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"Gamma-Block" – A new structure for protecting abrasive shores of water bodies from erosion – short communication

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ABSTRACT:
The article deals with a new type of breakwater bank protective structure made from reinforced concrete called a "Gamma-Block", the embankment of which is arranged on the abrasive shores of water bodies (reservoirs, lakes and sea) in the zone of wave runup and fall on the slope. The effectiveness of the embankment model on wave damping and slope stability was tested in the hydraulic trough at the Ts. Mirtskhulava Water Management Institute of the Georgian Technical University in Tbilisi. Initial laboratory test results show positive effects of using the new gamma block. The new type of block weighs significantly less than the most commonly used elements while maintaining similar parameters.

KEYWORDS:
erosion; concrete structure; hydrodynamic characteristics

1. Introduction

Protection of the abrasive shores of water bodies with the help of new, modern embankment structures, with a high wave-absorbing capacity and low cost is an urgent problem all over the world.

In the modern period, many countries have already abandoned the use of massive, one-piece and expensive shore protection structures. Latticed structures made of shaped arrays of various outlines, the weight of which ranges from 0.5 to 5.0 tons, have been created.

With the use of shaped arrays, it is possible to reinforce abrasive steep (up to $\alpha = 33°$) slopes. The main factor of the effective operation of structures made of shaped arrays is damping of wave energy and reduction of wave runup height on the slope (2-3 times). In the practice of hydraulic engineering construction, the maximum weight of arrays reaches 60.0 tons.

This paper is a continuation of research on a new type of reinforced concrete coastal protection block – the so-called "Hexablock" characterized by improved wave attenuation properties, blocking capacity, slope stability and longer service life, described in publications [1, 2]. This is also particularly important in view of the occurrence of flood waves on many streams, rivers,

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canals and reservoirs, which are the result of intense, heavy rainfall. They contribute to significant destruction of the banks of these facilities due to erosion.

2. Proposed "Gamma-Block" model for the protection of the shore of a hydrotechnical structure made of material susceptible to erosion

To increase the wave-absorbing capacity and mutual tautness of blocks for reducing the height of the wave runup on the slope, the "Gamma-Block" structure was developed, which refers to the field of hydraulic engineering and can be used to protect the abrasive shores of water bodies (reservoirs, lakes and sea) from erosion.

Known hydraulic engineering structures protecting the abrasive shores of water bodies from erosion are: stone embankments, various types of concrete blocks, gabions, concrete slabs, etc. [3-9]. The most famous concrete blocks are "Hexapod", "Dipod", "Dolos", "Stiblock", "Quadripod", "Stipod", "Tripod" and others. They are characterized by a significant height (H = up to 14.0 m), mass (M = up to 41.0 t) and, therefore, require expensive reinforced concrete material.

Based on the practice of methods of protection of abrasive shores of reservoirs, lakes and seas from erosion, the closest to the presented "Gamma-Block" is a type of similar block – "Dolos" [6], the disadvantage of which is its instability caused by the wave loading on the slope of the of reservoir shore, small effect of wave energy damping, significant mass of construction material (reinforced concrete) and significant height of wave runup on the embankment slope arranged with "Dolos".

The "Gamma-Block" consists of three quadrangular square cross-section bordering prisms connected and united with each other by central areas at an angle of 90° and is distinguished by the fact that each end of the prism has a Γ-shaped protrusion – the knee, with a size equal to the cross-section of the prism and facing each other (Fig. 1). Stability of the blocks on the slope increases with the mutual tautness of protrusions. The height of the blocks is determined depending on the height of the water wave coming on the shore, which is established by the results of laboratory studies – the higher the wave height of 1 % ($h_{1\,\%}$), the heavier the mass of the "Gamma-Block" (M) should be (Fig. 1).

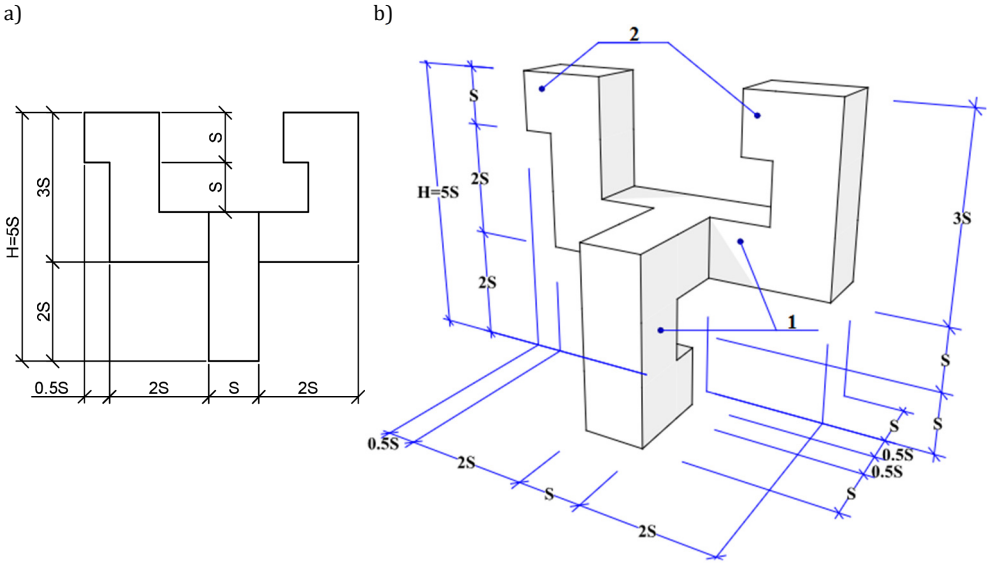

Fig. 1. "Gamma-Block" front view (a) and general view (b), 1 – 2 quadrangular square cross-section prisms connected at an angle 90°; 2 – Γ-shaped protrusion (knee)

3. Testing of the natural "Gamma-Block" hydrodynamic characteristics with model characteristics in the laboratory

The proposed "Gamma-Block" embankment model was tested in the hydraulic trough (9.0 m × 0.5 m × 0.4 m) in the hydrotechnical laboratory of the Ts. Mirtskhulava Water Management Institute of the Georgian Technical University (Fig. 2).

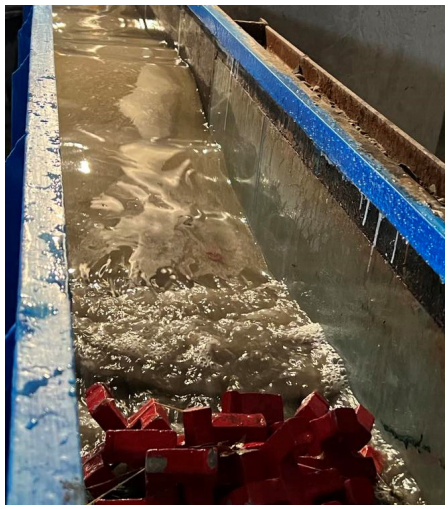

Fig. 2. "Gamma-Block" embankment test in the laboratory

Table 1 shows the results of calculations of the natural hydrodynamic characteristics of the "Gamma-Block" with model characteristics in the laboratory (using the Froude criterion $F_r = \frac{V}{\sqrt{gH}}$, g = idem, p = idem).

Table 1
Characteristics of model waves in the breakwater zone on the coastal slope

Physical values	Scalable linear multiplier $a_H = H_{nat}/H_{mod}$	Characteristics of model waves in the breakwater zone on the coastal slope
Linear dimensions		
h (wave height on the water surface) [m]	$a_h = a_H = h_{nat}/h_{mod}$	$h_{mod} = h_{nat}/a_H$
λ (wave length on the water surface) [m]	$a_\lambda = a_H = \lambda_{nat}/\lambda_{mod}$	$\lambda_{mod} = \lambda_{nat}/a_H$
H_{wat} (water depth in the breakwater zone on the coastal slope)/m	$a_H = H_{nat\,wat}/H_{mod\,wat}$	$H_{mod\,wat} = H_{nat\,wat}/a_H$
H ("Gamma-Block" height) [m]	$a_H = H_{nat}/H_{mod}$	$H_{mod} = H_{nat}/a_H$
Ω ("Gamma-Block" surface area) [m^2]	$a_\Omega = a_H^2$	$\Omega_{mod} = \Omega_{nat}/a_H^2$
W ("Gamma-Block" volume) [m^3]	$a_W = a_H^3$	$W_{mod} = W_{nat}/a_H^3$
$H_{run\,up}$ (height of wave runup on the shore slope) [m]	$a_{run\,up} = a_H$	$H_{run\,up\,mod} = H_{run\,up\,nat}/a_H$
T (water wave propagation time) [s]	$a_T = a_H^{1/2}$	$T_{mod} = T_{nat}/\sqrt{a_H}$
V (linear speed of water wave movement) [m/s]	$a_V = a_H^{1/2}$	$V_{mod} = V_{nat}/\sqrt{a_H}$
α^0 (angle of shore slope), degrees	$a_{\alpha 0} = 1$	$\alpha_{mod} = \alpha_{nat}$
M ("Gamma-Block" mass) [t]	$a_M = a_H^3$	$M_{mod} = M_{nat}/a_H^3$
F (wave impact force on the slope of the shore) [t] (force)	$a_F = a_H^3$	$F_{mod} = F_{nat}/a_H^3$
E_{penetr} ("Gamma-Block" embankment penetrability)	$E_{penetr} = 1$	$E_{penetr\,mod} = E_{penetr\,nat}$
P (wave impact pressure on the slope of the shore) [t/m^2]	$a_P = a_H^{1/2}$	$P_{mod} = P_{nat}/a_H$

The dependence of the masses (M) of the existing "Dolos" embankment and our proposed "Gamma-Block" on the height of 1 % ($h_{1\%}$) water wave provision on the coastal slope is shown in Figure 3.

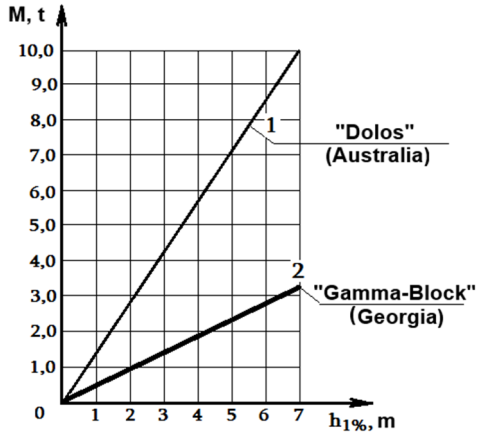

Fig. 3. Graphical comparison of the dependence of the mass (M) of "Dolos" (1) and "Gamma-Block" (2) on the height of 1 % ($h_{1\%}$) water wave provision on the abrasive bank of the reservoir

4. Conclusions

The conducted experiments clearly show that the "Gamma-Blocks" embankment on the slope of the reservoir bank is characterized by stability on the slope; a significantly large wave--absorbing effect (up to 30 %); small mass (M) and small height of water wave runup on the bank slope. Due to the favorable results, further work on the solution is suggested. The next steps should be parametric analyses based on numerical studies in order to achieve the most favorable dimensions of the element.

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"Gamma-Block" – nowa konstrukcja do ochrony brzegów zbiorników i cieków wodnych przed erozją – krótki komunikat

STRESZCZENIE:
Omówiono żelbetową konstrukcję zabezpieczającą brzegi cieków i zbiorników wodnych nowego typu – "Gamma-Block". Konstrukcja przewidziana jest do ochrony brzegów zbiorników wodnych (zbiorniki, jeziora i morze) wykonanych z materiałów podatnych na erozję, w strefie rozbiegu fal i opadania na skarpie. Skuteczność modelu nasypu w zakresie tłumienia fal i stateczności zboczy została przetestowana w korycie hydraulicznym, w Instytucie Gospodarki Wodnej im. Ts. Mirtskhulava Gruzińskiego Uniwersytetu Technicznego w Tbilisi.

SŁOWA KLUCZOWE:
erozja; konstrukcja betonowa; charakterystyka hydrodynamiczna