

Use of concrete mats to protect slopes of water bodies in urban areas

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Abstract. Plots of land located in close proximity to the boundaries of the water body within the city limits are used both for recreational purposes and participate in the creation of a favorable comfortable urban environment. Since the banks of water bodies are subject to change as a result of the influence of natural factors and human activity, the construction of a shore protection system is required to protect them. A study of the structural solutions of shoreline anchorages in urban areas showed that the use of concrete mats for these purposes is most appropriate. The analysis included a comparison of the strengths and weaknesses of the existing and considered design solutions of hydraulic structures included in the urban environment improvement complex. Considerable attention is also paid to assessing the qualitative and quantitative volume of contaminants entering the water body during the construction of a shore-protecting hydraulic structure. In order to solve this problem, laboratory studies were performed simulating the process of concreting mats. The studies shows that concrete mats are a “clean coastal protection technology” compared to traditional technical solutions.

1. Introduction

Cities and settlements historically develop on the banks of water bodies: rivers, reservoirs, lakes, ponds, etc. In modern urban construction, open spaces formed by water bodies and green spaces are of the greatest importance in the formation of the landscape (Figure 1). In this regard, coastal territories are the most valuable for use in urban planning purposes. In addition to the aesthetic and functional features of the urban environment, water bodies also have sanitary and hygienic significance, improving the microclimatic conditions of urbanized areas. Work on the arrangement of the coastal, coastal strip and water protection zone within the city limits is being actively carried out in our country as part of the priority federal project “Formation of a comfortable urban environment” (from 2019 to 2024), providing for the integrated use and development of territories near water bodies [1].

At the same time, along with a positive impact on urban areas, water bodies have negative effects. So the shores of water bodies are subject to transformation, the causes of which can be currents, level fluctuations, wind waves, ice impacts and other causes of a natural and technogenic nature.

The protection of the coast of water bodies from collapse is provided by a system of shore-strengthening hydraulic structures. The choice of bank protection type should take into account the functional, structural, engineering and architectural features of the structure. Bank protection should prevent the destruction of the coastline, and, therefore, ensure the safety of objects and form species compositions located in the coastal zone [2].



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The analysis of the structural solutions of shoreline fastenings in urban areas showed that stone fastening, reinforced concrete slabs, gabion structures and geosynthetic materials were widespread; in the future we consider these structures as traditional.

In addition to advantages such as the availability of building materials, manufacturability, these structures have several disadvantages that limit their use for securing the coastal strip, including design restrictions on ice and wave effects for gabions and geosynthetic materials, size, and frost resistance of the delivered stone for stone fastening and its absence at the construction site, the impossibility of mounting devices in the underwater part for concrete slabs. In addition, during the construction process, water bodies have a significant negative impact due to pollutants entering the water body. Basically, in the process of constructing shore protection structures, suspended solids enter water bodies and streams, which harm water and biological resources. So, in the framework of the project [6, 8] when pouring rock mass into water, the concentration of suspended particles of substances was estimated at 833 g/m^3 , in [7] for concrete slabs – 45 g/m^3 and for gabion structures – 121 g/m^3 .



Figure 1. Example of urbanized areas on the banks of water bodies: a – Master Plan Revealed for Binhai Eco City in Tianjin; b – project “Development of the embankment of the river”, Znamenki, Kazan

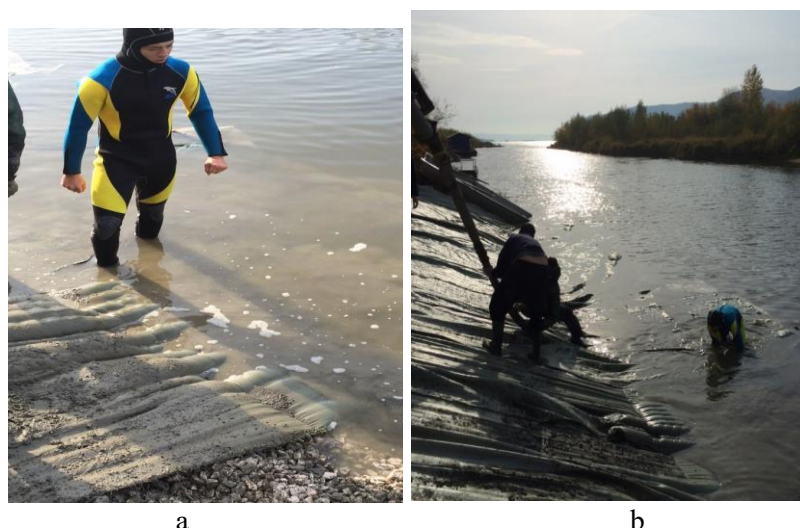


Figure 2. Filling concrete mats at the experimental site in the Salt "Builder" p. Volzhsky, Samara region.

In order to reduce the negative impact of shore protection while maintaining reliability requirements, we recommend the use of concrete mats. Concrete mats have a unique design,

namely: two interconnected high-strength woven webs form a formwork into which concrete mixture is fed, with the possibility of forming concrete slabs with a thickness of 5 to 60 cm. This design allows erecting shore protection structures under water without erecting temporary jumpers, similarly structures made of stone materials, concrete blocks or gabion structures, while the performance of laying concrete mats can reach 100 m²/hour, which leads to cheaper construction of shore protection. [3] In the process of creating a pilot block for the study of concrete mats of the Incomat Flex type (Figure 2) during field observations, it was recorded that "cement milk" penetrates through the woven fabric during concrete filling. The authors could not find data on the nature, quality and quantity of contaminants entering the water when fastening the shores with concrete mats.

2. Materials and methods

The study of the quality and quantity of contaminants entering the water when fastening the shores with concrete mats was planned to be carried out in laboratory conditions. For this, a laboratory setup was created (Figure 3).

The installation is a polyethylene pipe, on the lower end of which is attached a synthetic textile fabric of a concrete mat, clamped into a clamp. Synthetic textile fabric is a square 300×300 mm in size from a roll of Incomat Flex material. According to the manufacturer, the fabric has the following characteristics: raw materials – polyamide and polyethylene threads; maximum tensile strength – 45 kN/m; elongation at break – less than 20%; pore size O_{90} – 250 microns; water permeability – 20 l/m²/s.

The pipe section with the textile fixed on it is placed in a control tank filled with water. In the control tank, a graduated cylinder is installed directly within the end of the pipe.

During the experiment, the concrete mixture is fed into the pipe and pressure is created simulating the injection of the mixture into the concrete mat. In the process of experiment, the following actions are performed:

- fixed the time of receipt of "cement milk" in the control tank;
- the time of maximum saturation of the control capacity with "cement milk" is determined;
- sampling is performed during maximum saturation.

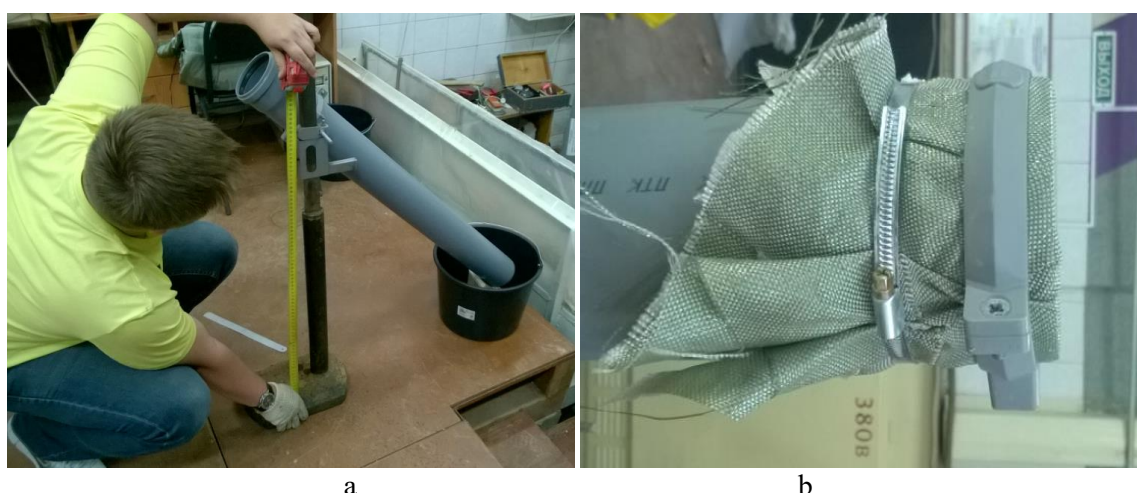


Figure 3. Experimental model for determining the pollution of the aquatic environment after concreting concrete mats: a – a fixed pipe to a tripod; b – Fixed synthetic textile concrete mat with a clamp.

For the experiment we used concrete grade B 25 with a fine aggregate with a fraction of not more than 10 mm and a water–cement ratio of 0.50 [5].

Water from a measuring cup was poured into an empty bottle, closed with a lid and marked. The

selected samples are given within one day to the laboratory for chemical analysis. Work on the analysis of substances was carried out according to standard methods.

The arrival time of "cement milk" was recorded visually using a stopwatch until the textile pores were clogged. The time of maximum saturation of the control tank with "cement milk" was also recorded visually using a stopwatch until the water in the control tank was clarified and particles precipitated.

3. Results

During the course of the experiment, the desired duration of receipt of "cement milk" was determined (Table 1).

Table 1. Experiment timelines

Experience	Concrete thickness in the pipe, cm	Concrete laying, sec	Duration of maximum saturation for sampling, sec	Duration of receipt of "cement milk" in the control tank, sec
1–4	10	120	19	126
5–8	20	204	20	517

The results of chemical analysis of water samples are presented in Table 2.

Table 2. The results of chemical analysis of water sample Experiment

Name of component (indicator)	Units	Test results			SanPiN 2.1.4. 1074–01 requirements	SanPiN 2.1.5.980–00 requirements
		Background	Experience 1–4	Experience 5–8		
Hydrogen indicator	units pH	7.36	9.97	10.44	6–9	6.5–8.5
Dry residue	mg / dm ³	304.00	348.00	372.00	1000.0	–
Chlorides	mg / dm ³	39.78	57.86	57.86	350.0	350.0
Sulphates	mg / dm ³	86.85	107.43	116.89	500.0	500.0
Total hardness	mEq / dm ³	3.80	3.80	3.70	7.0	–
Calcium	mEq / dm ³	2.80	3.00	3.00	–	–
Smell	point	1.00	–	–	2.0	2.0
Suspended matter	mg / dm ³	2.00	254.00	470.00	–	At ≥ 30 mg/dm ³ , an increase of 5% is allowed
Silicic acid	mg / dm ³	9.70	9.90	9.90	–	–

4. Conclusion

Based on the results of the study, the following conclusions can be drawn:

1. The duration of the suspension of suspended solids into a water body during the concreting of mats depends on the parameters and the intensity of cement clogging the pores of the fabric, so the maximum flow is observed within 19–20 seconds from the moment of concreting;

2. The duration of contaminants and their volume depends on the thickness of the mat. Thus, with the increase in thickness from 10 to 20 cm, the duration increased four times, while the incoming volume of pollutants doubled.
3. Among the pollutants entering the water body, it is possible to distinguish suspended substances, which amounted to 254–470 mg/dm³. Moreover, an increase in silicic acid occurred by 2%. The values of the hydrogen index changed, it increased 1.41 times.
4. Comparing the indications of pollutants entering the water body with the requirements of regulatory documents [9, 10]. We can conclude that the fastening device using concrete mats has an acceptable impact on the environment during the construction process and can be called “clean coastal strip protection technology”.
5. Comparison of the concentration indicators of suspended particles of substances of various coastal protection technologies, it can be concluded that the use of concrete mats will reduce the flow of pollutants into water bodies by 257 times compared to laying gabion structures and 1735 times with a stone draft.

Acknowledgments

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