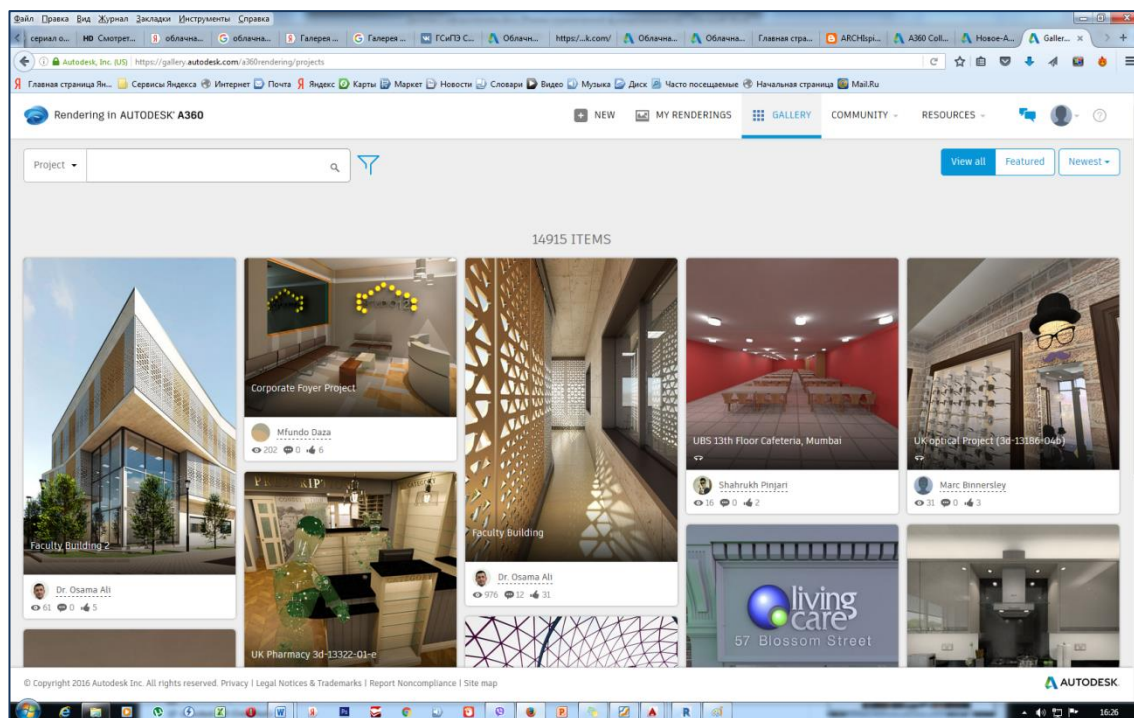


Figure 31. Render Gallery online (124)

Thus, one of the features of Revit Architecture 2017 has been detected. It should be taken into account in the preparation of the Company's computers.

10.3.3 Export of drawings to AutoCAD 2015

Methods

To assess the possibility of export of drawings it has been decided to export a building facade drawing in the axes A-Sh from Revit Architecture 2017 in AutoCAD 2015. Created in AutoCAD the drawing is presented in Appendix 5. The facade drawing was created by Revit Architecture 2017 and then exported to AutoCAD presented in Appendix 6.

Resume

Exporting drawings from Revit Architecture 2017 to AutoCAD 2015 is carried through by the Export tool (see Figure 32). In itself export of the drawings is a simple and not time-consuming operation. However, to obtain an acceptable quality of drawings required a prolonged setting Export tool or long-term follow-up formatting of drawings directly in AutoCAD.

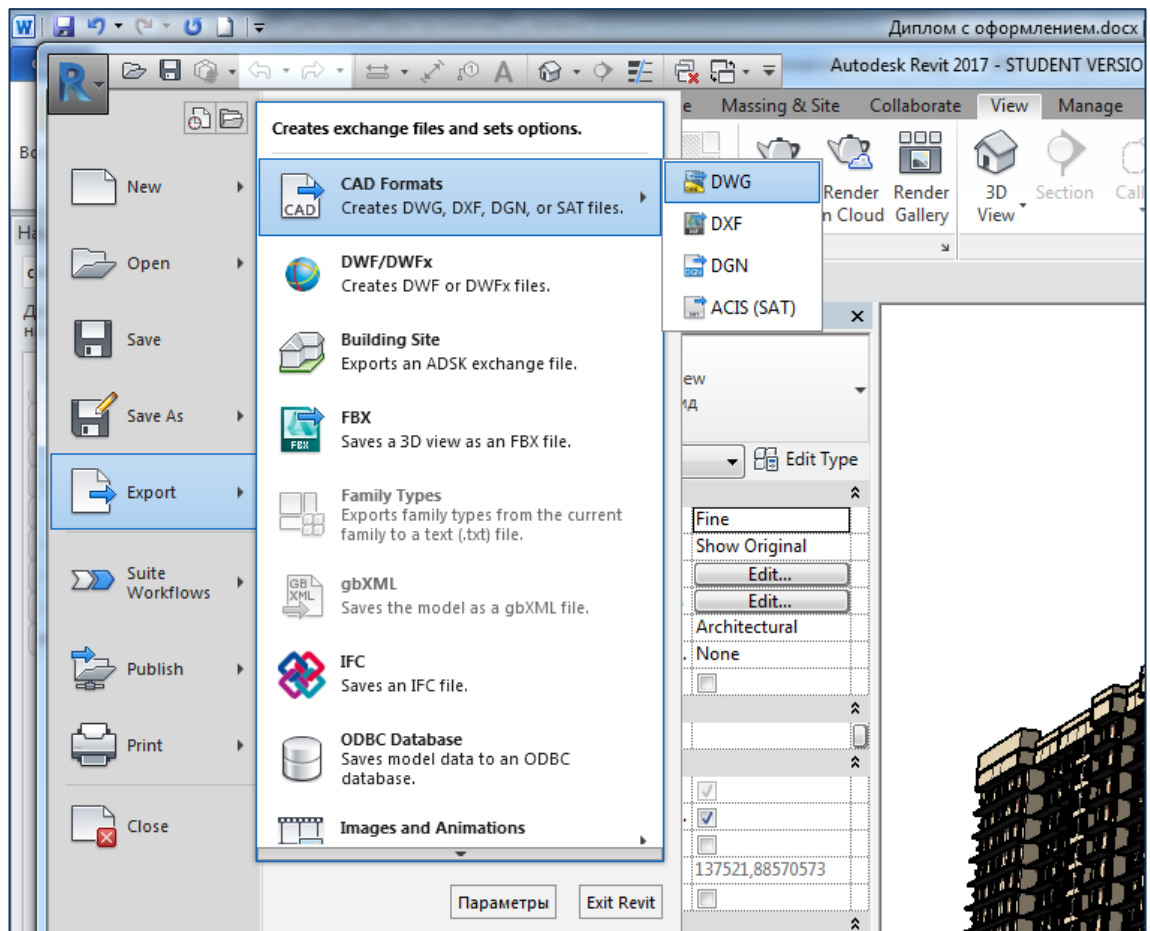


Figure 32. Export tool

At the same time, Revit Architecture 2017 has enough options for printing flat drawings with acceptable quality directly from software, bypassing the export to AutoCAD.

Thus, the export of drawings from Revit Architecture 2017 into AutoCAD 2015 is possible, but in the case of performing BIM project is recommended for use only for working with the contractors carrying out the work by the traditional method.

In the case when export of a significant number of drawings is needed, a pre-setting Export tool is recommended. In the case when export of only few drawings is needed, follow-up formatting of drawings in AutoCAD is recommended.

10.3.4 Making section and joint drawings

Methods

To assess the possibility to quickly create joint and section drawings, the vertical cross section of the fragment of roof output from the staircase was chosen. The drawing made in AutoCAD is presented in Appendix 7. The drawing printed from Revit Architecture 2017 is presented in Appendix 8.

Resume

The section drawing was carried out by Revit Architecture 2017 almost automatically. To do this, Section tool was used (Figure 33). Dimensions were manually affixed.

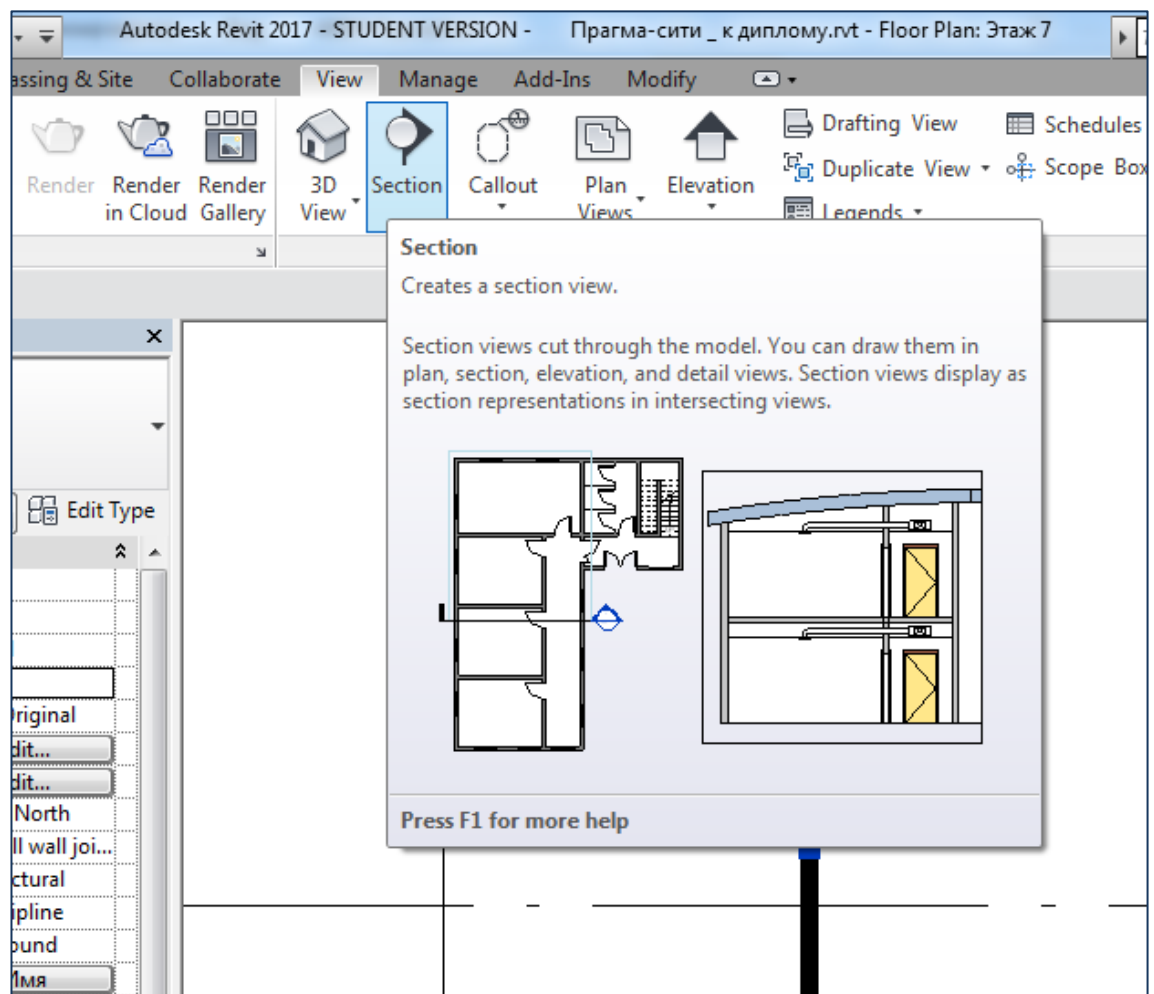


Figure 33. Section tool

Some differences between drawings in this case are based on the level of model detail. It means that BIM was made without consideration of the detailed elements that were taken into account when section drawing was prepared in AutoCAD. However, if necessary, the addition of such elements is also not a time-consuming process.

Thus, it can be noted that the execution of joint and section drawings is much more convenient to carry out in the case of BIM project implementation even if there are no further changes, clashes or mistakes.

10.3.5 Automatic replacement of all identic elements to the others

Methods

To assess the possibility of automatic replacement of all identic elements to the others, it was decided to replace all the windows of Type 4 with two sashes, 1510 mm in height and 1645 mm in width to new windows with one sash, 1460 mm in height and 1720 mm in width, as well as to change sill height from 800 mm to 100 mm.

To do this, the function Select All Instances in Entire Project (see Figure 34) has been used. Then the selected windows were changed to the required windows (see Figure 35). In the end, the sill height has been changed (see Figure 36).

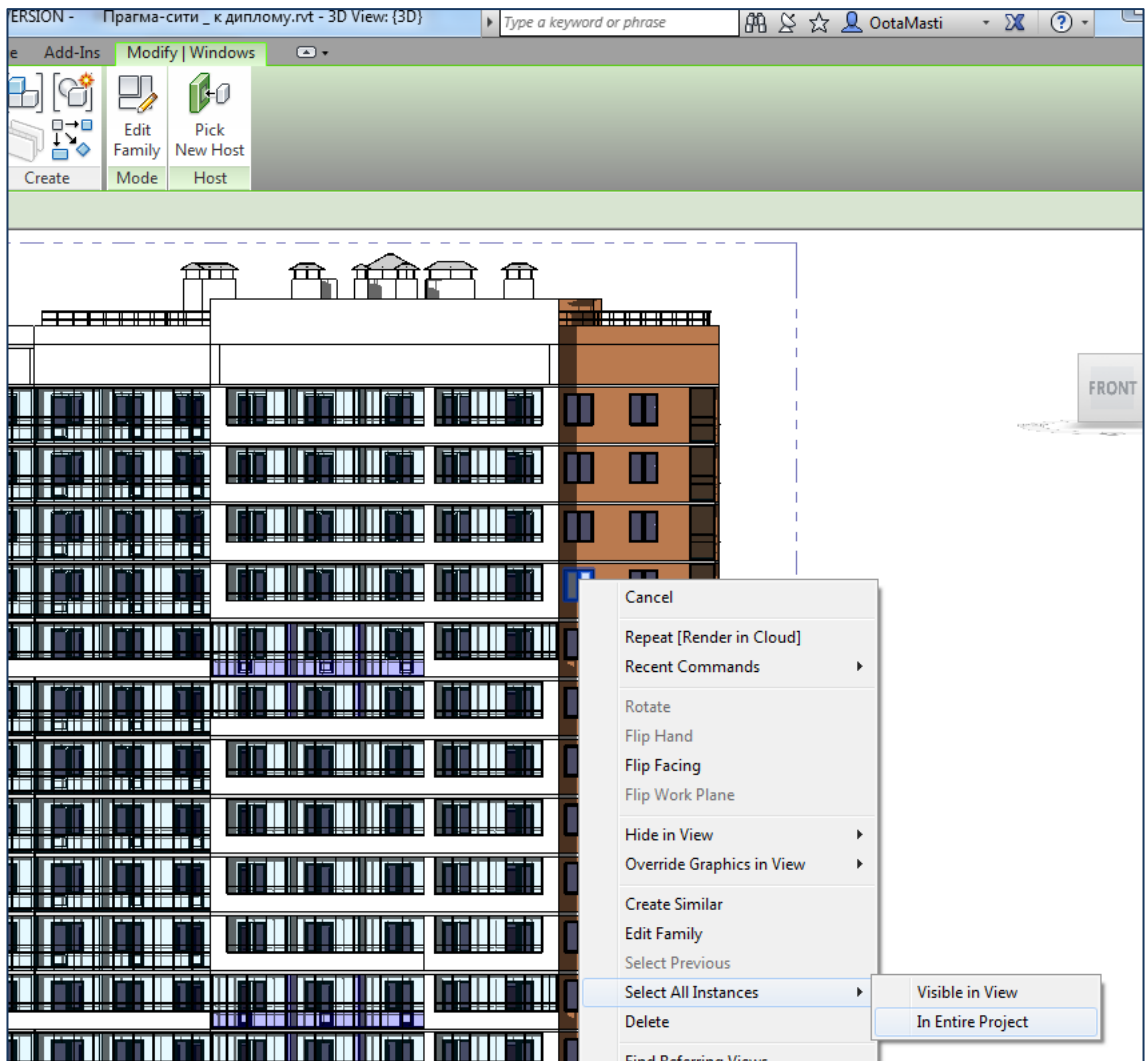


Figure 34. Select All Instances in Entire Project function

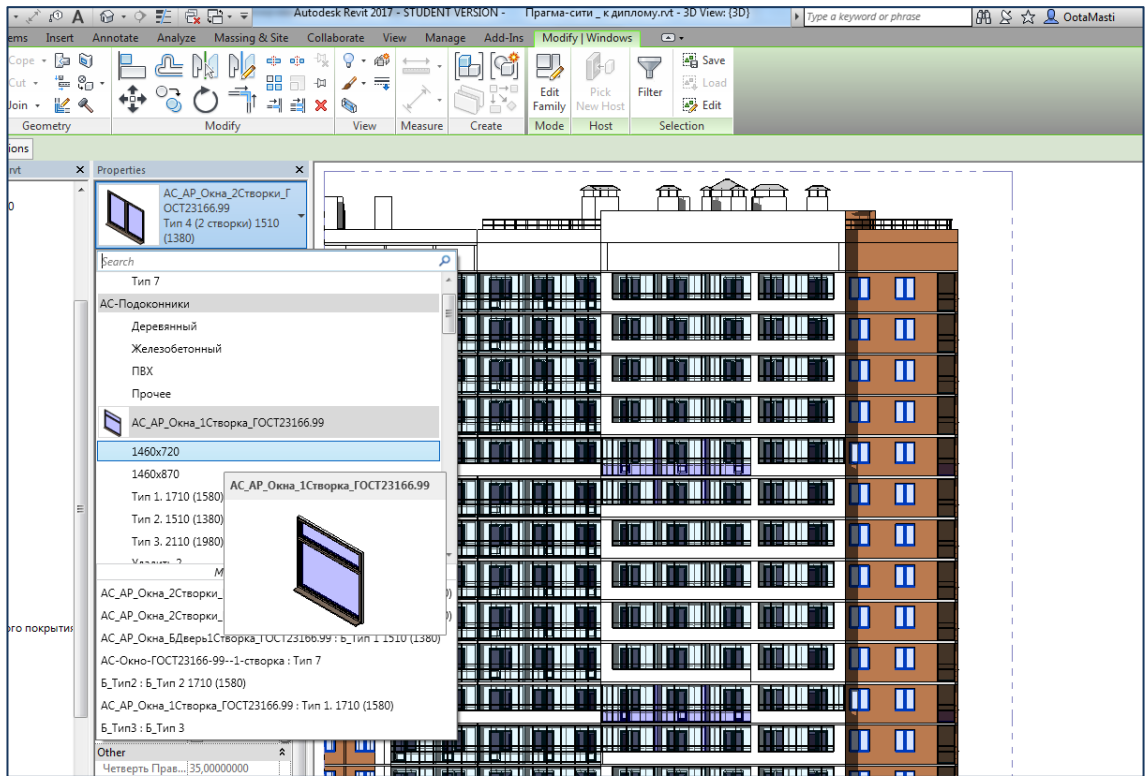


Figure 35. Process of changing the selected windows to the required windows

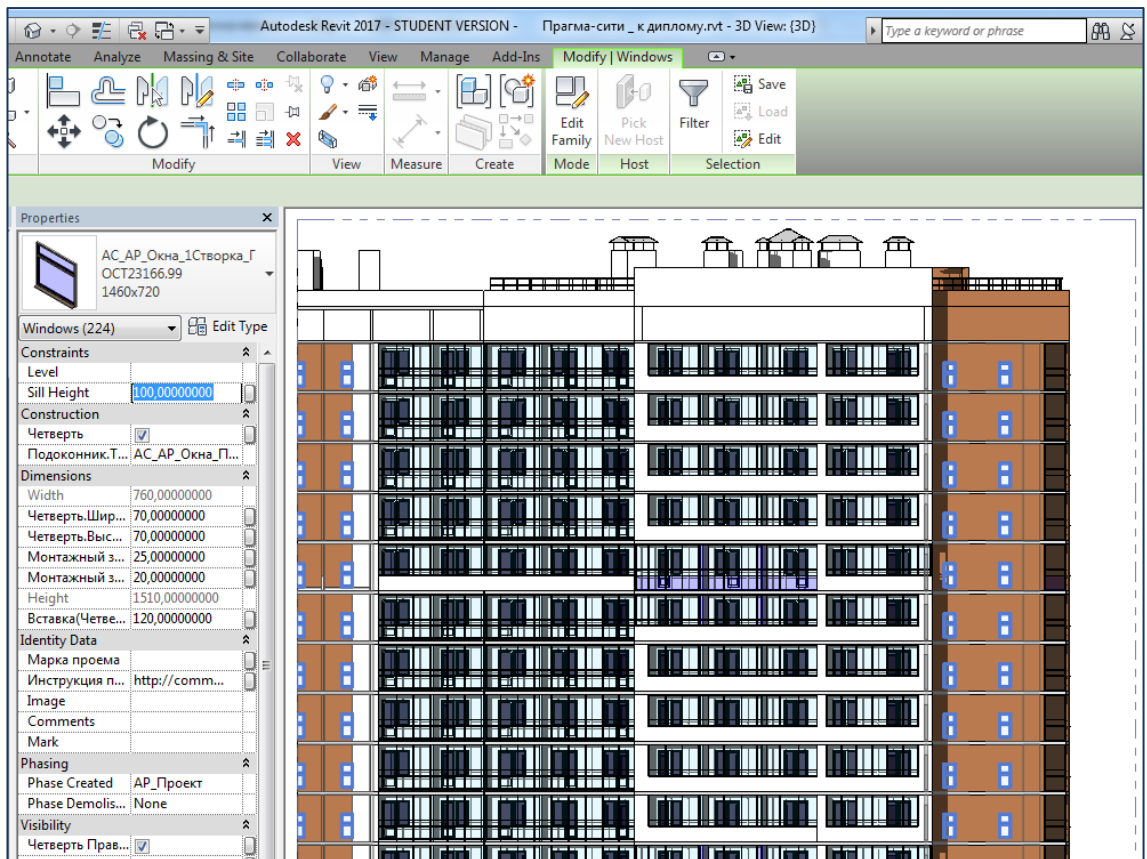


Figure 36. Process of changing the sill height

Resume

Thus, the selection of the identic elements, their changes and replacement to other elements does not pose any problems in the Revit Architecture 2017.

10.3.6 Creating a breakdown of floor premises

Methods

To assess the possibility of creating the breakdown of floor premises, Floor 7 rooms have been created using Room tool (see Figure 37).

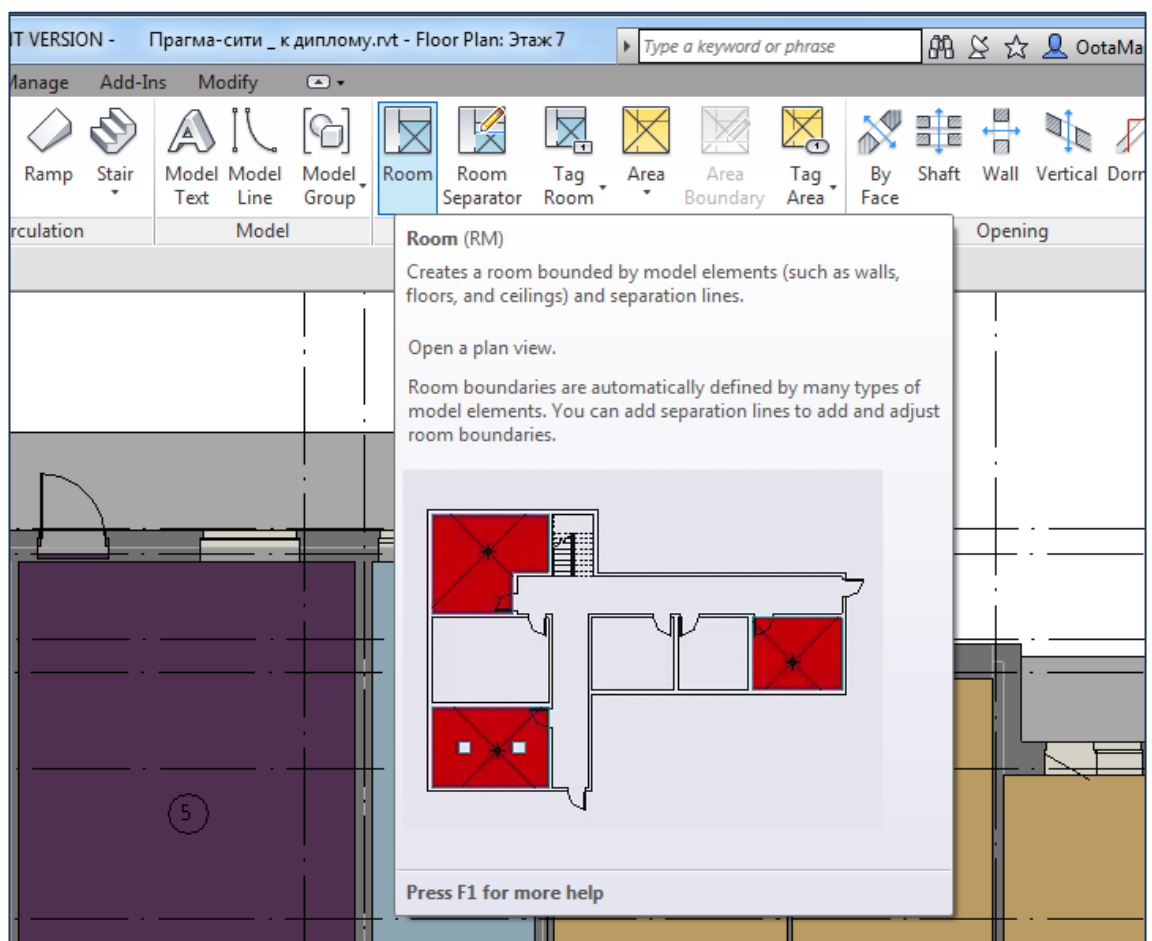


Figure 37. Room tool

Then the colour scheme for these rooms was created using Colour Schemes tool (see Figure 38).

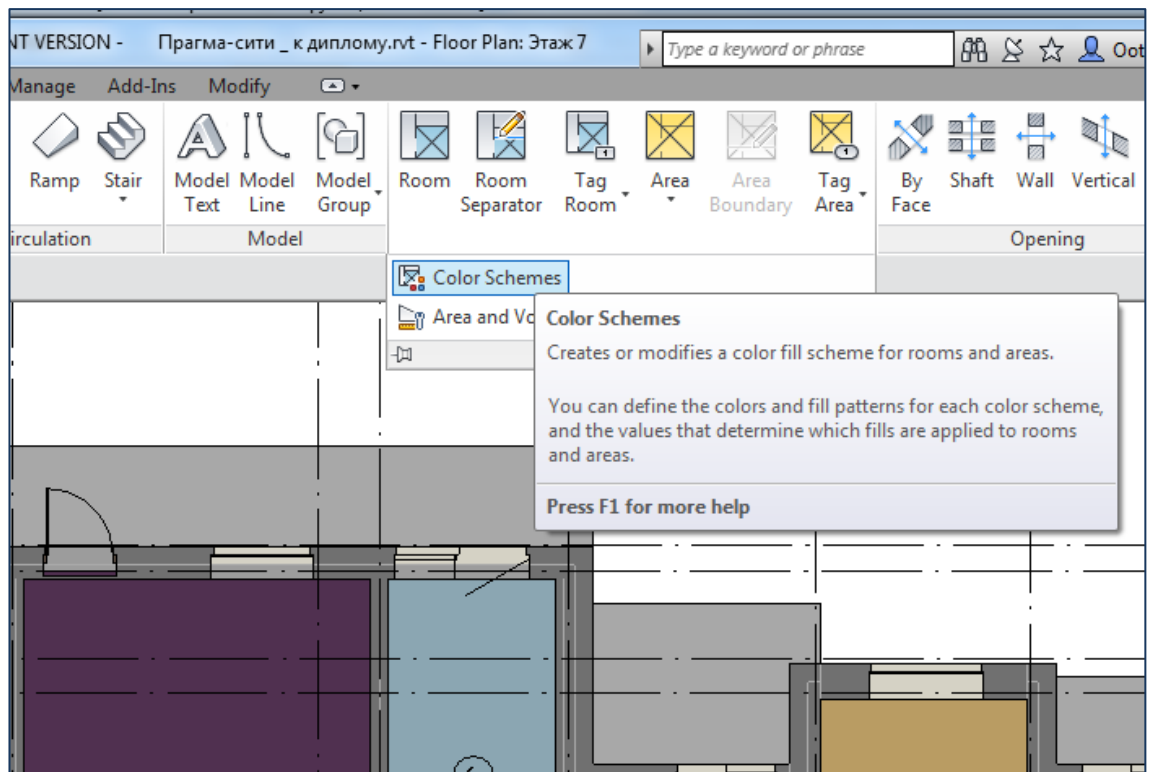


Figure 38. Color Schemes tool

The breakdown of floor premises was created using Schedule/Quantities tool (see Figure 39).

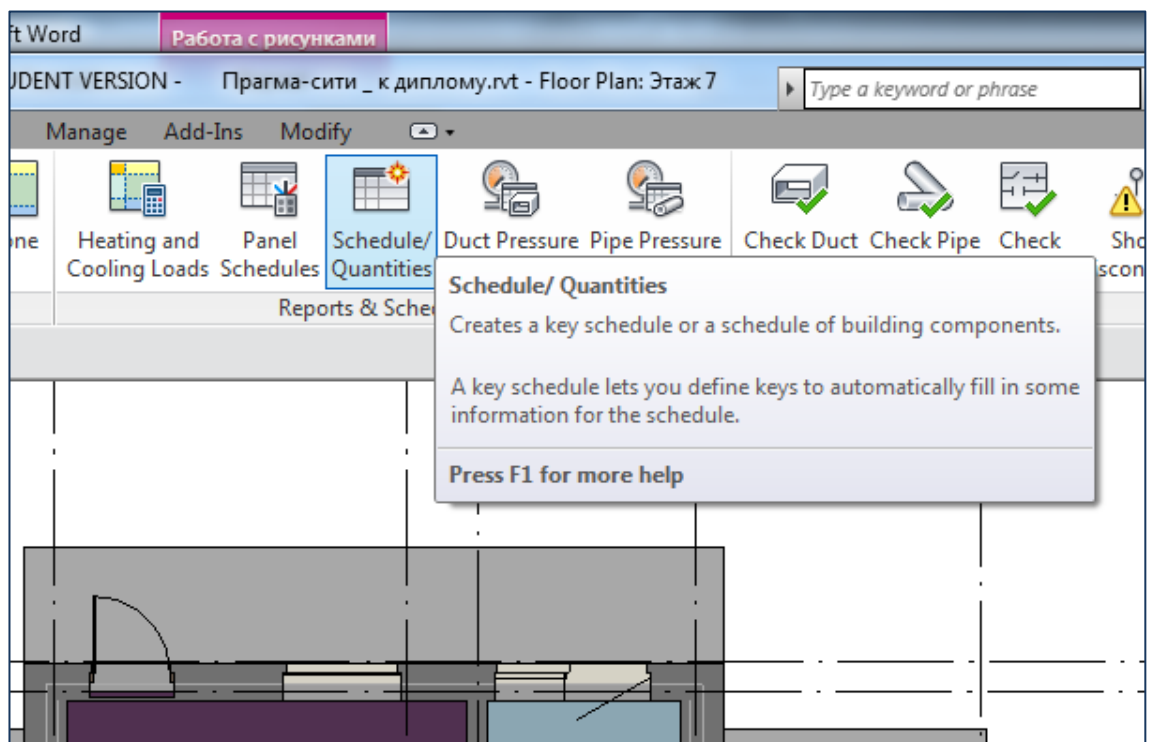


Figure 39. Schedule/Quantities tool

Category Rooms was chosen as the most appropriate variant (see Figure 40).

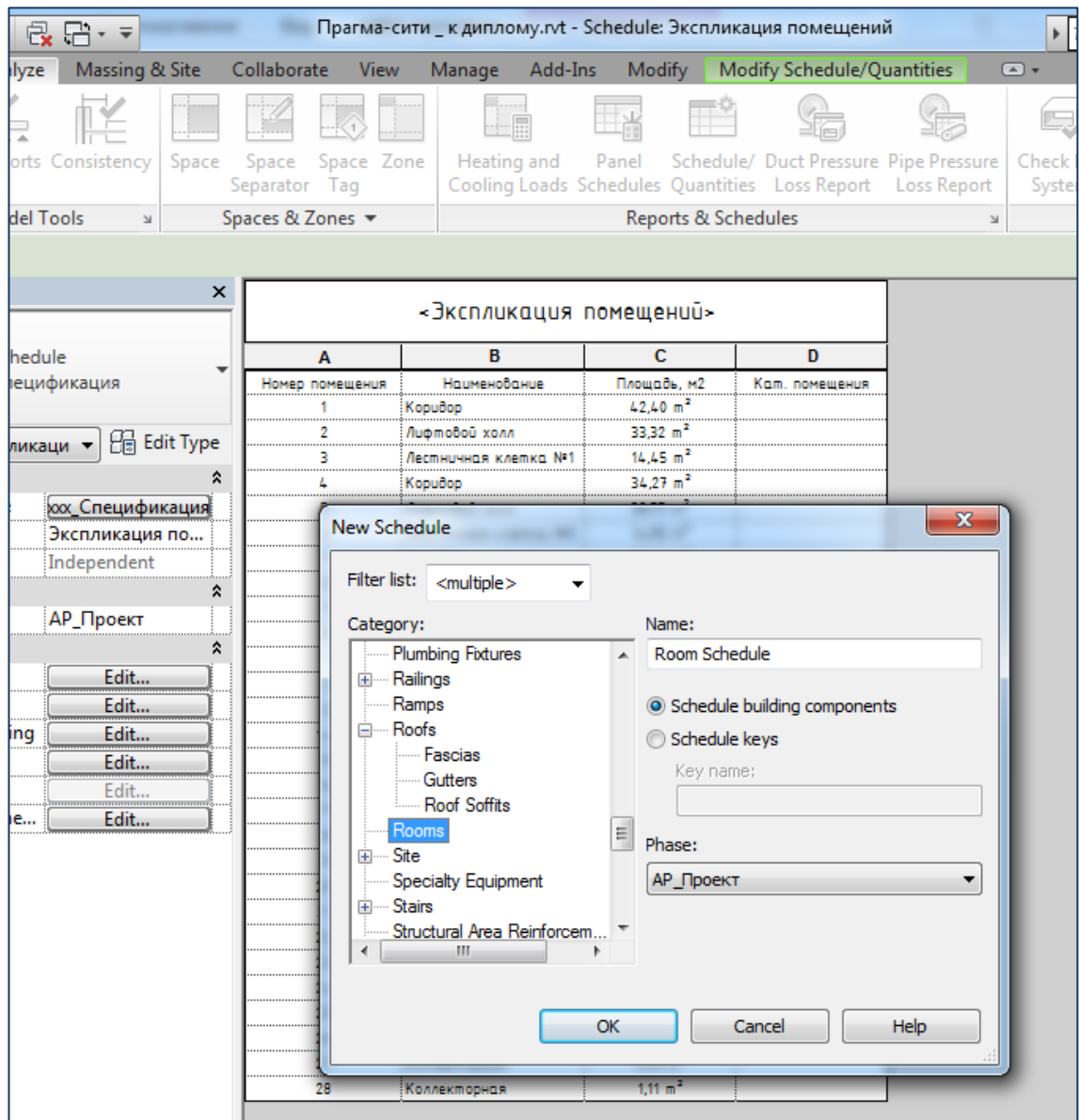


Figure 40. Category Rooms in Schedule/Quantities tool

The following scheduled fields were selected: number, name, area, comments (see Figure 41). The preliminary result is shown in Figure 42.

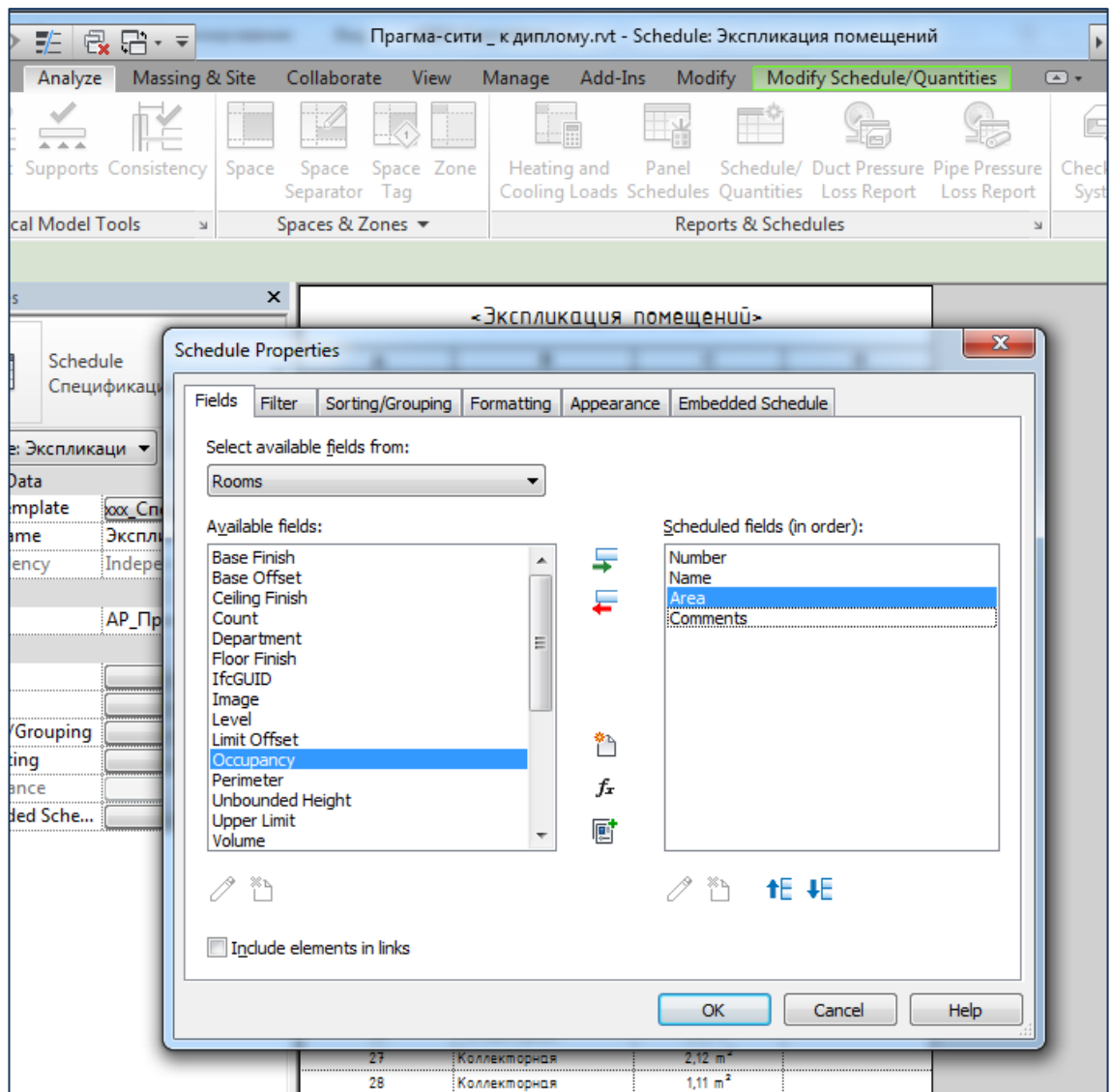


Figure 41. Scheduled fields in Schedule/Quantities tool

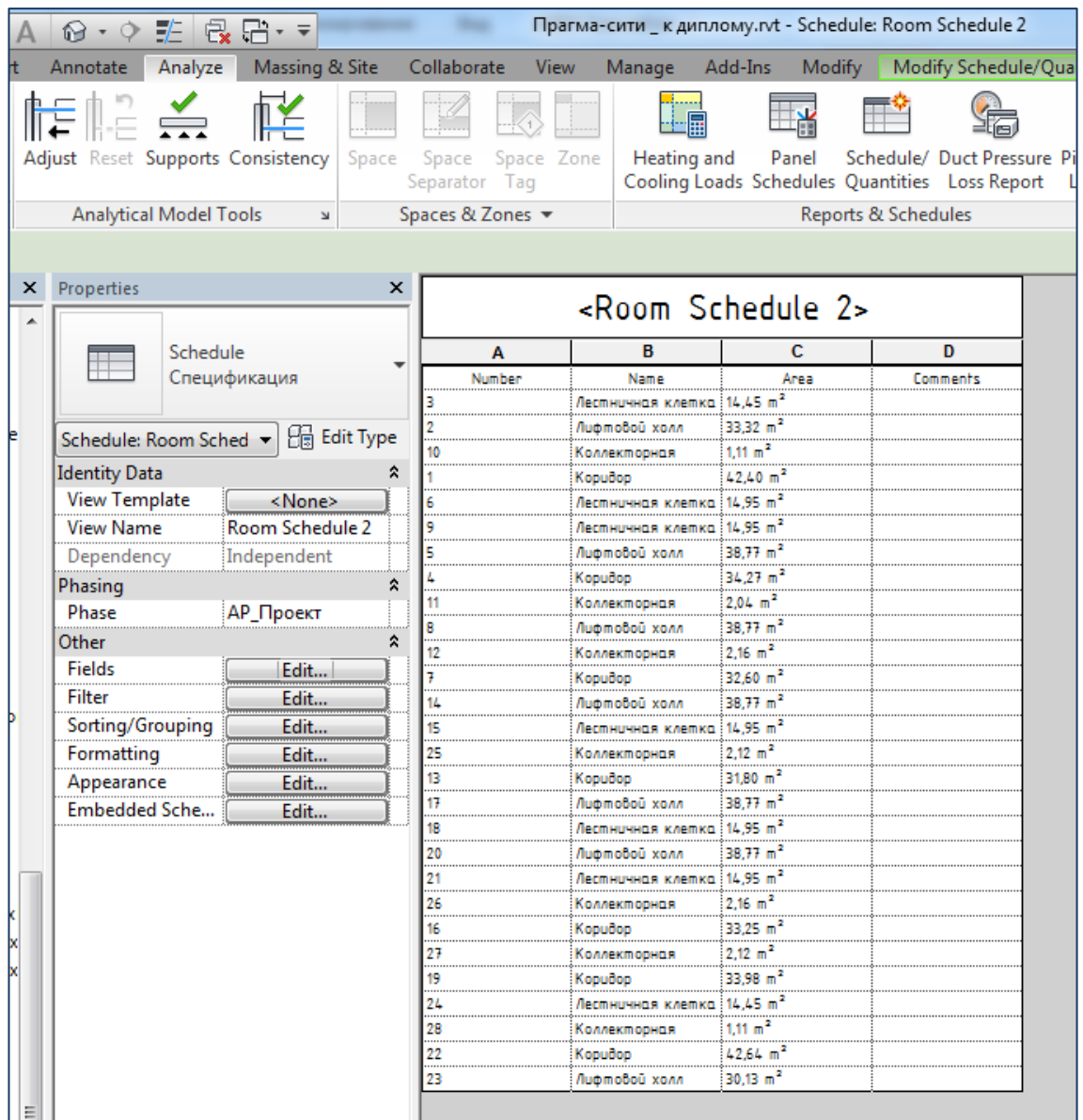


Figure 42. Preliminary result of creating the breakdown of floor premises

To exclude from the list of rooms all the rooms that are not related to Floor 7 and to sort the list the following setup has been done:

- 1) In the list of Scheduled Fields the field Level was included (see Figure 43)
- 2) In the Filter menu the filter by field Level, the value of which is equal to Floor 7, was added (see Figure 44)
- 3) In the Sorting/Grouping menu the sort by ascending numbers was switched on (see Figure 45).
- 4) Column Level was chosen and hidden (see Figure 46)

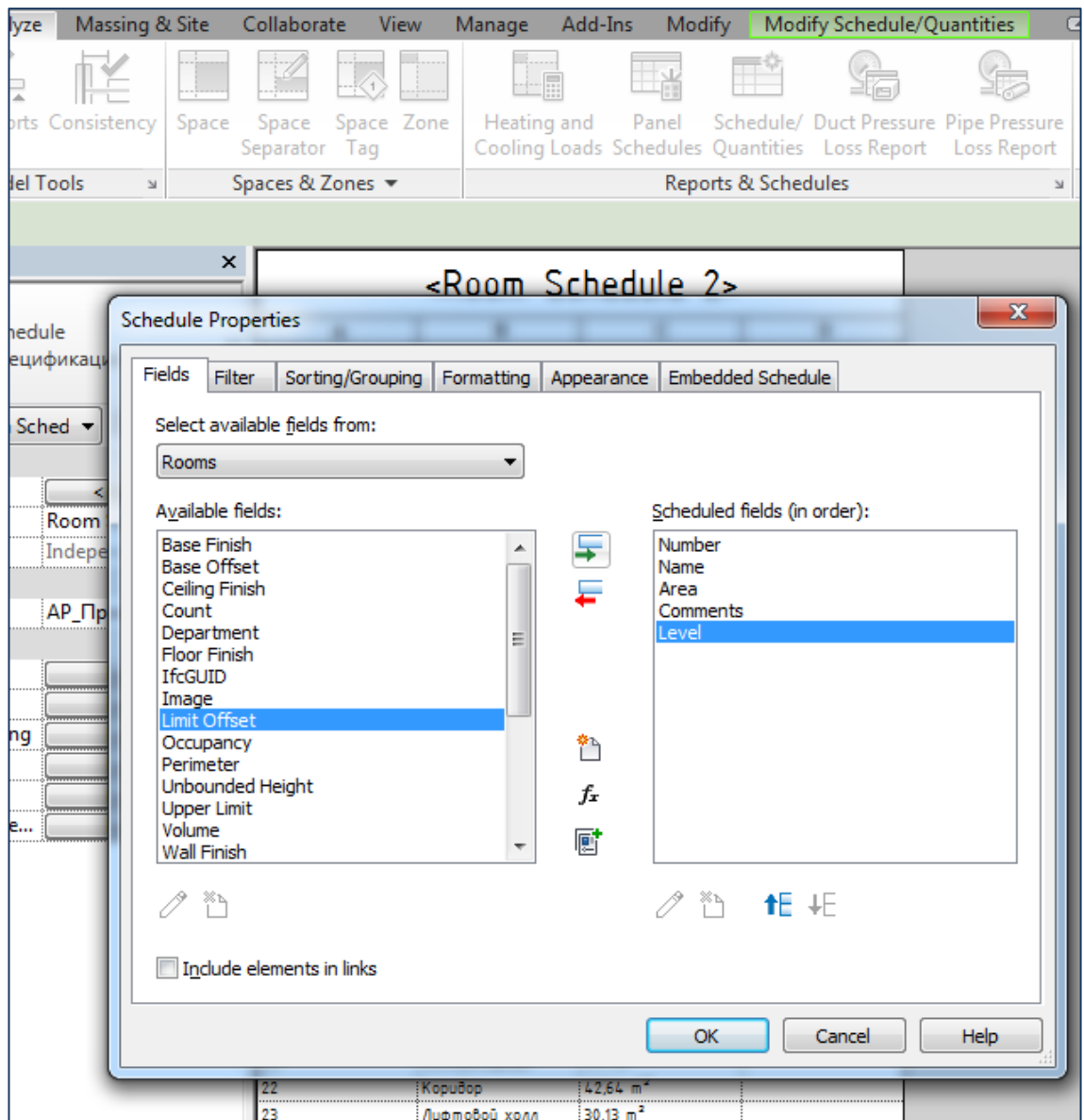


Figure 43. Field Level in the list of Scheduled Fields

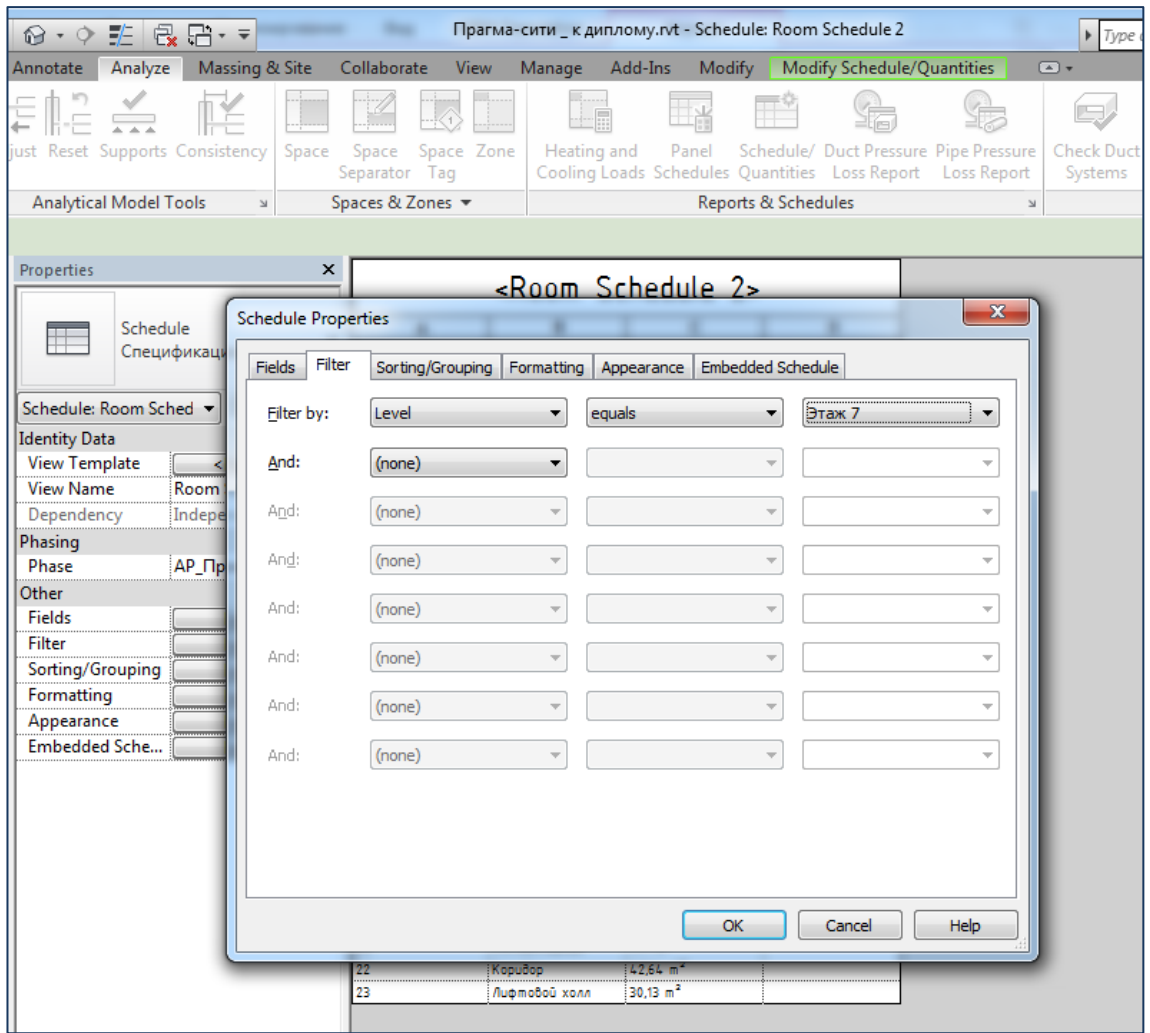


Figure 44. Filter by field Level in Filter menu

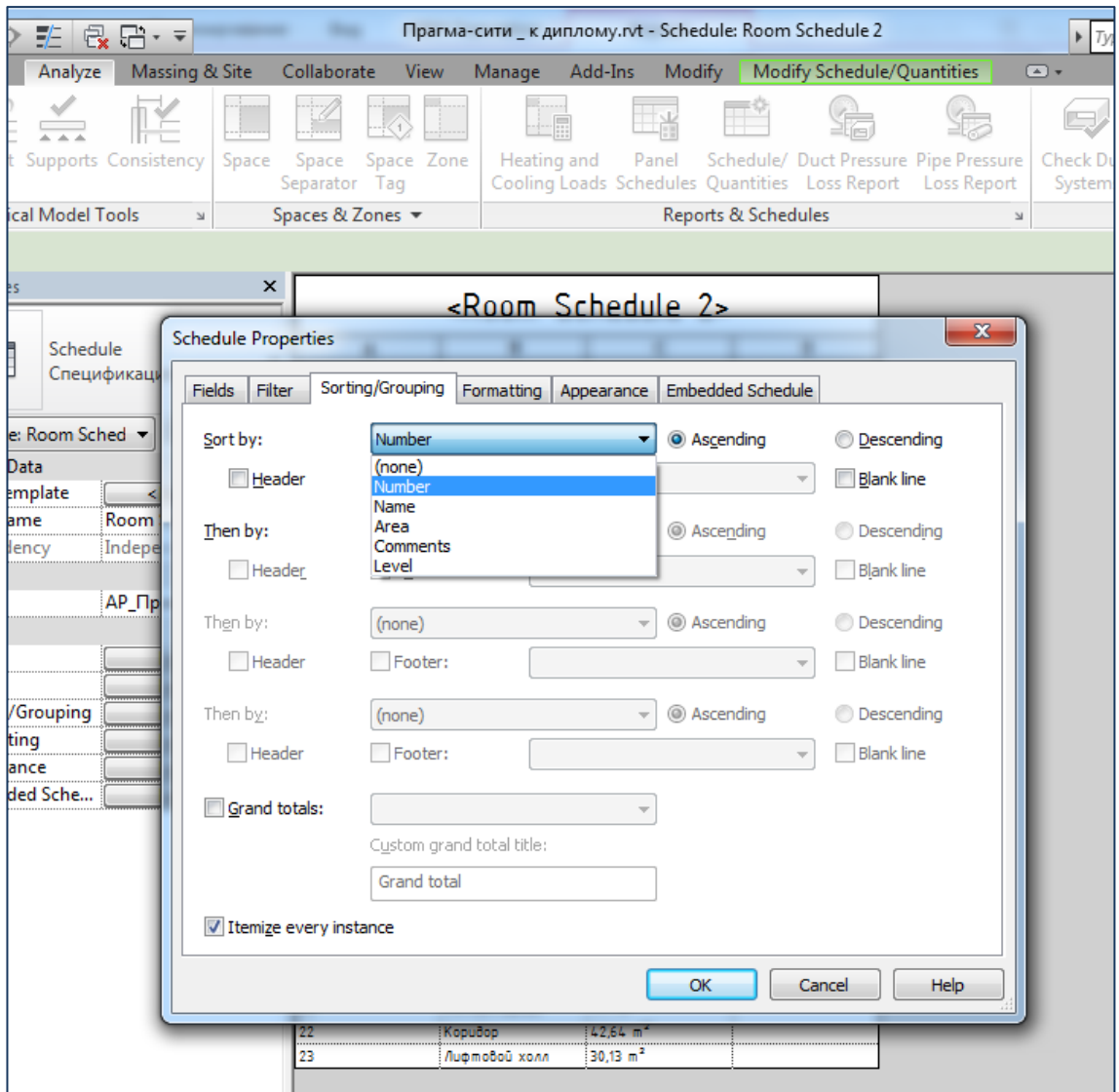


Figure 45. Sort by ascending numbers in Sorting/Grouping menu

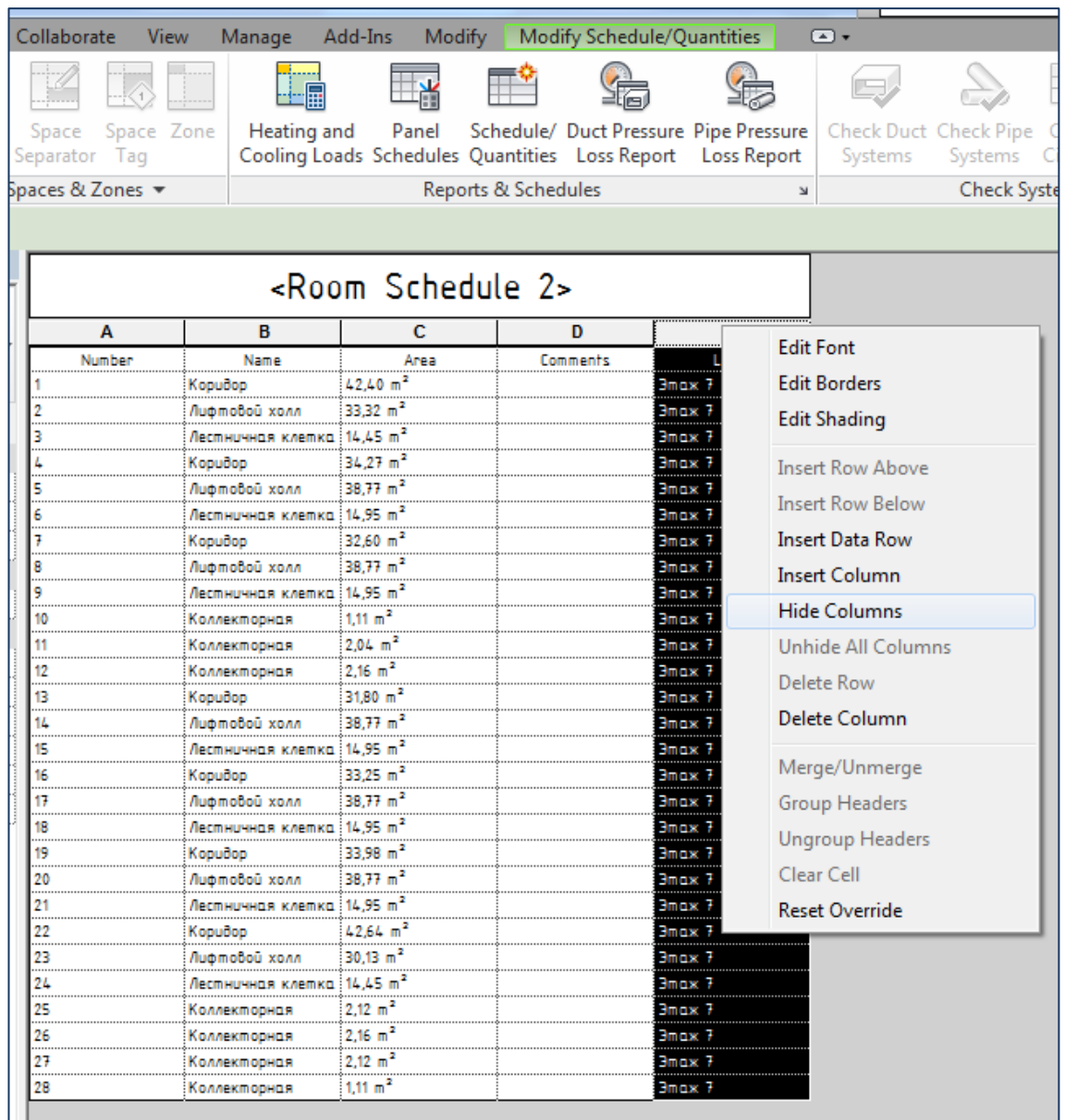


Figure 46. Process of Column Level choosing and hiding

The breakdown of Floor 7 premises performed in AutoCAD is shown in Appendix 9. The breakdown of Floor 7 premises performed in Revit Architecture is shown in Appendix 10.

Resume

The possibility to create the breakdown of floor premises has been confirmed. The values obtained in the Revit coincide with values counted by hand. It confirms the correctness of the implementation of the breakdown of floor premises in both cases.

Creating the breakdown of floor premises in Revit Architecture 2017 is multi-stage, but not time-consuming process.

The problem of creating schedules in Revit Architecture is the appearance of the end schedule which does not meet the requirements. The possibility of adding the summing rows, which summarize the area of only a few rooms, was also not found

However, based on the internet search results, it could be said that the creating of such rows and changing the schedule appearance according to the requirements are possible. Thus, it can be noted that the breakdown of floor premises requires continuous, accurate and skilful adjustment and is not easy to perform.

One of the benefits is the possibility to establish the relationships between the schedule and the model. For example, the schedule is automatically changed if the rooms are renamed, their sizes, marks, attributes changed and in many other cases. At the same time, the model is changed if the schedule is changed. For example, the room can be renamed or deleted in the model directly through the specification.

There is also a convenient search of the rooms from the schedule using Highlight in Model tool (see Figure 47).

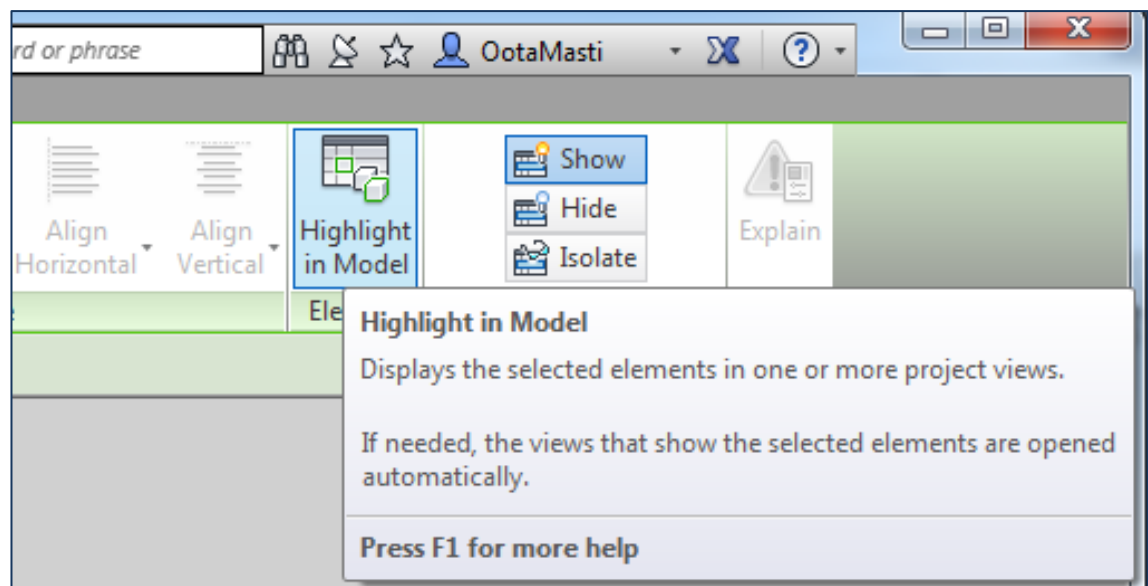


Figure 47. Highlight in Model tool

10.3.7 Design and visualization of an apartment interior

Methods

Interior of a one-room apartment was designed and visualized to assess the possibility of the design and visualization of the apartment interior (see Appendix 11)

Resume

Revit Architecture 2017 has a functionality that provides virtually unlimited opportunities for the creation and visualization of the interiors. However, the creation of furniture and other elements is quite a laborious and time-consuming procedure. The maximum application of built-in library elements, public and private (with paid access) online library elements with further editing and creating their own (developed for Company) library elements is recommended.

10.3.8 Counting the volume of the materials used

Methods

To create a material, Material Takeoff tool (see Figure 48) was used. It was decided to create the wall material list. To do this, the category Wall (see Figure 49) and fields Material: Name, Material: Volume (see Figure 50) were chosen. In the Formatting menu the Calculate totals mode for Material: Volume field was chosen (see Figure 51).

The final Material Takeoff is presented in Figure 52.

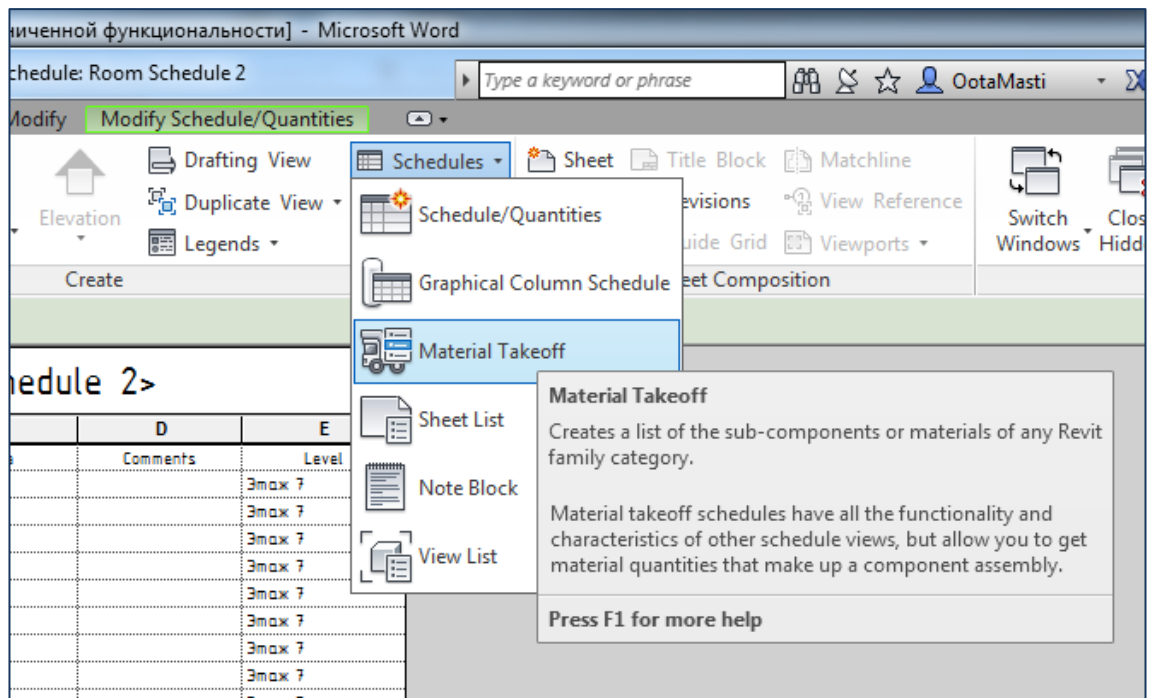


Figure 48. Material Takeoff tool

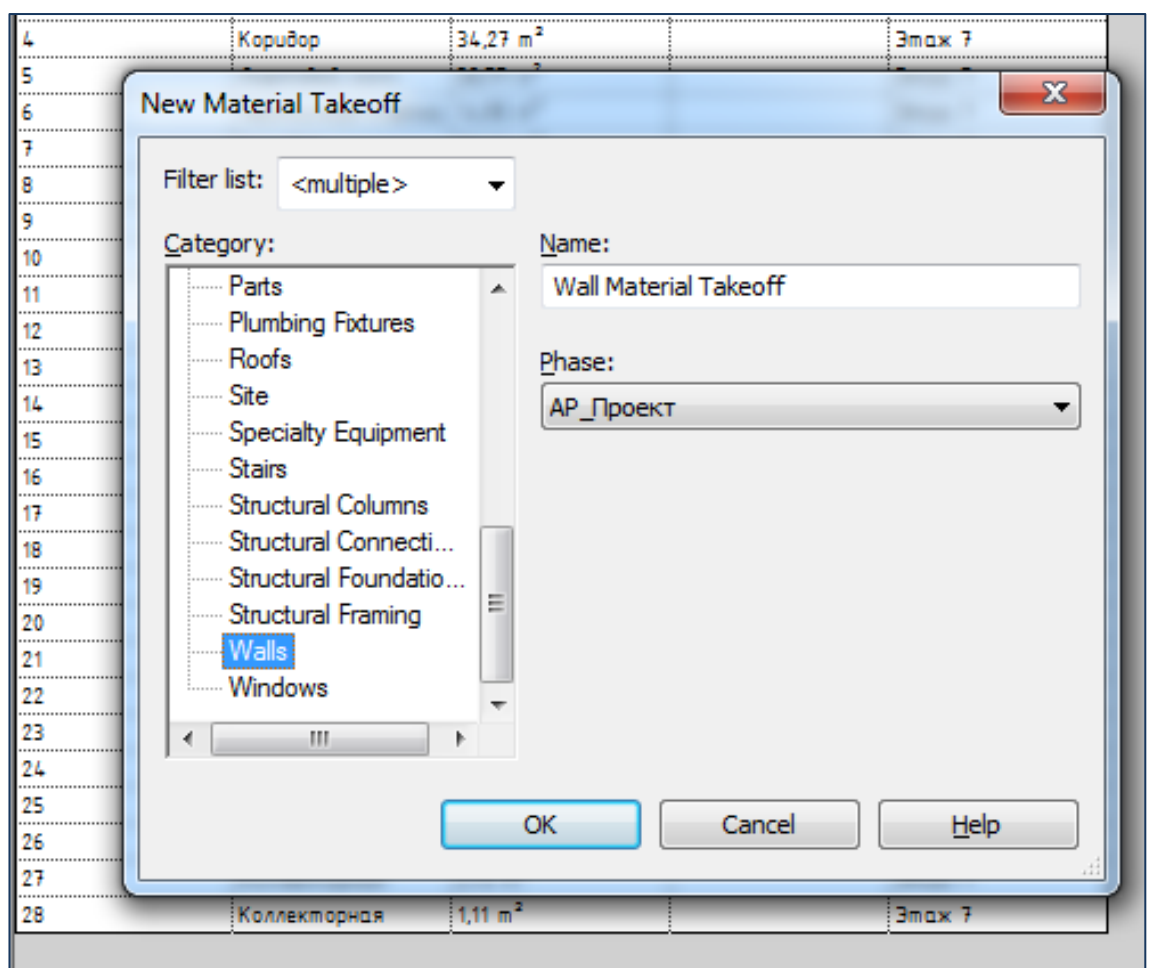


Figure 49. Category Walls in Material Takeoff tool

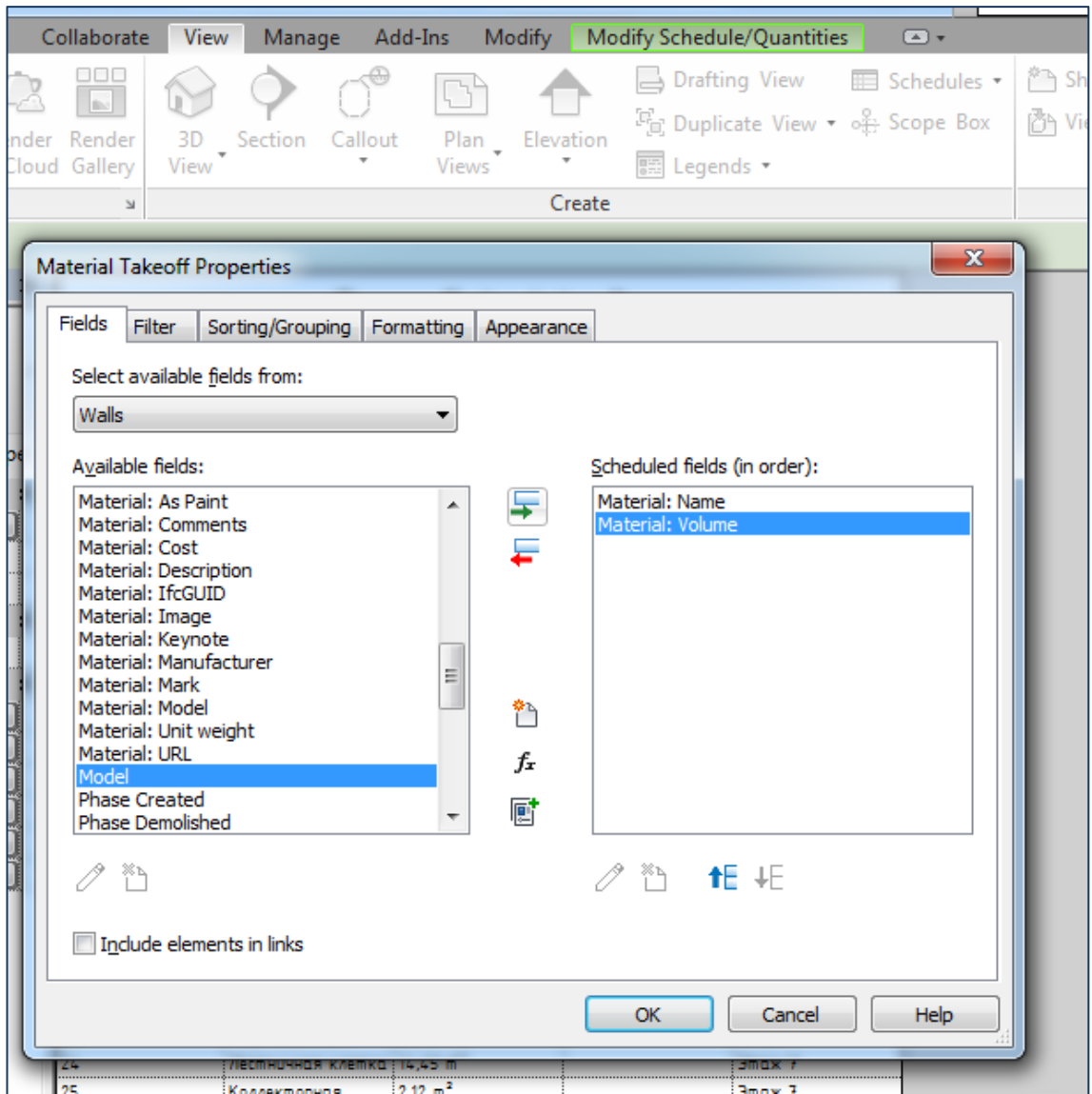


Figure 50. Scheduled fields in Material Takeoff tool

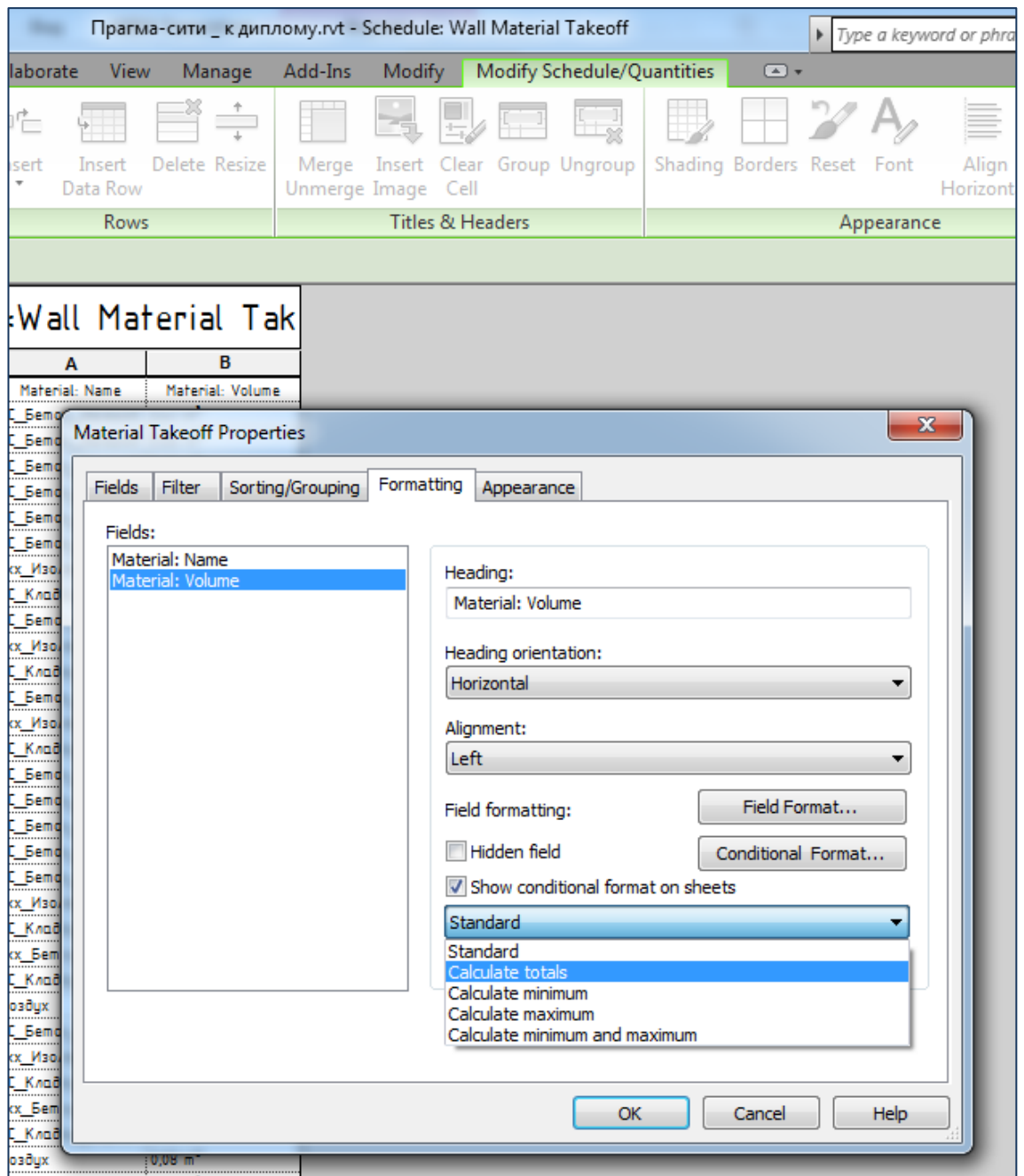


Figure 51. Calculate totals mode in Material Takeoff tool

Wall Material Takeoff	
A	B
Material: Name	Material: Volume
АС_Бетон_Железобетон	11301,55 m ³
АС_Кладка_Кирпич	3208,54 m ³
АС_Стена	1162,90 m ³
xxx_Бетон_Газобетон	5688,98 m ³
xxx_Гипсокартон	2332,48 m ³
xxx_Изоляция_ТепловыеБарьеры	2683,58 m ³

Figure 52. Wall Material Takeoff

Resume

Creating material takeoffs in Revit 2017 is not a problem. However, Paint tool actions are not taken into account by software. To account this feature in material list, the walls from the same material of different colours should be modelled as different types. Paint tool should be used as little as possible.

10.3.9 Assessing of the accuracy of calculating the volume of materials

Methods

To assess the accuracy of calculating the volume of materials it was decided to carry out a check on the accuracy of the simple model (see Figure 53), where the height of the walls is 1 m. For this purpose, the calculation was performed manually and using Revit Architecture 2017.

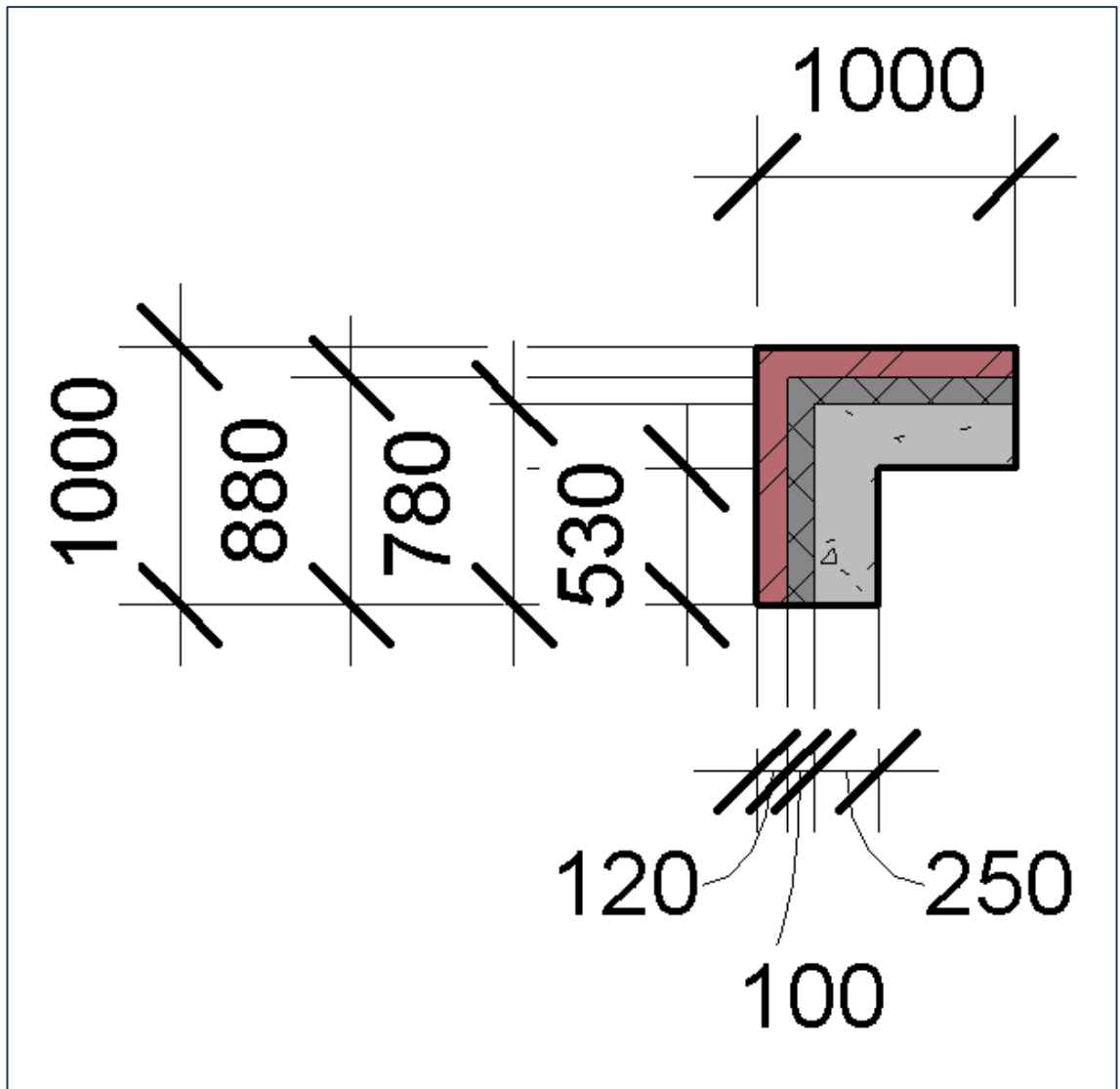


Figure 53. Model for assessing the accuracy of calculating the volume of materials

Manually calculation

As it can be seen from Figure 52, the volume of the materials used will be following:

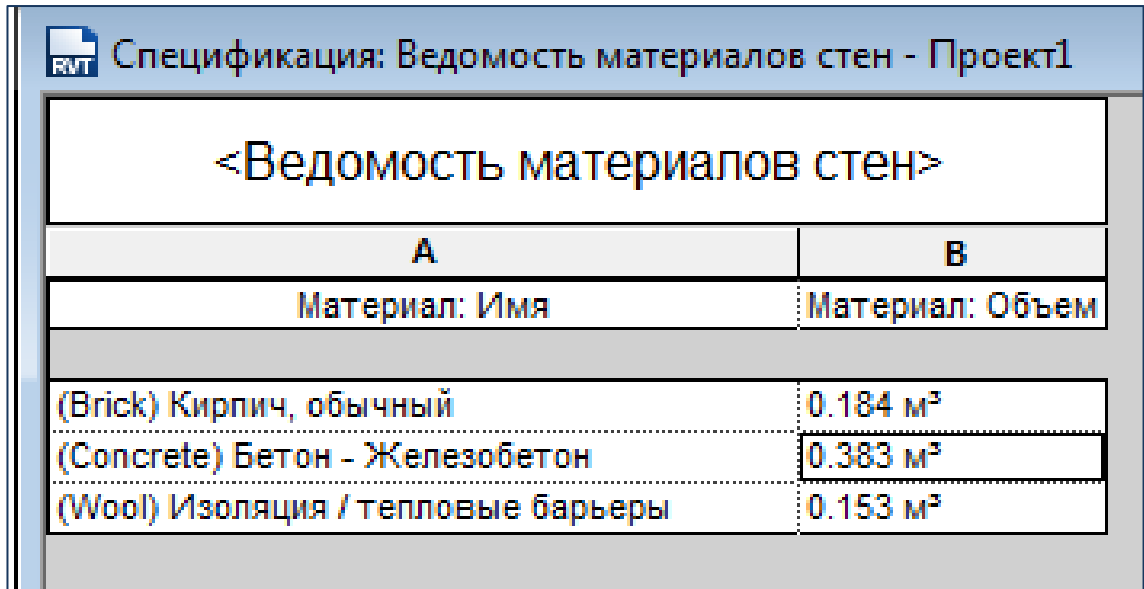
$$V_{brick} = (1 + 0,88) \cdot 0,12 \cdot 1 = 0,2256 \text{ m}^3$$

$$V_{wool} = (0,88 + 0,78) \cdot 0,10 \cdot 1 = 0,1660 \text{ m}^3$$

$$V_{concrete} = (0,78 + 0,53) \cdot 0,25 \cdot 1 = 0,3275 \text{ m}^3$$

Calculation in Revit Architecture

Calculation of the volume of materials is being prepared by Revit Architecture automatically with Material Takeoff tool, as it was mentioned. The result is shown in Figure 54.



Спецификация: Ведомость материалов стен - Проект1	
<Ведомость материалов стен>	
А	В
Материал: Имя	Материал: Объем
(Brick) Кирпич, обычный	0.184 м³
(Concrete) Бетон - Железобетон	0.383 м³
(Wool) Изоляция / тепловые барьеры	0.153 м³

Figure 54. Inaccurate Material Takeoff of the experimental model

It can be seen that the results are not equal.

To avoid this error in calculating is possible using the Wall Joins tool (see Figure 55). The configuration of the joint should be changed from Butt to Miter (see Figure 56). In this case wall join takes the form presented in Figure 57 and Material Takeoff takes the form presented in Figure 58.

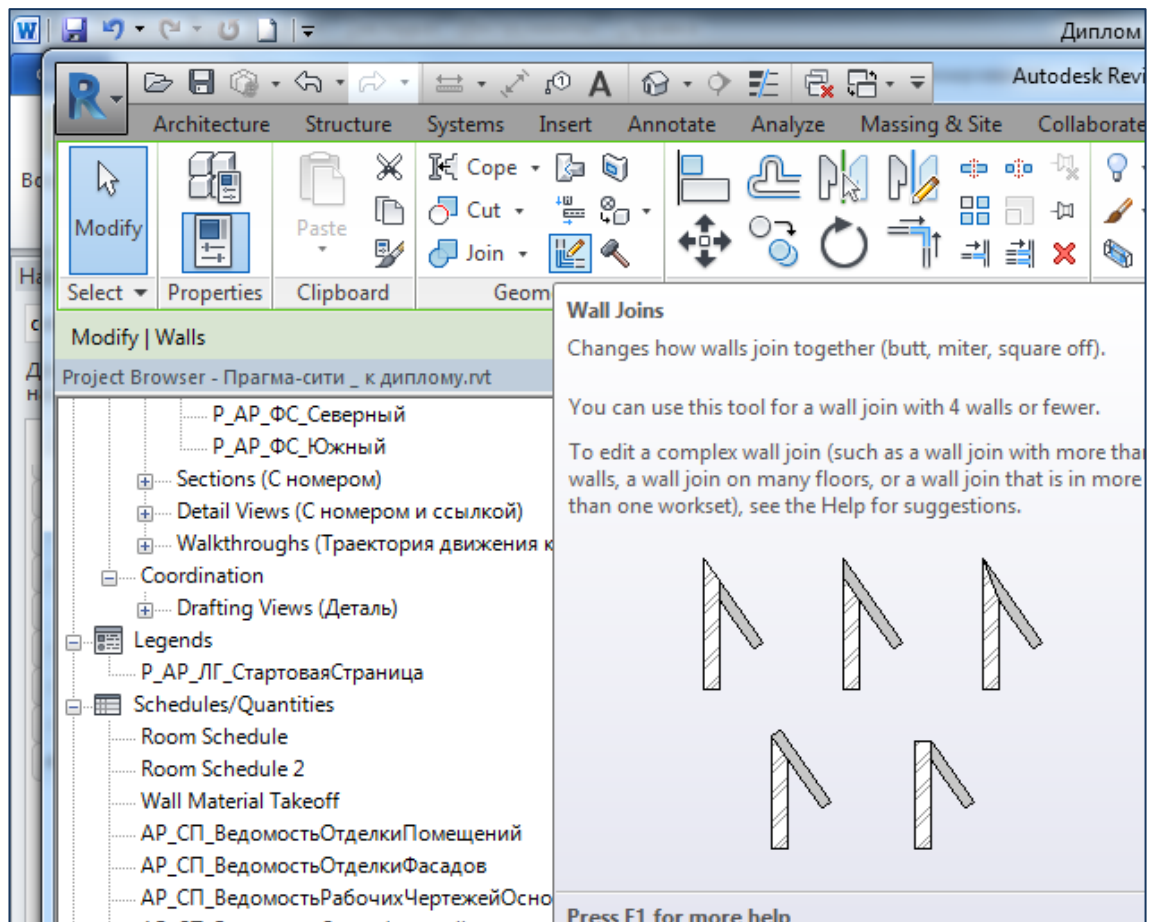


Figure 55. Wall Joins tool

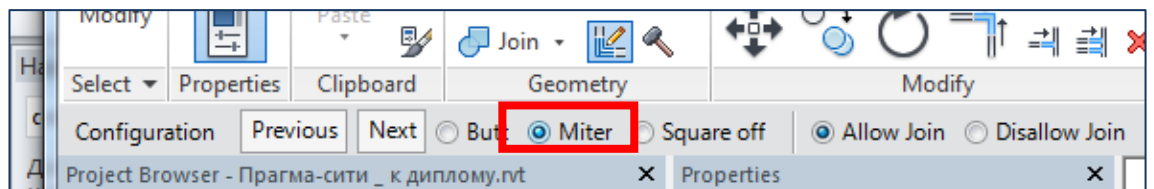


Figure 56. Wall Joins tool settings

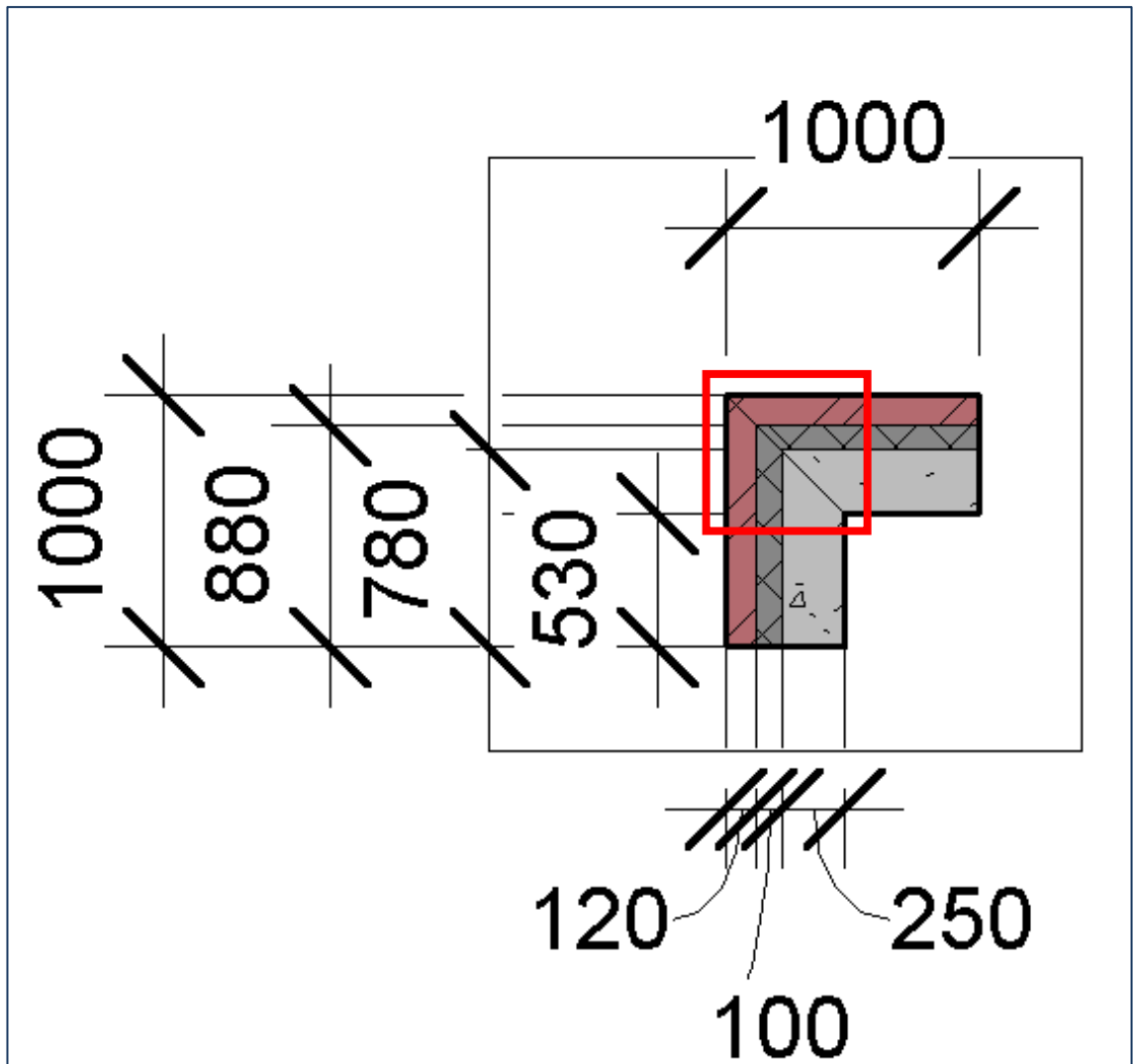


Figure 57. New form of the wall joint

RT Спецификация: Ведомость материалов стен - Проект1

<Ведомость материалов стен>

A	B
Материал: Имя	Материал: Объем
(Brick) Кирпич, обычный	0.226 м³
(Concrete) Бетон - Железобетон	0.328 м³
(Wool) Изоляция / тепловые барьеры	0.166 м³

Figure 58. Accurate Material Takeoff of the experimental model

As it could be seen in Figure 58, the volumes of materials are the same as the volumes, counted manually.

Resume

The accuracy of material volume calculations in Revit Architecture 2017 depends on the degree of maturity of wall and structure joins. This should be taken into account when creating a model that has a lot of complex shapes and multilayer structures. In the case of creating a model consisting of only single-layer structures, counting materials is always accurate. If the multilayer structures have relatively few corners, the inaccuracy of the calculation can be neglected.

10.3.10 Creating windows used specification

Methods

Specification of windows used was performed by analogy and with the same tools as creating the breakdown of floor premises. The result is shown in Figure 59

Спецификация окон				
A	B	C	D	E
1 Марка	2 Высота	3 Ширина	4 Маркировка типа	5 Число
1	2310,00000000	810,00000000	OK49	1250
2	2310,00000000	910,00000000	OK78	518
3	2430,00000000	1100,00000000	OK118	149
4	2310,00000000	910,00000000	OK177	86
5	2010,00000000	1710,00000000	OK46	14
6	2010,00000000	1510,00000000	OK43	47
7	2010,00000000	2110,00000000	OK44	4
8	1645,00000000	1510,00000000	OK96	224
9	1645,00000000	1710,00000000	OK101	406
10	1645,00000000	2110,00000000	OK105	2
11	1145,00000000	1510,00000000	OK153	159

Figure 59. Accurate Material Takeoff of the experimental model. 1 – Mark, 2 – Height, 3 – Width, 4 – Mark of the size type, 5 – Quantity

Resume

Creating the windows used specification in Revit Architecture is the process, which is similar to creating any other schedule or specification. The problem, as with creating the breakdown of floor premises, is editing and bringing the appearance of the specification to the appropriate format.

Creating the windows used specification in Revit Architecture does not allow doing any mistakes in counting. The resulting specification has the relationship to the original model. The model and specification will be changed in the case of making changes in one of them.

10.3.11 Thermal calculations

Methods

In theory, the possibility of making thermal calculations with the Revit Architecture 2017 or Revit MEP 2017 is realized. However, to assess the accuracy of performing such calculations, it was decided to conduct a series of tests.

First test

It was decided to check the correctness of the program counting thermal resistance value. The load-bearing wall thermal resistance was calculated manually, with the special program and with Revit Architecture 2017.

Wall description

Wall type: multilayer, load-bearing (124)

Operating environment: B (125)

Layers (124):

- Layer 1 (internal)
 - Material: reinforced concrete
 - Volume weight: $\rho_0 = 2500 \text{ kg/m}^3$
 - Thermal conduction coefficient: $\lambda = 2.04 \text{ W/(m} \cdot \text{°C)}$
 - Thermal absorption coefficient: $S = 18.95 \text{ W/(m} \cdot \text{°C)}$

- Specific heat capacity: $c_0 = 0,84 \text{ kJ}/(\text{kg} \cdot ^\circ\text{C})$
- Thickness: $\delta_1 = 250 \text{ mm}$
- Layer 2 (126)
 - Material: ROCKWOOL FACADE BATTS
 - Volume weight: $\rho_0 = 145 \text{ kg}/\text{m}^3$
 - Thermal conduction coefficient: $\lambda = 0.042 \text{ W}/(\text{m} \cdot ^\circ\text{C})$
 - Thermal absorption coefficient: $S = 0.75 \text{ W}/(\text{m} \cdot ^\circ\text{C})$
 - Specific heat capacity: $c_0 = 0,84 \text{ kJ}/(\text{kg} \cdot ^\circ\text{C})$
 - Thickness: $\delta_1 = 160 \text{ mm}$
- Layer 3 (external)
 - Material: ceramic facade brick M400, F75
 - Volume weight: $\rho_0 = 1200 \text{ kg}/\text{m}^3$
 - Thermal conduction coefficient: $\lambda = 0.52 \text{ W}/(\text{m} \cdot ^\circ\text{C})$
 - Thermal absorption coefficient: $S = 6.62 \text{ W}/(\text{m} \cdot ^\circ\text{C})$
 - Specific heat capacity: $c_0 = 0,88 \text{ kJ}/(\text{kg} \cdot ^\circ\text{C})$
 - Thickness: $\delta_1 = 120 \text{ mm}$

Manual calculation

One of the standardized values according to (125) is the thermal resistance of the individual structures defined by Formula 1.

$$R_0 = \frac{1}{\alpha_{in}} + \sum_l R_l + \frac{1}{\alpha_{out}} \quad (1)$$

Wherein: R_0 – total thermal resistance of the structure

R_l – thermal resistance of the structure layer in $(\text{m}^2 \cdot ^\circ\text{C})/\text{W}$

α_{in} – heat transfer coefficient of the inner surface of the building envelope in $\text{W}/(\text{m}^2 \cdot ^\circ\text{C})$

α_{out} – heat transfer coefficient of the outer surface of the building envelope in $\text{W}/(\text{m}^2 \cdot ^\circ\text{C})$

Thermal resistance of the structure layer defined by Formula 2.

$$R_l = \frac{\delta_l}{\lambda_l} \quad (2)$$

Then:

$$R_1 = 0,12 (m^2 \cdot ^\circ C)/W$$

$$R_2 = 3,81 (m^2 \cdot ^\circ C)/W$$

$$R_3 = 0,23 (m^2 \cdot ^\circ C)/W$$

$$\sum_l R_l = 4,16 (m^2 \cdot ^\circ C)/W$$

$$\alpha_{ex} = 23 W/(m^2 \cdot ^\circ C)$$

$$\alpha_{out} = 8,7 W/(m^2 \cdot ^\circ C)$$

$$R_0 = 4,32 (m^2 \cdot ^\circ C)/W$$

Calculation by the special program

The program Thermal Protection written in MS Excel for the students of Peter the Great St. Petersburg Polytechnic University has been selected for this test.

The result of the calculation in this program is the same as the results of the manual calculation (see Figure 60).

Критерий 1: Безопасность тепл						
Таблица 1.9						
Сравнение расчетов с требованием СНиП						
А Б	Стены при параметрах А и Б			Потолки при параметрах А и Б		
	R_{0a}	R_{0b}	R_{ϕ}	R_{0a}	R_{0b}	R_{ϕ}
	кв.м К/Вт	кв.м К/Вт	кв.м К/Вт	кв.м К/Вт	кв.м К/Вт	кв.м К/Вт
728	0,804598	0,51724	4,321263	1,086207	0,698276	3,2556075
Справка:						
1.	R_{0a}	нормативное термическое сопротивление огражд				
	R_{0b}	нормативное термическое сопротивление огражд				
	R_{ϕ}	фактическое термическое сопротивление огражд				
2.	Перепад температуры между внутренней стенкой огражден					
	воздухом принят в соответствии с СНиП 2.04.05-86					

Figure 60. Result of calculating the thermal resistance of the wall using Thermal Protection

Calculation using Revit Architecture 2017

The thickness of layers and material types has been set in Revit Architecture (see Figure 61). Thermal characteristics were added to the materials and corrected (see Figure 62). The total value of thermal resistance is shown in Figure 63.

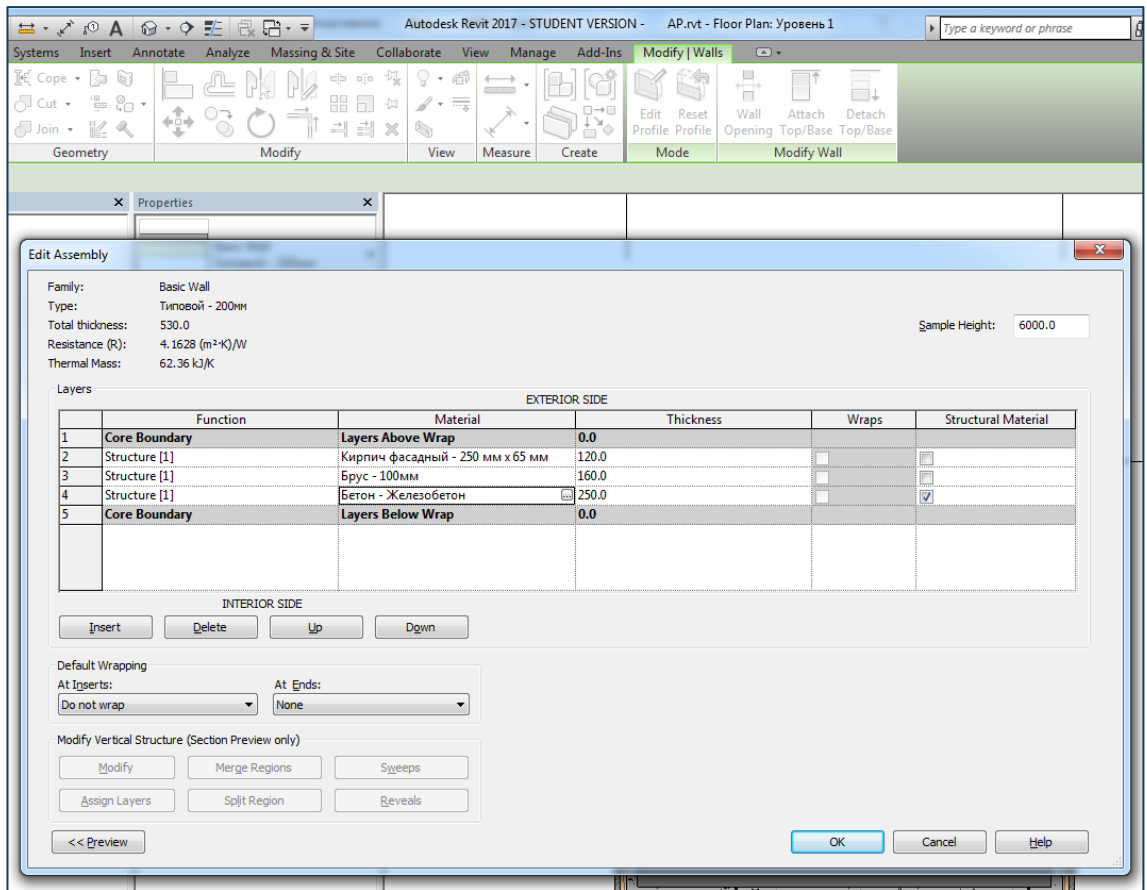


Figure 61. Thickness of layers and material types of the calculated structure

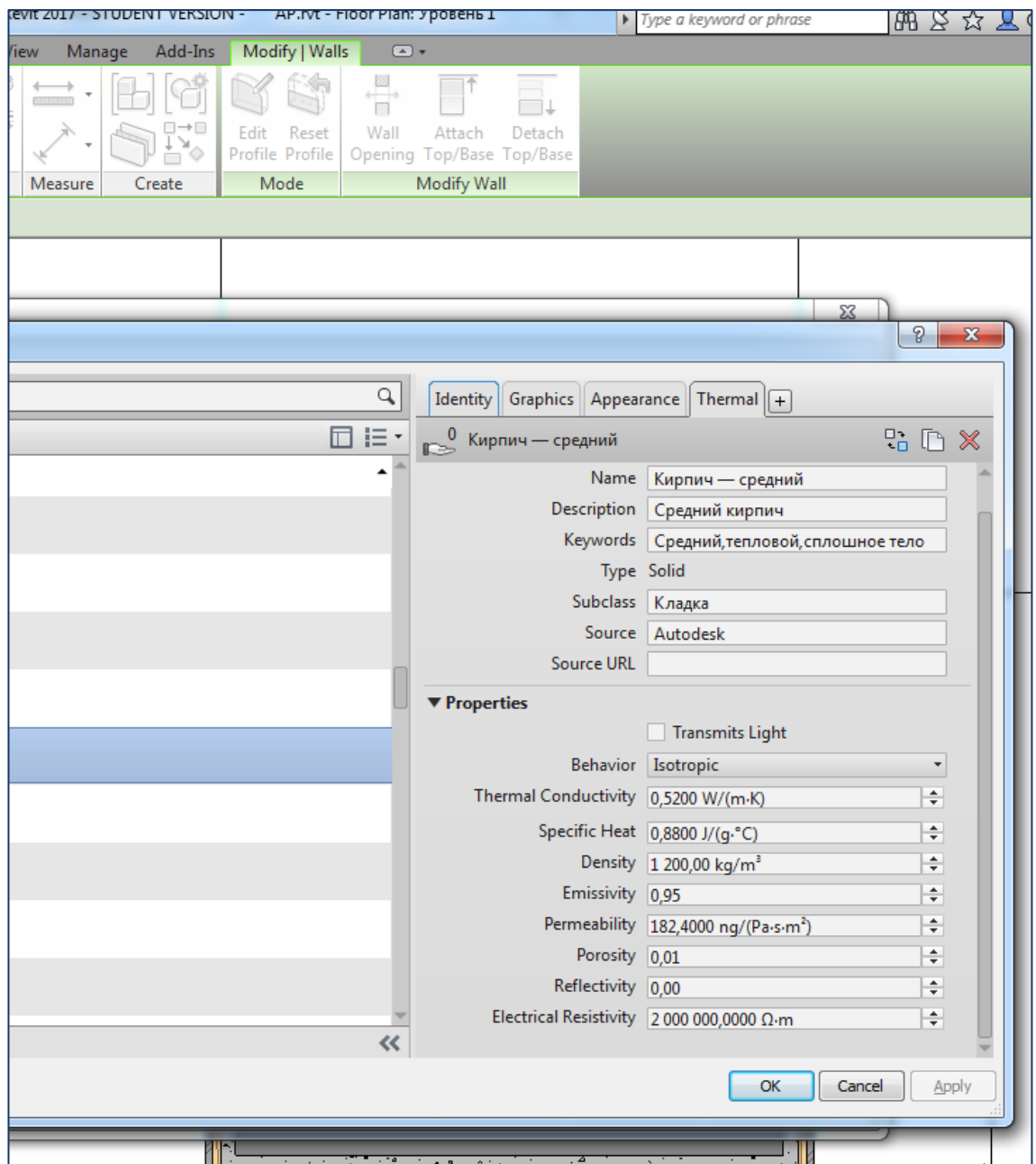


Figure 62. Thermal characteristics of the layers

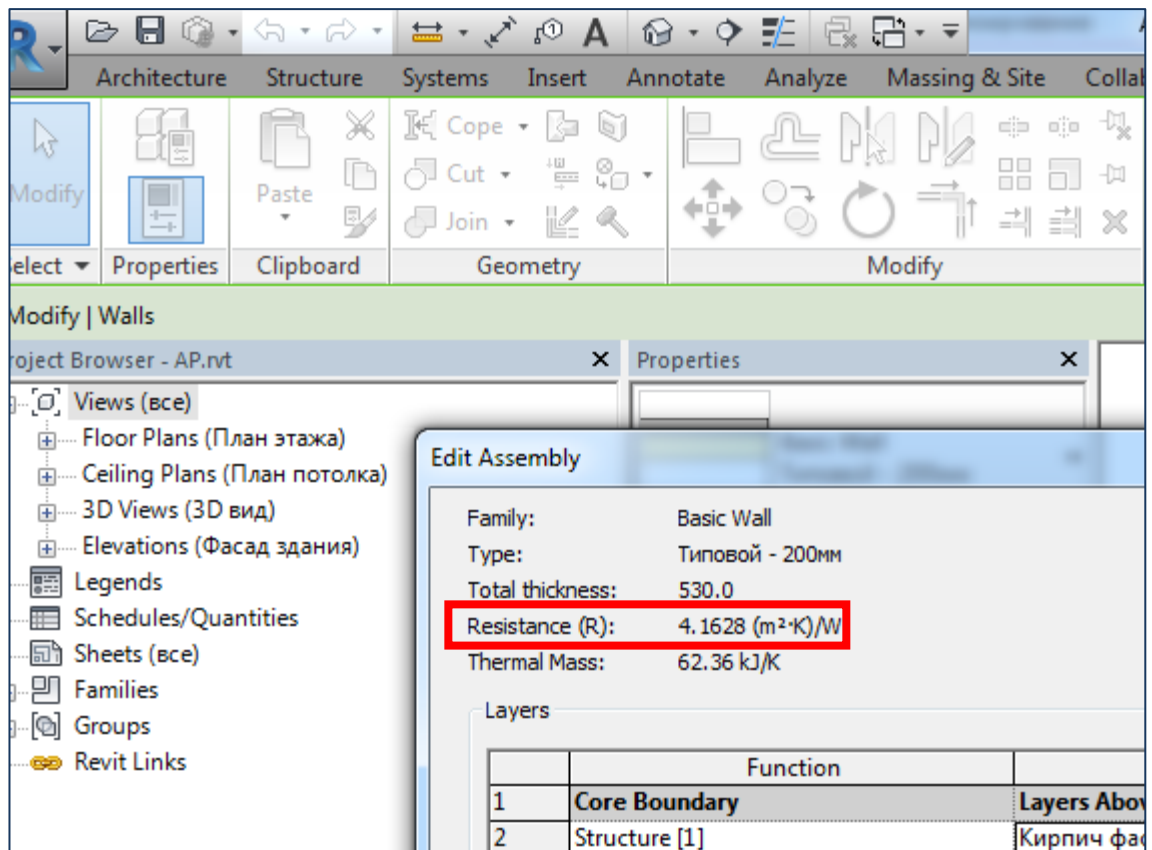


Figure 63. Total value of thermal resistance calculated by Revit Architecture 2017

This result coincides with the value of thermal resistance, resulting in the case of ignoring the heat transfer coefficients of the inner and outer surfaces. Thus, it can be noted that Revit Architecture 2017 ignores them.

Second test

It was decided to check the correctness of the heat loss value calculated by Revit MEP 2017. For this purpose the total heat loss of the simple model is shown in Figure 64. There is one floor with 3.3 m height.

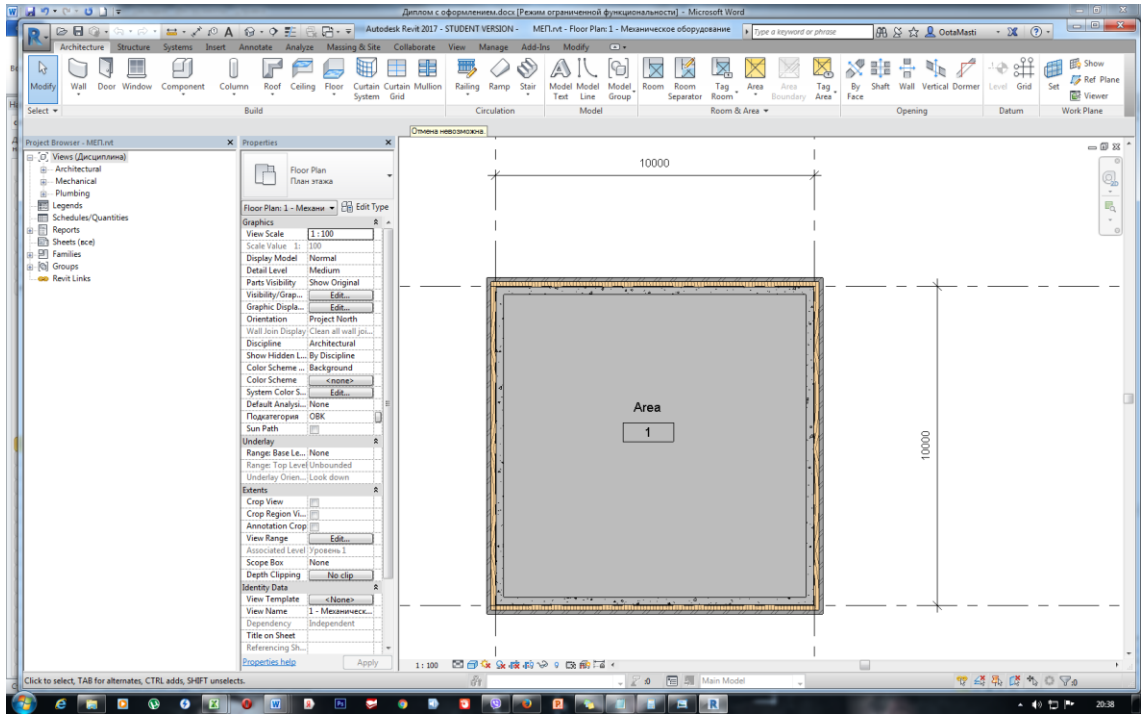


Figure 64. Model tested during the heat loss calculations

Calculation by the special program

The program Thermal Protection has been selected for this test. The heat transfer coefficients of the inner and outer surfaces were not taken into account intentionally.

The result of the calculation is shown in Figure 65.

	0	Стены	Окна	Пол	Потолок	Инфилтр.	Общие
Всего(Вт):	999	0	51408	51408		0	103815
Всего(кВт):	1	0	51	51		0	104
В % от общих	1%	0%	50%	50%		0%	100,00%

Figure 65. Result of heat loss calculation by Thermal Protection

As it can be seen in Figure 65, the total heat loss amounted to 103815 W, 50% of which had been lost through the floor (it is assumed that the building has an open basement).

Calculation by Revit MEP 2017

The model of the calculated building was modelled In Revit MEP 2017 (see Figure 64). The calculation was performed using Heating and Cooling Loads tool (see Figure 66)

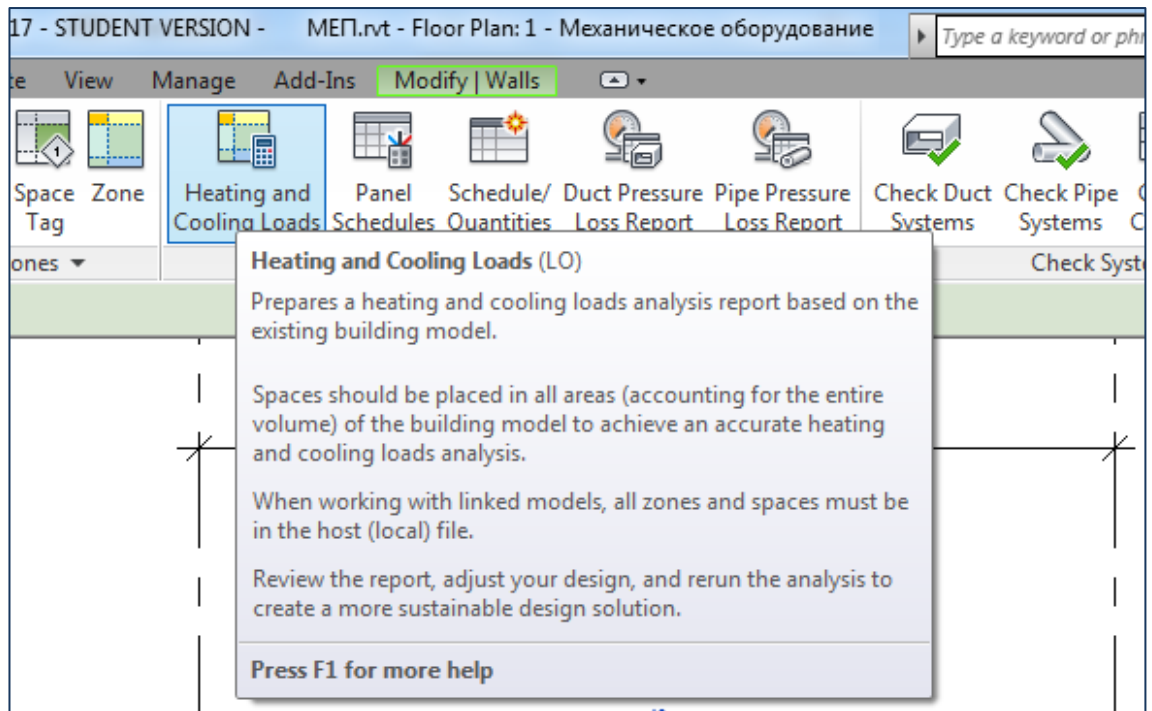


Figure 66. Heating and Cooling Loads tool

The calculated space and the elements of the analytical model are well defined (see Figure 67). The result of the calculation is shown in Figure 68

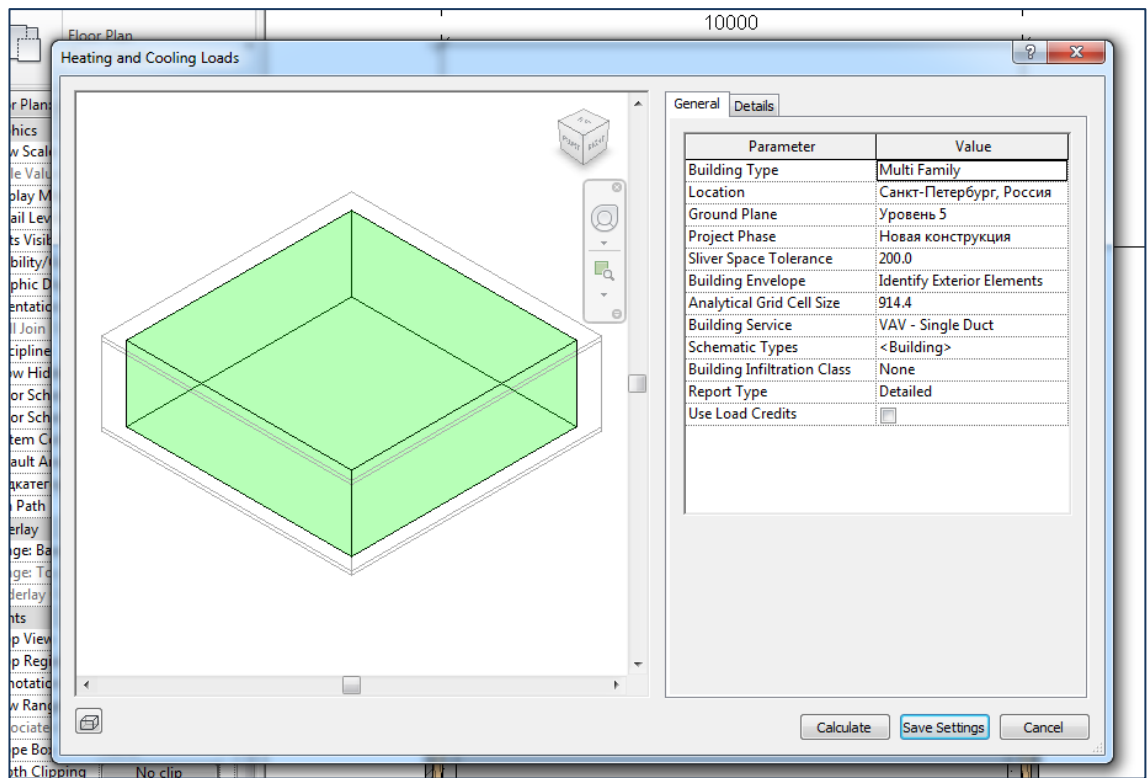


Figure 67. Analytical model of the heat loss calculation

Peak Cooling Sensible Load (W)			
Peak Cooling Latent Load (W)			
Peak Cooling Airflow (L/s)			
Peak Heating Load (W)			
Peak Heating Airflow (L/s)			
Cooling Components			
	Total (W)	Percentage	North (W)
Wall	117	0.37%	
Window	0	0.00%	
Door	0	0.00%	
Roof	31,020	99.63%	
Skylight	0	0.00%	
Partition	0	0.00%	
Infiltration	0	0.00%	
Lighting	0	0.00%	
Power	0	0.00%	
People	0	0.00%	
Plenum	0	0.00%	
Total	31,136	100%	
Heating Components			
	Total (W)	Percentage	North (W)
Wall	1,002	2.28%	25
Window	0	0.00%	
Door	0	0.00%	
Roof	42,991	97.72%	
Partition	0	0.00%	
Skylight	0	0.00%	
Infiltration	0	0.00%	
Total	43,993	100%	25

Figure 68. Result of heat loss calculation by Revit MEP 2017

As it can be seen in Figure 68, the total heat loss amounted to 43993 and the heat loss through the floor was not taken into account.

Resume

Heating and Cooling Loads tool is realized in Revit 2017. However, this feature does not work properly: does not take into account the heat transfer coefficients of the inner and outer surfaces and heat loss through the basement. The differ-

ences in results of heat loss values for walls and roof could not be explained. The calculation is not clear enough.

Using the Revit 2017 as a tool for thermal calculations is not recommended.

10.3.12 Export of an architectural model to Revit Structure and Revit MEP

Methods

In order to assess in this case it was decided to use Autodesk Revit Basic Sample Project.

Export of the Architectural model is provided using Link Revit tool (see Figure 69). To do this, a new project (MEP or Structure) should be created. Then it should be linked with Architectural project using Link Revit tool. The link between the projects will be displayed in Manage Links (see Figure 70). Also, through the Project Manager it is always possible to reload the model (see Figure 71).

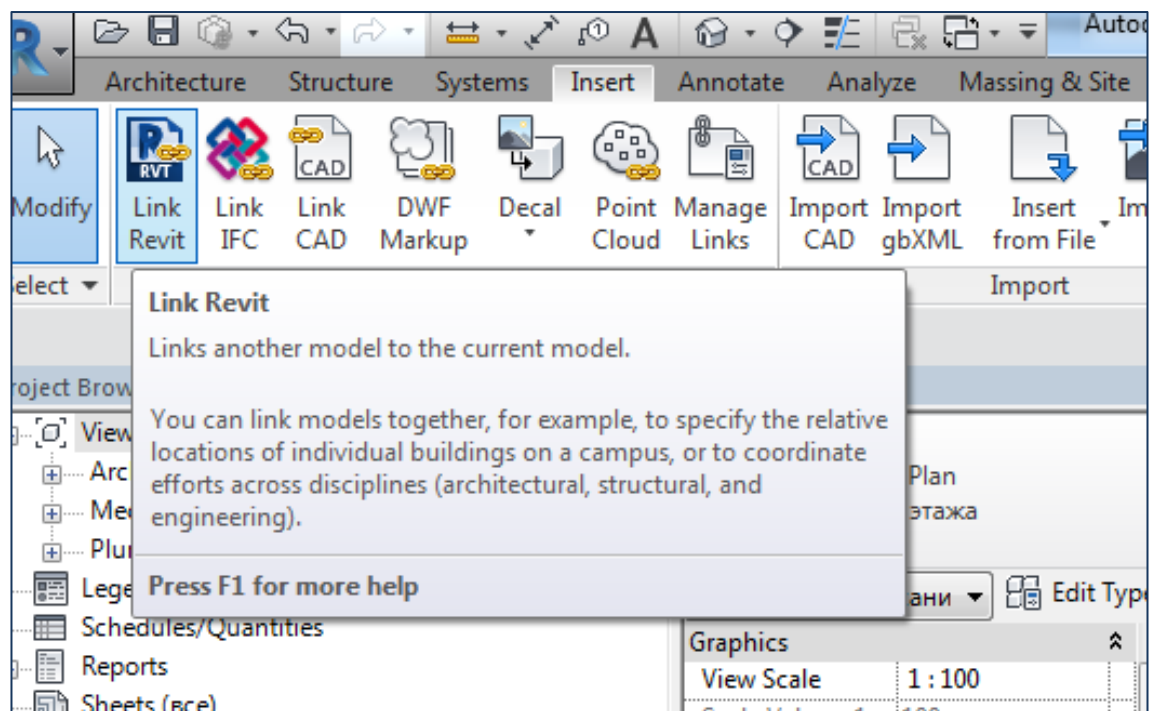


Figure 69. Link Revit tool

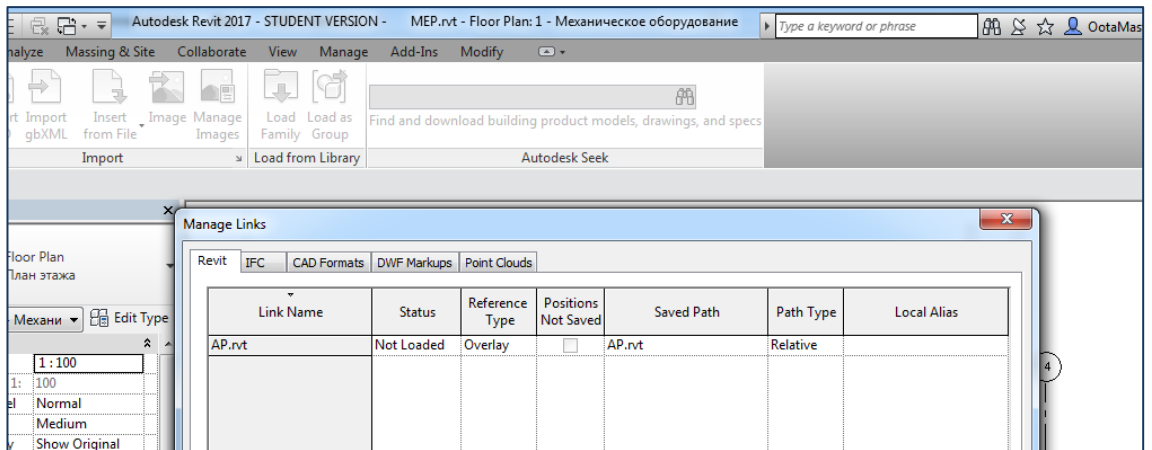


Figure 70. Manage Links tool

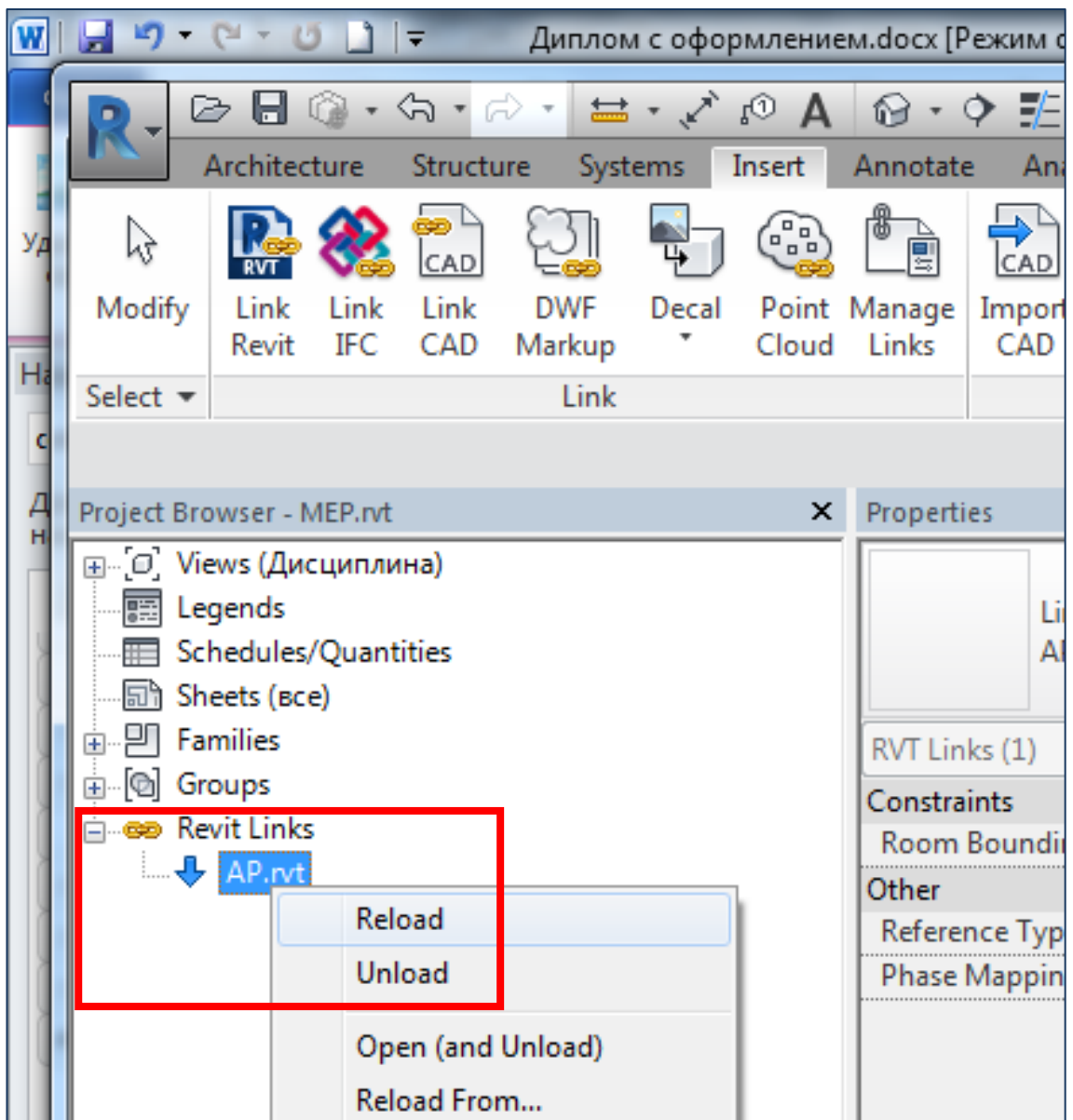


Figure 71. Project Browser tool

Architectural, Structural and MEP models are shown in Figures 72-74, respectively.

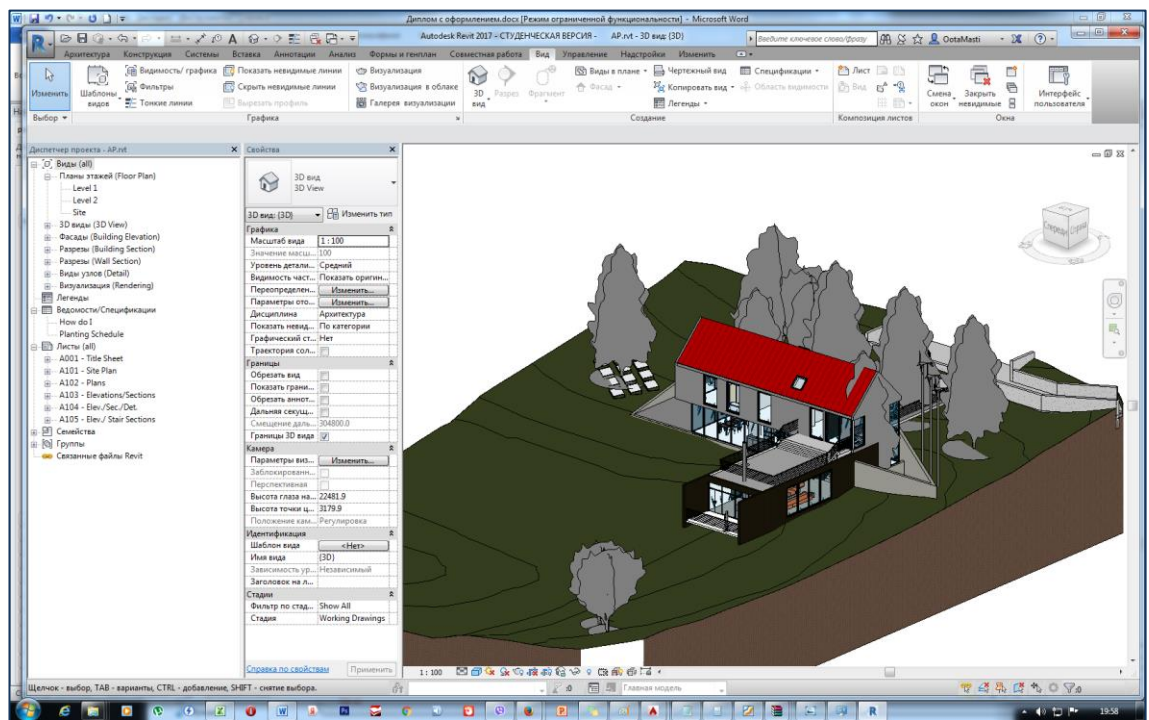


Figure 72. Architectural model

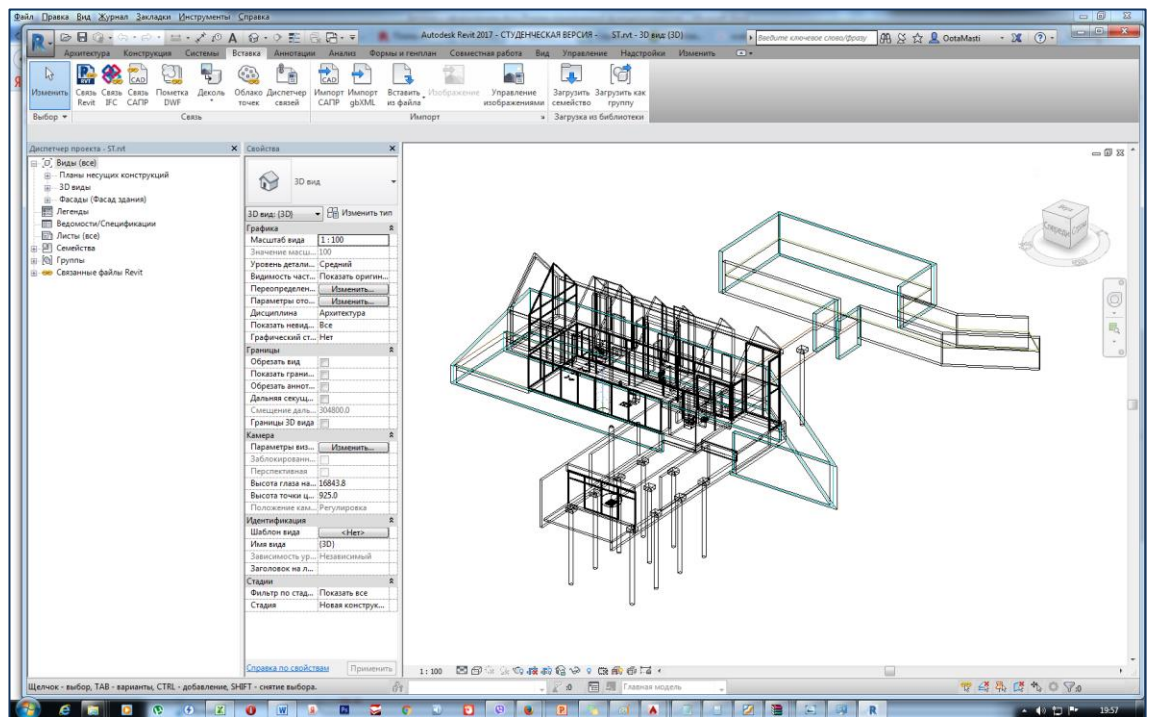


Figure 73. Structural model

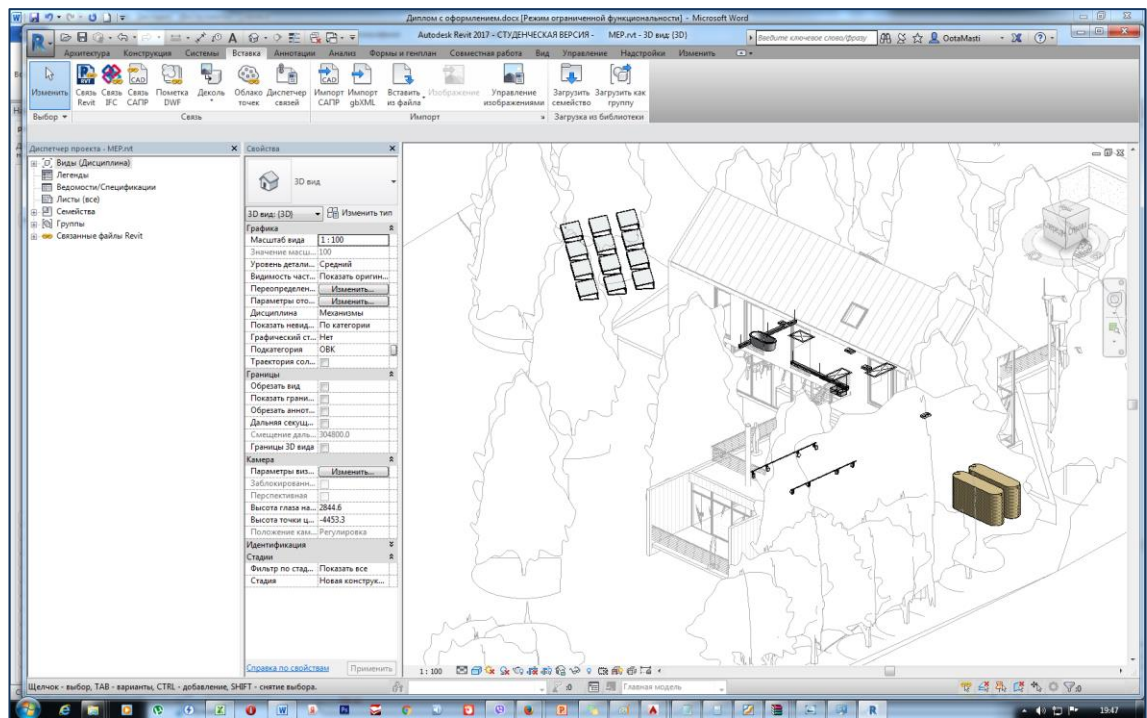


Figure 74. MEP model

Resume

Creation of unified project environment, which includes different disciplines (architecture, structure, networks), is possible using Revit 2017.

10.3.13 Export of structural model to the calculating software

Methods

In order to assess in this case it was decided to use Autodesk Revit Basic Sample Project.

To assess the possibility to import models into the program for the calculation, SCAD Office was chosen as the most widely used software in Russia. The previous version of SCAD Office (version 11.5) did not support any BIM model files, but in the latest version (version 21.1) this function is implemented.

To export a model from Revit 2017 to SCAD Office 21.1 the creation of *.ifc file is needed (see Figure 75) and then import this file into the SCAD Office (Figure 76). The result of the import is shown in Figure 77.

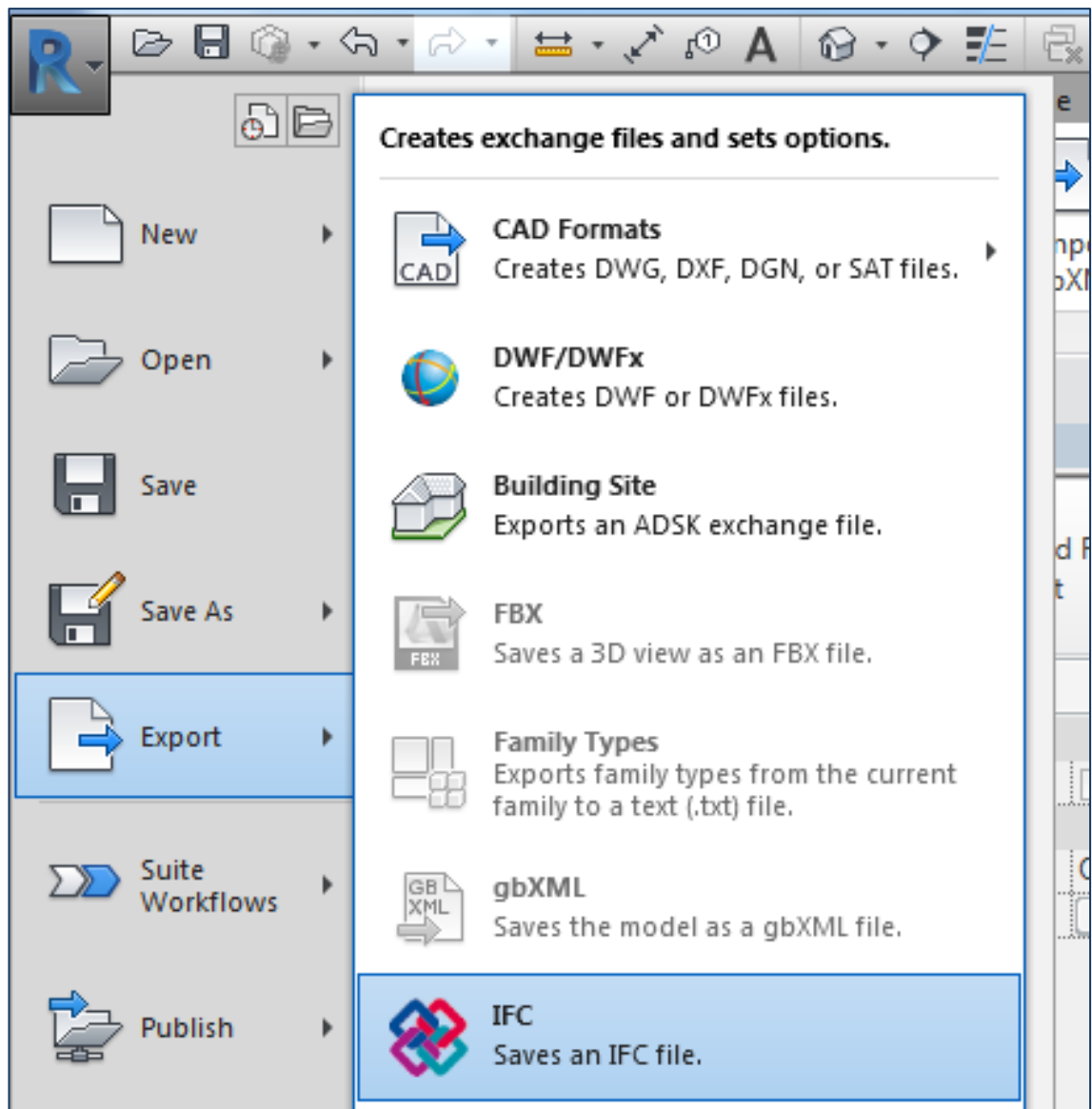


Figure 75. Export of IFC file from Revit 2017

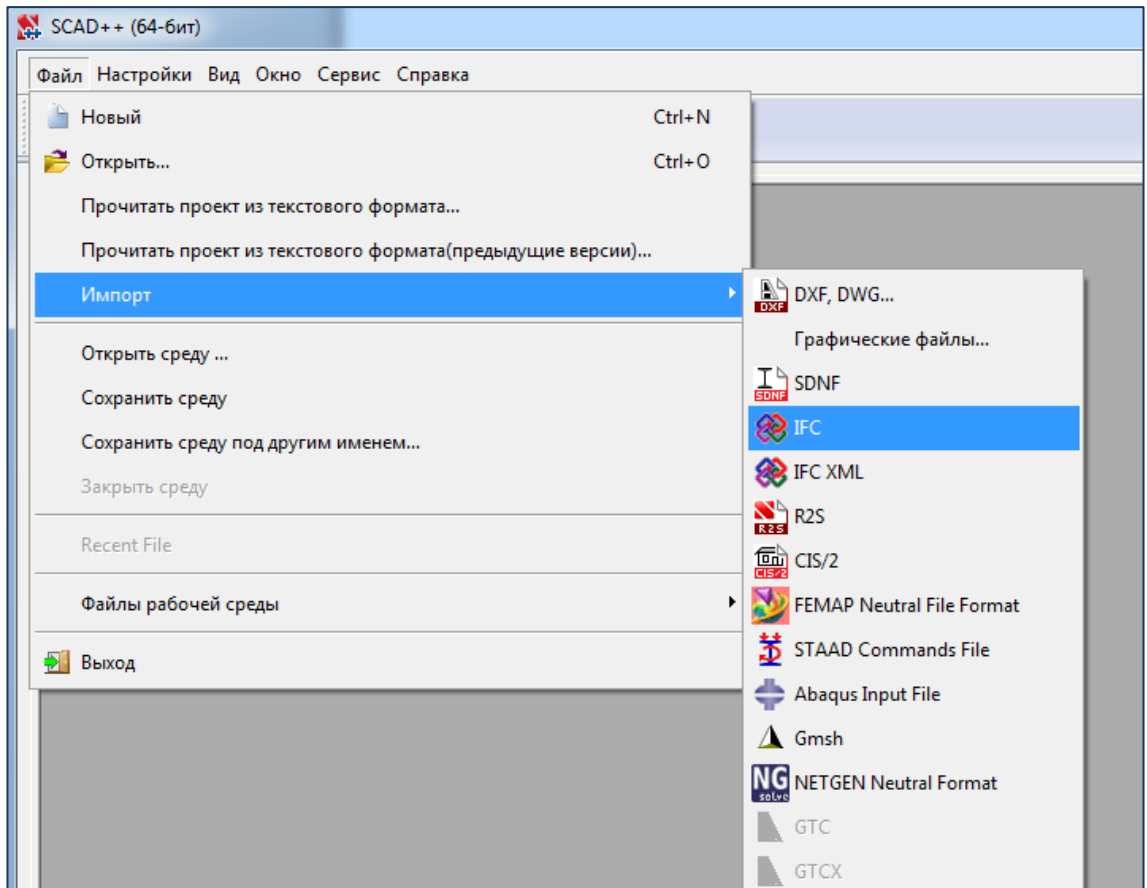


Figure 76. Import of IFC file into SCAD Office 21.1

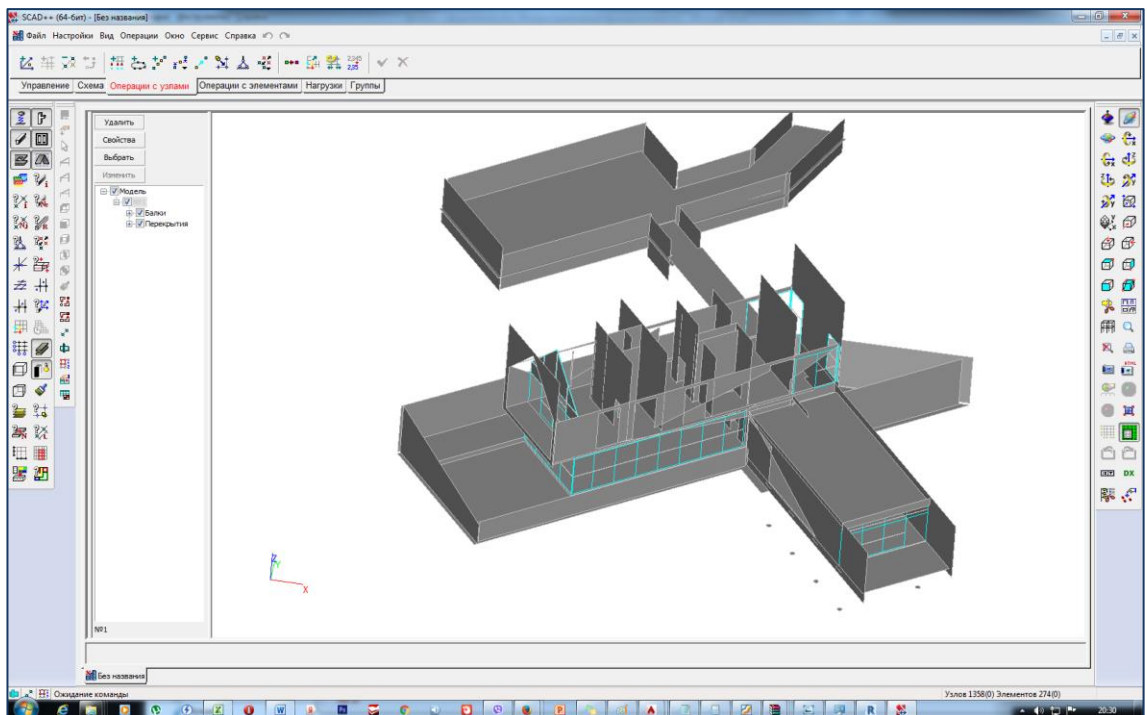


Figure 77. Result of the import IFC file into SCAD Office 21.1

Resume

The model may be transferred from Revit 2017 to SCAD Office 21.1 for calculation using the IFC file format. Moreover, the model is transferred quite correctly. The construction scheme is created from the load-bearing elements. However, the quality of the transfer is difficult to estimate, as in this case, the model has not been previously prepared (such preparation should be carried out by specialists).

10.3.14 Exporting a model to other software for further view on the construction site

Methods

In order to assess in this case it was decided to use Autodesk Revit Basic Sample Project.

As a program that can be used at a construction site Solibri Model Viewer has been selected. IFC model file created using the Revit Architecture 2017, had been open in Solibri Model Viewer (see Figure 78).

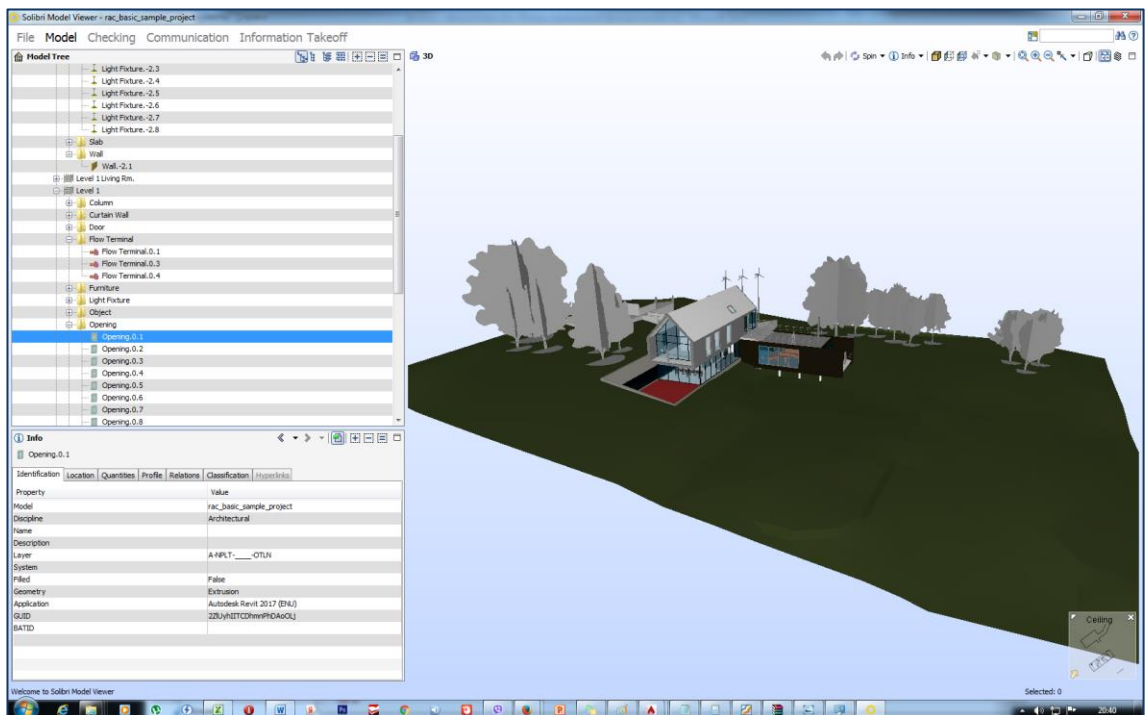


Figure 78. Result of the import IFC file into Solibri Model Viewer

Resume

The opening of the model in a program designed to view the model (for example, on a construction site) is not a problem with using the IFC file format. All the elements are correctly displayed and available for viewing. All the functions of Solibri Model Viewer are available. Due to the viewing mode Walk and Game in the navigation, the model is much more simply navigated than in Revit Architecture 2017 (see Figure 79).

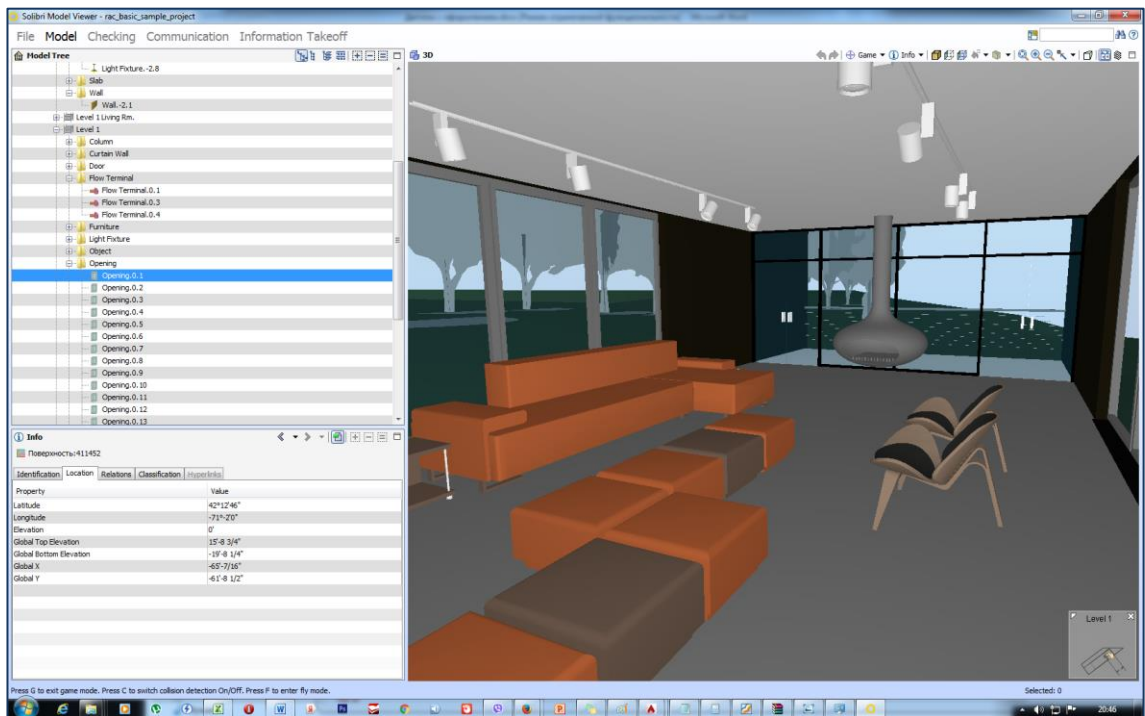


Figure 79. Navigation in Solibri Model Viewer

11 Summary and Discussion

In this thesis the term BIM was discovered with many sides. It was shown that BIM is not just a software or a 3D model, and not just a new design method. This is a very broad concept that was born in 1974 and was continuously expanding and developing since then, gaining more and more new opportunities, providing more and more benefits for the users.

Because of this versatility of BIM, BIM technology implementation is also a complex and multifaceted process, that was shown above, which can bring a

company or the entire construction industry to a whole new level, as well as to become a disaster.

Therefore, in this thesis an attempt to provide the actual information about BIM, its advantages and disadvantages was made. Subtleties and basic principles for the BIM implementation in the Russian construction industry and Russian construction companies were presented. Recommendations for such an implementation have been developed.

As part of the evaluation of the possibility of using BIM technology to satisfy the needs of the Russian construction companies, the comparison of such needs with the capabilities of BIM software was carried out. Such work can be an important step in preparation for the transition to BIM technologies.

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Appendix 1. State of the construction site in September 2016



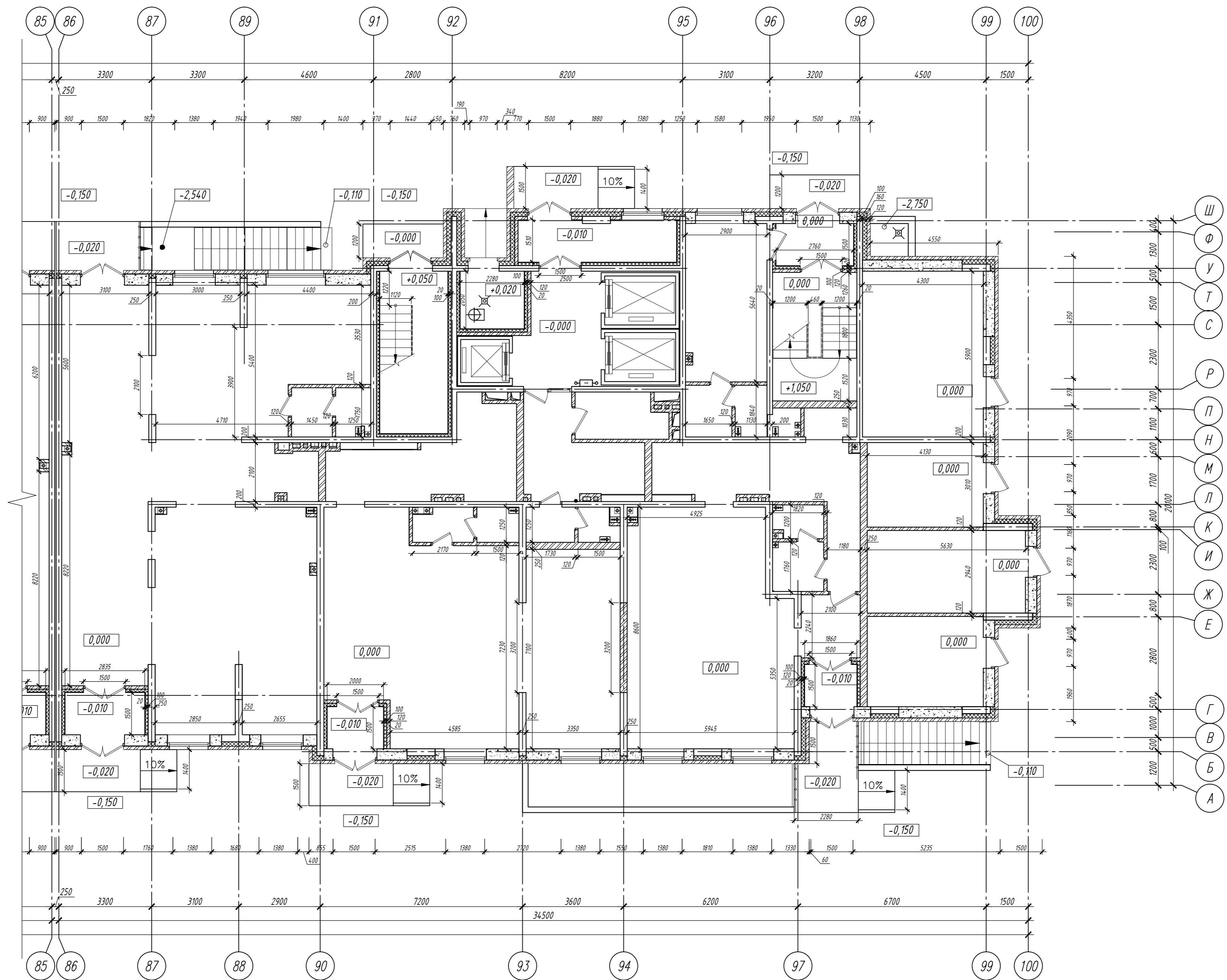








**Appendix 2. Provided architectural drawing. Floor plan
(Floor 1 between axis 85 and 100)**



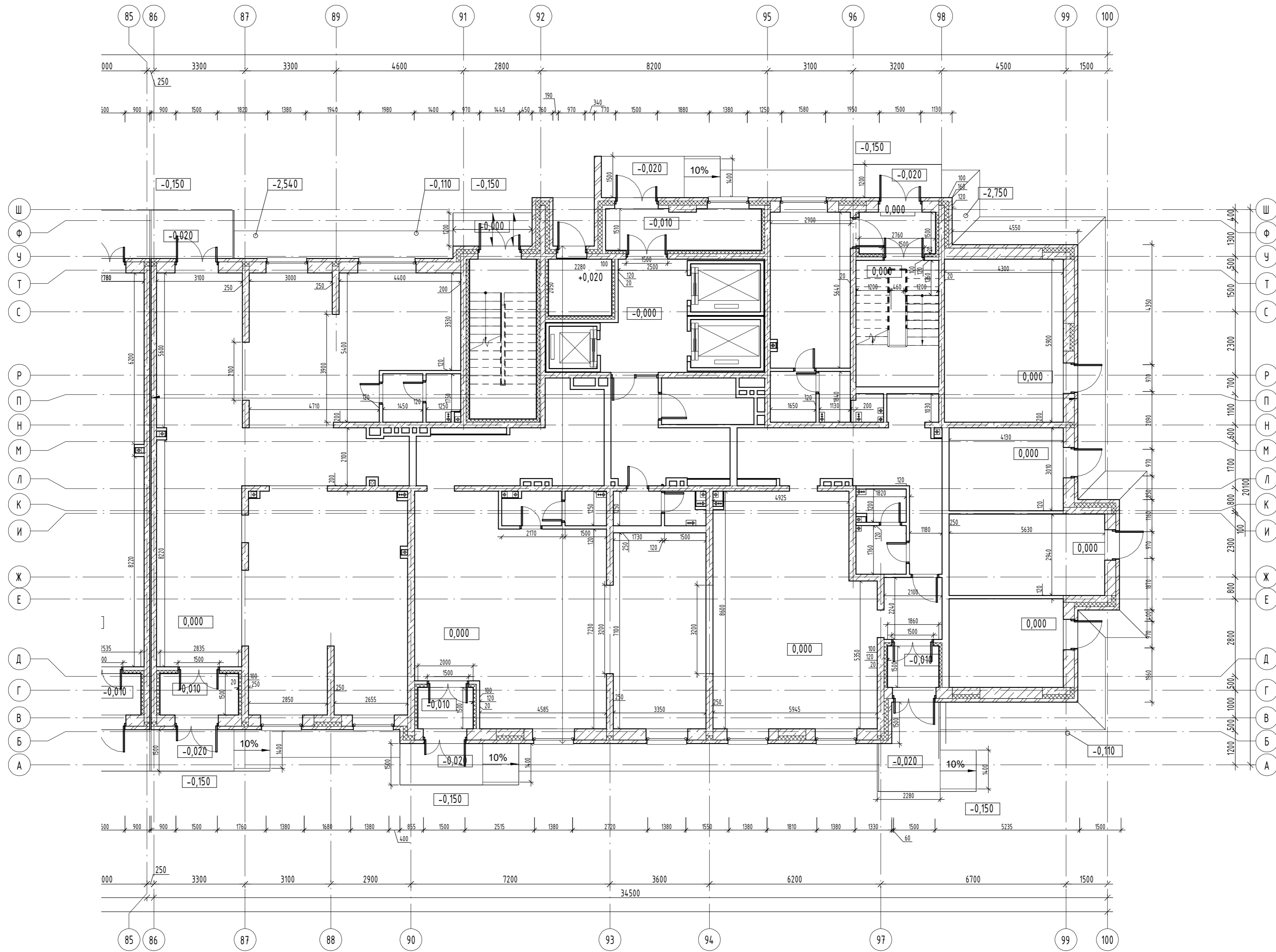
Примечания

1. Состав полов см. 1712-П-4-АР-24,25.
2. Сечения по наружным стенам см. 1712-П-4-КР2-21.
3. Чертеж рассматривать совместно с чертежами 1712-П-4-АР-16,17,18.

					1712-П-4-АР		
					Санкт-Петербург, п.Парголово, Торфяное, Ольгинская дорога уч. 4(северо-восточнее дома 4литера А по Заречной улице)		
					Многоквартирный дом со встроенно-пристроенными помещениями встроенно-пристроенным подземным гаражом		
					П 4		
					План 1 этажа между осями 85-100		
					ЗАО "Прагма"		
					Формат А2		

Согласовано	
Васм. инв. №	
Подпись и дата	
Инв. № подл.	

Appendix 3. Floor plan prepared with Revit Architecture (Floor 1 between axis 85 and 100)



Создано	
И.А. № подл.	Подп. и дата
	Взам. инв. №

Изм.	Кол.уч.	Лист	№ док.	Подпись	Дата

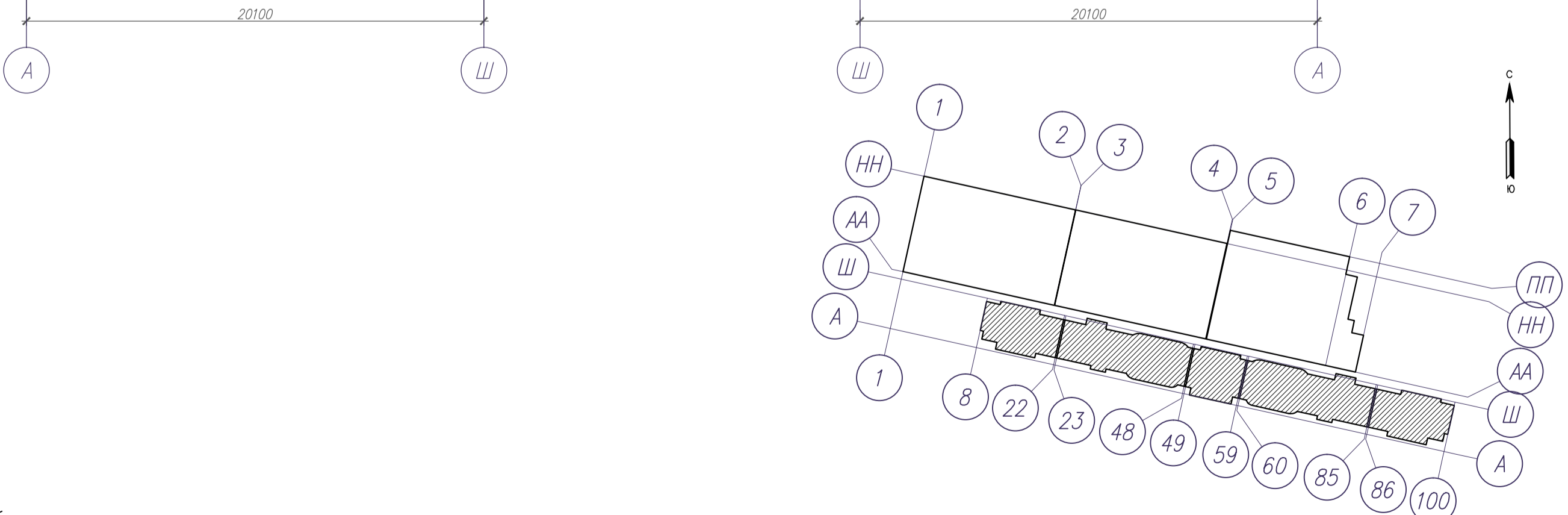
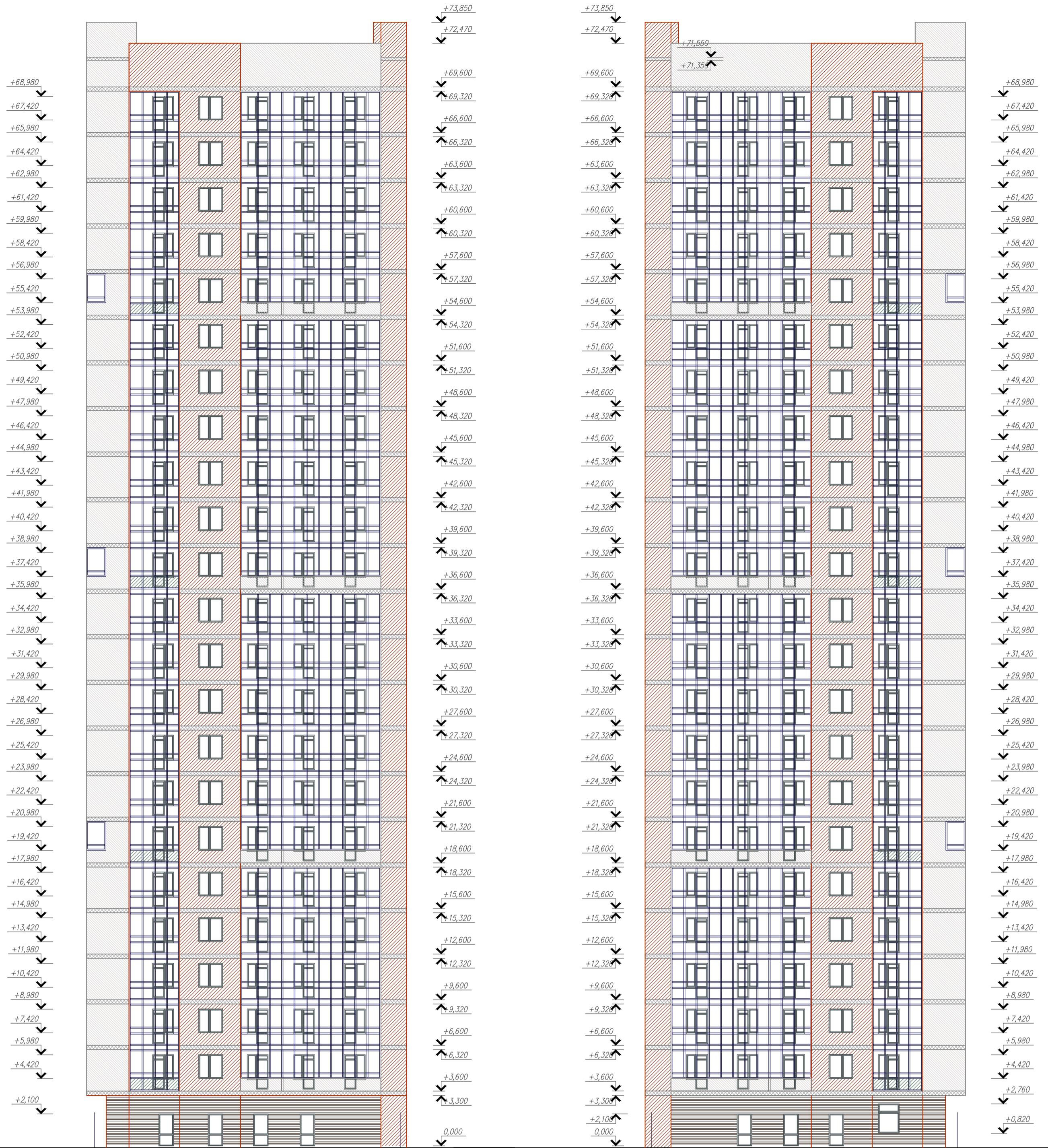
1712-П-4 - АР		
Санкт-Петербург, п. Парголово, Торфяное, Ольгинская дор., уч. 4 (СВ дома 4 лит. А по ул. Заречная)		
Многоквартирный дом со встр.-пристр. помещениями и встр.-пристр. гаражом		
Стадия	Лист	Листов
П	4	
План 1 этажа между осями 85-100		ЗАО "Прагма"

Appendix 4. Results of the Section 7 visualization





Appendix 5. Facade drawing in axis A-Sh created in AutoCAD



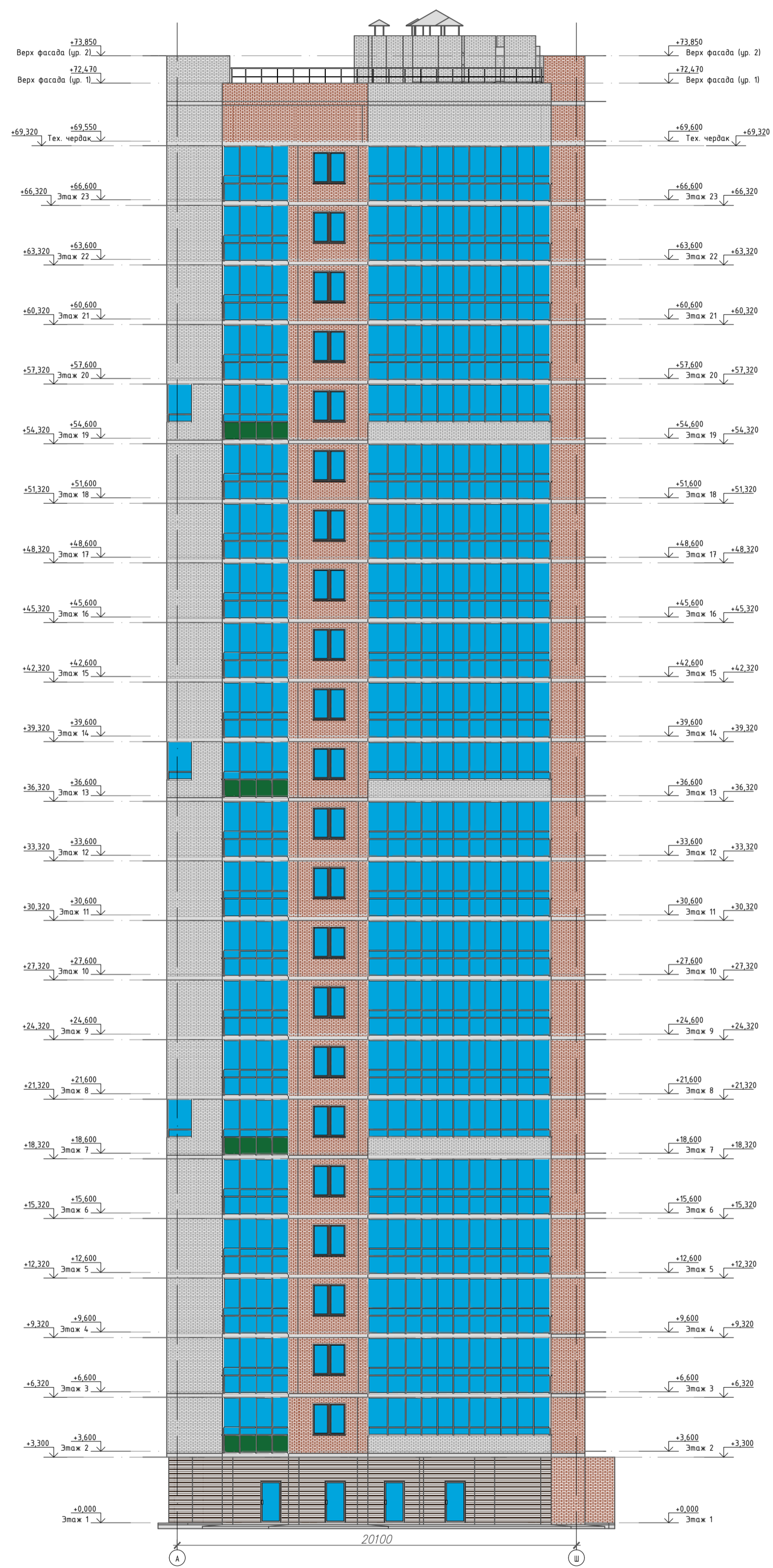
Условные обозначения

- серый лицевой кирпич
- терракотовый лицевой кирпич
- светлый лицевой кирпич
- бетонный камень пр-ва "МЕЛИКОНПОЛАР"
- стекло солнцезащитное серое светопропуск-16%, отражение-14%, солнц. фактор-30%

1712-П-4-АР									
Санкт-Петербург, п.Парголово, Торфяное, Ольгинская дорога уч. 4(северо-восточнее дома 4литера А по Заречной улице)									
Изм.	Кол. уч.	Лист	№ док.	Подп.	Дата	Многоквартирный дом со встроенно-пристроенными помещениями встроенно-пристроенным подземным гаражом	Стадия	Лист	Листов
Нач.пр.бюро	САМОЛОВА						П	21	
ГАП	Кунерт								
Рук.группы	Ткаченко								
Проверил	Кунерт								
Разработал	Казанцева								
Н.контр.	Смирнов								
Фасад Ш-А М1:200							ЗАО "Прагма"		

Согласовано
 № вкл. инв. N
 Подп. и дата
 Инв. N подл.

Appendix 6. Facade drawing in axis A-Sh created in Revit Architecture and exported to AutoCAD

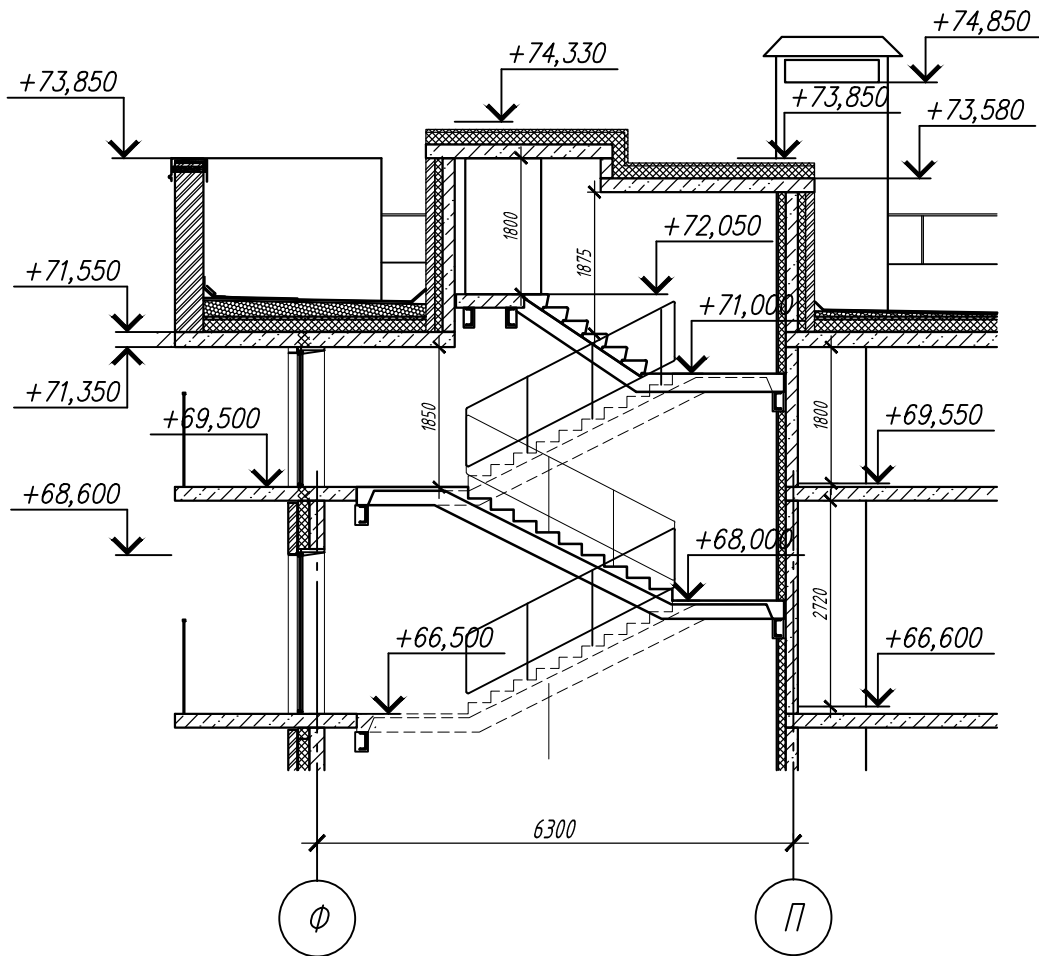


Согласовано	
Изм. N подл.	Взам. инв. N
Подп. и дата	
Изм. N подл.	

1712-П-4-АР					
Санкт-Петербург, п.Парголово, Торфяное, Ольгинская дорога уч. 4(северо-восточнее дома 4литера А по Заречной улице)					
Изм.	Кол. уч.	Лист	№ док.	Подп.	Дата
Нач.пр.бюро	Самойлова	Кунерт			
ГАП	Кунерт				
Рук.группы	Ткаченко				
Проверил	Кунерт				
Разработал	Казанцева				
Н.контр.	Смирнов				
Многоквартирный дом со встроенно-пристроенными помещениями встроенно-пристроенным подземным гаражом				Стадия	Лист
Фасад Ш-А М1:200				п	21
ЗАО "Прагма"					

Appendix 7. Vertical crosssection of the fragment of roof output from the staircase made in of AutoCAD

Согласовано



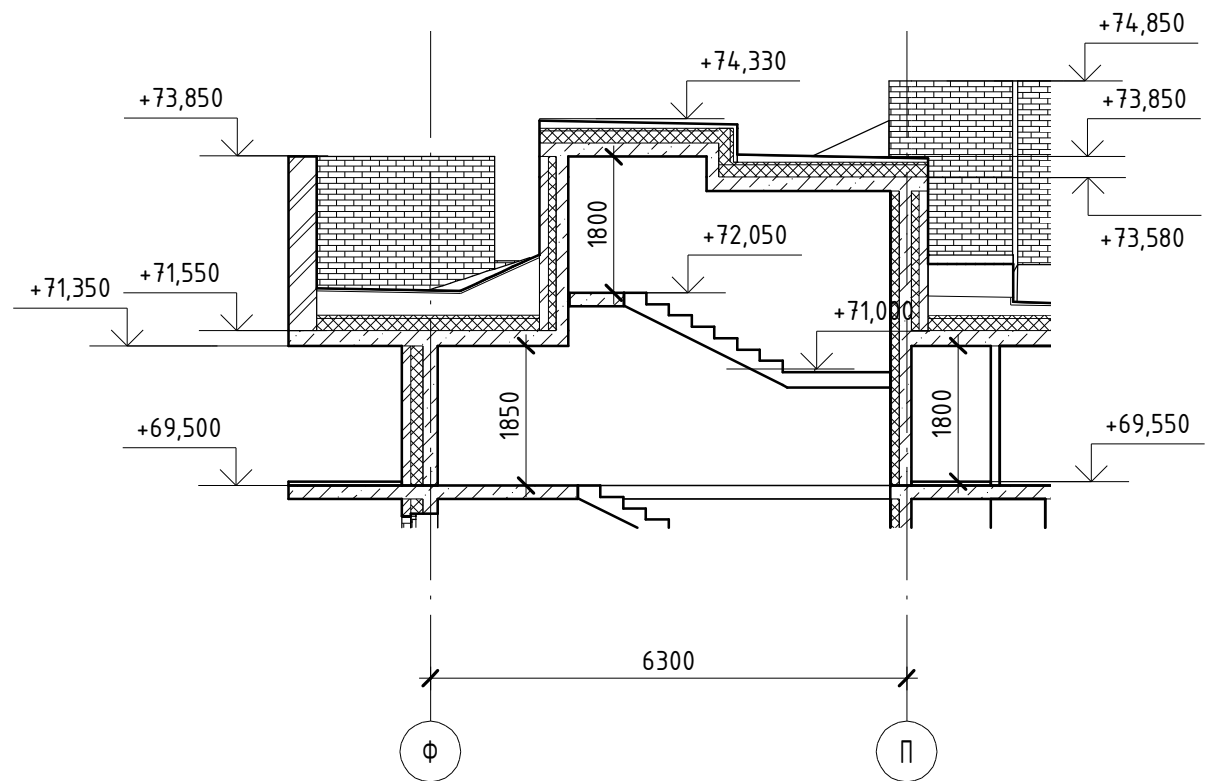
Взам. инв. №

Подпись и дата

Инв. № подл.

						1712-П-4-АР			
						Санкт-Петербург, п.Парголово, Торфяное, Ольгинская дорога уч. 4(северо-восточнее дома 4литера А по Заречной улице)			
Изм.	Кол. уч.	Лист	Ндок.	Подп.	Дата	Многоквартирный дом со встроенно-пристроенными помещениями встроенно-пристроенным подземным гаражом	Стадия	Лист	Листов
Нач.пр.бюро							П	12	
ГАП						Фрагмент выхода на кровлю	ЗАО "Прагма"		
Рук.группы									
Проверил									
Разработал									
Н.контр.									

Appendix 8. Vertical crosssection of the fragment of roof output from the staircase made in Revit Architecture



Инв. № подл.	Подп. и дата	Взам. инв. №

Изм.	Кол.уч.	Лист	№ док.	Подпись	Дата

1712-П-4 - АР			
Санкт-Петербург, п. Парголово, Торфяное, Ольгинская дор., уч. 4 (СВ дома 4 лит. А по ул. Заречная)			
Многоквартирный дом со встр.-пристр. помещениями и встр.-пристр. гаражом		Стадия	Лист
Фрагмент выхода на кровлю		П	12
		ЗАО "Прагма"	

Appendix 9. The breakdown of Floor 7 premises performed in AutoCAD

Экспликация помещений

Номер помещения	Наименование	Площадь, м ²	Кат. помещения
1	Коридор	42,4	
2	Лифтовой холл	33,3	
3	Лестничная клетка №1	14,4	
4	Коридор	34,3	
5	Лифтовой холл	38,8	
6	Лестничная клетка №2	15,0	
7	Коридор	32,6	
8	Лифтовой холл	38,8	
9	Лестничная клетка №3	15,0	
	Итого: общедомовые помещения	264,6	
10	Коллекторная	1,1	
11	Коллекторная	2,0	
12	Коллекторная	2,1	
	Итого: общедомовые помещения	5,2	

13	Коридор	31,8	
14	Лифтовой холл	38,8	
15	Лестничная клетка №4	15,0	
16	Коридор	33,2	
17	Лифтовой холл	38,8	
18	Лестничная клетка №5	15,0	
19	Коридор	34,0	
20	Лифтовой холл	38,8	
21	Лестничная клетка №6	15,0	
22	Коридор	42,6	
23	Лифтовой холл	30,1	
24	Лестничная клетка №7	14,4	
	Итого: общедомовые помещения	347,5	
25	Коллекторная	2,1	
26	Коллекторная	2,2	
27	Коллекторная	2,1	
28	Коллекторная	1,1	
	Итого: Технологические помещения	7,5	

Appendix 10. The breakdown of Floor 7 premises performed in Revit Architecture

<Экспликация помещений>			
A	B	C	D
Номер помещени	Наименование	Площадь, м2	Кат. помещения
1	Коридор	42,40 м ²	
2	Лифтовой холл	33,32 м ²	
3	Лестничная клетка №1	14,45 м ²	
4	Коридор	34,27 м ²	
5	Лифтовой холл	38,77 м ²	
6	Лестничная клетка №2	14,95 м ²	
7	Коридор	32,60 м ²	
8	Лифтовой холл	38,77 м ²	
9	Лестничная клетка №3	14,95 м ²	
10	Коллекторная	1,11 м ²	
11	Коллекторная	2,04 м ²	
12	Коллекторная	2,16 м ²	
13	Коридор	31,80 м ²	
14	Лифтовой холл	38,77 м ²	
15	Лестничная клетка №4	14,95 м ²	
16	Коридор	33,25 м ²	
17	Лифтовой холл	38,77 м ²	
18	Лестничная клетка №5	14,95 м ²	
19	Коридор	33,98 м ²	
20	Лифтовой холл	38,77 м ²	
21	Лестничная клетка №6	14,95 м ²	
22	Коридор	42,64 м ²	
23	Лифтовой холл	30,13 м ²	
24	Лестничная клетка №7	14,45 м ²	
25	Коллекторная	2,12 м ²	
26	Коллекторная	2,16 м ²	
27	Коллекторная	2,12 м ²	
28	Коллекторная	1,11 м ²	

Appendix 11. Result of the one-room apartment interior design and visualization





