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DEFINITION OF BREAKING WAVES PARAMETERS IN RESERVOIRS

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Abstract. *In the presented article the method of the breaking waves and surf parameters determination, caused by catastrophic events on the slopes of the reservoir and the dam is discussed.*

The task, due to its complexity, is solved using a hydraulic apparatus, which, despite some assumptions, fully meets the practical-engineering requirements.

It is worth noting that the impact of friction forces on the current events and therefore the energy losses will be taken into account in hydraulic form, according to Shazey-Manning. The density coefficient is taken according to Ganglie-Kutter.

Obtained dependencies determine the surf front speed on the slopes of the reservoir, the height of the broken wave flow, the length of the flow up the slope, the flow of water overflowing the dam or the slope.

Obtained dependences are suitable for calculating the surf ' parameters in the case of both long and short wave excitation. However, the solutions do not include any experimental constants and represent only the result of the theoretical approach adopted.

Key wards*: Surf, breaking waves, reservoir, density coefficient, hydraulic apparatus.*

Since the last century, global processes have been activated on our planet, which significantly complicates the safe existence of man. Although the world has made significant progress in the management of natural disasters, the risk of their dangers remains an insurmountable problem. It should be noted that in the last decade more than 700 thousand people died, more than 1.4 million were injured, 23 million were left homeless as a result of natural disasters in the world. The total economic loss exceeds 1.3 trillion dollars. A special process is the instability of the current climate and the "demographic explosion", since the world's population has exceeded 7 billion and this number will increase again in the near future.

Georgia belongs to one of the most difficult mountainous regions in the world in terms of the development of natural geodynamic processes, the degree of damage to the territory and the risk of danger to the population and infrastructural facilities is more than 70%. From which up to 60% of settlements are under various categories of danger. It belongs to the most difficult place of the mountainous regions of the planet due to the diverse range of natural processes, scale of development, repeatability in time, population, agricultural fields and agricultural engineering facilities. The entire territory of the country more or less damaged by natural processes is in the risk zone of their impact.

Landslides, rockfalls, floods, mudstreams, washing of sea and reservoir banks, various types of erosion, water falls, rockfalls, karst-suphos subsidence and their socio-economic consequences cover all spheres of human activity. The situation is further complicated by the fact that, to a large

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extent, in the same territory, different types of events are activated at the same time (as it happened in August 2023, during the tragedy that happened in the Shovi recreation complex in Racha. As a result, 32 people died and the infrastructure was destroyed, also in Guria One month later, 3 children died as a result of a mud stream), which is why it is difficult to predict individual events and plan preventive measures in the mentioned area.

Georgia belongs to the region where the unprecedented occurrence and activation of natural-anthropogenic processes, especially floods and the development of mud stream' processes, the socio-economic problems caused by them have reached the irreversible limit of ecological crises. That is why it is necessary to study the causes of these processes in detail.

Obtaining a strict hydrodynamic solution of the process of spreading of the surf caused by the impact of the wave on the inclined slopes is associated with significant, in some cases unsolvable, difficulties. Due to this circumstance, below we present an approximate hydraulic solution to the problem, which, despite some assumptions, fully meets the practical-engineering requirements.

As a rule, when the gust flow spreads on the slopes, there is a dependence:

$$h^* = l^* Sin\alpha \qquad (1)$$

where h^* - is the height of the flow up the slope, l^* - is the maximum length of the surf spread, α - is the angle of inclination of the slope, the x-axis is directed along the slope.
In the case of shallow water, which takes place under the conditions of our task, to determine the length l^*, let's consider the spread of the front of the surf on the slope , the marginal location of which is determined by the of h^* and l^* values.

For the propagation speed of the braking wave front, in which the exponent of the transfer velocity of the water relative to the phase velocity is neglected, we have:

$$\tilde{c} = \frac{dx}{dt}\ , \qquad (2)$$

For the crushing phase , the speed of the wave front $\tilde{c}$ is variable along the slope [1] and is expressed as:

$$\tilde{c} = \sqrt{\frac{g}{k_*} thk_* H_*}\left(1 - \frac{x}{l^*}\right)^p \cos\alpha\ , \qquad (3)$$

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where P - is the quality indicator, which is obviously positive, because otherwise $\tilde{c}$ will not decrease along the slope. In addition, as it is clear from the calculations below $P<1$; $k_* = \frac{2\pi}{\lambda_*}$ - is a wave number.

Taking into account (3), we get:

$$\frac{dx}{dt} = \sqrt{\frac{g}{k_*} thk_* H_*} \left(1 - \frac{x}{l^*}\right)^p \cos\alpha \tag{4}$$

As a result of the integration of the obtained equation, taking into account the initial conditions, $t=0, x=0$ (4) we get

$$\frac{1}{1-P}\left[\left(1-\frac{x}{l^*}\right)^{1-P} - 1\right] = -\frac{t}{l^*}\sqrt{\frac{g}{k_*} thk_* H_*} \cos\alpha \tag{5}$$

to determine l^* if we enter in (6) that when $t = \frac{\tau}{4}$ (is the period) then $x = l^*$ we get

$$l^* = \frac{1-P}{4}\tau\sqrt{\frac{g}{k_*} thk_* H_*} \cos\alpha = \frac{1-P}{4}\tau\tilde{c}_* \cos\alpha \tag{6}$$

Let us introduce the notation $\beta = \frac{\tilde{c}_*}{\tilde{c}_{cr}}$ and rewrite (6) in the following form:

$$l^* = \frac{1-P}{4}\frac{\lambda_\infty}{\tilde{c}_\infty} c_{cr} \beta \cos\alpha \tag{7}$$

At this time we take into account that away from the slope

$$\tau = \tau_\infty = \frac{\lambda_\infty}{c_\infty} \tag{8}$$

It follows from the condition of constancy $\tau_X = \tau_{cr}$, of wave motion periods:

$$\frac{\lambda_X}{c_X} = \frac{\lambda_{cr}}{\tilde{c}_{cr}} \tag{9}$$

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where the sign x indicates the assignment of values to the section of the slope, which is quite far from

the section of breaking waves, i.e. in depth H_{cr} from the breaking section.

For the general case (we assume that for any case $KH = \frac{2\pi H}{\lambda}$) and taking into account that the phase speed in the breaking section is close to the speed of long waves, relation (9) can be written as follows [2]:

$$\lambda_{cr} = \sqrt{g\, H_{cr}} \times \frac{\lambda}{\sqrt{\frac{g\lambda_\infty}{2\pi} th \frac{2\pi H_\infty}{\lambda_\infty}}} \qquad (10)$$

Using relations (9) and (10), the (7-th) will take the form:

$$l^* = \frac{1-P}{4} \beta \sqrt{\frac{2\pi H_{cr} \lambda_\infty}{thk_\infty H_\infty}} \cos\alpha \qquad (11)$$

To determine the β magnitude , we understand the use of phenomenological methods.

In particular, it is clear that the arrival of long waves l^* at the coastline should not depend on the length of the incoming waves.

And in the case when short dispersive waves approach the shore, the surf actually represents the deformed form of the waves coming down the slope, and therefore (10) attitude should be approximately fair for those waves that still "feel" the bottom. Moreover, the length l^* can be approximately replaced by the length of $\frac{\lambda}{4}$, because l^* corresponds to the fourth period of the wave motion, when $P \approx 0$.

It is not difficult to see that both of these limiting cases (especially the intermediate ones) will be satisfied if we assume that

$$\beta = thk_\infty H_\infty \qquad (12)$$

In such a case the relation (11) will take the form:

$$l^* = \frac{1-P}{4} \sqrt{2\pi H_{cr}\, \lambda_\infty thk_\infty H_\infty} \cos\alpha \qquad (13)$$

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In the case of long waves $thk_\infty H_\infty \approx k_\infty H_\infty$, the (13) relation is written in the form:

$$l^* = \pi \frac{1-P}{2} \sqrt{H_{cr} H_\infty} \cos\alpha \qquad (14)$$

At this point, l^* obviously does not depend on the wavelength

$$thk_\infty H_\infty = 1, \;\; P = 0, \;\; \cos\alpha \approx 1 \qquad (15)$$

In case of short waves, coming to the shore

$$l^* = \frac{1}{4}\sqrt{2\pi H_{cr} \lambda_\infty} \qquad (16)$$

Thus, the length l^* of the flow already depends on the length of the incoming wave. If we take into account that the critical depth of breaking is $H_{cr} \approx \tilde{h}$, then for marginally short surface waves $\frac{\lambda_\infty}{\tilde{h}} = 2\pi$ (corresponding to the marginal Stokes stability of the wave profile), we have:

$$l^* = \frac{\lambda_\infty}{4} \qquad (17)$$

The quality indicator P reflects the intensity of the influence of the frictional forces on surf stream coming to the shore, as a result of which the latter obviously decreases, as the closer P to one, the more intensively the speed of the waves decreases due to the friction of the flow breaking at the surface of the slope, and therefore the shorter the length l^* and the lower the height h^*.

Therefore, the condition $P \ll 1$, under which the image $h^* = l^* \sin\alpha$ can be written in the following form:

$$h^* = l^* \sin\alpha = \frac{1}{8}\sqrt{2\pi H_{cr} \lambda_\infty thk_\infty H_\infty} \sin 2\alpha \qquad (18)$$

The latter corresponds to the case of wave breaking on a frictionless slope.

On the contrary, when it is close to one, we are dealing with a slope on which the friction is very high (for example, a slope built with crushed stones).

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Due to the above-mentioned features, the dependence of h^* can be given an energetic explanation if we write it in the following form:

$$h^* = h_0^* - h_W^* \quad (19)$$

Where h_0^* - corresponds to the potential energy with the marginal value, i.e. we are dealing with a virtually ideal fluid, and h_W^* there is energy loss due to friction

$$h_W^* = \frac{P}{8}\sqrt{2\pi H_{cr}\lambda_\infty thk_\infty H_\infty}\,\sin 2\alpha \quad (20)$$

Let express the energy losses in hydraulic form according to Shazey-Manning [3]:

$$h_W^* = \frac{V^2 l^*}{c^2{}_W H} = \frac{\overline{V}^2 n^2 l^*}{H^{1.33}} \quad (21)$$

And let's take it as an approximation

$$\overline{V} = \overline{c}_{av}\sqrt{\frac{g}{k} thk\overline{H}} \quad (22)$$

where $\overline{H}$ - is the average depth of the wave flow in the breaking zone, it is accepted that it is equal to 0.25 H_{cr}.
Considering that when $k\overline{H} = 1$, $thk\overline{H} = k\overline{H}$ we have

$$\overline{V} = \sqrt{g\overline{\overline{H}}} = 0.5\sqrt{gH_{cr}} \quad (23)$$

And respectively

$$\overline{H}^{1.33} \cong 0.16 H_{cr}^{1.33} \quad (24)$$

So we will have

$$h_W^* \cong 1.5\frac{gn^2 l^*}{\sqrt[3]{H_{cr}}} \quad (25)$$

If we equate relations (17) and (18) to the right sides and take (11) into account, we get:

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$$1.5\frac{gn^2}{\sqrt[3]{H_{cr}}}\frac{1-P}{4}\sqrt{2\pi H_{cr}\lambda thkH}\sin\alpha\cos\alpha = \frac{P}{4}\sqrt{2\pi H_{cr}\lambda thkH}\sin\alpha\cos\alpha \qquad (26)$$

from where we get

$$P = \frac{1.5gn^2}{\sqrt[3]{H_{cr}}+1.5gn^2} \qquad (27)$$

Thus, to calculate the height of the broken wave flow (surf), we get the following calculation relationship:

$$h^* = 0.25\sqrt{2\pi H_{cr}\lambda_\infty thk_\infty H_\infty}\,\frac{\sqrt[3]{H_{cr}}\sin\alpha\cos\alpha}{\sqrt[3]{H_{cr}}+1.5gn^2} \qquad (28)$$

which does not include any experimental constant and represents only the result of the accepted theoretical approach.
The coefficient of mass (according to the table of Ganglie-Cutter) should be taken according to the Sribny. For large debris dams n = 0.15 - 0.20.

Thus, the greatest height of the breaking wave flow is determined by the relation (21), and the length of the flow along the slope by the relation:

$$l^* = \frac{h^*}{\sin\alpha} \qquad (29)$$

in l^* -the length zone, the speed of displacement of the front of the crushing wave flow is reduced according to relation (3), which can also be written as follows:

$$\overline{c} = \sqrt{gH_{cr}}\left(1-\frac{x}{l^*}\right)^P \cos\alpha\ , \qquad (30)$$

in which P it is determined according to (27), and l^* according to (30).

According to relation (25), the speed of the front of the breaking waves decreases after the calm water surface.

The height of the breaking wave flux in the length l^* zone can be taken as linear, therefore

$$\overline{h}_H = \overline{H}_*\left(1-\frac{x}{l^*}\right) \qquad (31)$$

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where $\bar{H}_* = 0.67\, H_{cr}$ - represents the height of the wave after its breaking.

In the event of overflowing of a surf flow breaking on a dam or a slope, the discharge of overflowing water is calculated according to the following relationship [4]:

$$q = 0.67 H_{cr} \sqrt{gH_{cr}} \left(1 - \frac{l_{sl}}{l^*}\right)\left(1 - \frac{l_{sl}}{l^*}\right)^P \qquad (32)$$

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