UDC 556.537

MODELING OF WASHING-OUT OF NON-CONVERSE SOILS

A. Bagration-Davitashvili, I. Inashvili, *L. Dzienis, V. Khorava

(Georgian Technical University)

(* Bialystok University of Technology)

Abstract: *Laboratory data are more often used to predict the onset of channel deformation, mainly due to the difficulty of performing full-scale studies. In addition, the results of field studies are not always reliable and in terms of accuracy they are not so rarely inferior to laboratory ones based on the theory of similarity.*

Comparison of observational speeds for cohesive soils in full-scale and laboratory conditions shows, that the scouring speeds established by the erosion of samples (fragments) of undisturbed addition under laboratory conditions are significantly higher, than those for the same soils recorded in nature.

The Model, that describes relationship between eroding and non-blurring permissible flow rates show good convergence between experimental and of field observations.

Key words: *non-converse soils; theory of similarity; soil erosion; modeling of soil erosion.*

1. INTRODUCTION

Laboratory data are more often used to predict the onset of channel deformation, mainly due to the difficulty of performing full-scale studies. In addition, the results of field studies are not always reliable and in terms of accuracy they are not so rarely inferior to laboratory ones based on the theory of similarity [1].

The theory of similarity is based on three theorems:

1. If physical processes are similar to each other, then similar criteria for the similarity of these processes have the same magnitude.

2. Equations describing physical processes can be represented, as a functional connection between similarity criteria.

3. Kirpichev-Guhman Theorem. In order for physical processes to be similar to each other, it is necessary and sufficient, that these processes are qualitatively the same and their like-defining criteria are numerically identical.

By qualitatively the same we mean such processes, the mathematical description of which coincides in everything, except for the named numbers contained in them.

The processes of erosion, the destruction of various soils mainly occur due to the movement of viscous liquids, as well as their interaction with the base, composed of different soils.

In modeling, hydromechanical and mechanical similarities are of particular importance. Therefore, the main criterial dependences of erosion processes will be the equations of hydromechanics.

2. THE BODY OF THE ARTICLE

In the case of stationary fluid motion, the phenomenon of flow around a spherical body is determined by three similarity numbers: Euler, Froude and Reynolds. These criteria are known to be based on Newton's criteria.

$$f = m\frac{dV}{d\tau} \qquad (1)$$

where f is force; m is the mass; V is the flow rate (or rate of particles); τ - characteristic time interval

If we compare the two systems, then for the first we have:

$$f_1 = m_1\frac{dV_1}{d\tau_1} \qquad (2)$$

and for the second:

$$f_2 = m_2\frac{dV_2}{d\tau_2} \qquad (3)$$

For resembling points of similar systems, the similarity constants have the form:

$$\frac{f_1}{f_2} = C_f;\ \frac{m_1}{m_2} = C_m;\ \frac{\tau_1}{\tau_2} = C \qquad (4)$$

If we express the variables of system I in terms of the variables of system II and add them to equation (2), we get:

$$C_f f_2 = C_m M_2\frac{C_v dV}{C_\tau d_\tau} \qquad (5)$$

After conversion:

$$\frac{C_f C_\tau}{C_m C_v} = m_2\frac{dV}{d\tau} \qquad (6)$$

The last equation is identical to equation (3) provided

$$\frac{C_f C_\tau}{C_m C_v} = 1 \tag{7}$$

In the theory of similarity, these quantities are called indicators of similarity. The selection of similarity constants is limited by the following condition:

$$\frac{V_f C_\tau}{C_m C_v} = \frac{(f_1/f_2)(\tau_1/\tau_2)}{(m_1/m_2)(V_1 V_2)} \tag{8}$$

или

$$\frac{f_1\tau_1}{m_1 V_1} = \frac{f_2\tau_2}{m_2 V_2} = idem \tag{9}$$

Thus, provided, that the two systems are similar, only three values can be changed arbitrarily, and the value of the fourth will be determined by the equation (9).

The dimensionless complexes $f\tau/mV$ are the invariant of similarity and for the two systems under study (model and nature) must have the same numerical values.

In the similarity theory are widely used modified similarity criteria. Modification is used in the case, when the physical parameters included in the similarity criteria cannot be established experimentally.Then they are eliminated by the combination of two, or more similarity criteria and thereby themselves get the new arbitrary criteria. For example, from the Reynolds and Froude criterion new dimensionless complex is obtained, called the Galileo criterion:

$$\frac{Re^2}{Fr} = \frac{V^2 l^2 \rho_0^2 g l}{\mu^2 V^2} = \frac{l^3 \rho_0^2 g}{\mu^2} = Ga \tag{10}$$

The obtained criterion in such flows is characterized by the ratio of the forces of molecular friction and the forces of gravity.

As a result of multiplying the Gallileo criterion by the dimensionless simplex $(\rho - \rho_0)/\rho_0$, we obtain the Archimedes criterion

$$A_r = \frac{Re^2}{Fr}\frac{\rho-\rho_0}{\rho_0} = \frac{l^3\rho_0^2 g}{\mu^2}\frac{\rho-\rho_0}{\rho_0} = \frac{l^3 g}{\mu^2}\frac{\rho-\rho_0}{\rho_0} \tag{11}$$

where ρ, ρ_0 respectively the density of water and soil particles, kg / m^3.

Archimedes criterion characterizes the balance of gravity, lift force and friction.

It can be considered, as a combination of two numbers of similarity, Reynolds and Richardson:

$$Re^2 \cdot Ri = \frac{Re^2}{Fr}\frac{\rho-\rho_0}{\rho_0} \tag{12}$$

$$Ri = \frac{\rho-\rho_0}{\rho_0}\frac{gl}{V^2} \tag{13}$$

When modeling complex processes with which we deal with the interaction of flow with the moving bottom, depending on a large number of variable parameters, a number of criteria are required to describe them. But the equality of some of them in some cases cannot be obtained. Then for approximate similarity it is necessary to limit oneself to the similarity of the most essential factors.

When the influence of physical quantity (or complex of quantities) can be neglected, the process is considered self-similar with respect to this quantity and the simulation is greatly simplified.

Experiments on non-cohesive soils were modeled using the Archimedes, criterion.

Experiments were conducted in the quadratic resistance region. Experimental flows in a tray by the number of Froude were similar to full-scale ones.

Simulation of washing out of cohesive soils

The degree of study of the theory of turbulence, channel processes, erosion of the channel, composed of cohesive soils, does not allow with sufficient certainty to solve a number of problems without appropriate physical modeling [2, 3].

Comparison of observational speeds for cohesive soils in full-scale and laboratory conditions shows, that the scouring speeds established by the erosion of samples (fragments) of undisturbed addition under laboratory conditions are significantly higher, than those for the same soils recorded in nature.Thus, the use for practical calculations of the results obtained in the laboratory by washing out samples of relatively small sizes is associated with a certain risk.

When testing samples in the laboratory does not take into account a number of factors observed in nature. As established by studies begun in the 50s, the main factors are: changes in the strength properties of soils (fatigue strength) with decreasing sample sizes and changes in the pulsating nature of flow rates.

The effect of a change in the pulsation nature when, conducting laboratory and field experiments is manifested in the fact, that the ratio of maximum instantaneous bottom velocities at a point to their resolute values at the same point $V_{\Delta max}/\overline{V}_{\Delta}$, which characterizes the blurring ability of the flow, differs significantly in laboratory and field flows.

Considering, that the integral indicator characterizing the resistance of cohesive soils to erosion is an indicator of soil cohesion, translating laboratory data into nature, it is necessary to keep in mind the degree of change in strength with changes in sample size, which can be approximately characterized by the scale factor.

Experimental data on the erosion of samples of cohesive soils suggests, that their resistance to erosion depends on the geometric dimensions of the sample and decreases with increasing its area.

This should be explained by the probabilistic nature of the fatigue fracture of the surface of a cohesive soil during erosion.

Analyzing the effect of sample size on its mechanical, strength properties and, therefore, on erosion resistance, it can be noted, that the probability of having the weakest points, inhomogeneities, flaws, defects on the surface of initiating erosion specimens will obviously increase with its sizes. The technology of manual selection of monoliths in the field also influences the probabilistic growth of strength properties for small samples.

The issue of taking into account the scale factor in modeling has been considered in many papers.

One of the first, explaining the manifestation of the scale effect, is the work of Griffiths [4].

Such a process of erosion of the soil model and nature should be considered such, that at appropriate points, the depth of erosion in the model, or determined their non-blurring speeds are either equal to the erosion in kind, or constitute a certain constant part.

In this aspect, the erosion of the channel can be considered similar if the ratio between the bottom and non-washed speeds in nature and in the model is the same, i.e.

$$V_{\Delta}/V_{\Delta m} = idem \tag{14}$$

where V_{Δ} is the bottom flow velocity at the height of the roughness protrusions in nature; $V_{\Delta m}$ is the bottom velocity in the model.

Here, to eliminate the influence of the nature of the velocity distribution from the analysis of the process, instead of the ratio of average speeds, the ratio of bottom ones is taken, since the velocity field in nature and model should be similar.

If the relationship between bottom and non-blurring rates in nature and in the model is the same, the erosion processes will be similar.

Depending on $C_{у}^{н}/C_{ум}^{н}$the ratio between the endurance limit for field and laboratory conditions is expressed by the coefficient, that takes into account the scale effect ε:

$$V_{\Delta}^{2} = V_{\Delta M}^{2} \frac{K\varepsilon n_{M}}{K_{m} n} \tag{15}$$

or

$$V_{\Delta} = V_{\Delta M} \sqrt{\frac{K\varepsilon n_{M}}{K_{n}}} \tag{16}$$

The value of ε can be set according to V.S. Ivanova, describing the manifestation of the Weibul scale effect.In the first approximation, ε can be taken equal to 0.58.

In order to obtain convenient dependency, we approximately take $K_м = K$, and also introduce in (16) the averaged, frequently used value = 4.0 and$n_{м}$ = 1,25.

Then, when soil samples of undisturbed addition are selected in the model, selected in field conditions, non-flushing bottom velocity for environmental conditions, depending on the model values, can be set:

$$V_{\Delta} = 0.42 V_{\Delta M} \tag{17}$$

Considering the commonly used relationship between eroding and non-blurring permissible flow rates:

$$V_{\Delta \mathrm{p}} = 0.41 V_{add.} \tag{18}$$

Sieve diameter, mm	6-4	4-2	3-1	1,5-0,5	1-0,5	0,6-04
Average particle diameter, mm	5	3	2	1	0,75	0,5

3. CONCLUSION

The results of such experiments selected in field conditions, when compared with the data of field observations, show good convergence.

REFERENCES

1. Assessing, Measuring and Modelling Erosion in CalanchiAreas: a Review. N. A. Caraballo-Arias, Vito Ferro. Journal of Agricultural Engineering, Vol 47, No 4. 2016.
2. W.S. Merritt a, R.A. Letcher, A.J. Jakeman. A Review of Erosion and SedimentTtransport models. Environmental Modelling & Software 18. 2003, pp.761–799
3. A. Pandeya, S. K.Himanshua, S.K.Mishraa, V. P.Singhbc. Physically Based soil Erosion and Sediment Yield ModelsRrevisited. CATENA Volume 147, 2016, pp. 595-620
4. Modelling the Effects of Vegetation on Stability of Slopes. Y. H. Chok, W. S. Kaggwa, M. B. Jaksa, D. V. Griffiths. Conference: 9th Australia New Zealand Conference on Geomechanics, Vol. 1. 2004. pp. 391–397.