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THEORETICAL METHOD OF SILT PROPAGATION FORM PREDICTION IN ESTUARIES AT UNSTEADY BASE EROSION LEVEL

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The work studies river-bed transformation processes occurring at rivers mouths. Solution of this problem is of an important theoretical and practical interest, for silt sedimentation in the costal zone by rising marks of the river bottom builds up favorable conditions for delta formation which is a serious danger for nearby located objects. For prediction of possible development of channel conditions on the basis of the developed mathematical model a method is suggested for calculation of parameters of stabilized channel transformations in case of the coastal mark rise at the mouth section.

Key words: ***stream, silt, river mouth, bed-formation, prediction***

Introduction

Water and sediment discharge in mountain and submountain rivers increases dozens of times and sometimes more than that when high water occurs. Parallel to this bed-formation processes are developed. Washed out silt from slopes and from upper rivers by the stream are transported downwards. A part of the silt deposits at lower streams of rivers, and the rest empties into seas and lakes. Because of this the slope of the river mouth reach decreases and the main part of the silt now deposits along the given section. Naturally, on the given process a considerable influence exerts the change of the reservoir level (due to waves and other causes) to which rivers run. Usually the period of bed formation, covering more or less large scopes, coincides with the flood time interval, which means that the duration of the said processes is also sufficiently short. The started bed-formation process lasts till the sediment transport budget is set. In new conditions when stabilization of the river-bed has been settled, the stream again starts carrying significant mass of silt to the sea. From year to year marks of the river bed at the mouth reach and of the sea coast are rising. Concurrently the level of the river waters must rise to provide passage of the incoming stream. As a result of this occurrence at the most narrow cross-section of the channel a burst of coast happens and a part of the stream forms a new

branch. The described deltaic formation process in a larger or smaller degree is common for all rivers. (Fig.1 and 2).

Fig.1. The Danube Piver delta

Fig.2. The estuary and delta of the Rioni (Poti) river

The purpose of the work: to develop a method for prediction of propagation form of deposited silt at coastal parts of a river and change of the sea shore mark (base erosion).

The results of the investigation. The final purpose of problems related to bed formation processes is establishing characteristics of its final result, that is coordinates of stabilized surface of the bed Z (surface y – y in Fig.3) and parameters of the stream running through a new transformed channel).

Let us assume that the sea shore mark at the initial cross-section is x = 0, where the river falls into the sea, because of artificial and natural causes rose (fell) at a certain value Z_0 (Fig.4).

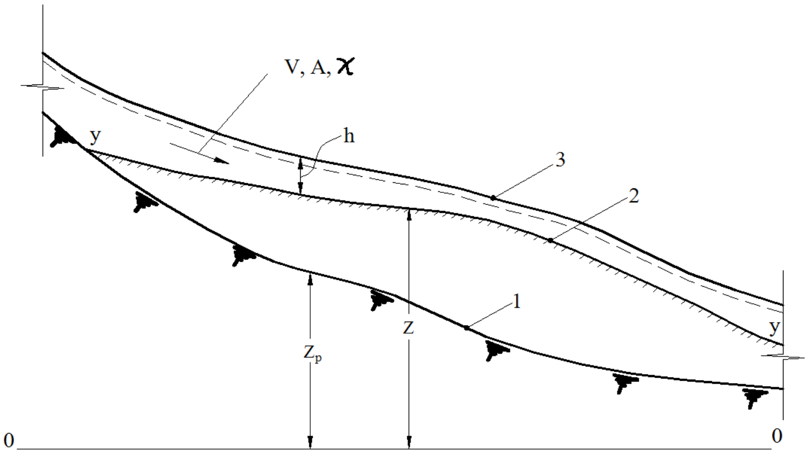

Fig. 3. The longitudinal grade of a part of the channel at the stabilization stage of the bed forming process

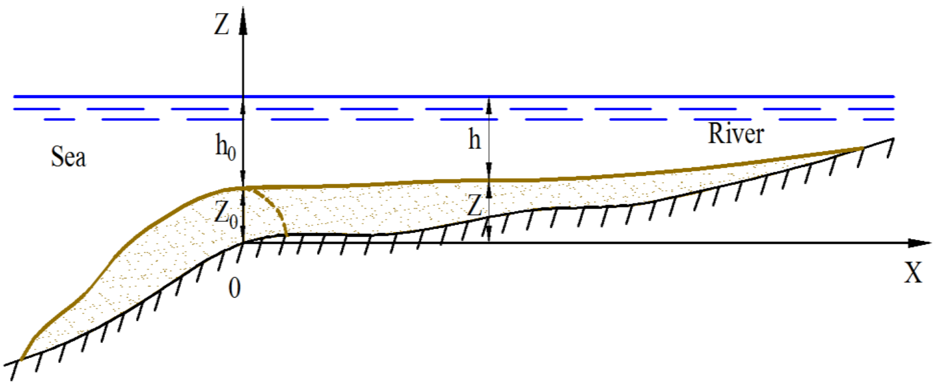

Fig. 4. Diagram of the silt propagation in the mouth of the river

It is necessary to predict the new form-setting of the channel's bottom surface after completion of the silt deposition, i.e. to determine coordinates Z of the bottom and also parameters of the stream running through the new channel.

Initial hydrological, geometric, and hydraulic parameters of the stream and the channel before the beginning of the process are the following:

Q , Q_T are flow of the stream and silt, respectively;

Z_r , i_r are coordinates and longitudinal grade of the channel;

h_r , b_r, A_r , χ_r , V are the depth of the stream, wetted perimeter, area, and average velocity of effective cross-section, respectively.

On the basis of an analysis of known solutions on theoretic description of channel transforming processes and a number of finding out of existing mistakes and faults, made while deriving them, in the work [1] was suggested a theory for prediction of parameters of various types of channel change. According to that theory a combined solution of the stream flow, continuity of fluid and slit balance in dimensionless values may be written by the following differential equation

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

where $\bar{h}$ is the depth of the stream in a stabilized new channel of an effective cross-section area $\bar{A}$ (Fig.3). Besides $\bar{Z}$, $\bar{h}$, and $\bar{A}$, the rest of values of Eq.(1) are determined by known methods (as a dimensionless linear scale is taken the breadth of the "boundary section" of the channel [2]).

This equation is universal, for it is applicable in the following cases:

- silt movement is of different types (from low saturated two-phase to turbulent mud flow inclusive);
- bed-forming processes are of different kinds (caused by artificial and natural reasons);
- forms of longitudinal and transverse section of the channel are of all kinds [1].

To solve specific problems related to bed formation along with the universal equation (1) it is also necessary to use geometric regularities of cross-section, initial and boundary conditions of the given problem.

In particular, for a channel of trapezoidal cross-section the breadth $\bar{b}$ of a stabilized channel and the depth $\bar{h}$ of the stream may be written in the following form

$$\bar{b}=\frac{2\sqrt{1+m^2}+\beta_0}{\beta_0}\bar{A}^a-2\bar{h}\sqrt{1+m^2}, \tag{2}$$

$$\bar{h}=\frac{2\sqrt{1+m^2}+\beta_0}{2\sqrt{1+m^2}-m}\,\frac{\bar{A}^a}{2\beta_0}\pm\sqrt{\left(\frac{\bar{A}^a}{2\beta_0}\,\frac{2\sqrt{1+m^2}+\beta_0}{2\sqrt{1+m^2}-m}\right)^2-\frac{(\beta_0+m)\bar{A}}{\beta_0^2(2\sqrt{1+m^2}-m)}}. \tag{3}$$

Differentiating the above equations, we have

$$\frac{d\bar{b}}{d\bar{x}} = f_1(\bar{A})\,\frac{d\bar{A}}{d\bar{x}}\,, \tag{4}$$

$$\frac{d\bar{h}}{d\bar{x}} = f_2(\bar{A})\,\frac{d\bar{A}}{d\bar{x}}\,, \tag{5}$$

where $f_1(\bar{A})$ and $f_2(\bar{A})$ are known functions obtained as a result of differentiation.

Substituting $\frac{d\bar{h}}{d\bar{x}}$ from Eq.(5) into Eq.(1), we get

$$\frac{d\bar{z}}{d\bar{x}} + f_2(\bar{A})\,\frac{d\bar{A}}{d\bar{x}} - \frac{Fr_0}{\beta_0\,\bar{A}^3}\,\frac{d\bar{A}}{d\bar{x}} = i_0\,\bar{A}^{(4a-10)/3}\,\bar{d}_{OT}^{1/3}\,, \tag{6}$$

where the derivative $\frac{d\,\bar{z}}{d\,\bar{x}}$ is a variable slope I(x) of the stabilized surface y-y (Fig.3).

In Eq (6) we already have two sought for parameters $\bar{A}$ and $\bar{Z}$. To solve the problem yet another dependence between these parameters is drawn up taking into account the form of the channel. In particular, for a channel of trapezoidal cross-section the following equation can be written (Fig. 5)

$$Z = Z_p + \frac{b - b_p}{2\,m}. \tag{7}$$

After a simple transformation, we have

$$\frac{d\bar{Z}}{d\bar{x}} = \frac{d\bar{Z}_p}{d\bar{x}} + \frac{1}{2\,m}\,\frac{d\bar{b}}{d\bar{x}}\,, \tag{8}$$

Taking into consideration Eq.(4) from Eq.(8) we obtain the relation between parameters $\bar{A}$ and $\bar{Z}$

$$\frac{d\bar{Z}}{d\bar{x}} = i_p + \frac{1}{2\,m}\,f_1\left(\bar{A}\right)\,\frac{d\bar{A}}{d\bar{x}}\,, \tag{9}$$

where $\frac{d\bar{Z}_p}{d\bar{x}} = \frac{dZ_p}{dx} = i_p$ is the initial slope of the channel.

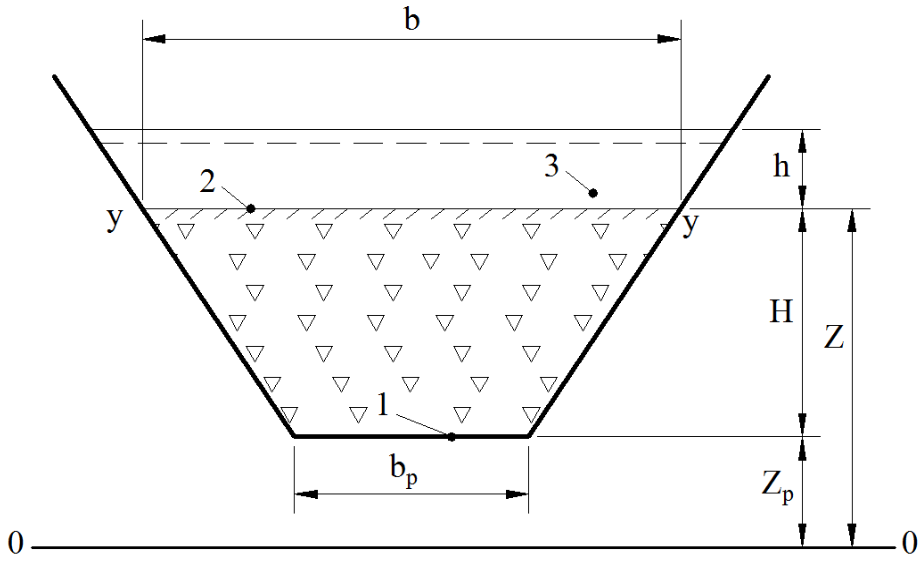

Fig. 5. Trapezoidal cross-section of the channel

Joint solution of Eqs.(6) and (9) result in an ordinary linear differential equation.

And finally, integration of Eq.(6) is carried out taking into consideration boundary conditions of the given problem. If at the cross-section of the river mouth (x=0) the value of the sea shore mark rises (drop) is equal to $Z = Z_0$ (Fig.4), then by simple hydraulic calculations the area of effective cross-section is determined at that cross line $A_{нач}$ [3].

Integration of Eq (6) enables to set up the value A along the bed-formation section. Solving Eqs.(2),(3), and (7) respective parameters of the stream, including coordinates of the stabilized new channel's bottom are obtained. Comparison of depth with the height of the river bank at each cross-section enables to find location of such cross-sections of the river where burst is most of all possible.

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