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# Technology of soil compaction of the base of the track with vibrating static machines of blocking action

**K Hlavatskyi<sup>1,2</sup>, V Cherkudinov<sup>1,3</sup> and O Posmitiukha<sup>1,4</sup>**

<sup>1</sup>Dnipro National University of Railway Transport named after Academician V. Lazaryan, 2, Lazaryan St., Dnipro, 49010, Ukraine

<sup>2</sup>kazimir.glavatskij@gmail.com, <sup>3</sup>volodymyrcherkudinov@gmail.com,

<sup>4</sup>AleksandrP@3g.ua

**Abstract.** The directions of combination of working bodies in the existing soil compactors and machines of the new generation and the technologies of their application for productive and effective soil compaction of the lower track structure, soil structures of roads and other construction objects are given. The basis of the research is the principle of accelerated soil compaction due to the creation on the surface of the contact with the working bodies of the sealing machines pressure, which exceeds the limit of plasticity of the soil and at the same time limiting the slipping of the sides from under the working sealing surface. It is proposed that the working sealing surface modular type that can change its profile depending on the technological requirements. Further research is aimed at creating the required profile of the working body based on the desired compaction core and the structural formula of the working body of the soil compactor. In this case, replacing the elements in the working bodies with the corresponding mathematical models, we obtain a common mathematical model of the working body of the soil compactor, as well as the profile of its working body, based on the specified energy consumption and technological requirements.

## 1. Problem statement

Soil compacting machines used at the modern level of construction or reconstruction of the track structure mostly have working elements of the traditional type with a simple or embossed profile of the working surface. As a rule, such working elements have a vibrating contour with a constant vector of vibration and adjustable disturbing force, which intensifies the compaction of the soil.

Technologically compacting machines are used in the traditional sequence (light, medium and heavy) as the soil is compacted and depending on its physical and mechanical properties (for loose or weakly connected soils – vibration action machines; for connected machines – static machines, shock and shock).

In the operation of such machines, their working equipment is limited in its forceful action on the soil by its physical and mechanical properties and the ability to slip out from under the working equipment in case of failure to balance the conditions of working stresses at the boundary of contact of working equipment-soil and soil strength.

## 2. Analysis of recent research

The research of the issues mentioned above has been reflected in a number of works, including dissertations [1, 2, 3], educational publications [4, 5, 6], materials on technological parameters of machines and technology of performance of soil compaction works [7, 8], and building codes [9]. But



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the study of issues related to changing the profile of the working surface of the GUM RO, the force vector and its magnitude, a rational combination in one GUM RO of different types, and creating the conditions for the intensification of soil compaction is relevant, since it is directly related to improving productivity GUM, their efficient use and economy of energy resources.

### 3. The purpose of the work

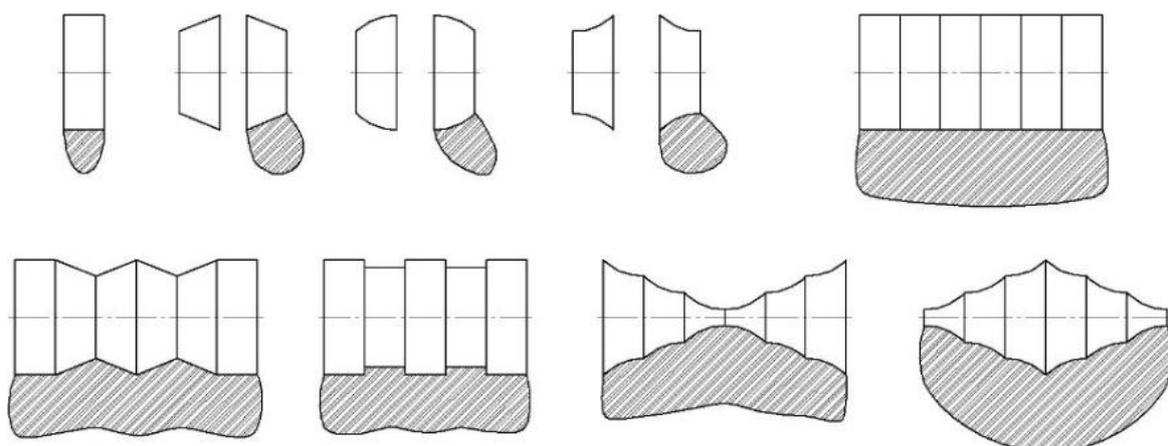
Is to justify the conditions of accelerated compaction of the soil by blocking its dislocation from under the working equipment during accelerated compaction, and reducing the number of sealing machines in the technological process.

### 4. The main section

Achieving this goal is ensured by the following sequence of material presentation: setting criteria for the selection of parameters of work equipment and evaluation of research results; proposals for basic solutions of work equipment; schemes of working equipment; sketches of technical solutions of working equipment and sealing machines; conclusions and directions for further research.

When finding rational and optimal solutions, the criteria are taken into account: maximum productivity with the maximum volume of dense soil zone, called the compaction core; optimum energy consumption; minimum cost of work within the specified time with restrictions: by engine power; the speed of movement on a given section of the seal; by overall dimensions of the work equipment.

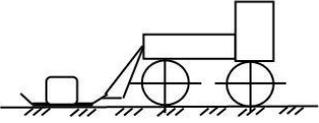
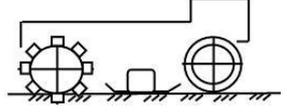
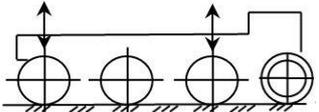
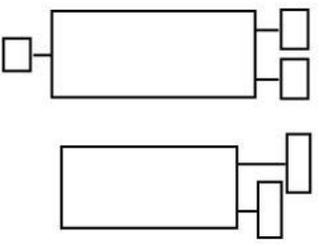
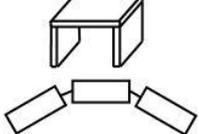
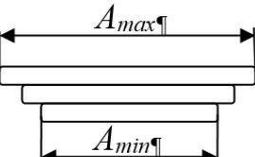
For the effective execution of the soil compaction process, it is necessary that the work equipment (rollers, fiberboards) adapt to the necessary technological conditions of the work, namely, quickly change their weight, dimensions, surface profile in order to maximize the efficiency of soil compaction in one pass of the work equipment. for the soil in its present condition. Thus, the construction of work equipment with a smooth surface can be taken as a basis for comparison, and on this basis it can be divided into components in the form of, for example, type work equipment from disks, sections, etc., which have different profiles, and also lay in design of work equipment with an elastic frame the possibility of change of internal pressure in each element or its rigidity. Depending on the size of the work equipment elements, compared to the width of the soil sealing strip, they can be used as standalone work equipment or by combining several elements into one work equipment. Schemes of possible forms of work equipment are shown in Figure 1, and schemes of options for work equipment are shown in table 1.

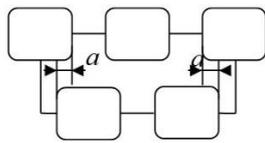


**Figure 1.** Diagrams of work equipment items and their relative positions depending on the orientation of the seal.

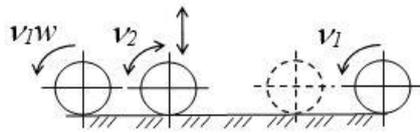
When rolling a freshly ground soil with a heavy two-roller, it is advisable to pre-compact the soil with a vibrating plate that has an adapter working surface of the appropriate shape (Figure 2, a). Given that cohesive soils are compacted by vibration at shallow depth and are prone to sideways sliding under the influence of a heavy cat when used in the first stage of compacting loose soil, the vibrating plate will play the role of a light cat, but will be more effective on the soil and will have the ability to act on the ground change the magnitude and vector of the force of excitement as needed. As a result, the soil sealing layer will gain sufficient strength and will not collapse under the action of a roller of 2 or 3 heavy rollers. The vibrating plate 1 is mounted on a hinged frame 4 driven by hydraulic cylinders 5.

**Table 1.** Options for combining work equipment to accelerate effective soil compaction.

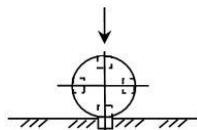
Scheme of work equipment	The result of technological application
	<p>1. Pre-compacting the soil, loading the cat with a vibrating plate. Three stages of sealing in one pass due to the implementation of the disturbing forces with separate working equipment.</p>
	<p>2. Compaction of the topsoil, loading of the smooth roller with a vibrating plate, cam roller or vibrating roller.</p>
	<p>3. Changing the area of contact of work equipment with soil by gradually selectively withdrawing from contact with the soil of its elements and (or) using vibrations in them.</p>
	<p>4. Absence of non-sealed areas after the passage of the ramming machine due to the overlapping of the ramming zones by:</p> <ul style="list-style-type: none"> <li>- installation of the third plate;</li> <li>- placement of plates with overlapping stripes;</li> <li>- regulation and joint selection of the impact force of the plates, their overall dimensions, the surface area of contact of work equipment with the soil (telescopic plate, plate with sliding sections); increasing the impact force by providing initial acceleration; providing each plate with amplitude and frequency.</li> </ul>
	<p>5. Smoothing the surface due to the vibrating plate; vibratory roller, static action cat attached to the ramming machine, their use in the last passage.</p>
	<p>6. Blocking of soil from its displacement to the side due to:</p> <ul style="list-style-type: none"> <li>- the shape of the surface of the work equipment;</li> <li>- location of work equipment;</li> <li>- the operation of the equipment.</li> </ul>
	<p>7. The gradual approximation of the working equipment pressure to the soil to the soil strength limit by changing the working equipment area. Automatic change of contact area of work equipment with soil depending on soil density at intermediate stages of compaction; <math>A_{min}</math>, <math>A_{max}</math> – sealing area.</p>



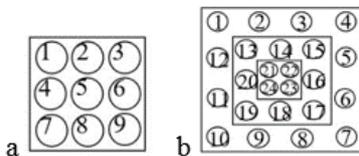
8. Increasing the width of the sealing strip and reducing the number of passes due to the clutch of several vibration plates similar in characteristics. Automatic change of the speed of movement of the plate depending on the density of the soil;  $a$  – overlapping area.



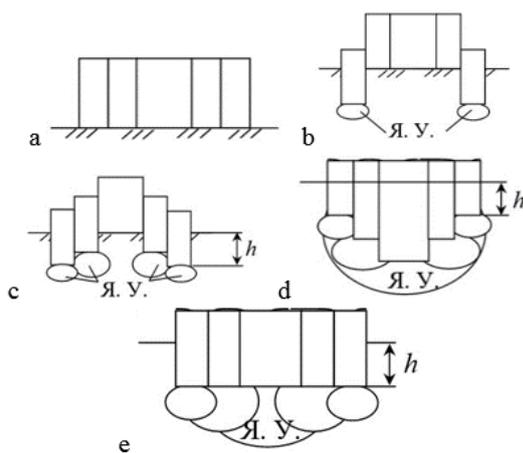
9. Reducing the number of passages of sealing machines due to the multiple reciprocating movement of the middle roller between the extreme rollers at speed  $v_2 \gg v_1$ ;  $w$  - angular velocity.



10. Absence of soil destruction at the exit of its cams due to the control of the moment of entry - the exit of the elements of the working equipment from the cat into the soil array (with the use of momentum).



11. Different form of working equipment in contact with the soil, their number and the order of immersion (first 1... 12, then 13... 20, then 21... 24, or 13... 20, then 1... 12, then 21... 21, etc.).



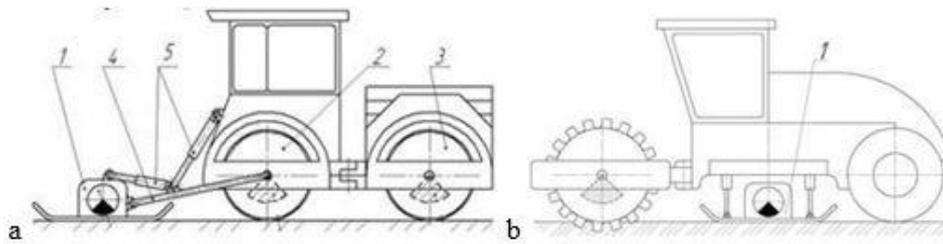
12. Flowchart of the soil compaction process with a roller working equipment or vibration and impact plate with a variable adapter profile of the working surface to illustrate the enlargement of the compacted zone by blocking the soil by sliding sections of working equipment of a certain shape and size (as an option, these profiles can be made in the form of rotating bodies) involves the use of soil properties for better compaction: a – working equipment of the traditional profile; b – blocking of the soil parting by the outer sections; c – sealing of blocked soil with internal sections of work equipment; d, e – variants of mutual arrangement of sections by working equipment depending on the necessary technological conditions and physical and mechanical properties of the soil;  $h$  – sealing depth.

The possibility of realizing the sealing in one pass due to the gradual increase of the disturbing forces of individual work equipment is achieved by the use of adjustable vibrating circuits. Also, the vibrating plate is a delivery to the cat, and can be used when working in compressed conditions.

It is known that when the soil is compacted with a cam roll, the surface of the sealing upper layer remains slightly loosened.

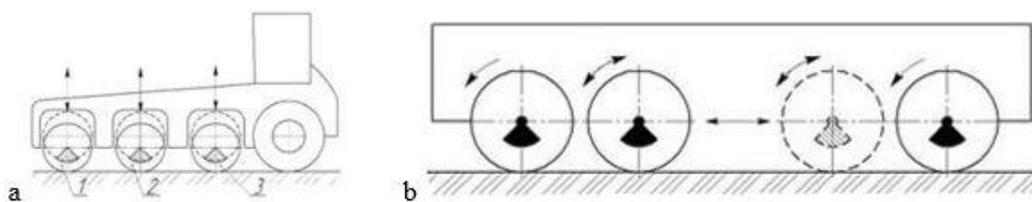
To eliminate this drawback, compacting and smoothing the soil layer can be installed on the vibrating plate 1 sealing machines (Figure 2, b).

When performing work where roller seals are not possible in the area, for example, insufficient width of the embankment, the vibrating plate 1 can be used as a support around which, by weighing, the sealing machines will be able to return to the desired angle by staying in place (for example, due to a pivot-mounted circle on sealing machines). Also, if the soil is lumpy or frozen, it is advisable to use a vibrating circuit inside the cam roller, and if the soil is loose, then vibration can be used to create additional static force.



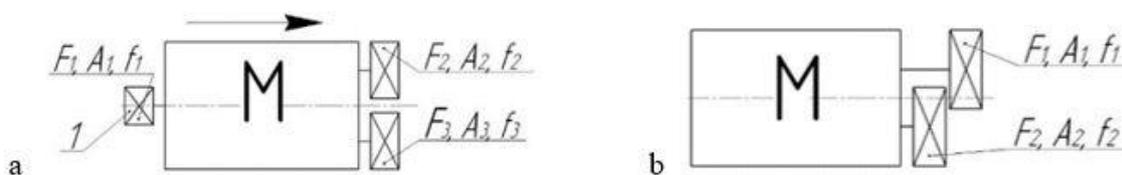
**Figure 2.** Double roller with vibratory plate (a) and cam roller with support plate (b).

In order to create a universal roller with rollers of different types, in terms of adjusting the values of the contact pressure of the working equipment on the soil within wide limits, a scheme of sealing machines with four rollers can be proposed (Figure 3, a). As a result, we will be able to effectively compact the soil at different stages due to the selective output from contact with the soil rollers 1, 2, 3, or their pairs 1–3, 2–3, and to use vibration circuits installed in them at certain stages and modes. The acquired strength of the soil at a certain stage of its compaction.



**Figure 3.** Sealing machine with three reciprocating rollers (a), moving the middle roller (b).

In order to reduce the number of passes of sealing machines along the sealing section, sealing machines with three working equipment of roller type of one or more of them, relative to the base of sealing machines in the longitudinal or longitudinal direction, may be used to achieve the required soil density (Figure 3, b). This is achieved by repeatedly originating one of the working equipment (for example, the middle) of the sealing section, which is located among the other working equipment sealing machines. That is, its angular velocity must be much greater than the angular velocity of the latter and is multiple of it. As the working equipment of sealing machines can act as vibrating smooth and cam rollers, and pneumatic wheels.

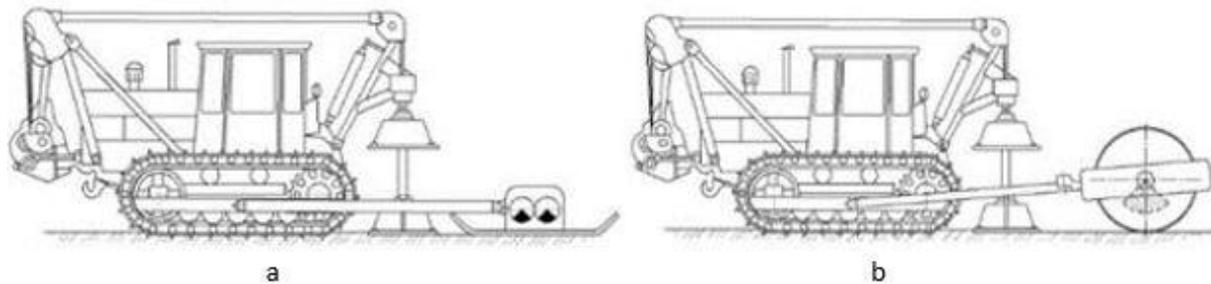


**Figure 4.** Placement of tractor ram plates (plates are conventionally shown by diagonally crossed rectangles, and the tractor unit is a rectangle with the letter "M"):  $F$  – disturbing force.

When the soil is compacted by tractor rammers with falling plates, the non-compacted zone of the soil layer between the lateral inner planes of the plates is inevitably formed. This problem can be solved by installing a third plate 1 (Figure 4, a), or by placing the plates so that one plate overlaps the sealing strip of another (Figure 4, b).

Moreover, the impact force of the first plate is less than the forces of the second and third equal to each other (Figure 4, a) and the overall dimensions of the plates must be reduced accordingly. It is also possible to adjust the surface area of contact of the surface of the slab with the soil, for example, by installing a telescopic plate or a plate with sliding sections. In this case, it is possible to obtain an increase in the impact force by providing an initial acceleration for each of the plates with its

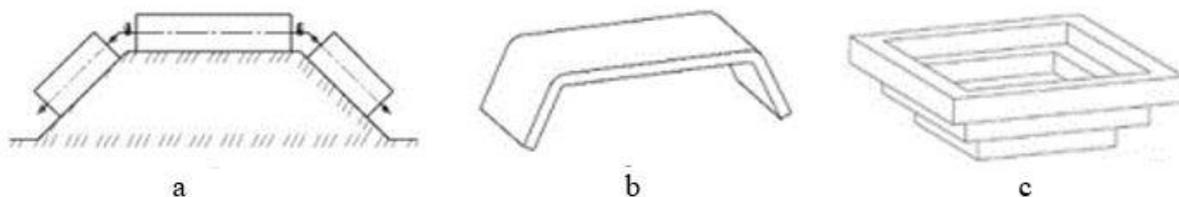
individual amplitude  $A$  and the frequency of impacts  $f$  (Figure 4). On the other hand, the problem is solved by attaching to the tractor-tractor of the vibrating plate (Figure 5, a), or the vibrating roller (Figure 5, b). Not only do they additionally seal the soil layer, they also smooth it out. By changing the direction of travel, you can effectively compact both loose and loose soils of varying degrees of loosening.



**Figure 5.** Combined action rubber.

For compacting the entire width of the embankment, along with slopes, relatively large and road-specific sealing machines (Figure 6, a) and ramming, vibrating or combination plates (Figure 6, b) can be created. Thus, conditions are created for blocking the soil from its displacement from under the working equipment to the side due to the shape of the surface of the working equipment and their location.

The possibility of regulating the contact pressure of the working equipment of the vibrating plate on the soil is achieved by telescopic execution of its surface (Figure 6, c), namely: at a constant mass of the vibrating plate, when the contact area of its working equipment is maximum, the contact pressure on the soil will be minimal. Conversely, with a minimum contact area of the work equipment, the contact pressure is maximum. Thus, effective soil compaction is ensured by automatically changing the contact area of the work equipment with the soil, depending on the density of the soil at intermediate stages of its compaction.

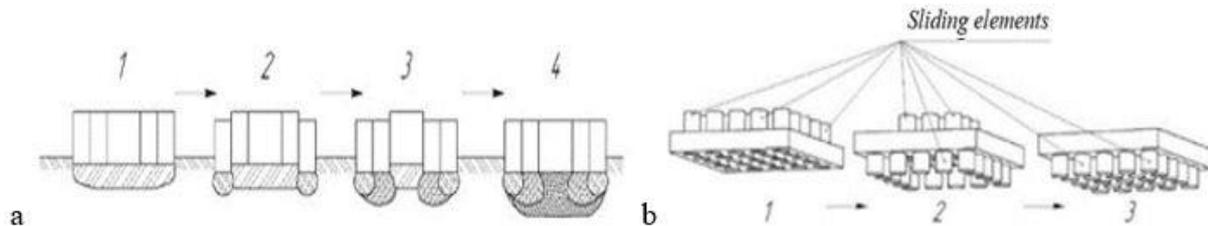


**Figure 6.** Schematics of working equipment sealing machines, sealing the entire width of the embankment in one pass.

To increase the core of the seal can be used plate with sliding sections-plates (Figure 7). First, the extreme sections are immersed in the soil, followed by alternate pairwise lowering of the other sections, ending with the middle one. Thus, moving towards the middle, the sealing soil is between opposite plates-sections that prevent it from diverging from the side of the working body, and as a consequence, the soil moves the maximum volume to the center of the sealing core in the sealed zone by the shortest possible path. by compacting and forming the core of the compaction, as well as being the transfer link between the working body and the non-compressed soil.

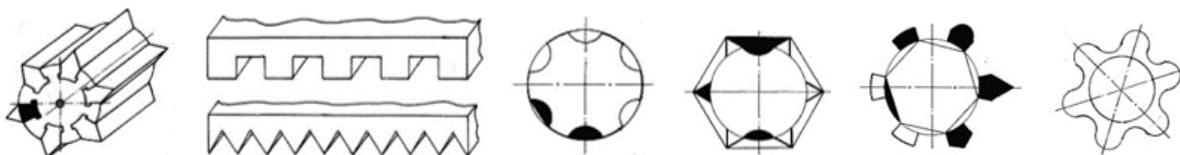
This effect is also achieved by a plate with sliding sections of different shape and their mutual arrangement. Sections can move relative to each other in different combinations, depending on the desired shape and volume of the sealing core. An embodiment of such a plate is presented in Figure 7, b. Initially, the slab compacts the soil only with its support plane, without extending sections. Then the

rows of sections located along the outer perimeter are immersed in the soil, and with the subsequent immersion of the rows of sections of the next relatively smaller perimeter, and to the smallest. Such operations result in a concentrated sealing core. In the general case, a certain group of working equipment of sealing machines of roller and flat type that would keep the soil from sliding out from under the working surfaces, can be formed on the basis of working equipment of sealing machines of the traditional form by installing on their working surfaces variable elements (Figure 8).



**Figure 7.** Slab with sliding sections (a) and sliding elements (b).

In this case, the replaceable elements can be designed so that the working surface of the working equipment of sealing machines on which they will be installed remains unchanged, or of another form suitable for mounting and dismantling when designing working equipment of sealing machines of the new generation.



**Figure 8.** Working equipment of sealing machines with interchangeable elements.

Components of working equipment of sealing machines in the general case can be: the shape of the main surface (cylindrical, profile, multifaceted, flat, combined); shape of interchangeable elements (cams, plates, combined); a way of installing interchangeable elements (permanent, solid and detachable bandages, sliding, insert sections, combined).

Further research is aimed at creating the required profile of working equipment based on the desired NAV and the structural formula of working equipment of sealing machines. In this case, by replacing the elements in the working equipment with the appropriate mathematical models, you can get a common mathematical model of working equipment of sealing machines, as well as a profile of working equipment of sealing machines, based on the specified energy consumption and technological requirements.

## 5. Conclusions

Thus, justified conditions of accelerated compaction of the soil by blocking its sliding from under the GUM during accelerated compaction and reducing the amount of GUM in the technological process will allow to accelerate the process of compaction of the bulk soil and to increase the productivity of machines for compaction.

The results of the research will be useful for scientists and engineers involved in rolling stock brakes and calculations in terms of the effect of soil base compaction on the dynamics of rolling stock braking [10, 11].

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