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Hydrology

The Influence of Cross Section River Bed Form on Hydraulic Elements of Debris Flow

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ABSTRACT. The introduced dependencies give the possibility to define the run-off and rate of cohesive debris flow in prismatic channels with different cross sections using inertia moment of distortion of prismatic form core. *© 2019 Bull. Georg. Natl. Acad. Sci.*

Key words: cohesive debris flow, inertia torsion

Cohesive (structural) debris flow (mudstone mixture) consists of rock fragments, crushed stones, plant remains and covered with mud debris flow constituents. Such flow includes 80-90% (in mass) of hard material and 10-20% of water (in cohesive state). Density of such mixture is 1.8-2.3 t/m3, moving medium is plastic mudstone conglomerate.

Cohesive debris flow run-off at uniform motion regime in cross section river bed is defined according to dependence [1-4]:

$$Q = \frac{BgiH^3}{\nu} f(\beta), \tag{1}$$

where

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

B – rectangular river bed width;
H – full flow depth;
h – depth of flow structural part;
$\beta = \frac{h}{H}$ - relative depth;
g – gravitational acceleration;
i – river bed slope;
ν – kinetic coefficient of viscosity.

Dependencies (1)(2), noted above, are mainly true for wide river beds with rectangular cross sections.

Taking into account any form of the river bed cross section, we can use methods suggested in [5-8], where characteristics of river bed cross section are changed by formula:

$$\frac{H^3 B}{3} = Y_{кр.}, \tag{3}$$

where $Y_{кр.}$ – inertia moment of core distortion of rectangular cross section (in this case, prismatic channel with rectangular cross section), when $B/H \to \infty$.

In that case, instead of (1), we shall have:

$$Q = \frac{giY_{кр.}}{\nu} f(\beta) \tag{4}$$

The truth of the given change for Newtonian fluids, in which secondary flows are observed, is proved [6-8].

Such the change is more evident in the non-Newtonian fluids, where due to high viscosity value and initial shift resistance at flow motion, dead levels are formed in directing walls with river bed bottom angles. In the above cases, the phenomenon causes sharp redistribution of both normative and shearing stresses in hydraulic cross section.

In the frames of one-dimensional (i.e. hydraulic) statement of the phenomenon, it is necessary to use also the averaged characteristics of shearing stresses in the limits of hydraulic cross section, as it is accepted in hydraulics (run-off, averaged hydraulic cross section rate, etc.).

Then the averaged flow-rate for non-Newtonian fluids (structural debris flow) will relatively be:

$$V_0^{нн} = \frac{Q_{нн}}{\omega} = \frac{giY_{кр.}}{\nu\omega} f(\beta)\,, \tag{5}$$

where: ω – hydraulic cross section flow area.

Let us designate the radius of distortion inertia via:

$$i_{кр.} = \sqrt{\frac{Y_{кр.}}{\omega}}\,. \tag{6}$$

Then, instead of (5), we have:

$$V_0^{нн} = \frac{gi\,i_{кр.}^2}{2} f(\beta)\,. \tag{7}$$

Numerical values $Y_{кр.}$ for bars with different cross sections are provided in the guides on strength of materials. For instance, for channels with rectangular cross section the following relation can be used [9]:

$$i_{кр.} = K_1 B \cdot H^3\,, \tag{8}$$

where K_1 is the proportionality constant.

Table. Numerical values of the aforementioned coefficient K_1 depending on the ratio B/H

B/H	1	2	3	4	10	∞
K_1	0.141	0.229	0.263	0.281	0.312	0.333

The coefficient of proportionality can be defined by means of approximate dependence:

$$K_1 = \frac{1}{3 + 2\left(H/B + \dfrac{H^2}{B^2}\right)}\,. \tag{9}$$

For wide rectangular river bed $K_1 = \frac{1}{3} = 0.333$.

Taking into account (8) and $\omega = BH$, from (6) it follows:

$$i_{кр.}^2 = K_1 H^2 \tag{10}$$

or

$$H = \frac{i_{кр.}}{\sqrt{K_1}}. \tag{11}$$

The presented statements give the possibility to calculate run-off and averaged on cross section flow rate for cohesive debris flows in prismatic chanels with different rectangular cross sections.

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