WATERPROOFING METHODS COMPARISON IN RUSSIA AND FINLAND

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ABSTRACT

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ABSTRACT

The purpose of this bachelor's thesis was to collect information about waterproofing materials used in Russia and Finland, as well as to determine the features of the markets of both countries, and thus, to understand what dictates the use of certain waterproofing methods.

The stage of waterproofing works is one of the most important during construction, since the durability of the structure depends on it. Properly selected waterproofing can significantly reduce the cost of particular works and the project as a whole. The aim of this thesis was to overview waterproofing materials, on the basis of which a simplified instruction for choosing waterproofing methods was formulated. In addition, a BIM analysis scheme was provided for understanding of how waterproofing method might be selected based on a larger number of factors.

Keywords Waterproofing, construction, materials, methods, BIM

Pages 53 pages including appendices 23 pages

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1 INTRODUCTION

1.1 Relevance

In modern construction, there are diverse construction objects with various functions, many construction participants and organizational management structures. Construction processes are significantly dependent on the climatic conditions. Today, materials and production technologies are rapidly developing, legislation is being tightened, digitalization is gaining momentum. In order to respond to the changing customer needs, the market has to be studied, new innovative products, solutions and services should be created.

Since the main building materials (concrete and reinforced concrete structures) have a porous structure, the value of waterproofing is very high (Latysheva & Smirnov, 2003, pp. 24-25). The moisture that fills the pores freezes in winter and due to the expansion of water during freezing, the material of the underground part of the building is destroyed to the entire depth of wetting. For example, what happens with asphalt during the winter can be observed every spring.

To choose a waterproofing method, it is necessary to study the hydrogeological situation and the operating conditions of the building, changes in the temperature and humidity, the composition of the structural elements of the building, porosity and the strength of materials, etc. Based on these data, a selection of protective compounds with certain characteristics is carried out (*Severoslavyanskoe Byuro Reklamy*, 1999). In addition, materials intended for waterproofing must allow the fulfillment of other conditions - for example, vapor transmission, to ensure the comfort of the interior. This can be achieved by using the target functional additives, which provide vapor transmission, water resistance, shrinking resistance, ductility and other required qualities.

“Foreign technologies and materials are breaking into the Russian construction industry, which require additional checks and careful research for their application in our climatic and geotechnical conditions” (Kupriyanov, n.d.). At the same time, there is a shortage of high-quality building materials on the Russian market. In his speech, V. Kupriyanov expresses the hope that successful cooperation with foreign partners will fill the market with building materials, which will provide construction organizations with a wider choice in terms of price and quality.

All these contradictions and the relevance of their resolution determined the choice of the topic of the work.

- Object: waterproofing methods.
- Subject: comparison of waterproofing methods in Russia and Finland.
- Purpose: to compare waterproofing methods, to identify effective advantages for further use.

In accordance with the set goal, it is necessary to complete the following tasks:

- Identify the problem of waterproofing of buildings and structures;
- Establish differences in the regulations of construction, as well as in natural and climatic conditions in Russia and Finland;
- Determine the knowledge base on the problem of waterproofing methods;
- Consider the implementation of a specific method on a specific object;
- Formulate conclusions and recommendations.

1.2 Research methods

- study of special and general construction literature, regulatory documents.
- comparative analysis of the database on the researched topic.
- study of the design documentation for construction and reconstruction facilities.
- conducting laboratory experiments.
- general scientific methods.

1.3 Knowledge on the issue

The materials of the book by Sergei Nikolaevich Popchenko (Popchenko, 1981) were studied. The book examines the properties of the most promising types of waterproofing and waterproofing materials based on new polymers and polymer-bitumen compositions, design rules and calculation of structures made of progressive materials and their field of application, covers the methods of complex mechanization and industrialization of waterproofing, works on the basis of domestic and foreign experience, gives technical economic assessment of modern technological methods of performing work.

Also, the work refers to the monograph of Mangushev R. (2010), the professor of the department of Geotechnics in St. Petersburg Governmental Architecture and Construction University (SPBGASU), who for the first time in a summary form provides information on the methods of construction and reconstruction of foundations of a number of historical buildings of St. Petersburg, analyses the geotechnical features of the city's territory and types of waterproofing of old buildings, reviewed and analysed the emergency situations and problems related to their basements and foundations, reviewed structures of the main modern technologies for waterproofing of basements and foundations, including underground spaces of large volumes, made in recent years in St. Petersburg, described the main structures of a unique urban object - a complex of structures for protecting the city from floods.

A significant amount of materials published in professional periodicals concerns various aspects of the design and construction of urban and architectural objects, but a comparative analysis of waterproofing methods in Russia and Finland is being done for the first time, and a comprehensive BIM model for choosing an effective method based on cost analysis, taking into account all accompanying factors (e.g. climatic and geotechnical conditions) has not yet been developed.

1.4 Novelty

The novelty of the research is in building a model of system analysis of waterproofing methods, ensuring the required economic indicators; in the development of a scheme for the system analysis of waterproofing methods; in identifying problematic elements in the methods of waterproofing residential and public buildings; in the formulation of tasks related to reducing costs and increasing the level of performance of functions in a comprehensive review of modern promising waterproofing technologies.

The stages of the construction process are closely related to each other. Firstly, project documentation is developed, which is based on urban planning documentation. Secondly, investments are needed, and the person who carries them out is the investor, as well as the customer, whose functions include the acceptance of the constructed objects into operation. Finding optimal characteristics is one of the research tasks. For the latest materials and technologies, such a task has not yet been set.

2 FORMULATION OF THE PROBLEM

2.1 The waterproofing problem of buildings and structures

All buildings and structures are exposed to moisture. Wetting of enclosing structures can occur in the following cases: as a result of moisture ingress into the walls of a building, as a result of moisture condensation in the wall material due to temperature differences, underground part - due to groundwater, aboveground - from moisture in the form of precipitation. The consequence of this is a decrease in the thermal insulation properties of structures, their premature destruction and violation of the indoor microclimate. (Savilova, 2003, pp. 32-34)

Such underground elements of a building as basements, foundations, especially with a high level of groundwater, are constantly exposed to moisture, which can cause mould and mildew to appear on them, and lead to leaks. There are structures that, by virtue of their purpose, work in constant contact with water: surface and buried water storage tanks, swimming pools, showers, bathrooms, etc. Mistakes in the implementation of waterproofing, for example, in the structures of open pools, can cause waterlogging or waterlogging of the surrounding plot. Unlike roofing waterproofing, which is easily accessible for inspection and repair, the waterproofing of underground structures is hidden from direct observation, its inspection and repair is complicated or not possible at all (most often, drilling is used to inspect the foundations). Therefore, the choice of materials and the quality of waterproofing of underground and underwater structures must be impeccable.

The development of new innovative technologies and waterproofing materials is especially relevant not only in conditions of aggressive impact of water and vapours, but also in the presence of vibration currents, pressures and other complicated conditions for the construction and operation of buildings and structures.

Large metropolitan areas are characterized by the development of underground space, which makes it possible to free the surface of the ground from numerous engineering, transport, industrial structures and devices. Thus, providing the most environmentally attractive living conditions for the urban population and allowing to choose the most convenient layout for the population of urban infrastructure facilities. This requires the development of new, more efficient and economical solutions in the field of waterproofing, which is one of the main tasks of underground construction.

The main trends and features of the market for modern waterproofing materials are focused on environmentally friendly water-borne materials, for example, dry mixtures - ready-made powders that require mixing with water or aqueous polymer dispersions; from polymer-cement materials, mineral-based materials are preferred. At the same time, the market is focused not on certain types of waterproofing materials, but on systems, including a set of materials: salt suppression, sanitizing plaster, horizontal diaphragm, etc. Polymer-bitumen compositions are widely used. Special attention is paid to the issues of plasticization of materials, increasing their frost resistance and technical and economic assessment.

2.2 Differences in construction regulations of Russia and Finland

In 1989, the Council of Europe adopted the European Construction product directive No. 89/106/EEC, which is essentially the law for all EU member states. The directive established uniform requirements that must be met so that construction products manufactured in different countries of the European Union can be CE marked and freely circulate in the single European market. In support of this Directive, harmonized European standards have been developed.

In addition, the Directive provides that each member state of the European Union may, within the framework of the Directive and harmonized standards, develop additional requirements that reflect the specificity of a given country climatic conditions and features of the construction process. These additional requirements are called national annexes and are added to the harmonized standards. Eurocodes have been developed and introduced in the EU as harmonized standards.

Eurocodes are a set of European standards (EN) for the design of buildings and structures and construction products, developed by the European Committee for Standardization (CEN). For the development of system Eurocodes within the framework of CEN, a special technical committee for standardization TC250 has been established. Member States of the EU and the European Free Trade Association (EFTA) use these documents for the following purposes:

- to harmonize projects of engineering structures (including high-rise ones) with the current Directive 89/106/EEC concerning construction products, with requirements No. 1 "Mechanical resistance and stability" and No. 2 "Fire safety";

- as a basis for the specification of contracts for construction work and the engineering work required for them;

- as a framework condition for the preparation of agreed technical specifications for construction products.

The Eurocodes cover all major building materials (concrete, steel, wood, stone / brick and aluminium), all major structural design areas (structural design fundamentals, loads, fires, geotechnical design, earthquakes, etc.) and a wide range of types structures and products (buildings, bridges, towers, etc.). The EU also has the European Parliament and Council Directive 2010/31/EC on the energy performance of buildings (EPBD). The European Union has adopted a new regulation governing the conditions for the distribution of products on the EU market. With the entry into force of this Regulation, Directive 89/106/EEC on construction products terminates. And this is not a formal replacement of an old document with a new one, but a fundamental increase in its legal status.

In the hierarchy of EU legislation, regulations are above directives. Directives are generally not directly actionable. The provisions of the directives are subjected to implementation into national legislation in accordance with the individual procedures established in each of the EU Member States, and only then become binding. A regulation is a direct-action document containing all the necessary data (up to schemes and formulas) and procedures, having the force of law and binding on all EU member states.

In Finland, rules related to construction are compiled into the Land Use and Construction Law (MRL) and the related regulation (MRA). These documents contain the regulations of the authorities regarding the construction of buildings, inspection, design, etc. These regulations clarify the general requirements for the construction site, technical requirements (structural strength, fire safety, etc.), as well as the general duties and responsibilities of the builder (design, construction in accordance with the permit). The MRL sets out the basic rules related to construction, and the MRA contains detailed rules and regulations based on the laws (Nykänen, 2009, p. 36).

The Municipal Building Regulations provide additional rules and regulations based on local conditions. Each municipality has its own building regulations, which may differ markedly from the building regulations of other municipalities. The municipal authority that oversees construction can also set construction rules (for example, materials for construction and the colour of the building) that apply to the territory of the municipality. Finally, the official responsible for the supervision of the construction sector on the part of the municipality (usually a construction inspector) can give instructions and recommendations on specific points of construction. The Finnish Building Code regulates and guides design, construction and supervision (Nykänen, 2009, p. 36).

The quality of construction work in Finland is largely due to the high level of responsibility of construction contractors for the work performed. The standard warranty period for identifying possible defects in the work of builders is one year. We are talking about minor flaws in decoration or quality of materials. In the event of a violation by the builders of the work technology, which leads, for example, to a leak, the liability of the builders remains for 15 years. High responsibility is the main reason for the renowned Finnish quality. No builder will use substandard, uncertified materials or deviate from the project, as this entails long-term personal liability.

All construction projects are insured against the main types of risks during construction. The liability of builders is insured in the amount of half a million euros (Bondarenko, 2018). As far as construction project management is concerned, by law, a responsible construction foreman (vastaava työnjohtaja) must be present at each construction site. This independent specialist is the link between the customer and the builders and reports directly to the customer and the construction inspector. In addition to monitoring the compliance of project documentation and the quality of work at all stages, the responsible foreman monitors compliance with safety regulations, fire-fighting measures, the cleanliness of the construction site, etc. The responsible foreman maintains reports for instance for the credit institution and tax authorities. The responsible foreman is a high-level professional with the necessary education and long-term experience. Approved by the municipal building inspector. General project management is often entrusted to a responsible foreman, or a specialized management organization, responsible for the management of a construction project from obtaining a building permit to the delivery of a finished house to a construction inspection (Bondarenko, 2018).

In Russia, the regulations for organizing low-rise housing construction are very simplified, all control functions of the State and municipalities are excluded. This leads to numerous violations and arbitrariness.

Regulatory and legal regulation in the field of construction in Russia is carried out through a system that includes urban planning legislation of the Russian Federation and the system of state executive authorities of the Russian Federation. The town-planning legislation of the Russian Federation regulates town-planning activities and consists of the Town-planning code of the Russian Federation and other regulatory legal acts and federal laws of the Russian Federation.

In the sphere of Russian urban planning activities, the following management system has developed:

- technical regulation;
- state construction supervision;
- state expertise (including environmental) of the results of engineering surveys and project documentation;
- obtaining a building permit, then commissioning;
- pricing and estimated rationing.

State management is balanced by those non-state institutions that can influence the quality of construction and the products and services produced in the construction industry.

Today in Russia, due to changes in the normative base in the field of urban planning, many normative acts are losing their significance, but since there are often no substitute normative documents today, these acts still play an important role in contractual practice. The bulk of the normative material is contained in acts adopted by federal ministries and departments - the so-called departmental legislation, referred by general civil legislation to the category of other legal acts. In the legal hierarchy of normative acts, these documents must comply with the Constitution of the Russian Federation, the Civil Code and other normative acts of a higher level.

The basis of urban planning legislation are the federal laws. They determine the fundamental principles of construction activities, the legal status of participants in design and construction (Law on investment activity in the RSFSR 1488-1 /1991. Edited 26.07.2017). In addition, the norms of Chapter 37 of the Civil Code of the Russian Federation, including paragraph 3, which indicate the norms of construction contracts, are of paramount importance. A number of documents are aimed at ensuring that legal acts do not contradict the above-mentioned legislative acts. The following departmental regulations are of great importance:

- Decree of the Government of the Russian Federation N 145. Regulation on the organization and conduct of state examination of project documentation and the results of engineering surveys in edition from 12 November 2016;

- Decree of the Government of the Russian Federation N 500. Regulations on the federal information fund of technical regulations and standards and a unified information system for technical regulation, 15 August 2003;

- Letter of the Ministry of Construction of the Russian Federation on the legislation of the Russian Federation, in accordance with which the cost of construction is determined, 6 July 1995;

- Letter of the Ministry of Finance of the Russian Federation on methodological recommendations for the composition and accounting of costs included in the cost of design and survey products (works, services) for construction, and the formation of financial results, 23 May 1994;

- Letter of the Ministry of Finance of the Russian Federation on standard guidelines for planning and accounting for the cost of construction work, 30 December 1993;

- Letter of the Ministry of Finance of the Russian Federation on standard methodological recommendations for planning and accounting for the cost of construction work, 30 December 1993;

- Regulations on contract bidding in the Russian Federation, approved by the Order of the State Property Committee of Russia and the Gosstroy of Russia dated 13 April 1993 (with additions);

as well as the Resolution of the State Statistics Committee of the Russian Federation N 185 on approval of the Instruction on the procedure for compiling statistical reports on capital construction, 24 September 1993, edition 3 October 1996, can be called as sources that regulate relations in urban planning. This document contains the definition of several concepts such as "construction object", "start-up complex", "construction stage", "construction site", which are widely used in contractual practice and construction legislation.

There are similar definitions in Finnish legislation: The Land Use and Construction Law contains some concepts, the interpretation of which in practice is difficult. For example, the law defines the concept of a building as precisely as possible, although it is impossible to list absolutely all objects that are considered buildings. The main issue for Finns is the concern for the health of the nation, and therefore comfortable living conditions come first. For this reason, the Union of Architects of Finland is called upon to strictly monitor the implementation of only comfortable projects in the country.

With the adoption of the Federal Law No. 184 "On Technical Regulation" dated December 27, 2002, edited from December 9, 2015, and then the Urban Planning Code of the Russian Federation, the reform of the previous system was initiated, which affected not only the construction industry, but all sectors of the national economy as a whole.

Currently, the main legal document of technical regulation is the Federal Law of the Russian Federation "Technical Regulations on the Safety of Buildings and Structures" No. 384-FZ dated December 30, 2009 (hereinafter TR No. 384-FZ), which establishes the minimum necessary mandatory requirements for ensuring the safety of capital construction at all stages of design and construction, among them safety requirements: fire, mechanical, the level of impact of construction facilities on the environment, in case of hazardous phenomena and processes of a natural and man-made nature, as well as safety for human health: living conditions in construction facilities, stay, use, accessibility for disabled people and other groups of the population with limited mobility, energy efficiency.

Each waterproofing material is designed for a specific job. There are strict rules for its application in a particular area of construction and installation work. Failure to comply with the prescribed norms and standards can lead to poor quality results. In Russia, the use of any material is accompanied by strict observance of all Russian legislative norms (Set of Rules on insulation and finishing coatings 71.13330.2017/2017).

First, the waterproofing material must have the appropriate documentation and certificate, and fully comply with them. If waterproofing is carried out on an industrial scale, then storage, transportation, as well as the use of materials must strictly comply with the prescribed requirements and standards.

Secondly there is GOST (governmental standard) for waterproofing, for example, GOST 3054797 "Roll waterproofing materials". Many materials used, if stored or used improperly, can harm others. Failure to comply with standard rules and violation of technology will lead to the fact that waterproofing will not only not bring the intended benefit, but also harm. Materials and components that are used in modern technologies work for the benefit only if the standards attached to them are carefully observed.

Thirdly, if individual repairs or construction are carried out, a waterproofing act is required - a document confirming the work carried out with a listing of all actions and applicable materials.

Currently, Russia has organized the revision and update of several building codes and regulations aimed at convergence (harmonization) of the requirements of domestic norms with the standards of the European Union, including the Eurocodes. The need to make changes and additions to the current building codes and regulations is dictated by the fact that the existing regulatory framework did not provide the required level of safety established by law, the degree of compliance of buildings and structures with their functional purpose, reduction of energy costs, and did not meet the norms and requirements of international standards. The leading scientific research and design organizations of the construction complex are engaged in revision and updating of building codes and regulations. The task was to study and consider the most progressive provisions of national norms and standards of other foreign countries. Eurocodes, as building design standards, are based on a significant array (more than a thousand) of reference standards for materials, methods of their testing, production methods, etc., many of which are either not yet known or have not been studied by either design or production organizations. Therefore, mastering the entire regulatory framework of European building standards, including the Eurocodes, causes a certain number of difficulties. Updating building codes, regulations and GOST, studying and mastering European Union standards, as well as creating a unified regulatory framework for the Customs Union of Russia, Belarus, Kazakhstan and the EurAsEC are considered within the framework of a coordinated interstate program designed for more than one year.

A significant package of building codes and regulations for the design of various types of structures is a direct analogue of Eurocodes. It should be noted that the methods for calculating building structures based on limit states were adopted in Russian standards before they were included in the Eurocodes.

The introduction of Eurocodes into the Russian regulatory system revealed several difficulties and problems, for example, significant differences in climatic and geotechnical conditions, and in construction technologies. In the future, there is a large field of work in the direction of improving Russian legislative regulation in the field of construction.

2.3 Differences in natural and climatic conditions

Finland is a country located in the north of Europe. Large part of the territory (about 25%) is located beyond the Arctic Circle. The climate in most of Finland is transitional from maritime to continental.

Most of Finland is low-lying, but in the northeast some mountains reach heights of over 1000 meters. The highest point of the country is Mount Halti (1324 m), located in Lapland in the Scandinavian mountains, near the border with Norway (Wikipedia, 2020).

There are three geographical areas in Finland. The northern upper reaches and Lapland are located beyond the Arctic Circle. The relief is characterized by small hills and rocky mountains. The soils are scarce and infertile. The coastal lowlands stretch along the Gulf of Bothnia and the Gulf of Finland, along the coast of which there are many rocky islands. The coast is highly dissected, on the western coast it passes into the largest archipelago - the Archipelago Sea. Other main archipelagos are the Turku archipelago and the Åland Islands.

On the inner plateau, south of the central regions, there is a region of lakes. The territory is characterized by the presence of a large number of lakes, swamps and marshes, a lot of forests. There are about 200 thousand lakes on the territory of the country, which abound in islands, peninsulas, bays. The lakes are connected by channels that form branched water systems. The largest lakes include: Saimaa, Päijänne, Oulujärvi, Inarijärvi.

Almost all rivers flow into the Baltic Sea, except for the rivers of the northern territories that flow into the Arctic Ocean. Finland's rivers abound with waterfalls and rapids. Most of the rivers connect lakes with each other or represent the flow from the lake to the sea. The largest rivers: Oulujoki, Kemijoki.

In Finland, there are strong changes in sunlight depending on the season, due to the extreme northern location of the country. Precipitation falls all year round. At the end of December, the thickness of the snow cover averages 40 cm in the north, 30 cm in the central regions and 10 cm in the south of the country. The southern regions are covered with snow throughout the year on average 75 days, the northern (northern Lapland) - 200-225 days. Average annual precipitation in the south is 600-700 mm, in the Arctic Circle - 400-450 mm. More precipitation falls in the inner lacustrine regions than on the western coast. Humidity varies depending on the month from 62% to 95% (Wikipedia, 2020).

Finland is located on an ancient (1.4-3 billion years old) granite crystalline shield extending under the entire Scandinavia and the Kola Peninsula. The Baltic Sea and the Gulf of Bothnia are also on this shield, and are, in fact, a lake that was formed during the Ice Age. The thickness of the ice reached 3 km, which caused a deflection of the earth's crust up to 1 km. After the glacier disappeared, a reverse process began, which continues at the present time. The ascent rate is highest in the north of the Gulf of Bothnia - about 90 cm per century. In some places, there are steel rings embedded in granite for tying ships, but now they are hundreds of meters from the coast. When the glaciers descended, on average, about 7 meters of bedrock were “stripped off”, at present 3% of the country's territory is open granite and 11% is hidden under a layer less than 1 meter thick. Most of the bedrock is hidden by the formed sediments up to several tens of meters thick. Glacier footprints are visible, for example, in a complex system of lakes and in the huge boulders found throughout the country. 52% of the bedrock are various grades of granite, 22% are mixed rocks, 9% are layered rocks, 8% is diabase, 4% are quartz and sand, 4% are granulites, 0.1% are limestones (the oldest in Europe) (Wikipedia, 2020).

The territory of Russia lies in four main climatic zones at once, each of which has its own temperature and precipitation rates (NatWorld, 2018). From east to west, there is a transition of the monsoon climate to the continental one, so it is advisable to compare with those areas in Russia that are closest in climatic characteristics to Finland. The issue of waterproofing residential and public buildings is acute in areas with flooded and swampy areas, which is typical, for example, for St. Petersburg - the Russian metropolis closest to Finland. The soils of St. Petersburg are characterized by high natural moisture, porosity, anisotropy of mechanical properties, high and uneven compressibility, heaving and thixotropy. The groundwater level in the city is usually at least 2 m from the daytime surface, but in the autumn and spring seasons it reaches the ground surface. Seasonal fluctuations in the groundwater level are within 1-2 m. The chemical composition of groundwater is variable and also depends on the season of the year, and on the composition of industrial wastewater, the presence of landfills, soil dumps and process waste. Interstratal groundwaters are contained in intermoraine layers of sands and sandy loams, in sandy lenses of moraine deposits and can have local pressure. The solution to the issues of waterproofing structures in St. Petersburg, such as the building of the second stage of the State Mariinsky Theater (St. Petersburg) and the St. Petersburg metro, testifies to the high technology of solutions.

From the very beginning St. Petersburg was built on often flooded territories with a high level of groundwater. In the 18th century the groundwater level was 1-1.5 m higher than the current levels. During the operation of many buildings built in the 18th - early 20th centuries, the water protection structures, provided during construction, failed, which led to flooding of basements, moistening of the walls of buildings to the level of 2-3 floors, the formation of mold on the walls, floors and ceilings. In modern construction, the issue of protecting underground parts of structures from underground waters is no less acute. This applies to residential and non-residential buildings, metro facilities and underground urban infrastructure - underground parking lots, pedestrian crossings, engineering structures. These issues are becoming especially acute in connection with the beginning of the widespread development of underground space both under the existing buildings, and during the new construction of underground facilities. Waterproofing of underground structures and underground parts of buildings is a rather laborious and responsible process and ranges from 0.1 to 0.5% of the estimated cost of construction and installation work, but it accounts for up to 3% of the total labour costs for the construction of a structure. At the same time, the protection of underground parts of buildings and structures from the effects of groundwater is a set of measures that should include elements of engineering preparation of the territory, water-lowering and the development of the waterproofing system itself.

3 ANALYSIS OF THE MODERN BASE OF TECHNOLOGIES AND METHODS OF WATERPROOFING OF BUILDINGS AND STRUCTURES

3.1 Types of waterproofing of buildings and structures. Basic concepts and definitions

Waterproofing - a set of measures to protect the structure from moisture of surface or filtering water (ground water, precipitation) or other aggressive environment - anti-filtration waterproofing, as well as to ensure the durability of construction materials under chemical or physical aggressive effects - anti-corrosion waterproofing. It should be noted that work on horizontal surfaces is different from the isolation of vertical ones.

According to the classification of Popchenko S. (Popchenko, 1981), waterproofing materials are subdivided according to their (1) purpose, (2) type of the main initial component, (3) technological features, (4) method of construction. Let's consider these classifications.

1) According to the purpose, waterproofing materials are divided into anti-filtration, anti-corrosion and sealing. At the same time, they are subdivided into surface and internal waterproofing, working for tearing and pressing, for sealing joints and for coatings, also for complex purposes - combined (for example, heat and waterproofing or in combination with protection against corrosion, cavitation and abrasive erosion, and also often used combination of waterproofing with heat and vapor barrier).

2) According to the type of the main initial component (material), waterproofing materials are divided into mineral, asphalt, polymer and metal.

3) By technological features - it is divided into liquid and paint compositions, mastics, piece materials and dry mixtures of local or factory production.

4) By implementation method:

- impregnating,
- painting (the work considers the latest materials included in the international "Register of products that meet environmental requirements");
- coating (the work considers innovative technologies of elastic penetrating coating waterproofing),
- gluing (the work considers waterproofing of roll and flexible materials),
- injection (in the work, special attention is paid to modern injection waterproofing and injection systems),
- sprayable (for example, waterproofing materials Dorflex and Rauflex, which are the latest generation of modification of a bitumen-latex emulsion to obtain a membrane with high physical and mechanical characteristics).
- mounted: hydraulic diaphragms and impervious screens, which are independent structural elements of hydraulic structures.

A brief description of these technologies is given in the book by Fadeev (2007), as well as in the works of Rybiev (1991), Grachev (1990), Lufsky (1982) and others, as well as in the monograph of Mangushev (2010). The types of waterproofing by application methods are summarized in the table in Appendix 1.

3.2 Primary waterproofing technology.

Specialized construction works of structures constantly in contact with water require special materials. For example, concretes based on expanding and self-stressing cements are practically waterproof - the water resistance index W is from 12 to 20 units. Also, this material has high frost resistance (F 500 and more - withstand up to 1500 freeze-thaw cycles), gas tightness is 40 times higher than that of heavy concrete based on Portland cement and durability, respectively, – 3-6 times due to the fine-cellular structure with closed pores.

Hydraulic concrete in St. Petersburg is produced by the VelesArk company. The production of a mixture of moisture-resistant concrete is carried out using special additives in any class of hydraulic concrete, which provide it with the necessary properties. Crushed stone, gravel and other dense rocks are used as a filler. When selecting components for the composition of the mixture, they are guided by the scope and requirements for quality and properties: frost resistance, water resistance and strength. On the basis of these requirements, the holding time of the mixture, the ratio of water and cement, and vibration compaction are calculated (Velesark, 2009).

Expanding cements were used at such Russian facilities as underground structures of the "Medeo" ice rink in Kazakhstan, the stylobate of the Federation Council and the Moskovsky supermarket, Manezhnaya Square, the stands of the stadiums named after S. M. Kirov and "Petrovsky" in St. Petersburg, "Dynamo" and "Luzhniki" in Moscow. The pricelist for hydrotechnical concrete of the Veles-Ark company is given in Appendix 2.

In hydraulic structures, expansion additives are used (dense fine-grained structure that increases the corrosion resistance of concrete, including in sulfate environments). Concretes based on a mixture of Portland cement and an expansion additive do not require special protection in aggressive environments, for example, containing SO_4^{-2} ions (up to 5000 mg / l), and at a pressure of 20 atmospheres, they do not filter water. Of modern waterproofing cements, we will call "Hydro-S" and various mixtures "Hydro-SII Plus", which are used for waterproof structures in low-rise individual construction: walls of pools, basements, foundations, flat roofs, and for the repair of flooded and damp buildings in areas with a high level of groundwater.

In Finland, Lakan Betoni Oy produces dry mixes and building blocks. Lakka´s expanded clay and concrete foundation blocks are energy efficient and moisture resistant and are even suitable for basement construction (Lakan Betoni Oy n.d.). These blocks already have grooves for horizontal reinforcement, and their low weight makes it really quick and easy to erect wall structures. The price list for Lakan Betoni Oy foundation blocks for various typical blocks is given in Appendix 2. The block number corresponds to its width, the height of all blocks is standard 195 mm.

The foundation can be made with the LAKKA ANT600 foundation blocks. This technology makes it possible to build a foundation without formwork, significantly saving time and money. The blocks are installed on a sand cushion, reinforcement is laid in the grooves, after which the structure is poured with concrete. Concrete consumption is only 40 l / block. The structural frame of the building is made of Lakka EKO + 400 grafit, thermal insulation blocks.

In Finland, all solutions are aimed at fast and quality construction. This also dictated the development of the technology of concreting in fixed formwork, which is also offered by the Finnish company Lakan Betoni Oy. To obtain concretes and mortars with high water resistance, the technology of dry mixes is effective, while optimization of the composition and selection of mix components is carried out. In this case (in contrast to the usual technology of concrete preparation), the granulometric composition of fillers, aggregates and binder is carefully selected, which together provides high water resistance of concrete.

The introduction of chemical additives of various effects (sealing, expanding, water-repelling, plasticizing, etc.) into dry mixtures, makes it possible to increase the water resistance of concrete at times (Academy of Industrial Markets Conjuncture, n.d.). With water hardening, the lowest water permeability of concrete is observed. After one month, the water permeability of such concrete is several times lower than that of concrete with air-dry or air-moisture hardening.

It is also necessary to ensure the compaction of the concrete mixture and prevent technological filtering defects. Thanks to the development of the chemistry of binders, effective types of chemical additives and the improvement of production, a large nomenclature of dry mixtures based on mineral binders with a self-compacting effect has been developed. There are additives that prevent cracking of concrete structures, giving them elasticity, preventing the penetration of moisture from the outside (for example, additives of the "Polyplast" series). In addition, cracking is prevented by expansion joints. The table of moisture-resistant concretes and plasters used in Russia is presented in the table in Appendix 3.

3.3 Secondary waterproofing

When choosing a method of secondary waterproofing, it is necessary to proceed from the type of permeability of specific structures and the reasons for the violation of waterproofing. In case of intensive seepage as a result of a strong pressure of water over the entire surface of the floor or walls, or in case of cracking (cracks can be caused, for example, by uneven settlement of the building), it is necessary to use plaster mortars. If there are single cracks and there is no groundwater pressure causing the formation of new cracks, water-stopping compositions will be effective for the emergency liquidation of leaks. Also, in this case or in rooms for which a decrease in volume is not desirable (bathrooms, showers, etc.), a waterproofing mixture of penetrating action is used (Latysheva & Smirnov, 1999, pp. 16-17). They also use membrane-type materials - a traditional well-proven technology. From all the variety presented, it is necessary to choose the material that will ensure the reliability of waterproofing in the required range of deformations and temperatures. The methods of secondary waterproofing and the main materials used in Russia are given in the table in Appendix 4.

The Russian manufacturing enterprise ALFAPOL is a leader in the development of special-purpose building mixtures and materials for the construction of industrial floors and coatings.

In Finland, Kiilto Oy, founded in 1919, is one of the companies developing special-purpose mortars. It is a family business specializing in the production of chemical and technological products for the needs of the construction and industry. The company develops, manufactures and markets adhesives and building mixtures.

One of the waterproofing materials made in Finland is an updated, even faster-drying waterproofing membrane for indoor and outdoor use, Kiilto Keramix A + X, produced by the Finnish company Vahanen Rakennusfysiikka Oy. This material has passed the European CE certification. The material is well suited for sealing leaks (Kiilto Oy, n.d.).

3.4 Sustainability of materials

An integral part of the daily activities of Finnish companies, its guiding principle, the basis of corporate culture and business strategy is the responsible attitude to safety and environmental protection.

Responsible safety and environmental protection are a determining factor in the development of construction products and their life cycle planning, from the selection of raw materials and packaging materials to production, distribution, operation and final disposal of products and packaging. Research and development (R&D) play a significant role in the product chain of responsibility. Certified building materials eliminate hazardous exposure to chemicals.

3.5 Determination of waterproofing method

When it comes to choosing a waterproofing method, the following factors are considered first:

- value of hydraulic head of water,
- permissible indoor air humidity,
- crack resistance of insulated structure,
- degree of aggressive impact of groundwater.

It is also necessary to take into account the mechanical effect on waterproofing, temperature effects, working conditions, as well as the seismicity of construction area.

Depending on the hydraulic head, the scope of application of various types of waterproofing is determined from Table 1. Waterproofing of structures must be provided above the maximum groundwater level by at least half a meter.

Waterproofing properties	Waterproofing type				
	Painting		Plastering		Lining
	Bituminous	Polymer	Bituminous	Cement	
Hydraulic head, m	2	6	20	30	30

Table 1. Hydraulic head supported by various waterproofing materials.

Depending on the permissible indoor air humidity in underground rooms (basements, tunnels, ventilation chambers, etc.), the type of waterproofing should be assigned in accordance with table 2 (Sign "+" – allowed for use. Sign "-" – not allowed or not recommended for use. * – polymer based. ** – shotcrete should be provided on the outside and inside of the insulated structure, over the sprayed layer of paint waterproofing. *** – shotcrete should be provided only on the head side, over the sprayed layer of paint waterproofing).

Waterproofing type	Exposure to water	Room relative humidity, %		
		< 60%	60-75%	> 75%
Painting	Capillary suction	+	+	+
	Hydraulic head	-	+ *	+ *
Plastering, Cement	Capillary suction	-	-	-
	Hydraulic head	-	+ **	+ ***
Plastering, Bituminous	Capillary suction	-	-	-
	Hydraulic head	-	+	+
Lining	Capillary suction	-	-	-
	Hydraulic head	+	+	+

Table 2. Room relative humidity provided by various waterproofing materials.

The choice of waterproofing based on crack resistance of structure is carried out according to table 3.

<table>
<tr><th>Waterproofing type</th><th>Smoothness of the insulated surface</th><th>Protection of the waterproofing layer</th><th>Crack resistance of the insulated structure</th></tr>
<tr><td>Plastering, Cement</td><td>Uneven</td><td>Not required</td><td>Crack resistant</td></tr>
<tr><td>Painting</td><td rowspan="3">Smooth</td><td rowspan="3">Needed</td><td rowspan="2">Crack opening up to 0.2 mm</td></tr>
<tr><td>Plastering, Bituminous</td></tr>
<tr><td>Lining</td><td>All groups by crack resistance</td></tr>
</table>

Table 3. Crack resistance of various waterproofing materials.

When choosing the type and structure of waterproofing, it is necessary to consider the chemical composition of groundwater and presence of stray currents. In presence of aggressive groundwater, protective coating should be assigned depending on the degree of aggressiveness of the environment according to table 4 (Sign "+" – allowed for use. Sign "-" – not allowed for use).

Waterproofing type	The degree of aggressive impact of groundwater		
	Weak	Medium	Strong
Plastering cement	+	-	-
Plastering bituminous	+	+	-
Painting bituminous	+	-	-
Painting polymer	+	+	+
Lining	+	+	+

Table 4. Aggressiveness of the groundwater environment resisted by various waterproofing materials.

When the underlying factors are taken into account and choice is minimized, the price factor comes into play. Table 5 shows examples of price for waterproofing products from K-Rauta and Netrauta stores. In addition to the price on a product itself, it is also worth considering that different methods imply a different number of working hours as well as presence of special skills and equipment, which will significantly increase the price of one or another type of waterproofing. For example application of lining waterproofing requires a gas burner to heat the material to the working temperature, while the application of painting waterproofing is carried out with a roller or with a pump that allows the composition to be sprayed over larger areas. Among other things, depending on the first four factors, different waterproofing methods will require a different number of application layers, which will also affect the price.

Waterproofing type	Product name	Price	Usage	Unit cost
Plastering	Webertec 930 Waterproofing mortar	64,50 € for 25kg package	4,0-6,0 kg/m^2	10,3-15,5 €/m^2
Painting Bituminous	Kerabit BIL 105/85 bituminous waterproofing	45 € for 5l package	0,3-0,5 l/m^2	2,7-4,5 €/m^2
Painting Polymer	Webertec 827 S Epoxy waterproofing	219,40 € for 8kg package	1,6-2,6 kg/m^2	43,9-71,3 €/m^2
Lining	Kerabit 4100 UT	99 € for 10 m^2 roll		9,9 €/m^2

Table 5. Price comparison for various waterproofing types.

3.6 Conclusions to the analysis of the research base

Finnish construction technologies are aimed at high-tech construction methods based on complex ready-made standard solutions (for example, see Appendix 5 (Lakan Betoni Oy, n.d.)), which reduces construction time and is a significant factor in reducing the total cost of construction. The technology of ready-made standard solutions is developed for the climatic and geotechnical conditions available in Finland. The range of technical characteristics is not large here and does not affect waterproofing methods. In particular, roofing materials or foundation structures already have the required waterproofing, and therefore, little attention is paid to waterproofing problems separately. On all the websites of Finnish manufacturers of building materials and mixtures studied, the issue of waterproofing is not touched upon - it is a self-evident component already taken into account in a comprehensive solution to a building structure, and builders who buy materials from this company do not have to worry about their waterproofing separately.

Obviously, it is simply not profitable for Finnish manufacturers to develop waterproofing means for foundation structures of some abstract theoretically possible soil conditions. The Finnish foundation blocks listed in Appendix 2 are designed specifically for the conditions in Finland, are in great demand in local construction and bring the company a stable income.

Solutions are always tailored to specific needs. For example, if the groundwater does not contain certain chemically active components, then there is no need to add such expensive additives to concrete as, for example, the expansion additive RD (it is used in Russian cements "Hydro-S", "Hydro-SII Plus"). The use of this additive allows concrete structures not to filter water in aggressive media containing SO_4^{-2} ions (up to 5000 mg / l), even at a pressure of 20 atmospheres. If, for example, in Finland it will be necessary to build a complex hydraulic engineering facility with non-standard conditions, then, of course, it is more profitable to turn to foreign partners with existing experience and technologies of such construction than to start own developments for this facility.

In Russia, on the contrary, due to the significant difference in climatic and geotechnical conditions, much attention is paid to the issues of waterproofing materials and technologies, new high-tech solutions are being developed, such as injection methods and injection systems for the repair and reconstruction of damaged waterproofing of old and historical buildings and structures. Thanks to foreign construction experience, mainly German, these technologies have long been actively introduced into Russian construction technologies. Nevertheless, in the modern Russian market of waterproofing materials, there are still many imported products, despite their high cost (in the table of Appendix 4, Russian manufacturers are highlighted in blue, foreign ones - in red). Work on the creation of our own progressive waterproofing materials is ongoing, especially intensively in the latest waterproofing technologies such as membrane waterproofing and injection waterproofing (see table Appendix 4).

The leaders in the development of methods and technologies for waterproofing are St. Petersburg developers. The soils of St. Petersburg are characterized by high natural humidity, porosity, anisotropy of mechanical properties, high and uneven compressibility, heaving and thixotropy. The groundwater level in the city is usually at least 2 m from the day surface. Seasonal fluctuations in the groundwater level are within 1-2 m. In the autumn and spring seasons, it reaches the ground surface. The chemical composition of groundwater is variable and depends on the season of the year, the composition of industrial effluents, the presence of landfills, soil dumps and process waste. Interstratal groundwater is contained in intermoraine layers - sands and sandy loams, in sandy lenses of moraine deposits and may have local pressure.

These factors explain the special attention to methods and means of waterproofing. The solution to the issue of waterproofing structures similar to the building of the second stage of the State Mariinsky Theater (St. Petersburg) and the St. Petersburg metro indicates the need for non-standard high-tech solutions in each specific case, with a comprehensive study of the geotechnical environment and the characteristics of the composition of groundwater.

At present, specialized companies in St. Petersburg have accumulated significant experience in water protection of newly constructed underground parts of structures and restoration of waterproofing in old buildings. Here, in institutes and research and production firms, the latest developments of special building materials and waterproofing technologies are carried out, also in cooperation with foreign firms. For example, let us name several of the largest developers of innovative technologies in the field of waterproofing in specific areas of development: LLC Plant of Sealing Materials, one of the largest developers in the Russian Federation of technologies for sealing materials and protecting structures based on them, has developed the Abris® C-T technology based on mastic-polymer tape. The INJECT company, together with the Minova Carbo-Tech GmbH (Germany), has developed an injection waterproofing technology that makes it possible to eliminate any leaks, even pressure ones. LLC KalmaTreid develops a number of waterproofing materials to protect buried and underground structures and structures from aggressive environments, and others.

Another dynamically developing company, Innovative Technologies, is engaged in the development, production and implementation of innovative waterproofing materials and technologies of a new generation, combining the best international experience and the Russian scientific and practical base mainly on the domestic resource base and adapting the best technologies of foreign countries to domestic conditions. Among the company's developments in the direction of protecting building structures from the aggressive effects of moisture are waterproofing materials Dorflex and Rauflex based on bitumen-latex emulsion, which were used in the construction of such objects in St. Petersburg as the Sportivnaya metro and the building of the second stage of the Marinsky Theater. You can also name one of the largest scientific centers in Russia - the All-Russian Scientific Research Institute of Hydraulic Engineering named after B.E. Vedeneev St. Petersburg, founded in 1931, and among its scientists - Honored Builder of the RSFSR, Professor, Doctor of Technical Sciences SN Popchenko. The tasks of the institute include research, development and implementation activities in the field of hydraulic engineering, industrial and civil construction.

The latest developments are being carried out at the Department of Chemical Technology of Building and Special Binding Substances of St. Petersburg State Technological Institute, which, together with a number of companies is carrying out the development of building materials based on polymer (applies to them including the development in the polymer-based materials under the trade ETALON brand) and many others. Newly developed materials are thoroughly tested in the most reliable and well-known test centers in Russia before going into production.

4 PROSPECTS FOR THE PRACTICAL APPLICATION OF THE CONCLUSIONS OBTAINED BY A COMPARATIVE ANALYSIS OF WATERPROOFING METHODS

4.1 Practical application of new technologies and methods of waterproofing buildings and structures on the example of a specific building

Consider, for example, consider the construction of the foundations of a specific building located in St. Petersburg, with an underground parking lot for the residents of the building. Such solutions are now the most popular due to the increasing number of personal vehicles and the economy of urban areas for building. Underground parking lots are also being built during the reconstruction of old buildings in the central part of the city, for example, during the reconstruction of the "Stockman" shopping center located on Nevsky Prospect.

The underground part of the building is subject to design and construction. The preparatory calculations include:

1) Collecting loads on the foundations of the building as a result of the static analysis of the supporting structures of the building. The calculated loads acting on the upper edges of the foundations are determined. Allocation of permanent and temporary types of loads, the establishment of their basic and special combinations.

2) An assessment of the engineering-geological and hydrogeological conditions of the construction site is carried out, the systematization of the survey materials, the determination of additional indicators of the physical state of the foundation soils, the assessment of the aggressiveness of groundwater. Characterization of soils in terms of bulk density (sandy), plasticity (clay), assessment according to the criteria of subsidence and swelling, compressibility and strength.

3) A general conclusion is made about the suitability of the site for construction and possible types of foundations of the projected object.

4) Variants of foundations and structures of underground structures are being developed.

5) Determination of the foundation settlement. Calculation of reinforcement of foundations and grillages in characteristic sections of structural elements based on their calculation according to the first group of limiting states (in terms of strength).

6) Determination of the cost, consumption of basic materials (steel, cement), labor intensity and duration of construction, the degree of mechanization and industrialization of work on the construction of each option of foundations.

7) Based on the analysis of these and other indicators, a choice is made of the main, most appropriate type of foundation and type of foundation for a building or structure, including the choice of waterproofing.

8) When developing options for an underground structure, various types of structures or methods of erection are considered (a sinkhole, a “wall in the ground” method, construction in an open pit, a shield method or other special methods of erecting underground structures).

9) The issues of interaction of the surrounding soil massif with underground structures are considered. The pressure from the ground on the side walls, the bottom, the roof of the underground structure, the pressure from the static and dynamic loads of the earthen part of the structure (if necessary) is determined. The issues of drainage or dewatering, fastening of underground workings are being solved.

The settlement and explanatory note include:

a) assessment of the engineering-geological and hydrogeological conditions of the construction site with the determination of the aggressiveness of groundwater;

b) static calculation of the above-ground structure of a building or underground structure with calculation schemes, diagrams M, Q, N and summary tables of efforts, their combinations and combinations;

c) a complete calculation of various options for foundations and structures, a technical and economic comparison of options and the final decision on the choice of the type of foundation and foundations of the projected object or underground structure;

d) calculation of all foundations or structures according to the selected option, as well as an element of the aboveground structure. The design ends with the drawing up of a sketch or diagram of the reinforcement of the structure (or foundation) indicating the main dimensions, diameter, pitch and class of reinforcement, which will serve as the basis for the execution of working drawings;

e) substantiation of the chosen method of waterproofing the underground part of the building and structure with the necessary calculations and other developments.

The site for engineering and geological surveys is administratively located at the address: St. Petersburg, Moskovsky district, on the site between st.

Kuznetsovskaya (52) and st. Blagodatnaya, at the corner of Yuri Gagarin Avenue and st. Blagodatnaya.

The geographic location of the site is shown in Fig. 1 of Appendix 6. The plan-height reference of the building at the construction site is shown in Fig. 3 of Appendix 6 (dimensions and elevations - in meters). The groundwater level is located below the level of the planning from 0.5 m to 1 m (at absolute elevations +6.8 m …… + 7.47 m). Engineering-geological sections, built for the given wells, are shown in Fig. 4, 5 Appendix 6. For example, the soil strata in well 4 (6) are shown, which corresponds to the axis 3-3 of the projected foundation. When analysing and choosing the method of erection of the underground part, the method "Wall in the ground" was chosen. The method of waterproofing structures erected by the "wall in the ground" method is shown in Fig. 2 Appendix 6.

Waterstops and injection systems are used in the working joints of concreting. Waterproofing dowels are tapes for waterproofing movement and construction joints of concrete structures. Also, when erecting monolithic reinforced concrete structures, injection hose systems are used as a design solution for sealing the "cold" working joints of concreting, expansion joints and abutments of structures. Design solutions for waterproofing are presented in the drawings.

4.2 Application of BIM technologies for making a comprehensive solution for waterproofing

If traditional design deals with two-dimensional models of construction objects (plans, drawings, technical documentation, etc.), then BIM-design differs in that the collection and processing of data on architectural, planning, structural, economic, technological, operational characteristics of an object is united in a single information field (BIM - models). In addition, all the data embedded in the information model of the object are interconnected and interdependent. The interdependence and easy recalculation of indicators when changing the parameters of the information model greatly simplifies the variant design and the search for optimal solutions particularly when choosing various options for the production of construction and installation works. Variation can also apply to any other section of the project (selection of structures, selection of equipment, remodeling projects, etc.). A feature of the BIM model is the ability to simulate the entire life cycle of an object.

Appendix 7 presents a model of a construction production organization system based on the BIM system design meeting the following requirements:

- a description of the baseline conditions for construction, facilities and processes with the required degree of detail and accuracy;

- optimal compliance with the requirements, ensuring the completeness of the object or process representation, convenience and speed when analysing the model and choosing the best solution;

- possessing the property of adaptability and stability, i.e. adaptability to changes in given specific conditions and ensuring operability when making changes to the model; minimum complexity of the adjustment;

- taking into account the multivariance of construction production (composition, intensity, sequence and combination of types of work, the possibility of replacing one of the works with a similar one, changes in relation to parameters (volumes, cost, season of work, weather conditions, replacement of performers);

- taking into account the probabilistic nature of construction production;

- compatibility with other tasks, including changes in architectural and construction design, initial conditions, adopted technologies, accumulation of an experimental base, etc. (Molodin & Volkov, 2015, p. 216).

The decision is carried out according to a given criterion. Optimization is selected by comparing options.

In the proposed model, it is necessary to set the initial parameters (input information):

- Normative base of construction (as a data bank);

- CAD products (projects of buildings and structures).

Appendix 8 provides an example BIM block diagram of a sub-soil wall with different waterproofing methods. The parameters can be recalculated simultaneously for several parameters, as well as the selection of the parameters themselves according to the selected objective function (for example, reducing the cost, or reducing the construction time).

It is known that construction time affects the total cost of construction, especially in the construction of investment projects, when the investor is interested in the fastest return on investment. Delays in construction and untimely completion of works can lead to bankruptcy of the company. Therefore, the optimization of waterproofing works should be carried out according to the aggregate optimization criterion - the timing / cost of construction, taking into account the risks of untimely completion of the work (Ginzburg, 2010, p. 224). The main function of the organizational and technological design (OTD) is to determine solutions that will consider the conditions and ensure the readiness of construction for the execution of construction and installation works on waterproofing (Nebritov, 2011, p. 144). The table "Structure and functions of OTD for waterproofing" is presented in Appendix 9.

A parametric model of control of organizational and technological reliability based on BIM technologies is presented in Appendix 10.

5 CONCLUSIONS

The work is devoted to the comparison of waterproofing methods in Russia and Finland.

The first section is devoted to the formulation of the research problem. The section deals with the general problem of waterproofing buildings and structures as an object of research, and the features of the regulatory framework for construction and the natural and climatic conditions of Russia and Finland, as what forms the differences in the methods and methods of waterproofing in the countries under consideration - the subject of comparison.

The second section is devoted to a systematic review of the most innovative waterproofing materials and technologies. A feature of the Russian market of waterproofing materials is the use of imported products, despite their high cost. Recently, the proposals of domestic analogues have become much larger - work on the creation of our own progressive waterproofing materials and technologies is being carried out in Russia constantly. This is due to the wide variety of climatic conditions in Russia and the need to take these differences into account at each specific construction site. In Finland, on the contrary, the relative uniformity of natural and climatic conditions makes it possible to unify construction solutions and achieve high technological effectiveness and speed of construction of objects, which in general has a positive effect on the quality and cost of construction.

The section discusses the methods of primary waterproofing in new construction (various modifying additives in concrete to increase their moisture resistance), secondary methods, including modern injection technologies and injection systems for the repair and reconstruction of damaged waterproofing of old and historical buildings and structures. These methods are beginning to be introduced into Russian construction technologies thanks to foreign, predominantly German, experience in waterproofing.

A fairly complete overview given in the work can serve as a guide for the selection of waterproofing technologies and materials, help navigate the huge market of modern offers, take them into account at each specific facility, and promote the establishment of mutually beneficial partnerships.

The third section is devoted to the prospects for the practical application of the conclusions obtained in the comparative analysis of waterproofing methods. In the future, it is proposed to solve the choice of waterproofing methods in the work by creating unified information systems within the framework of BIM technologies. BIM technologies allow coordinating the activities of various manufacturers in the field of construction, reconstruction and further operation of a building, creating a unified information base, performing parametric calculations when selecting various parameters with the choice of a key function (for example, the total cost of construction). BIM-technologies are based on the integrated implementation of computer-aided design systems, documentation, estimates, etc. Such a technological level allows obtaining a high-quality functional production associated with a further increase in the scale and improvement of product quality.

When switching to BIM and choosing different waterproofing options, there are many more opportunities in choosing an organizational and technological design (OTP) model. There are special names for models containing additional data: 4D - a three-dimensional BIM model with information about the timing or cost of construction; 5D - the same as 4D, but there is also data on the timing and cost. When choosing a model of organizational and technological design, many parameters are linked to each other, including climatic data on the construction site, therefore, the informatization of the modelling process using BIM technologies significantly simplifies the choice of waterproofing methods for a given building. As an example, the section provides waterproofing drawings for a specific building considered in the section.

REFERENCES

Академия Конъюнктуры Промышленных Рынков. *Добавки для бетонов: классификация.* Academy of Industrial Markets Conjuncture. Additives for concrete: classification. Retrieved 9 August 2020 from: http://www.newchemistry.ru/printletter.php?n_id=3433

Bondarenko, V. (2018). *Строительный Эксперт.* Россия – не Финляндия. Особенно в «малоэтажке». *Construction Expert.* Russia is not Finland. Especially in the low-rise building. Retrieved 12 July 2020 from https://ardexpert.ru/article/12274

Fadeev, A. (2007). *Waterproofing of underground parts of buildings and structures.* St. Petersburg: SPbGASU.

Ginzburg, V. (2010). *Design of organizational and technological tasks of construction.* Moscow: MGSU.

Grachev, I. & Narbut, P. (1990). *Recovery technology recommendations waterproofing brick walls of buildings in Leningrad.* St. Petersburg: Ленжилпроект; НТО Стройиндустрии

Kiilto Oy. Official website. Retrieved 15 August 2020 from: http://www.kiilto.ru/ru/o-kiilto/okruzhayushchaya-sreda-i-bezopasnost/

Kupriyanov, V. (n.d.). Speech n.d. Kazan State University of Architecture and Enigeering

Lakan Betoni Oy. Official website. Lakka foundation blocks. Retrieved 8 August 2020 from: https://lakka-rus.ru/products/category/lakka-foundation-blocks

Lakan Betoni Oy. Official website. Toimitussisältö. Retrieved 8 August 2020 from: https://www.lakka.fi/lakkakivitalot/kivitalon-rakentaminen/toimitussisalto/

Latysheva, L. & Smirnov S. (1999). Domestic waterproofing materials based on binders. *Building materials* 9, pp. 16-17.

Latysheva, L. & Smirnov S. (2003). How to protect yourself from water and dampness. *Building materials* 8, pp. 24 – 25.

Law on investment activity in the RSFSR 1488-1 /1991. Edited 26.07.2017. Retrieved 12 July 2020 from http://www.consultant.ru/document/cons_doc_LAW_89/

Lufski, K. (1982). *Waterproofing of building structures.* Moscow: Стройиздат.

Mangushev, R. & Osokin, A. (2010). Geotechnics of St. Petersburg. Moscow: Издательство Ассоциации Строительных Вузов.

Mangushev, R. (2000). Experience in waterproofing a basement in the Senate building in St. Petersburg. *Urban reconstruction and technical construction* 2/2000. Retrieved 2 August 2020 from http://georec.narod.ru/mag/2000n2/13/13.htm

Mangushev, R., Karlov, V., Sakharov, I. & Osokin, A. (2011). *Basements and foundations.* Moscow: Издательство Ассоциации Строительных Вузов.

Molodin, V. & Volkov, S. (2015). Organizational and technological design of the construction of residential buildings. Novosibirsk: NGASU (Sibstrin).

NatWorld. (2018). What climate is typical for Russia: arctic, subarctic, temperate and subtropical. Retrieved 25 July 2020 from https://natworld.info/raznoe-o-prirode/klimat-rossii-osobennosti-tipy-oblasti-zony-i-regiony

Nebritov, B. (2011). *Organizational and technological design in construction.* Moscow: University book.

Nykänen, P. (2009). *Kiinteistön ostaminen ja rakentaminen* Lappeenranta: Etelä-Karjalan Liitto.

Popchenko, S. (1981). *Waterproofing of structures and buildings.* St. Petersburg: Стройиздат.

Rybiev, I. (1991). *Waterproofing materials technology*. Moscow: Высшая школа.

Savilova, G. (2003). Waterproofing of buildings and structures with BIRSS materials. *Building materials* 7, pp. 32-34.

Set of Rules on insulation and finishing coatings 71.13330.2017. Updated edition of Construction Codes and Regulations 3.04.01-87 (with Amendment No. 1). Retrieved 12 July 2020 from http://docs.cntd.ru/document/456082588

Severoslavyanskoe Byuro Reklamy. (1999). Modern waterproofing materials. *Construction Review* 3 (30), pp. 23-32.

Velesark. Official website. (2009). Hydraulic concrete. Retrieved 8 August 2020 from: https://velesark.ru/beton/gidrotexnicheskij

Wikipedia. (Last edited 2020). Finland. Retrieved 26 July 2020 from https://ru.wikipedia.org/wiki/Финляндия

Wikipedia. (Last edited 2020). Geology of Finland. Retrieved 26 July 2020 from https://en.wikipedia.org/wiki/Geology_of_Finland

Appendix 1/1

Types of waterproofing by application method.

Types	Variations	Material	Technology	Advantages/ Disadvantages	Application area
1	2	3	4	5	6
PLASTER	Cement plaster	Hot or cold mastics and polymer-cement masses.	Cement plaster with a thickness of 8 - 10 mm, applied layer by layer in 2 - 3 batches w1ith cement-sand mortars (1: 1 or 1: 2), with the addition of mineral fillers or water repellents.	Excellent adhesion to various types of surfaces, resistance to aggressive environments / lack of elasticity.	Can be used both indoors and outdoors in swimming pools, ponds and ordinary bathrooms, on walls and floors.
	Asphalt plaster	Bitumen-based mastics.	A layer-by-layer (2-3 basting 2-4 mm) coating of hot or cold mastics, which is applied to a surface subject to hydrostatic pressure or moisture. The vertical waterproofing must be protected with a wall of concrete slabs, bricks or a layer of concrete plaster on a steel mesh - reinforcement. On a horizontal base, mastic is sprayed or poured, then levelled, making only 2 layers of 7 - 8 mm, and then protect it with a concrete or cement mortar screed.	Unlike cement plaster, has elasticity / requires protection, cannot be used in acid aggressive environment.	Insulation of concrete, reinforced-concrete, stone and brick structures, basement walls, tanks, pools.
	Cast asphalt plaster	Bitumen-based mortars.	Pouring hot mortar into the cavity between the insulated base (behind the formwork) and the protective wall (steel, brick or concrete). The asphalt composition is poured onto a horizontal surface and levelled with scrapers, and from above it is covered with a mortar or cement screed.	Faster and more efficient than mastics / requires special equipment and formwork for vertical insulation.	Insulation of floors and walls in wet areas, roofs.

Appendix 1/2

1	2	3	4	5	6
PAINTING (AS WELL AS BUTTING AND GAS FLAME SPRAYING)	Hot application (heating up to 170°C)	One-component or two-component elastic materials (two-component polyurethanes) Varnishes, paints, mixtures on bitumen or rubber base. Bituminous mastics with fillers (talc, asbestos, lime - fluff), rubber; acrylic; silicone; polyurethane and epoxy-polyurethane - high-tech paints and varnishes made of synthetic resins and plastics.	It involves coating with one-component or two-component elastic materials in several layers. Waterproof thin film formed by painting with plastic or liquid formulations. Multi-layer application (not less than two layers, after the previous layer has completely dried, with an interval of 1 - 16 hours), the thickness of each layer of bitumen is 2 mm, and of synthetic materials - up to 1 mm.	Seamless insulation with elastic properties, hot mastics has higher water and frost resistance than cold ones / low resistance to hydrostatic head.	Applied on concrete and reinforced concrete surfaces from the wetted side, to prevent capillary moisture.
	Cold application - slightly warmed up, works at an air temperature below +5°C)	Cold mastics, paints and varnishes made of epoxy, furyl, vinyl chloride and other synthetic resins.			

1	2	3	4	5	6
IMPREGNANT		Waterproofing mortar based on polymer varnishes or an astringent base made of bitumen, bituminous mastic and emulsion primer (primer) - a solution of petroleum bitumen.	The building material is impregnated using a special waterproofing solution (primer). Soften it in special organic solvents. The softening temperature of the bituminous primer exceeds 80 ° C.	Eliminate the need for external waterproo fing.	Inside reinforced concrete and other stone-like premises (asbestos cement, tuff, limestone), priming of surfaces of roll materials, saturation of concrete, reinforced concrete and brick surfaces and processing of metal surfaces.

1	2	3	4	5	6
LIQUID	**Filling membrane**	Liquid materials on bitumen, or rubber bases.	It is carried out by pouring into cracks, as well as for coating surfaces with liquid materials (see 3. material).	Environmentally friendly, do not pollute the environment. Significant reduction in work costs. High flexibility and elasticity - the coating is strong enough (withstands water pressure up to twenty-five atmospheres).	Use for both external and interior finishing works. Application in difficult points, such as seams and corners in the bathroom.
	Hot application	Hot asphalt mastics. They are based on foam epoxies, bitumen perlite and asphalt clay concrete.	Pouring is done in several layers on a horizontal surface, or the mixture is poured into the formwork.	1. Resistance to ultraviolet radiation. 2. The basis of the liquid material is water, there are no volatile organic and flammable elements. 3. The liquid layer lays down evenly and hardens almost instantly. Industrial waterproofing, expensive at cost.	

1	2	3	4	5	6
LIQUID	**Using liquid glass**	Liquid glass for waterproofing - potassium and sodium silicate solution.	Mortar is added to concrete	This can significantly improve performance indicators such as: Material hardness; Decrease in moisture absorption; Resistance to damage that is carried out mechanically.	Manufacturing of various types of concrete and cement, unique in their characteristics, improves the performance of plaster layers.
	Cold spray	Liquid rubber	The material applied by the cold spraying method hardens after a while, creating a durable protective layer.	Not worse than similar, but more expensive options. It retains its unique qualities of waterproofing and anti-corrosion for over 50 years. Resistance to aggressive environments, chemical influences, anti-slip and anti-corrosion qualities, high noise insulation. high rate of elasticity and flexibility; ease of application; environmental friendliness; excellent adhesion; ease of repair.	For the protection of foundations, basements, swimming pools, roofing works.
FILLING		Grainy, fibrous, powdery materials. Most effective one is perlite sand.	Material is placed on the surface to be treated or in a niche, then compacted.	Fast and not expensive / Can have a fairly large layer thickness, settles with time and requires repair.	Pipes, engineering networks, temporal waterproofing.

Appendix 1/5

1	2	3	4	5	6
LINING		Rot-resistant rolled and sheet materials, spike membrane. As glue - hot and cold mastics, bitumen or synthetic resins (do not use thinned or emulsion). On horizontal surfaces, bitumen-rubber mastics are replaced with bitumen. Ruberoid, tar paper, glassine are not suitable because of their cardboard base.	Glued in several layers, glue the panels, connecting them to each other along and across with an overlap of 100 mm. The joints of adjacent panels should not coincide, they are located at a distance of 300 mm from each other. The last layer is completely covered with hot bitumen mastic and protected with a brick, metal wall, and on the foundation such waterproofing can be strengthened by digging in with clay. On horizontal surfaces, the waterproofing is slightly brought onto the walls, thereby increasing the quality of protection.	Protects from cracks appearing on structure´s surface, crack resistant themselves / quite expensive, requires protective layer.	Foundations and roofs.

1	2	3	4	5	6
INJECTION METHOD		Furan and urea resins Acrylate, polyurethane, silicate resins, acrylate gels, special emulsions, cement or the latest water repellents.	Waterproofing material is pumped into holes specially made by gentle devices (without damaging neighbouring areas) under high pressure.	Expensive, it is used if simple plastering is not possible due to the inaccessibility of the site: for example, the foundation cannot be freed from the soil. The elasticity and reliability of such waterproofing is especially necessary in the so-called moving parts.	For covering inaccessible places, movement and cold joints, abutments, seams, pores, cracks. During repair work.

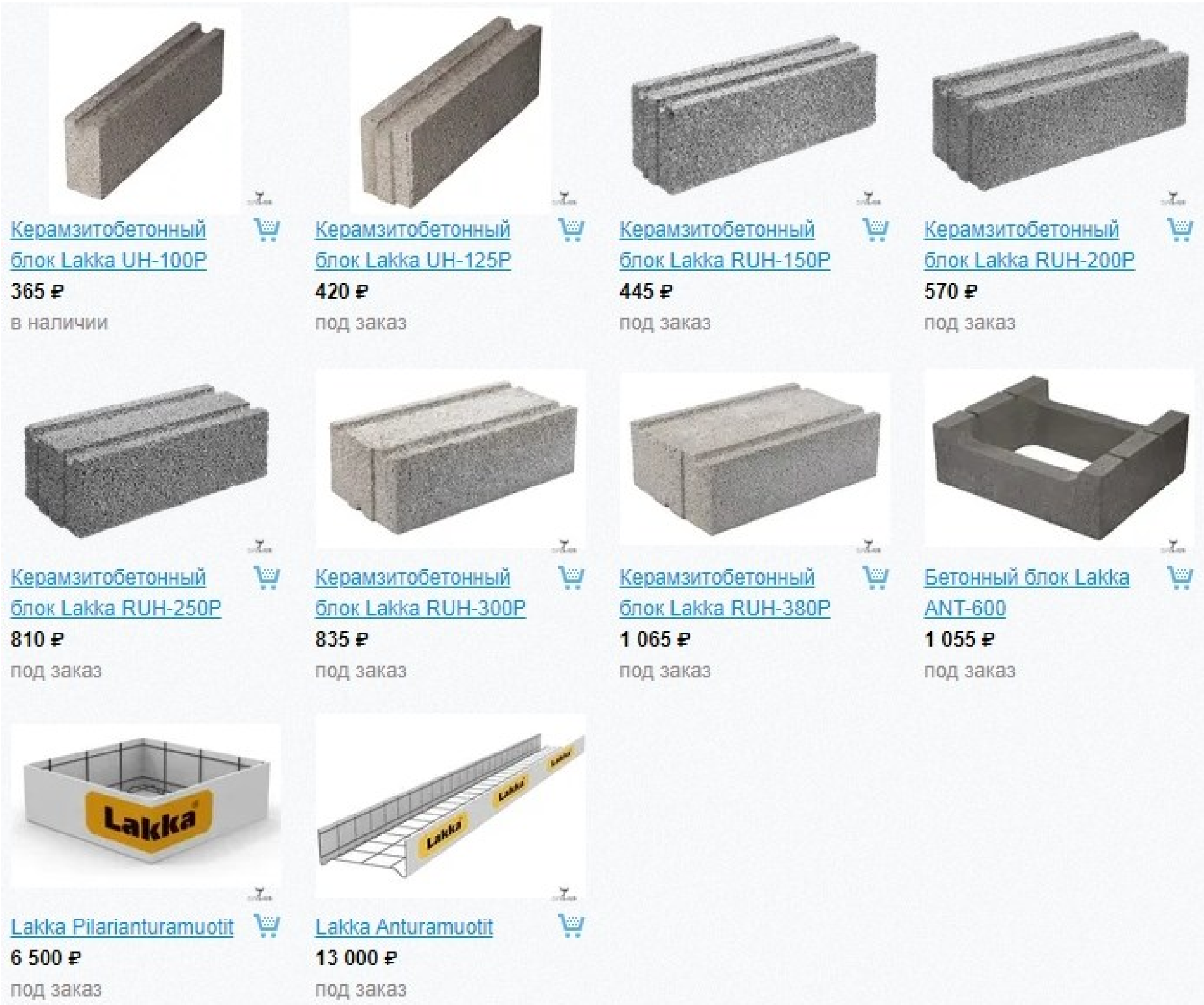
1	2	3	4	5	6
MOUNTABLE		Profile tape or special insulating elements made of fiberglass and polyvinyl chloride.	Glued to the surface, or pre-laid on the soil before the installation of structures.	Strong protection against high pressures and aggressive environments / expensive.	Used when other waterproofing methods are not enough.
PENETRATING		Mixtures based on cement and quartz sand with active additives in their composition.	Mixtures are applied to the surface, enter into a chemical reaction with the material. Provides good effect in the presence of moisture, which dissolves active additives. In this case, the dissolved mixture is absorbed into the pores and microcracks of the material and creates reliable protection against further water ingress.	The crystallized mixture not only blocks moisture, but also gives additional strength to concrete structures - the strength of concrete after it increases by 20%. Does not interfere with the movement of air, does not deteriorate from frost, does not require a primer, levelling the surface or its perfect dryness, it does not need protection with a wall, backfill, as well as the presence of metal reinforcement / Can be used only on crack resistant structures, monolithic, concrete strcutures.	Monolithic concrete and reinforced concrete structures in combination with a surface waterproofing.

Appendix 2

Price list for hydraulic concrete (Russia, St. Petersburg, VelesArk company).

Concrete grade	Price
B20 M250 П3 W8 F200	2890 rub/ m3
B22,5 M300 П3 W8 F200	2980 rub / m3
B25 M350 П3 W10 F200	3010 rub / m3
B30 M400 П3 W12 F300	3220 rub / m3

Price list for foundation blocks Lakan Betoni Oy
(Finland).



Note: the number of the block corresponds to its width, the height of all blocks is standard 195 mm.

Appendix 3

Technology of primary waterproofing. Compositions of waterproof concrete and plaster used in Russia.

Name	Manufacturer, supplier	Characteristic
Hydro SI – non-shrinking cement	Nizhegorodstroytekhtsentr (Nizhny Novgorod)	Portland cement with an expanding additive and superplasticizer for the production of waterproof plasters and concrete.
Hydro S II - dry mix	Nizhegorodstroytekhtsentr (Nizhny Novgorod)	Cement-sand mixture based on Hydro SI
BIRSS	Ao "Opytnyy Zavod Sukhikh Smesey" (Moscow)	Dry mix
Lakhta plaster	Rastro (St.Petersburg)	Dry mix
Concrete admixtures	Beton-Modifikator (St.Petersburg)	For waterproof, anti-freeze, etc.
Zokkelputz	Knauf (Germany); Тиги-Кнауф Маркетинг (St.Petersburg)	Basement plaster
Thoroseal PM	Thoro (Belgium)	Consumption 5-11 kg / m2
Addiment	Heidelberger Zement (Germany)	Additives for the manufacture of waterproof plasters and concrete
Remmers	Remmers (Germany)	Additives for the manufacture of waterproof plasters and concrete

Appendix 4/1

Secondary waterproofing technology. Basic materials used in Russia.

Name	Manufacturer, supplier	Characteristic
1	2	3
Cement coating waterproofing.		
BIRSS coating	Ao Opytnyy Zavod Sukhikh Smesey (Moscow, Russia)	Dry mixture
Лахта-coating	Rastro (St. P., Russia)	Adhesion to concrete 1.6 MPa
Барс	Нижегородстройтехцентр (N. Novgorod, Russia)	—
Aquafin-IK	Schomburg (Germany)	Waterproof up to 7 ATM
Thoroseal	Thoro (Belgium)	—
160	Imperpol (Belgium)	—
Y-cex BB 75	Vandex (Switzerland)	Consumption 3-6 kg / m2
Aiii Bauschlaemme	Remmers (Germany)	Consumption 4-6 kg / m2
Ceres: CR 65	Henkel (Germany)	—
Epasit ds	Epasit (Germany)	Adhesion to concrete 1.4 MPa
Waterproofing coating. Dry repair mixes.		
BIRSS repair	Ao Opytnyy Zavod Sukhikh Smesey (Moscow, Russia)	Dry mixture
Барс В 45	Нижегородстройтехцентр (N. Novgorod, Russia)	Strength 30 MPa after 3 hours
HD-25,50	Interakva (Moscow, Russia)	High strength after 1 hour, work at temperatures up to minus 12 C
Aida Vergussmoertel	Remmers (Germany)	
Structurite	Thoro (Belgium)	—
Ceresit CN 83	Henkel (Germany)	—
Vandex uni mortar	Vandex (Switzerland)	For repairs and coating waterproofing
Salt-absorbing (sanitizing) plasters.		
BIRSS C1, C2, C3	Ao Opytnyy Zavod Sukhikh Smesey (Moscow, Russia)	Renovation plaster system
Aisit Sanierputz	Remmers (Germany)	With light mineral filler
Ceresit CR 62, 63	Henkel (Germany)	Dry mixture
Ceresit CO 84	Henkel (Germany)	Liquid foaming additive for the production of porous renders for damp walls
Thermopal-CP22	Schomburg (Germany)	Dry mix. Lightweight filler - expanded polystyrene
Thermopal-P	Schomburg (Germany)	Powder additive for the manufacture of porous plasters. Consumption 2.5 kg / m3
Porogen system	Index (Italy)	Dry mixture
Epasit lpf- renovation plaster	Epasit (Germany)	Density 1.32 kg / dm, strength 3.9 MPa

Appendix4/2

1	2	3
Water plug technology.		
Лахта-water plug	Rastro (St. P., Russia)	Setting time 5 min
Акватрон-8	Полиэкс (Biysk, Russia)	Setting time from 30 s
Гидроплаг	Нижегородстройтехцентр (N. Novgorod, Russia)	Setting time a few minutes
Aida Rapidhaerter	Remmers (Germany)	
Epasit dsf- водяная пробка	Epasit (Germany)	For stopping leaks in concrete and other mineral structures
Ceresit CX 1	Henkel (Germany)	Stopping water inflows, pipe leaks. Setting time 50 s
Vandex plug	Vandex (Switzerland)	To eliminate leaks
Penetrating waterproofing. Penetrating materials.		
Лахта-penetrating	Rastro (St. P., Russia)	Increases the water resistance of concrete from W4 to W10
Гидро-тех	Нижегородстройтехцентр (N. Novgorod, Russia)	Penetrating material for concrete repair and waterproofing
Акватрон-6	Полиэкс (Россия,Бийск)	Adhesion to concrete 1.2 MPa
Гмдротэкс-В, -У	Спецгидрозащита (St. P., Russia)	—
Penetron	Penetron (USA)	—
Aquafin-IC	Schomburg (Germany)	Water resistant up to 1.5 ATM for tear off
Xypex	Xypex (Canada)	Consumption 0.8-1.0 kg / m2
IR PUR 250	Remmers (Germany)	For contact with drinking water
Vandex super	Vandex (Belgium)	Consumption 0.75-1.0 kg / m2
Membrane waterproofing. Polymer cement materials.		
BIRSS Гермоластик	Ao Opytnyy Zavod Sukhikh Smesey (Moscow, Russia)	Adhesion 2.2 MPa
Gydrolast	TEKS (St. P., Russia)	Water pressure for separation 3 ATM
Mapelastic	Mapei (Italy)	
Maxseal flex	Drizoro (Spain)	Consumption 2-3 kg / m2
Aquafin-2K	Schomburg (Germany)	Waterproof up to 7 ATM for clamping and 1 ATM for pull-off
Barralastik	Heidelberger Zement (Germany)	Water resistant up to 9 ATM for clamping and 4 ATM for pull-off
Epasitdsf/2k	Epasit (Germany)	Adhesion 0.88 MPa
AidaElastoschlaemme	Remmers (Germany)	Consumption 3.5-4.5 kg / m2
Ceresit CR 66	Henkel (Germany)	Consumption 4-5 kg / m2
Vandex BB 75 E	Vandex (Switzerland)	Consumption 3-5 kg / m
STA-DRI Masonry paint	STA-DRI (USA)	Consumption 0.5 kg / m2 with a tear-off water pressure of 5 ATM
Rauflex and Dorflex based on bitumen-latex emulsion	Ooo Innovatsionnyye Tekhnologii (Moscow, Russia)	The latest generation of bitumen-latex emulsion modification to obtain a membrane with high physical and mechanical characteristics

Appendix 4/3

A list of the main objects in the construction of which Rauflex and Dorflex materials were used		
— Alabyano-Baltic Tunnel (Moscow); — Baltic Pearl (St. Petersburg); — Konstantinovsky Palace (St. Petersburg); — Transport interchanges of the Ring Road (St. Petersburg); — Transport interchanges of objects of FKU Uprdor Severo-Zapad (St. Petersburg); — Metro of St. Petersburg, second lobby of the Sportivnaya station; — The building of the second stage of the State Mariinsky Theater (St. Petersburg).		
Protective coating of the reinforced and highly reinforced type - construction "Abris®"	LLC "Plant of sealing materials" (Russia)	Technology based on a mastic-polymer tape "Abris® S-T" in accordance with the requirements of GOST R 51164 -98 and a very reinforced type in accordance with GOST 9.602-2005 for waterproofing a mastic-polymer layer with increased frost resistance, with high resistance to aggressive environments, radiation, electromagnetic radiation, resistance to vibration and dynamic loads
The list of the main objects, during the construction of which the technology based on the mastic-polymer tape "Abris® S-T" was used		
— anti-corrosion protection of metal surfaces in various climatic zones of Russia using the Abris® technology on an area of more than 180 000 m2. — The materials were used at such facilities as Kalinin NPP, Rostov NPP, Novovoronezh NPP, Nyaganskaya SDPP, Krasnodar CHP, Cherepetskaya SDPP, main gas pipelines of OOO GAZPROM Transgaz Chaikovsky and OAO Krasnodargazstroy, OAO Belgorodoblgazburg, OAO Yekaterinburg underground drainage tanks for oil and petroleum products produced by OJSC Rosneftekomplekt and OJSC Orenburgneft, pipelines at OJSC Lukoil-Nizhegorodnefteorgsintez, Kurskaya CHPP, etc.		
Installed waterproofing. Drainage mats.		
Sheet drain	Interakva (Moscow, Russia)	Double-layer panels: tabbed sheet + geotextile
Megadrain 1230, 1240	«Polyfelt» (Австрия)	2x25 m / roll 30 kg
Installed waterproofing. Bentonite Materials.		
Bentomat,Voltex	CETCO (USA)	Waterproofing mats
NaBento	Huesker (Germany)	
Injection waterproofing. Injection resins.		
Injection waterproofing. Injection resins	company "ИНЖЕКТ" Minova Carbo-Tech GmbH (Joint production Germany-Russia)	Waterproofing restoration works are carried out from the inside, i.e. in the course of work it is not required to attract heavy equipment for the purpose of excavation
Compositions Kalmatron Additives Kalmatron-D	ГК КАЛЬМАТРОН (Russia)	Polyurethane resin. Penetrating compositions of the Kalmatron line.
The principle of action of the protective waterproofing composition Kalmatron is based on the interaction of its chemically active part with cement in the presence of water. Moreover, with cement, which is not only in the composition of Kalmatron, but also in the concrete structure.		

Appendix 4/4

The list of the main objects, during the construction of which Kalmatron materials were used		
— Restoration of reinforced concrete structures at Norilsk Nickel, Beloyarsk, Kalinin, Leningrad, Novovoronezh NPPs; — The complex of protective structures of St. Petersburg against floods; — Novosibirsk, St. Petersburg, Nizhny Novgorod, Moscow metro; — Treatment facilities in many regions of Russia and the near and far abroad; — Vilnius International Airport; — Zeyskaya, Boguchanskaya, Sayano-Shushenskaya hydroelectric power stations and many, many other objects.		
1	**2**	**3**
Тимпизол	Investevrostroy (Moscow, Russia)	One-component polyurethane resin
W-157	Interakva (Moscow, Russia)	Two-component polyurethane resin
Cut, Flex, Soil	De Neef (Belgium)	One-component polyurethane resin
Rofaplast 2K PUR Injektionsharz	Remmers (Germany)	Polyurethane resin for injection into concrete, ground
Epasit ikh/2k, ipu/2k	Epasit (Germany)	Epoxy and polyurethane two-component non-foaming resins
Carbo stop U (etc.)	Carbo Tech (Germany)	One-component flow stopping resin
Injection system. Seam seals.		
Waterproofing cord	Interakva (Moscow, Russia)	Swellable cord with bentonite or acrylic backing
Dowels Ватерстоп	Interakva (Moscow, Russia)	Rubber profiles for joints with deformations up to 20 mm at pressures up to 0.5 MPa
Hydrotite	Drizoro (Spain)	
Waterstop	CETCO (USA)	Bundle with a section of 15x25 mm with rubber-bentonite filling
Duroseal	Schomburg (Germany)	Swellable profile for construction joints
Tricosal	Schomburg (Germany)	Expansion joint profiles
Vandex expaseal	Vandex (Switzerland)	Swellable profile for construction joints
Swellseal	DeNeef (Belgium)	Swellable profile for construction joints
Impregnating coating and painting waterproofing Hot-applied bituminous materials.		
Bitumen mastic for roofing and insulation grades 1БК-Г-55, 65, 75, 85, 100	Manufactured by local manufacturers in accordance with GOST 15836-79 (Russia)	The numbers indicate the softening point
Bitumen-rubber mastic brands МБР-Г-55, 65, 75, 85,100	Manufactured in accordance with GOST 15836-79 (Russia)	With crumb rubber
Bitumen-rubber mastic МБР-Г-90	Rastro (St. Petersburg, Russia)	Softening point 95 degrees
Bituminous materials in organic solvent.		
Bituminous-rubber mastic with the addition of solvent gasoline, naphtha, etc.)	Manufactured by local manufacturers in accordance with GOST 15836-79 (Russia)	Pourable to pasty consistency is determined by solvent content
Mastic "Slavyanka"	Rastro (St. Petersburg, Russia)	Adhesion to concrete 0.5 MPa

Appendix 4/5

1	2	3
Waterproofing mastic МГ-1	Khimprodukt (St. Petersburg, Russia)	Polymer bitumen, inexpensive, ready to use
Magir	Норвест (St. Petersburg, Russia)	Light polymer waterproofing and suture mastic
Sulfiton Profi Baudicht	Remmers (Germany)	Rubber-bituminous mastic. Consumption 4-5.5 kg / m2
Materials based on aqueous emulsions.		
Силар	Ампир (St. Petersburg, Russia)	Water-based waterproofing rubber-bitumen mastic
Sulfiton Dickbeschichtung	Remmers (Germany)	Water-polymer bitumen dispersion. Consumption 4-5.5 kg / m2
Flachendicht	Knauf (Germany); Тиги-КнауфМаркетинг (Russia)	Water-polymer bitumen emulsion. Consumption 1.5-2.5 kg / m2
Papered waterproofing. Roll and flexible materials.		
Geomembranes	Ooo Plasteks (St. Petersburg, Russia)	Thick PE and PVC films
Hydroizol brand ГИ-Г	Manufactured by local manufacturers in accordance with GOST 7415-86 (Russia, St. Petersburg)	A bare material obtained by impregnating asbestos paper with petroleum bitumen. A roll 1 m wide and weighing 18 kg contains 20 m of waterproofing
Isol	Manufactured by local manufacturers in accordance with GOST 10296-79 (Russia, St. Petersburg)	Baseless rubber-bitumen material with a mass of 1 m2 2.4 kg withstands elongation up to 80% without breaking. It is produced in rolls with a web width of 1 m, length. 10 m, thickness d - 2 mm
Glass roofing material brand С-РМ	Manufactured by local manufacturers in accordance with GOST 15879-70 (Russia, St. Petersburg)	Roll material on fiberglass base and double-sided bitumen coating with a mass of 1 m2 2.1 kg
Новопласт, Изопласт	Izofleks (Kirishi, Leningrad Oblast, Russia)	Has a non-decaying base and polymer-bitumen coating, weight 1 m2 3-5.5 kg
Техноэласт, Унифлекс, Бикрост	Tekhnonikol’ (Vyborg, Russia)	Has a non-rotting base and polymer-bitumen coating, weight 1 m2 4-5.5 kg

Appendix 5

Complex building solutions from Lakan Betoni Oy.

Lakka®

1 Anturat

Lakka Anturamuoteilla teet anturat ilman laudoitus- ja purkutöitä. Näin säästät aikaa, materiaalia ja rahaa. Mallistossamme myös paaluantura- sekä pilarimuotit.

2 Runko

Rakennuksen runko perustuksista lähtien samalla ulkoseinäharkolla EMH-400 grafit.

* U-arvo 0,17 W/m2K.
* Hiottu mittatarkka kevytsorabetoniharkko.
* Onteloiden jälkivalu betonilla muodostaa hyvin kantavan ja tiiviin seinärakenteen.
* Kellarikerroksen maanpaineseiniin.
* Hyvin ääntä eristäviin seinärakenteisiin.
* Järjestelmään kuuluvat T-teräkset toimivat aukon ylityksissä kanta vana rakenteena ja valumuottina.
* Aukonylitysjärjestelmällä jopa 5 m leveät aukonylitykset.
* Soveltuu hyvin kosteisiin tiloihin, laatoitusalustaksi sekä painavien kalusteiden kiinnitysalustaksi.
* Kulmaharkko käännettävissä oikea- ja vasenkätiseksi.
* Saatavana myös 1/3- ja 2/3-osakiviparit.

3 Välipohjat

Ontelolaatalla saat kaksikerroksiseen taloosi hyvin askeläänteristävän, tukevan välipohjan. Ontelolaatat myös tuulettuviin alapohjiin. Ontelaatoissa valittavana kolmea eri paksuutta 175,200 ja 265 mm.

4 Yläpohjat

Lakka materiaalipakettiin saat halutessasi mukaan kattoristikot, yläpohjan puutavarat valitsemallenne vesikatteelle mm.ruoteet, tuuletusrimat, aluskatteet, höyrynsulut, sisäkaton koolaukset sekä sisäverhous levyt tai paneelit.

5 Vesikatto

Vesikatevaihtoehtoina voimme tarjota pelti- tiili tai huopaketteen toiveidenne mukaisesti.

6 Yläpohjan eristeet

Yläpohjan eristeiksi on valittavanasi puhallusvilla tai vaihtoehtoisesti levyvilla. Paksuus määritellään aina siten että yläpohjan energiamääräykset täyttyvät.

7 Levyeristeet

Voit halutessasi sisällyttää toimitukseen mukaan myös ala-, väli-, sekä yläpohjan eristelevyjä.

8 Tiivistystuotteet

Tiivistalotuoteperheen liitoskankaat ja teipit yläpohjan liitokseen, höyrynsulun limityksiin ja aukkoihin varnistavat,että talostasi tulee oikeaoppisesti tiivis.

9 Ikkunat ja ovet

Ikkunat ja ovet luotettavilta sekä tunnetuilta kotimaisilta valmistajilta.

Kivitalotoimitukseesi voimme tarjota mukaan myös hormit, sekä kiviportaat.

Lakka Kivitalorakentajana sinulla on käytettävissäsi kaikki yhteistyökumppaniemme rahanarvoiset edut. Saat myös pihakivet, tasoitteet ja julkisivupinnoitteet edullisin rakentajahinnoin suoraan tehtaaltamme.

Kysy lisää toimitussisällöistä ja eduista lähimmältä edustajaltasi.

Appendix 6/1

Practical application of new technologies and methods of waterproofing buildings and structures on the example of a specific building.

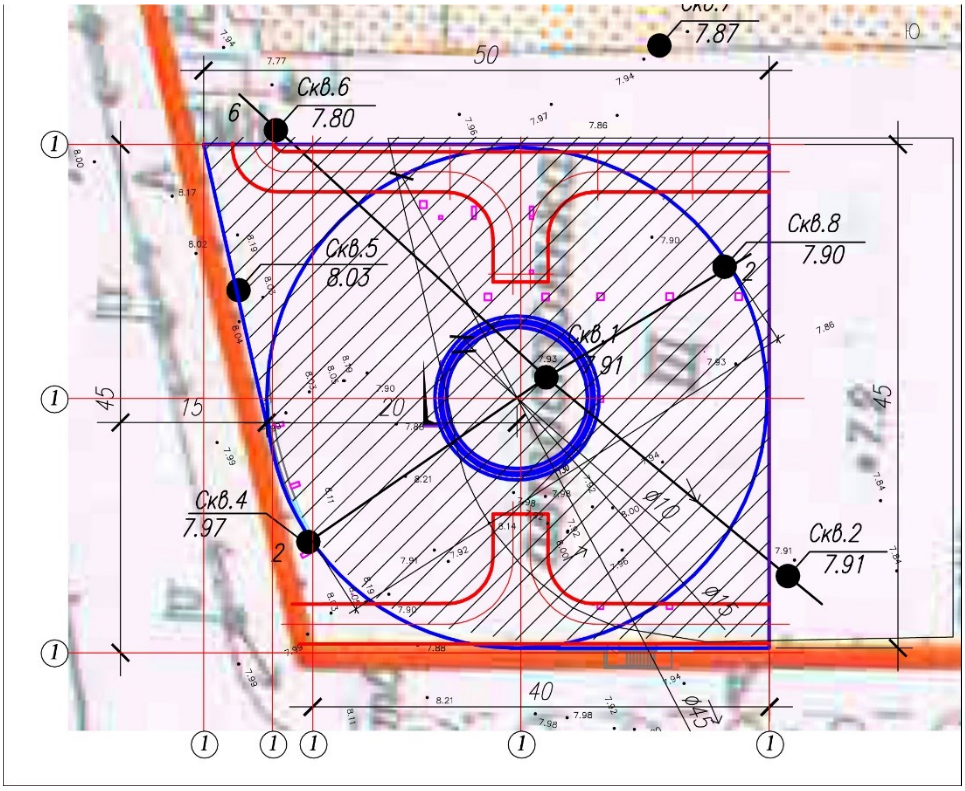


Figure 1. Layout of workings and engineering-geological sections relative to the geographic location of the site.

Appendix 6/2

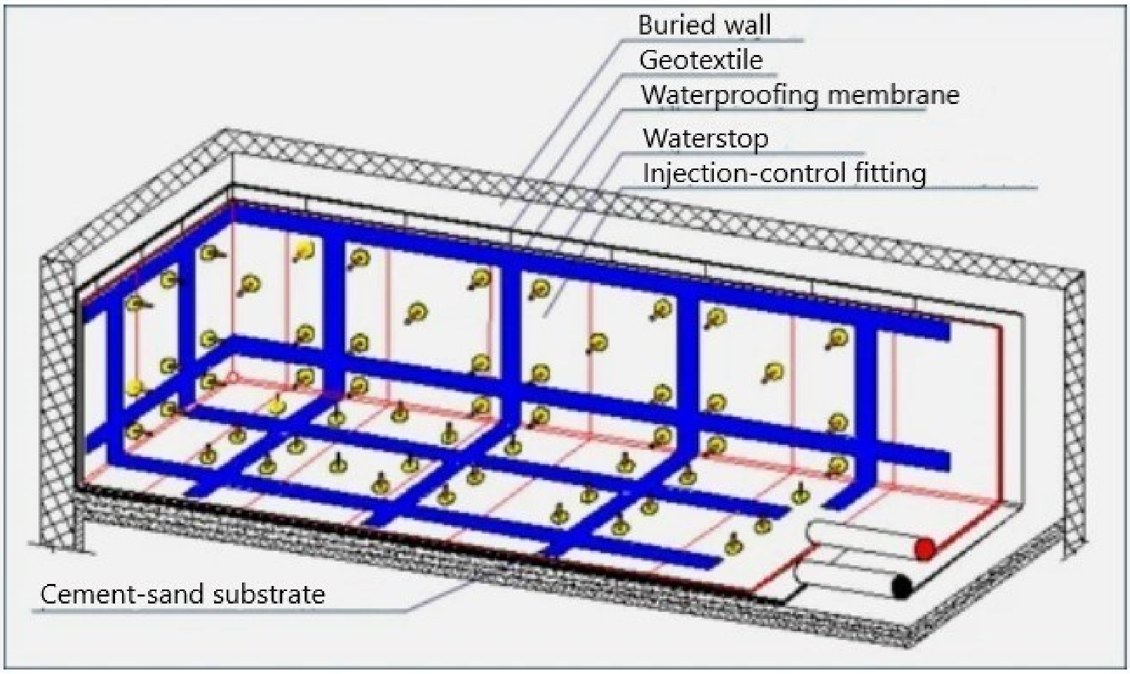


Figure 2. The scheme of waterproofing underground structures using the "buried wall" method.

Appendix 6/3

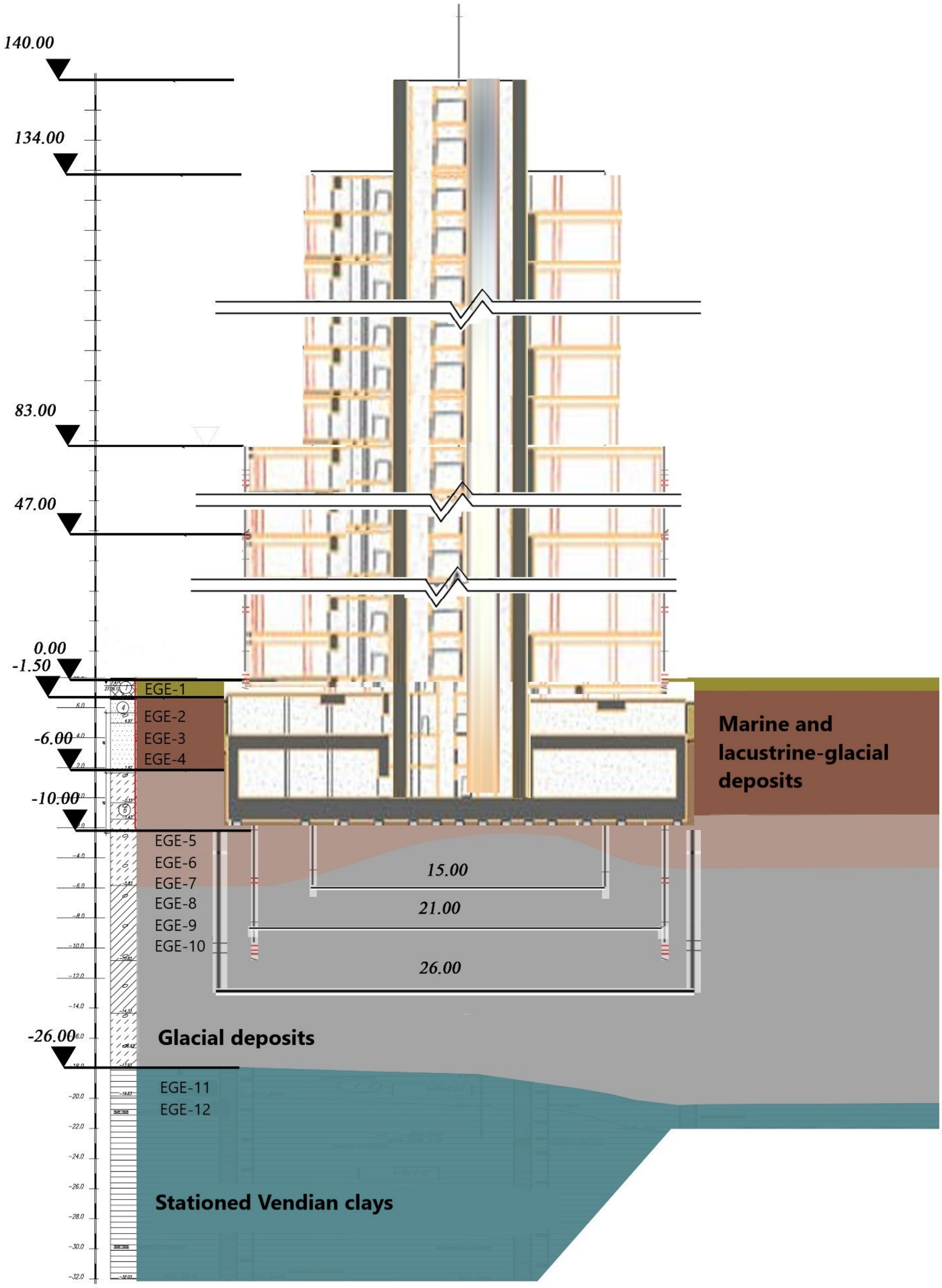


Figure 3. Scheme of the plan-height reference of the building at the construction site, section along the axis 3-3, section I-I.

Appendix 6/4

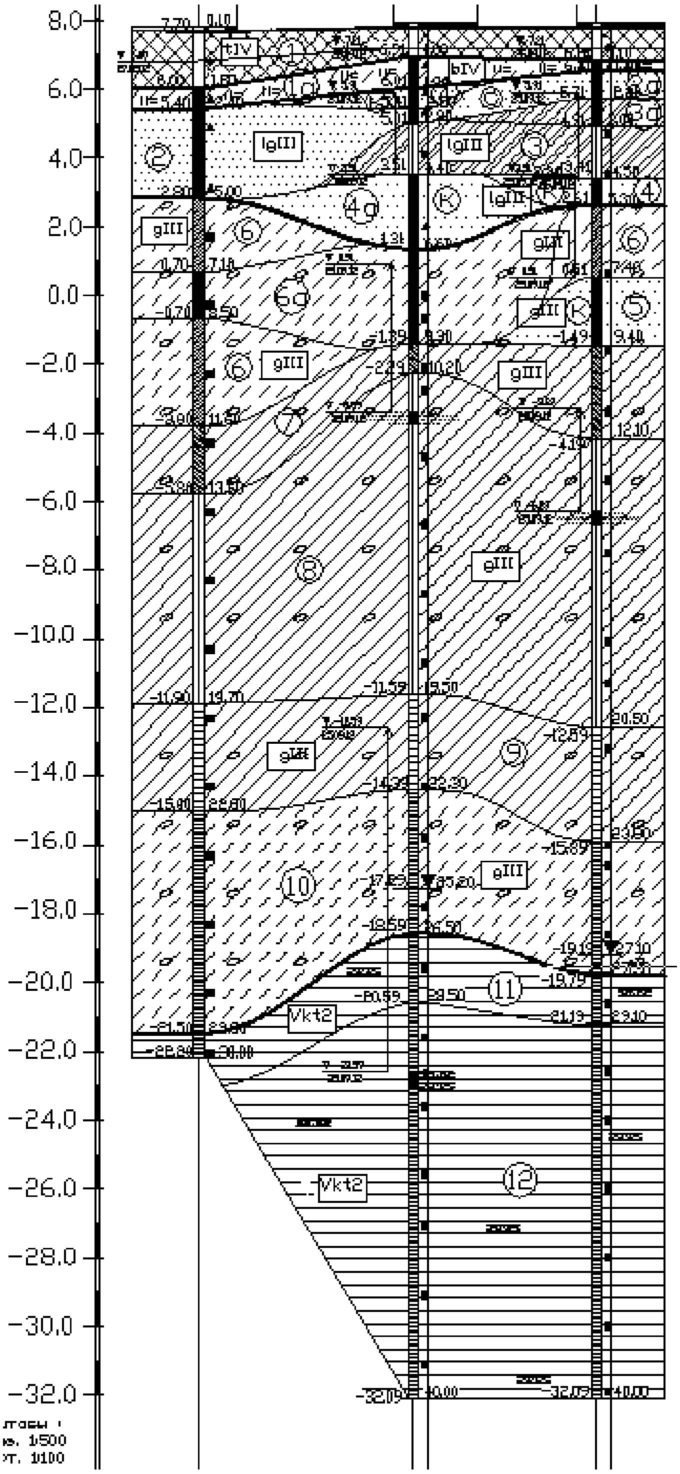


Figure 4. Engineering-geological section 6-6

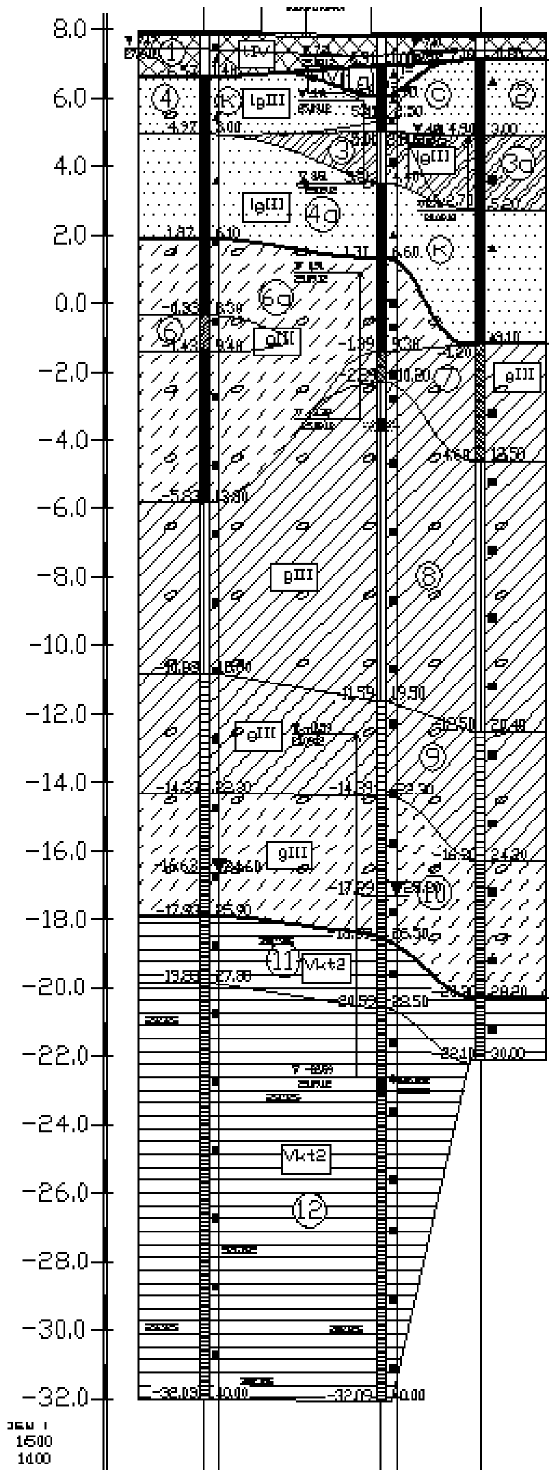
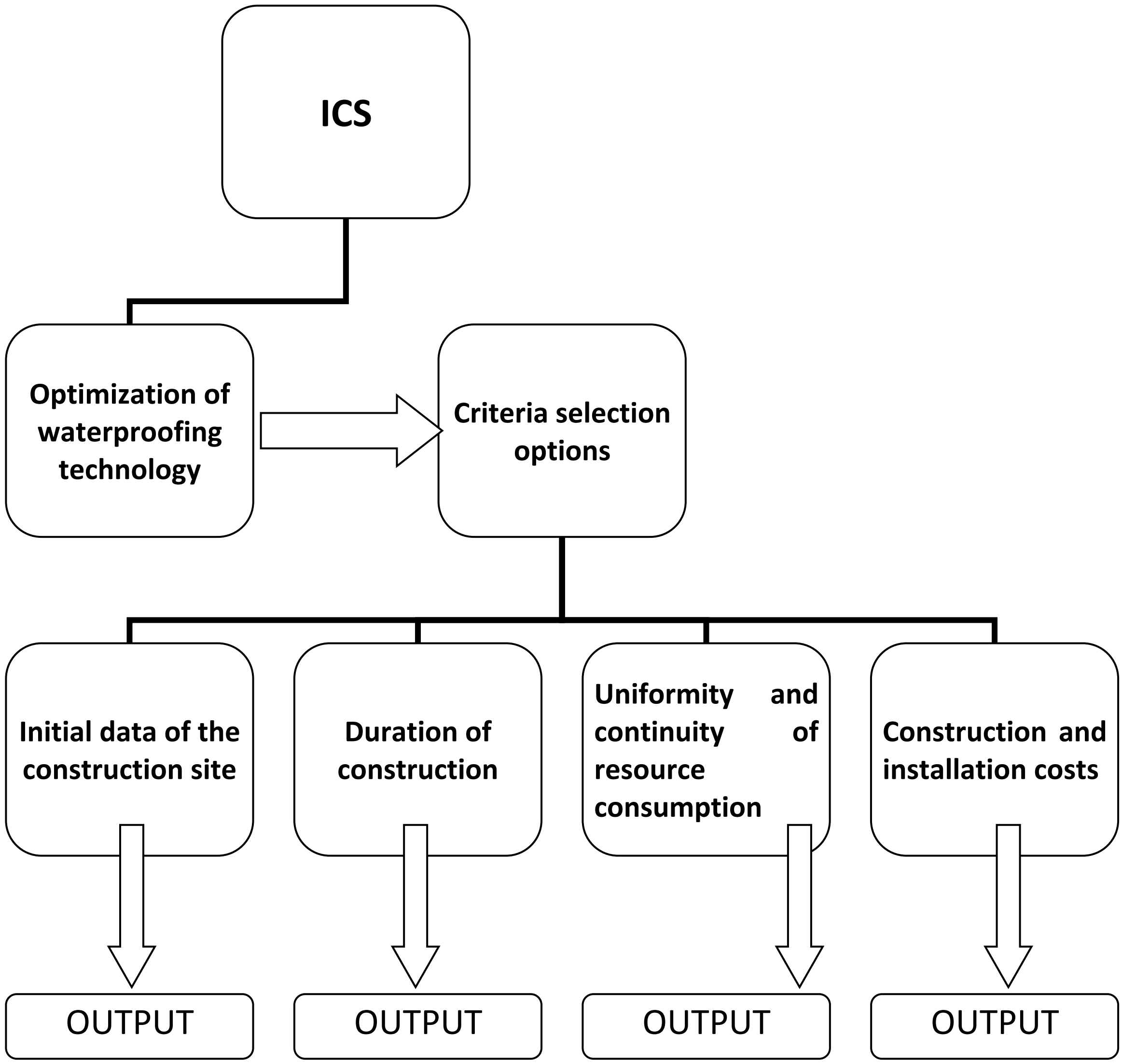


Figure 5. Engineering-geological section 2-2

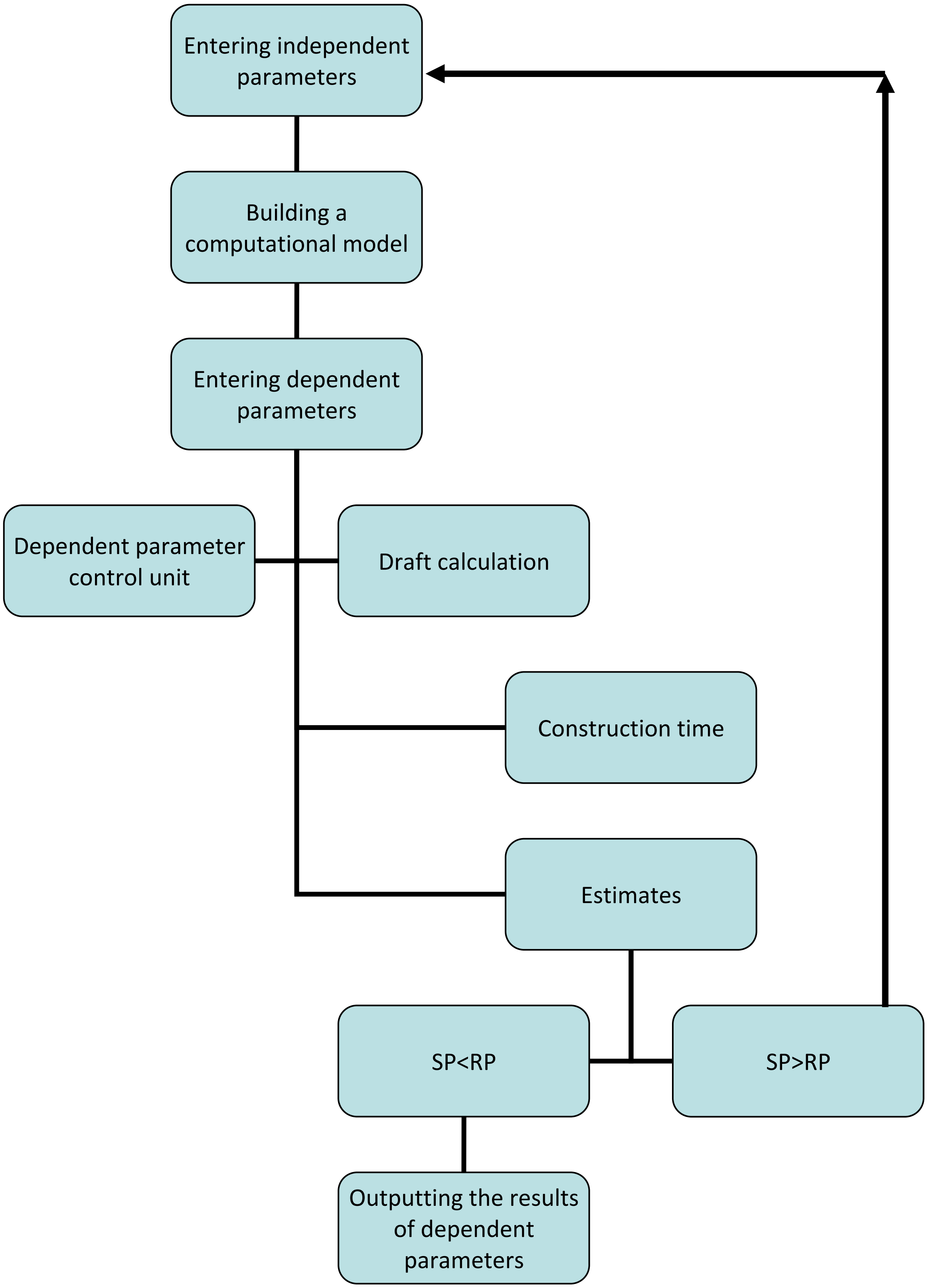
Appendix 7

ICS (Industrial Control System) design scheme



Appendix 8

Scheme "BIM-model with accepted optimization criteria"



Note: the following designations are introduced in the model: “SP” - sought parameter, “RP” – required parameter.

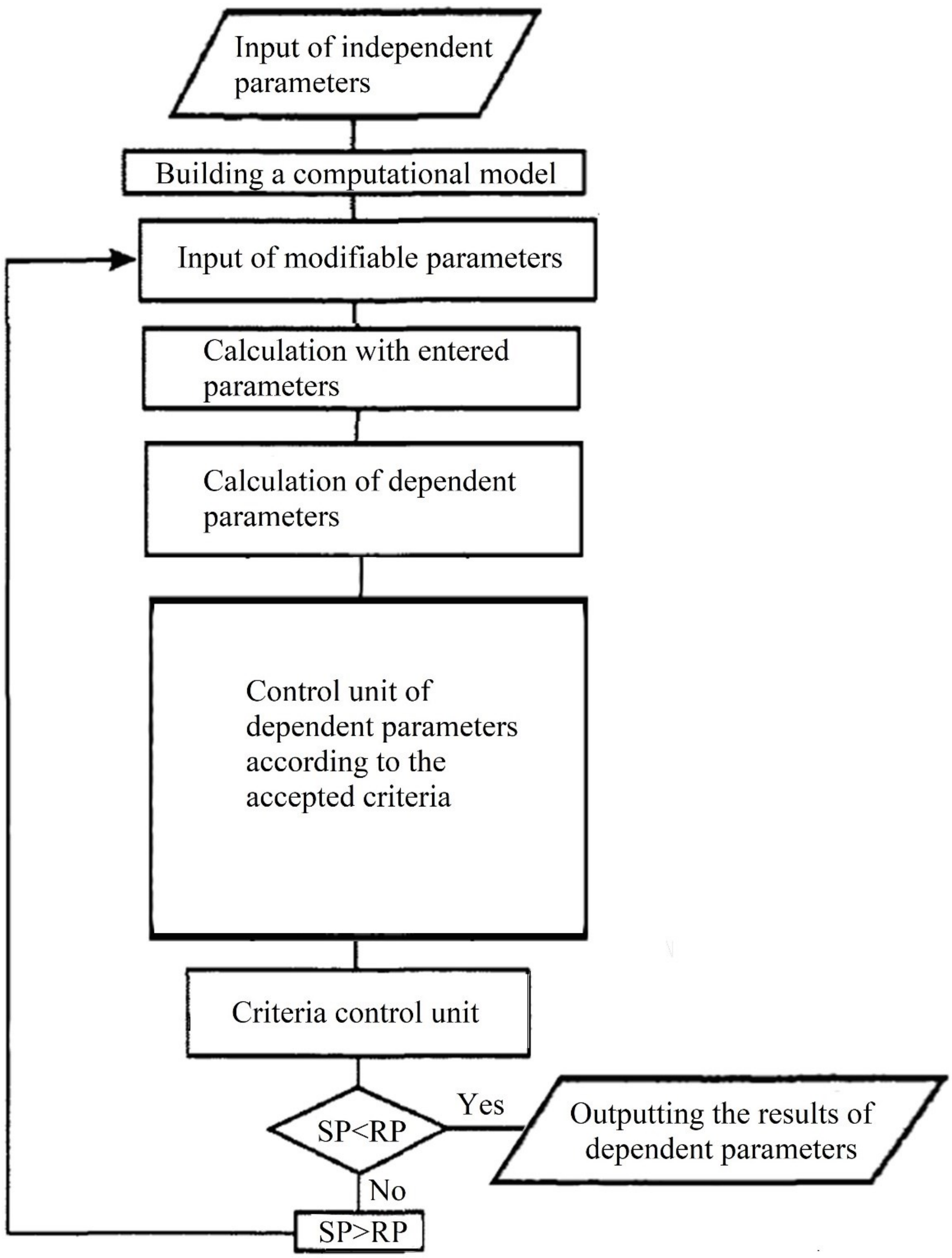
Appendix 9

Functions and elements of organizational and technological processes (OTP) for waterproofing.

№	**OTP functions**	**What the modelling is based on**
1	Preparation of information for the organization, planning and management of construction, determination of the procedure for the construction of facilities and their commissioning.	This information is based on the adopted architectural and design decisions.
2	Determination of the timing of construction and installation works, technological sequence of their implementation and combination (linkage).	Scheduling according to approved standards.
3	Determination of resources, including labor and material and technical.	Based on the volume of construction and installation work.
4.1	Development of models for the construction of buildings and structures.	Based on the adopted architectural and design solutions
4.2	Selection of a general organizational and technological scheme (OTS) of construction	In the construction management projects, a choice is made of the general OTS for the construction of buildings and structures as part of an enterprise or complex and the OTS for the construction of individual main buildings and structures that are part of them.
5	Selection of construction management methods and production technology	OTS for the construction of a separate building (structure) establishes the sequence of its construction in parts (nodes, sections, spans, cells, floors, tiers, production departments, workshops, etc.) depending on: - technological scheme of the production process or another functional diagram. - construction solutions. - accepted work methods.
6	Creation of an information base to provide construction with all the necessary resources.	

Appendix 10

A parametric model for monitoring organizational and technological reliability in construction based on BIM technologies



Note: the following designations are introduced in the model: “SP” - sought parameter, “RP” – required parameter.