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# APPLICATION OF SOIL-FILLED BLOCKS IN SOLVING PROBLEMS OF SHORE PROTECTION

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The authors discuss the possibility of using combined structures consisting of blocks filled with crushed stone in hydraulic engineering construction. Tasks are set and problems of using soil-filled blocks as part of bank protection structures are identified. Then, calculations are given, and the construction of the structural elements of a slipway in Narva Bay, Primorsky Kray, is illustrated.

**Keywords:** soil-filled blocks; shore protection; numerical modeling.

A current area of research in the field of hydraulic engineering is the justification and determination of the scope of application of new design solutions for hydraulic structures, including solving problems of bank protection. Currently, a significant impetus to development in related areas of construction (e.g., transport, industrial, and civil) is being received by rapidly erected combined structures consisting of thin-walled blocks such as hollow shells and boxes made of durable material (reinforced concrete) and filled with soil (crushed stone) [1]. For example, retaining structures made of box-type hollow blocks filled with crushed stone have been used since the early 2000s in the construction of transport and urban engineering infrastructure. The concept of such a solution with the subsequent development of structures was first adopted in Japan [2].

The structures in question are made from separate hollow blocks. These blocks are filled with soil (crushed stone) and installed on top of each other in steps (usually offset toward the slope). They are not fastened to each other, and the joint work of the rows of blocks is ensured by frictional forces due to the dense placement of crushed stone inside each of the blocks. Blocks can be of different designs. These are reinforced concrete hollow shells of complex shapes. The most popular are Japanese blocks from Aizawa Koetsu and blocks made in the USA by Stone Strong Systems. For filling (backfill), soils with high internal shear resistance should be used. In most cases, crushed stones are used.

Currently, Russian construction companies have established their own production of structures with similar functionality. These structures are a system of thin-walled reinforced box-type concrete blocks filled with crushed stone (KBP type, Fig. 1) with dimensions (m) of 2 × 1.25 × 1 (h), installed on top of each other with an offset toward the retained soil [4].

According to the classification of retaining structures based on the involvement of the surrounding soil in ensuring structure stability [3], such walls are semigravity combined building structures in which the filler material functions together with the blocks (shells) holding it in the design position. Soil as a filler participates in ensuring the structure's overall stability and can be considered an integral part of the retaining wall structure. Meanwhile, soil is also a load that creates internal pressure on the walls of closed block structures.

The designs under consideration have important advantages. The main advantages are as follows:
— quick installation and dismantling;
— absence of "wet" processes during construction;
— aesthetics;
— design flexibility; and
— relatively high resistance to dynamic loads.

The blocks are installed on a prepared base in rows in a stepped manner. The size of the indents varies from 0.25 to 0.5 m from row to row and is determined through calculation (Fig. 2*a*).

With proper justification, box-type blocks filled with crushed stone can be used for the needs of hydraulic engineering construction. With their help, small embankments,

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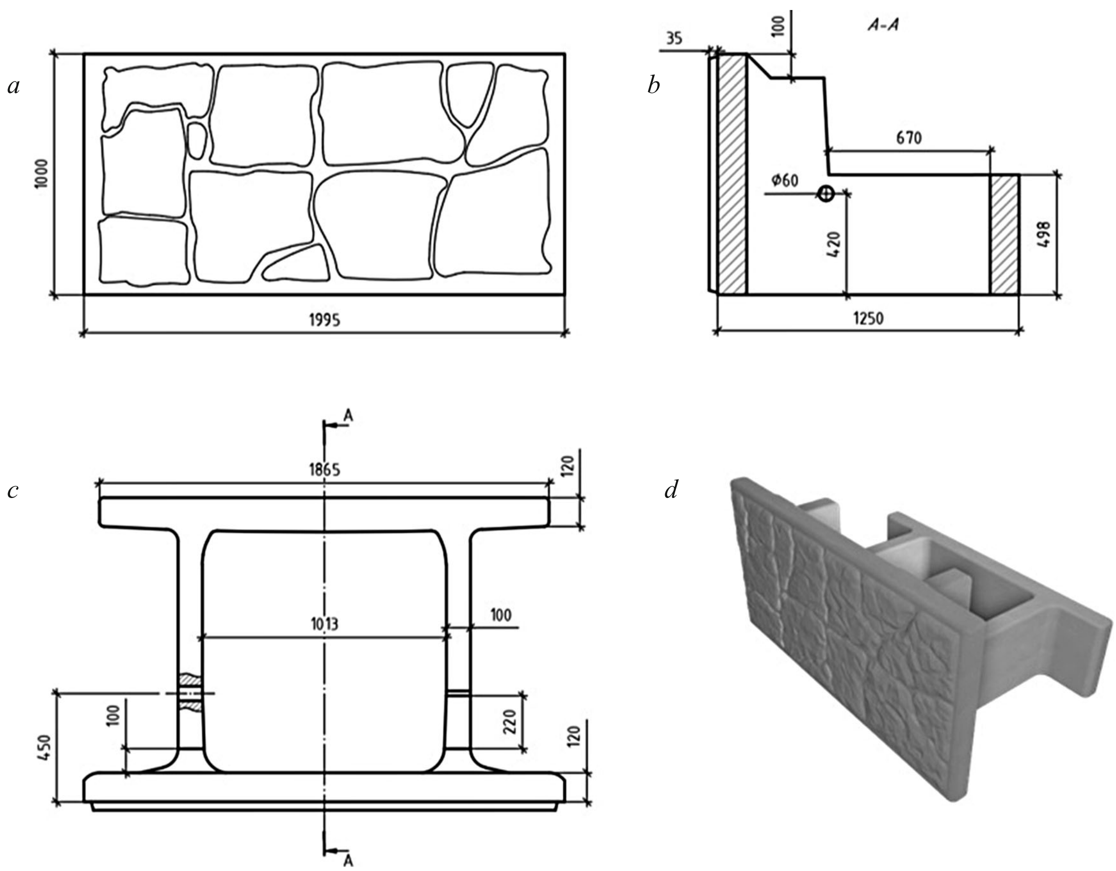


**Fig. 1.** KBP 100/200 block [4]: *a* — front view; *b* — cross-section; *c* — top view; *d* — axonometry (dimensions in mm).

structural elements of slipways, mooring walls of reservoirs, formation of slopes at water intakes, and strengthening of stream and river beds, among others, can be performed (Fig. 2*b*). One of the additional advantages when blocks are used in hydraulic engineering can be that they generally do not disturb the ecological balance of reservoirs and, due to natural indentations, can serve as a habitat for birds and animals.

The calculation and design of bank protection structures in hydraulic engineering are based on the provisions of regulatory documents and guidance materials, including primary ones (RD 31.31.55–93 [5], SP 38.13330.2018 [6], SP 32-103–97 [7], SP 22.13330.2016 [8], SP 23.13330.2018 [9], Guidelines [10], and others).

The specificity of bank protection structures indicated in these documents, including in terms of the loads and operating conditions taken by the structure, and the presence of requirements imposed by more severe operating conditions in Russia require the adaptation of appropriate methods for calculating these structures. In this case, first of all, theoretical problems arise.

For example, one of such problems is determining the active soil pressure on the conditional pressure face of such a structure. In this case, the pressure face represents a polygonal line, and some peculiarities arise when developing an analytical solution. The usual approach adopted in calculation practice (replacing a polygonal line with a straight line) cannot be used in this case. This simplification leads to an underestimated value of the active soil pressure as part of the weight of the retained soil mass is not considered in this approach. This problem was solved by the authors using the classical principles of the Coulomb theory. Therein, a set of equations was obtained and used to perform a stepwise procedure for determining the active pressure from row to row, from top to bottom with an accrual total, including the consideration of the surcharge on the surface, and under the condition that the structure is erected in a seismically dangerous environment of the construction area [11]. In this case, the active soil pressure acting on the structure was determined considering the inertial force acting on the collapse prism.

Calculations indicate that without backfill reinforcement, for average values of the physical and mechanical characteristics of the retained soil mass, the constructions of the structure under consideration can maintain their performance characteristics at a height of no more than five to six blocks (5 – 6 m). An increase in height is possible when installing reinforcing mesh in a retained slope or when using these blocks to form a rock slope, when lateral pressure on the wall is practically not formed and its height is determined by the strength of the blocks themselves under the influence of the own weight of the overlying rows and the soil thrust arising in the soil filler of the blocks of the lower rows. In this case,