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DESTRUCTION OF INTER-AGGREGATE RELATIONS BETWEEN PARTICLES OF SOIL IN THE PROCESS OF WATER EROSION

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Abstract

The resistance to the breaking of soil samples is three orders of magnitude greater than the shear stresses at the bottom of the slope flows, which produce work for the separation and transport of soil particles. Mirtskhulava believed that the separation of soil particles by a stream occurs as a result of fatigue breaking of bonds between soil particles (Mirtskhulava, 1966). With this in mind, the resistance of the soil to the gap is reduced by two orders of magnitude. Nearing M.A. believed that the separation of soil particles occurs at the points of vortex breakdown from the bottom of the stream, where the shear stress is two orders of magnitude greater than its average value (Nearing, 1991). These approaches do not explain the overcoming of the adhesion force between soil particles by slope flows. The results of the study of the effect of water temperature on the erosion rate of model soil samples showed a strong dependence of erosion on water temperature, which is close to the Vant-Hoff`s rule. It was experimentally shown that the destruction of bonds between particles soil in a sample of black earth mono-grained soil occurs under a layer of still water (Rose, 1985).

***Key words**: erosion, inter-aggregate relations, soil resistance to tearing, Vant-Hoff rule.*

INTRODUCTION

Nearing et al. (1991) paid much attention to this issue. Studies of resistance to the breakthrough of 33 different soils of the United States showed that, according to this characteristic, all soils fall within the range of 0.9 to 3.2 kPa. An analysis of the results of his studies on monoaggregate soil samples showed that their resistance to rupture fits within the given range and is three orders of magnitude more than the shear stresses at the bottom of the slope shallow-water flows. However, soil samples were successfully eroded.

To explain this paradox, Nearing (1991) used the results of Grasse's research (Grass, 1970), according to which the tangential stresses at the points of the near-bottom area, where the vortex disturbances (burst event) are separated, exceed by two orders of magnitude the average tangent stresses at the bottom of the stream that it is at these points that the particles of the soil break away. Since the separation of the vortices from the bottom of the flow is stochastic, the equation for the separation of soil particles includes a probability block.

However, this solution does not seem to be entirely correct, since the tangential stress at the point of separation is the same, although it is two orders of magnitude higher than the average value of the tangent stress, and yet it is an order of magnitude lower than the resistance of the soil sample to the gap.

At the same time, the solution to this problem proposed by Mirtskhulava, also cannot be considered perfect. If we assume that the adhesion of the soil, determined by the method of pressing a spherical punch into the soil with full water saturation (Tsitovich, 1963), is equivalent to the resistance of the rock to break, as Mirtskhulava (1966), then the fatigue strength of the gap, of the same order as the shear stress in the places of the separation of the vortices.

Thus, the solution of the problem of the separation of particles of a cohesive soil by sloping water flows from the position of fatigue failure of the connection between soil particles is not quite correct.

MATERIALS AND METHODS

The resistance of soil particles to separation by the flow of water, as a rule, is much greater than those of hydraulic origin that the flow bed undergoes as a whole, as well as the soil particles composing it. That is why Mirtskhulava, in the erosion equation proposed

by him back in 1970, used the notion of fatigue breaking of bonds between soil particles and soil particles under the influence of dynamic loads experienced by the flow bed due to local pulsations of water velocity.
Studies on the fatigue strength of soils and the rate of erosion showed the similarity of these processes, therefore, by analogy with the equation describing the fatigue strength curve, the number of stress cycles (N) before the moment of separation of a particle can be represented as:

$$N = \frac{188000}{\frac{v_{\Delta_x}^2}{v_{\Delta_{don}}^2} - 1} \quad (1)$$

Where: v_{Δ_x} and $v_{\Delta_{don}}$, respectively, the bottom velocity at the height of the roughness protrusions at a distance x from the beginning of the stream and the admissible (not blurring) speed.

The ratio of the squares of these velocities is equivalent, respectively, to the tension of the gap at the initial moment of the load on the soil particle and at the moment of its separation by the flow of water.
From equation (1), knowing the frequency of the velocity pulsations in the stream, it is easy to determine the number of particles disrupted by the stream per unit time and, spreading this number per unit area, get the flush equation in the form:

$$q = 0.0000064 * \gamma \omega d^2 \left(\frac{v_{\Delta_x}^2}{v_{\Delta_{don}}^2} - 1\right) \quad (2)$$

Where: q is the flushing of soil per unit area d - diameter of detachable particles; γ is the particle density; ω - the frequency of the velocity pulsations in the stream. Later Mirtskhulava (1970) accepted the frequency of pulsations in sloping streams as a constant. The permissible speed, according to his ideas, is a function of the square root of the weight of a soil particle in water and the fatigue strength of a soil to tear (S_y). The latter is determined by the dependency:

$$S_\gamma = 0.035 * S \quad (3)$$

Where: S is the adhesion determined by indentation of a spherical stamp into the soil.

RESULTS AND DISCUSSIONS

There are other facts that contradict the idea of the hydraulic nature of the forces responsible for the destruction of bonds between soil particles. According to many erosion models (Foster, 1982; Rose, 1985), the intensity of the flush is linearly dependent on the magnitude of the active erosion factor.
In the hydrophysical model of erosion (Larionov & Krasnov, 2000), the intensity of the washout is proportional to the cube of the flow velocity in the velocity range 1.5-2 times higher than the threshold values. To confirm this position, experiments were conducted on erosion of model soil samples with a density of 1.2 g/cm^3 in a wide range of velocities. The experiments yielded positive results (Figure 1), except for the region of low velocities, a linear relationship was obtained between the flush and the cube of the flow velocity.

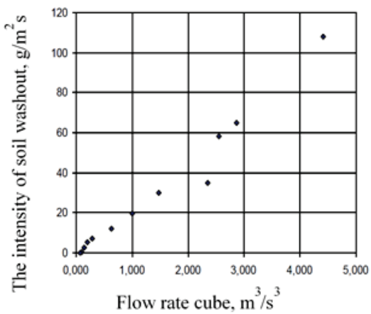

Figure 1. The dependence of the intensity of erosion model soil sample with a density of 1.2 g/cm^3 from the cube flow rate

However, the study of samples of higher density found that the relationship between the rate of erosion of the samples and the cube of the flow velocity has a distinct fracture (Figure 2).

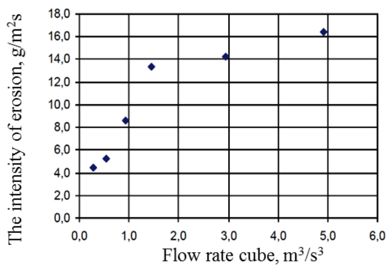

Figure 2. The dependence of the intensity of erosion model soil sample with a density of 1.5 g/cm^3 from the cube flow velocity

It turned out that the intensity of the separation of soil particles is not proportional to the cube of the average flow velocity in the entire studied range of velocities. Starting from a certain speed, there is a sharp flattening of the trend line on the graph of the dependence of the intensity of flushing from the cube of the flow velocity.

The first attempt to explain this phenomenon was based on a fatigue approach to breaking bonds between soil particles. As is well known, in the process of fatigue disturbance, cyclic oppositely directed loads lead to the movement of material relative to each other at points with a structural defect, where cracks appear over time, and then the material is destroyed.

In the case of unidirectional cyclic loads, which is typical for particles lining the flow bed, reciprocating motion in the material can take place only if there are elastic properties in the material. If we assume that soil particles have the property of elasticity, then we can assume that the separation of particles by water flow occurs due to multiple cycles of reciprocating movements, which are possible only in the case when the minimum values of hydraulic loads are less than the elastic forces of the particles.

With an increase in minimum loads, the amplitude of reciprocating movements will decrease, which may be the cause of the relative slowing down of the intensity of the separation of particles with increasing flow velocity. With an unlimited growth of the flow rate, the minimum pulsating loads obviously exceed the elastic forces of the soil particles, as a result of which the reciprocating translational oscillations of the particles will cease and, accordingly, their separation will stop. However, the erosion of the model soil samples did not stop at a speed of more than 7 m/s. Thus, the idea of fatigue breaking of bonds between soil particles in the process of erosion and in this case does not work.

The case suggested the direction in which to look for a solution to the problem of breaking bonds between particles in the process of erosion by slope flows, shear stresses at the bottom of which are three orders of magnitude less than the resistance of the soil to breaking. Once, when conducting a series of experiments at a constant flow rate, the water temperature increased as a result of the pump operation from 13 to 25ºC, while the erosion rate of soil samples increased. In this regard, an experiment was conducted to study the effect of water temperature on the erosion rate of samples in the range from 0 to 25ºC with a step of 5ºC (Figure 3).

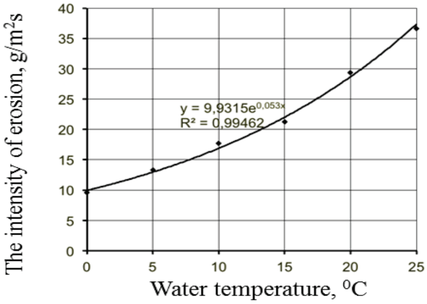

Figure 3. The effect of water temperature on the erosion rate of a soil sample

It turned out that when water temperature increases by 10ºC, the erosion rate (erodibility) increases by 1.5-1.6 times, which practically fits into the framework of the Van't Hoff rule, which reflects the influence of the speed of movement of molecules, reactants, frequency and force of their collisions. From this it follows that the destruction of bonds between soil particles is the result of the action not of hydraulic forces, but of the kinetic energy of water molecules.

In this regard, exploratory studies have been conducted, the purpose of which were: 1) developing a methodology for determining the rate of destruction of bonds between soil particles; 2) search for factors determining the rate of destruction of inter-aggregate bonds in model soil samples.

The destruction of bonds between soil particles is not visually determined; it is also impossible to mechanically separate particles that have lost contact with the soil mass. The most optimal is the use of water flow to remove particles that have lost contact with the underlying particles from the sample surface. In this regard, to assess the role of water as a substance that causes disruption of bonds between soil particles, the following method was adopted. Water was fed into the tray with pauses, in the continuation of which the water flow was absent, but the soil sample was under water with a layer of 1 cm. The experiment began with a pause.

At 1-2 cm below the sample, a blind jumper with a height of slightly more than 1 cm was placed and water was poured in an amount that provided a water depth of 1 cm. After a pause, the active phase of the experiment followed the jumper was removed and the pump was turned on. Water was fed into the tray for a specified time. Then the pump was turned off, the jumper was installed again, and the resulting container was filled with water. In the very first seconds, all particles that had lost contact with the sample were washed off the sample surface.
This process can be visually observed a mass of soil particles moves along the tray (Figure 4), while with the traditional method of testing samples, individual particles or groups of particles are rarely observed.

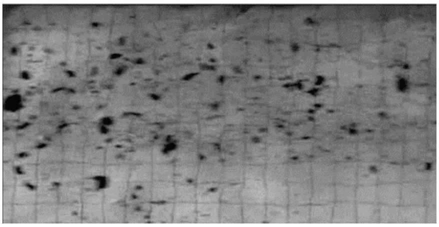

Figure 4. View of the tray below the sample. Dark spots are particles and groups of soil particles, torn off by a stream

With an increase in the duration of the pauses, the number of particles that have lost their bond increases with some delay (Figure 5). This can be explained in two ways. With the accumulation of particles lacking bonds, they all more strongly press down (press down) the underlying particles, which makes it difficult or completely stops the propagation of the process of breaking bonds deep into the sample (substance).

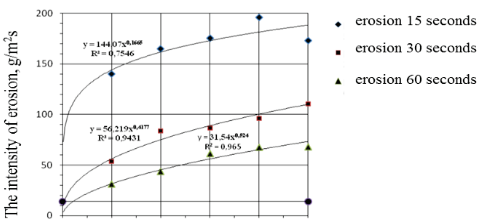

Figure 5. Slowing down the intensity of erosion of the sample with an increase in the duration of the pause

Another explanation may be that the molecular movement of water between soil particles slows down as the front breaks the destruction of bonds between particles inwards, which leads to a decrease in the rate of breakdown of bonds between particles.
Maximal significance decreases with increasing magnification, so that witnesses are shifted and destroyed by the extent of the active actives of the front. This type of character may, in any event, be in the same way that it has a role in disturbing the interplay between the players playing the forces of the non-military nature, namely, the forces of mediation. Attention is drawn to the fact that the circumstance, the gradient of the graphical dependencies and the intensity of the cubic velocities (Figure 2) can be considered as a follow-up. On the perimeter of the crown, the lines cut the graph of the speed of the destruction between the particles, which is under the action of the molecule of the water molecules, which is carried out in the water, which is free of charge. By increasing the speeds, the flow increases the intensity of the particle grows, and the increase in the acceleration of the water vaporizes the chemical substances as a layer of the soil, with the non-destructive effects between the particles of the soil. Otherwise, with the acceleration of freeze-thrust acceleration, it increases the speed of destruction between consoli-dirovannımy particles.
However, the ability to flow into the unconsolable parts, the speed of the deconsolation particles, the line of the graph (in Figure 2).
By increasing the speeds, the flow of the gyra-skiing stream is taking part in disturbing the intersection of the parts of the soil in a supreme layer of the image of the soil, and, hopefully, the hydraulic force is increased by the increase of the increase in the number of droughts. Check and quantify the value of this item in the top of the page.
In Figure 6 presents three options for placing fields on a bilateral slope.
The first option (a) provides for the location of 2 and 3 fields with long sides along the slope with tillage in the same direction, which is unacceptable for reasons of protecting the soil from erosion.
In the second variant (b) with tillage strictly along horizontals, the best protection of the soil from flushing is provided; however, this option is difficult to implement due to technological and economic considerations.

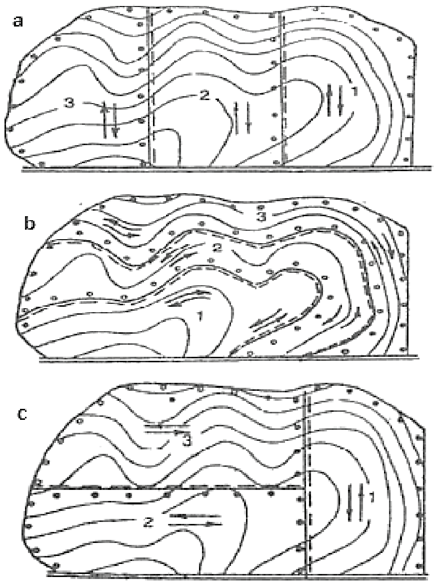

Figure 6 (a, b, c). Placement of fields on the slope and the direction of tillage

In the third variant (c), the soil is slightly worse protected than in the second, however, if we consider that the costs of tillage in the third variant are less than in the second, the third variant (c) will be optimal for the farm.

As a result of the fact that this is likely to be the result of a deterioration in the speed of destruction between particles under the water. It can be avoided, however, that it is not acceptable to use that model. The second part of the thesis is based on a detailed description of the size of the figure in the gypsum building, in which the roughness of the substructure is about 0 and in the other about 1 atm.

In the second case, speeding up the pattern of soil and, consequently, speeding up the destruction of particles between the particles of water and the chemical substances in the course of the chemical process, in the case of zero chemical reactions.

Finally, it can be assumed that the adhesion between the soil particles is ensured not only by Van-der-Waals forces, but also, for example, by polymer compounds. To confirm this hypothesis, several samples were dried, then moistened to their original condition and then subjected to erosion testing. And this assumption was justified. After drying, the samples were practically not eroded.

Since the soil is still washed off under natural conditions, it has been suggested that the bonds between the particles can also be destroyed by cyclic wetting and drying, as well as other weathering factors.

Thus, the research results allowed to reveal the mechanism of destruction of bonds between soil particles in the process of water erosion, which will serve as the basis for the development of physically sound models of erosion.

CONCLUSIONS

The first attempt to explain this phenomenon was based on a fatigue approach to breaking bonds between soil particles. As is well known, in the process of fatigue disturbance, cyclic oppositely directed loads lead to the movement of material relative to each other at points with a structural defect, where cracks appear over time, and then the material is destroyed.

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