UDC 556:626:627.5

DEVELOPMENT OF OVERALL PREDICTION THEORY FOR RIVER CANALS TRANSFORMATIONS IN WATERCOURSES AND ITS PARTICULAR APPLICATIONS

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Steady soil progradation in channels of rivers and their tributaries, and sediment accumulations transported by water cause natural transformation of channels. These fluvial processes change the view of riverbeds in plan and especially vertical views.

The analysis of the present state of the problem in question has revealed a number of considerable shortcomings and errors. They are consequences of erroneous assessment of water flow discharge characteristics, as well as use of connections having inadequate substantiation in fundamental equations.

Statements, provisions, and equations generalizing stabilized states of different channel forming phenomena have been assumed in the work, their application boundaries being substantiated. In consequence of carried out investigations for stabilizing channel formation a universal mathematical model was developed applicable for the following cases:

- *channel formations of natural and man-made origin,*
- *different sediment regimes of flow (from under saturated flows to turbulent mudflows,*
- *various cross-sections of channels (rectangular, trapezoidal etc.).*

Key words: *water, river, channel, flood, turbulence, reservoir, anti-mudflow.*

Introduction

Figure 1. The gorge formed by flood

Canal transformation of water streams (deformations of river canals) aside from natural reasons also occurs engineering structures are build on rivers. During the last 50 years various large land-reclamation in submountain regions was accompanied by construction of many river structures. As a result the specific portion of man-made transformations of river canals have been essentially growth.

Figure 2. Sediment accumulations at downstream

For example, the portion of supports failure caused by floods in all damages of bridge and other river passages designed for various pipelines and communication lines is averaged ¾ (Fig.3).

Figure 3. Failure of bridge supports caused by flood

Figure 4. High-water dam

Many reservoir dams, flood and mud flow barriers (Fig.4) currently are in operation and are being built. In each one of such structures accumulated sediment at the upper bowl produces bottom changes of river canals.

Current state of issues related to river canals transformation. First of all it is important to note that the majority of researchers usually is specialized in a hypotheses specific problem related to river beds. Theoretical and experimental researches are mainly carried out to solve a specific problem. In our opinion this is the reason that no attempt was made to investigate and define the general basic provisions enabling to cover all kinds of river bed transformations. To ground such a statement let us briefly return to the current state of questions under discussion.

Development of economy is conditioned by creation of wide communication networks. For this reason from the beginning of the last century among represented problems first research works were devoted to bridge hydraulics which studies hydrodynamics and canal deformations of bridge passages. A number of Soviet and foreign researchers made an important contribution [1,2]. They on the basis of several accepted hypotheses obtained first simple regularities on determining depth of river canals flooding. Later on this problem especially for lowland large and middle size rivers arrived to quite well and reliably solutions, including machine ones. For mountain and submountain rivers where there are more various and rapidly changing factors conditioning this phenomenon we have not thorough solutions [4]. In each of these cases at the top bowl accumulations of silt cause transformations of the river bed.

Current state of bed transformations related problems. First of all it should be noted that the majority of authors are specialized in a specific bed phenomena or research of the problem. Theoretical and experimental researches are curried out to solve individual aspects of problems. For that reason these issues and problems have never been investigated in width and depth and no attempt was made to set up such fundamental link between all kinds of bed transformations. To ground the above situation let us briefly represent the current state of problems under discussion.

It has always assumed that a high quality transport infrastructure is an essential prerequisite for economic growth. Therefore from the beginning of the 20th century the first scientific works were devoted to hydrodynamics of highway stream crossings and defining of river canals deformations (bridge hydraulics). A number of Soviet and foreign scientists [1,2] made important contributions trying to answer a number of complex questions. They through accepting several hypotheses obtained first simple regularities of canal flooding depth. In following decades for lowland large and middle size rivers this problem has come to a quite fundamental and reliable solution, including machine solution [3]. In case of mountain and submountain rivers, where there are more heterogeneous and dynamically varying factors conditioning the present phenomena, solutions still are not final [4]. Still there are not reliable and complete models describing process of silt accumulation in reservoirs. Still far from reality approaches are used in designs [5]. If large reservoirs can not be affected by erroneous decision of this problem, then in case of small and middle-size reservoirs that error often leads to serious consequences. And such reservoirs account for a large share in all existing reservoirs.

At upstream reach of high-water dams and anti-mudflow dams especially in spring and autumn begins silt accumulation process [6]. A current and especially stabilized, final surface, being shaped in a river canal is an important prerequisite on the basis of which calculation of accumulated sediment volume and dimensions of the structure is made. In the late forties of the last century many natural and laboratory investigations were carried out in the former Soviet Republics (Russia, Kazakhstan, Georgia, Armenia) to predict coordinates of such surfaces. The suggested formulae are quite simple and do not express running hydrodynamic multifactor physical phenomena. There also are a number of suggestions on theoretical approach for solution of these problems (USA, Japan, Denmark Institute of Hydraulics), where some arguable provisions were used [7, 8, 9].

The above given objective account of the problem enables to set the objective of the present paper and important problems to achieve the purpose in view.

Conflict settings

The goal of the work is to develop a generalized theory on hydrodynamic phenomena attending canal transformation and for particular cases to suggest prediction techniques for stabilizing canal transformations.

With this end in view the following problems should be solved:

- setup and substantiate those peculiarities of the canal and flow which generalize all transformations of the cannel,
- clearly define conditions which present the problem statement, define the framework of equations applicability and prove reliability of provisions describing the problem,
- develop a system describing stabilizing canal transformations and following them phenomena and on its basis for a particular case suggest methods for determining coordinates of the canal's stabilized shape.

Research results

Quantitative and qualitative analyses of obtained solutions for riverbed formation variety problems have been carried out. It enabled to assess the validity of the main provisions and approaches accepted by these suggestions. For most general and strict statement of the problem the phenomena under study are non-steady. It means that riverbed transformations and flow parameters causing them are changed over a long period of time (months, years) also with time.

Thorough analysis of existing methods has revealed a number of shortcomings and mistakes. They, in the main, result from not correct assessment of real values of water flow output characteristics, as well as making use of links having partial application and weak substantiation in fundamental equations. In particular:

- In determining parameters of the river canal transformed section, in the developed model as output values of parameters describing water flow are accepted confirmed values laying just above that section. It turned out that in different sections while predicting transformations different output characterizing values are referred to the same river, which results in unreliable solutions. Such an approach is a result of insufficient notion about silt transport regime:
- To determine Q_T flow of silt used in balance (3) equation each authors uses his preferable formula. In a number of works it has been shown that Q_T flow calculated by different formulae for the same condition strictly differ from each other (up to 50%) [5,10]. It means that disadvantages of this or that formula having narrow range of application or many inaccuracies automatically take place in further developments.
- The next serious mistake is made in (1) equation when presenting energy losses for bi-phase fluid flow; to calculate the losses clean water regularities are used. In the last two decades a number of carried out experimental investigations have shown that the presence of silt is essentially raises energy consumption [11].
- The disadvantage is of methodic nature and concerns prediction of the most important final result for the riverbed transformation through non-linear differential equations of non-steady flow, a number of linearization and arguable assumptions being made during solution of the system. Instead of the above approaches a more simple and reliable mathematical model describing phenomena under study is suggested below.

To correct main shortcomings and mistakes existing in the proposed models designed for predicting various canal transformations the authors of the paper a number of researches and developments have been carried out and the main results are given below.

Statement of the problem

Let us assume that in any section of a riverbed transformations of an arbitrary shape development begins due to a natural or man-made cause. Before the beginning of the phenomenon hydrological, geometrical, and hydraulic actual, output parameters of the riverbed are:

- flows of stream and sediments, carrying capacity of the stream - Q, Q_T, S
- slope of the riverbed and the coordinate of the bottom $-i_r, z_r$,
- depth and width of the stream, cross-section area of the stream, wetted perimeter and average velocity of the cross-section - h_r, b_r, A_r, X_r, V_r, values of these parameters are determined by field investigations.

The above parameters in stabilized regime of the water (except the first three ones) are changed along the river.

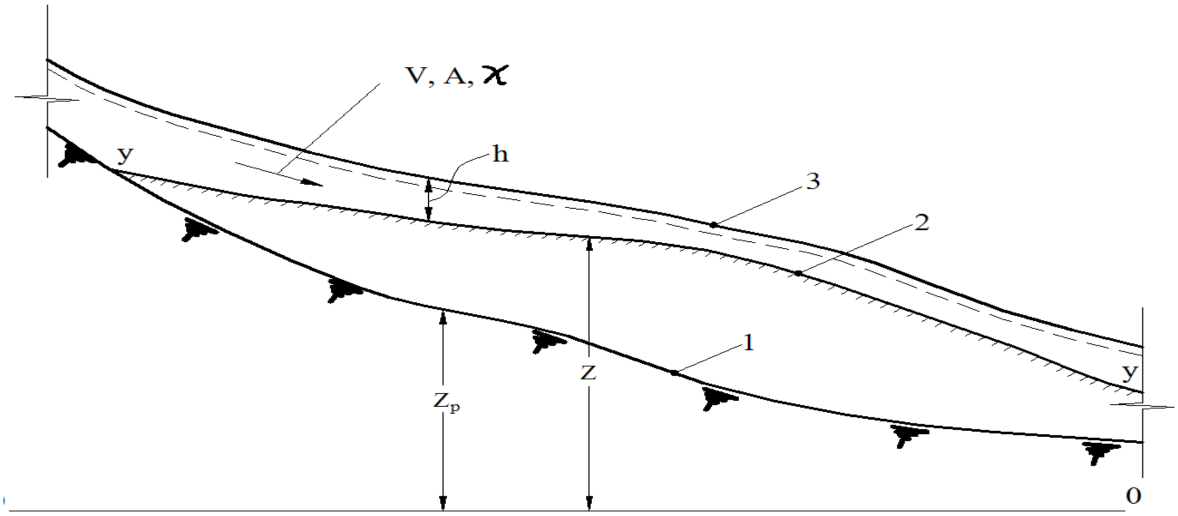

Figure 5. Longitudinal profile of the stabilized riverbed

Irrespective of causing reasons (natural or man-made) and running form (flooding or accumulation of silt) after dying of riverbed changes in the given section a new practically stabilized riverbed is formed (in Fig.5 its bed is marked by a surface).

Assumed problems and approaches

Before proceeding to the solution of the problem let us present those important principles of which assumption enables to correct the above mentioned disadvantages and inaccuracies.

Values of parameters describing the riverbed and flow along water flow are strictly changed. Therefore, it is most important to make clear and substantiate those values which lead to stabilizing state of riverbed transformations. To this end a number of natural observations and silt regime clarifying researches have been carried out. On the basis of the obtained results analysis has been proved that most complete and accurate description of the river bed and water flow moving through it is provided by values taken in sections where sediment carrying capacity gets its maximum. Thus, according to the flow direction in adopted classification of separate sections an addition is made.

In particular, between sediment transition and sections of accumulation for the given water flow a “boundary section” concept is assumed [10].

The mathematical model of stabilizing riverbed transformations

Real and complete explanation of hydrodynamic phenomena following riverbed transformations enables to suggest a very simple physical model for the problem solution. It is assumed that stabilization of riverbed transformations has already been reached.

An objective is set to define values corresponding to a stabilized phenomenon. Such an approach provides prerequisites to avoid a model describing non-steady phenomena. Instead, the following simple system is suggested

$$\frac{dz}{dx} + \frac{dh}{dx} + \frac{d}{dx}\left(\frac{V^2}{2g}\right) = \frac{dh_f}{dx}, \tag{1}$$

$$A \cdot V = const, \tag{2}$$

$$Q_T = const, \tag{3}$$

(Here the direction of x is opposite to that of flow).

Before proceeding problem elaboration it is also important to specify and set a applicability framework for the system of equations, the point which is missing in existing methods. Balance Eqs.1,2, and 3 of energy, fluid, and sediment rate derived for single-phase real fluid indeed have a strict validation. However, it also is necessary to make clear the conditions where they can be applied for double-phase fluid. To this end in view V.G.Sanoyan's standard equation was used. By a number of transformations making it applicable for engineering solutions was shown that in a wide range (0 to 0.8) of hard and fluid parts ratio Eqs.1,2, and 3 of single-phase fluid flow are also applicable for double-phase fluid unidimensional motion [12].

In transforming the above equations a number of known hydrodynamic regularities have been used. Simultaneously expressions [10,11] derived by the authors for conditions of energy losses and sediment balance have been taken into account. As a final result to describe phenomena running in stabilizing transformations the following differential linear equation [13] has been obtained by joint solution of Eqs.1,2, and 3.

$$\frac{d\bar{z}}{d\bar{x}} + \frac{d\bar{h}}{d\bar{x}} - \frac{Fr_0}{\beta_0\, \bar{A}^3}\, \frac{d\bar{A}}{d\bar{x}} = i_0\, \bar{d}_{OT}^{1/3}\, \bar{A}^{(4a-10)/3}. \tag{4}$$

The above equation generalizes fundamental balance equations of energy, fluid and hard components of the flow, as well as links and regularities representing silt regime and channel conditions.

In addition due to this equation a relation between coordinates $\bar{z}$ of the new bed, depth $\bar{h}$ of the flow moving through that channel and water cross-section $\bar{A}$ is established. Other members of this equation are either output or determined making use of these values through classic methods. In particular, the developed mathematical model has been applied to predict channel bottom transformations in the Rion river (in Georgia) mouths and flow parameters in new conditions [14].

Conclusion

The mathematical model developed for stabilized state of a channel formation phenomenon is applicable for the following cases:

- channel transformations of natural and antropogenic origins,
- various sediment regimes of the flow (from low saturated flows to turbulent mud flows),
- various shapes of channels cross-sections (rectangular, trapezoidal),

The result of performed developments enables:

- to clear up conditions necessary for delta formation and silt propagation possible shapes in adjacent to river mouths areas depending on changes of the “erosion base”,
- to predict the bottom flooding measure in bridge passages,
- to receive coordinates of the upper surface of sediments accumulated against mud flow dams.

The work has been performed within the framework of 11-30/15T theme.

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ՋՐԱՀՈՍՔԵՐՈՒՄ ՀՈՒՆԱՅԻՆ ՁԵՎԱՓՈԽՈՒԹՅՈՒՆՆԵՐԻ ԿԱՆԽԱՏԵՍՄԱՆ ՀԱՄԸՆԴՀԱՆՈՒՐ ՏԵՍՈՒԹՅԱՆ ՄՇԱԿՈՒՄԸ ԵՎ ՄԱՍՆԱՎՈՐ ԿԻՐԱՌՈՒՄՆԵՐԸ

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Գետերի ու դրանց վտակների հուներում մշտապես ընթացող գրունտների ողողումները և հոսանքով եկող ջրաբերուկների կուտակումները պատճառ են հանդիսանում հունային բնական ձևափոխությունների՝ փոխվում են հուների հատակագծային և հատկապես ուղղաձիգ տեսքերը:

Նշված հիմնահարցի առկա վիճակի վերլուծությունը ի հայտ է բերել մի շարք էական թերություններ և սխալներ: Դրանք հետևանք են ջրահոսքի ելքային բնութագրերի ոչ ճիշտ գնահատման, ինչպես նաև հիմնարար հավասարումներում ոչ բավարար հիմնավորում ունեցող կապերի օգտագործման:

Աշխատանքում ընդունվել են տարբեր հունակազմական երևույթների կայունացած վիճակներն ընդհանրացնող սահմանումներ, դրույթներ և հավասարումների: Հիմնավորվել են դրանց կիրառման սահմանները: Կատարված մշակումների արդյունքում առաջարկվում է կայունացող հունակազմության համար ստացված մաթեմատիկական համակիրառելի մոդել, որը կիրառելի է.

- բնական և արհեստական ծագման հունաձևափոխությունների,
- հոսանքի տարբեր ջրաբերուկային ռեժիմների (ցածր հագեցված հոսանքներից մինչև տուրբուլենտ սելավներ),
- հուների տարատեսակ ընդլայնական հատույթների (ուղղանկյունաձև, սեղանաձև և այլն) պայմանների համար:

Բանալի բառեր. ջուր, գետ, ջրանցք, հոսանք, տուրբուլենտություն, ջրամբար, հակասելավային կառուցվածք:

РАЗВИТИЕ ОБЩЕЙ ТЕОРИИ ПРОГНОЗА ИЗМЕНЕНИЯ РУСЕЛ В ВОДНЫХ ПОТОКАХ И ИХ ЧАСТНЫЕ ПРИМЕНЕНИЯ

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Размыв грунтов русел рек и их притоков, а также скопление наносов приводят к изменению характеристик параметров русел. Анализ современного состояния проблемы, выявил некоторые значимые ошибки и упущения, которые связаны как с ошибочной оценкой выходных параметров потока, так и с применением необоснованных зависимостей в основных уравнениях.

Ключевые слова: вода, река, канал, поток, турбулентность, водохранилище, противоселевое сооружение.