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Construction of reservoirs using polymer-mineral materials N1 and PMM

Vache Tokmajan[1] (*orcid id: 0000-0001-8096-064X*)
Artur Vartanyan[2] (*orcid id: 0000-0002-6530-0675*)
Nver Mikayelyan[1] (*orcid id: 0000-0002-2536-501X*)
[1] Shushi Technological University
[2] MIREA – Russian Technological University

Abstract: This paper presents technological innovations based on new hydraulic insulating materials, the use of which in reservoir construction will essentially reduce construction costs by up to half. New polymer-mineral based waterproofing materials N1 and PMM can be used to construct inexpensive reservoirs. In particular, a thoroughly mixed mixture of soil taken from the bottom of a reservoir or other substrate with PMM material at a ratio of 30 grams PMM to one kg of the substrate, laid on the bottom of the reservoir with a thickness of at least 10 cm, and tamped down to a layer of 7 cm or less, will withstand at least 2.5-3 atm pressure of water column. A similar result can be obtained if a 5 cm thick layer of N1 material is laid on the reservoir bottom, together with pebbles to reduce the cost of the proposed solution.

Keywords: dam, waterproofing, basin, resistance, economic effect, construction, highlands, precipitation

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Introduction

Global fresh-surface water resources are unevenly distributed across the surface of the Earth. In some regions there is an excess of water resources, in others there is a constant lack. The economy is especially sensitive to seasonal fluctuations in the level of rivers. Water bodies are characterized by: significant seasonal fluctuations in the water level, which rises in spring and autumn, and decreases in winter and summer; colder water than in lakes due to the current; freezing of small reservoirs earlier than and larger reservoirs later than rivers; greater amounts of dissolved minerals in the reservoirs than found in rivers. To reduce the influence of reservoirs and to make rivers flow more evenly, networks of reservoirs are being created. Today there are about 30,000 reservoirs in the world, with a total water volume of 6,000 cubic kilometers. During economic activities, about 3500 cubic kilometers of water are used – equal to a tenth of the total annual runoff of all rivers. At the same time, an area totaling about 350,000 square kilometers was flooded with water. The reservoirs are used to meet drinking and communal needs, irrigation, fish farming, etc.

To preserve water storage, waterproofing work is carried out in reservoirs using various techniques and materials, of which the life of reservoirs depends. Economic entities spend significant financial resources to build reservoirs with the price of one cubic meter of water in an artificially created reservoir costing about three euros and often much more. Therefore, the construction of cheaper, and at the same time, high-quality reservoirs, as well as the efficient and optimal use of river water is a complex task that is difficult to solve without technological and managerial innovations.

The following materials are mainly used for waterproofing the bottom of reservoirs:

- **Polyethylene film,** currently the cheapest option. However, there are drawbacks – the material is short-lived, it does not tolerate ultraviolet radiation well and does not have good elasticity. It is used for the hydraulic insulation of small reservoirs, consists of a combination of polyethylene in synthesis with stabilizers, and can remain intact under water all the year round, as it withstands temperatures of +60 to –60°C. It has good stretching qualities due to the use of stabilizers, however, it does not have good elasticity. It also does not produce fumes, therefore, does not produce harmful additives to the water and does not cause harm to the environment. This material is stored in rolls. If the size of the film coating is not satisfactory, then several strips can be connected using a special welding technique. The arrangement of the reservoir consists of the following stages: the bottom of the excavated pit, where the reservoir will be located, is covered with a 15 cm layer of sand, a geotextile cloth is laid on top of the sand followed by a hydraulic insulating film, then everything is covered with geotextile and gravel.
- **Ready-made plastic forms**, which are buried like a bath in the ground and do not require additional work, except for the supply and descent of water masses.
- **A concreted reservoir** is one of the most expensive and difficult-to-implement options, but it is the most reliable. However, concrete material does not react well to temperature changes and cracks easily. The concrete base of the reservoir gives off elements that are not suitable for fish, therefore it is not recommended to use it immediately.

1. Formulation of the problem

It is necessary to develop a technology based on new waterproofing materials, the use of which in construction of reservoirs will significantly reduce construction costs. To this effect, the possibility of using waterproofing materials PMM and N1 is under consideration. The materials can also be used in agriculture (Tokmajyan et al., 2018), in the waterproofing of buildings and structures, preventing leaks in basements and flooding in tunnels, underground passages, in utility wells, conservation and arrangement of landfills for household waste, waterproofing in the nuclear, oil, or chemical industries and in road construction.

2. Research results

2.1. Technical characteristics of waterproofing polymer-mineral mixtures

Concentrates of PMM materials and N1 material mixed with soil make it possible to obtain a waterproofing mixture suitable for water-accumulating reservoirs, the bottom of which can withstand pressure of tens of atmospheres (Vartanyan et al., 2020b). Polymer-mineral material has been developed on the basis of bentonite powder, with a particle size of up to 1 mm, to which natural polymers have been added. The material has a unique ability to retain water, is characterized by multiple cyclicity, does not degrade under the influence of soil, biological and atmospheric factors, and is environmentally friendly and safe (Vartanyan et al., 2020a). Physical and technical characteristics of the material: inertness to aggressive media and non-polar liquids – does not enter into a reaction; frost resistance of the material during the operation of the structure of not less that 200 cycles; chemical resistance of the material to aggressive media; stability in the range of pH from 4 units to 12; material stability when laying on slopes 1: 3; resistance of the material to groundwater currents; resistance to erosion by water flow at a speed of up to 5 m/s, not subject to internal erosion; stability of physical and mechanical properties of the material in freezing and thawing; durability when used; resistance to frost heaving is in the range of indicators of sand and sandy loam.

The material has two varieties: N1 – for creating bulk waterproofing (dry backfill); N2 – for the preparation of waterproofing pastes. Consumption of material N1 is 70-75 kg of dry mix per 1 square meter, when forming a waterproofing layer of 5 cm thickness only from this material. Consumption of paste from material N2 is 20-27 kg per 1 square meter of surface in the absence of voids.

When using N1, a protective layer of cement lining with a thickness of at least 4 cm is provided, or – a layer of sand or soil at least 10 cm to protect against mechanical stress during the operation of the structure. With additional waterproofing of the joints of structures, the laying of the waterproofing mixture N1 is carried out along the surfaces of the structures.

The mixtures are stored in covered warehouses, protected from moisture, and transported by all types of transport in accordance with the established rules for transportation of cargo. Mixtures of N1 and N2 do not form toxic compounds in the air and wastewater, do not pollute the environment, and are environmentally friendly materials; they are used in the form of a dry construction mixture and are used as waterproofing in the construction of new structures. The base material under N1, for waterproofing underground structures, can be compacted soil, a concrete layer cleared from stones and construction debris, or crushed stone preparation.

With additional waterproofing of the joints of structures, the waterproofing mixture is laid along the surfaces of the structures. If necessary, on inclined surfaces, the N1 is reinforced with additional materials (for example, geogrids). When installing vertical waterproofing, a retaining wall must be provided. Waterproofing N1 layers are designed for the outer surface of the structure where there is water exposure and should be laid down at least 0.5 m higher than the maximum groundwater level. When the foundation is located in a zone of active water inflow, the need for a drainage device is determined. When N1 waterproofing is used, to protect against soil displacement and other mechanical damage, a retaining wall must be erected. The N2 material as a paste is used in reconstruction and overhaul that is injected behind the enclosing structures through holes drilled in the structures and restores the waterproof properties of the structures to the design values.

Before starting work on water tightness restoration and elimination of leaks using N2 in structures under construction or in operation, a survey of the structures is carried out to determine: the level of penetration of the insulated structure into the ground; the presence of possible voids; the actual depth of soil freezing. Particular attention should also be paid to the joints of reinforced concrete structures, waterproofing of bolted joints and holes for installing studs.

When installing vertical waterproofing of an underground structure the material N1 is laid in the cavity between the structure and the formwork with layer-by-layer compaction in height, not less than every 0.3 meter in order to avoid ruptures inside the layer during settlement, the compaction is carried out manually using rammers or mechanically using submersible vibrators. The erection of the protective screen is carried out taking into account the formation of a waterproofing layer with a thickness of at least 5-7 cm. Backfilling of N1 is carried out simultaneously with the construction of the pressure wall.

In places of intense leaks, holes are drilled (the number of holes and the pitch are determined from the parameters of the leak and the material of the structure) that go beyond the lining space of the structure. Discharge pipes are embedded in the holes, the outer diameter of which must correspond to the inner diameter of the mortar pump hose. The number of nozzles is 1-2 pieces per 1 square meter of the insulated surface, depending on the nature of the leaks. Drilling holes for sealing injection is carried out to the ground, with a depth of 1-15 cm, depending on leaks, watering area and type of structure. Sealing injection of the paste with N2 should be carried out until the voids are completely filled at an operating pressure of at least 0.5 MPa. Injection of the paste in defective areas should be done from the bottom up along the perimeter. Complete filling of voids through the injection nozzle is considered to be achieved when paste appears from adjacent nozzles. When eliminating single leaks, injection should be started through the central well in the place of the leak with pastes of increased concentration, which have less erosion, and proceed sequentially to injection through other wells with mortar of lower concentration and a more liquid consistency.

The injection should be done through injectors installed in the drilled holes and equipped with plug valves or check valves that ensure the sealing of the injection holes. The paste is pumped behind the enclosing structure of the facility until it emerges from the adjacent nozzles, further injection into this nozzle is stopped, then a flat plug is installed, and the hose of the mortar pump is connected to the adjacent nozzle. According to this scheme, the paste is pumped through all the nozzles.

After pumping the paste over the entire surface of the building envelope, a technological break of at least two days must be performed to absorb water. After that the surface is checked for leaks, additional injection is performed if necessary. When pumping for reinforced concrete and stone structures of underground structures, the pumping pressure is set depending on the engineering and geological conditions of the facility and the characteristics of the enclosing structures and should be at least 0.5 MPa.

Special attention is required for various seams, joints, mating of the insulated surfaces of the structure, places of passage of communications. After eliminating all defects and drawing up a report on completion of work, it is allowed to carry out waterproofing with other structural elements. The quality of waterproofing of structures with materials N1 and N2 is determined by the results of control assessments (external inspection, assessment of filling the construction gap and voids behind the structures, hydraulic testing of wells).

Waterproofing work at all stages is hidden, therefore, the completed work is accepted by stages, with drawing up appropriate reports, which determine the quality of the work performed and indicate the absence of defects. During the production of waterproofing work, it is necessary to accept areas of finished insulation that are to be closed, for example, with soil or screed coat.

Materials are produced according to TU 5745-012-01373565-09. They have a certificate of conformity and a hygienic certificate, they have the ability to withstand multiple cycles of swelling and drying, they do not collapse under the influence of soil, biological and atmospheric factors, they are environmentally friendly and safe. The supply of materials is made in paper bags and transported on pallets.

Waterproofing dry mixtures N1 and PMM, according to the degree of influence on the human body, are classified as low-hazardous substances, they are fire and explosion proof, have a sanitary-epidemiological conclusion, do not form toxic compounds in the air and wastewater, do not pollute the environment, are environmentally friendly materials, possess the ability to retain in their structure various microelements and fertilizers necessary for the development of plants and their dosage release together with the accumulated water.

PMM or N1 with a filler (gravel, pebbles, crushed stone, other inert material) creates a reliable and durable waterproofing layer that prevents uncontrolled water leaks from irrigation systems, as well as withstand pressure of tens of atmospheres. It is not washed out by the flow, is not disturbed by deformations of the surface of the water-conducting channel, and can withstand mechanical effects. It can be used to quickly and efficiently solve the problem of waterproofing canals, tunnels, underground structures, dams and reservoirs, drainage and sewerage systems, isolation during recycling and radioactive waste burial, conservation of objects, protective coating of underwater parts of reinforced concrete structures, and for the repair and elimination of leaks in structures (tunnels, bunkers, underground passages, tanks, storage facilities, basements, etc.). PMM is also effective for reducing soil filtration, which makes it possible to use it when growing crops in dry conditions (Vardanyan et al., 2020c).

PMM creates an impenetrable screen between the foundation and groundwater, which is important when creating: waterproofing of foundations and underground enclosing structures, waterproofing of technical water supply facilities (reservoirs – reactor coolers, reservoirs, pools, dams and others, waterproofing of ground structures: tailings, solid waste landfills, for the repair and elimination of leaks in existing engineering structures and structures (tunnels, bunkers, underground passages, tanks, storage facilities, basements, etc.).

N1 and N2 can be used in waterproofing constructive solutions for stone, concrete, reinforced concrete and metal structures. Examples of serious problems with leaks in waterproofing layers are in basements of buildings, in the subway, fountains, water reservoirs, in landfills, in tailing dumps of nuclear, oil, ore, gas and chemical enterprises.

It is more economically efficient to use a mixture of soil with PMM additives as a waterproofing material, which is thoroughly mixed before laying on the bottom of reservoirs and, after laying it in a 10 cm thick layer, is well rammed to a thickness of less than 7 cm. In particular, experiments on a laboratory installation showed that a thoroughly blended mixture of soil with PMM at a ratio of 20 to 1, laid in the installation and well rammed up to 7 cm, on the top and bottom of which was placed a 5 cm thick earth layer, and from above water was pumped under pressure. The load in the installation was added gradually; for a month, such a layer was kept under a pressure of 25 meters of water.

Thus, a compacted mixture of earth with PMM with a thickness of 7 cm can easily withstand a pressure of 2.5 atmospheres, both with a gradual increase in pressure, and with an abrupt one. Therefore, it can be used as a waterproofing material for the construction of inexpensive reservoirs of several thousand cubic meters with a depth of at least 15-20 meters.

Such a small test pond was made in the courtyard of the Research Institute of Mechanics of Moscow State University and is under test (the water level fluctuates due to rain and evaporation).

2.2. A man-made pool in Armenia with N1 waterproofing

In Armenia, in 2019, a pool was built in the form of an upturned truncated cone with a top circle diameter of about 12 m. At the bottom of the tamped pool, 5-6 cm thick sand was first laid and tamped again, then gravel 5 cm thick was poured on top, which was sprinkled with material N1 at a ratio of 30 kilograms per 1 m^2, and all rammed again, then covered by a 5 cm thick sand layer. On top of the layer was put a 10 cm thick layer of soil from a dug-out pit, and tamped down to protect it from mechanical processes (as a waterproofing layer a mixture of gravel and sand with

N1 material at a ratio 1: 1 was used). Water was gradually poured into the created basin, which did not pass through the waterproofing layer of N1 and sand with gravel (Fig. 1). Observations have been going on for two years now.

A reservoir constructed in this way is cheaper and more reliable than those in which other materials described above are used as waterproofing (Tokmajyan et al., 2020).

Fig. 1. Water-filled pool in Armenia (*own photo*)

2.3. Moscow State University pool where a mixture of PMM with soil was used

The use of PMM material makes construction of such pools even cheaper (Tokmajyan et al., 2020). A small pool using PMM was made in Moscow on the territory of Moscow State University (Fig. 2), into which water was filled and young fish were introduced into the pool. The small pool has the shape of an upturned truncated cone with a depth of about 140 cm and the top water surface diameter of about 6 meters. On the tamped bottom of the pool a 10 cm thick layer of soil and PMM material mixture was laid at a ratio of 3 to 100, which was tamped down to 7 cm, and another 7-10 cm of earth dug from the bottom of the pit was placed on top. Water was gradually poured into the pool over a period of 3 hours, and after a few days the fish was let free.

Fig. 2. Moscow State University pool where PMM was used (*own photo*)

Conclusion

1. New technology is presented for creating a waterproofing mixture from innovative materials N1 and PMM for reservoirs and irrigation canals, as well as their repairs.
2. Reservoir indicators: water level and volume, its physicochemical properties, evaporation volume, water flow and water inflow from rivers, or the amount of accumulated precipitation can be effectively determined using information monitoring and management systems.

Bibliography

Tokmajyan, V.H., Markosyan, A.Kh., Khalatyan, A.A. & Khachatryan, N.B. (2018) *The perspectives of providing the storage of irrigation water in the case of using water collecting additives in the ground*. Bulletin of High Technology, Shushi, 2(6), 9-14.

Tokmajyan, V.H., Vardanyan, A.A., Galstyan A.G. & Miqayelyan N.A. (2020) *The application of anti-filtering polymer mass to solve the water storage problem in highland regions*. Construction of Optimized Energy Potential, 9, 2, 17-22.

Vartanyan, A.A., Galstyan, S.B., Tokmajyan, H.V. & Gorshkova, N.E. (2020a) *The regulation of water regime of field crops and decorative woody plants in natural conditions by applying polymer-mineral raw material*. Bulletin of High Technology, Shushi, 1(11), 3-11.

Vartanyan, A.A., Shaknazarov, A.A. & Tokmajyan, V.H. (2020b) *Increase of soil moisture storage by applying polymer-mineral material*. Bulletin of High Technology, Shushi, 1(11), 12-19.

Vartanyan, A.A., Markosyan, M.V., Tokmajyan, V.H. & Galstyan, S.B. (2020c) *Management of processes of growing winter crop in rainfed conditions using innovative technological solutions*. Bulletin of High Technology, Shushi, 2(13), 3-13.