IRRIGATION AND MELIORATION

Akmalov Sh., Blanpain O., Masson E.
STUDY OF ECOLOGICAL CHANGES IN SYRDARYA PROVINCE BY USING THE REMOTE SENSING AND GEOBIA ANALYSIS METHOD

Akhatov A., Akhmetkanova G.A.
METHOD FOR DETERMINING CLAY MINERALS CONTENT IN SOIL

HYDRAULIC ENGINEERING STRUCTURES AND PUMPING STATIONS

Mirsaidov M.M., Toshmatov E.S., Takhirov S.M.
STUDY OF DYNAMIC BEHAVIOR OF EARTH DAMS CONSIDERING THE DAM BASE

Yangiev A.A., Gapparov F.A., Adzhimuratov D.S., Kovar P.
FILTRATION STUDY IN THE BODY OF EARTH DAM AND ITS CHEMICAL EFFECT ON PIEZOMETERS

Mirsaidov M.M., Sultanov T.Z., Kisekka Isaya, Yarashov Zh.A., Urazmukhamedova Z.V.
STRENGTH ASSESSMENT OF EARTH STRUCTURES

Bazarov D.R., Berdiyev M.S., Urazmukhamedova Z.V., Norkulov B.M., Kurbanova U. U., Bestuzheva A.S.
RESULTS OF NUMERICAL RESEARCH OF DISCHARGE CAPACITY OF A SPILLWAY WITH A WIDE THRESHOLD

Sultanov K.S., Loginov P.V., Salikhova Z.R., Takhirov S.M.
STRAIN CHARACTERISTICS OF SOILS AND THE METHODS OF THEIR DETERMINATION

Ikramov N.M., Majidov T.Sh., Khodzinskaya A.G.
EFFECT OF BEDLOAD SEDIMENT NATURAL COMPOSITION ON GEOMETRIC AND DYNAMIC CHARACTERISTICS OF CHANNEL FORMS

ELECTRIFICATION AND AUTOMATION OF AGRICULTURE AND WATER RESOURCES MANAGEMENT

Radjabov A., Turdiboyev A., Akbarov D., Keshuev S.A.
THE PROBLEMS OF ENERGY EFFICIENCY IN EXTRACTING FAT AND OILS FROM COTTON SEEDS AND THEIR SUFFICIENT SOLUTIONS

ECONOMICS OF WATER MANAGEMENT AND USE OF LAND RESOURCES

Chertovitsky A.S., Narbaev Sh.K., Demidova M.M.
LAND USE SYSTEM MODERNIZATION: ENVIRONMENTAL ASPECT OF MANAGEMENT
Abstract

The article brings up data on sediment diversity at watercourse bed and on their movement in the form of ridges. The ridge form movement of sediment leads to the reduction of reservoir volume and canal cross section area, which has an effect on their carrying capacity, filling of pump station forechambers and hydroelectric station pressure basins with sediment. The presence of sediment in flow leads to abrasive deterioration of pumps, water motors and pressure pipes and to other negative consequences. Research work tasks on the study of these effects have been examined with the purpose of preventing such negative consequences. On the basis of laboratory data diagrams and relationships were obtained for ridge length, height and movement velocity vs. sediment hydraulic and geometric sizes.

Key words: ridge shapes, bedload sediment, heterogeneous sediment composition, flow velocity, ridge length, height and movement velocity.

Introduction. Periodical structures form on an erodible surface when it interacts with air or water flow. Such periodical structures can be seen on the bottom of all waterways and reservoirs, on snow surface, in hydro and pneumatic transport pipes. Data about waveline movement of Karakum sands in shape of pocks, ridges and dunes are given in work [1]. Formation of ripples are observed even in the Pacific ocean under the action of deep current [2]. Movement disperse medium under influence of turbulent flow in the form of periodical structures yield a huge loss to the humanity, since it deforms river and man-made waterway channels and carries sand and snow into the sites of national economy and etc. This has made people fight against the negative consequences of this phenomenon since olden times.

For the first time they have started to study sediment movement in China in the 15th century. Channel control works were required for rivers in China (for instance, Huang He), which carry huge amount of sediment.

Later, with the development of navigation, the science about sediment movement has started to develop in Europe. First DuBua and later Dikon have carried out their research in this area. DuBua observed bedload form creation and movement in laboratory conditions, and Baumgarten observed bedload form movement in field conditions for the first time and measured the parameters in Garonne river.

It is impossible to solve the problem, related with formation and realization of bedload periodical structural forms in turbulent flow by analytical methods, since the process depends on many factors. In present, such problems are solved by laboratory research and the accuracy of obtained results are estimated with field observations. Discrepancy in estimated and observed parameters of ridges is mainly related with bedload structure variation in space and time, imperfection of measuring technology and methods. As a result of laboratory and field research until now huge amount of theoretical and empirical formulas have been obtained, which determine the connection of bedload form parameters to flow and sediment characteristics. Range of new tasks have been revealed, and their solution are yet to be obtained. After Dikon and Engels’s experimental research, in 1914 G.Jilbert’s and E. Merfy’s experimental work came out.

Some of the main works in development of science about sediment movement are V.N.Goncharov’s and G.N.Lapshin’s works.


T.Sh. Majidov have attempted to account sediment composition for qualitative and quantitative estimation of ridge characteristics in his works [3,4]. He conducted experiments with three groups of disperse soils, each of which is one homogeneous and one heterogeneous material with equal mean diameters.

Experimental research allowed Majidov to obtain formulas for ridge parameters with the account of sediment size in the following form:

- for ridge form length:

\[ l = 1.3 \times 10^{-1} \left( \frac{\omega}{g \theta_0} \right)^{2.2} \exp(-1.58 \frac{\theta}{\theta_0}) \]  

(1)

where: \( \omega \) – hydraulic size of particles with diameter \( d_{50} \).

- for ridge height:

\[ h = \frac{g \theta (\theta H)^{4.4}}{0.01178 \times 10^{-4}} \]  

(2)

for heterogeneous composition of sediment;

\[ h = \frac{g \theta (\theta H)^{1.5}}{0.00520} \]  

(3)

for homogeneous composition of sediment;

- for ridge movement velocity:

\[ C_z = 4.0 \times 10^{-5} \left( \frac{\omega}{g \theta_0} \right)^{3.35} (\theta - \theta_0)^{2.5} \]  

(4)

All the above listed works lack consideration of impact of sediment natural composition change on the length, height and velocity of ridge movement, therefore we decided to conduct additional research in this area.
Research methods.

The goal of the research is to estimate the impact of the various types of heterogeneous sediment of constant size on the length, height and velocity of channel ridge form movement.

The following research tasks were set:

1. Improving methods for accounting varieties of heterogeneous soils.
2. Checking the applicability for the coefficient of heterogeneity of mixtures as \( \varepsilon = \frac{d_m}{d_i} \), involving the existing data on grain-size distribution of bedload heterogeneous sediment.
3. Set up the following relationship of flow characteristics and ridge parameters with the coefficient of mixture heterogeneity:

\[
H, l, \theta, \theta_0, q_m = f(\varepsilon = \frac{d_m}{d}) \tag{5}
\]

\[
h, l, \theta, C = f(\varepsilon = \frac{d_m}{d}) \tag{6}
\]

4. Determining the impact of sediment mean size, composition and flow hydraulic characteristics on ridge parameters:

\[
h, l, C = f(H, \theta, Q, I, \theta_0, d_m, d_m, d_i) / d
\]

where:
- \( d_m \) – mean sediment diameter;
- \( d_m \) – maximum sediment diameter;
- \( d_i \) – particle sizes with corresponding probability (i=5, 10, 15, 25, 35, 50, 60, 65, 70, 75, 85, 90, 95);
- \( \theta \) and \( \theta_0 \) – mean and eroding flow velocity;
- \( H \) – mean flow depth;
- \( I \) – water surface slope;
- \( q_m \) – bedload sediment discharge;
- \( \varepsilon \) – coefficient of sediment heterogeneity;
- \( h, l, C \) – height, length and velocity of ridge movement, accordingly.

Since it is difficult to estimate the impact of heterogeneity of various types of natural sediment on the process of bedload ridge formation and movement in field conditions, main experiments were conducted in laboratory conditions (tab.1, fig.1).

Experimental research was conducted on hydraulic channel in the laboratory, field observations of ridge movement for various sediment composition were done on canals and rivers of the republic [5].

Results and Discussion.

Ridge length. Ridge length is one of the important ridge form characteristics. Almost in all the theoretical works, related with study of ridge formation mechanisms, ridge form lengths are studied. Since one of the goals of our research was to set the connection of ridge length of various sediment composition with constant mean particle size and relative flow velocity, from the obtained experimental data we created graphical relationships of \( \varepsilon / d = f(\theta / \theta_0) \) (fig.2).

The following design formula was obtained on the basis of analytic and graphical relationship with accuracy of 0.8÷0.95:

\[
\frac{l_r}{d} = -\left(49.9 e^{-2} - 127.4 e + 594\right) x
\]

\[
x \left(9 \theta_0\right) + 262.9 e^{-2} - 682.4 e + 1824
\]

Ridge height. Determining ridge height in channel flow is necessary for estimating bed roughness in

<table>
<thead>
<tr>
<th>No.</th>
<th>Type of sediment</th>
<th>Grain-size distribution in % mass, for particle size in mm</th>
<th>( d_{mm, MM} )</th>
<th>( \varepsilon = \frac{d_m}{d_0} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Edge fractioned</td>
<td>10%: 7, 7%: 5, 3%: 3, 2%: 2, 1%: 1, 0.5%: 0.25, 0.25%: 0.1, &lt;0.1</td>
<td>2.49, 0.83</td>
<td>2.51, 2.24</td>
</tr>
<tr>
<td>2</td>
<td>Small fractioned</td>
<td>10%: 9.5, 5%: 8.5, 3%: 8.75, 2%: 13.75, 1%: 22.25, 0.5%: 14.75, 0.25%: 8.75, 0.1%: 9.25</td>
<td>4.5, 14.9, 14.25</td>
<td>4.6, 2.51</td>
</tr>
<tr>
<td>3</td>
<td>Large fractioned</td>
<td>10%: 11.1, 5%: 10.1, 3%: 11.1, 2%: 11.1, 1%: 11.1, 0.5%: 11.1, 0.25%: 12.1, 0.1%: 12.2</td>
<td>1.25, 5.07</td>
<td>0.62, 2.53</td>
</tr>
<tr>
<td>4</td>
<td>Evenly fractioned</td>
<td>10%: -14.4, 5%: 14.8, 3%: 15.3, 2%: 32.7, 1%: 18.6, 0.5%: 2.2, 0.25%: 1.25, 0.1%: 0.75</td>
<td>2.48, 1.88</td>
<td>2.50, 1.0</td>
</tr>
<tr>
<td>5</td>
<td>Mean fractioned</td>
<td>10%: -100, 5%: -100, 3%: -100, 2%: -100, 1%: -100, 0.5%: -100, 0.25%: -100, 0.1%: -100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>6</td>
<td>Homogeneous</td>
<td>10%: -100, 5%: -100, 3%: -100, 2%: -100, 1%: -100, 0.5%: -100, 0.25%: -100, 0.1%: -100</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
determining channel hydraulic resistance, bedload sediment discharge and channel deformation calculations, also for setting threshold height in water intake structures, installation depth for pump station exhaust pipes and etc.

In order to set the connection of ridge height of various sediment composition with constant mean particle size and relative flow velocity, from the obtained experimental data we created graphical relationships of \( h_r / d = f (\vartheta / \vartheta_0) \) (fig.3).

![Fig. 3. Plot of ridge height and sediment composition to the relative flow velocity](image1)

### Ridge movement velocity.

Ridge dynamic parameters, i.e. movement velocity is particularly important in designing channel deformation and bedload sediment discharge. Researchers have been studying these characteristics for almost two centuries. In order to set the connection of ridge movement velocity of various sediment composition with constant mean particle size and mean/scouring flow velocity, from the obtained experimental data we created graphical relationships of \( C_r / d = f (\vartheta / \vartheta_0) \) (fig.4).

The following design formula was obtained on the basis of the analysis of the graphical relationship with accuracy of 0.75±0.9:

\[
C_r = \left( 0.0026 \vartheta^2 - 0.0066 \vartheta + 0.033 \right) (\vartheta - 1) - 0.11 \vartheta^2 - 0.6
\]

### Results:

1. The relationships (7, 8, 9) obtained from experimental data give more precise determination for ridge length, height and movement velocity change depending on sediment composition heterogeneity of waterways in valley and piedmont regions.

### Conclusions:

1. Bedload sediment movement in waterways take place in form of ridges.
2. Geometric and dynamic bed-load ridge characteristics depend on bedload sediment composition.
3. Relationships of heterogeneous bedload sediment ridge length, height, and moving velocity vs. flow relative velocity were obtained.
4. The obtained relationships show that sediment heterogeneity and flow relative velocity change has a direct effect on the bedload ridge form length, height and its moving velocity.
5. The increase of the relative flow velocity result in the decrease of ridge length.
6. The increase of the relative flow velocity up to 2.2÷2.4 result in the increase of ridge height at first, then in its decrease.
7. The increase of the difference between mean and scouring flow velocities result in the increase of ridge movement velocity from even to mean fracture composition.
8. The obtained relationships are applicable for waterways in valley and piedmont regions with more accuracy.

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