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THE RESULTS OF A MUD AND ROCK FLOW CONTROLLING NEW FACILITY DESIGN STUDY

The analysis of the mud-rock flow controlling facility operation enables to reveal regularities and, consequently, mechanisms providing passage of the given values of solid and liquid flow for different slopes of a channel and parameters of its cross section. To solve such problems it is assumed that if the mud-rock moving along a given slope of a prismatic bed with the maximum concentration, then its flow can be controlled and direct along small slopes of the channel, providing at that the constancy of the first value of sediment carrying capacity. At the same time, the sections of the channel where steepness of the bed is relatively gentle require corresponding design innovations of the mud-and-rock flow controlling facilities. The received design solutions for mudflow controlling structures enable reliable control of mudflows where downward grade is small.

Keywords: water, river, channel, flood, turbulence, reservoir, anti-mudflow

INTRODUCTION

The constancy of the sediment carrying capacity or the balance of sediments, among other results, enables to derive a relationship between hydraulic parameters of the effective cross-section [1]. The analysis of revealed regularities makes it possible to arrive at a very important and interesting conclusion: passing through the given values of solid and liquid flows is possible in different values of the channel slope i_0 and parameters of the cross-section b and h. However, these values are not arbitrary, but must satisfy the balance of sediments. In considering this problem researchers had be all the better to refer to the first works by V.G. Sanoyan [2, 3] devoted to mudslides. Using this concept a number of interesting results were obtained theoretically. Their essence lies in the fact that the flow of water moving in a prismatic channel of a given slope with a certain limiting concentration (transporting ability) can be transported further and along small downgrades of the riverbed, while ensuring the constancy of the initial value of the silt carrying capacity. However, the sections of the channel at the site of decreasing slopes require corresponding new design developments.

RESEARCH RESULTS

To build a mathematical model for solving the problem under consideration, equations of nonuniform motion and continuity, sediment balance and a number of known relationships were used [2]. On the basis of this formulation several problems of great practical importance have been solved. Mud-and-rock stream moving down the hill gradually losses its speed, for the down-hill gradient gradually decreases from the top to the foot of the hill or mountain. Due to natural conditions or existing types of pass channels begins intense deposition of sediment. As a result mudflow or mudslide gradually is becoming wider, covering large area causing more sever and larger destructions.

The obtained theoretical solutions the authors subjected to experimental check [3]. These studies have proved the reliability of carried out theoretic developments. On the basis of the obtained results, the authors have registered two author's certificates for inventions, as a fundamentally new type of sediment and silt passing structures [4, 5].

The first type of these structures is a prismatic channel, which in places where down-hill gradient decreases is transformed to a wider non-prismatic channel. A number of such design were subjected to a series of laboratory tests when the slope of the upper channel was 0.03, and the lower one - 0.01 (two models with different estimated flow rates) and 0.0 (horizontal bottom), where the slope of the upper channel was 0.05, and the lower one - 0.01. In all cases the obtained theoretical solutions corresponded quite well to the experimental data (Tables 1, 2 and 3). The paper presents the results obtained for one of models (when the prismatic channel of a rectangular cross-section passes to the non-prismatic channel of the same shape), since these results are described in sufficient detail in researched reports, and in methodological recommendations [1, 3, 6].

The initial data of the presented example are: for the upper prismatic channel the slope of the bottom is $I = 0.03$, mudflow rate - $Q = 48.6$ l/s, transporting capacity of the stream $S_m = 70$ kg/m^3, the channel width - $b_p = 0.37$ m, weighted average diameter of the silt $d = 2.64$ mm. The slope of the channel lower section is $i = 0.01$.

The plan and the longitudinal section of the structure are shown in Figures 1 and 2. As can be seen from the presented there schemes, with the ratio of slopes of the upper and lower sections is equal to 3, the lower section of the channel, having the expansion corresponding to the calculations, still passes the maximum flow of sediment arriving from the upper channel. The values of the calculated values of the channel width and the depth of the flow in it are given in Table 1.

Table 1. **Results of channel width and flow depth calculations**

x [m]	0.5	1.26	2.3	3.4	4.4	5.0
b [m]	0.40	0.45	0.54	0.74	1.01	1.33
h [m]	0.059	0.053	0.046	0.036	0.028	0.023

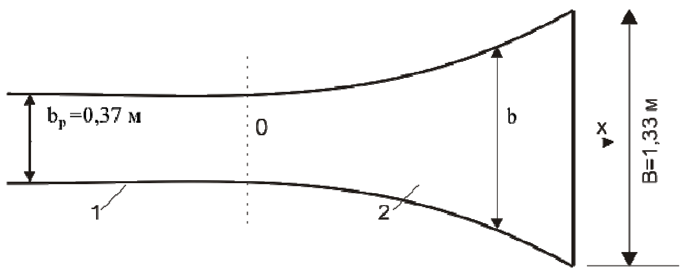

Fig. 1. The plan of the experimental model of the new facility design: 1 - prismatic channel with slope I = 0.03, 2 - non-prismatic, expanding channel with slope i = 0.01

From the calculated expressions, here only the basic differential equation is presented obtained from the joint solution of the equations of steady no uniform flow and sediment balance, in case the given configuration of the channel bed is taken into consideration. The derived equation enables depending on the x distance (the reference point - the final site of the upper channel corresponding to the initial site of the lower section) to determine the value of the area of the effective cross-section A in the non-prismatic section of the channel. This equation has the following dimensionless form

$$\frac{d\overline{A}}{d\overline{X}} = I \frac{\frac{1}{2} + \frac{i}{2 \cdot I} - \left(1 - \frac{i}{I}\right)\frac{\mathrm{thc}\overline{x}}{2} - \overline{A}}{\frac{13}{16}\left(\beta_p + 2\right) \cdot \overline{A}^{9/4} - \sqrt{\frac{\beta_p}{8\overline{A}}}\, \frac{\frac{13}{16}\frac{\left(\beta_p + 2\right)^2}{\beta_p}\overline{A}^{11/2} - 1}{\sqrt{\frac{\left(\beta_p + 2\right)^2}{8\beta_p}\overline{A}^{11/2} - 1}} - \frac{Fr_p}{\overline{A}^3}} \tag{1}$$

when:

$\beta_p = b_p/h_p$ is the linear scale of dimensionless h_p;
C is the dimensionless coefficient depending on i/I;
Fr_p - Froude number for the upper stream.

After setting the values of A, the values of the channel width b and the stream depth h are determined using corresponding dependencies. Having he values of h (Tab. 1) the curve of the free surface of the stream along the length of the structure has been plotted in Figure 2. In the same place the results of the experimental data are also indicated (Tab. 1). As is seen from the graph, there is a fairly good correspondence between the two values. At the same time, a transit passage of the mudflow from the upper channel is observed, with a design flow rate Q = 48.6 l/s and sediment carrying capacity S_m = 70 kg/m^3 through the lower channel of which the slope is three times less.

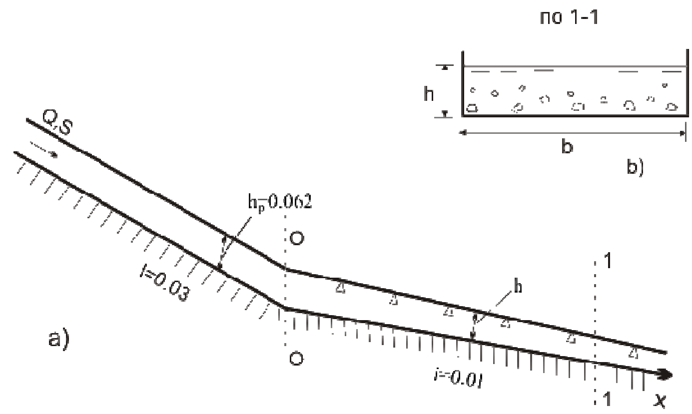

Fig. 2. The longitudinal profile (a) and the cross-section (b) of the sediment passing structure of a new design - the calculated curve of the free surface of the stream; Δ - the results of experimental studies

The second type of mudflow passing structures, allowing to solve the same problem (with a decrease in the slope the sediment balance is not violated), but another design solution is a completely prismatic channel. In this case, in a section of a gentle down-hill gradient, as it is paradoxical, the bed should be built with an increasing roughness along the flow [7]. The roughness value is determined by the depth of the flow. The latter, in turn, is calculated from the differential equation obtained from the joint solution of those expressions which were also used for the first type of the mud-rock passing structure.

In dimensionless values, these two dependences have the following form

$$\frac{d\bar{h}}{d\bar{x}} = \frac{\bar{h}^3\left(i - I \cdot \bar{h}\right)}{\bar{h}^3 - Fr_p} \tag{2}$$

$$\bar{n} = \bar{h}^{-3/2}\left[\frac{\bar{h}\left(\beta_p + 2\right)}{\beta_p + 2\bar{h}}\right]^{2/3} \tag{3}$$

The plan and longitudinal profile of the structure are shown in Figures 3 and 4, and calculated values of h and n as a function of distance are given in Tables 2 and 3. In this case, the initial parameters of the calculations of the presented model had the following values: the slope of the upper channel I = 0.03, the flow rate Q = 38.8 l/s, the carrying capacity $S_m = 60$ kg/m^3, the width of the entire channel $b_p = 0{,}37$ m, the slope of the lower section i = 0.00, the average diameter of the sediments is d = 2.64 mm (as in the first case, several models have been tested), the diameter of the sediments is d = 2.64 mm (in this case several models have also been tested).

The calculated values of h and n are given in Table 2, and in Figure 4 shows the results of the calculation (Tab. 3).

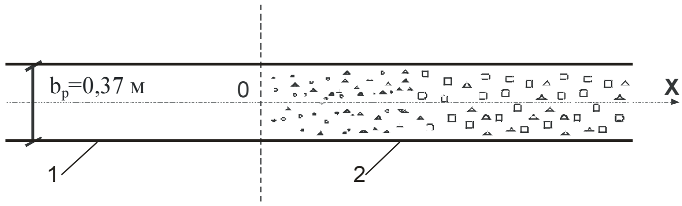

Fig. 3. The plan of the pilot model of the sediment passing structure 1 - prismatic channel with slope I = 0.03, 2 - prismatic channel with enhanced roughness with slope i = 0

As can be seen from Figure 4, the similarity between them is satisfactory.

Table 2. **Results of calculations *h = f(x,n)***

x [m]	0	0,5	0,75	1,0	1,25
h [m]	0.055	0.60	0.62	0.66	0.74
n	0.013	0.015	0.017	0.019	0.024

Table 3. **The results of experiments on sediment passing channels with a decreasing bottom gradient**

Sediment passing facility (the lower section of the channel is expanding)			Sediment passing facility (the bottom section of the channel with reinforced roughness)		
slope of the channel	distance x [m]	depth of the flow h [m]	slope of the channel	distance x [m]	depth of the flow h [m]
0.03	–2.0	0.063	0.03	–1.5	0.053
	–1.0	0.062		–0.5	0.052
0.01	0.6	0.056	0.0	0	0.056
	1.2	0.053		0.4	0.058
	1.8	0.049		0.7	0.062
	2.5	0.044		0.9	0.065
	3.2	0.037		1.1	0.069
	4.4	0.025		1.3	0.071

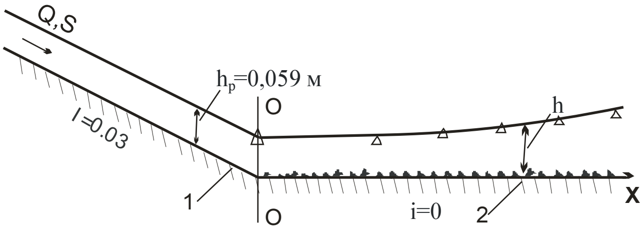

Fig. 4. Longitudinal profile of the structure - - design curve of the free surface of the flow; Δ - experimental data; 1 - prismatic channel with slope I = 0.03, 2 - prismatic channel of reinforced roughness with slope i = 0.0

Here there is some discrepancy in the final section of the lower channel. An analysis of the results of experiments on the second type of structures gives rise to the following conclusion: if the results are theoretically interesting, then in terms of practical implementation of the variable roughness, there are certain technical difficulties.

CONCLUSION

The resulting design solutions for new types of mud-and-rock passing structures enable reliable passage of mud-and-rock flows through places where the slope of the channels is decreasing. These structures can be used to protect the roads and railways, communications, economic and other objects from destruction.

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WYNIKI BADAŃ KONTROLOWANEGO SPŁYWU GRUZOWEGO - NOWE STUDIUM PROJEKTOWANIA OBIEKTÓW

Analiza działania układu kontrolującego zapewniającego spływ gruzowy (mieszaniny błota i skał) pozwala na wykrycie prawidłowości, a w konsekwencji mechanizmów zapewniających przepływ o określonych wartościach składników stałych i wody w przypadku różnego nachylenia kanału i parametrów jego przekroju. Aby rozwiązywać ten problem założono, że mieszanina błota i kamieni o maksymalnej gęstości porusza się w kierunku spadku pryzmatycznego złoża, wówczas jego przepływ może być kontrolowany i kierowany w strefę małych spadków kanału, zapewniając tym sposobem zdolność do przenoszenia osadów. Jednocześnie sekcje kanału, w których spadek koryta jest stosunkowo łagodny, wymagają wprowadzenia innowacji konstrukcyjnych urządzeń do regulowania spływu gruzowego. Otrzymane rozwiązania konstrukcyjne dla struktur regulujących spływ gruzowy umożliwiają niezawodną kontrolę przepływu błota i skał w kanałach o niewielkim nachyleniu.

Słowa kluczowe: kanał, powódź, turbulencja, osady, spływ gruzowy