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Hydrology

Calculation Characteristics of the Cohesive Debris Flow Front Part Motion

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ABSTRACT. Methods of defining the calculation characteristics of the motion of cohesive debris flow front part in the cases, when surface of the river consists of easy and heavy deformed materials, are described. *© 2018 Bull. Georg. Natl. Acad. Sci.*

Key words: debris flow front part, surface of the river

Powerful, saturated with sediments debris flows, are mainly formed in erosion cuts, representing in a whole system of channels in the upper reaches of mountain streams. As a result of continuous destruction of rocks and their motion from the above lying areas the flows filled with detrital mass under weathering, pressure and under influence of various natural factors, grab detrital materials and fill the cavities between them. Mud and rock mixture prepared in this manner in the erosive incision is in cohesive state. Heavy shower, intense snow melting, ground waters grabbing rock fragments, tree trunks along the way advance downslope and turn into a powerful debris flow with huge destructive force [1-3]. Formed in this way mixture moves along the channel in the form of cohesive (structural) debris flow. The density of cohesive flow is 1.8 ÷ 2.3 т/м^3, making moving medium of the plastic mudstone conglomerate.

The motion of the cohesive debris flow is usually characterized by pronounced form of the front part, caused by mass variability of the due to inflow channel deviations or discharge of a part of debris mixture smoothing the surface of the directing channel. The process (the capture or flow-back, Fig. 1) depends on the level of stability of friction surfaces. In the case when the surface of the channel consists of an easily deformed (soft) material, the front (head) part of the stream destroys and captures the upper layer of channel deposits during motion, thereby increasing the mass (the depth) of the head part of the stream. In that case, the surface has the form of descending curve and specific discharge of the flow along the length has negative value.

Let us consider the scheme of flow motion in easy deformed channel (Fig. 1)

Assume that in the section 1 ÷ 1 the total depth of the flow is H (i.e, the tail part of the front flow) and discharge intensity (unit discharge per width) is $q = \frac{Q}{B}$. Taking into account that the discharge of cohesive debris flow [2] is:

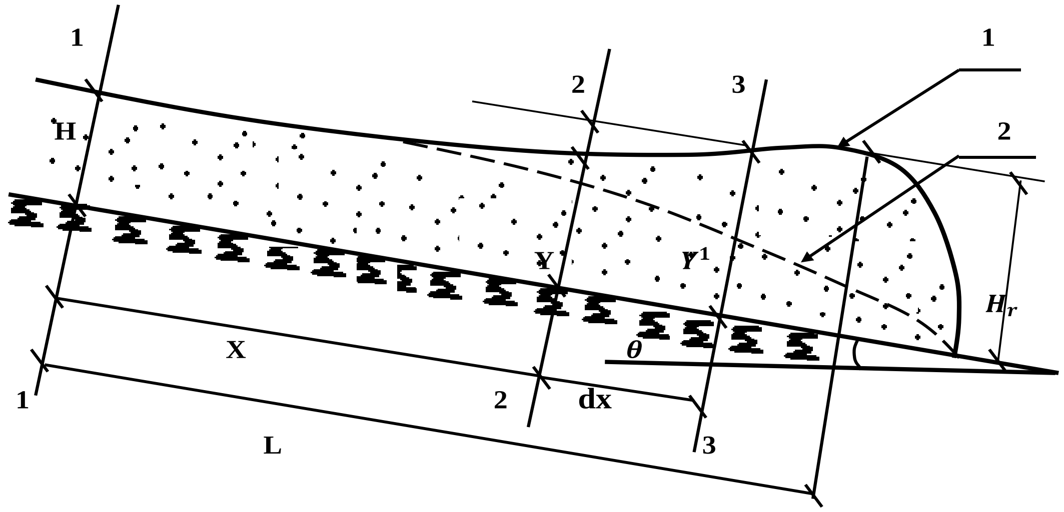

Fig. 1. Scheme for calculation of the profile of the head part of the coherent flow with deformable channel surface, where 1- for an easy deformed channel surface; 2 - for heavy deformed channel surface.

$$Q = \frac{BigH^3}{\nu}\varphi(\beta), \quad (1)$$

where $\varphi(\beta) = \frac{\beta}{2}(\beta^2 - 1) + \frac{1}{3}(1 - \beta^3),$

$\beta = \frac{h}{H}$ – the relative depth;

h - the depth of the core (the structural part of the flow i.e, the depth of flow from the free surface to the gradient layer);

ν – the coefficient of kinetic viscosity;

i – the slope of the channel;

B – the flow width in the channel with rectangular cross-section;

g – the acceleration due to gravity.

Then, considering (2) it follows from (1):

$$V = K_1 H^2, \quad (2)$$

$$q = K_1 H^3, \quad (3)$$

where V is the average section flow velocity

$$K_1 = \frac{gi}{\nu}\left[\frac{\beta}{2}(\beta^2 - 1) + \frac{1}{3}(1 - \beta^3)\right], \quad (4)$$

K_1 – has the dimension $\frac{1}{t \cdot e}$.

The specific discharge in section 2 ÷ 2, which is at X distance from the range 1 ÷ 1 will be:

$$q_x = K_1 Y^3, \quad (5)$$

in the range of 3 ÷ 3

$$q_x^1 = K_1 (Y + dy)^3. \quad (6)$$

Omitting small summands we have:

$$q_x - q_x^1 = -3K_1 Y^2 dy \quad (7)$$

or

$$q_0 dx = -3K_1 Y^2 dy, \quad (8)$$

where q_0 - flow rate per unit length and width within the head part of the flow.

Integration (8) is simplified if we assume that K_1=const and q_0 =const. Then the form of the front surface of the head part for both cases can be written by equation:

$$Y = \sqrt[3]{H^3 \pm \frac{q_0 x}{K_1}}, \quad (9)$$

where Y and X are the ordinate and abscissa of the curves describing the surface of the head part of the flow, respectively.

It is not difficult to note that before selecting the design of the anti-debris protective structure, first it is necessary to evaluate the stability of friction surfaces (debris flow and directing channel). From the dependence (9), it is possible to calculate the parameters of the head part of the flow and if it (the head part) has a convex shape, then the strength of the anti-debris construction should be taken with significant safety margin rather than at descending curve. The volume and shape of the head part of the flow determines the force of the flow impact, as well as the area of the protective structure being subjected to impact. During the impact of the debris flow, the entire volume of the head part influences the construction. The maximum height of the head part with convex shape (H_r), as observed, is in the range of H_r=(1.5÷1.8) H.

ჰიდროლოგია

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