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APPLICATION OF A RHEOLOGICAL MODEL IN THE INTERACTION OF SOIL WITH THE WORKING BODY OF A COMPACTION MACHINE

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Cover Page Footnote

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Erratum

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APPLICATION OF A RHEOLOGICAL MODEL IN THE INTERACTION OF SOIL WITH THE WORKING BODY OF A COMPACTION MACHINE

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Abstract. *It has been established that compaction is one of the most important technological processes carried out during the construction of automobile roads. At the same time, an analysis of the schemes and views on the use of compaction machines consisting of working bodies of various shapes is given. It has been established that the importance of rheological models in the study and research of the physical essence of the process of interaction of the roller with the soil is very great. For this reason, it is explained that it is important to analyze the processes occurring in the roller body, the roller itself and in the compaction zones, using one or another type of modeling. In turn, it was believed that this contributes to the study and research of the rheological aspects of the process of compaction of the soil of the road base, which acts as a foundation on a solid foundation. The article substantiates the parameters of the rheological model used in the study of the technological working process of interaction of the working body and the soil of the rollers during compaction of the road base. When analyzing the process, data related to the assessment of the indicators of its contact stress were studied. In particular, a rheological model scheme was developed for studying the method of compaction of the soil of the subgrade by rollers. In this case, the process was studied using the system "roller- reel -soil" and expressions were given on this basis.*

Keywords: *subgrade, compaction machine, humidity, technology, rheology, vibratory roller, working element, contact stress.*

Annotatsiya. Zichlashtirish - *avtomobil yo'llari qurilishida amalga oshiriladigan eng muhim texnologik jarayonlardan biri ekanligi keltirilgan. Ushbu jarayonda turli shakl ko'rinishdagi ishchi organlardan iborat zichlashtiruvchi mashinalar ishlatilishi bo'yicha sxemalar va ko 'rinishlar tahlili berilgan. Katok valetsi va grunt orasidagi o'zaro ta'sir jarayonini fizik mohiyatini o'rganish va tadqiq etishda reologik modellarning ahamiyati juda kata ekanligi bayon etilgan. Shu sababli mashinalar korpusi, valets o'zida va zichlashtirish zonalarida ro'y beradigan jarayonlarni modellashtirishning biror turini qo'llash orqali tahlil qilsh muhim ahamiyatga ega ekanligi izohlangan. Bu esa o'z navbatida mustahkam asosda poydevor vazifasini bajaruvchi avtomobil yo'llari yo'l poyi gruntlarini zichlashtirish jarayonining reologik tomonlarini o'rganish va tadqiq etishga yordam berishi ko 'rib chiqilgan. Maqolada yo'l poyini zichlashtirishdagi katoklarning ishchi* organi va grunt orasidagi *o'zaro ta'sirining texnologik ish jarayonini tadqiq etishda qo'llaniladigan reologik model parametrlarini asoslandi. Jarayon tahlilida uning kontakt kuchlanishi holati ko'rsatkichlarini baholashga tegishli ma'lumotlar tadqiq etilgan. Jumladan, yo'l poyi gruntlarini katoklar bilan zichlashtirish uslubini tadqiq etish bo'yicha reologik model sxemasi ishlab chiqilgan.* Shu bilan birga *jarayon "katok-valets-grunt" tizimi asosida o'rganildi va shu asosida ifodalar keltirilgan.*

Kalit so'zlar: *yo'l poyi, zichlashtiruvchi mashina, namlik, texnologiya, reologiya, vibratsion katok,ishchi organ,kontakt kuchlanish.*

Аннотация. *Установлено, что уплотнение является одним из важнейших технологических процессов, осуществляемых при строительстве автомобильных дорог. При этом дан анализ схем и взглядов на использование уплотняющих машин, состоящих из рабочих органов различной формы. Установлено, что значение реологических моделей при изучении и исследовании физической сущности процесса взаимодействия катка с грунтом очень велико. По этой причине поясняется, что важно анализировать процессы, происходящие корпусе катка, самого вальца и в зонах уплотнения, используя тот или иной тип моделирования. В свою очередь считалось, что это способствует изучению и исследованию реологических аспектов процесса уплотнения грунта дорожного основания, выступающего фундаментом на прочном основании. В статье обоснованы параметры реологической модели, используемой при исследовании технологического рабочего процесса взаимодействия рабочего органа и*

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грунта катков при уплотнении дорожного основания. При анализе процесса были изучены данные, связанные с оценкой показателей его контактного напряжения. В частности, разработана реологическая модельная схема для исследования способа уплотнения грунта земляного полотна катками. При этом процесс изучался по системе «каток-валец-грунт» и на основе этого приводились выражения.

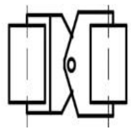
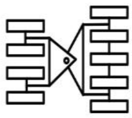
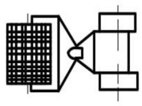
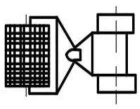
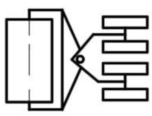
Ключевые слова: *земляное полотна, уплотняющая машина, влажность, технология, реология, вибрационный каток, рабочий орган, контактное напряжение.*

Introduction

In recent years, the traffic of vehicles from foreign countries has increased significantly in the system of transport and communication networks of our country, including on international automobile roads. This, in turn, created the need to solve the requirements for automobile roads in our country, in particular, issues related to increasing the stability, durability and load-carrying capacity of the road structure layers. Therefore, several decrees and decisions were issued by the leadership of our government in order to solve these problems in the field [1,2].It is known that the field of automobile roads is one of the most complex sectors, and in turn, it is necessary to carry out all the technological processes of design, construction and operation in a high-quality, thorough and demanding manner. In particular, carrying out construction works taking into account the physical and mechanical properties of the soil and materials used in the layers of the road structure will have a positive effect. Compaction machines occupy an important place among technological machines and mechanisms used in the stages of construction of road structures (preparatory work, soil work, compaction work, stone materials and road pavement laying). Machines of this type are used in the construction of automobile roads in all its components. Scientific researches and studies on the improvement of currently used static and vibrating coils as well as their working bodies are ongoing [3,4,5,6,7,8,9]. The characteristics of the compacting machines used in practice are listed in this table. (Table 1)

Table 1

Compaction machines

№	Machine name	Appearance	Scheme	Method of compaction	Working body
1	**Smooth reel**			Static, vibration	Valets
2	**Pneumatic wheel**			Static	Pneumatic car
3	**Fistful**			Static, vibration	Fist
4	**Lattice**			Static	Grill, net, mesh.
5	**Combined**			Static, vibration	Reel, pneumatic car

Research Methods

Rheology is a science that studies the deformation and resulting stresses of various media over time under the action of forces applied to them. When modeling complex processes in processed media, especially under dynamic effects, the behavior of the medium is described using the basic laws of mechanics, which is why existing models are often called mechanorheological [10].

Scientists and researchers use rheological models to analyze the laws of interaction between the working body and the environment of technological machines. In particular, from foreign researchers, Guiyan Xing, K. Terzaghi, W.A. Lewis, Mooney, Michael A. Robert W. Rinehart, CIS scientists V.I. Balovnev, A.V. Zakharenko, N.N. Ivanov, G.V. Kustarev, Yu.M. Lvovich, V.V. Mikheev, S.V. Nosov, V.B. Permyakov, S.V.Savelev, N.Ya.Kharkhuta and Uzbek scientists A.D., Kayumov, T.Q., Hankelov, and other scientists were reflected in their scientific research.

The types and views of the models are shown in Figure 1 [7].

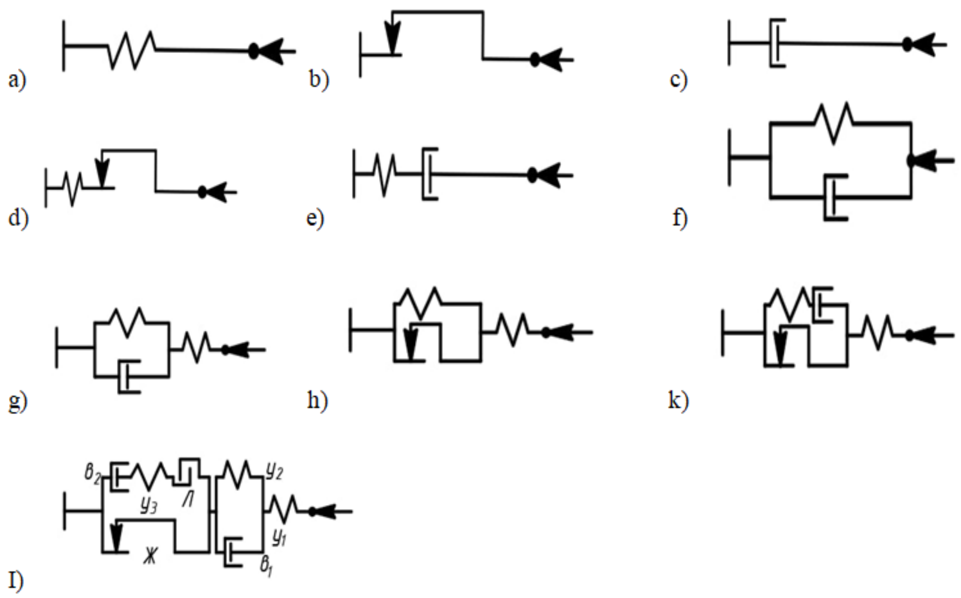


Figure 1. Rheological models.
a) Hook; b) Sen Venan; c) Newton; d) Prandtl; e) Makswell; f) Foigt; g) Kelvin; h) Bingham; k) Shvedov; l) Combined Kelvin and Shvedov model.

Undoubtedly, the working bodies of each compaction machine are in the process of interaction with the soils. Rheological models are used to reveal this situation more fully and to study its original law, as well as to analyze the relationship between the impact force, deformation and tension [8,9,10]. The models used in the research work are mainly focused on the issues of researching the nature of the interaction of the roller working bodies with the pavements in the road structure [11,12,13].

Based on the essence of the given problem, we derive the equations based on the improved rheological model for the compaction of road structure soils with rollers.

It should be noted that, considering that the soils used for road pavements are mainly clay soils (supes, silt, and clay), at the compaction stage, the characteristics of the material, including indicators such as moisture, density, porosity, filtration, and compaction coefficient [14,15] taking part in rheological processes, these parameters should be reflected in the hypotheses and theoretical studies put forward by researchers. These conditions are not manifested in other construction materials used in the road structure layers of automobile roads.

In this respect, the rheological model being developed or improved differs from the models created for other structural elements of the road according to the process of transition from one to another in its transition zones. A schematic of the proposed improved model is shown in Figure 1.

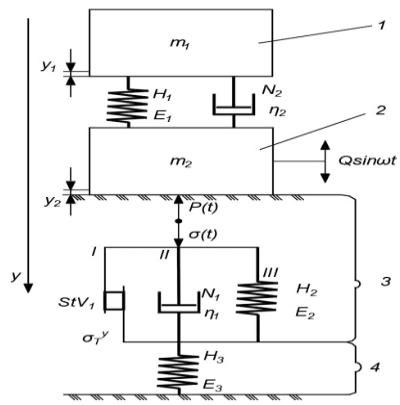


Figure 1. The rheological model of compaction of subgrade soil with a vibrating roller:
1- load; 2 - reel; 3 - subgrade soil; 4 - base; N_1, N_2 - Newton's models, η_1, η_1 - viscosities in Newton's models; H_1, H_2, H_3 - Hook's models; E_1, E_2, E_3 - modulus of elasticity in Hooke's models; StV - Sen Venan model; σ_m^y - yield stress of the Sen Venan model.

The system of differential equations of "load" - "reel" - "soil" of the vibrating system is as follows

$$\begin{aligned} m_1 \cdot \ddot{y}_1 + \eta_2(\dot{y}_1 - \dot{y}_2) + E_1(y_1 - y_2) &= m_1 \cdot g \\ m_2 \cdot \ddot{y}_2 - \eta_2(\dot{y}_1 - \dot{y}_2) - E_1(y_1 - y_2) &= Q \cdot \sin \omega t + m_2 \cdot g - P(t) \end{aligned} \qquad (1)$$

here: m_1 - loading mass (reel frame mass), kg; m_2 - mass of reel transmitting harmonic vibrations from the vibrator, kg; y_1 - amplitude of vibration of the coil body, resulting from the rotation of the reels imbalance shaft, mm; y_2 - reel vibration amplitude, mm; η_2 - viscosity of rubber dampers, $Pa \cdot s$; E_1 - rubber shock absorbers deformation modulus, Pa; Q - the excitation force of the vibrator, N; ω - angular frequency of rotation of the vibrator shaft, rad/s; t - oscillations time, s; $P(t)$ - impact reaction on reel by compacting roadbad soil, N.

The following differential equation can be derived from the system of equations (1):

$$m_1\ddot{y}_1 + m_2\ddot{y}_2 = m_1 \cdot g + Q \cdot \sin \omega t + m_2 \cdot g - P(t) \quad (2)$$

From the expression (2), we determine the impact reaction of the ground on the reel:

$$P(t) = m_1 \cdot g + Q \cdot \sin \omega t + m_2 \cdot g - m_1\ddot{y}_1 - m_2\ddot{y}_2 \quad (3)$$

The relationship between the vibration amplitude of the roller body and the vibration amplitude of the reel can be written as follows:

$$y_1 = cy_2 \quad (4)$$

c - constant value.

The voltage of the roller reel and soil contact area is determined by the following relationship:

$$\sigma_k(t) = \frac{P(t)}{F_k(t)} \quad (5)$$

here, $F_k(t)$ - reel and the surface of the soil contact area, m^2.

$$F_k(t) = B \cdot L_k(t) \quad (6)$$

here, B - width of reel, m; $L_k(t)$ - arc length of the reel and the contact area with the soil, m.

Then the expression (5).

$$\sigma_k(t) = \frac{(m_1 + m_2) \cdot g + Q \cdot \sin \omega t - m_1 c\ddot{y}_2 - m_2\ddot{y}_2}{B \cdot L_k(t)} \quad (7)$$

n research studies, the arc length of the contact area in expression (7) is determined from the following scheme [16]:

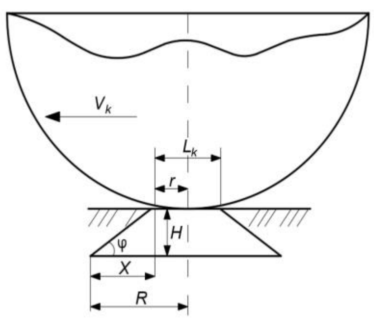


Figure 2. The scheme of interaction of reel with the soil.

The cross-sectional surface of the soil layer is defined by this expression:

$$S(t) = \left(\frac{L_k(t) + 2R(t)}{2}\right) \cdot H(t)$$

$$2S(t) = L_k(t) \cdot H(t) + 2R(t) \cdot H(t) \quad (9)$$

$$L_k(t) \cdot H(t) = 2S(t) - 2R(t) \cdot H(t) \quad (10)$$

$$L_k(t) = \frac{2S(t) - 2R(t) \cdot H(t)}{H(t)} \quad (11)$$

As a result, the expression (7) becomes the following form.

$$\sigma_k(t) = \frac{((m_1 + m_2) \cdot g + Q \cdot \sin \omega t - m_1 c\ddot{y}_2 - m_2\ddot{y}_2) \cdot H(t)}{B \cdot (2S(t) - 2R(t) \cdot H(t))} \quad (12)$$

$$\sigma_k(t) = \frac{((m_1 + m_2) \cdot g + Q \cdot \sin \omega t - \ddot{y}_2(m_1 c + m_2) \cdot H(t)}{B \cdot (2S(t) - 2R(t) \cdot H(t))} \quad (13)$$

(13) is the expression of the contact stress through the cross-sectional surface of the soil layer.

We simplify expression (13) by introducing conditional designations.

$$(m_1 + m_2) \cdot g = A; \quad (14)$$

$$Q \cdot \sin \omega t = C(t); \quad (15)$$

$$\ddot{y}_2(m_1 c + m_2) = K(t); \quad (16)$$

$$2S(t) - 2R(t) \cdot H(t) = N(t). \quad (17)$$

After conditional designations, expression (13) becomes:

$$\sigma_k(t) = \frac{(A + C(t) - K(t)) \cdot H(t)}{B \cdot (N(t))} \quad (18)$$

The tasks of the next stage of the research work are carried out on the basis of conducting experimental work to provide expressions that reveal the process of transition from one to another parallel connected (I, II, III) blocks in vibrational intensification.

Conclusion

The scheme presented above is a rheological model of densifying valets and road pavement, and as mentioned in the research, it is a parallel connected model that reflects the processes in the plasticity, viscosity and elasticity zones [17]. In revealing the physical essence of these processes, that is, in generating transition state expressions, there is a need to take into account the physical - mechanical, strength and deformation properties of the used soils. Asphalt mixture composition properties and road base soil composition properties are very different from each other. Because these features of the road base require consideration of several parameters related to the working body and soil in order to clarify the tension and deformation relations between the valets and soil in their mutual contact in the technological process of compaction.

In particular, the vibration parameters (load falling on the roller, amplitude and frequency) and indicators related to the clay building material (moisture, compaction coefficient, internal friction coefficient and adhesion force) should be reflected in the calculation expressions.

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