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APPLICATION OF RHEOLOGICAL MODELS IN THE STUDY OF COMPENSATION OF ROAD STRUCTURE SOILS WITH CABLES.

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Abstract– In the article, the types of rheological models used to reveal the essence of the working process of the interaction between the working body of the rollers and the soil in the densification of the soil of the road structure and the analysis of their use are mentioned. At the same time, it is explained that the indicators of the technological operation mode of the rollers in providing the soil compaction coefficient of the road structure layers are evaluated through these models.

Key words– working body, soil, interaction, vibration, rheological model, elastic, plastic, viscous, Maxwell's model, Newton's element, operating mode, efficiency.

I INTRODUCTION

In recent years, a lot of attention has been paid to the design, construction and use of modern highways in our country. We know that the highway structure belongs to one of the types of complex artificial structures, and there are technical regulations that must be followed during their construction, as well as standard requirements that regulate the physical and mechanical properties of the soils used in the structure [1]. Taking into account these aspects, several technological operations are carried out during the construction of the road structure with the participation of earth digging and road construction machines, but in all layers of the road structure (road structure base, road base, road pavement base, pavement) one important process is the compaction of structural soil. technological processes are carried out using rollers and tamping machines [2].

Many scientists and researchers are conducting scientific research on the process of soil interaction with the working bodies of the compacting machine and the wide application of the obtained results to production practice. In this direction, the world's leading scientists, including foreign researchers, Michael Leonard, Paulwan Susante, Guiyan Xing, K. Terzaghi, W.A. Lewis, Mooney, Michael A. Robert W. Rinehart, CIS scientists V.I. Balovnev, V.V. Badalov, M.A. Zavyalov, N.N. Zaitsev, A.V. Zakharenko, N.N. Ivanov, S.I. Ivanchenko, G.V. Kustarev, M.P. Kostelov, E.N. Kuzin, D.K. Lomanov, Yu.M. Lvovich, A.G. Maslov, V.V. Mikheev, S.V. Nosov, I.A. Nedorezov, V.B. Permyakov, S.V. Savelev, V.A. Smolentseva, N. Ya. Kharkhuta, AM Kholodov, A. Hall and Uzbek scientists A.D., Kayumov, T.Q., Hankelov, R.M. Khudaikulov, D.A. Makhmudova and other scientists.

The densification process involves complex technological operations, in which different types of cages are used [3]. On the other hand, the working bodies of the compacting machines are of different types, depending on the physico-mechanical properties of the soil layers of the road structure, indicators and technological processes, static, vibrational and combined compaction methods are used.

In this case, various types of models are used to study the laws of the process of interaction between the working body and the soil and the physical and technological essence of the work operation, as well as to illuminate the complete work cycle performed in each layer. evaluation of the technological process using differential equations allows obtaining positive results in research.

II THE MAIN PART

Many types of models are used in scientific research including mathematical, simulation, probabilistic and rheological models. The system of equations modeling the process of interaction of the machine's working body with the environment is determined from the the properties of the environment and the characteristic movement of the working body. The mechanical characteristics of the medium in rheological models (RM) are determined from the following main properties: elastic; plastic; viscous.

Other mechanical properties are derived from the underlying invariants, i.e. constants. Simple types of RMs are used in studying and researching the general laws of the process of interaction of working bodies with the environment. The types and views of these models are shown in Figure 1 [4].

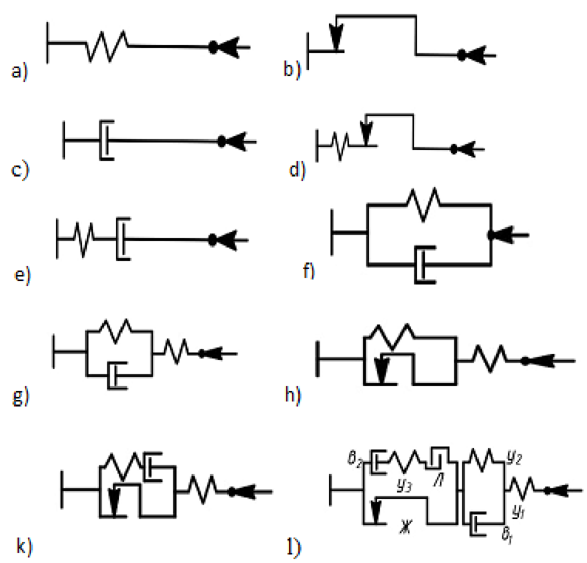

Fig. 1: Types of rheological models.
a) Hook; b) You are Vena; c) Newton; d) Prandtl; e) Muswell; f) Voigt; g) Kelvin; h) Bingham; k) Shvedov; l) Combined Kelvin and Shvedov model.

The specified types of rheological models are used to reveal the essence of the interaction process between the working bodies of compacting machines and soils, as well as to study the mechanical regularity in the organic continuation of the technological operation in compaction. In this respect, by placing the rheological models in parallel and in series with each other, it provides an opportunity to analyze the required criteria by introducing various quantities, including deformation, stress, uniformity and excitation force indicators into differential equations.

III APPLICATION OF RHEOLOGICAL MODELS IN THE PROCESS OF DENSIFICATION.

Various types of rheological models are used based on the nature of the research, as well as the physical-mechanical properties of the layer elements in the road structure. In particular, the researcher, A.A. Shestopalov, V.S. Serebrennikov, used the rheological model shown in Figure 2 to reflect the situation in the process of compaction of asphalt concrete pavements with vibrating rollers [5].

The first differential equations related to this rheological model is described by the following expression :

$$\dot{m}_1 \cdot \ddot{x}_1 + b \cdot (\dot{x}_1 - \dot{x}_2) + c \cdot (x_1 - x_2) = m_1 \cdot g$$

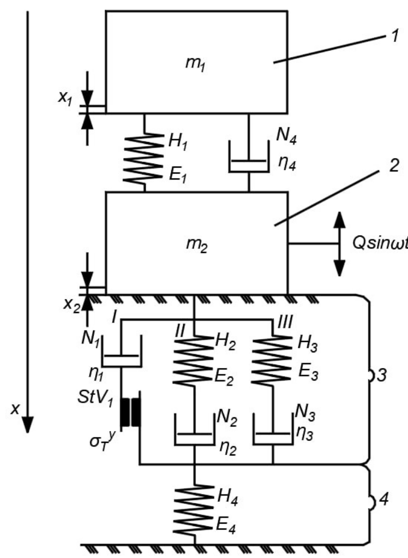

Fig. 2: Rheological model of asphalt concrete pavement.
1-loading; 2-valets; 3-asphalt concrete mixture; 4-base.

$$\dot{m}_2 \cdot \ddot{x}_2 - b \cdot (\dot{x}_1 - \dot{x}_2) - c \cdot (x_1 - x_2) = Q \cdot \sin\omega \cdot t + m_2 \cdot g - P(t)$$

Researcher V. V. Mikheev [6] in his research proposed a single and multi-mass model in order to study and analyze the process of interaction of the roadbed with the deformable soil environment. According to it, a multi-mass model of rheologically non-equivalent bodies was considered, which allows to connect the distribution of normal stresses caused by the action of road rollers over the thickness of the compacting soil (Fig. 3).

A one-mass model is in the form of Lagrange's equation, which is modeled by an elastic viscoplastic body and takes into account the possibility of a section mass change in the distribution of layer characteristics during densification, and the initial expression is as follows:

$$m(\sigma_1,\sigma_0)\ddot{z} + \frac{\partial m(\sigma_1,\sigma_0)}{\partial t}\dot{z} = -(c_{def}((\sigma_1,\sigma_0)(1-\theta(\sigma_1-\sigma_{fl}))z -$$

$$-b(\sigma_2,\sigma_1)\dot{z} - \frac{\dot{z}}{|\dot{z}|}\theta(\sigma_1-\sigma_{fl})S_{cont}(\sigma_1)\sigma_{fl} + F_{out}(t)$$

$$\rightarrow \theta(x) = \begin{Bmatrix} 1, x \succ 0 \\ 0, x \leq \end{Bmatrix}$$

Researcher E. A. Shishkinn [7] proposed a rheological model for densification of asphalt concrete mixture.

As a result of the scientific research, the researcher proposed this rheological model shown in Figure 4 under the conditions of densification of asphalt concrete mixture with smooth valets.

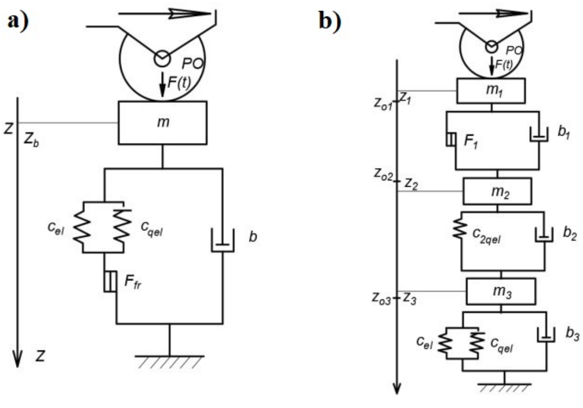

Fig. 3: One- and multi-mass model for the study and analysis of the interaction process of the roadbed with the deformable soil environment.
a) One mass. b) Multi-mass.

This model consists of the following elements : Hook elements 1 and 2, characterized by elastic modulus b and c, respectively; μ Newton's element 3, which describes viscosity; De Saint - Venan element describing the conditional yield strength σ_t. Element 4 in the rheological model serves to account for the accumulation of plastic deformation when the asphalt concrete mixture is loaded, which in this case is equal to the residual deformation for the model. According to this rheological model, the total deformation consists of the deformation of Hooke's elements (1 and 2) and is determined by the following expression:

$$h = h_b + h_c = h_b + h_\mu$$

where h_b - the deformation of the elastic element of model 1, cm; $h_c = h_\mu$- fit respectively elastic 2 and viscous deformation of model elements, cm.

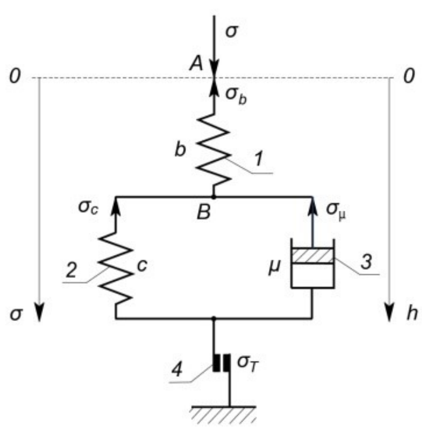

Fig. 4: Rheological model of asphalt concrete mixture taking into account elastic, viscous and plastic properties.

After some substitutions, we have the following expression:

$$\frac{d\sigma}{dt} + \frac{b+c}{\mu} \cdot \sigma = b \cdot \frac{dh}{dt} + \frac{bc}{\mu} h$$

Researcher K. V. Belyaev [8] also proposed a rheological model related to the densification of asphalt concrete mixtures. According to this, the densification mode provides such a state of deformation stress of the mixture that as a result of such an effect residual deformation is formed and the maximum increases, which is considered effective. In this case, the efficiency of thickening agents increases, and the energy capacity of the process decreases.

A rheological model was developed in order to explain the state of deformation stress in the process of densification of the asphalt-concrete mixture. The formula of the model view is $\mathbf{StV_1} - ((\mathbf{N_1} || \mathbf{StV_2} - (\mathbf{H} || \mathbf{N_2})))$ and its mechanical analogue is presented in Figure 6. This model explains the densification of the asphalt-concrete mixture in two stages - the initial and the main stage.

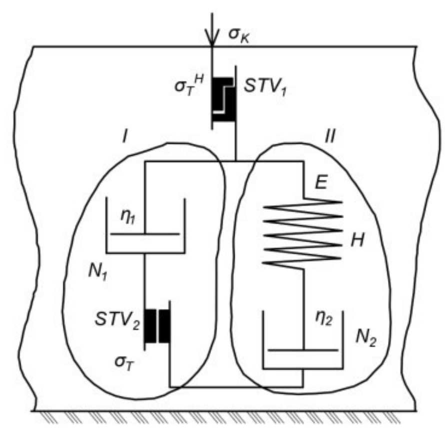

Fig. 5: Rheological model in the process of densification of asphalt concrete mixture.

In this case, the viscoelastic deformation in the thickening layer coating is expressed by an equation of this form:

$$\frac{d\sigma}{dt} + \frac{\sigma_k}{\theta} = \eta \frac{d^2\varepsilon}{dt^2} + E_d(1 + \frac{\eta 1}{\eta 2}) \frac{d\varepsilon}{dt}$$

where $\eta_1 = \eta_2 = \frac{1}{2}\eta$ is the viscosity of the mixture, Pa s.

The rheological model of the asphalt concrete mixture proposed by V.B. Permyakov [9] was taken as a basis for modeling the processes occurring in the compacted layer without taking into account the basis of the road surface.

In order to apply the given rheological model in the development of densification technology at the initial stage, it is necessary to exclude the viscosity from the considered calculation scheme, using the known legal relationship between the deformation modulus and the relaxation time.

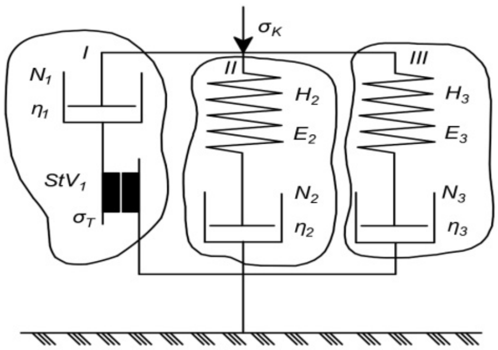

Fig. 6: Rheological model in the process of densification of asphalt-concrete mixture without taking into account the base.

According to the developed rheological model, the expression of bonds is in the form of the following equation:

$$(n+m)\cdot E_m(t)\cdot \theta_2\cdot\theta_3\cdot\frac{d^2\varepsilon}{dt^2}+\frac{(n+m)^2\cdot E_m(t)\cdot\theta_2\cdot\theta_3}{n\cdot\theta_3+m\cdot\theta_2}\frac{d\varepsilon}{dt}=$$

$$\theta_2\cdot\theta_3\cdot n\cdot m\cdot\frac{d^2\sigma}{dt^2}+(\sigma_k-\sigma_F)+(n\cdot\theta_2+m\cdot\theta_3)\cdot\frac{d\sigma_k}{dt}$$

IV CONCLUSION

A number of scientists V.B. Developed by Permyakov, K.V.Belyaev, E.A.Shishkin. These rheological models can be used to study the laws of soil compaction. The main reason for this is that the elasticity, viscosity and plasticity characteristics of asphalt concrete are fully manifested in soil, but in developing the rheological model of the soil compaction process, it is necessary to take into account the conditions that show the soil's unique properties. These are the determination of the laws of change of elasticity, viscosity or plasticity with time and their numerical values.

The developed rheological models, in turn, connect the value of the stress that appears in the soil during the compaction of the soil to such parameters as the value of the load applied to the soil, the vibration frequency and amplitude of the working body, and allow to control the condition of not exceeding the value of the strength limit of the soil and to justify the basic structural and technological parameters of the compacting machine. It should be noted that during the analysis of the models considered above, other types of soils of the road structure layer can be used in the research of the interaction process with the working bodies of the road. For this purpose, it is appropriate to take into account the specific characteristics of the soils used as construction materials on the roads under construction.

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