HIGH-SPEED DEFORMATION OF COHESIVE SOILS

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ABSTRACT

During design and research stages of various structures of actuating elements of track and road-building machines (hereinafter-TRBM) a multi-step gradual study of the process of interaction of actuating elements with environment for further improvement served as a generally accepted technique without considering changes in the characteristics of the soil. But the change in the properties of the material imposes certain restrictions on working equipment of TRBM, affects its effectiveness. The objective of the author was to present results of theoretical and experimental research related to obtaining rheological characteristics of soils on the basis of device created with participation of the author, using engineering analysis, comparative and mathematical methods. The dynamic deformation device allows simulating an interaction of actuating elements of track and road-building machines with soil ground, while using a method for determining rheological properties of dispersed materials. Finally it was confirmed that machine-soil interaction speed in the range of 3–4 m / s should be considered optimum in terms of impact on the soil.

Keywords: track and road-building machines, soil, dynamic deformation, rheology, viscosity coefficient, speed of impact.

Background. *During design and research stages of various units of actuating elements (hereinafter-AE) of track and road-building machines (hereinafter-TRBM) a multi-step gradual study of the process of interaction of AE with environment for further improvement was a generally accepted technique without considering changes in the characteristics of the soil.*

Such an approach, however, is not absolutely justified by the fact that the change in the properties of the material imposes certain restrictions on working equipment of TRBM, affects the effectiveness of the equipment.

The nature of impact and magnitude of destructive forces in case of mechanical dispersion of soil are caused by physical-mechanical properties of the material, especially strength, hardness and toughness. The most rational way to break the bond between aggregated elements of soil is based on the creation of tensile stresses in their contact zone. To create such a stress in a deformable ground, it is necessary to apply a pressing force in pure form or in combination with other types of forces, such as shear. The real picture of the destruction in clay soils is of rheological nature, i. e. shear stress, developing along the sliding plane depends on the shear rate.

Existing methods of assessing shear-resistance of cohesive soils are competent at the test stage of the latter in relation to low speed impact on the environment. According to the procedures [1], from the point of view of most authors,shift can be considered as fast if its duration is of 0,5–1 min., which with account of exposure time of AE of a machine is a quasi-static process, inappropriate to customary speed parameters of the equipment. Although it is often thought that quasi-static dependence expresses the basic properties of the material and its applicability corresponds to the deformation speed at which the tests are made.

Objective. *The objective of the author is to present results of theoretical and experimental research related to obtaining rheological characteristics of soils on the basis of device created with participation of the author.*

Methods. *The author uses analysis, comparative and mathematical methods.*

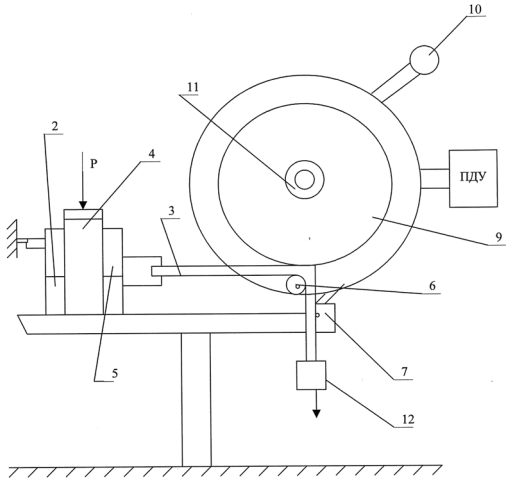
Results.

1.

With increasing deformation speed the very nature of the relationship between stress and deformation may change,thus requiring recourse to other types of tests. Therefore, obviously, the results of laboratory tests will be accurate only when the method of their implementation simulates the behavior of the soil under the impact of AE to the fullest extent possible.

In order to determine the optimal speed of impact on the environment when its physical and mechanical properties change a theoretically grounded test methodology is required, reflecting particular design scheme and taking into account the characteristics of the material response under dynamic loads in the range V = 1–11 m/ s. Conventional techniques and shear devices are not able to provide obtaining rheological properties of materials within the specified speed range.

So, for cohesive soils typical state is a large dependence of the deformation properties changes on the speed of impact. Methodically it is considered that the conditions of interaction of the mobile carriage of a shear device simulate adequately the conditions of interaction of AE of a unit size with the ground. Indeed, the length of the shear zone of existing devices is 17 mm, that, if applied to practices of cutting by a rotor with diameter of 0,5–1,0 m, corresponds to conditions of interaction of a blade with ground when the rotor

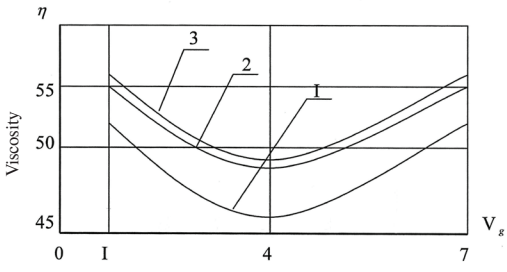


Pic. 1. Stand to study rheological properties of soil: 1 – table; 2 – fixed holder; 3 – draft; 4 – camera; 5 – holder; 6 – roller; 7 – hanger arm; 8 – engine; 9 – disc; 10 – handle; 11 – clamping sleeve; 12 – cargo.

Table 1

Plan of experimental studies

Factor	Measuring unit	Variation interval	Main level	Lower level	Upper level
Speed of impact	Vд, m/s	4,12	6,76	2,64	10,88
Soil density	ρ, g/cm^3	0,2	1,9	1,7	2,1
Soil moisture	W,%	7,5	15	7,5	2,5
Soil plasticity	$I_ρ$,%	4	16	12	20
Shear gap of a device	Δ, mm	1	2	1	3



Pic. 2. The dependence of viscosity on the speed of impact by changing soil moisture at the section of intense deformation (at Iρ=20, ρ=1,9 g/cm³)); (1 – W=7,5%, 2 – W=15%, 3 – W=22,5%).

shaft is rotated at an angle in the range of 2–3°. That is, with a sufficient degree of accuracy we can assume that the movement of the blade in this way is actually straightforward.

Therefore, the search for technical solutions to determine rheological properties of dispersed materials subject to their high-speed deformation leads to the need to improve and create devices and equipment on a new basis.

Method and device of dynamic deformation [2] developed with the participation of the author adequately simulate the process of interaction of AE with the environment (ground) and link its impact with determination of rheological properties of the material under study (Pic. 1).

2.

Setting of research objectives included:

1. Selection of physically reasonable range of velocity impact on the ground, with account for a wide range of properties (such as moisture, density, plasticity, dispersity etc.).

2. Determine the ability to influence the process of deformation and management.

Planning methodology of experimental studies suggested variation of factors that take into account physical and mechanical properties of the soil, the rate of exposure and device characteristics (Table 1).

The implementation of multi-factor methodology witnessed features of rheological curves of cohesive soils. The resulting S-shaped curves of deformation reflect the process of interrelated phenomena: soil compaction, its destruction and shear, expressed in dilatant nature of properties with the change in speed of impact. Given the differences in initial, final and most intense periods of deformation, the study of rheological properties was carried out by stages, taking into account the procedural time.

Experimental data revealed several patterns of speed deformation. It was determined that the greatest impact on the energy, power, rheological and criterial characteristics of the process is caused by initial speed of impact on the environment. The impact of the shear gap Δ, plasticity $I_ρ$, soil moisture and soil density is less noticeable and approximately equivalent.

Correlation and regression analysis of obtained values revealed the optimal value of the speed of deformation of cohesive soils in the investigated range of parameters (Pic. 2).

The regression equation for viscosity at the site of intense deformation was edited as follows:

$$\eta = (0{,}1 + 3\cdot10^{-4}V_д - 2\cdot10^{-3}I_ρ - 2\cdot10^{-3}\cdot V^2{}_д - $$
$$-0{,}05\Delta + 0{,}01\Delta^2 + 2\cdot10^{-3}\rho^3)^{-1}.$$

A generalization of experimental data on rheology of considered systems indicates that viscosity minimum throughout the moisture range corresponds to speed of impact within Vд=4 m/s, which may be considered as optimum in terms of soil deformation in the proposed device, and when under the impact of AE of TRBM.

Conclusions

1. A device and method for studying rheological properties of soils and mixtures, based on them, were developed.

2. It is confirmed that impact speed in the range of 3–4 m / s should be considered optimum in terms of impact on the soil.

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