DOI: https://doi.org/10.5281/zenodo.12346255

A BRIEF ANALYSIS OF METHODS FOR CALCULATING THE FLOW RATE OF FLOW IN AN UNBOUND SOIL CHANNEL

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Abstract: *Based on the Ackers-White dependencies for determining sediment flow in stationary flows, a method for calculating sediment with an unsteady flow is proposed, taking into account the division of sediment into bottom and suspended, which relates to the calculation of sediment transport itself.*

Key words: *sediment, bottom and suspended sediment, unsteady flow, wave, dimensionless parameters, passing flow.*

During the washing process of a watercourse, the nature of the flow represents active forces, and the physical-mechanical properties of the soil represent weak (resistance forces). We will consider the influence of flow dynamic factors on the washing of riverbed soil.[2]

Currently, the following two methods are used to assess the reliability and strength of the watercourse:

1) the method of non-washing rate of flow, which represents the resistance of soils to washing;

2) the method of forces acting on the bottom particles in the direction of movement of the water stream and dislodging them (displacement or frictional forces).

One of the main issues in the design and calculation of the channel is the choice of permissible velocities, the determination of the width, average and maximum depth of the channel at the water level, and the shape of the bed at the normal water level of the channel.[3]

The main purpose of the method of non-washout velocities is that the average speed of the channel water flow should not be greater than the flow speed that washes the soil of its bottom and sides, and at the same time should not be less than the sedimentation speed, i.e.

$$\vartheta_{чўк} \leq \vartheta_{ўр} \leq \vartheta_{adm}$$

where $\vartheta_{чўк}$- the minimum average speed of the flow that does not allow sedimentation of channel discharges and vegetation growth; ϑ_{adm}- permissible speed of flow; $\vartheta_{ўр}$- the average speed of the flow.

As a result of the fulfillment of this condition, the channel soil is not washed away by the flow and the moving liquid does not sink to the bottom, that is, the correct operation mode of the channel is ensured.

At the same time, it is required to ensure sufficient stability of the cross-sections of the channel to be designed. For this, S.A. According to the Girshkan formula, the relative width of the solid core is determined:

$$\beta_{mus} = \frac{b}{h} = 3\sqrt[4]{Q} - m \tag{1}$$

Channel beds that satisfy this condition are called static stable beds.

The method of non-flow velocities is more widely used in the CIS, Asia and the USA. This method is based on roughness coefficient, channel side slopes, maximum permissible velocities, followed by hydraulic radius, wetting perimeter, etc. includes accounts. Calculation algorithms of these methods are detailed in many works.[1]

The mode theory method is based on the idea of flow stability or mode channel design. Regulated channel is defined as a channel in which the unbound subsoil of the channel is in a state of equilibrium, that is, it is not washed away during the transport of liquid, and the liquid does not settle in it .

Research shows that the following functional relationship can be written for the average non-flushing flow velocities :

$$\vartheta_0 = f(\gamma_s, \gamma, S, T, N, M) \tag{2}$$

where T is the parameter taking into account the turbulent flow; N is a parameter that takes into account the connection between particles; M - other sizes.

The study of the indicated functional binding began after the studies of Dubois. On the other hand, the following analytical connection for determining the flow velocities was proposed:[4]

$$\vartheta_0 = A_1\sqrt{\gamma_s - 1}\sqrt{gd} \tag{3}$$

V.N.Goncharov and G.N.Lapshin, on the basis of Dubois's calculation scheme and laboratory studies conducted in a very wide range of flow depths, express the force moving the particle through subsurface velocities, and accept the parabolic law of velocity distribution over depth, and recommend calculating the non-washout velocity of the flow from the following formula :[5]

$$\vartheta_0 = 1{,}25(1 + 0{,}14/d)^{0{,}3}\sqrt{gd}(h/d)^{0{,}2}. \tag{4}$$

Velikanov , V.N. Goncharov, I.V. Egizarov, V.M. Makkaveev, G.I. Shamov, A.N. Gostunsky, A .M.Mukhamedov, Ts.E.Mirtskhulava and other scientists conducted a number of their researches and proposed their formulas based on their results.

Acad.Ts.E. Mirtskhulava among the available formulas The correlations for establishing non-leaching velocities of unbound soils proposed by This connection was made on the basis of the analysis of the conditions of equality of the shearing forces of individual particles and the forces acting on the turbulent flow, as well as the shear resistance forces, taking into account the fatigue state of the soil from the total mass, on the uneven surface of the bottom of the channel. The link looks like this:

$$\vartheta_{\text{r.e}} = \left(lg\frac{8.8h}{d}\right)\sqrt{\frac{2m}{0{,}44\rho n}\left[g\left(\rho_{gr}-\rho\right)d+2C_{k.m}^{n}k\right]} \quad (5)$$

$$\vartheta_{\Delta r.e} = 1.25\sqrt{\frac{2m}{0{,}44\rho n}\left[g\left(\rho_{gr}-\rho\right)d+2C_{km}^{n}k\right]}$$

(6)

where $\upsilon_{\text{r.e}}$- the permissible non-flushing speed of the flow on the cross-section, м/с; $\upsilon_{\Delta\text{r.e}}$- uzan gadir - the permissible speed of the stream in front of the bottom at the height of м/сthe turbidity , Δ; $\rho_{\text{gr}}$and ρ - the density of soil particle material and water, respectively кг/м^3; d - average diameter of soil particle, $м$; $C_{\text{k.m}}^{n}$- the weakened strength at break of the unbound soil, that is , the coefficient that takes into account Pathe formation of significant cohesive forces in small Unbound soils with this parameter , $d < 0{,}25мм$; m - the coefficient that takes into account the effect of colloidal substances contained in the stream on the washing ability of the stream. If there are 0.1 clay particles in the water кг/м^3, $m = 1$. If there are 0.1 or more of $m > 1$these particles in water кг/м^3, n - the coefficient that takes into account the speed pulsation in the upstream zone; k - the coefficient characterizing the probable deviation from the bite force equal to the average ( ) value.$k = 0{,}5$

From the studies conducted by the authors to determine the rate of non-flushing of the stream, the ratio of the rate of flushing to the rate of non-flushing is equal to the value of 1.3 **- 1.5.** If this ratio is considered to be equal to the average value of 1.4, then it has the following expressions:[6]

$$\frac{\vartheta_{ю}}{\vartheta_{adm}} = 1{,}4 \quad (7)$$

or

$$\vartheta_{ю}=1.4\,\vartheta_{adm}, \quad (8)$$

where $\vartheta_{ю}$- the washing speed of the stream; ϑ_{adm}- non-flushing flow rate.

The relationships proposed above for determining the rate of runoff give different results under conditions of the same hydraulic and soil characteristics. The results of the comparison of these links showed that they differ from each other $\pm$by up to 50%. This is because each author has proposed their own connections based on their own experiences in different settings.[7]

The basis of the method of forces that eject particles from the soil under the influence of flow is the friction of the allowable tensile stresses at the solid boundary of the flow when the soil particle has not yet moved. In essence, the basis of this method is the same as the flow rate method. In this or other cases, the cross sections of the channel should be selected in such a way that the bed bottom and side slopes should not be washed away.

In the movement of water in the channel, a force appears that acts on its bottom in the direction of the flow. This force manifests the attraction of water on the wetting surface and is called the release force or friction force (sliding force). The average magnitude of the yield force on the surface of the live cross-section (underlying stress) per unit current is equal to the following:

$$\tau_0 = \frac{\rho g \omega \ell I}{\ell \chi} = \rho g R I. \qquad (9)$$

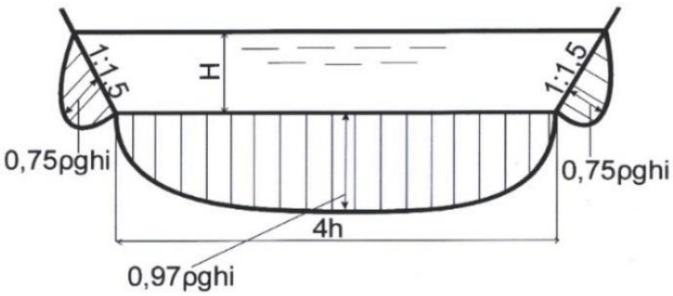
$\chi$the wetting perimeter $R$is very large compared to the hydraulic radius (1.9), it will have the following form:

$$\tau_0 = \rho g h I \qquad (10)$$

(1.10) formula$\chi > 30R$ is appropriate when the condition is met. It is in these types of channels that the stress can be considered to be evenly distributed along the perimeter of the damping. But this legality can theoretically happen only in special cases.

In trapezoidal channels, the experimental stresses are unevenly distributed along the perimeter of the damping. There have been many attempts by researchers to establish the regularity of the distribution of experimental stresses.

A number of scientific works in this field have been carried out by US researchers. Based on the theoretical hypothesis by the engineers of the US Bureau of Reclamation, the maximum values of the effort stresses at the bottom of the trapezoidal channels $0{,}97\rho ghi$, and the values on the side slopes$0{,}75\rho ghi$ is set to be equal (Fig. 1.1).



1. Distribution of the relative forces of the flow along the perimeter

From another point of view, the distribution of test stresses is based on the connection at any point of the damping perimeter (from the corner of the test bed to the point of the channel profile). (Fig. 1. 2).

$$\rho ghi = \frac{\tau_0}{\cos \Theta} \quad (11)$$

or

$$\tau_0 = \rho g h_в i \cos \Theta \quad (12)$$

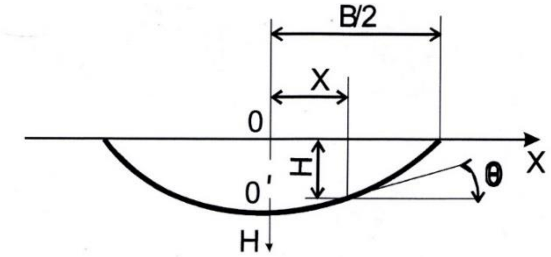


Figure 2. Distribution of the relative forces of the flow along the perimeter

Channel depth$h_в$ At the end of the channel, the stress on the subsurface axis will be less compared to the wide channels with the same depth. G.P. Skrebkov [42; p. 85-89], taking into account this condition, offers the following formula for calculating the test voltage:

$$\tau_0 = \lambda g \frac{\vartheta^2}{2} \quad (13)$$

or

$$\tau_0 = \frac{\rho g \vartheta^2}{C^2} \quad (14)$$

E. Lane developed the method of forces for releasing underground fluids. As a result of this method , the equation of the ratio of allowable stress on the bottom and side slopes of the channel was created:

$$\left(\frac{\tau_{ot}}{\tau_{tub}}\right) = K = \sqrt{1 - \frac{\sin^2 \psi}{\sin^2 \Theta}} \quad (15)$$

where τ_{ot}- permissible stresses on the side slopes of the channel; τ_{tub}- allowable stresses under the bottom of the channel; ψ - the angle of the side slope of the channel with the horizon; Θ - natural slope angle.

The special value of this method is that it is possible to evaluate the strength of the soil in the bottom of the channel and on the side slopes, which is difficult to implement using the non-washout method.

However, the factors determining the physical **and** mechanical properties of bonded and unbonded soils are not fully taken into account, which does not provide sufficient accuracy in determining the allowable stress.

Studies on the distribution of ultimate stress in open channels were carried out by S. Cosh and N. Roy at the Indian Institute of Technology. In order to have high accuracy at different points of the cross-section, the experimental stresses were measured using three different methods. According to the results of the research, the following conclusions were reached:

- the distribution of local effort stresses on the side slopes of the channel according to the flow depth does not correspond to the law of depth change;

- from the flow level on the side slopes of the channel (0.55 - 0.77) h it was found that the values of the maximum effort stresses on the side slopes of the channel are 10-30% higher than the values at the bottom.

In the Leningrad Polytechnic Institute and in the central research institutes for the integrated use of water resources, **a** number of studies were conducted on the distribution of experimental stresses along the perimeter of wetting. Based on the condition of equilibrium in the elemental part of the liquid located between two vertical planes parallel to the flow movement, the connection of the distribution of longitudinal stress along the perimeter of the wetting channel without pressure is assumed as follows:

$$\tau_{в} = \left[\rho g h i + \frac{d\tau_{xy}h}{dy}\right] \cos \Theta \tag{16}$$

where h **-** the depth of the stream in the vertical; τ_{xy}**-** the average turbulent stress in the vertical; y **-** transverse coordinate; Θ **-** the angle between the attempted perimeter and the horizontal plane at the point.

Despite the existence of many scientific works devoted to this issue by a number of researchers, even now this problem has not been excluded from the field of hydraulics of streams.

Underlying the method of mode theory is the idea of fluid stability or the design of mode channels. Regulated channel is defined as a channel in which the underlying unbound soils of the channel are in a state of equilibrium, that is, it does not wash out during the channel transport and sediment does not settle in it.

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