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Study of the Development of Soil in the Formation of Channels Hydraulic and Static Stability of Cross-Sectional Shapes

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Abstract: During the construction and maintenance of canals, irrigation and drainage systems is essential from what soil is composed of the bed of the channel. Investigation of the development process and making the soil channel hydraulically and statically stable form is of great practical importance, since halved inter-cleansing period and fed guaranteed given volume of water. It is proved that the main mechanism for the creation of parabolic shape channels are hydraulic suction dredges. Research revealed the advantages and effectiveness of soil hydraulic transport on the level of dissipation of mechanical energy flow for coarse soils on the factors affecting the amplitude-frequency characteristics (AFC).

Key words: Channels · Siltation · Sediment · Hydrotransport · Cleansing · Consistency · Turbulence · Pulsation and snapper

INTRODUCTION

Theoretical and experimental studies of the development and transportation of soil using pump dredges have shown that the most effective design cross-sectional shape of channels installed in a semi-cohesive soils and disconnected, is curved, contoured parabola third or fourth degree. Creating such a channel cross-sectional shape is provided with joint work of the dredger in the slot, depth gauge and vacuum meter.

As a result, the development of existing soil reclamation and construction diggers channel cross-section becomes trapezoidal. Moreover, the development of channel shovel with one hand inception significantly steeper slope of the left right, because of having a large difference between the outer and inner slopes face, especially for cohesive soils.

Isotachs velocities in trapezoidal cross-sectional shape (having a shape similar to the shape of the wetted perimeter) illustrate the presence of stagnant zones, located near the water's edge and within the joint slope and bottom of the channel [1-6]. As experience shows operating channels, these areas make up about two percent of the living section, filled with sediments in the initial period.

MATERIALS AND METHODS

In order to reduce siltation of irrigation canals is necessary to establish the flow regime providing for the safe transportation of irrigation technique amounts of sediment (mostly silt and clay fractions). The usefulness of these sediment transports on the field is explained by their content of a large number of mineral salts that increase soil fertility and decline in sewage works.

Meets this requirement hydraulically stable form, the channel cross section [1, 2], which has the highest flow kinetism:

$$F_r = a^1 V^2 / gH_1 , \qquad (1)$$

where: Fr - Froude number; a^1 - the coefficient of kinetic energy; V - average velocity in the living section, m / s.

Substituting in the formula (1) $V = NR0^{0,5+V}$, $N = n/\sqrt{i}$ and use ¬ $H_1 = \sqrt{W_o / W_h}$ dependence and obtain $R = \sqrt{W_0 / X}$

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$$F_r = a_1 W_0^{?} \sqrt{W_h / X^{1+2?}} / qN^2 \,, \quad (2)$$

where: R-hydraulic radius, m; n - roughness; W_0 - cross-sectional area, m2; V - exponent in the formula academician N.N. Pavlovsky; W_h - open area with H_1=1; $X_0 = X/R$ - relative wetted perimeter, X-wetted perimeter.

From formula (2) it follows that for a given section *i*, *n, Y,* W_0=const parameter depends on kinetism $\sqrt{W_h / x^{1+2?}}$.

From discussed below formulas (3) to one and the same relative widths of the water's edge, the channels of curved shape have smaller specific wetted perimeter compared to the trapezoidal channels:

$$W_0 = \sqrt[4]{(QN)^3 X} \,;\; x = \sqrt[8]{(QN)^3 X_0^{-5}} \,. \quad (3)$$

Therefore, for the given values $W_{0,}$ *n*, *i*, и β^1 they have a greater capacity for the given values or smaller values of cross-sectional area and the wetted perimeter, which is particularly important for the cleansing works. A characteristic feature of silted sewer cleaning is the presence of a small volume of sediment per meter slope. Also cleaning of canals on a curved shape allow at constant total volume of cleaning concentrate sediment per meter slope compared to the trapezoidal shape. Each linear element characterizing the size of the effective cross section of any shape, given *Q*, *N*, X_0 и β^1 may be defined by the formula:

$$l_0^1 = \sqrt{(QN)^3 X_0 W_1^{-4}} \,, \quad (4)$$

Where W_1 – the live cross-section at $l^1{}_0 = 1$.

The comparison included in the formula (4) the values calculated for the cross sections of various forms, shows that with the same values *Q*, *N*, X_0 и β^1 curved section has a narrower water's edge «B_2», than trapezoidal cross section.

Due to smaller values of X and B2 canal curved shape traversed path dredge machines in the cleaning of the canals of sediment less than trapezoidal. It will improve the performance of machines, moreover and reduce the complexity of the most complex process- development.

Outlines extremely stable (for channel static and dynamic balance) channel slopes composed of medium and fine sand soil, according to the research results have curved shapes described parabolas 3-5 degrees. Their shapes depend on the angle of repose of the soil under water (φ), the linking of fine soil (C_1), pulsatile character of turbulent flow (τ) and the maximum depth of flow. The full width of the channel at the top of Y.M. Kuzminov [1] recommends defining the following formula:

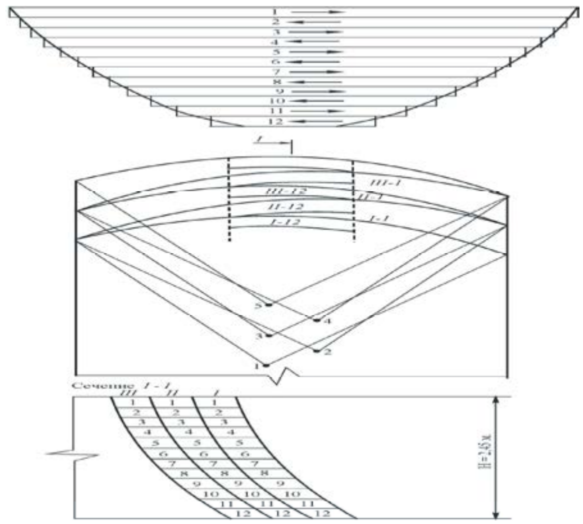

Fig. 1: Flow chart of the development of the curved shape channel.

$$?_2 = \pi \sqrt{?_2^{\,2} + tq\phi} / \tau tq\phi + B_1 \,, \quad (5)$$

Where B_1 – the horizontal channel bottom portion formed by sediment transport in the channel.

The numerical values of the specific channel wetted perimeter having a parabolic cross-sectional shape, very little change with the degree parabola describing these sections. Furthermore, with increasing values of the exponent of the parabola β^1 hydraulically stable channel section increases.

This allows you to not require the formation of high quality slopes in the development of channels and assign degree parabola meet the conditions of static stability of slopes in the channel depending on the soil, which is composed of its channel. The proposed scheme of automation of the process involves excavation work dredger in maintenance mode channel in working order using a device of the type of controller as КЭП-12V (Fig. 1).

According to R.M. Karimov [2] relative to the channel width at surface β^1=6,0 (most likely for drainage systems of southern Kazakhstan) the length of the wetted perimeter at the parabolic cross-sectional shapes of 17.2% shorter than trapezoidal. Thus, giving the channels of southern Kazakhstan curved cross-sectional shape will reduce the distance traveled dredge more than 17%. Replacement of trapezoidal parabolic sections will reduce the channel open area of 6.5% and the width of the water surface by 25%, turn off the land in the section where sediments are deposited. In addition, increasing the depth of water off the coast and increasing flow velocity help to reduce the intensity of overgrowing channel, which ultimately reduces the cost of money and labor to combat overgrowth and facilitate the work of the mechanisms in the coastal zone.

When water levels in the channel (changing the water flow downwards) in parabolic sections observed minimal lowering of the water table than the trapezoidal. This ensured that the water level in the command channel over the irrigated area and at minimal cost.

In view of the small values of the wetted perimeter length and width of the channel at the water's edge in parabolic sections less loss of water through seepage (especially for the channel, the channel which is composed of sandy soils) and evaporation. In addition, the operation of channels in earthen channel with a stable profile is 2-3 times cheaper [6] operating siltation and eroded sections.

Development of farm canals on a curved shape can be made only because of dredge placing them in the process of being developed within the channel and the oscillating motion of the receiving opening tip.

Giving channels curved cross-sectional shape on the basis of tests will: increase the nano transportation ability of flow, reduce overgrowth channels, reduce the amount of clean-up operations to 20 percent depending on the soil, which is composed of the channel, assign differentiated degree parabola provides a static slope stability channels, use the most effective technology works; increase productivity by focusing on soil slopes channels at constant total development; reduce water level fluctuations with decreasing flow in the channel; reduce right of way for the channels, reduce water loss through seepage and evaporation; cheaper operation channels 2-3.

RESULTS AND DISCUSSION

For hydraulic characteristic of joint movement of water and soil, which forms a mixture of various physico-mechanical properties of dredge flows. Study of the problems of conveying the water flow of suspended particles is closely linked with the development of the doctrine of the turbulence, as particulate transport water flow is carried in a turbulent flow.

Conveying capacity flow is largely determined by its turbulence, so a special role in hydrodynamics research dredge flows play patterns of distribution of turbulent characteristics in the cross section of pipeline. They reveal their mechanism of weighing and transport of particulate matter, evaluate the impact of particles on the flow of energy costs. Due to the complexity of these methods for measuring characteristics of the study carried out in three directions. In the first study conducted unpressurized dredge flows containing solids low relative density. Second-studied dredge flows in coal slurry with particles of the same density. The third studied air pressure flows, particle content of relatively large density [7].

Study on the dynamic and kinematic characteristics dredge flows covered a wide range of changes in average speeds hydrotransportation bulk pulp consistencies (2÷50%), size of solid particles (0.16÷15 мм) and density (1.6÷3.4 т/м^3).

Currently there are two types of averaged equations obtained by applying two methods of averaging.

In the first method averaging occurs in time, space, space-time cylinder or probability. In a second-not instantaneous characteristics and pre-smoothed small volume or space-time values of the cylinder. The complexity of the flow phenomena when transferring liquid particles due to the presence of moving boundaries between internal flow components (their interface) determines not only the emergence of additional forces for each component of external and internal to the entire flow, but turbulent diffusion solids. Based on the equations of continuity, momentum and energy equations near complete transformation of the averaged equations obtained, pulsation and thermal motion separately for each component.

F.I. Frankel suggested [5] the following equation for particles: the energy of the mean flow, energy pulsatile motion, heat flow continuity solids. Similar equations are obtained for liquid flow components. These equations are very complex and difficult to solve. These averaging methods do not provide a term characterizing the turbulent diffusion.

Second averaging allows you to go from rapidly changing in time and space smoothed values ??turbulent characteristics to their mean values ??and is actually averaging. Dyunin A.K. and Dementev M.A. [5] smoothing performed in space and Fidman B.A.-Temporary cylinder. Method B.A. Fidman more strict and general. In addition to these methods proposed averaging only theoretical-probability, while it is assumed that the distribution of characteristics in time and space from the average of discrete move into continuous.

The equations obtained by these authors and also have a complex mathematical model and hard to resolve. This creates difficulties for the theoretical study of turbulent characteristics. Therefore it is important to take experimental studies.

A lot of research is devoted to the study of one of the most important kinematic characteristics of flows- averaged longitudinal velocity distribution over the cross section dredge flow [3]. The main conclusion of these studies is - a violation of the symmetry of the velocity field. This is due to the inhibitory effect of the lower layers of the flow, which are heavily saturated portable particles. The velocity gradients in that part of the flow increases, the maximum velocity location along the tube axis and its magnitude is greater than the flows of pure water. For a homogeneous fluid mathematical model of turbulent flow on Prandtl -lu- Karman has the form:

$$\bar{U}/V_? = SinY/x + C\,, \qquad (6)$$

where $\bar{U}$ – averaged distance from the wall; X – Karman constant.

This logarithmic dependence is derived on the basis of the following assumptions: shear strength are taken constant and discarded member, describing the viscous stress. For this equation and based [3] describe the laws of distribution of the longitudinal velocity in dredge flows.

Of great importance is the distribution of concentration of solid particles in a cross section dredge flows. Since the discharge flow is turbulent, then the process of transferring them to particles of various sizes since the local vortices and velocity of pulsation is constantly being transferred from one layer to a specific substance (solids, heat, etc.). Study of distribution of solid concentration across the stream carried by most authors of the turbulent diffusion equation for steady uniform motion and for the cases of a flat flow [5]:

$$\bar{S}W + Ed^s/dy = Const\,, \qquad (7)$$

where $\bar{S}$ –averaged value of the concentration of solid particles at a distance V from the bottom; E-turbulent transport coefficient.

Differences in research methodology were the adoption of the laws of change of longitudinal velocity and assumptions in determining the coefficient of turbulent transport of suspended particles. Longitudinal velocity distribution law accepted logarithmic, parabolic or elliptic. Adoption of a specific law for the velocity distribution of predetermined and turbulent transport coefficient.

In the theoretical substantiation of the laws of distribution of the concentration of solid on the cross section of the flow has two directions: the first-using the theory of turbulent diffusion; second-gravitational theory. Comparison of these two directions will give different results. This happens for the reason that according to the theory of turbulent diffusion concentration of particles at the surface flow is the ultimate value and the gravitational theory it is always zero. Last contradicts the experimental data obtained at high speeds [5]. Some researchers distributions of the concentration of particles in depth flow offer describe the dependencies obtained from the equations of hydrodynamics. Dependences obtained, researchers have quite a complex mathematical model, many controversial assumptions and, mainly, are the conditions in which they were held. In addition, it should be noted that many studies have been conducted in hydrotransport of small particles and their low concentration. Since the results of theoretical research of characteristics of pressure dredge flows among the various authors contradictory, are of great importance experimental research in this area.

General conclusions of the work [5] suggest that the increasing saturation of the flow of pulp finely fractional and homogeneous material causes a decrease in the intensity of pulsation. This is due primarily to significant increase of viscosity and density of the pulp. Lower ripple within those threads with increasing consistency of a solid (if d<l) is more intensive than in the diversity of fractional solid and d solid>8-10 mm

Theory and in practice studies have shown that the introduction into the flow of soil particles violates the symmetry of the distribution of the longitudinal velocity averaged over the cross section of flow occurring during the movement of clean water. This is due to higher particle density and therefore their inertia, particles in the stream by reacting with each other, when the large- ground and fractionated significant hydrodynamic resistance. All this considerably slows down the speed of motion of a solid stream. At the same time, the occurrence of the relative velocity of the particles is largely determined by the average flow rate, concentration of solids in the stream and its fractional composition. Most of the velocity field asymmetry observed at medium speeds, close to critical at higher consistencies and densities of solids. With a significant increase in the mean flow velocity V<$(2\div3)V_{кр}$ or decrease its consistency and density of particulate matter asymmetry and smoothed velocity profile approach similar to pure water. Increasing the amount of flow of solid particles fractional composition leads to the fact that the bulk of the particle begins to move at the bottom of the stream, causing increased resistance to movement of the lower layers. Movement in the area and benthic slows the speed decreases. This phenomenon is so closely connected with the laws of distribution of the cross section of flow, solid concentration and fractional composition. Concentration and size distribution of solid particles was determined at the same points of the vertical diameter or living section of stream, which measured the averaged longitudinal velocity. Research analysis shows that the form of diagrams depends on the average speed, average consistency and density of the solid particles. The highest value is consistency in the bottom layers of the lower stream. With increasing distance from the bottom of the flow is gradually reduced and the consistency in the upper layers, directly on the upper wall of the pipe, it remains minimal. This is particularly noticeable at low flow rates, with an increase of the latter are equalized distribution curves.

For large values of velocity at the top of the consistency can be achieved by flow values of 20-50% of medium consistency, depending on the composition of the solid component and its density. During the investigation, it was found that the distribution of horizontal sections consistency also uneven. Presumably, it increases in the direction towards the pipe wall, depending on the medium consistency, flow rate and particulate size.

Studies also showed that the solid particle size is distributed unevenly along the depth of the flow: the average particle size increases from the top downwards. Most irregularity observed at medium speeds, close to critical. With an increase in the average flow velocity increases and the weighting ceiling redistribution depth particle stream. Thus, the analysis of experimental research in this field and theoretical studies show that pressurized hydrotransport pulp is a complex phenomenon and may be considered for the studied mixtures with a low concentration of solids in the flow and transportation of fine soil.

The predominance of the forces of gravity forces over the forces weighing bulk soil move in close proximity to the bottom of the stream. This leads to increased stress of the friction forces, since there is not only the interaction of particles with a flow-limiting surfaces, but also between particles arising pressure gradient between the upper and lower layers of the flow, portable saturated soil particles generates circulation of water from areas of high pressure to smaller, thereby, creating additional strength weighing the particles in the stream. In such flow diagrams of the velocity distribution over the cross section is not symmetric.

Consequently, the state of flow, it is possible to judge the conveying ability for dissipation of mechanical energy level in the stream. According to the law of conservation of energy dissipation in the kinetic energy of the flow goes to other species. Hence any pressure slurry flow, due to the existence of vortices arising from a variety of reasons, plays the role of broadband acoustic energy generator [3, 4]. Therefore, on the basis of established fields AFC acoustic energy released pulp flow can judge the state of flow, its transport capacity in the discharge mode hydrotransport soil.

Investigation of the processes of soil development in the formation of cross-sections of the channels by the proposed method was carried out on the basis of the theory of design of experiments. A series of studies on the dynamic and kinematic characteristics dredge flows covering a wide range of changes in average speeds hydrotransportation, bulk pulp consistencies, particulate size and density. The state of flow, it is possible to transport capacity to judge the level of dissipation of mechanical energy in the flow. According to the law of conservation of energy dissipation in the kinetic energy of the flow goes to other species. Consequently, every head flow of pulp due to the existence of vortices arising from a variety of reasons plays the role of broadband acoustic energy generator. Therefore, based on established amplitude-frequency characteristics (AFC) of the acoustic fields of energy released pulp flow can judge the state of flux, its transport capacity in the discharge mode hydrotransport soil.

Study modes based on changes hydrotransport AFC allocated flow, was carried out in the laboratory at the stand of "simulator dredge flows" at different speeds of solid particles in a flow V=1.0-2.5 m/s weight and consistency C=0-32% and fractional composition of soil d=0.3-80.0 мм. Studies cited by the three-factor plan allowed us to establish the dependence of the frequency response of the flow of pulp from its basic parameters C, d, V.

Mathematical model of the process of hydrotransport alluvial sediments has the following form

$$? = 1{,}3675 - 0{,}016875X_1 - 0{,}055X_2 - 0{,}02375X_3 - 0{,}03X_1X_2 - \\ -0{,}02375X_1X_3 - 0{,}01125X_2X_3 - 0{,}0075X_1X_2X_3 \quad (8)$$

where V-value of the total AFC; X_1 - normalized value of the consistency of the pulp; X_2 - normalized value of the diameter; X_3 - the speed of motion of solid particles.

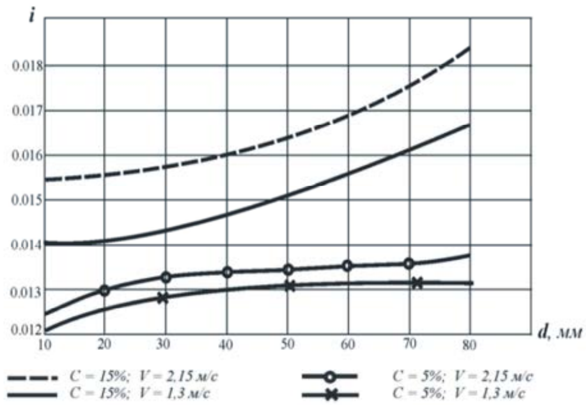

Fig. 2: Functional dependence of the total AFC of the average diameter of the silting deposits

From the resulting mathematical model (8) that the main factor affecting the AFC allocated flow through the particle energy is the speed and the average diameter of the alluvial deposits. Somewhat less influence consistency pulp. Moreover, increasing the weight consistency, the fractional composition of the alluvial deposits and the rate of particulate matter lead to a reduced yield (coefficient of the regression equation in X_1, X_2, X_3, with a negative sign). At zero (C=10 %, d=2.5 мм, V=1.725 м/С) yields are 1.3675 units. Based on this model are set and summarized the functional dependence of the total frequency response of specific zones and working conditions (one example is shown in Figure 2).

A study carried out on three factor plan built to link the overall AFC from the main parameters of flow in the form of incomplete polynomial second order after elimination of insignificant members:

$$I=70,24-7,77C-4,01d-1,86V-1,12Cd-0,35CV, \quad (9)$$

CONCLUSION

Studies and theoretical developments suggest the following conclusions: for coarse-grained soils the most significant factor affecting the AFC is the weight consistency of particles in the flow and their average diameter (slightly smaller than the impact velocity) due to the dynamic interaction of the particles carrying flow with the bounding surfaces, it is necessary examining the status of the flow, its transport capacity, the flow characteristics (V, C) in terms of dissipation of mechanical energy of the flow.

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