Bentonite Grout Backfill Technology for Underground Structures

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Abstract. The article presents the basic methods of the most effective durable solution for the restoration of underground waterproofing of the structures in use, which are in impossible conditions for the application of outdoor protection. New types of resistance to aggressive environments of mineral waterproofing are considered, along with the technological scheme for the work. In addition, organizational methods have been developed for hydro protection of building structures. This technology can be applied from the basement of buildings in operation and be implemented at any time of the year. The proposed modern materials and technological solutions for the protection of underground structures of buildings were confirmed by the authors using an analysis carried out using the mathematical apparatus. Creating protection of premises against leaks from the mineral composition allows to increase the durability of the building itself, to ensure the normal operation of equipment and monitoring devices of the stations, as well as comfortable conditions for staff. Technological maps for the device of a new type of filling waterproofing have been developed, allowing to carry out and monitor all technological processes for operations.

1. Introduction

The buildings of the first and second capital groups have a fairly long service life of about 125-150 years. Waterproofing of underground parts of buildings and structures has a design service life that is much lower. Only now in the design and construction is there an opportunity to use materials with a service life of 40-50 years. Buildings built before 2006 that are operating in Moscow included 114,257 buildings, of which 39,648 are residential and 74,609 are non-residential. These buildings have a waterproofing of underground structures of bitumen and bitumen-polymer materials with a lifetime of 15-25 years. Therefore, the restoration of waterproofing is required for a huge number of buildings. If we take into account the damaging effects of changes in external impacts of a natural or man-made nature, then the number of these repairs might be even greater. Unreliable or missing waterproofing reduces the life of the building itself, so its restoration is an urgent task. In addition, the restoration of underground waterproofing is a rather complicated, costly and time-consuming process.

In this work we consider technological solutions for filling waterproofing in the form of powders. The aim of the work is to select the optimal technological solution for waterproofing underground critical structures with innovative materials with a maximum service life in various operating conditions.
The main leaks in underground structures of buildings arise in working cold joints, expansion joints, in moving and fixed joints, in through and non-through cracks, in communication aisles through the structure, at the junction of structural elements, [1-5].

To restore the underground waterproofing of walls and foundations from the basement, materials and technologies that are the most efficient and high-tech have been adopted. MGSU together with the company OOO «Colorful world» offers a new material, GSS N1 (STO SRO-P 60542948 00038-2015) and the technology of its application for the restoration and creation of reliable waterproofing of the underground supporting structures of buildings in operation, which is a very urgent task. The service life of the new waterproofing coincides with the service life of the supporting structures.

For use on critical structures, a special composition of the GSS N1 has the following physical and technical characteristics, which are shown in Table 1:

- inertness to aggressive media and non-polar fluids - does not react;
- frost resistance of the material during the operation of the structure - not less than 200 cycles;
- chemical resistance of the material to aggressive media (sulphate resistance, acid resistance) resistance in the pH range from 4 to 12;
- material resistance to groundwater flows - resistance to erosion by water flow at speeds up to 5 m/s, not subject to suffusion;
- the immutability of the physical and mechanical properties of the material, taking into account freezing and thawing;
- durability when using more than 100 years.

| Uniformity, number of inclusions | Bulk density, g/cm³ | The filtration coefficient, m/day |
|----------------------------------|---------------------|----------------------------------|
| No more than 2                   | 1.300-1.600         | No more than 5x10⁻⁵              |

2. Materials and methods

At the choice of the optimal waterproofing system, the main problem related to the search and comparison of various options according to the mathematical proof of the device of this system should be solved.

The basis for these authors of the technique was the logiko-probability (LPM) method proposed by English scientists [6–13] and which was constantly improved by mathematicians. Some researchers used this method in direct or indirect application to prove the effectiveness and estimate the value of standard blocks for transmitting information, for creating security to systems of any nature, for operational process control. As well as Russian scientists, Burkov V. N., Borkovskaya V. G., in the field of discrete optimization and project management, the theory of active systems, [14-17]. Ryabinin I.A. (Russian scientist) fullesty examined the logiko-probability method using examples of various systems, [18-19]. The authors have developed organizational and technological documentation that regulates the rules for performing technological processes, the choice of technological support (technological equipment, tools, inventory and accessories), machines, mechanisms and equipment, the necessary material and technical resources, requirements for quality and acceptance of work, as well as safety, health and environmental measures.

Before the waterproofing device, an inspection of the protected structure and the surrounding soil is carried out, as well as the preparation of the defect list. The main criteria for assessing damaged areas are the type, cause and size of defects as well as the condition, mobility and access to the damaged surface [15-24]. The dry mix is designed to create impervious screens in industrial and hydraulic
engineering construction and repair by the method of dry filling with sealing between the insulated surface and the pressure protective wall.

The waterproofing device using the GSS N1 is carried out in dry weather at an ambient temperature from +2 to +50 °C degrees. During cyclic defrosting and freezing of the soil, the mixture from the GSS N1 material does not change its properties. During the production of works, as well as during interruptions in the operation of the GSS N1, it is necessary to protect against adverse atmospheric influences (rain, snowfall) and mechanical damage by the shelter with foil, wooden boards, etc.;

The structure of the technological process includes the following integrated operations:
- surface preparation and retaining wall construction;
- backfill GSS N1;
- tamping;
- final work.

In the preparation of concrete surfaces (in accordance with the project documentation), the following work must be performed:
- correct defects of concrete surfaces and clean the surfaces with mechanical brushes;
- the filling of joints and holes in prefabricated structures with sealing materials and sealing of bolt holes should be carried out in accordance with the requirements of the design documentation;
- bags with GSS N1 are delivered to the place of laying manually or by means of lifting mechanisms and carts.

Vertical waterproofing using GSS N1. The need for materials is defined in Table 2.

| Appointment       | Main technical specifications                                      |
|-------------------|-------------------------------------------------------------------|
| GSS N1            | Consumption of waterproofing dry mix Depends on the presence of voids per 1 m², when forming a waterproofing layer 5-7 cm thick |
| Anchor            | Armature with a diameter of 20 long 150 mm 50 pieces             |
| Brick             | Ordinary clay GOST 530-95 1.500 m³                                |
| Cement-sand mortar| M 100 0.250 m³                                                   |
| Edging board      | Thickness = 20 mm, l = 800 m GOST 8486-86                         |

2.1 Vertical waterproofing

When constructing vertical waterproofing using GSS N1, the latter is placed in the cavity between the structure and formwork (protective screen) or brick, with layer-by-layer compaction with manual or mechanical tamping not less than 0.3 meters in order to avoid gaps inside the layer during the sediment. The compaction is made by hand using rammers weighing 3 kg. Construction of the pressure wall (protective screen) is made taking into account the formation of a waterproofing layer with a thickness of at least 5-7 cm. A retaining wall should be provided in accordance with 8.1 STO SRO-P 60542948 00038-2015 to protect the waterproofing layers of GSS N1 from the displacement of soils and other mechanical damage. The material for the device of the retaining wall is selected taking into account the bending moments. The filling of the GSS N1 is carried out simultaneously with the construction of the
pressure wall (protective screen) of brick with anchoring. The GSS N1 may not be from a height of more than 1 m relative to the horizontal surface or a previously compacted layer.

2.2 Horizontal waterproofing

Depending on the volume of waterproofing of the horizontal surface of the underground structure, the installation of the GSS N1 is done manually or in a mechanized way. On a concrete or other base cleared of debris, a layer of a dry mixture GSS N1 not less than 5-7 cm thick is scattered along guides in the form of wooden slats with a size of at least 50 × 50 mm, within this way, the laying area must exceed the area of the base for subsequent connection with waterproofing of walls or vertical surfaces. The joints of the vertical and horizontal layers are subject to particularly careful compaction. At the same time on top of the waterproofing layer must be protected by a cement screed. Cement screed serves as protection against mechanical stress during operation of the structure.

It is allowed to lay a dry mixture of GSS N1 on a wet surface, with a thickness of water layer less than 2 mm. When constructing a cement screed using solutions of pumps or silos with a mortar, the waterproofing layer must be temporarily protected from being washed by a stream of mortar with a sheet of plywood or metal measuring 1 × 1 meter. In order to eliminate cases of violation of the waterproofing layer in the course of the work, it is recommended that the mixture and screed be laid in strips 2-3 meters wide and passages between them 0.5 meters wide. It is forbidden to walk directly on the laid waterproofing layer. In the place of completion of the waterproofing and joint installation with the unprotected part of the structure, lay of bentonite measuring 7.5 cm.

Waterproofing surfaces are consistently on grabs, defined in the binding of the flow chart to the object, [25-30]. When performing waterproofing, surfaces are broken up into vertical or horizontal grippers, depending on the scaffolding used. When broken down into horizontal hooks, the alignment of links is carried out along the entire front of work within the limits of the hook, with each link occupying the next plot. The size of the plots is set according to the daily production of links.

Works on the device waterproofing requires the following composition of workers:

- waterproofing insulator (insulator) 4 digits (I4) 1 person;
- waterproofing insulator (insulator) 3 discharge (I3) 1 person
- waterproofing insulator (insulator) 2 level (I2) 1 person.

The link is an independent production cell, fully performing independently the work included in the technological process. Depending on the amount of work at the facility, several links can work simultaneously. Insulators that are part of the link should be able to independently perform all technological operations and be able to replace each other, as well as know the basic properties of the materials used, know the safe methods of work, be familiar with the requirements for the quality of the insulation coatings. Technological operations associated with the supply of material to the place of work, as well as unloading them from vehicles, carries out the link of workers of the following composition:

- Slinger of the 2nd category - 2 people (C2).

Work on the horizontal and vertical movement of materials in the areas of storage and production can also produce one or two maintenance workers of the 1st category - PR1. The installation and disassembly of the used scaffolding tools is performed by workers of relevant specialties, trained and certified in the prescribed manner. The design of technological trucks, scaffolding, etc. should provide free access to the place of work with manual and mechanized tools. The following composition of the links are recommended. The composition of the link must be clarified when associating a technological map, depending on the specific conditions of work, quality requirements, available staff and the availability of workers in related professions, [31-32].

Knot of application of GSS N1 for a waterproofing indoors shown in Figure 1.
Figure 1. Knot of application of GSS N1 for a waterproofing indoors, waterproofing indoors with the help of a frame clamping wall.

3 Results and Discussion
The result of this work is the work schedule of work at the installation of the waterproofing system GSS N1.

Table 3. Work schedule

| Type of work                                      | Unit of measure | Amount of works | Labour costs per unit of measurement (man-hours) | The cost of labour in the total amount of work, man-days (machine change) | Structure of crew |
|--------------------------------------------------|-----------------|-----------------|-----------------------------------------------|--------------------------------------------------------------------------|-------------------|
| Cleaning the concrete surface from the influxes   | m²              | 10              | 0.100                                        | 1,000                                                                     | insulation worker |
| Drilling holes D20mm length 100mm and installing an anchor | piece           | 50              | 0.090                                        | 4,500                                                                     | insulation worker |
| Installation of a protective wall made of bricks 0.5k thick with fastening with anchors | m³              | 1.5             | 6.200                                        | 9,000                                                                     | insulation worker |
| Backfilling and tamping GSS N1                   | kg              | 80              | 0.130                                        | 10,400                                                                    | insulation workers |
|                                                  | m²              | 10              | 6.410                                        | 24,900                                                                    |                   |
From the table it is clear that the duration of the work is 7 days, the labour intensity of the work is 24.9 man-hours (3.1 hours-day) and the output for 1 person-day is 0.4 m². The presented technological solutions for a new type of waterproofing from a mineral composition make it possible to carry out the control and work step by step through the smallest operations at each stage, which allows improving the quality and reliability of the hydraulic protection of structures.

4. Conclusions
In this article the most effective technological solution was developed to restore the underground waterproofing of the structures in operation. In addition, organizational methods have been developed for hydroprotection of building structures. Technological solutions are determined using multi-criteria optimization of feasible solutions. Creating protection against leakage of premises allows to increase the durability of the building itself, to ensure the normal operation of the equipment, as well as comfortable conditions for the staff.

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