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ON ROUGHNESS COEFFICIENT IN MOVEMENT OF SEDIMENT CARRYING FLOWS

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Existing formulas for determination of roughness coefficient relates to deformable, natural channels. Moreover, most of them have been suggested only for particular cases, namely, for mountain streams of small concentration. Recommendations applicable for sediment carrying streams of large concentration practically are not available in the literature, all the more, for mudflows moving on tough, rigid channels, specifically, in case of the limit sediment carrying capacity of the flow.

Key words*: water, river, channel, flood, turbulence, reservoir, anti-mudflow.*

Introduction

In mountainous and submountain regions a certain part of the land located in a zone of the destructive action of mud-and-stone flows. The area of such zone under anthropogenic impact can undergo essential increased. Restoration of damaged areas in consequence becomes difficult, therefore, all necessary measures should be taken to minimize development of negative processes including mudrock streams causing disruption of relatively stable landscapes surface conditions.

Powerful mudflows are formed, mainly, in erosion cuts representing a whole system of channels in the upper reaches of mountain streams, which, as a result of continuous destruction of rocks and their quick movement down the side of a mountain or hill, are filled with a mass of soft, wet, unconsolidated earth and debris, then affected by weathering, crushing and grinding under the influence of various factors [1].

The slippery mass of mud, formed as a result of such events envelops (in a mixture with crushed rocks) pyroclastic rock and fills the voids between them. The mud mixture prepared in this way in the erosive cuttings is in a connected state - enough rainfall, intense thawing of snow or other causes, triggered a collapse down, grabbing rock fragments, stones, trees, etc. along the way. Morainic and subglacial deposits are often also components of an already prepared mud mixture. If the moraine deposits are saturated with water by 10-20% (by weight), then the formed mud-and-stone flow travels rushing down a steep slope very quickly [2].

In the absence of glaciers, the collapse of subglacial deposits also causes their movement. M

Mud-and-stone flows in such centres occur without heavy rains. Mudrock flows can also be formed on bared surfaces of steep slopes in the upper reaches of mountain streams when a long dry season is followed by excessive rains. As a result, almost the entire surface of the centre is covered with a layer of dust, and since it is waterproof, almost one hundred percent runoff of storm precipitation occurs in the form of a mudrock mass, which entrains a large amount of debris in its movement.

The formed mixture moves along the channel of the watercourse in the form of a cohesive (structural) mud-and-stone flow (if the amount of rainfall is in the range of 10-20% of the weight of the entire mudflow mixture) or a not cohesive stream (the amount of rainfall is 70-80% of the whole mixture weight) or storm rainfall (the amount of storm precipitation is more than 95% of the total mixture [2].) Thus, a structured (cohesive) muddy (mud-and-stone mixture) stream consists of rock debris, crushed stone, plant residues, and covering them mud components. Such flow contains 80 ÷ 90% (by weight) of solid material and 10 ÷ 20% of water (in a bound state) .The density of such a mixture is 1.8 ÷ 2.3 t/m^3, the driving medium is a plastic mud-and-stone conglomerate. Turbulent mudflow is an aqueous medium enriched with a colloidal suspension, it conveys a chippy mass and some large stones, its density varies from 1,1 to 1,7 t/m^3, solid inclusions within 10 ÷ 70 percent.

The transporting medium is a water-colloidal mixture. As can be seen from the foregoing, mudrock flows, depending on the density, can be attributed to both Newtonian and non-Newtonian fluids. Therefore, in solving specific practical problems, it is required to use the laws of mechanics of both Newtonian and non-Newtonian fluids. It should also be noted that in the stream of water, where bound mudflows are formed, it is also possible to form inbound mudflows. Where such mudflows are formed, the formation (in this particular basin) of bound mudflows is not necessary [1, 2].

A precise estimate of the resistance of the channel plays an important role in determining the values of the flow velocities. For a purely water flow, this problem can be solved successfully, for the roughness factor ***n*** is set in dependence on the material which constitute the channel bottom and the walls. The values of ***n*** for different types of channels are listed in the tables [3].

For mountain and mudrock flows, the solution of the problem of determining the resistance of the bed and, especially, the roughness coefficient becomes much more complicated. As field and laboratory studies show, the dynamics of sediment carrying flows, the roughness coefficient in this case, even in the developed turbulence, depends not only on the roughness of the channel material, but also on a number of the flow and sediment characteristics.

In [4], a detailed analysis of works of a number of authors (Yu.V. Chernov, R.A. Shestakov, B.A. Topchevskaya, G.V. Zheleznyakova, A.K. Ananyan and others), where indicate the influence of the channel slope, the Froude number and other parameters on the roughness coefficient is indicated has been presented. And in the work of O.M.Ayvazyan [5], it is noted that the coefficient ***n*** depends on the slope or on the Froude number not only in sediment carrying flows, but also when the water flow moves in channels with high and/or reinforced roughness.

When generalizing the experimental data obtained for trays with reinforced roughness, A.A. Alekperov [6] also indicates the presence of the effect of the slope on the roughness coefficient.

Artificial, reinforced roughness is developed in rapid channels with the aim of reducing the kinetic energy of the flow. The heights of the reinforced roughness are also developed in natural channels in which fine particles are washed out under the impact of the flow and the unconsolidated large boulders form a naturally reinforced roughness. As pointed out in the work of M.A.Velikanov [7], in such problems "... we have a case of channels of extreme roughness, generally little explored experimentally, where the resistance increases very rapidly with speed."

Conflict settings. A number of formulas are available for determining the roughness coefficient for sediment carrying flows. Existing in the literature dependencies, almost without exception, refer to natural, deformable channels. For artificial structures this problem has not yet been solved and is of a certain practical importance.

Research results. Mountain streams and sediment carrying flows slightly differ from each other in terms of qualitative structure of the resistance formation. If roughness heights (boulders) are mainly consolidated along the bottom in mountain beds, then in sediment carrying streams the role of such protrusions is played by large and medium-size particles of moving sediments (especially in man-made structures - channels), whose speed is quite lower than the average velocity of the flow itself . If the average flow velocity is taken equal to the difference of the above two velocities, then in such a case the sediments relative to the flow will be in a relative rest, as if fixed to the bottom.

One of the first formulas for determining the roughness coefficient for mountain sediment carrying flows is the Shtrikler-Chang formula [8]

$$n = Kd_o^{1/6}, \tag{1}$$

where K is the experimental dimension coefficient. According to the Strikler, K = 0.047, according to Chang, K = 0.052; d_o is average diameter of bottom sediments or self-paving, m.

Later, the structure of the formula (1.8) was used and confirmed by other researchers. In particular, for different ranges of variation of the ratio h/d_o (h is the depth of the flow) V.F.Talmas and A.N.Kroshkin suggested corresponding values for K and the exponent for d_o [9, 10].

Later, by using the formula that determines the diameter of the bottom sediments, they propose the following expression for determining the coefficient of roughness of mountain rivers:

$$n = A \cdot (h \cdot i)^m, \tag{2}$$

where A and m are determined as a function of h/d_o.

A form similar to formula (1.9) has a V.M. Makkaveeva's semiempirical formula [11], which he derived from some theoretical considerations using the full-scale measurements on the Rhine River.

Formulas (1) and (2) and similar to them expressions have the following drawbacks: each of them is valid only for a certain interval of hydraulic and granulometric parameters of flow and self-paving of the channel, there do not take into account the influence of the amount of sediment load. For highly saturated streams this parameter is quite essential.

The velocity of the sediment carrying flow is the most important factor determining its dynamics. Unlike single-phase flow, the two-phase one is inhomogeneous. Constantly changing factors impart the movement a more unsteady character. The interaction of sediment and water in the process of movement, the channel characteristics are variable (sometimes very sharply), to which the solid and liquid phases react differently, complicate and make difficult the solution of the problem.

Therefore, the possibility of obtaining reliable theoretical dependences, particularly, for determining the mudflow rate, now is practically impossible. The solution of this problem even in simple cases, when the flow is uniformly steady-state, presents serious difficulties.

As for the experimental field data, they have been accumulated in a sufficient amount for the water flow, whereas for mudflows such data are not very limited, and the accuracy of their measurements is doubtful. Therefore, to determine the velocity of sediment carrying mudflows, the structure of the Chezy formula is often used.

The overwhelming majority of the formulas available for velocity determination rely on the processing of data gathered by field and laboratory measurements of sediment transporting flows. These dependencies give more or less good results for certain intervals of characteristic parameters of the flow, sediments and the channels, limited with initial data. Basically, the proposed formulas refer to the determination of the velocity of mountain streams and mudflows in natural channels, the bottom of which is deformed.

Recommendations for determining the average velocity of sediment transporting high-concentration flows in channels with a non-deformable bottom, and moreover, in the case of the limiting transport capacity of the flow, are actually absent in the literature. By its structure, the existing dependencies can be divided into two groups:

1. Formulas in which the average velocity of a sediment carrying flow is determined depending on the maximum dimensions of the transported particles and on the hydraulic flow parameters.
2. Formulas based on the structure of the Chezy formula, with its appropriate correction and the introduction of parameters that take into account additional resistances, conditioned by the presence of solid particles in the water stream.

We note that according to Thierry's formula [12] and similar to it expressions of the first group, which have not found wide application, it is reasonable to determine the flow velocities corresponding to the movement of solid particles of maximum dimensions. In this case, these formulas give more reliable results.

From the formulas of the second group, we note the empirical and semiempirical dependences of V.M.Makkaveev [11], I.F.Sribnogo [13], and Khan [8], which have the following common limitations:

on the one hand, the characteristic of the resistances of different channels in them is taken into account by constant numbers, while in this channel it can vary quite essentially;

on the other hand, these formulas do not include such important factors as the granulometric characteristics of transported sediments.

In the methodical instructions on the anti-mudflow structures developed by the association "Soyuzavtomatika", researchers M.F.Talmaz and A.N.Kroshkin using the obtained connection (2), suggested the following formula for calculating the average speed of the sediment transport

$$V = K\left(\frac{h}{d_o}\right)^{0,3}\sqrt{qIh}, \tag{3}$$

where K is a coefficient that depends on the concentration of the stream, and is in the interval from 1.4 to 2.9; q is the specific flow rate; h is the depth of the stream; I is the slope of the channel; d_o is the diameter of the bed-forming soil.

Conlusion. The carried out review and analysis of techniques available in the professional literature for calculating the hydraulic characteristics of the flow (sediment carrying capacity, roughness coefficient, average velocity) show that the problem of studying the motion of mud flows is not sufficiently studied. This means that until now the problem of determining the sediment carrying capacity of the flow in different channel, ground and relief conditions remains insufficiently solved. Existing formulas for determining the velocity of sediment trnasport, mountain streams refer to natural, deformable channels. For rigid channels, such formulas are not available in the literature, especially for flows with high limiting sediment transport (mudflows).

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Բերվածքատար հոսքերի շարժման դեպքում խորդուբորդության գործակցի վերաբերյալ

Վ.Գ. Հայրապետյան
Շուշիի տեխնոլոգիական համալսարան

Խորդուբորդության գործակցի որոշման գոյություն ունեցող բանաձևերը վերաբերում են դեֆորմացվող, բնական հուներին: Ավելին, դրանցից շատերը առաջարկված են մասնավոր դեպքերի համար՝ փոքր կոնցենտրացիայի լեռնային հոսքերի համար: Գրականությունում առաջարկները, որոնք կիրառելի կլինեն մեծ կոնցենտրացիայի բերվածքատար հոսքերին, գործնականորեն բացակայում են, առավել ևս սելավային հոսքերի համար, որոնք շարժվում են կոշտ, չդեֆորմացվող հուներով, մասնավորապես՝ հոսքի սահմանային բերվածքատարողունակության դեպքում:

Բանալի բառեր. ջուր, գետ, ջրանցք, հատակ, տուրբուլենտություն, ջրամբար, հակասելավային:

О КОЭФФИЦИЕНТЕ ШЕРОХОВАТОСТИ ПРИ ДВИЖЕНИИ НАНОСОНЕСУЩИХ ПОТОКОВ

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Существующие формулы по определению коэффициента шероховатости относятся к деформируемым, естественным руслам. Более того, большинство из них предложены лишь для частных случаев – для горных потоков малой концентрации. Рекомендации применительно к наносонесущим потокам большой концентрации в литературе практически отсутствуют, тем более для селевых потоков движущихся по жестким, недеформируемым руслам, в частности, в случае предельной наносонесущей способности потока.

Ключевые слова. вода, река, канал, дно, турбулентность, резервуар, противоселевое