SPECIFICATION OF SEDIMENT-CARRYING CAPACITY BY STREAM BASED ON THEORY OF DIMENSIONS

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Analysis of calculation methods of sediment-carrying capacity by stream allowed the authors to determine basic parameters conditioning the sediment-carrying capacity by the stream S or the sediment discharge value Q_t.

The value of the motion of the sediment-capacity of the mountain rivers is less determined today. Based on the research analysis of the field and in-situ observations, the issues of flow, drift and bed parameters determining the sediment discharge value are worked out. Using the theory of dimensions, criterion equation for specifying the sediment-carrying capacity by the stream is obtained.

Key words: Flow/stream, sediment discharge, river bed, theory of dimension.

An attempt to work out criterion equation for specifying the sediment-carrying capacity based on the theory of dimensions was made in the work.

A lot of methods were proposed for calculating the sediment-carrying capacity or sediment discharge. They involve various conditions and forms of motion: bed silt and weighted sediments, hydrotransport, flood and mud streams, etc.

These design expressions also vary from one another by their obtaining methods, there are just completely theoretical (M. A. Velikanov, V. M. Makkaveev and A. V. Karaushev), completely experimental (M. A. Mostkov, A. H. Gostunski, I. B. Bekimbetov) and semiempirical (I. I. Levi, U. Graph, G. A. Einshtein, P. O. Baldjan) ones. Major part of the mentioned dependences has very narrow interval of applicability since they are obtained for insignificantly saturated streams. For mountain and submountain channels scanty design expressions have number of substantial defects: either due to heterogeneousness of the factors effecting the sediment discharge their structure is complicated enough (Z. Mayer-Peter, R. G. Asatrjan, P. O. Baldjan, etc.), or they are too simple due to not considering important parameter parts (M. A. Mostkov, I. I. Rossinski, O. Brein, etc.).

It is obvious that the motion of the sediment-carrying flow occurs under the conditions of the flow, bed and sediments permanently affecting one another. Some characteristics of the flow, bed and sediments specify the carrying capacity value S or the sediment discharge capacity Q_T.

Analysis of the applied and above mentioned methods to calculate the carrying capacity value S as well as the analysis of the results of many experimental and field researches (M. A. Vinogradov, R. Ter-Minasjan, R. G. Asatrjan, P. O. Baldjan) allowed the authors of the work to identify a circle of main parameters conditioning the carrying capacity value S (the sediment discharge value Q_T).

These parameters are average and dynamic flow velocity - V, V_*; inclination and average value of the prominence of the channel roughness i_0 and Δ, and sediment diameter and their nonuniformity d_0, j. They allow to write the following functional relationship for the carrying capability of the mountain channels:

$$S = f\left(V, V_*, i_o, \Delta, d_o, j\right). \qquad (1)$$

Nonuniformity factor j is a nondimensional parameter. Its value according to A. Kramer changes within the interval of $0 \lhd j \lhd 1$. The less j, the more heterogeneous the sediment composition. As the experimental researches [1] and field observations [2] show, the more heterogeneous the composition, the more the carrying capacity. Taking into the account this fact, it is accepted to present the sediment parameters d_0 and j in form of relation d_0 / j.

Based on the above, according to the method of the theory of dimensions [3], functional dependence (1) can be presented in form of the product of degrees:

$$S_0 = K \cdot V^X \cdot V_*^Y \cdot i^Z \cdot \Delta^t \left(\frac{d_0}{j} \right)^{\varphi}, \tag{2}$$

Where K - nondimensional factor of proportionality; S_0 - carrying capability in undimensional form:

$$S_0 = \frac{Q_T}{Q}. \tag{3}$$

(Here the sediment discharge Q_T and flow discharge Q have equal dimension – m^3/d).
Degree values x, y, z, t, φ have to be specified from the conditions of unit equality of the values of left and right parts of the equation (2). Taking into the account the main units: length, mass and time (L, M, T), the equation (2) in terms of these units can be written as:

$$L^0 M^0 T^0 = \frac{L^X}{T^X} \cdot \frac{L^Y}{T^Y} \cdot L^t \cdot L^{\varphi}. \tag{4}$$

In equaling the indicators of the respective units, will have:

$$\begin{cases} x + y + t + \varphi = 0; \\ x + y = 0. \end{cases} \tag{5}$$

Solution of the equation system provides $x = -y$ и $t = -\varphi$, however the factual indicator values were not obtained because the number of unknown values in the equation (2) is 5 (x, y, z, t, φ) and there are two equations of the dimension equality (parameters with the mass unit is absent). For further elaboration the method of the theory of dimensions called "theorem π" is used. Based on the theorem the equation like (2) can be presented by the criterion equation with nondimensional criteria where each of which, except for the remainder, includes two basic independent parameters selected from the function (1). Flow velocity V and prominence of the channel roughness Δ were selected as these independent parameters. Than, instead of the dependence (1), can be written [4]:

$$f(\pi_1, \pi_2, \pi_3, \pi_4) = 0. \tag{6}$$

Based on the "theorem π" will have:

$$\pi_1 = V^{-x_1} \cdot \Delta^{-y_1} \cdot S_0. \tag{7}$$

Equality of the units of this equation gives:

$$\left(\frac{T}{L}\right)^{x_1} \cdot \frac{1}{L^{y_1}} = L^0 \cdot T^0, \tag{8}$$

or

$$\begin{cases} x_1 + y_1 = 0; \\ y_1 = 0, \end{cases} \tag{9}$$

According to which $x_1 = y_1 = 0$. Respectively, the first obtained criterion - $\pi_1 = S_0$.

Similarly, instead of the dimensional equation (2), the following nondimensional criterion equation is derived:

$$S_0 = K_0 \cdot \left(\frac{V}{V_*}\right)^{X_0} \cdot i_0^{Y_0} \cdot \left(\frac{d}{\Delta j}\right)^{Z_0}. \tag{10}$$

It is necessary to determine the indicator values of the degrees of this equation x_0, y_0, z_0 based on processing the experimental and full-scale data.

As a result of determining the above values, the equation (10) can be used for the identification of the carrying capability or the sediment discharge of the mountain channels.

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