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Hydrology

Solution of the Tasks of Small Deflection on Free Surface of Cohesive Debris Flow from the Depth of Uniform Motion

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ABSTRACT. Antidebris hydraulic constructions are used to catch and provide safety passage of debris flows by means of flumes over or under different types of objects (automobile roads, railways, etc.). Often waves in flumes having big amplitudes occur. It makes debris flows to spill over the walls of construction, while the uniform flow having the same mass quantity of debris would be kept in the borders. In present paper the task of small deflections of debris flow from normal depth in debris flume constructions with big slopes are solved. *© 2017 Bull. Georg. Natl. Acad. Sci.*

Key words: debris flow, hydraulic construction, debris waves

Heavy debris flows are mainly formed in erosive cuts presenting the whole system of river-beds in upper mountain areas and as a result of continuous destruction of mountain rocks and their motion from the upper areas, they are filled with broken mass grinded due to the impact of different natural factors. Mud mass formed in the process covers broken materials and fills the cavities between them. Prepared in this way debris mixture stays in cohesive state and in case of showers, intensive snow melting or any other similar reason it breaks down the stream grabbing pieces of rocks and trunks, etc., forming powerful debris flow with huge destructive force.

Such flow includes $80\div 90\%$ (in mass) of hard material and $10\div 20\%$ of water (in coherent state). Density of the mixture is $1.8\div 2.3$ t/m^3, moving medium is plastic mudstone conglomerate.

Antidebris hydraulic constructions are used for capturing and safe passage of debris flows with the help of debris flumes under or over different types of objects (automobile rode, railway, etc.) Often, waves having big amplitude appear in flumes. Debris flow spills over the walls of construction while the uniform flow having the same mass quantity would be just kept in the same borders.

From the above mentioned prognosis the solution of small deflection on free surface of debris flow from the depth of the uniform over in debris flume has great practical meaning.

This task can be solved by means of Saint-Venant long waves of finite amplitude equations.

These equations have the following form:

$$Y_0 - Y + \frac{\partial H}{\partial x} = \frac{1}{2g}\frac{\partial}{\partial x}\left(V^2\right) + \frac{1}{g}\frac{\partial V}{\partial t} \qquad (1)$$

$$\frac{\partial \mu}{\partial t} + \frac{\partial (V\mu)}{\partial x} = 0 \qquad (2)$$

where Y_0 – is the water flow slope;

H – full depth of the flow in the given cross section;

μ – area of live cross section;

V – average velocity in cross section;

Y – value of hydraulic slope for cohesive debris flow [1]:

$$Y = \frac{Q\neg}{g\mu H^3 f(\ \ )}, \qquad (3)$$

Q - debris flow discharge;

$\neg$ - Coefficient of kinematic viscosity.

$$f(\ \ ) = \frac{\ }{2}\left(\ ^2 - 1\right) + \frac{1}{3}\left(1 - \ ^3\right), \qquad (4)$$

where $= \frac{h_1}{H}$ is relative depth.

While integrating the above mentioned Saint-Venant equations (1) and (2) the adopted in hydraulics traditional assumptions are used.

Using method of "small perturbations" from (1) and (2) equations the liner differential equation of disturbed motion of cohesive debris flow is introduced [1]:

$$\frac{\partial^2 h}{\partial t^2} + 2V_0\frac{\partial^2 h}{\partial x \partial t}\left(V_0^2 - \frac{g\mu_0}{B_0}\right)\frac{\partial^2 h}{\partial x^2} + $$
$$+ \frac{Y_0 g \partial h}{V_0 \partial t} + \left(Y_0 g - 2\frac{Y_0 g \mu_0}{B_0 H_0}\right)\frac{\partial h}{\partial x} = 0 \qquad (5)$$

Here, index "O" means the values corresponding to undisturbed flow motion, i.e., to uniform regime of motion, and "h" is the height of the wave of disturbance, B is the flow width. Taking into account that $H = H_0 + h$; $V = V_0 + u$; $Q_0 + q$, a „u" and „q" is the velocity and discharge of the wave of disturbance correspondingly, then general integral of one-dimensioned differential equation of disturbed motion of cohesive debris flow will have the following form:

$$h = a_1 e^{\frac{Y_0 g\left(1 - 2\frac{\mu_0}{B_0 H_0}\right)x}{g\frac{\mu_0}{B_0} - V_0^2}} + a_2, \qquad (6)$$

where „ a_1 " „ a_2 " are constants determined from the boundary equations. At the established regime, when the flow motion is uniform and there are no significant deflections, free flow surface form can be set. In that case, when

$$\frac{Y_0 g\left(1 - 2\frac{\mu_0}{B_0 H_0}\right)x}{g\frac{\mu_0}{B_0} - V_0^2} > 0, \qquad (7)$$

then in the direction of flow motion, i.e. at positive value „x", depths will increase (backwater curve) and at negative value „x" the depths will decrease (dropping curve) that shows about approximation of the depth value to a_2.

When x streams to minus infinity $(-\infty)$, the curve of free surface flow asymmetrically approximates to horizon of the surface of uniform motion. In this case " a_2 " is equal to zero. When doing engineering calculations, the curve of the length of free surface is defined to the cross section where the flow depth maximally approximates to the depth of uniform motion. In that case when $x = x_1$ it is possible to calculate the growth of the depth h, i. e., $a_1 = h'$ and instead of (6) it will be as follows:

$$h = h' e^{\frac{Y_0 g\left(1 - 2\frac{\mu_0}{B_0 H_0}\right)(x - x_1)}{g\frac{\mu_0}{B_0} - V_0^2}} \qquad (8)$$

The obtained dependence makes it possible to find connection between the depths of different cross sections, which are distanced from each other on the distance $(x - x_1)$. The form of free surface, (the curve of backwater or the dropping curve) will depend on the sign before h' (positive or negative).

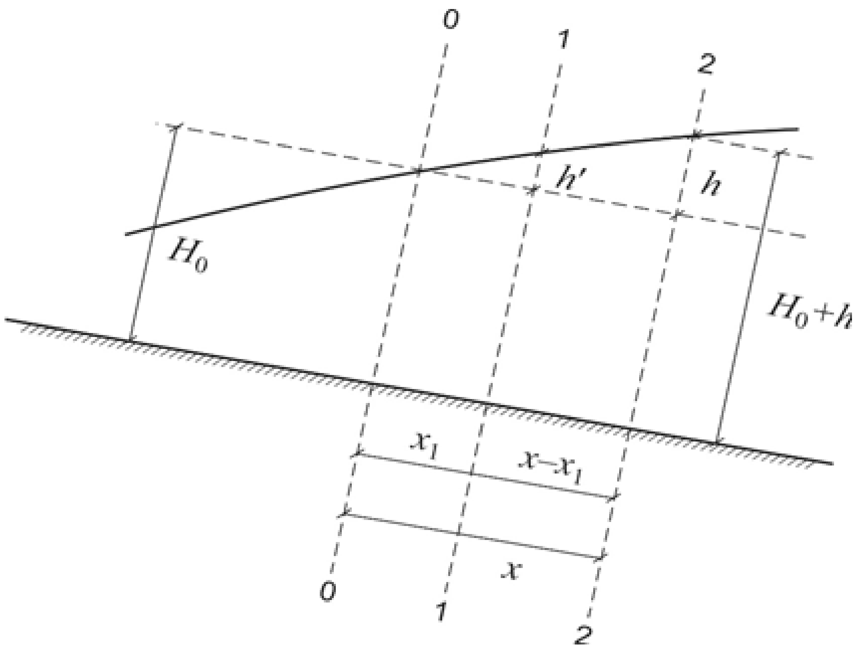

Fig. Scheme of calculation of the wave of disturbed (height deflection) on free surface at uniform motion of cohesive debris flow.

The Example of Calculation

To find the height of the disturbed wave „*h*" in the relation to the depth H_0 of the uniform motion of cohesive debris flow for flume with straight angle form of lateral cross section, i.e., to find in 2÷2 cross section depth „*h*" from cross section 1÷1 on the distance $(x-x_1)=30-10=20$ m. (Fig.).

At $Q_0=60m^3/c$, $B_0=10m$; $Y_0=0.09$, $\beta=0.8$, $h^{'}=0.1m$, $\nu=0.003m^2$/C.

Solution. Depth of uniform regime of flow motion at $Y=Y_0$ equals (3):

$$H_0=\sqrt[3]{\frac{Q_0\nu}{B_0 g Y_0 f(\beta)}}=\sqrt[3]{\frac{600\cdot 0.003}{10.9.81\cdot 0.09\cdot 0.18}}=1.042$$

Then the velocity of uniform flow motion is:

$$V_0=\frac{Q_0}{B_0H_0}=\frac{60}{10\cdot 1.042}=5.76m/c$$

Define the ratio:

$$\frac{Y_0 g\left(1-2\dfrac{\omega_0}{H_0B_0}\right)}{g\dfrac{\omega_0}{B_0}-V_0^2}=\frac{0.09\cdot 9.81(1-2)}{9.81\cdot 1.042-5.76^2}=0.0386$$

Then from (8) it follows that

$$h=h^{'}e^{\frac{Y_0 g\left(1-2\frac{\omega_0}{B_0H_0}\right)(x-x_1)}{\frac{g\omega_0}{B_0}-V_0^2}}=$$

$$0.1\cdot 2.718^{0.986(30-10)}=0.216m$$

Correspondingly the height of the wave in cross section 2÷2 will be

$$H_0+h=1.042+0.216=1.26m.$$

ჰიდროლოგია

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