Saimaa University of Applied Sciences
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Civil Engineering

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# MODERN TECHNOLOGIES IN RENOVATION AND RESTORATION CASES

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# ABSTRACT

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Modern technologies in renovation and restoration cases,
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The objective of the study was to analyse topical issues and their solutions by using modern technologies and new methods in renovation and restoration cases for an optimization of the process of managing a project on all stages of it. This analysis is based on the experience of the implementation of modern technologies and new methods in different countries and companies with a purpose of comparing and making conclusion about their effectiveness in current situation is renovation and restoration field.

The study was conducted in OOO «Архиграция» and it also received information, blueprints and other materials from the company's archives. All blueprints were made by using Autodesk AutoCAD.

Throughout the thesis the main important issues in renovation and restoration fields are discussed with examples of their solutions and analysis of the effectiveness and rationality of using such methods to present a full picture of this specific part of the construction field.

In conclusion, lack of modern technologies integration in the design and construction phase in restoration and renovation field in Russian Federation is still actual. The market continues to lose money and time due to old, unsafe and ineffective methods.

As a result, the effectiveness of modern technologies was proven compared to traditional methods by analysis of the several facilities and related issues. The BIM technology and the laser scanning technology were properly discovered and have shown themselves as significantly effective ways of solving most of the problems, related to the restoration and renovation fields. The necessity of investments into modern technologies in Russian renovation and restoration design process was proved. Rough cost estimation of technologies integration was also presented in this study.



Keywords: renovation, restoration, modern technologies, optimization, effectiveness, information.

**CONTENTS**

# 1 INTRODUCTION

The renovation and restoration fields are a large part of the construction business in almost all European countries. For example, in Finland according to the Statistics Finland publications in 2017 around 8.9 billion euros were directed to the buildings renovation, which equals 43.6% of a total building projects value. Moreover, this percentage keeps growing from the 2014. The share of renovation is also growing in all European Union partly because of Energy Efficiency Directive (2012/27/EU), due to which many old houses must be renovated to low the level of energy consumption. Meanwhile in Russia the percentage of renovation and restoration field is much lower, but currently it begins to grow because of a large Moscow's renovation program (Town-Planning Policy and Construction Complex of Moscow) and the beginning of the energy efficiency renovation of Russian residential districts in cold urban regions.

Thus, renovation and restoration fields probably will keep growing up and attract more investments. In this way companies are more and more up against the problems and start searching for its solutions. Probably, one of the most common problems, that occurs in the renovation projects, especially for a client, is a fact that renovation and restoration are typically much more expensive than new building construction. Throughout this thesis parts of the reasons will be explained. However, in the beginning it is important to mention, that globally the cost problem could be solved only by processes' optimisation due which less people must be engaged in such projects, less time is required and less unexpected problems occur. Thereby, the main question of this final thesis is: How could modern technologies and new methods help to solve cost issue by solving over local problems?

The study is focused on a detailed analysis of each problem and each solution of it by using modern technologies and new methods to make a conclusion about its effectiveness and rationality. The main scope is to investigate what kind of modern technologies are helpful in renovation and restoration fields, in which cases the usage of them is smart and in which it is not.

The main body of the text is separated into two main parts: The most significant current issues in renovation and restoration (Chapter 3 Main restoration and renovation issues) and solving of the current issues in renovation and restoration field by using modern technologies and new methods (Chapter 4 Solutions by using modern technologies). These two parts should give a clear picture of how renovation and restoration fields could function now and in the future to avoid the considered wide scale problems.

The analysis of issues in renovation and restoration cases and their solution is based on the projects of ООО "АрхиГрация" and theoretical information from the sources which are described in the list of references.

## 2 GENERAL INFORMATION

In this chapter basic data about the current situation in renovation and restoration fields in Finland and Russia is presented.
Before moving to the statistic data it is important to explain the meaning of the keywords "renovation" and "restoration" in this study. Such a description is needed because of the different meanings of these words in Russian and Finnish terminology. The word "renovation" in the Russian system means "demolishment and then replacement of the old structures with a relocation of dwellers of it to the new structures" (Reality Urist). The word restoration in Russian Federation means "a complex of activities which are directed on prevention of a destruction of parts of the structure, decor elements with a purpose of extension of the life time of a building in its current mode or functional affiliation". While in Finland (Statistics Finland) "In broad terms renovation refers to all activity aimed at improvement and maintenance of the condition of an existing building or parts thereof". The word "restoration" indicates "the act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive

upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project." (the U.S. Secretary of Interior's standards). Throughout this text the Finnish/American meaning of these words will be used, except cases of Russian authoritative sources quoting.

## 2.1 Statistics

The renovation field forms a large part of the construction field in Finland according to Statistics Finland publications. In this way it would be appropriate to give more information about tendencies in this sphere. As it is shown on the chart below (Chart 2.1, Chart 2.2), the shares of renovation building and newbuilding in all projects directed to construction of buildings came still closer to each other.

Renovation building accounted for 44 percent of all projects while the corresponding figure was 42 percent in 2016. The value of renovation building was EUR 8.9 billion and that of newbuilding EUR 11.5 billion. The growth in renovation building took place in both building construction and specialised construction. (Statistic Finland)

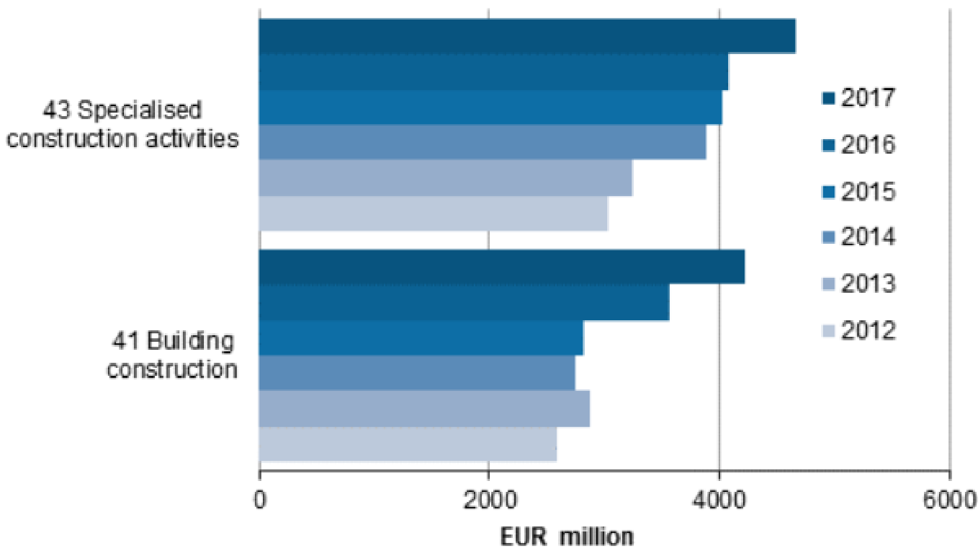


Chart 2.1 Renovation building projects by industry (Statistics Finalnd)

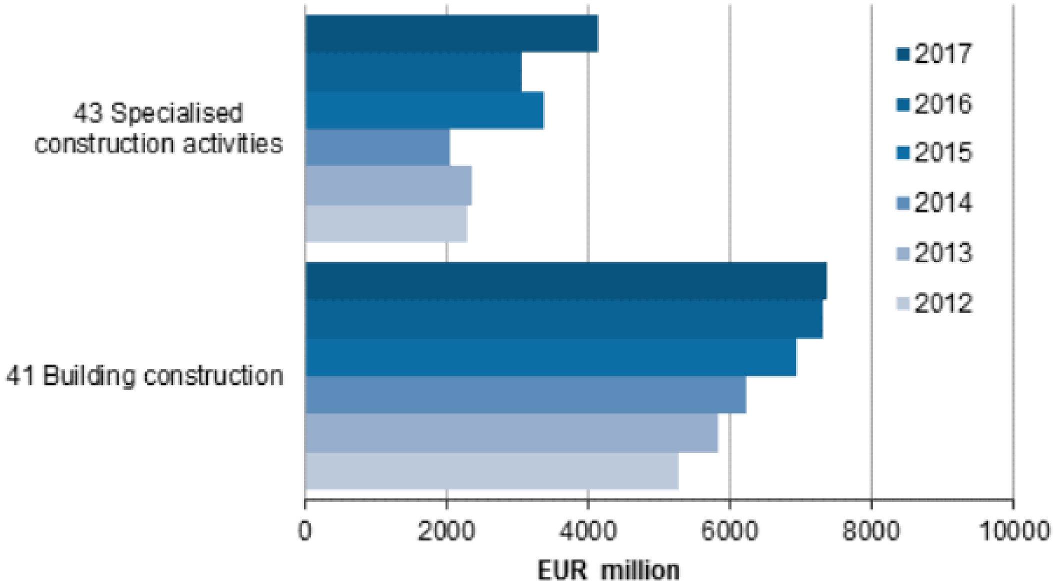


Chart 2.2 Newbuilding projects by industry (Statistic Finland)

These charts and statistic data reflect that renovation field in Finland is a large part of the country's economy. Meanwhile in Russia such a statistic is not available because Russian statistic organisations do not separate newbuilding projects and renovation building projects in their researches. Thus, objective comparison of data in the considered two countries is impossible. That is why for approximate estimation restoration statistics from Saint-Petersburg are used. According to the information from The Committee on State Control Use and Protection of Historical and Cultural Landmarks website the restoration market in Saint-Petersburg keeps growing up due to large federal projects. Wherein almost 100% of the restoration market is based on government contracts, meanwhile the share of private investments account 2.51 billion euros which does not exceed 2% of the whole restoration market. To compare, in Europe the share of private investments of restoration projects exceeds 50%. The Restorers Union council chair Nina Shangina explains it: "This happens because in Europe more objects of cultural heritage belong to the private sector. For example, dwellers of the historical houses often restore it by their own expense, because they could afford it. In our country, unfortunately, we do not have such practice".

## 2.2 Historical background in Russia

To create a clear picture of the current situation in renovation and restoration field in Russia and understand modern issues, it is important to briefly describe initial reasons.

Russian czars were always impressed and inspired by Italian and French architecture trends which significantly affect on the cities' appearance. The end of the $19^{th}$ century and the beginning of the $20^{th}$ century was an era of the modern, especially in Saint-Petersburg and Moscow. Many rich people began to build their palaces and commercial apartment buildings designed by famous architects in this style.

However, the October Revolution has significantly changed the situation in the country. After this occasion almost all structures in the city center changed their purposes. For example, the F.F. Teodory's House of Furnished Rooms, which was initially a property of the Turkish national and was functioning as a guesthouse, after revolution became a governmental property and was used as a dormitory. Moreover, currently this house keeps its purpose. Obviously, such an inappropriate usage of an architectural legacy strongly affects its condition. That is why similar types of structures make up most of the restoration objects.

Figure 2.1. the F.F. Teodory's House of Furnished Rooms (Photo by the author)

The renovation field also has a strong correlation with the Soviet Union legacy. After the Second World War the government was trying to solve housing problem by massive building of standard panel houses. The main characteristic of such structures was an opportunity to build it as fast and cheap as possible. However, still these standard houses are a low-quality dwelling with a short lifecycle, poor esthetical appearance and low energy efficiency rating. For this reason, in Russian Federation renovation program has begun for this type of buildings to rise up energy efficiency, accommodations and to change cities' appearance.

Figure 2.2. Standard panel house. Series 1-507.
http://domavspb.narod.ru/index/0-26

Figure 2.3. Renovated panel house. (Photo by the author)

## 2.3 Historical background in Finland

Meanwhile Finnish renovation and restoration markets have a different situation. One of the biggest motivations for the Finnish renovation market has become an energy efficiency issue which each year becomes more and more important. This problem played such a big role in construction because of two global challenges: Energy dependence of Finland and the Europe Energy Efficiency directive.

According to the Multidisciplinary Digital Publishing Institute (MDPI), as illustrated in Figure 2.4., “the most important primary energy sources in Finland are biomass (25.9%, 2016 figures), oil (23.2%) and uranium (18.2%). Finland imports practically all of its fossil fuels, and a vast majority of the imports come from Russia. In total, imports comprised 64.0% of the total primary energy supply in 2016, of which the majority originated in Russia.”

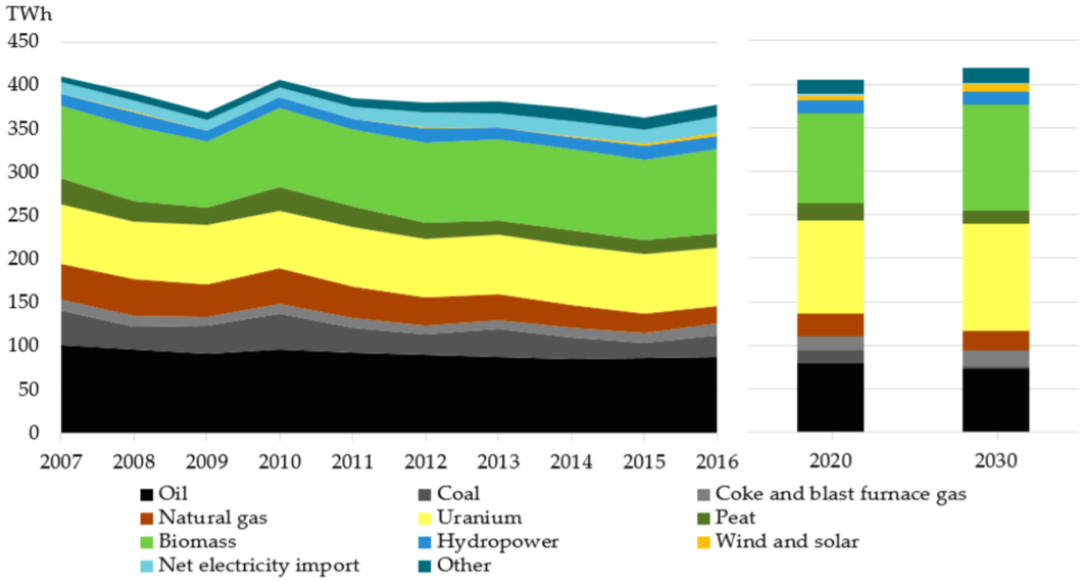


Figure 2.4. Primary energy consumption and energy sources in Finland in 2007 - 2016, 2020, and 2030.
https://www.mdpi.com/2071-1050/10/10/3445

Finnish building industry consumes lots of energy because of the cold and wet climate. According to MDPI the main sectors of electricity consumption are industry and construction (47%, 2016 figures).

The second challenge, which is partly affected by the first issue is the European directive which set a 20% energy saving target by 2020 and at least 32,5% by 2030. According to European Commission buildings are responsible for approximately 40% of energy consumption and 36% of $CO_2$ emission in EU,

making them the single largest energy consumer in Europe. The Energy Performance of Buildings Directive requires all new buildings to be nearly zero-energy buildings (NZEB). The low amount of energy that NZEB require comes mostly from renewable energy sources. Also EU countries have had to submit long-term renovation strategies (LTRS) that foster investments in the renovation of buildings. These strategies will as of 2019 form a key part of EU countries' integrated national energy and climate plans (NECPs), which have to be submitted every 10 years.
Meanwhile restoration field has a more obvious reason to function – maintaining of old structures, which are a part of historical and architectural heritage, and recovering of it because of the end of their life cycle.

# 3 MAIN RESTORATION AND RENOVATION ISSUES

## 3.1 Regulatory issues

In restoration cases client can be different. It can be local authorities, a federal centre or a private sector. However, regardless of this the main issue for a client is the same – cost. Restoration projects are often much more expensive than a new building construction. Wherein, typically, law will not let the owner of the property to demolish the structure and even restore it by using materials and colours, which differ from the original variant. In this way, the owner does not have a choice beside properly restore his own facility. Such a strong regulation brings many additional problems and expenses, extend a period of a construction and compel to coordinate with a regulatory authority. However, why such an attention even to private sector housing, if it represents historical and architectural heritage, is so important? The main reason is saving the original appearance of cities. Since 1964 partly this question is regulated by The Venice Charter for the Conservation and Restoration of Monuments and Sites. For example, the 6$^{th}$ article of it declares:" The conservation of a monument implies preserving a setting which is not out of scale. Wherever the traditional setting exists, it must be kept. No new construction, demolition or modification which would alter the relations of mass and colour must be allowed." Basically, it means that an existing monument represents not only itself, but is strongly connected with the appearance of its surrounding.

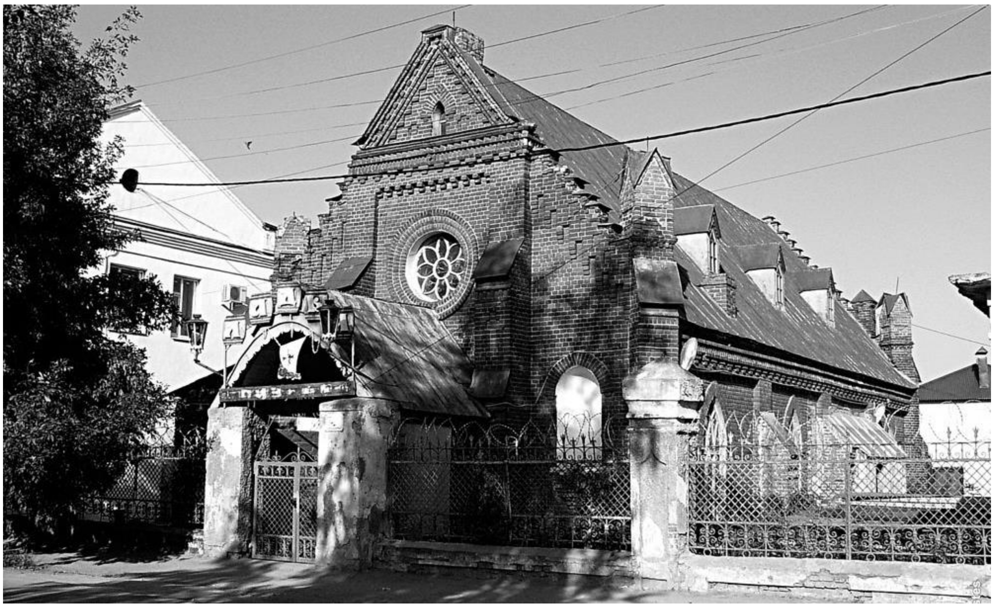

Figure 3.1. Jeiletz Deutche Kirche before inappropriate restoration. Lipetsk region. http://vif-vrn.ru/viewtopic.php?t=868

Figure 3.2. Jeiletz Deutche Kirche (Currentry – building material shop) after inapproriate restoration. Lipetsk region. http://vif-vrn.ru/viewtopic.php?t=868

In the Figures 3.1 and 3.2 examples of ignoring the restoration rules are shown. Undoubtedly, such method of restoration is much cheaper than an appropriate way with saving of the original appearance. However, this decision significantly changed not only considered church, but also the appearance of its surrounding, turning the whole street into an unaesthetical place. Therethough, the economy on the materials and architectural decisions is inadmissible as well as regulation laws cannot be canceled to keep cities comfortable and precious.

So, if it is impossible to reduce costs and time limits by the mentioned method, other issues, which affect on the project, should be considered.

In Russian Federation the authority which globally controls restoration and partly renovation field is called The Culture Ministry. This is a Federal organization, which is responsible only for global issues and an accreditation of specialists. The local authority, which practically controls restoration and renovation in cities is called The Committee on State Control Use and Protection of Historical and Cultural Landmarks. This organization is responsible for signification of cultural heritage objects, control of a condition of it, coordination between restoration design and building companies, giving guidelines and setting up of limitations for each project. Local authorities are also partly responsible for restoration and renovation control.

In Finland control of historical heritage is the responsibility of The Finnish Heritage Agency. This organization consists of several departments, which are responsible for their own field. For example, Cultural Environment Services "is responsible for expert and official tasks related to cultural environments, such as significant archaeological sites and findings, historical architecture, restoration, landscapes and historical ships. It produces information and creates awareness on the protection of cultural environments, as well as on pertaining values and opportunities." (The Finnish Heritage Agency). Meanwhile the Archives and Information Services Department "is responsible for for the archive, picture, library, and knowledge management services, and its other tasks include expanding and managing the archives, archaeological collections, picture collections and library collections. The department provides information and image bank services, as well as instructions and guidance on appropriate matters within the Finnish Heritage Agency and the field of cultural heritage." (The Finnish Heritage Agency).

### 3.2 Inaccessibility issue

One of the main issues in restoration from the engineering and architectural points of view is the inaccessibility of important parts of a structure. Typically, authorities or a client provide you with old blueprints of a structure. If a structure is not very old, project documentation can be found in archives. However, almost always these blueprints conflict with the real situation. It happens due to additional issues which could appear during the construction process, such as lack of materials, incompleteness of the design, inappropriate technique of erection, intricacy of building according to the project, human factor and so on.

All these reasons could significantly change dimensions, types of loadbearing structures and some elements of a building design. Part of these changes could be checked and noticed simply by visiting the object and many investigations. For example, dimensions could be checked by measuring them with a tape ruler or a laser measuring tape, as well as configuration of the walls and other elements could be checked by a comparison of old blueprints and the current situation. However, even these methods sometimes can be impossible. Parts of an old building often are in an ultimate limit state. In such cases people cannot visit and investigate this place. For example, during the investigation of the truss system in the Kirov’s Palace of Culture in Saint-Petersburg, Russia (Figure 3.3.) (Appendix 8), part of spaces and roof structures were extremely dangerous to enter (Figure 3.4.).


Figure 3.3. The Kirov’s Palace of Culture in Saint-Petersburg. Southeast wing. (Photo by the author)

Such an example is illustrated in Appendix 1. This is the blueprint of the segment of the roof structure in the Kirov’s Palace of Culture with graphical symbols, one of which is marking as “collapsing of the roof”. Such parts of buildings cannot be reached by people without special techniques, which obviously complicate the process of engineering-technical investigation. Modern solutions of this problem are discussed in Chapter 4.

Figure 3.4. The Kirov's Palace of Culture in Saint-Petersburg. South wing. Collapse of the roof. (Photo by the author)

However, even if a structure is safe for visiting, parts of it still could be difficult to access. Such an issue is especially very actual during a façade renovation. The height of a human with a ruler is not typically enough for measuring of a façade, if a building is higher than one floor. In such cases, if the façade has relatively simple form, it is possible to measure general dimensions by a laser ruler and mark defects on the scheme according to photos and by rough estimate. However, if it has at least one architectural element, such as cornice, keystone, device and other elements, which are important parts of a building appearance, an architect should have precise measures to design a proper blueprint for the restoration of this object. A similar problem has appeared during the restoration project of the Russian Research Geological Institute named after A.P.Karpinsky. The backyard facades are illustrated in Appendix 2 and Appendix 3. This building has five floors which makes it difficult to measure or even to give rough estimations, especially the cornice on the top of it. In this case general dimensions were measured by a laser ruler and the location of each window was identified according to the location and dimensions of the windows of the first floor. The only one possible way to define the cornice was to measure it from the roof. However, even this method was not a good solution. The roof of the Russian Research Geological Institute named after

A.P.Karpinsky is not suitable for visiting by people. Thus, it is not safe to enter, because it does not have any safety railing and bridges. Although it was the only one possible way to at least approximate the dimensions from the smaller distance. However, there is no doubt that such methods are absolutely unacceptable and should be replaced by modern solutions as unsafe and ineffective.

Often if the structure is in a satisfying condition, one-story and accessible this problem is still actual. Such elements as loadbearing walls, partition configuration, height of the space and layout concepts are “external” and approachable. Often during a restoration project the condition of structural elements should be defined. Such parts as columns, steel or wooden beams and floor or wall structure including all layers of it are typically covered by other elements. According to the law an engineer is allowed to dissect a small part of a structure to explore the condition and configuration of it. However, in some cases it is not enough. For example, in wooden structures all covering should be removed from wooden parts, so that engineers could strongly confirm that the structure is not damaged or, alternatively, fined and mark all defects. Nevertheless, the law will not allow removing all covering in the building which is included into historical and architectural heritage register. The similar problem has appeared during the renovation project of the in House, in which in 1764-1768 was the officer assembly of the Suzdalskii infantry regiment, the leader of which was Suvorov Alexander Vasilievich in Novay Ladoga. (Figure 3.5., Appendix 4) The object was a relatively new wooden structure, which was erected on the base of the old structure. Such a radical decision was made because the original building was in an extremely critical condition, so that partial repairs were not enough. Consequently, the new facility was erected by using the same materials as the original structure.

Nevertheless, after a couple of years because of the builder’s mistakes the floor has reached an inappropriate condition. The initial target was to investigate the wooden floor inside the building, which was made inaccurately after renovation, to develop a fixing project. However, during the investigation even more problems were detected. Almost all plastering on the ceiling and walls was covered by lots of cracks of different sizes. The tile due to a wooden floor warping has begun to come off and the holes near windows have appeared.

Figure 3.5. House, in which in 1764-1768yy. was the officer assembly of the Suzdalskii infantry regiment, the leader of which was Suvorov Alexander Vasilievich. Appearance. (Photo by the author)

To fix these problems and avoid them in the future it would be logical to find reasons of it and explore all structural elements, especially the floor system. The type of structure is important for the future calculations. However, only a very small sector of the floor was allowed to be explored by sawing it (Figure 3.6.). In fact, it is impossible to receive a full picture of the wooden building condition according to such limited amount of information, so it was mainly used to define the floor type.

Problems were not just in the floor. The walls structure also should be investigated to find the reason of cracks in plastering. Sawing of the wall structure or removing of the covering layers was not possible. So the only way was a visual analysis, which is typically not precise and based only on an engineer or an architect experience. In this particular case it was not very critical, because the building was relatively new. It means that the amount of potential problems was limited. For example, during a couple of years new wooden walls rarely rotten or are damaged by mold.

Figure 3.6. Sawed sector of the floor. (Photo by the author)

That is why one of the most logical reasons of cracks was a lumber shrinkage, which happened due to a building erection flow disruption and lack of time for logs to dry. Nevertheless, typically wooden buildings in restoration field are not new. It could have some new replaced parts, but the most of it is made of old materials. Thus, to determine the condition of the wooden loadbearing structure it is necessary to remove all covering layers to reach the hidden parts of it. If only a part of covering layers was removed there is no possibility for an objective estimation of the condition. For example, the structure could be partly damaged by mold and fungus, partly by shrinkage cracks, partly rotten, and partly – without any defects. Wood is a heterogeneous material. It means, that if only one little sector of covering is removed, and there are no serious defects to be detected on loadbearing parts, other hidden parts still could be damaged. However, mostly in historical and cultural heritage buildings it is impossible to remove even a little sector of covering, which makes an investigation by old methods ineffective and very rough.

### 3.3 Measuring issues

The most part of a restoration or a renovation project consist of blueprints. Types of blueprints highly vary depending on the type of a project, but usually these drawings are based on an existing structure and old blueprints. In this way, for proper restoration project blueprints an architect should have lots of basis information. Typically, this data for future drawings includes a photofixation document, measuring sketches and juridical documents, which determinate the type of a project, give guidelines and limitations. A photofixation document helps an architect to keep in mind all defects and their location, a building appearance and a planning of it, to recreate it in a blueprint. This document is also important for a client, especially if a photofixation document has photos which were made during restoration works. Measuring sketches are made on an object and include dimension information and rough representation of important parts, such as windows frames, cornices, keystones and so on. Moreover, often measuring sketches are conflicting with old blueprints so they also often represent changes in the structure. Juridical documents, which restrict actions of a company making the restoration and determinate the limits and list of possibilities for architecture decisions in Russia are given by The Committee on State Control Use and Protection of Historical and Cultural Landmarks. Meanwhile in Finland it is the responsibility of The Finnish Heritage Agency (Museovirasto). Thus, these parts of a project are the foundation of any blueprint. Creation of a photofixation document in fact is not a very hard process. However, the human factor is always playing a big role in each project. All defects, details and other parts, which are included into the blueprint, should be captured. If a building is relatively small and does not have lots of external defects or elements, it is not a big issue. However, if a structure is large and covered by many cracks from inside and outside, has difficult and curvy facades full of architecture elements (Appendix 6) – even photofixation becomes a “painful” process. The situation becomes even more difficult, if an object is far away from the office, so there is no possibility to return and explore again all parts, which were not captured initially. For example, such a problem has occurred in The House, in which in 1764-1768. was the officer assembly of the Suzdalskii infantry regiment, the leader of which was Suvorov Alexander Vasilievich (Figure 3.5., Figure 3.6., Appendix 4) which is a relatively small building. Nevertheless, even in this structure some important parts were missed. In addition, this object was in Novaya Ladoga, which is three hours from the office. Another example of this issue is the Kirov's Palace of Culture (Figure 3.3., Appendix 1, Appendix 8). As it was already mentioned, this building has an extremely complex truss system, which is located on the roof in darkness (Figure 3.7.).

Figure 3.7. The fragment of the truss system in The Kirov's Palace of the Culture. (Photo by the author)

Trusses consist of lots of small elements, which are important for restoration, such as bolts, joints, chords and bracings. Its dimensions, appearance and configuration should be correctly represented on a blueprint. However, it was almost impossible to capture all these parts on a camera, because of darkness and a complexity of it. Each time when the process of blueprints drawing was begun, lack of information was appearing. Thus, to draw a correct model of the truss system it was necessary to return many times to the object. The same issue was appearing each time with measurements.

This part requires even more attention and accuracy. Often dimensions conflict not just with dimensions from old blueprints, but even with themselves. For example, a full length of the truss sometimes does not equal summarized other intermediary dimensions according to the measurements (Appendix 8). It means, that an error has occurred, so the measurements must be redone. Thus, to sum up, all this process of premeasuring and taking photos takes a lot of time, patience and is strongly connected with a human factor. That is why mistakes could not be avoided. Such an ineffective way should be and could be replaced by modern technologies.

### 3.4 Coordination issues

Another important, but not very obvious problem in restoration and renovation is a lack of coordination between all participants of a project. Typically, one big project requires attention of at least one engineer, two architects and some assistant personnel to step up progress. All these people work parallel on different things. Somebody is responsible for facades, somebody for plans, and somebody for structure types and calculations of them. Meanwhile, all drawing work in most of the Russian companies is performed in Autodesk AutoCAD. Typically, one of architects begins to draw planning blueprints according to the old ones and measurements and photos, which were made during an investigation. Then, based on these actual planning blueprints another architect begins to draw facades, while an engineer starts to draw structure types and calculate them. At the same time, the architect, who was responsible for planning, continues his work by writing specifications, different tables and other plans. During this process an architect always finds mistakes in his own blueprints or just decides to change layers, colours, etc. However, others keep working with old blueprints without all these changes, and probably, with mistakes. And when an architect shares the recreated blueprints with other participants, mismatches begin to appear. It means, that from this moment according to these new planning blueprints some sizes and layers of facades, structure types and so on should be changed. Moreover, even if the drawings themselves do not conflict with each other, a process of blueprints combination in Autodesk AutoCAD is still difficult and takes lots of time. This problem leads to time losses and mismatching of different blueprints, produced by the same company at the same time, but by different people.

AutoCAD itself is a useful program, especially for restoration projects, where many detalization blueprints are required. It is very suitable for defect schemes and structural types as well as for electricity blueprints. However, beside the issue of blueprints merging and coordination, it has several other problems, which often decrease the effectiveness of a design process. One of the most important issues is the difficulty of connection between information data and objects. Objects in AutoCAD are just a set of different lines without any information beside it. Data is given in specifications and notes, which are made in manual mode (Appendix 4). Creation of tables and annotations takes lots of time and could be optimized by using modern technologies. Another AutoCAD disadvantage is inconvenience of editing, because objects do not have any connection between each other (except the “blocks” instrument) in this program. In this way, to correct even a small part of a blueprint, a user should move lots of objects, which are close to each other. For example, to change the width of one type of wall, all walls of this type must be widened or narrowed down individually. Because of this issue in some projects the process of correction takes even more time than the creation process. Beside these issues, AutoCAD does not have proper visualization possibilities. Although, it has three-dimension functions, it is still not suitable for the creation of a colorful picture, which is useful not just for builders, but also for a client.

### 3.5 Calculation issues

Almost all restoration and renovation projects require lots of calculations. In simple structures typically these are calculations of loadbearing capabilities of columns and beams. For beams in most of cases only shear and bending calculations are performing, meanwhile for columns pressure force calculations are more important. The cross-section of a beam or a column can be symmetrical or unsymmetrical. If it is symmetrical, then most of the calculations could be done fast and correct even with a calculator or Excel, without using special engineering software. This is the reason why such calculations in Russia are still performed mostly as “hand calculations”. However, even this amount of actions and numbers takes lots of time and is enough for making mistakes. Moreover, such estimations should be done not just for one single beam. In each building there are several structural types with different cross-sections. In this way, the quantity of work became significant, so this process requires optimization and more progressive instruments.

The load bearing structure elements are not limited just by columns and beams. In old buildings, which are not rare in the restoration field, could be used such elements as: cupolas, arches, buttresses, cantilevers, spires, etc. Those architectural elements could not be calculated by several relatively simple formulas in Excel. For example, the cupola of The Cathedral of the Saint Life-giving Trinity was restored after the fire hazard (Figure 3.8) during twenty-one years (Figure 3.9).

Figure 3.8. Fire hazard in The Cathedral of the Saint Life-giving Trinity.
By Oleg Siromyatnikov - Praca własna, CC BY-SA 3.0,

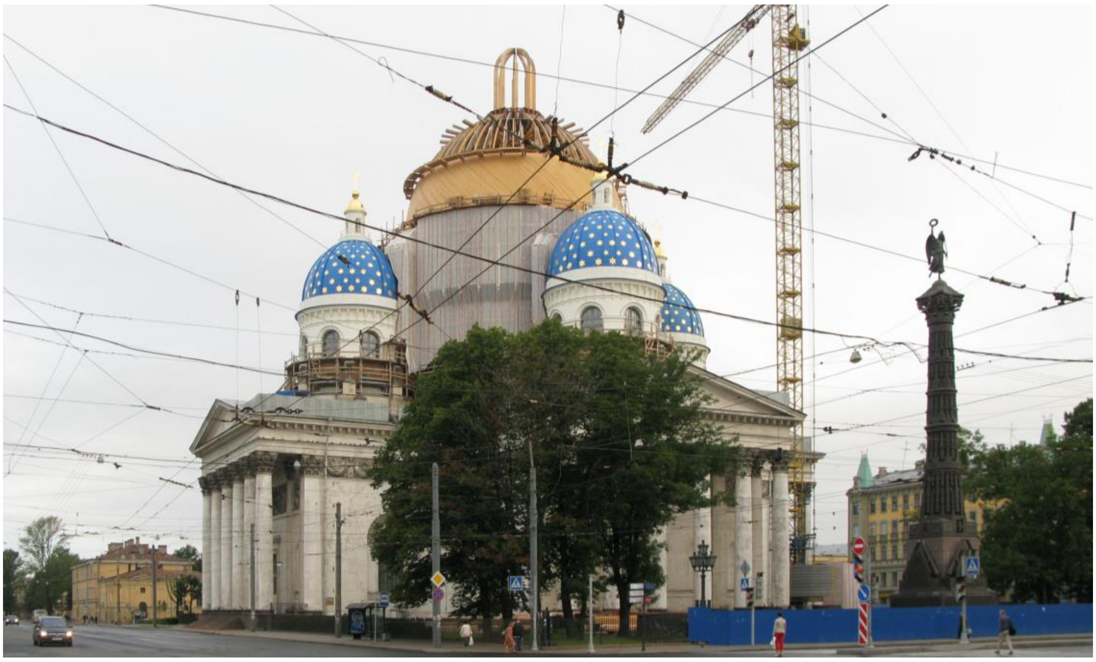

Figure 3.9. Restoration process of The Cathedral of the Saint Life-giving Trinity.
Author: AlexanderKonov - CC BY-SA 3.0,
https://commons.wikimedia.org/w/index.php?curid=4713017

# 4 SOLUTIONS BY USING MODERN TECHNOLOGIES

## 4.1 Inaccessibility issue solutions

The issue of inaccessibility often appears in restoration and renovation projects. In many cases, people physically cannot reach some important for an investigation parts of a building. However, an investigation of an old structure could not be performed without a survey of load-bearing structures, roof and other hidden or unsafe parts of a building.

### 4.1.1 Drones

If this particular problem is taking place due to a height of a building, special cars with elevators could be used (Figure 4.1). However, a rent of such a bucket truck is expensive and seems irrational, if only one top element of the building should be investigated. For example, the total cost of a bucket truck rent with work of two operators in Helsinki will be equal to roughly 600 euros per hour. Meanwhile the professional drone DJI Mavic Pro PLATIMUN costs about 1463 euros. In such cases a usage of drones is one of the most effective and economical ways to solve the issue of inaccessibility. Moreover, it is possible to combine laser scanning with a drone.


Figure 4.1. Bucket Truck Scania.
https://autoline.com.pl/-/sprzedaz/podnosniki-koszowe/SCANIA-94G-260--18020323575970268400

Quattro copters (drones) could be widely used in the renovation and restoration fields. They are very suitable for an aerial surveying, which helps a project company to create a proper situation plan and reach a full and clear picture of a construction site and an associated area. This method is especially effective for big cities with a dense development, where many things cannot be seen from the ground because of other objects hiding them. Drones could also be very useful for a photofixation document with its possibility to take close photos of final cornices, dripstones, fielded panels and other architectural elements, which could be a part of historical heritage. Moreover, this facility can help to measure these shaped elements for a proper design and do it without any risks for people. Possibility of viewing from a height and great distance also gives an opportunity to control a construction process, when the design stage of a project is finished (Figure 4.2). Additionally, this method allows to do this from different points of view, while the picture could be received by a client or a project manager even from the office. For example, quattro copters could easily solve the problem, which was described in Chapter 3.2 and appeared during the restoration project of the Russian Research Geological Institute named after

A.P.Karpinsky without necessity of visiting unsafe roof by the stuff. However, drones could be useful not only when a view from a high is required. It is also relevant in dangerous places, where people cannot enter because of risks. Such a situation was also described in Chapter 3.2 and appeared during the technical-engineering investigation of The Kirov's Palace of Culture.

Figure 4.2. The view on the construction site in the city Pushkin. Photo was captured by a drone.
https://dmstr.ru/articles/ulyetnoe-stroitelstvo/

A quattro copter in this object can give a possibility to investigate parts of a roof, which are not accessible for people (Appendix 1), to measure and take photos of truss systems, which were located in parts of a building, which are in a critical condition. Thus, without this content, which could be reached only by using drones, the investigation is not accomplished.

Drones in the future could also solve safety problems by replacing people's labor in dangerous places. According to the statistics of The Ministry of Labor in Russia in 2015 from January till October 1180 people died in industry. Furthermore, one-third of it accounts for falling from a height. Most of these fallings are related to the construction industry.

Although, using of drones for construction works has many advantages, there are a few challenges to take into account when considering making use of one. For operation of a commercial drone at least two people are required. This operation staff should know the exact flight route of the drone and be experienced in usage of it. These individuals must understand all important aspects of it, especially the drone's sensor, in order to retrieve the best possible footage and information. Weather conditions and light are also important. Strong wind could affect the route of a drone, meanwhile lighting conditions must be considered while choosing the settings and the height of flying.

Meanwhile, in Finland drones are already actively used in restoration and renovation fields to solve the issue of inaccessibility and increase the effectiveness of the investigation and construction process. Finnish companies often combine quattro copters with BIM technologies and Laser scanning, which will be discussed in Chapter 4.2.1 and Chapter 4.3.1. Finnish government also has already developed and approved laws concerning drones and gives special licenses for the usage of it.

### 4.1.2 Non-destructive methods

"Non-destructive methods are a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage." (Nondestructive Testings. ASM International). Such methods allow to inspect objects without the destruction of it and keep it functioning. Moreover, if it is necessary, this procedure could be continuous during an object lifecycle, which gives an opportunity to detect and fix defects timely.

Currently, the most popular methods of non-destructive control are:

- Sonic or ultrasonic
- Magnetic
- Radiological or X-ray
- Thermal
- Electrical

Ultrasonic method is multifunctional and could be applied to any type of a welded seam. It is based on the evaluation of material properties by receiving of an ultrasonic wave's speed of transmission. This method gains its popularity due to relatively simple usage of it and an applicability of ultrasonic for a majority of materials. Due to this method of survey such defects could be found as cracks, segregation, cissing, etc. Ultrasonic instruments have a high penetrating power, high sensitivity, greater accuracy than other non-destructive methods in determining the depth of internal flaws and the thickness of parts with parallel surfaces. It also gives immediate results, which is very useful during investigations. However, this method requires a clean and well prepared surface, extensive technical knowledge and in some cases parts that are rough, irregular in shape and very small or thin or not homogeneous are difficult to inspect. Such a method was used, for example, during the investigation of external walls in the Kirov's Palace of Culture. (Figure 4.3., Figure 4.4.) This project had strong time limits, so this method was used as the fastest one and which gives a finite data without additional calculation.

Figure 4.3. Using of the ultrasonic strength meauring instrument in Kirov's Palace of Culture. (Photo by the author)


Figure 4.4. Using of the ultrasonic strength meauring instrument in Kirov's Palace of Culture. (Photo by the author)

Magnetic method is based on analysis of an interaction between controlling object and a magnetic field. The instrument is receiving signals of diffusion of magnetic fields near defects or magnetic properties of an investigating object. This method is used mainly for objects consisting of ferromagnetic materials, such as iron, nickel, cobalt and so on. The investigated object is magnetizing, and then its properties are measured. If the object has any hollows, the magnetic inductivity will decrease, the magnetic flux rounds defects, creating the magnetic waves of diffusion. Also this method is cost effective (Table 4.1), environmental friendly and safe for an operator. The disadvantage of this method is depth limitations. This method could detect defects to a depth of 2-3 mm. Moreover, “weld reinforcement could significantly reduce sensitivity of control method”. (The magazine “Science and Technique of Kazakhstan”). Another issue of this non-destructive method is a dependence of reliability of results on subjective factors: qualification, experience and good faith of an operator.

Radiological method (Figure 4.5) is absolutely multifunctional, because it is based on the physics of x-rays, which could go through all materials. The radiation is passing through an investigated object and affects a photosensitive film, which is located right behind an object. In places with defects the image will be brighter, because beam absorption is decreasing due to less density of a material. Such a method could help to detect such defects as cracks, cissing, metallic and non-metallic inclusions, pores and burn-throughs. Moreover, by using X-ray it is possible to explore an internal configuration and mutual bracing of a controlling object, which is inaccessible for visual investigation in the process of fixing or exploitation. The most important disadvantage of this method is a risk of harm for a person's health, which requires additional radiation protection.

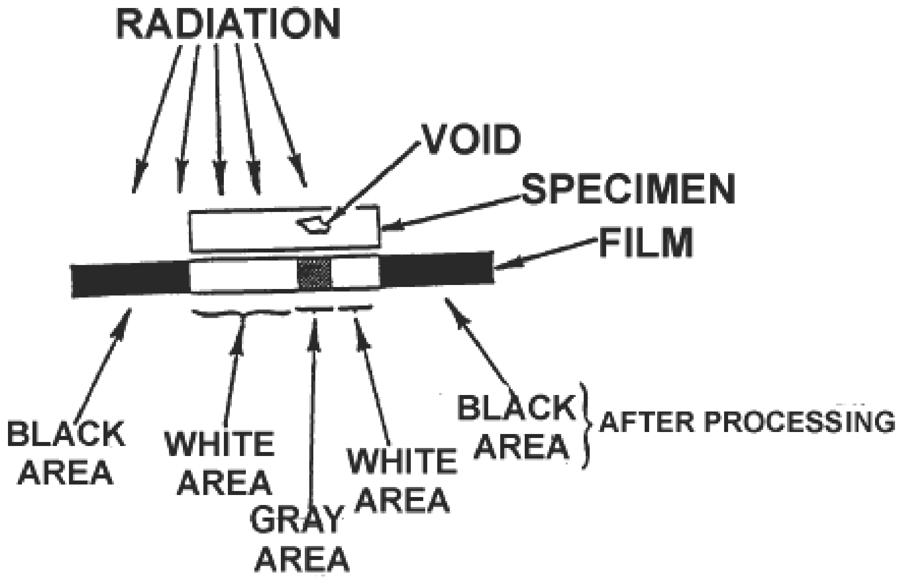


Figure 4.5 Scheme of the radiological method principle of operation.
https://www.engineersedge.com/inspection/radiography.htm

Thermal control is based on measuring, observing and analysis of an investigated object temperature. For this method a special instrument called a thermal camera is used. This method is suitable only if an object has heat flows in it. Thermal non-destructive method could be two types – active and passive.

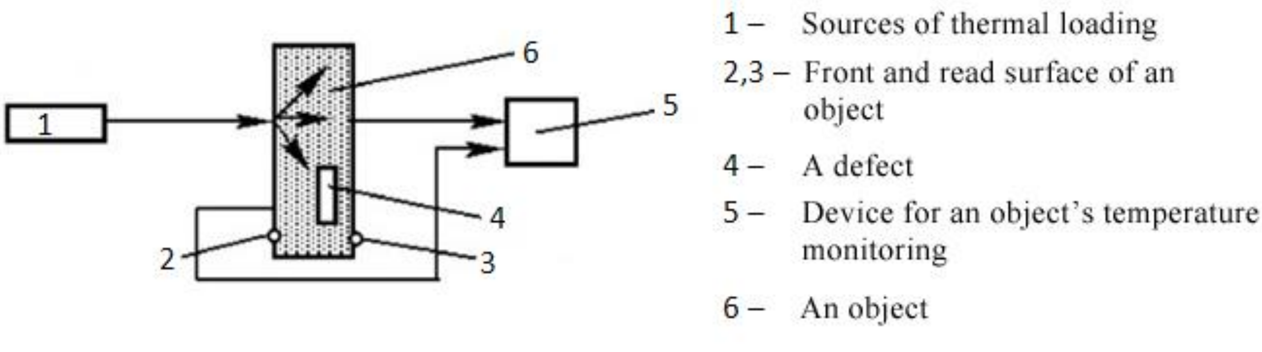


Figure 4.6 Scheme of the active thermal method principle of operation.
http://www.devicesearch.ru.com/article/metody_nerazrushayuschego_kontrolya

Active method (Figure 4.6) is used for the objects, which do not produce enough heating radiation for a thermal test. For analysis this object is heated by external sources. Typically, such objects are multi-layered composite materials. Meanwhile passive thermal control is just defining thermal field, which is produced by an object itself during its exploitation. The temperature of a controlling object is changing proportionally its surrounding by producing or absorbing the heat. As a result, the thermal camera shows and marks the coldest and the hottest points on the whole surface area of an object. Nowadays thermal cameras costs highly vary from very cheap for simple and not precise ones to an extremely expensive professional tools, which makes this method relatively available for everyone. Moreover, this method is safe for an operator, effective even in dark places, and could be used without any contact with an object's surface. It also allows an operator to investigate large areas and relatively easily find defects. However, for a proper analysis this method requires expensive software for some cameras and a skill to use it. Another issue is inaccurate measurements in some cases. "If temperatures are very close in range, infrared imaging can lead to misreading information taken in from the camera; objects can become indistinguishable. The current technology in thermography only allows for imaging to be applied to surface temperatures". (Sciencing.com). Glass surfaces also strongly affect the measurement accuracy. An example of thermal test is demonstrated in Appendix 5.

The electrical method of non-destructive control (Figure 4.7) is based on receiving and an analysis of the electrical field parameters, interacting with an investigating object or appearing in it due to external action. In places with internal defects a voltage drop is detected and measured by electrodes. Based on an analysis of these measures the location and type of a defect is determined. Beside detection of defects, this method also gives a possibility to measure the width of walls, covering and layers, sort steel grades and control dielectric or solid state materials. However, this method also has disadvantages, such as necessity of contact with a controlling object, hard requirements to cleanness of the object's surface, difficulty of measuring process automatization and dependency on the results from surrounding conditions.

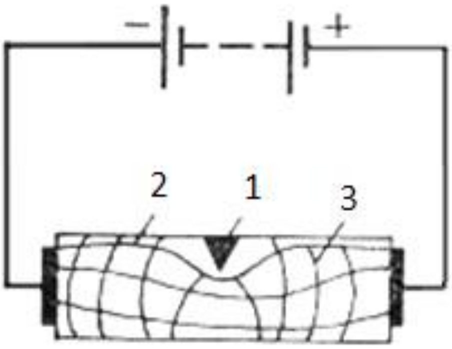


Figure 4.7 Scheme of the electrical method principle of operation.
http://www.devicesearch.ru.com/article/metody_nerazrushayuschego_kontrolya

| Type of the instrument | Materials | Cost | Disadvantages | Advantages |
|---|---|---|---|---|
| Ultrasonic | Majority of materials | ≈1000-1500€ | -Requires clean surface<br>-Requires extensive technical knowledge<br>-Some parts are difficult to detect | -Penetrating power<br>-Sensitivity<br>-Accuracy<br>-Do not harmful for people<br>-Immediate results |
| Magnetic | Objects consisting of ferromagnetic materials | ≈500-1200€ | -Depth limitations<br>-Weld reinforcement could significantly reduce sensitivity<br>-Dependence of reliability of results on subjective factors | -Cost effectiveness<br>-Environmental friendliness<br>-Safe for an operator |
| Radiological | Multifunctional | ≈2000-3000€ | -Harmful for people<br>-Require additional radiation | -Multifunctionality<br>-Possibility of exploring internal configuration<br>-Clear and |

| | | | | |
|---|---|---|---|---|
| | | | protection<br>-Expensive | detailed picture |
| Thermal | Objects with heat flows | ≈350-16000€ | -Expensive software<br>-Requires skills for using software<br>-Inaccurate measurements in some cases | -Wide choice of thermal cameras<br>-Safe for people<br>-Does not require a contact with a surface<br>-Could be used in dark places<br>-Gives a possibility to investigate large areas |
| Electrical | Majority of materials (Including dielectric and solid state materials) | ≈800€ | -Requires contact with an object<br>-Requires clear and prepared surface<br>-Difficulties of measuring process automatization<br>-Dependency from the surrounding condition | -Suitable for different materials<br>-Possibility to measure width of layers<br>-Possibility to sort steel grades |

Table 4.1. Comparing of the different non-destructive control methods. Costs are specified roughly for a standard kit.

### 4.2. Measuring issues solutions

Restoration and renovation fields are strongly connected with existing buildings. These structures often have difficultly shaped facades, enriched by different architectural elements such as cutting, cantilevers, cornices, rustication and so on. These types of buildings require much more attention than standard ones and are difficult to measure. Moreover, they make up the majority in restoration and typically include in the historical heritage register.

#### 4.2.1 Laser Scanning

A creation of blueprints for these structures by using only AutoCAD and simple measuring instruments takes lots of time and attention. Additionally, by using only this list of tools the end result probably will not be accurate enough. An example of such blueprint is shown in Appendix 6. It is a segment of a graphical part of the restoration project. The illustrated wooden building represents the classical Russian Revival style, with an incredible amount of cutting, difficult shaped façade made of logs and highly decorated windows. Moreover, over the years, this structure has significantly fallen into despair. The façade has begun to deviate from the vertical. All these elements and all these defects, including deviation from vertical, should be measured and drawn on blueprints. In this particular project, the whole blueprints were made in AutoCAD by using only photos and rulers, because the company did not have any other modern tools. One of the participants of this project cannot announce the exact number of hours spent for these blueprints, but named it as a “painful process”. Certainly, modern technologies should give a solution for such issues, and one of them is a laser scanner.

In the beginning it would be appropriate to declare the terminology. “In modern surveying, the general meaning of laser scanning is the controlled deflection of laser beams, visible or invisible” (Gerald F. Marshall Handbook of Optical and Laser Scanning, Marcel Dekker). The laser scanner technology continues to gain more and more popularity in the construction industry, with its ability to collect tones of highly accurate information in a very short period of time. Currently, this tool continues its development, decreasing a speed of scanning and increasing accuracy of measurements. Scanning of objects most often is applied to existing building structures. Moreover, it greatly works with the BIM technologies for a creation of as-built models, which will be discussed in Chapter 4.3.1. A laser scanner could be divided into four main parts.

- The transit equipment. Usually, laser emitter and receiver are implemented in this element.
- The rotary multifaceted prims. This part provides laser beam propagation in vertical plane.
- The servomotor of the horizontal circle. This part provides rotation of the detector head (transit equipment) in horizontal plane.
- The computer. It is used to control the survey and to record data into storage.

A result of survey made by laser scanner is a picture, consisting of dots. “This detailed 3D representation of the building project is often called a point cloud.” (When to Use Laser Scanning in Building Construction, By Cathi Hayes and Eric Richie). (Figure 4.8.) This huge amount of dots and photos creates a basis for the future blueprints. The speed characteristics of laser scanners are highly varying from 50,000 to 1,000,000 points per second in a 3D space. In some cases, when the speed factor does not play an extremely important role, the cheaper one can be used. Although, if a project is facing strong time limits, it would be wise to use the fastest scanner, to get a full picture of the structure, even if it is large, for a relatively short period.

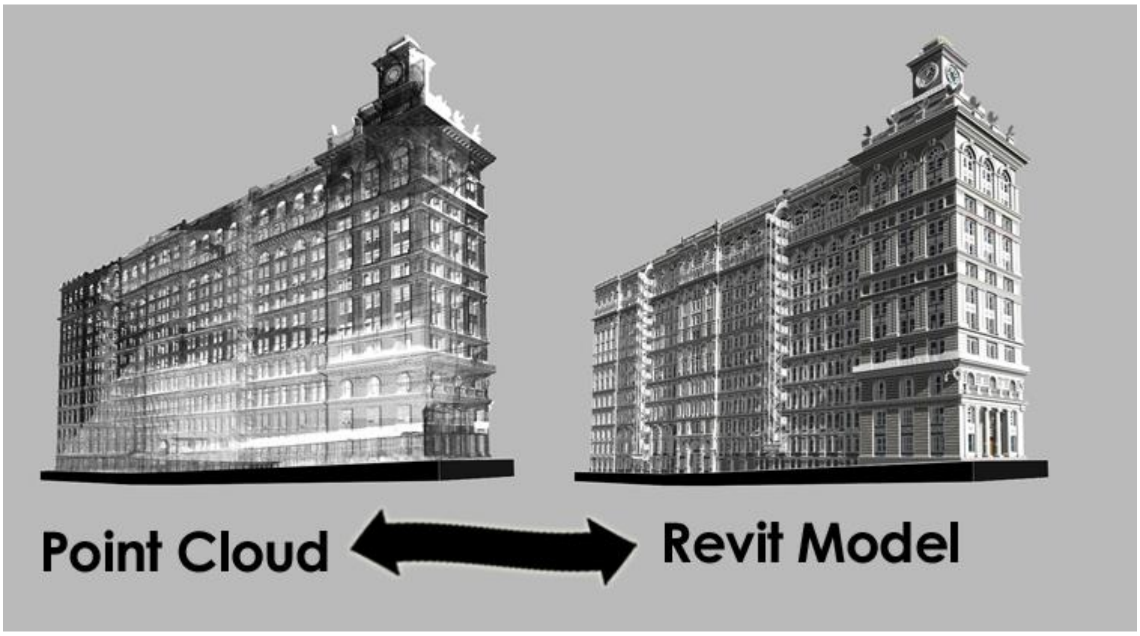


Figure 4.8. Point cloud data and revit model differance.
http://lanmarservices.com/3d-laser-scanning-basics/

The range characteristic of laser scanners is also very different and depends on an intended purpose of the tool. Some laser scanners for the topography could scan from a height of a helicopter or a drone flight, meanwhile scanners for small house investigations do not require such range distance of functioning. Far range distance scanners also could be useful for scanning of height structures without using any lifts or scaffoldings. “Measurement accuracy is the range within which measurements from point clouds are accurate.” (When to Use Laser Scanning in Building Construction, By Cathi Hayes and Eric Richie). Obviously, high-quality and expensive scanners will be much more accurate and, consequently, multifunctional than less accurate cheaper ones. However, if a company needs to rent a laser scanner, it would be wise to choose the correct one, with appropriate characteristics. Another important property of this tool is eye safety. “All laser scanners are rated by the Center for Devices and Radiological Health (CDRH) for their eye safety. The levels range from Class 1 to 3R, with a Class 1 device being the safest, as no precautions are required. A Class 2 laser is also considered quite safe because the human blink reflex will limit the exposure to no more than 0.25 seconds.” (When to Use Laser Scanning in Building Construction, By Cathi Hayes and Eric Richie). The laser scanner must be chosen based on these common characteristics and type of a project.

A laser scanner could be used for absolutely different purposes. However, when the restoration and renovation fields are discussed, the most interesting purpose is the as-built modeling. The as-built modeling is important for the future restoration or renovation of the building, because it solves the issue of incongruity between the existing building as it was built and the project idea of it. During construction many decisions are made according to a real situation on a construction site, and not only in accordance with a design. As-built modeling erases this problem by presenting the information about an erected structure, such as final planning, engineering solutions, structural types, and other elements, which could be changed during a construction process. However, most of the as-built models (or drawings) are inaccurate and incomplete. “And if a building renovation is designed on outdated or incomplete drawings, errors will be “designed in.”” (When to Use Laser Scanning in Building Construction, By Cathi Hayes and Eric Richie). Nevertheless, the main issue is that these errors will occur only during a construction phase, when solving of them is much more difficult and expensive. In this way, a correct as-built model could save money, time and reputation of the company, which is responsible for the restoration or renovation of the building. The best way to create the most accurate and full as-built model (or drawing) is using of a 3D laser scanner. Capturing as-built data for renovations or restorations requires first scanning all areas of a building, involved in a project, then registering or stitching together the point cloud data. If models and drawings already exist, this point cloud could help a user to set up a correct coordinate system, and then fix incongruities, if they occurred. After this process, as-built scan data could be compared with the original project drawings or models.

Without as-built model or drawing a project company, which is responsible for a renovation or restoration project must measure everything and investigate from the beginning by itself. Such a situation occurred during the project in Novaya Ladoga The House, in which in 1764-1768 was the officer assembly of the Suzdalskii infantry regiment, the leader of which was Suvorov Alexander Vasilievich (Figure 3.5., Figure 3.6., Appendix 4). The initial project blueprints significantly differ from the existing building. As it was already mentioned, the Novaya Ladoga is located far away from the office, so it was hard to measure, investigate and make a sketch for this existing building during one day to avoid a necessity to return.

However, if a building did not have initially as-built model and over time requires restoration or renovation, a laser scanning still could be useful. Each restoration or renovation project requires basic blueprints or models, which are reflecting the current structure’s condition and a configuration of objects, such as walls, windows and other architectural or interior design elements. Quite often as-built drawings for old buildings are lost or even did not exist from the beginning, while project documentation usually contradicts with an actual situation on object. In restoration and renovation projects the laser scanning technology can be useful due to such benefits as millimetric accuracy, fast speed of surveying and, most importantly, a possibility of using in hard-to-reach and dangerous places. The cost of using ground laser scanning in a small area is more than traditional methods of surveying. Although even with higher cost this method gives a tremendous advantage. The laser scanning technology has already proved its efficiency in Russia and Finland. As an example, the restoration project of the Church of the Holy Wisdom is presented (Figure 4.9).

This church was designed in 1862-1868 by the Russian architect N.I. Kozlovski in the Byzantine style and is located right in front of the Moscow Kremlin. In the beginning of 1990 the bell tower of the Church of the Holy Wisdom was in an advanced state of decay. Till 2013 this building was standing in a critical condition and was requiring a total restoration or demolishment. Since that year till present days there is an undergoing maintenance and restoration of the facades, as well as interior space of the church.

Figure 4.9. the Church of the Holy Wisdom
Author: Ludvig14 - CC BY-SA 4.0,
https://commons.wikimedia.org/w/index.php?curid=69519558

However, the main reason why this building is considered in this study is a usage of the laser scanning technology twice during restoration works. The first one survey was made by using the ground laser scanner RIEGL VZ-400 for capturing of the current condition of the facades and creation of visualization of the historical heritage object for the future facades fixing works. The survey was done by one realizer and took no more than forty minutes. The results of the capturing process by the RIEGL VZ-400 scanner are shown in Figure 4.10.

The second survey was done by using principally new approach on the laser scanning market. In this case the hand-held scanner GEOSLAM ZEB1 was used. While scanning by this tool there is no need for initialization by satellite GPS. For creation of a point cloud the SLAM algorithm is used with a simultaneous referencing and capturing. This scanner is working on smaller distances, which does not exceed thirty meters. However, it provides quick interior survey, small and hard-to-access spaces, where traditional methods of scanning are impossible or difficult to implement. This type of approach gives a possibility to measure building from the inside and outside with higher effectiveness than by using a ruler, and with much lower expenses than by using a common laser scanner. Although, it cannot provide such accuracy and detalization as a common ground laser scanner such as RIEGL VZ.

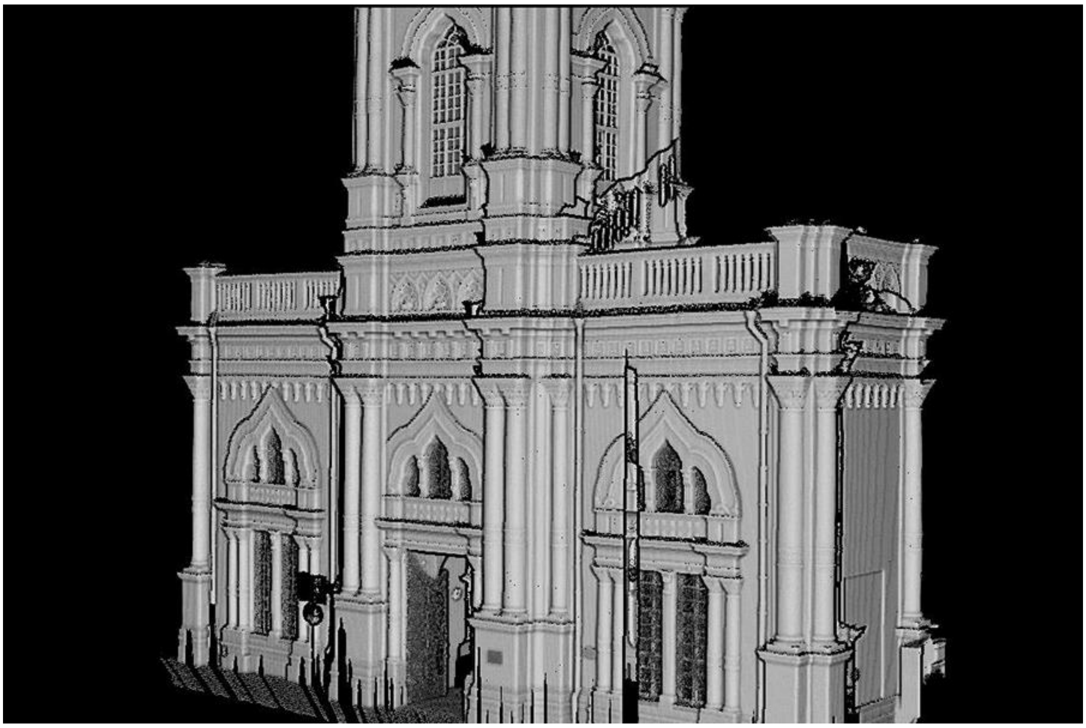

Figure 4.10. Point cloud of the Church of the Holy Wisdom created by the RIEGL VZ-400 laser scanner.
http://art-geo.ru/solution/lasernoe-skanirovanie-v-arkhitekture-khram-sofiya

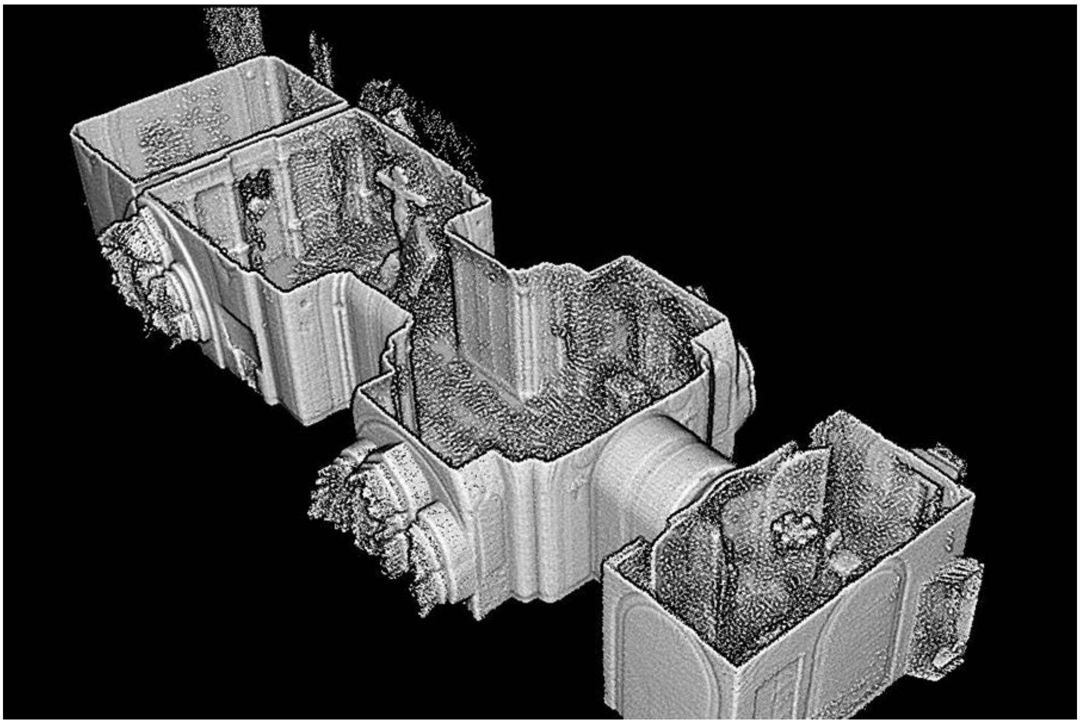

Figure 4.11. Point cloud of the Church of the Holy Wisdom interior created by the GEOSLAM ZEB1 laser scanner.
http://art-geo.ru/solution/lasernoe-skanirovanie-v-arkhitekture-khram-sofiya

The purpose of this second scanning was to make a survey of external walls and interior spaces, including spiral stairs and hub zones of the bell tower, church rooms and the altar. It was impossible to perform laser scanning during one survey, considering the difficult configuration of the building, quantity of passages and big amount of data. Thus, the process was separated into four parts. The amount of data in all these parts includes in total seventy-one millions of points. The surveying of each room takes around fifteen-twenty minutes (Figure 4.11).

During the processing and binding data achieved by using ZEB1 together, the old survey made by RIEGL VZ-400 was opened. Both point clouds were analyzed and compared. Thus, both scanning data were used during the process of the final 3D model creation. The resulting model is presented in Figure 4.12 and will be used during the future reconstruction and restoration.

Figure 4.12. Final model of the Church of the Holy Wisdom.
http://art-geo.ru/solution/lasernoe-skanirovanie-v-arkhitekture-khram-sofiya

However, laser scanning with all its advantages in some cases can be an inadequate approach. In such situations it would be wise to use additional tools or even totally abandon from this method. For example, a laser scanner should have direct visibility. Although, some objects cannon be captured directly from the ground, even if several points are used. In this way, this tool does not give a possibility to fully scan a bridge or other engineering structure, if there is no near point, which is a little bit higher and gives a direct view. The same situation could appear during scanning of a roof, if it is not open or safe for people. In such cases, additional tools can be used or a combination with a data gained by other methods to solve this issue. One of such approaches could be usage of an aerial survey. This technology is well-developed and actively used in Russia as well as in Finland, mainly by land-surveyors. Nowadays, very accurate photographic cameras with implementation of a GNSS receivers can be installed into a small unscrewed aerial vehicle or into a quattro copter. The results of a survey by these tools can be a point cloud, as well as a highly-precise orthophotomap. Thus, this collaborative usage of laser scanning and considered tools erase the whole problem.

Another significant issue of a 3D laser scanner is a high complexity or even impossibility of scanning of any glass structures, windows and other flawless surfaces. Due to the principium of a laser scanner functioning a laser beam is reflected with the same angle, as it falls on a glass, and does not return to the receiver. Thus, the gained data becomes inaccurate and with a big amount of defects. The solution of this problem is covering of smooth surfaces by special dyes or scanning of an object before an installation of glass surfaces.

Matching (referencing) of the scanner is also can be problematic. In some cases, a laser scanner cannot create its own geodetic chain and connect to a coordinate system without using additional tools. Nowadays, this issue can be solved by using connection with a tacheometer or a GNSS receiver.

Weather conditions as well as other factors of the environment could affect the scanning results and interfere the process. These factors could not be called disadvantages, because all geodetic tools are dependent on the environmental impact. However, it is an important moment to consider during a scanning process. Most of the scanners are equipped with ingress protection, but still strong wind and precipitations could worsen scanning results creating distributions in a point cloud. Such defects can be inacceptable during scanning of objects, which require high accuracy. Low temperatures could also make a survey impossible. The laser scanner manufactures offer different solutions for this problem, such as special “arctic” modifications of scanners and winter cases. However, weather conditions impact could be dodged only by waiting for a better weather.

To sum up, 3D laser scanning system can be characterized as a very perspective and revolutionary technology with some limitations and disadvantages in usage. Nevertheless, this method is still very effective in a renovation and restoration field and allows to significantly increase the accuracy and speed of modeling or drawing creation. Moreover, this technology continues to develop. Scanning by the last models of laser scanners, for example Leica RTC360 (Figure 4.13), provide an extremely fast survey with photos and a high accuracy point cloud. New models are simple to use and could be controlled from a tablet (Figure 4.14).

Therethrough, another benefit of this technology is that it does not require any special knowledge of the scanning process, so a company could save its money by not spending them on specialists, as it was before such a level of scanning development.

Figure 4.13. Leica 360 3D Laser scanner. (Photo by the author)

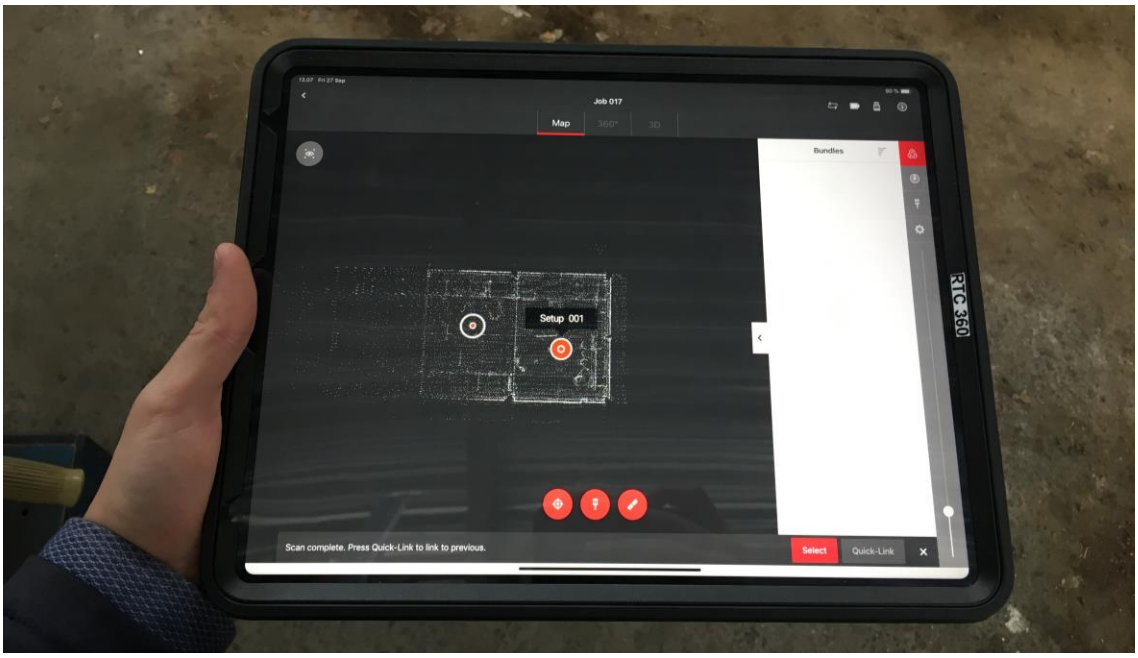


Figure 4.14. Leica software on the tablet. (Photo by the author)

### 4.3. Coordination issues solutions

Lack of coordination between project participants in every renovation or restoration project is one of the most time and money consuming issues. Lots of mismatches appear during blueprints creation which leads to decreasing of effectiveness. Moreover, by increasing project participants this problem is only progressing. An experienced project manager could partly solve this issue, but even if people work together as an ideal system without any delays and mistakes, a process of matching different blueprints would stay ineffective and time-consuming.

#### 4.3.1 BIM technologies

Thus, the core of the problem is hidden inside a software. AutoCAD does not have all necessary tools for proper matching of blueprints. Moreover, two dimensional drawings are not representative enough, especially in historical heritage objects. Modern challenges in construction industry require a new philosophy of engineering and design with actual tools, providing solutions for current problems. Such philosophy already exists and is called BIM – Building Information Modeling.

There are two main definitions of BIM. The first is specified by the Construction Project Information Committee (CPIC) as "… digital representation of physical and facility characteristics of a facility creating a shared knowledge resource for information about it forming a reliable basis for decisions during its life cycle, from earliest conception to demolition". Meanwhile the second definition is given by National BIM Standard as "a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward''

In this way the BIM itself is a conception of information modeling, based on which a special software is produced. The BIM usage highly varies and covers different parts of the construction industry. "Property and construction modeling aims to support a design and construction lifecycle process that is of high quality, efficient, safe and in compliance with sustainable development. Building information models are utilized throughout the building's lifecycle, starting from initial design and continuing even during use and facility management (FM) after the construction project has concluded." (Common BIM requirements. Building SMART).

Nowadays BIM is actively used in European countries, including Finland. Almost all, even small, construction companies have successfully implemented this technology into their working flow. However, according to Mascio & Wang "The impression given is that BIM is interrelated in the design, management and other processes of new construction, while less interrelated with existing buildings". Thus, even in developed European countries BIM is not fully implemented into all renovation and restoration projects, although, it could be extremely helpful. Meanwhile in Russia the BIM technology has just begun to be used in experimental projects. According to the Minstroi website only in April 2019 the Russian government became interested in the BIM and decided to start first governmental projects. Drimti Volkov, the deputy head of the Minstroi has mentioned:" the realization of the pilot projects will let us to know, which design problems could appear during the BIM technology usage on all stages of a project: a design, an expertise, a construction exploitation. As a result, we could supplement our technical standards basis". Investition-construction projects for building information modeling implementation plan were provided by "Mostotrest", "Gasprom Neft", Rosautodor, OAO "RZD", and the State Corporation RosAtom.

So, what benefits does the BIM technology provide?

1. BIM objects are not just a three-dimensional model. The most important part of it is information, which gives opportunities for automatically blueprints creation, project analysis etc.,
2. BIM supports parallel working by group, which could decrease time consuming and mistakes quantity.
3. The BIM technologies could provide high accuracy of engineering services modeling
4. Specifications and statements are more precise due to an automatization.
5. Gives an opportunity for a preliminary cost evaluation
6. General economical and ecological characteristics of a building could be estimated on a sketching stage, which gives a possibility to add changes into a project preventing future issues.
7. Optimization of the construction process, management, site control, and material and finance utilization is performed.
8. Typically, provides a better visualization, which could be used for client, workers, and other project participants.
9. The Open BIM gives a possibility to combine several models together by using the IFC extension.

To sum up, such a combination of information and three-dimensional modeling with an opportunity of matching models from different programs and parallel working of designing groups could significantly increase the effectiveness of a working flow and give better results in the end. Moreover, the Open BIM could solve the issue of mismatching and lack of a coordination between project participants, by using the IFC extension and a special software. However, even this progressive technology has its own disadvantages.

1. The BIM technologies are not adopted for an issue of a design documentation in Russian Federation. As a result, many parameters should be set up manually.
2. Relatively high expenses of the software ($6000-12000)
3. More complicated to learn than traditional methods
4. Could not be implemented without significant changes in a working flow.
5. Loss of the existing practice and experience in traditional methods
6. The IFC extension set up some limits of an editing.

Nevertheless, it is important to mention, that most of these disadvantages could appear only in the beginning of an implementation process. The longer the BIM technology is used, the more effective it is.

As it was already mentioned, the BIM technology is a philosophy, which includes different tools and software. The most popular BIM software is described in Table 4.2.

| Software | Purpose | Benefits |
|---|---|---|
| Autodesk BIM 360 | A possibility to completely manage a project entire lifecycle. Controlled working-sharing environment, design review, deliverable coordination. | Actively tracing and tighter project controls for handing submittals packages.<br>Get visibility over model versions when combined with extended team models<br>Centralizes viewing, marking up and publishing of comments for review. |
| Tekla BIMsight | Models combination, checking and identifying conflicts, team communicating issues. | Available for tablets.<br>Available to users for free.<br>Simple interface<br>Support IFC extension |
| Autodesk Revit Structure | Structural and MEP design, architect design. | Multifunctional<br>Synchronizing with the Robot Structural Analysis and AutoCAD<br>Support parallel working of a project team |
| Autodesk Navisworks | Project review software tool for AEC professionals. | Simplifies the sharing of data and workflow in the |

| | | |
|---|---|---|
| | Complements other Autodesk 3D design packages for opening and combining 3D models, reviewing the model and navigating around it in real time. Also used for clash detection | cloud with the projects<br>Improve clash detection process.<br>Provides better visualization through cut plane highlighting. |
| BIMobject | Cloud tool for architects, engineers, constructors, and designers to access manufacturer-specific BIM objects. | Available for free by a simple registration process.<br>Possibility to search and download thousands of options for BIM objects.<br>Helps to optimize workflows. |
| BIMx | Presentation of BIM models in 3D and 2D documentation. | Gives a clear visual representation of 3D model. |
| Tekla Structures | Information modeling and structural design. Could be used for design, detalization and information management on all stages of a project. | Possibility to create accurate and informative structural models. Progressive tool for a connection creation. Support Russian standards environment. |
| ArchiCAD | 3D architectural BIM tool for design and modeling. | No gaps between early stage design and BIM<br>Support open BIM<br>Could be used for MEP design. |
| AECOsim Building Designer | Design, analysis and management infrastructures of any scale and type. | Cloud capability and mobile support.<br>Users are unrestricted |

| | | |
|---|---|---|
| | | from designing and modeling infrastructures no matter how complex.<br>Building simulation provides prediction of the real-world performance of the structure. |
| Trimble Connect | Cloud-based platform for sharing BIM data between project participants. | Available for free.<br>Robust integrations that work for various systems. |
| Hevacomp | Building energy analysis. Real-world performances. | Conduct whole building energy simulations to help with design alternatives.<br>Possibility to use a common building model minimizing time consumption on re-entering building data information. |
| SketchUp | 3D modeling tool for sketching. | Free browser 3D modeling<br>Simple to use |
| AllPlan Architecture | Creation of 3D architectural models with visualization and physical and functional properties. | Opportune to spot errors during the early design phase. |

Table 4.2. The most popular BIM software.
Based on: https://financesonline.com/building-information-modeling/

However, the main question of this chapter is: How could BIM be used in renovation and restoration?

The answer is hidden in combination of Table 4.2 and Chapter 3.4. The BIM technology partly solves the coordination issue by an uninterrupted information flow during a design phase, by tools for merging models and by clash detection. Moreover, BIM could be combined with the laser scanning technology, especially for creation of an as-built model.

Actually, each renovation project starts with a process of measuring and investigation of an existing building. Then, this data is compared to a project documentation to find differences between the design ideas and the result of a construction. This model, which digitally represents the current configuration of an existing building, its appearance and structural types called as-built model. "All BIMs required for the project must be supplemented in the construction stage to reflect the modifications made so that they correspond with the end result 'as-built." (BuildingSmart Finland. Common BIM requirements 2012). As-built model is an important part of each renovation project based on BIM, without which other design stages cannot be started. To create a precise as-built model in the most efficient way it would be wise to use the laser scanning for a fast and accurate survey (Chapter 4.2.1), drones for exploring of dangerous parts of an existing building or to investigate a building from the top (Chapter 4.1.1) and non-destructive methods (Chapter 4.1.2) for an investigation of hidden parts of a structure.

It is important to mention, that a digital representation of an existing structure could be done as 2D blueprints in AutoCAD without using any BIM technologies. For example, in Russia such a method still is the most popular one (Appendix 4). Russian companies explain their conservativeness by cost of software and difficultness of the implementation process on all stages of a project. However, the purpose of an as-built conception is not just a representation of appearance. It should be enriched by information about materials, colors and dimensions, which traditional 2D blueprints could provide only by separated tables and remarks. It is not representative and informative enough, which leads the project to a decreased quality, mistakes, and inefficiency. Meanwhile, the as-built BIM model reflects all aspects of the existing building and could be used as a basis for the future renovation design model. The process of as-built model creation is even easier by using a laser scanner with a special software for an automatic connection of points to create surfaces, such as “Cyclone”. “Cyclone-SCAN is a data-capture application for use with Leica high definition laser scanners. User-specified scan area and density, data filtering, scan scripting, and automatic recognition and extraction of both planar and spherical Leica Geosystems HDS targets – all contribute to this easy-to-use, intelligent data capture application”. (See Chapter 6, References).

However, BIM in renovation and restoration projects is not limited only by as-built modeling. All other stages of a project could also be performed by using a BIM software. Such a method of modeling is especially effective in HVAC systems design and rebar modeling (Figure 4.15). Traditional blueprints cannot give a clear and easy understandable picture even for specialists, meanwhile 3D visualization and a possibility to import 2D blueprints from different sides of a model gives an illustrative representation.

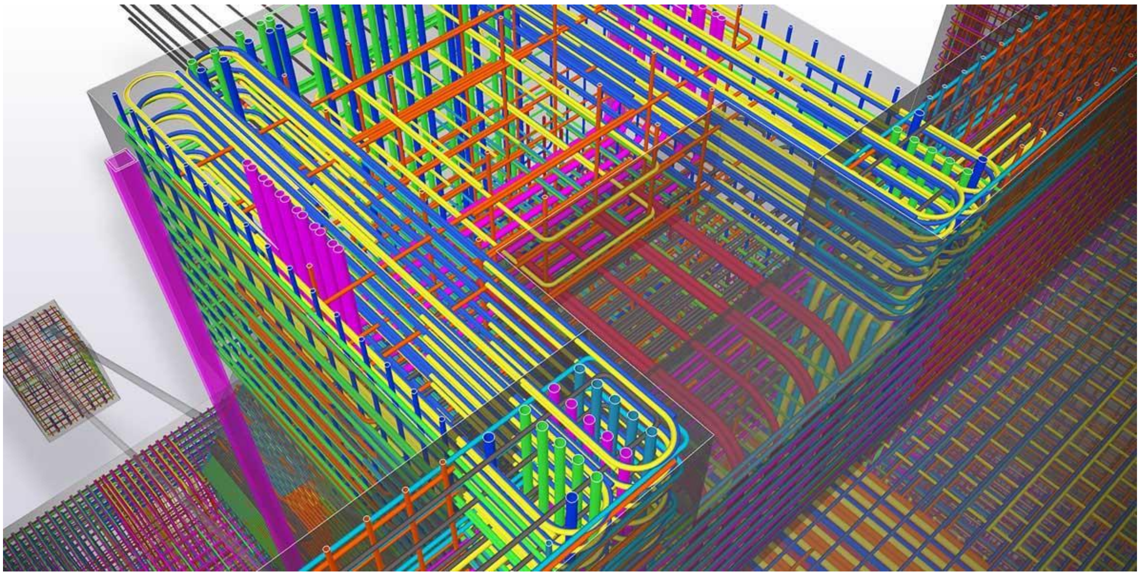

Figure 4.15. Rebar visualization in Tekla Structures.
https://www.tekla.com/solutions/rebar/3d-rebar-detailing

In addition to the design phase the BIM technology could be used in a construction lifecycle process. “Contractors utilize building information models in construction planning and construction phases in the following operations, for example:

- familiarization with the building and its design as well as data mining in the bidding, procurement, and construction phases
- quantity take-offs during the bidding phase and for purchases and production planning during the construction phase

- general coordination and data exchange during construction
- 4D scheduling of production, planning construction sequences and visualization of construction status
- merging of various design parties models for controlling MEP installation sequences and for constructability reviews
- structure position data exchange from BIM into measuring devices
- construction site layout planning and safety planning, such as fall prevention planning" (BuildingSmart Finland. Common BIM requirements 2012).

Thus, the BIM technology could have the same level of effectiveness in renovation and restoration as in new building construction, covering all stages of a project from sketching to facility management. Moreover, it can be synchronized with the laser scanning technology, which makes it even more effective. Possibility to easily merge and separate models could also decrease time consumption and increase informativeness, while the Open BIM provides uninterrupted information flow during a project development. Although a BIM software is more expensive than a traditional one, all advantages of it significantly increase cost efficiency. It this way, the end result could give to a company even more profit than before a BIM implementation.

### 4.4. Calculation issues solution

Almost all restoration and renovation projects require calculations. For some of them hand calculations could be enough, which helps to save companies from buying expensive calculation software. However, especially in restoration projects difficult load-bearing structures could be used, such as a cupola, spire, ribbed vault, arc-boutant, cantilevers, counterforces, etc. These types of calculations could not be performed by simple Excel programs and "hand calculations" according to basic formulas.

#### 4.4.1 Robot Structural Analysis

In this particular study the combination of Autodesk Revit and Autodesk Robot Structural Analysis is considered.The cost of a license for each program equals approximately 4200€. Moreover, the cost of a consulting company hired for studying of employees should also be included. As a result, even large companies in Russia are trying to avoid this BIM software. Most of the companies prefer to use the cheaper one SCAD++, which could also work with the Revit files. Moreover, SCAD++ is more optimized for the Russian Standard System, while Robot Structural Professional is more targeted on the Eurocodes. However, SCAD++ still has some disadvantages compared with Robot. According to Interviewee A, SCAD++ has an inconvenient interface (Figure 4.16, 4.17). Another issue is a lack of educational materials for SCAD, meanwhile Autodesk provides special instructions for Robot. The last, and the most important problem is impossibility of wind and snow loads simulations. Such calculations in SCAD++ require additional “hand-calculations” in, for example, Mathcad or additional modules, which are difficult to use. Moreover, Robot have a possibility of a live load calculation. Because Autodesk develop both Revit and Robot, these programs have a direct connection between each other, which makes it easier to import Revit files. However, it is important to mention, that most of the companies in Finland and Europe generally prefer Tekla Structures for structural modeling, while Revit only has begun to develop this function.

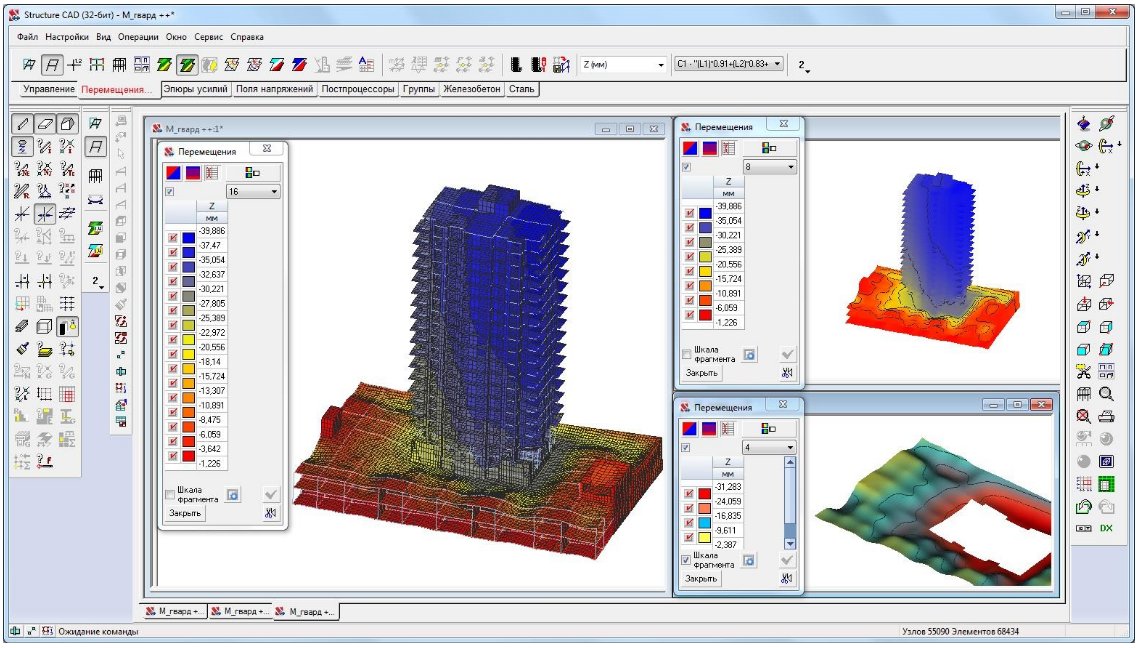


Figure 4.16. SCAD++ interface.

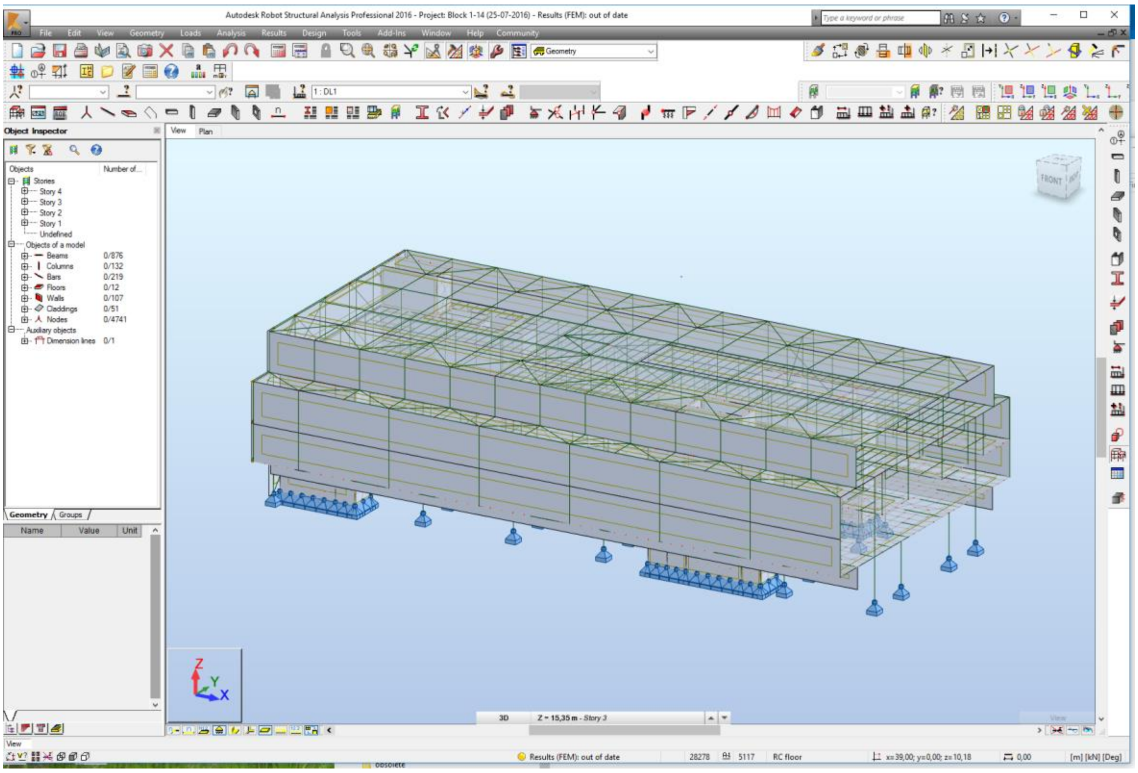

Figure 4.17 Robot structural analysis 2016 interface. https://forums.autodesk.com/t5/robot-structural-analysis-forum/foundation-design-missing-from-interface/td-p/6462403

Thus, Autodesk Robot Structural Analysis is a complex of the finite-element calculation and design, produced for structural engineers in construction industry.

| Calculated structures | Types of calculations |
|---|---|
| - 2D and 3D rod elements<br>- Planks<br>- Envelopments<br>- Pre-stressed planks<br>- Prestrained planks<br>- Axissymmetric structures<br>- Dissimilar materials of structural elements<br>- Volumetrical solid state elements | - Statical linear<br>- Dynamic (model, spectrum, seismic)<br>- Harmonic vibration<br>- Short-time load<br>- Nonlinear analysis of a short-time load<br>- Plasto-elastic deformation<br>- Vibration from people life activities analysis<br>- Cable-stayed elements<br>- Additional diagrams of calculation results |

Table 4.3. Types of structures and calculations supported by Autodesk Robot Structural Analysis

In this way, Autodesk Robot Structural Analysis completely covers most of the renovation and restoration calculations with a clear visualization of deflections and a possibility to synchronize with other BIM software. Thus, the implementation of this tool in difficult projects is not just recommended to save time and decrease chances of mistakes, but necessary to analyze non-typical structural elements, or additional complex for “hand calculations” loads.

### 4.4.2 WUFI

Heat and moisture analysis is also a great part of calculations applied to renovation and restoration projects. Although, most of it could be performed as “hand calculations” by using simple formulas, a large statistic base must be considered. This process of searching and combining statistic data about average temperatures, relative humidity and other factors, such as effect of building facades direction could take many hours. Moreover, drawing of diagrams, according to the results even in Microsoft Office Excel still requires additional time and will not give necessary representativeness. That is why, for simple thermal and moisture calculations companies prefer to use Dof-Therm. This cheap and easy-to-use software initially has a statistic data from different regions and characteristics of many materials. It is suitable for such calculations as (See Chapter 6, References):

- calculating thermal transmittance (U-value), for example walls or roofs
- calculating humidity conditions and evaluate condensation
- calculating energy consumption through the structure
- finding a structure which satisfies U-value demand

(Example of the Dof-Therm report is illustrated in Appendix 7.) However, this tool has limited possibilities of heat and moisture analysis. When a structure requires a proper and deep analysis with many graphs and data for several decades, WUFI is the correct software. “WUFI is a Windows-based program for the hygrothermal (i.e., heat and moisture) analysis of building envelope constructions.” (See Chapter 6, References). The WUFI software gives a possibility to estimate the drying times of masonry and lightweight structures with trapped or concealed construction moisture, investigate the danger of interstitial condensation or study the influence of a driving rain on exterior building components. Moreover, for example, WUFI 2D allows a user to create a model of the facility with information about structural types, climate zones, facades orientation, etc. Statistic data about climate conditions includes information for each hour, which helps to receive a precise simulation. A WUFI report includes much more information than a Dof-Therm report and consists of many different representative diagrams, which are especially useful for a mold risk evaluation. However, no version of WUFI is suitable for Russian Federation (Figure 4.15) due to lack of climate data. However, for Saint-Petersburg city data from Finnish Meteorological Institute could be used because of relatively the same conditions.

To sum up, WUFI software probably is the most progressive tool for a heat and moisture analysis and simulation. Although it does not have Russian Federation climate condition statistics, companies from Saint-Petersburg still should pay attention to this software and use it in difficult renovation and restoration cases, as well as in new building construction.

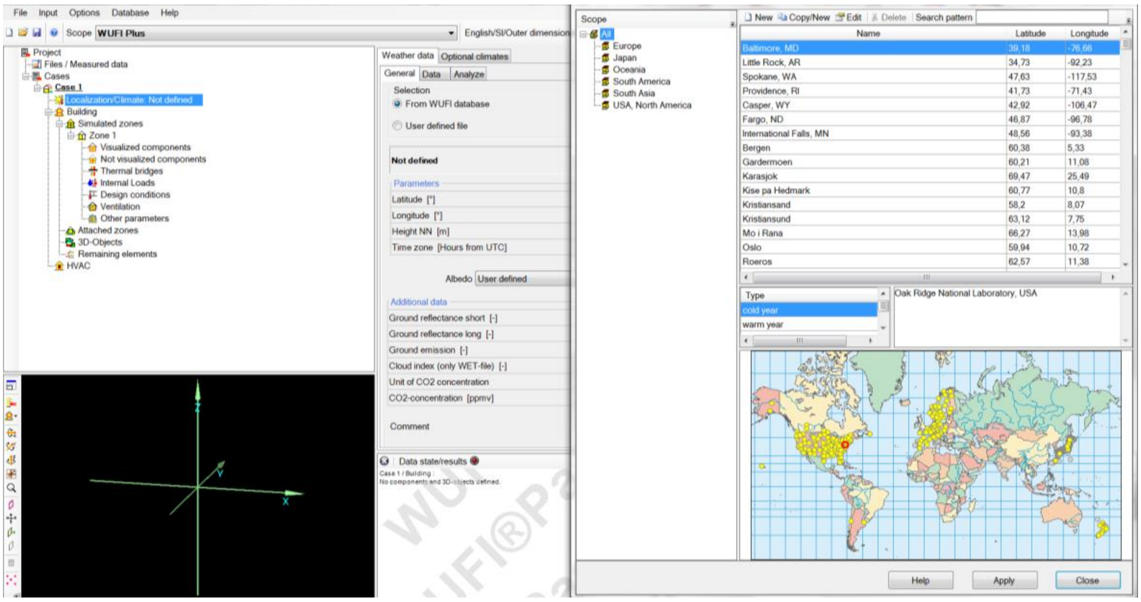


Figure 4.15 WUFI Passive interface with an open database.

## 5 AVOIDING OF THE FUTURE PROBLEMS

This short, but important chapter includes special recommendations for companies and designers to prevent problems, which were discussed above, and by this simplify the restoration and renovation of buildings and make cheaper.

### 5.1 As-built model

As-built modeling is an important part of each renovation and restoration project. However, it could also be a solution for the future problems. Currently, most of the issues in the considered fields of the construction industry are existing due to lack of information, mismatches or just losing of old blueprints. Almost half of the restoration or renovation projects consists of an investigation, which becomes more complicated without correct documentation. The core of this global problem is hidden in the history of construction. Typically, lack of coordination between the designers and the builders even in large projects has led to a significant difference of an existing building from the original project. Another reason for this issue is, that during a construction process of, currently, historical and cultural heritage, project participants were not thinking about the future of a particular structure. The purpose was just to create the building, while the renovation and restoration of it would be a problem of the next generation. Such a way of thinking is still popular in Russia and even a configuration of new buildings always significantly differs from the designers' initial decision. Currently, modern community all over the world should be more responsible for new structures and by using modern tools solve this problem.

As-built model must be created for each new building after finishing its erection or during a process of erection to represent a building or space as it was actually constructed. Using of laser scanners could also increase the accuracy of an as-built model and create a point cloud, based on which other designers could develop a new restoration or renovation project in case an as-built model is unavailable or has mistakes in it.

Moreover, the as-built model should always be actual and in case of modification implementations, they should be immediately included to avoid future mismatches.

The as-built model could be useful not only for renovation and restoration, but also for facility management activities. This elaborate model provides a clear picture of an engineering services location, such as HVAC systems and gives an opportunity to maintain it without unforeseen circumstances.

# 6 SUMMARY AND DISCUSSION

Renovation and restoration fields nowadays have lots of specific issues. Currently, Russian construction industry chose as a solution decreasing of the quality and accuracy of the final product and increasing time consumption by using traditional methods to solve problems, which require modern solutions. However, such a way of conservativeness helps companies to save money and be more profitable, which is especially an actual reason for such small businesses like the OOO “Архиграция”.

Meanwhile, Finland, facing the same issues, but with a different historical background of architecture development, has chosen the way of solving them by modern technologies, which are more expensive and require professionals with higher professional skills.

During this overview all the most important issues (based on the opinion of experienced designers and architects working in the considered field) were analyzed according to the experience of working in OOO “Архиграция”. For each issue there was an attempt to find one or more solutions by using modern technologies, based, where it is possible, on the Finnish companies’ experience. Especially great attention was paid to the laser scanning technology and a BIM software as the most effective and suitable methods for restoration and renovation. The laser scanning proves itself as a high precise and fast measuring tool. Moreover, this method allows to accurately measure parts of a structure, which are inaccessible for people. It also could be combined with drones or other flying objects. Meanwhile, BIM highly increases the level of coordination between project participants, optimizes the process of visualization, and simplifies the correction and calculation processes. BIM software also could be combined with the laser scanning technology, which makes it even more effective. In Chapter 5 the theme of the future problems solution was covered shortly.

As a result, ineffectiveness of the traditional methods and basic software in these considerable issues was proved. While, the analysis of the modern tools for the investigated cases clearly shows the effectiveness of them. Benefits of each technology were also described with rough cost estimations.

However, even these explored methods have their own disadvantages. Moreover, some of them turned out to be unsuitable for the Russian Federation standard system.

To conclude this overview of the issues in the renovation and restoration field, one of the main purposes of this study was to describe and prove to Russian companies, what modern technologies are and how the implementation of them could increase their effectiveness. This particular thesis shows, that the expenses of modern methods in the long term could increase income and let the company to participate in a bigger amount of projects, although in the beginning it will require additional investments and actions. Moreover, most of the modern technologies nowadays do not require any special skills, which could not be obtained during a working process. Thus, it is highly recommended for Russian restoration and renovation companies to begin the process of modern technologies implementation to keep their positions on the market, increase income, decrease time consumption and make a job much safer than now.

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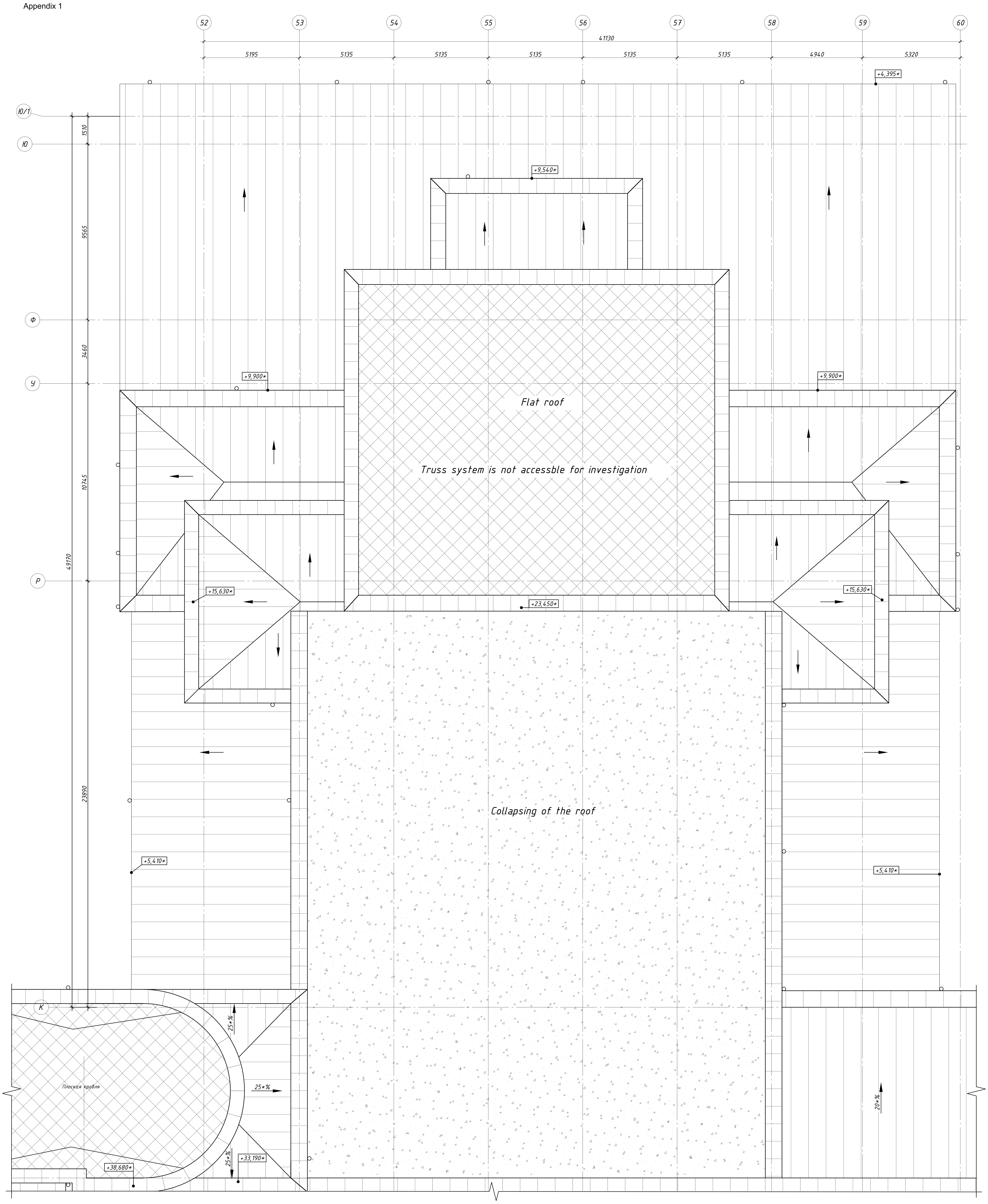
Building Information Modelling (BIM)-supported cooperative design in sustainable renovation projects: Benefits and limitations Danilo Di Mascio, Xiangyu Wang

Appendixes:

Appendix 1

*Plan of the roof in axal K-Ю/1, 52-60 (M1:100)*




*Graphical symbols*

| | |
|---|---|
| [steel sheets hatch] | Roof covering by steel sheets |
| [cross hatch] | Rolled roofing material |
| [dotted hatch] | Collapsing of the roof |

*Remarks:*

1) Dimentions with an * symbol are nomonal
2) As a relative ordinance datum 0.000 nominaly established the ground-level

*Defects, detected by visual investigation*

1) Minor repair of roof covering (Low-quality room repair)

2) Destruction of the junction between roof covering and wall

3) Corrosion of the 70% steel sheets (In axal 52-60, K-У)

| Chng. | QOA | Sheet | Doc.No. | Sign | Date |
|---|---|---|---|---|---|
| Developed | | Labovkin | | [signature] | 06.19 |
| Chief Engin. | | Ermakova | | [signature] | 06.19 |
| Chief Arch. | | Fedorov | | [signature] | 06.19 |
| N.contr. | | Fedorov | | [signature] | 06.19 |

Cultural teritage site federally significant «The Kirov's Palace of Culture», located at the address: Saint-Petersburg, Bolshoy prospect V.O., h. 83A

| Engineering-technical investigation | Stage | Sheet | Sheets |
|---|---|---|---|
| | P | | |

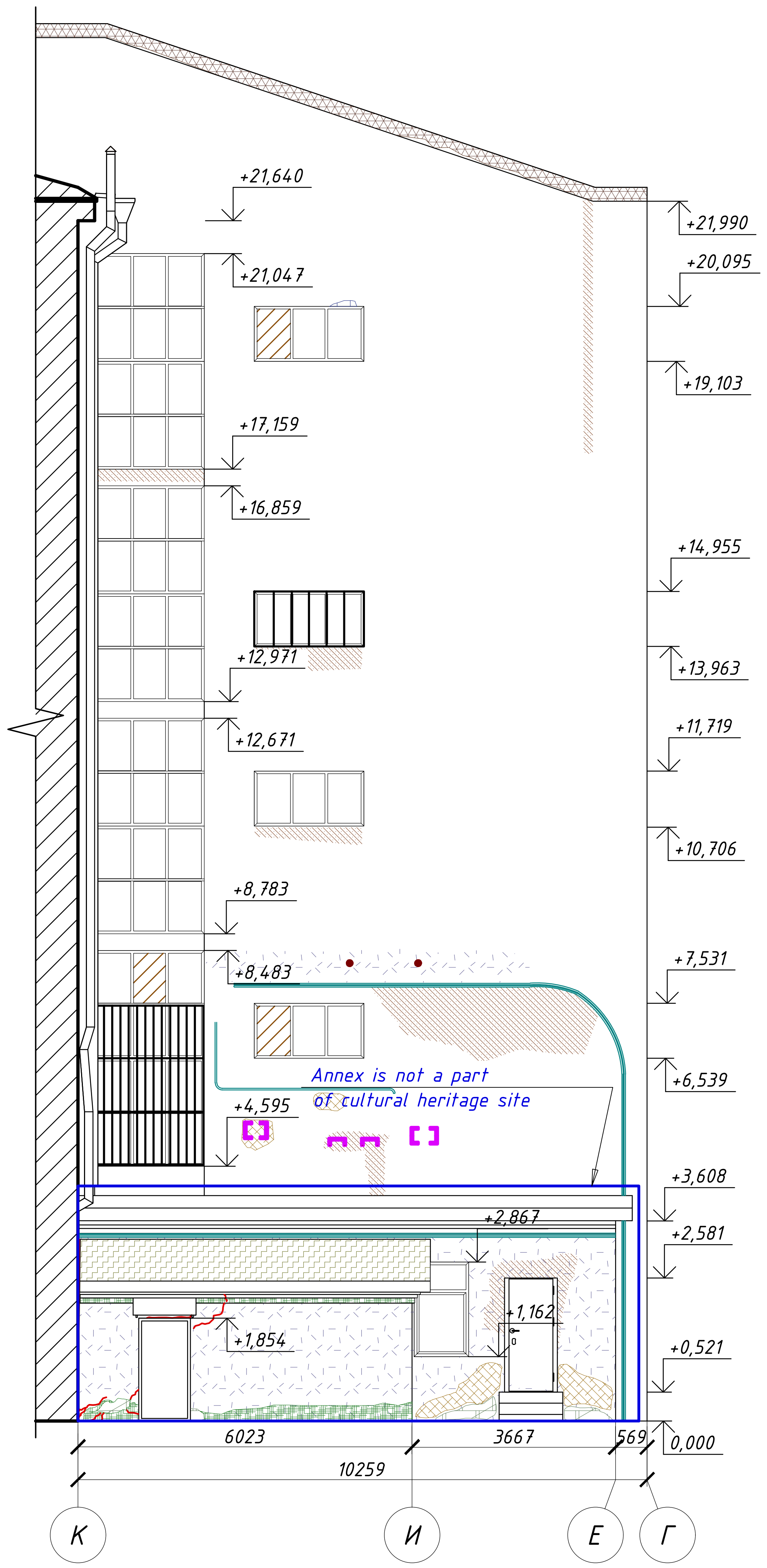
Plan of the roof in axal E-Ю/1, 52-60

Fromat A1

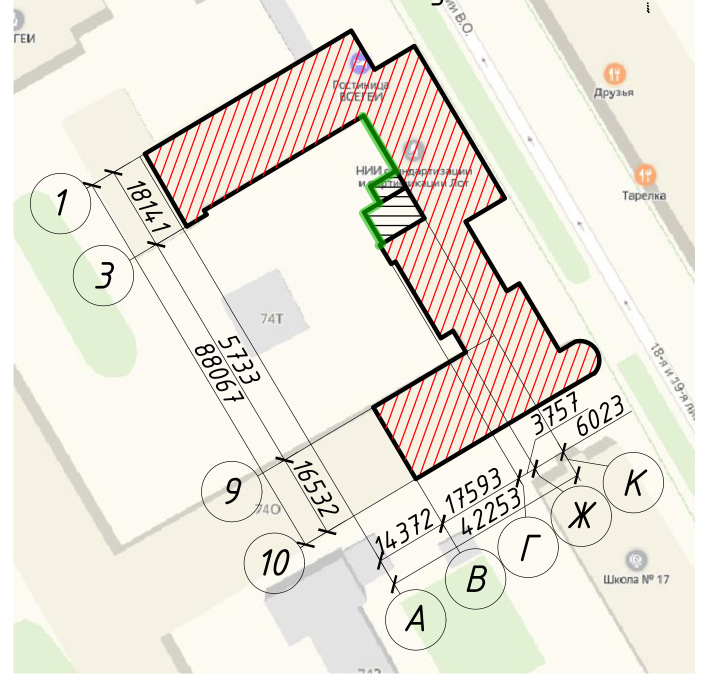
Appendix 2

Cartogram of facade defects in axes 2-6 (M1:100)


Cartogram of facade defects in axes К-Г (M1:100)




Scheme of building and annexes




## Legend

- Cracks with a width more than 3 мм
- Hairline cracks
- Flaking and loss of paint layer
- The loss of plaster exposing brickwork
- Loss of a plaster layers with an exposion of the coping and a brickwork of the eaves
- Sewned window opening
- Traces of mounts
- Low-quality repair of the roof
- Roofing corrosion
- Biological defect
- Elements for dismantling
- Jumper corrosion
- Dirting of the facade
- Open electrical wiring
- Viewed facade
- Annex
- Main building (cultural heritage site)

Agreed

Repl. inv. No | Sgn. and date | Orig. inv. No.

| Cng. | QOA | Sheet | Doc.No | Sgn. | Date |
|---|---|---|---|---|---|
| Developed | | Labovkin | | | 08.19 |
| Chief Arch. | | Ermakova | | | 08.19 |
| Chief Eng. | | Yusupov | | | 08.19 |
| N.contr. | | Yusupov | | | 08.19 |

The design documentation on execution of installation and construction works on repair of the facade of the building, which is located at : Saint-Petersburg Srednii av., h. 74,B

Measuring blueprints

| Stage | Sheet | Sheets |
|---|---|---|
| П | | |

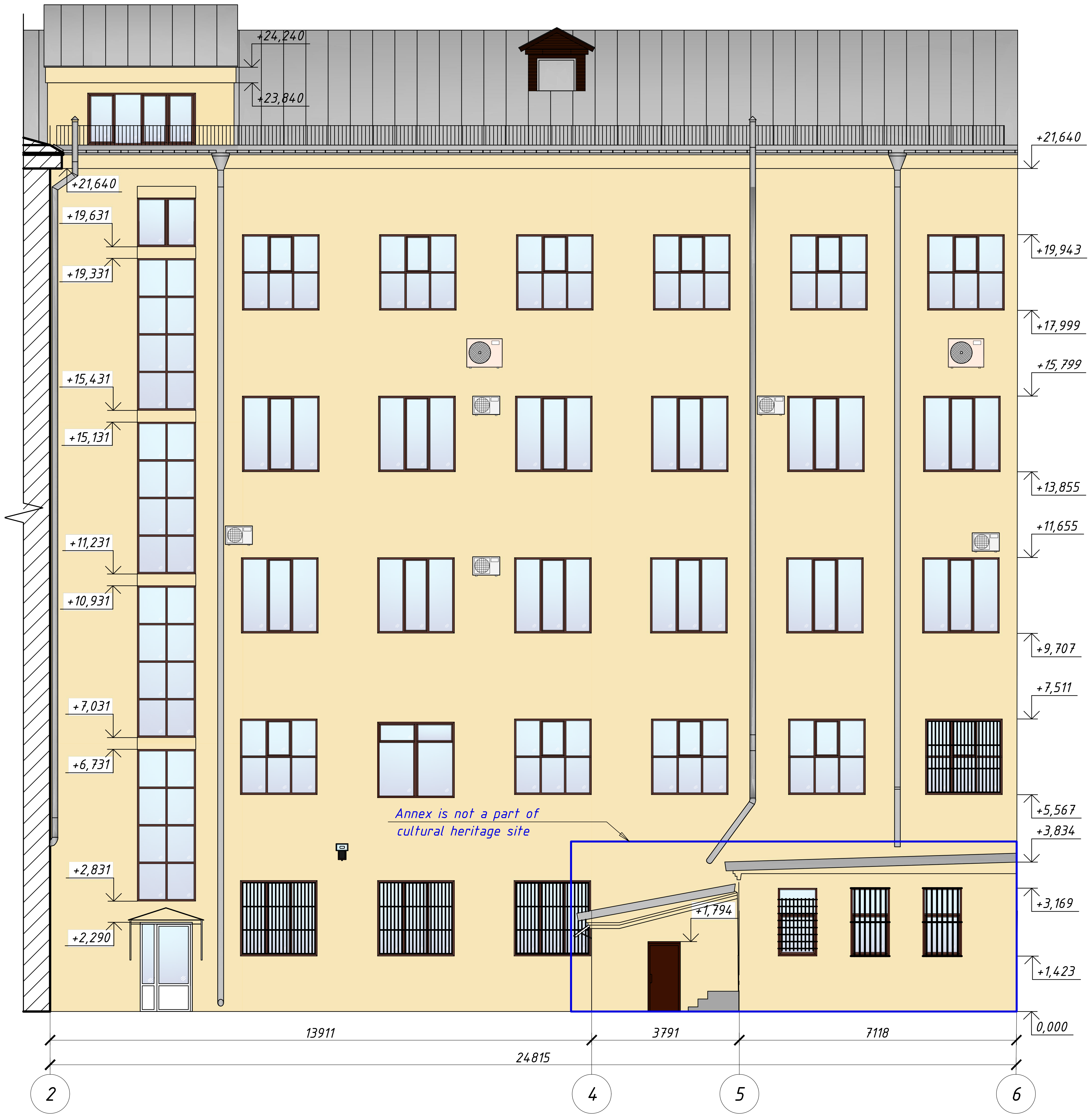
Cartogram of facade defects in axes 2-6 (M1:100) и К-Г (M1:100)

Copied

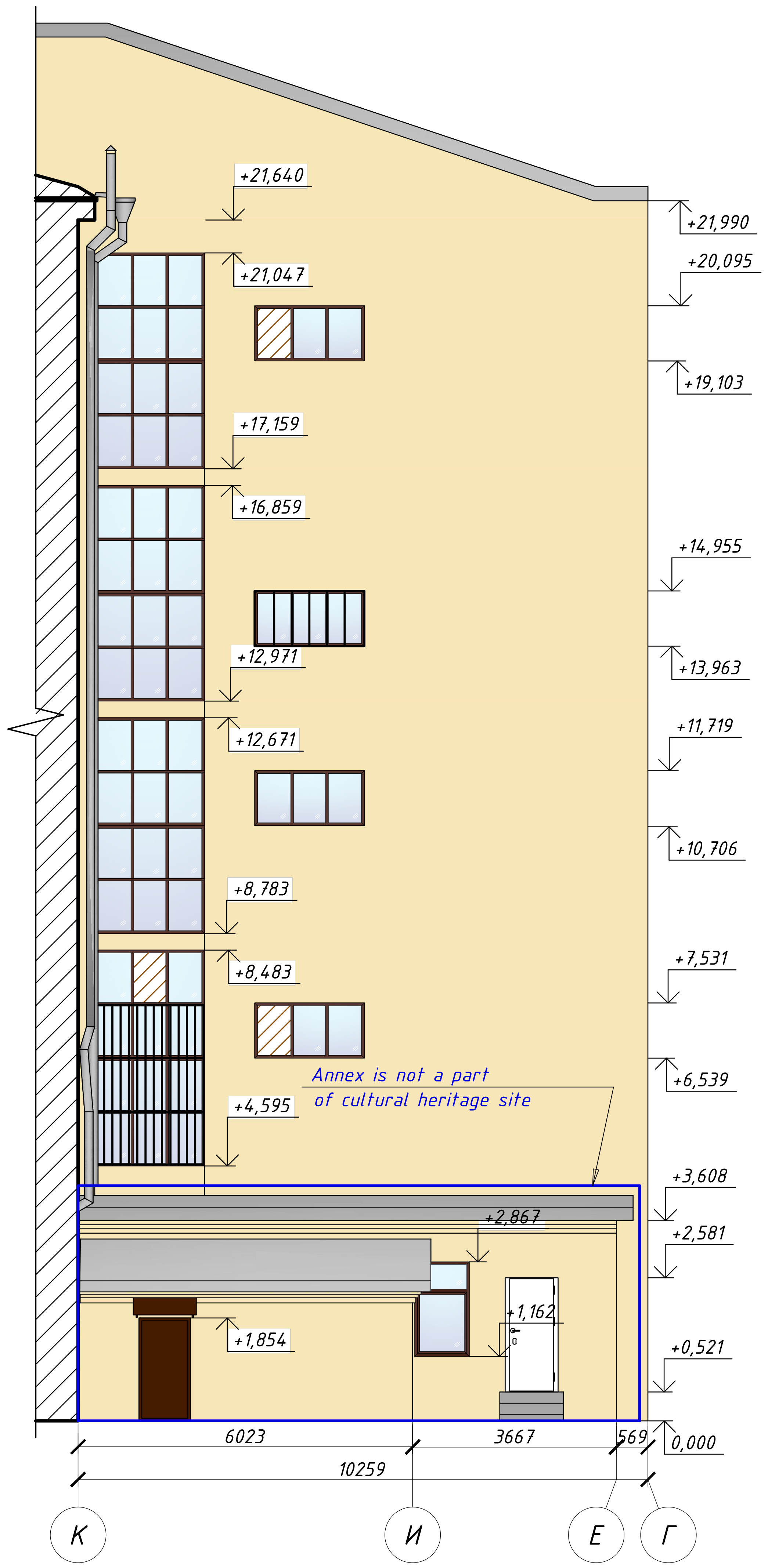
A3x2

Appendix 3

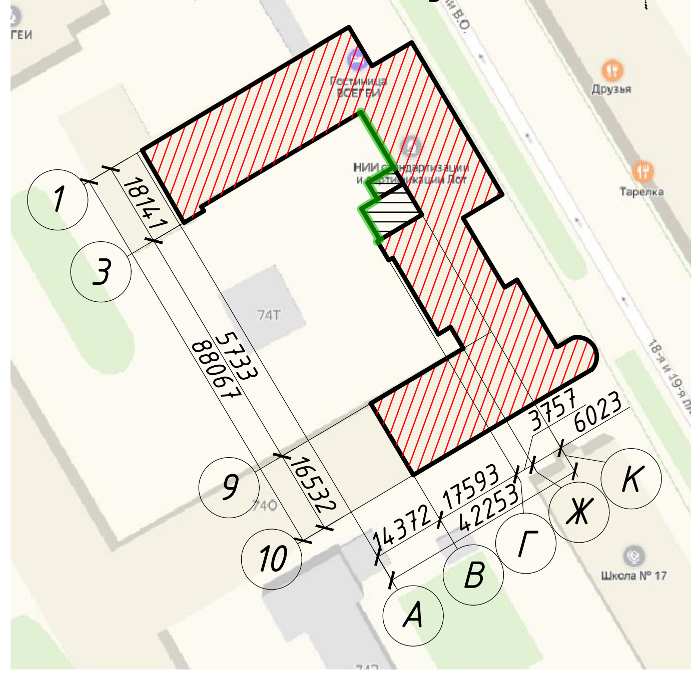
Facade in axes 2-6 (M1:100)




Facade in axes К-Г (M1:100)




Scheme of building and annexes




Legend

- Sewned window opening
- Viewed facade
- Annex
- Main building (cultural heritage site)

Notes:

For 0.000 the 0 mark of the adjacent territory is accep

| | | | | | | |
|---|---|---|---|---|---|---|
| Chg. | QOA | Sheet | Doc. No | Sgn. | Date | The design and estimate documentation on execution of installation and construction works on repair of a facade of the building, which is located at :Saint-Petersburg Srednii av., h. 74,B |
| Developed | | Labovkin | | | 08.19 | Architectural concepts — Stage: П; Sheet; Sheets |
| Chief Arch. | | Ermakova | | | 08.19 | |
| Chief Eng. | | Yusupov | | | 08.19 | Facade in axes 2-6 (M1:100) и К-Г (M1:100) |
| N.contr | | Yusupov | | | 08.19 | |

Agreed

Repl. inv. No.

Sgn. and date

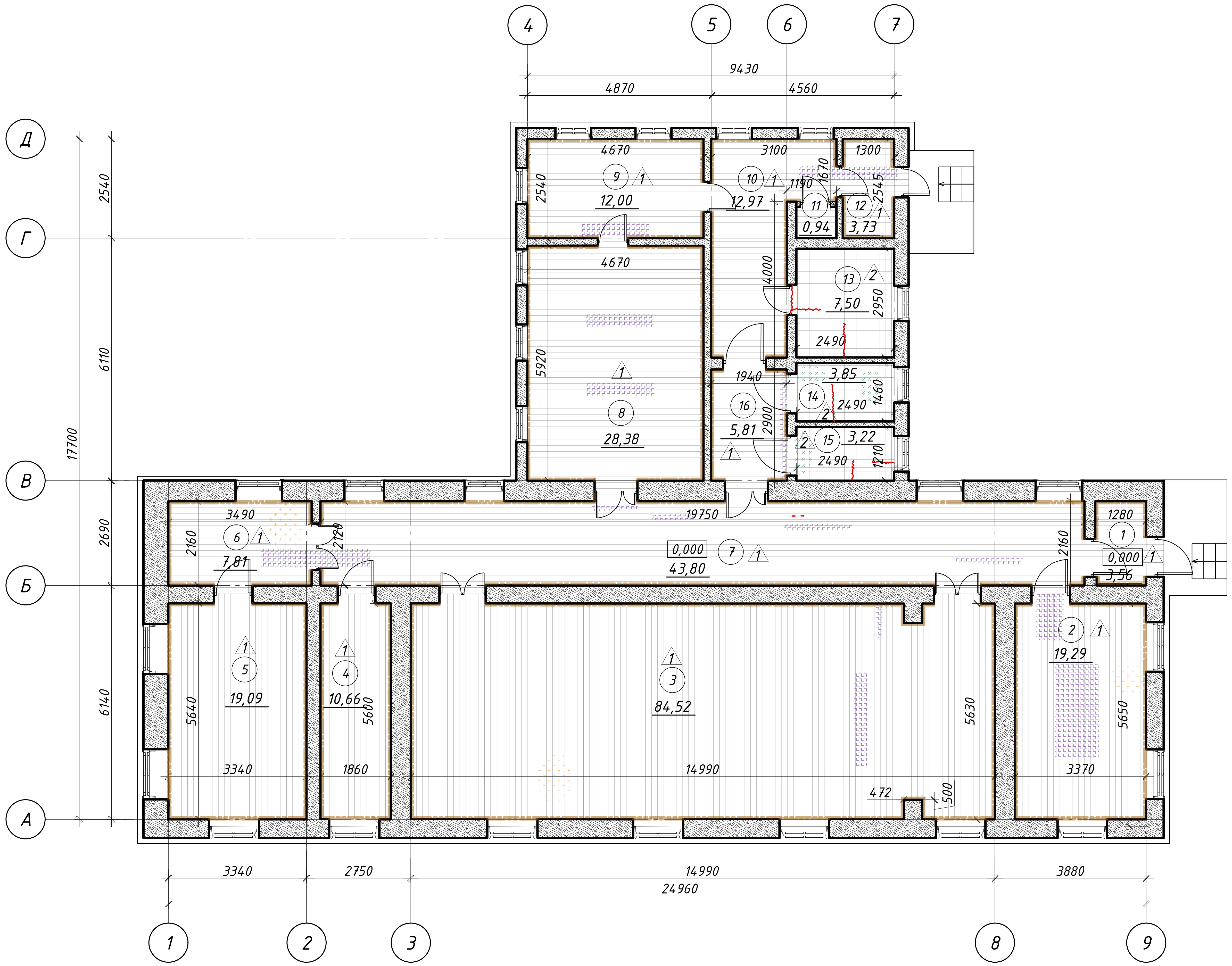
Orig. inv. No.

Copied

A3x2

Appendix 4

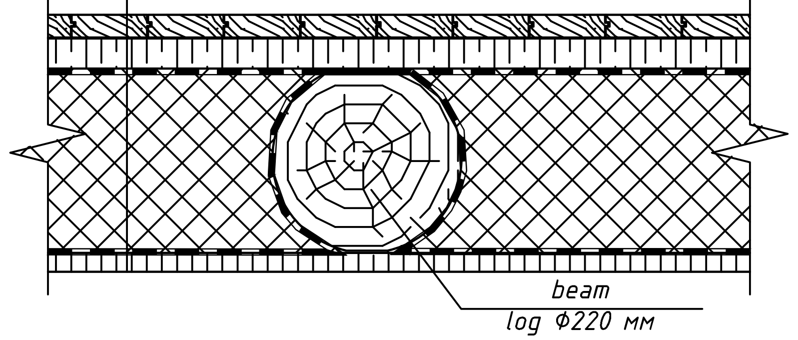
## Cartogram of the floors defects (M1:100)




## Type construction of the floor

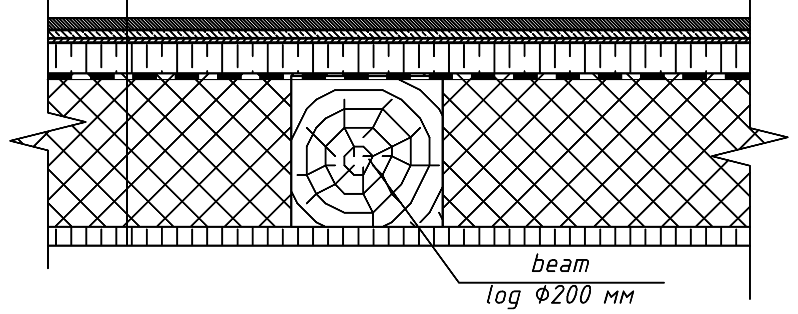
### Type 1

| | |
|---|---|
| fibreboard | – 25 мм |
| daft floor (wood board) | – 40 мм |
| vapor barrier | |
| insulator | – 200 мм |
| windproof membrane | |
| board | – 40 мм |




### Type 2

| | |
|---|---|
| tile+glue | – 15 мм |
| waterproofing | – 1 layer |
| cement-shaving plates | – 10 мм |
| fibreboard | – 5 мм |
| daft floor (wood board) | – 40 мм |
| vapor insulation | |
| Insulation | – 200 мм |
| windproof membrane | |
| board | – 40 мм |




Notes:

1. For the 0,000 is accepted storey level of the 1st floor
2. For counting of the building materials at arrangement of floors, floor surface areas in door openings are included in the room area

## Explication of the room of the first floor

| Room number | Name | Surface area, $м^2$ | Note |
|---|---|---|---|
| 1 | Vestibule | 3,54 | |
| 2 | Room | 19,29 | |
| 3 | Hall | 84,52 | |
| 4 | Administrative premise | 10,66 | |
| 5 | Administrative premise | 19,09 | |
| 6 | Corridor | 7,81 | |
| 7 | Corridor | 43,80 | |
| 8 | Hall | 28,38 | |
| 9 | Room | 12,00 | |
| 10 | Room | 12,97 | |
| 11 | Larder | 0,94 | |
| 12 | Vestibule | 3,73 | |
| 13 | Boiler room | 7,50 | |
| 14 | Lavatory | 3,85 | |
| 15 | Lavatory | 3,22 | |
| | TOTAL | 261,30 | |

Legend

- Wooden plinth
- Floor structure type
- Cracks
- Spillover of the floor boards from the plane and the riveting failure
- Floor boards sagging
- Floor tiles sneering
- Rabbeted boards
- Tiles

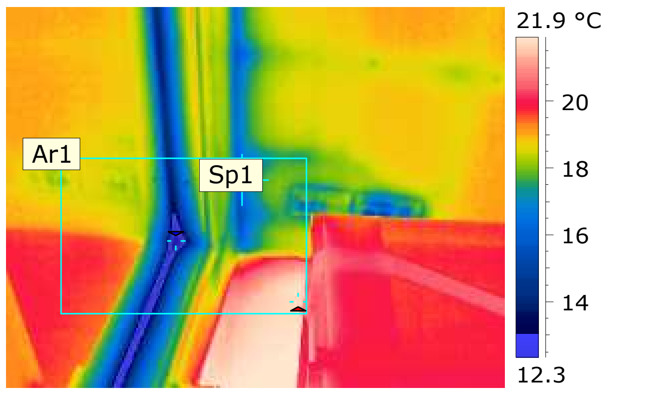
Development of the work documentation on carrying out local repair of wooden and tiled floors of cultural heritage site "Building, where at 1764-1768 years was an officer meeting of the Suzdal infantry regiment, which was lead by Suvorov Alexander Vasilyevich", which is located at: Len. oblast, Volchovsky district, Novaya Ladoga city, Suvorova street, 12 A

| Chg. | Кол.уч | Sheet | Doc.No | Sgn. | Date | | Stage | Sheet | Sheets |
|---|---|---|---|---|---|---|---|---|---|
| Developed | | Labovkin | | | 08.19 | Constructive solutions | P | | |
| Chief Arch. | | Ermakova | | | 08.19 | Cartogram of the floors defects | | | |
| Chief Eng. | | Yusupov | | | 08.19 | | | | |
| N.contr. | | Yusupov | | | 08.19 | | | | |

# Appendix 5

Vahvialankatu 10 thermal measurements

| | |
|---|---|
| **Place: Window's corner** | **Date of research:** 13.3.2019 |




Thermal image 4.

**Parameters**

| | |
|---|---|
| Time | 12:32:47 |
| Spot Sp1 temperature | 16.6 ℃ |
| Area Ar1 max. temperature | 21.8 ℃ |
| Area Ar1 min. temperature | 8.8 ℃ |
| temperature index in area | 45 % |
| temperature index in spot | 71 % |

| | |
|---|---|
| Emissivity | 0.95 |
| Reflecting temperature | 20.0 ℃ |
| Distance | 2.0 m |
| Camera | FLIR T620bx |
| Serial number | 55904528 |

**Outdoor air conditions**

| | |
|---|---|
| Wind speed | 2 m/s |
| Cloudiness | Cloudy |
| Temperature | -1 ℃ |

**Indoor air conditions**

| | |
|---|---|
| Relative humidity | 23 % |
| Pressure difference | -3,5 Pa |
| Temperature | 21 ℃ |

| |
|---|
| Comments: Window doesn't provide sufficient thermal protection |
| Repair class 1 |

**Correction classification suitable for residential and lounge area:**

**1. Have to be corrected** Surface temperature does not meet the minimum level of classification. Substantially weakens the building physics of structures. Area temperature index < 61%.

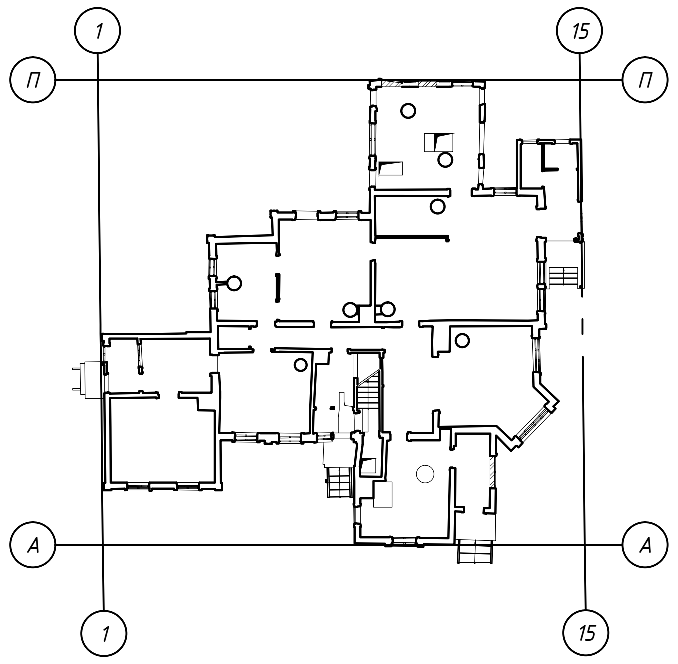
**2. Repair needs to be clarified** The need for repairs must be considered separately. It complies with the Residential Health Guidelines for an unsatisfactory level, but meets the minimum level of classification. TI 61-65%.

**3. Additional investigations** It complies with the required standards, but additional studies are needed to perform further research. TI > 65%.

**4. Good** Meets the good level of standards. No remedies. TI > 70%.

Appendix 6

*Planning scheme*




*Facades 1-11/A. M 1:50*


| Cng. | Sheet | № doc. | Sign | Date | | Sheet 13 |
|---|---|---|---|---|---|---|

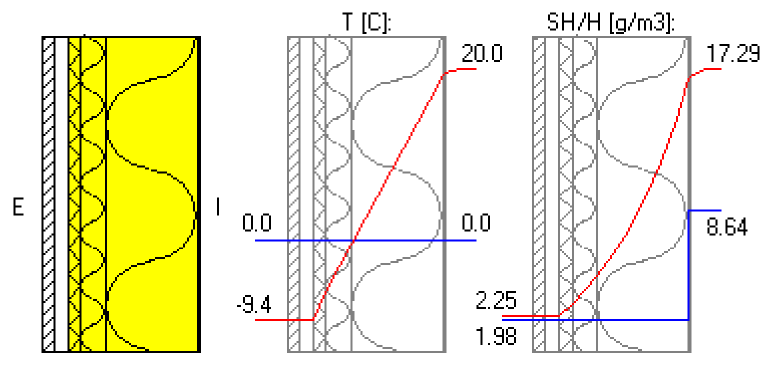
Format A2

Appendix 7

| Project: | Structure: | |
|---|---|---|
| Designer: | Date: 3.5.2019 | Code: |

**Main information of structure:**

| | |
|---|---|
| U-value: | 0.139 W/m2K |
| Thickness: | 303.150 mm |
| Area: | 1.00 m2 |
| Weight: | 22.21 kg |
| Price: | 0.00 euro |
| Steam resistance: | 7.016e+04 m2hPa/g |
| Steam transmittance: | 1.425e-05 g/m2hPa |
| Thermal resistance: | 7.210 m2K/W |
| External surface res.: | 0.040 m2K/W |
| Internal surface res.: | 0.130 m2K/W |
| Angle (0-90): | 90.000 |




**Layer information:** Layers from Outside (E) to Inside (I)

| | LAYER: | T [mm]: | TC [W/mK]: | SR [-] | Price [e/m3]: | Weight [kg/m3]: |
|---|---|---|---|---|---|---|
| 1 | Timber 700 kg/m3 | 23.00 | --- | --- | 0.00 | 700.00 |
| 2 | Air | 25.00 | --- | --- | 0.00 | 1.23 |
| 3 | ISOVER RKL-A | 25.00 | 0.0310 | 2.684464e+00 | 0.00 | 0.00 |
| 4 | ISOVER KL 35 | 50.00 | 0.0350 | 1.904762e+00 | 0.00 | 0.00 |
| 5 | ISOVER KL 35 | 175.00 | 0.0350 | 1.904762e+00 | 0.00 | 0.00 |
| 6 | Polyethylene 0.15 mm | 0.15 | 1.0000 | 3.333333e+05 | 0.00 | 0.00 |
| 7 | Gypsum 900 kg/m3 | 5.00 | 0.3000 | 4.000000e+00 | 0.00 | 900.00 |

| | THERMAL BRIDGE: | TC [W/mK]: | RA [%]: | Price [e/m3]: | Weight [kg/m3]: | EC [W/K](Pcs): |
|---|---|---|---|---|---|---|
| 4 | Timber 700 kg/m3 | 0.1800 | 1.0 | 0.00 | 700.00 | --- |
| 5 | Timber 700 kg/m3 | 0.1800 | 1.0 | 0.00 | 700.00 | --- |

T = Thickness, TC = Thermal Conductivity, SC = Steam Permeability, RA=Relative area, EC = Extra conductance

**Temperature and humidities:** **January (744.0 h)**

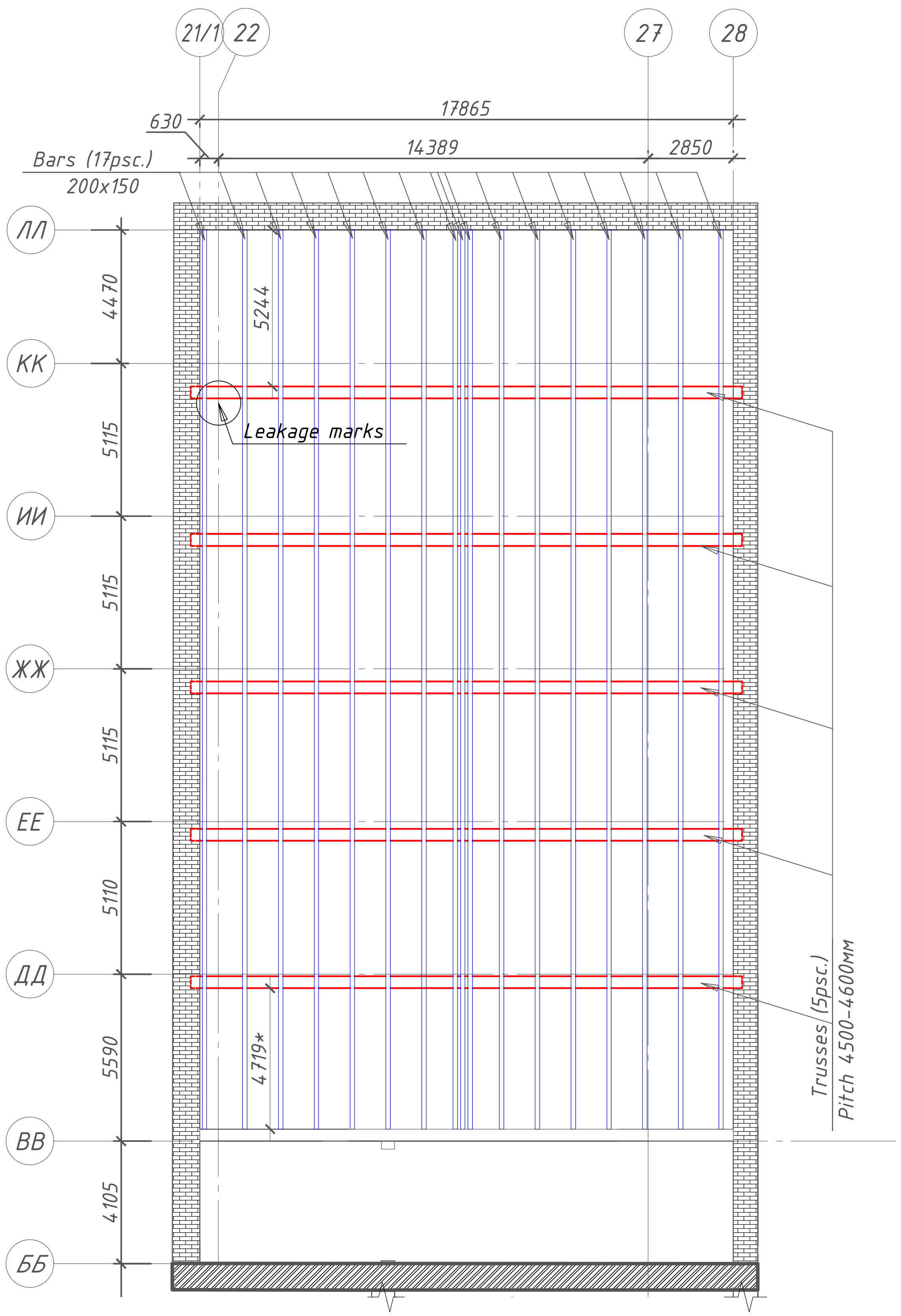
| Point: | T [C]: | SH [g/m3]: | H [g/m3]: | RH [%]: | C [g/m2]: |
|---|---|---|---|---|---|
| E | -9.40 | 2.25 | 1.98 | 88.0 | 0.00 |
| 1 | -9.24 | 2.28 | 1.98 | 86.8 | 0.00 |
| 2 | -9.24 | 2.28 | 1.98 | 86.8 | 0.00 |
| 3 | -9.24 | 2.28 | 1.98 | 86.8 | 0.00 |
| 4 | -6.05 | 2.98 | 1.99 | 66.8 | 0.00 |
| 5 | -0.39 | 4.70 | 2.00 | 42.6 | 0.00 |
| 6 | 19.42 | 16.71 | 2.04 | 12.2 | 0.00 |
| 7 | 19.42 | 16.71 | 8.64 | 51.7 | 0.00 |
| 8 | 19.49 | 16.77 | 8.64 | 51.5 | 0.00 |
| I | 20.00 | 17.29 | 8.64 | 50.0 | 0.00 |

T=Temperature, SH=Saturation humidity, H=Humidity, RH=Relative Humidity

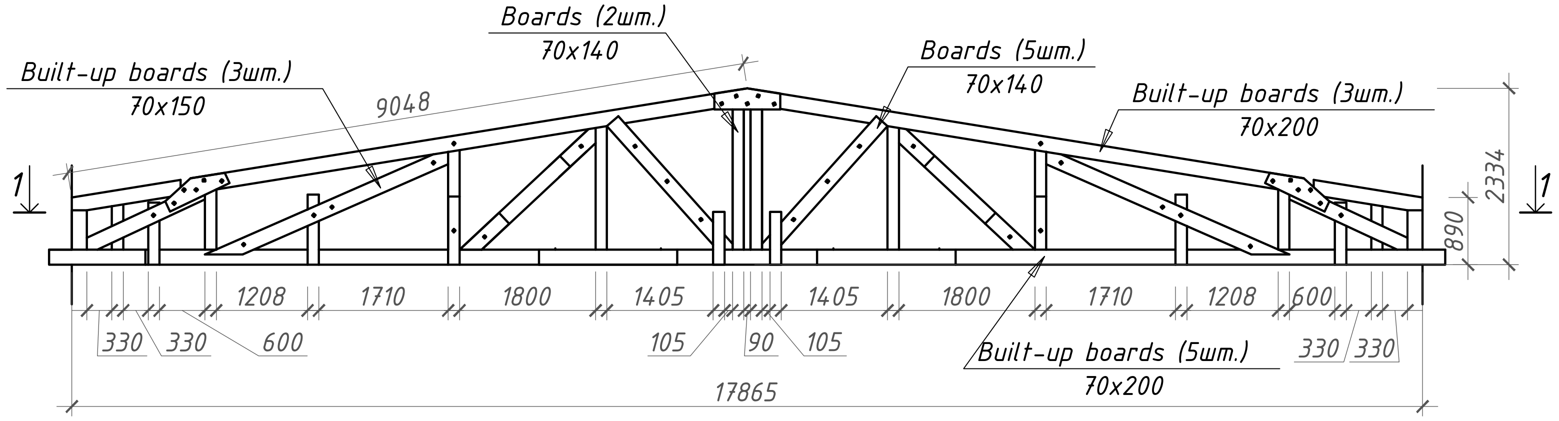
**Additional information:**

Appendix 8

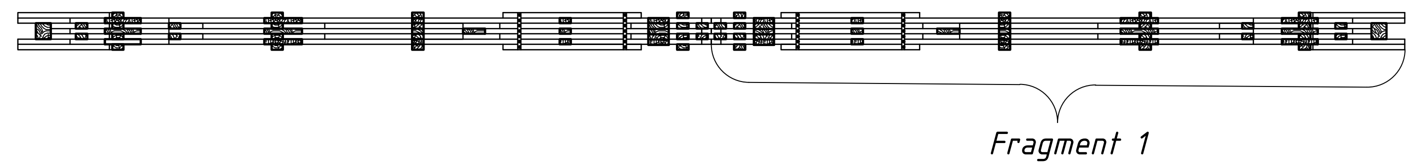
Truss system plan (M1:200)



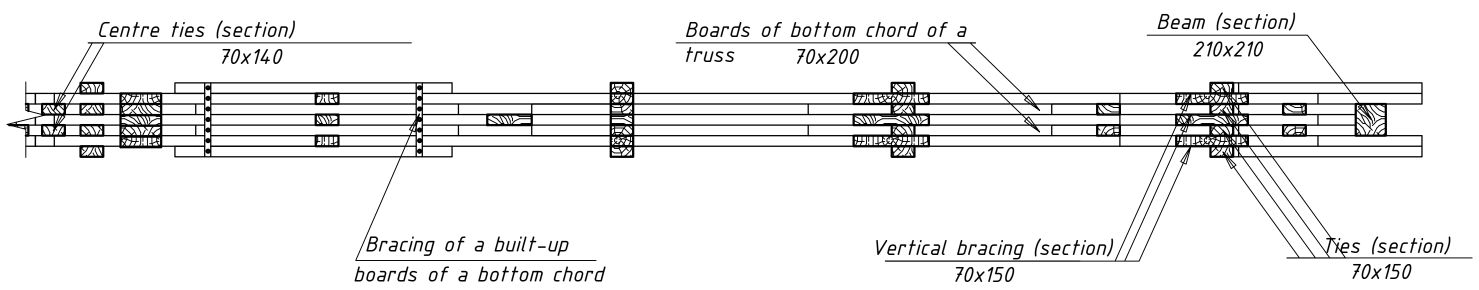

Truss (M1:100)




Section 1-1 (M1:100)




Fragment 1 (M1:50)




Legend:

Truss

Beams and bars

Notes:

1) Dimensions with a "*" specified notionally
2) Types of a bracing in the truss - bolt junctions
3) Boards are built-up by bolt junctions (shown notionally)
4) Defects were not detected during the visual investigation
5) Roof covering is not specified

| Chg. | QOA | Sheet | Doc.No | Sign. | Date |
|---|---|---|---|---|---|
| Developed | | Labovkin | | [signature] | 06.19 |
| Chief arch. | | Ermakova | | [signature] | 06.19 |
| Chief egn. | | Yusupov | | [signature] | 06.19 |
| N.contr. | | Yusupov | | [signature] | 06.19 |

Cultural heritage site «Kirov's Palace of Culture», which is located at: Saint-Petersburg, Bolshoy prospect V.O., b.83-A

Engineering investigation

| Stage | Sheet | Sheets |
|---|---|---|
| | | |

Truss system in axes ББ-ЛЛ, 21/1-28

A3