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CALCULATION OF PARAMETERS OF LIVING SECTION OF IRRIGATION CHANNELS

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Annotation: The article analyzes the existing calculation formulas for establishing the width of a stable channel, compared the calculated, laboratory and field data, and on the basis of this, a dependence was obtained to calculate the relative width of stable earthen channels in sandy unbound soils.

Key words: Channel, stability, hydraulic size, deposits, flow depth, hydrodynamic stability, quasistability of the flow.

A necessary requirement when designing earthen channels is the consciousness of an efficient system that could transport a given amount of water and sediment and would not require significant operating costs for channel straightening work throughout its entire period of existence.

Currently, when calculating the size of stable channels, two main approaches are used: analysis of the morphometry of channels based on regime theory and a physical approach based on the study of physical processes occurring in channels with deformable banks and bottom. The method of regime theory arose at the turn of the 19th and 20th centuries in connection with the construction of an irrigation system in India.

The physical approach includes three main methods for calculating channels: the limiting drag method, developed in the USA in the early 1950s, the permissible speed method, created in the USSR in 1930-1940, and the method for determining the morphometry of stable channels based on the theory of hydrodynamic stability. The latter method was developed relatively recently (late 60s early 70s), however, despite the short period of its existence, in a number of cases it made it possible to correctly describe complex physical processes occurring in channels with a movable bed.

The concept of the regime was formulated on the basis of field and laboratory studies conducted in a number of countries. Thus, Lindley [2] defined the starting position of regime theory as follows; "The dimensions, width, depth and slope of the channel for transporting a certain flow of water and sediment are always predetermined by nature (Dynature)". There are a large number of regime dependencies, confirmed by a large number of experimental data, the main ones of which include the following:

1) [3,4] Lacey:

$$V = 0{,}635\sqrt{f^{R}} \quad (\text{m/s})\,; \qquad (1)$$

$$\chi = 4{,}8Q^{0{,}5} \quad (\text{m})\,; \qquad (2)$$

$$1=0{,}000304\, f^{5/6}\ , \qquad (3)$$

where: V – average flow velocity;

R – hydraulic radius;

χ - wetted perimeter;

I – channel slope;

f – channel grounding parameter associated with the average diameter of bottom sediments by the dependence:

$$f = 50\sqrt{d_{cp}} \qquad (4)$$

2) Lacey, Pemberton [4]

$$\frac{V}{R} = U\left(R^{1/2}1\right)^{u} \qquad (5)$$

$$V=UR^{(u+1)/2}1^{u}$$

where: and U are the coefficient and exponent, respectively, which vary depending on the size of the sediment:

$$U=\omega^{1/2} / dc \qquad (6)$$

where ω is the hydraulic size of bottom sediments;

U=1, at 0.1 mm ≤ dav ≤ 0.2 mm, (7a)

U=1/2, at 0.2 mm < dav < 0.6 mm, (7b)

U=1/3, at 0.6 mm, dav < 2 mm, (7c)

U=1/4, for d > 2 mm. (7g)

3) Parker [5]:

$$B=4{,}4\ Q^{-0{,}5}, \quad (4.8)$$

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where B=B/d , $Q' = Q / d_{cp}^2 \sqrt{g d_{cp} (S-1)}$;

g – free fall acceleration;

$S=\rho_n/\rho_v$ – relative density of soil.

3) Simons, Albertson [5]:

$$B=k_1 Q^{1/2} \tag{8}$$

where k1 is the dimensional coefficient (m/s), depending on the characteristics composing the bottom and banks of the channel.

4) Chitale [7]:

$$B=6{,}592\ R^{0{,}209}\ 1^{-0{,}097}\ Q^{0{,}414} \cdot D_{sr}^{0{,}115} \tag{9}$$

The above formulas do not exhaust the list of existing empirical dependencies, which almost all represent power-law relationships between width, average depth, bottom slope, water flow and sediment diameter and differ in various coefficients and exponents.

Chitale [7] reviewed the suitability of regime equations based on a comparison of calculated data with measured characteristics in various duct systems and concluded that formula (9) turned out to be more reliable than most other regime dependencies. It was also discovered that the coefficient k takes different values for channels with different geographical conditions.

The method of permissible drag force (acceptable directions) is based on the following considerations. The physical properties of the material from which the banks of the canal are made (angle of internal friction, density, roundness, average soil diameter, etc.) determine their resistance to erosion. The mechanism of influence of the flow on the channel is associated with tangential stresses on the surface of the banks, and the calculation of channels using the maximum drag method is based on determining the permissible shear stress that the banks of the channel can withstand. The resistance of the banks to erosion is one of the limiting factors influencing the operating conditions of the canal - a sufficiently small cross-section for a given flow rate will create high velocities that can, in turn, destroy the banks of the canal.

Under experimental conditions, data were obtained that made it possible to calculate the limiting tangential stresses on the banks of a trapezoidal channel with uniform granular roughness. The maximum drag stress acting on the banks of the channel, the width of which exceeds twice the depth, is estimated as $0.75\ \rho_v\ g\ h_{sr}\ I$.

The maximum traction force method is widely used in the practice of irrigation construction under clarified flow conditions [9]. However, as recent studies show: "...a design based on the concept of ultimate drag stress is not suitable for irrigation canals with a moving bottom".

The method of permissible speeds is based on various calculation formulas for determining non-erosive and non-silting speeds. Depending on the ratio of the latter, the depth of the channels is adjusted in order to maintain its balance (no erosion or siltation). This method also assumes the absence of transport of bottom sediments, and for suspended sediments it is assumed that they transit along the canal route. Obviously, in connection with the above, the methods of drag force and permissible velocities become unacceptable when calculating channels capable of passing a certain amount of both suspended and dragged sediments.

In recent years, in our country and especially abroad, the results of analytical studies obtained on the basis of various hydrodynamic models are beginning to be used, in which the floating stability of channels with a moving bed is considered as one of the manifestations of the hydrodynamic stability of channel flows. Thus, as a result of using the analytical dependence for the length of planned channel disturbances (L_m):

$$L_m = \frac{h_{cp}}{\sqrt{2}} \frac{CM}{\sqrt{g}} \left(1 - K\frac{M}{C}\right)^{1/2} \qquad (10)$$

where: M – Boussinesq parameter (M=22+24 m0.5/s);

k – parameter of the logarithmic velocity distribution function;

h_{sr} – average flow depth;

C is the Chezy coefficient, in the application L_m = 8V. V.S. Altunin proposed a calculated relationship:

$$\frac{C}{\sqrt{g}} = \sqrt{0{,}2\left(\frac{B}{h_{cp}}\right)^2 + 43} \qquad (11)$$

which, for a given B/hav, makes it possible to calculate C and, conversely, for a known C, makes it possible to determine the relative width of B/hav.

As a result of solving the problem of hydrodynamic stability of the channel, taking into account its transporting capacity, an expression was obtained for the initial length of the meanders, which, assuming clear flow conditions, takes the form:

$$L_m = \frac{\pi C^2 h_{cp}}{g} \qquad (12)$$

Taking L_m=30 V as a characteristic scale at which the condition of quasi-stability of the flow is preserved, A.E. Mikhinov obtained a relationship for calculating the relative width of stable earthen channels in sandy, loose soils in the form:

$$\frac{B}{h_{cp}} = 0{,}1\frac{C^2}{g} \qquad (13)$$

Later A.E. Mikhinov, as a result of analyzing existing regime dependencies using the dimensional method, obtained dependencies for calculating the width and average depth of a dynamically stable channel, which are in fairly good agreement with empirical data.

B=7.76 dQ`0.440 at Q`≥1011;

B=0.0023 dQ`0.760 at 1010≤ Q`<1011 ;

B=0.30 dQ`0.550 at 109≤ Q`<1010 ;

B=88 dQ`0.275 at Q`<109 ;

h=0.04 dQ`0.503 at Q`>1011;

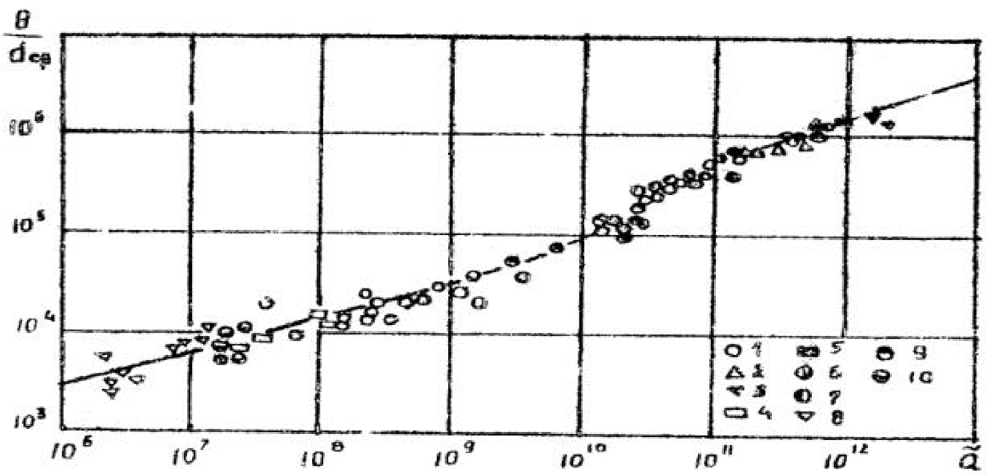
h=10.4 dQ`0.281 at 109≤ Q`≤1011;

h=0.19 dQ`0.475 at Q`<109 ;

$$Q` = \frac{Q}{d_{cp}^2 \sqrt{g d_{cp}} (S-1)}$$

where

The choice of the calculation formula for the channel width is based on a comparison of calculated, laboratory and field data. The dependencies (9,10,12,13) were checked as formulas. The results of a comparison of actual and calculated data are presented in Fig. 1. The analysis shows that the best agreement with the actual data is provided by dependencies (13). This made it possible to recommend it as a calculated dependence for determining the channel width along the free surface.



Picture.1. Comparisons of measured and calculated relative channel widths:

1-Indo-Pakistan channels; 2-Karakum Canal; 3-Volga-Caspian Canal; 4,8,10-laboratory data; 5-Amu-Darya; 6-Tash-Saka; 7-Kyz-Ketken; 9 rivers of Belarus.

Thus, the obtained results of laboratory studies make it possible to establish stable dimensions of the channel along the free surface based on a comparison of calculated, laboratory and field data.

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