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Study of the Influence of the Ballast Layer Thickness on the Bearing Capacity of the Dune Sand Bed

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ABSTRACT: With increasing axle loads and train speeds, the vibrodynamic load of the wheels on the ballast layer, which is characterized by vibration amplitude, frequency, vibration velocity and other parameters, increases.

The main indicators of the track condition, their deviations from the standard position in the profile and in the plan directly depend on the bearing capacity of the ballast layer.

Vibrodynamic effects on the ballast layer are known to have a negative impact on the strength and deformation characteristics, which leads to a decrease in the bearing capacity of the ballast layer.

KEYWORDS: crushed stone, amplitude, vibrations, railway, vibrodynamic load, ballast prism, train movements, velvet sand.

I.INTRODUCTION

The bearing capacity of a ballast prism with an earthen sand bed made of velvet sands that perceives vibrodynamic load is determined by the size and character of the distribution of vibrodynamic influence on the bed body, sensitivity to it of velvet sand and its structural features. At the same time, the bearing capacity of the earth bed is understood as the greatest load determined by the first group of limiting states, which causes such a stress state, when its minimum increase causes a disturbance of the existing balance with the formation of the ground displacement surface.

By virtue of the above mentioned calculation of the bearing capacity of the earth bed, which perceives the vibrodynamic load, it is reasonable to carry out, based on the theory of ultimate equilibrium. For this purpose, it is necessary in conditions of a flat problem to solve the equations of motion and a limiting stress state at the strength characteristics depending on vibrodynamic influence.

The bearing capacity of the earth bed, which perceives the vibrodynamic load, will be determined by the limiting stress state of the soil, at which the minimum increase in the external load leads to the violation of the existing limit equilibrium with the formation of a surface displacement of the soil [1].

II. THE BASIS FOR DETERMINING THE BEARING CAPACITY OF A BALLAST LAYER WITH A BASE OF DUNE SANDS.

The solution of the problem of the ultimate equilibrium of the earth bed, covered with dune sands, under the action of vibrations is reduced to a joint solution of the differential equations of motion and the conditions of the ultimate stress state at the strength characteristics changing under the influence of vibrodynamic load [2].

The basic system of equations consists of the equations of motion of the soil medium and the conditions of the limiting equilibrium of the Coulomb:

$$\begin{cases} \dfrac{\partial \sigma_z}{\partial z} + \dfrac{\partial \tau_{zy}}{\partial y} = \gamma \cdot cos\theta + \rho \cdot \dfrac{\partial^2 U}{\partial t^2} \\ \dfrac{\partial \tau_{yz}}{\partial z} + \dfrac{\partial \sigma_y}{\partial y} = \gamma \cdot sin\theta + \rho \cdot \dfrac{\partial^2 V}{\partial t^2} \\ \sigma_1 - \sigma_2 = (\sigma_1 + \sigma_2 + 2 \cdot C_{дин} \cdot ctg\, \varphi_{дин}) \cdot \sin \varphi_{дин} \end{cases} \quad (1)$$

where σ_z, σ_y- the components of normal tension;

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$\tau_{zy} = \tau_{yz}$- tangential voltage components;
θ - inclination angle to the horizon of y-axis;
ρ- soil mass $\rho = \frac{\gamma}{g}$
g- free fall acceleration, g=981 cm/sec2;
γ - volume mass of soil;
U, V - displacements at oscillations in the direction of z and y axes;
σ_1 andσ_2- maximum and minimum main stresses;
$c_{дин}$ and$\varphi_{дин}$- grip and internal friction angle of velvet sand, which perceives vibrodynamic load;

The angle of internal friction and specific bonding of ballast with the base of dune sands laid in the railway bed of the earth bed are determined under the action of vibrodynamic load in the conditions of three-axis compression. At the same time the value of vibrodynamic influence is determined by the received calculation or measured in nature by the maximum resulting amplitude of vibrations.

The resulting amplitude of ballast layer oscillations with the base of dune sands in any point of the earth bed and beyond it is determined by the formula:

$$A_{zy} = A_0 e^{nz - \delta_1^0 \varphi(y) + \delta_3 \varphi(h_{i,j})} \qquad (2)$$

where A_0 is the resulting amplitude of the main site soil oscillations, μm;
δ_1, δ_2', δ_2''- coefficients of damping of vibrations in vertical and horizontal directions;
z, y - coordinates of the point under consideration in the axes shown in Fig. 1;
δ_3 - coefficient taking into account the influence of slope on damping of oscillations in the embankment slope;
$h_{i,j}$ - slope height above the point under consideration, m;
b_0 - size of the main area of the main site that perceives external pressure, m;
α_1 - angle of the embankment slope;
a - calculated width of the shoulder, m.

$$a = \frac{b_{пл} - b_0}{2} \qquad (3)$$

where $b_{пл}$is the width of the main site of the earth's surface, determined for the operating lines by measuring in kind, and for those designed according to current standards.

The size of the area of the main site, which is able to absorb the load from the rolling stock, by the railroad tie rod and ballast prism is determined according to [3] according to the following formula:

$$b_0 = l_{шп} + 2 \cdot h_{бал} \cdot tg\, 30° \qquad (4)$$

where$l_{шп}$ the sleepers are the length of the sleepers;
Score - the power of the ballast prism.

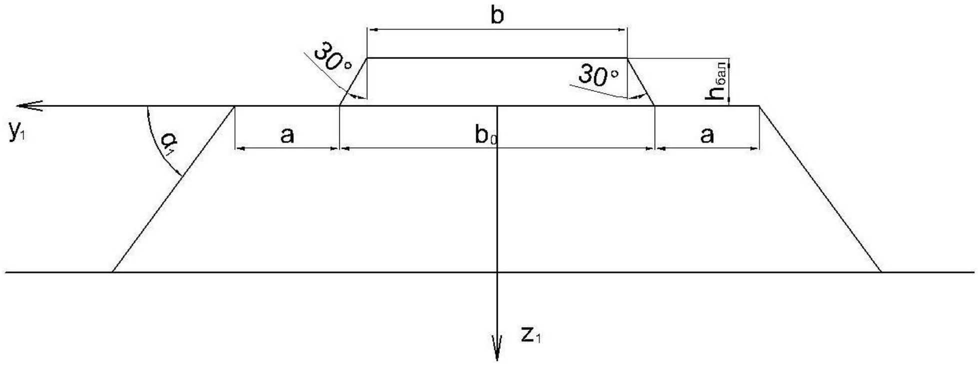

Fig. 1. Scheme for determining the width of the loading area.

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Having considered Fig. 1, it can be concluded that the width of the loading site $B_o$is less than the width of the ballast prism at the bottom. Thus, at a ballast thickness of 0.4 m, it will be 4.8 m, and the loading site width B_o is 3.2 m.

The determination of the load-bearing capacity of the earth bed made up of dune sand begins with the points located on the surface of the estimated embankment slope.

On the slope, any points are marked at equal distances from each other. Based on numerous calculations, the distance between adjacent points (ΔH) can be taken as a first approximation.

$$\Delta H = 0{,}1 \cdot B_o \qquad (5)$$

In order to simplify the accounting of loading on the side of the main embankment of the ballast layer trapezoidal stress diagram replace the triangular, distributed across the width of the design shoulder (a). This replacement is equivalent, as the area of the epaulets is equal, Fig. 2.

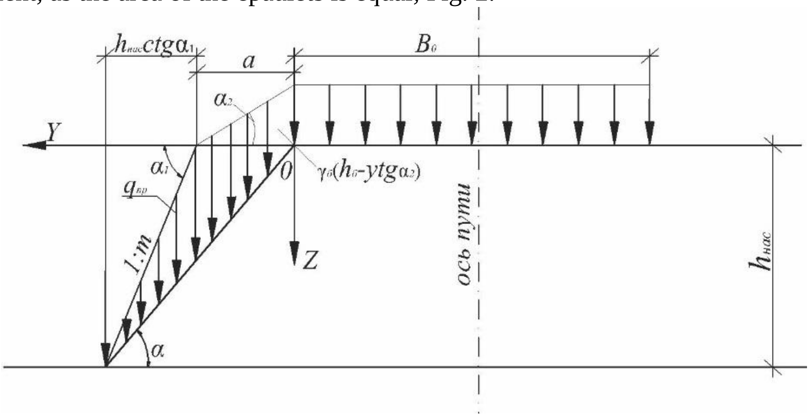

Fig. 2. Scheme for determining the boundary conditions taking into account the ballast layer.

Thus, a part of the ballast layer loads the main site of the earth bed. To account for this load, the ballast prism pressure has been replaced by a load of a legally distributed triangle, as shown in Figure 2, in order to simplify the calculation scheme. The angle α_2 (Fig. 2) is determined by the condition that the triangular load exerts the same pressure on the roadside as the pressure from the actual part of the ballast prism, i.e. the area of the actual voltage diagram and the calculated one are equal. Analyzing the scheme shown in Fig. 2 and the expression for the value of the mean voltage at a special point "O" at δ=α:

$$\sigma_i = \frac{C_{дн} \cdot cos\varphi_{дн} \cdot \cos\big(2(\delta-\alpha)\big) + q_{пр}}{1 - sin\varphi_{дн} \cdot \cos\,(2(\delta-\alpha))}$$

It can be concluded that the value of the bearing capacity at the special point "O" and, consequently, in the subrail zone will depend on the thickness of the ballast layer. This fact can also be proved by analyzing the expressions (6).

In fact, at the "O" point, the strength of the earth's surface is determined by the grip value C_dn and the loading value. If we do not take into account the ballast as a load at the "O" point, then we obtain that at $q_{пр}$=0 the load-bearing capacity is determined only by the grip value C_dn. If we consider sandy soils, which have practically no adhesion, or its value is very insignificant, then it turns out that the carrying capacity of the main site at a special point "O" to strive to zero, which is contrary to common sense. Taking into account the ballast as a load reduces this problem, because the strength in this case will be determined to a greater extent by the values of this load, i.e. the ballast thickness [4].

The results of the study of the influence of ballast thickness on the bearing capacity of the earth bed are presented in Fig. 3. The results of the calculation are given in the subrail section. The analysis of dependencies in this figure shows that with the growth of ballast thickness under the sleeper, the bearing capacity both in the vertical and horizontal planes increases linearly.

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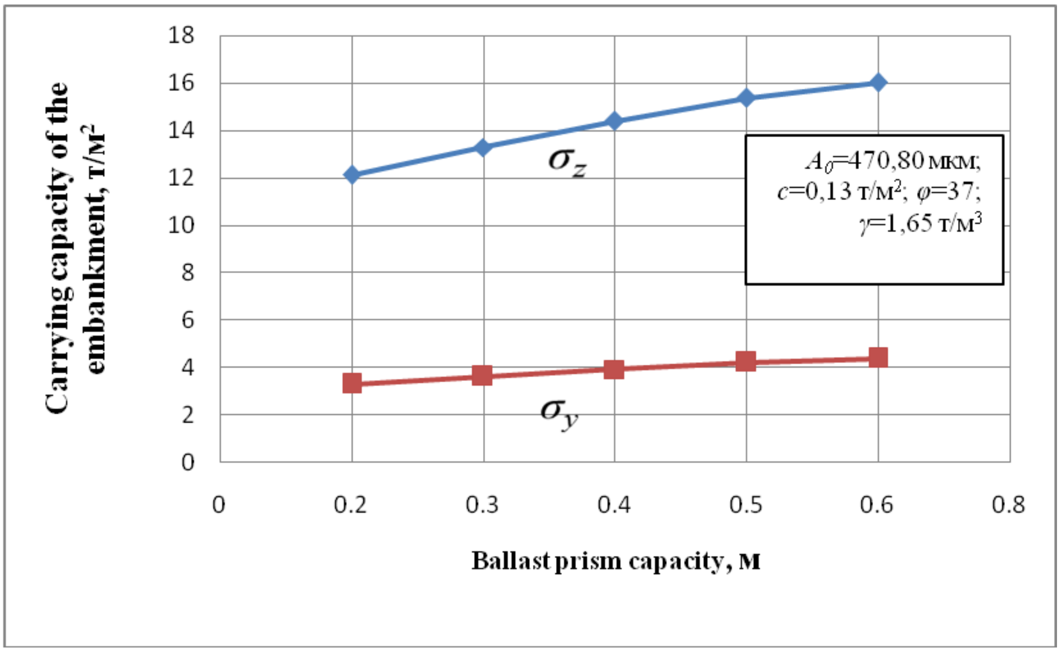

Fig. 3. Dependence of load-bearing capacity on ballast layer thickness.

III. CONCLUSION

1. The load-bearing capacity of the earth bed is greatly influenced by the ballast prism power. Increasing the thickness of the ballast layer by 0.1 m increases the bearing capacity of the earth bed by 8% in the vertical plane and 10% in the horizontal plane.
2. Increase of ballast capacity under the sleeper sole also leads to reduction of effective stresses. Thus, on the one hand, the increase in the thickness of the ballast layer leads to an increase in the strength of the main site, and on the other hand, to a decrease in the effective stresses. Consequently, this method allows to reduce the existing deficit of bearing capacity.

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