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Comparative analysis of the parameters of the strength of the subgrade at the transition to the higher axial loading up to 25 t

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Abstract. A review of the scientific and technical literature on the re-alignment of the route during the transition to high axial load from the accepted today (23.5 t / axis) to the perspective (25 t / axis) shows that in the stage of preliminary researches imitation modeling of the earth web by the finite element method (ITU) as the most convenient, accurate and illustrative of the known numerical methods. In order to provide recommendations on the strength of the subgrade when moving to a higher axial load up to 25 t / axis, an analysis was conducted, the essence of which was to compare the stress-strain state of the subgrade at two loads per axis: 23.5 t / axis (existing) and 25 (perspective). All the geometric and deformation characteristics of the formation are taken from data on a two-track section with a height of embankment of 3. The deformation characteristics are chosen so that the working material of the formation is in accordance with the average indices of deformation capacity of the railways used. The ITU train load calculus makes it possible to obtain all the factors of VAT in it, which is the main purpose of the study of the strength of the earth cloth, and allows to forecast their development in the future.

1. Introduction
A review of the scientific-technical literature concerning the re-alignment of the route while the transition to a higher axial load from the accepted up to now (23.5 t / axis) to the perspective (25 t / axis) shows that in the stage of preliminary researches, imitation modeling of the formation by the finite element's method (ITU) as the most convenient, accurate and illustrative of the known numerical methods. The practical implementation of ITU simulation was carried out on the basis of the licensed professional complex Structure CAD for Windows (SCAD) [1]. This package is known for its simplisity in usage, clarity of calculation results, sufficient convergence.

In order to give recommendations on the formation at the transition to increased axial load up to 25 t / axis, an analysis was carried out, the essence of which was to compare the stress-strain state of the earth at two loads per axis: 23.5 t / axis (existing) and 25 (perspective). All the geometric and deformation characteristics of the formation are taken from data on a two-track section with a height of embankment of 3 m.

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2. Methodology

The Figure 1 shows the calculation scheme of the farmation implemented in the complex SCAD.

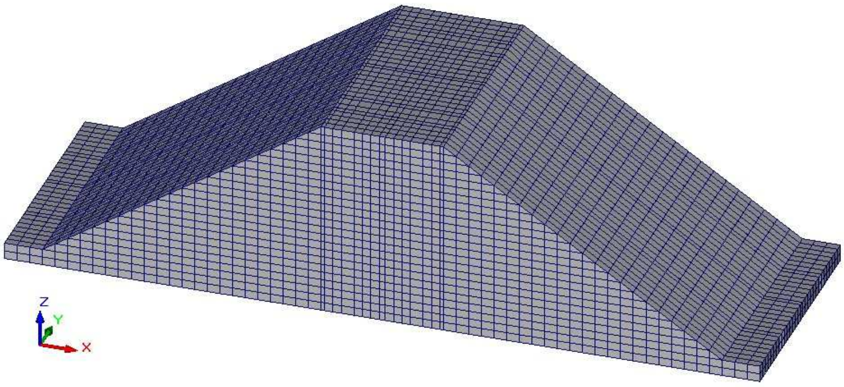

Figure 1. Calculation scheme of the farmation

The total number of junctions is 31 372 pcs, the number of finite elements (CE) is 28 980 pcs. The CEs in the scheme are made compatible, that is, all the nodes of adjacent elements coincide, what positively affects the accuracy of the solution. Dimensions of the model: length (base) - 44.75 m, width - 14.5 m, height - 13 m (where the height of the ground - 12 m). The dimensions of the CE range from 0.75 × 0.5 × 0.5 to 0.5 × 0.5 × 0.5 m, that is, the discretization of the scheme is sufficiently low. Both tetrahedral CEs (in slope modeling) and parallelepipeds (in the modeling of the formation and base) are used in this scheme.

Boundary conditions are imposed on the scheme: at the bottom of the model there is the prohibition of movement on all three axes X, Y and Z, on the sides of the basis there is the prohibition on the X and Y axes, on the transverse sides of the model - the prohibition on the Y axis. Such boundary conditions correspond to the actual operation of the formation most completely [2].

In Figure2. the map of the deformation characteristics provided by the CE model is shown.

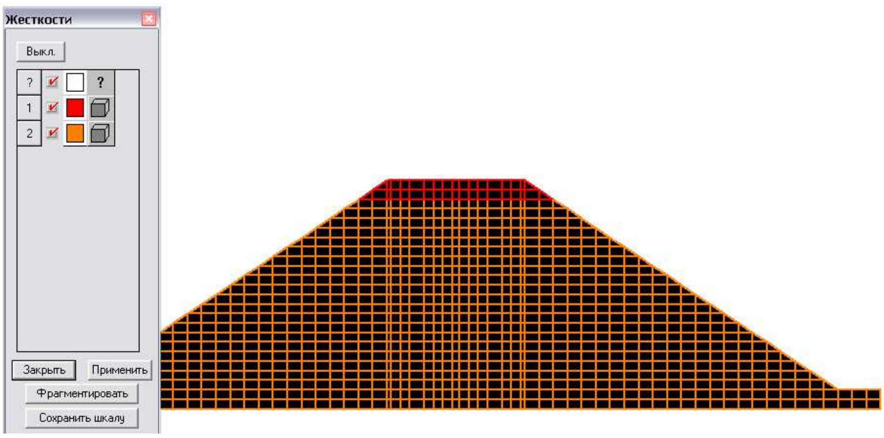

Figure 2. Map of distribution of deformation characteristics in the CE-model
(the figures indicate the deformation characteristics of the layers)

The deformation characteristics are chosen so that the working material of the formation is in accordance with the average indices of deformation capacity of the railways operated [8, 9]:

Layer 1 - dirty rubble, specific gravity γ = 18,5 kN / m^3, modulus of elasticity E = 60 000 kN / m^2, Poisson's ratio μ = 0,3;

Layer 2 - the loam of the formation and the foundation, the specific gravity γ = 19.0 kN / m^3, the modulus of elasticity E = 25 000 kN / m^2, the Poisson coefficient μ = 0.3.

The presented layered array repeats real formation with a slight deviations, but the thickness of the layers is taken constant, although in fact it slightly changes.

A wagon was taken as a model load, the distribution of its weight and distance between the axes is shown in Figure 3.

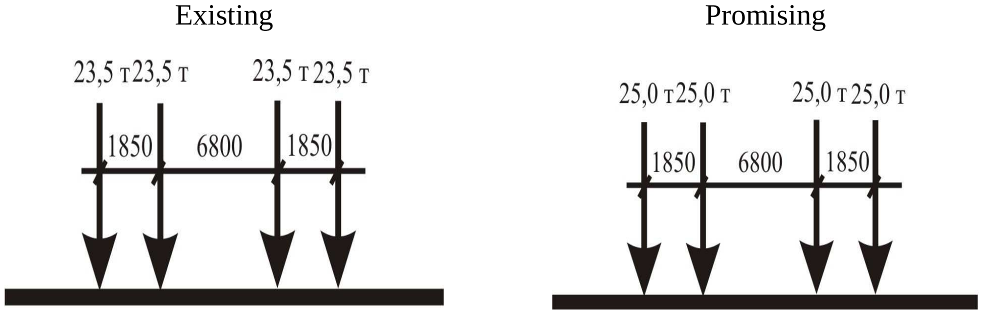

Figure 3. Train load diagram (shown in axles)

Two load schemes for the CE model were adopted:

Scheme 1- the gondola is on one path;

Scheme 2 - two gondola cars are on two paths.

In Figure 3 4 the location of loads of the 1st and 2nd circuits is shown. The load on the axle of the wagon [6, 7, 10] is distributed over the width of the sleepers it gets on, and it is distributed over 12 nodes of SE, which are included in the dogometric placement of the sleepers (total number - 4 sleepers) and is 19,58 kN for the existing one and 20,83 kN for the future one.

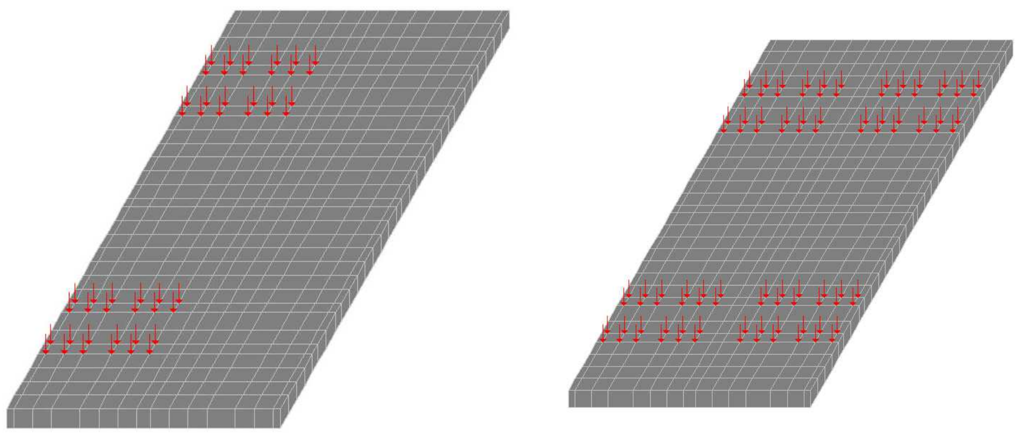

Figure 4. Location of loads: a) 1 scheme; b) 2 scheme

While calculating the ITU, the multifront method of decomposition of the stiffness matrix was used, as the most progressive method of working with matrices applied in the SCAD complex. The calculation results are the displacement and stress of the model along the X and Z axes, moreover the further results show a characteristic pattern of their distribution on the ground web. In Figure 5-6 the results of the calculation of the ITU of a formation with a train load are presented.

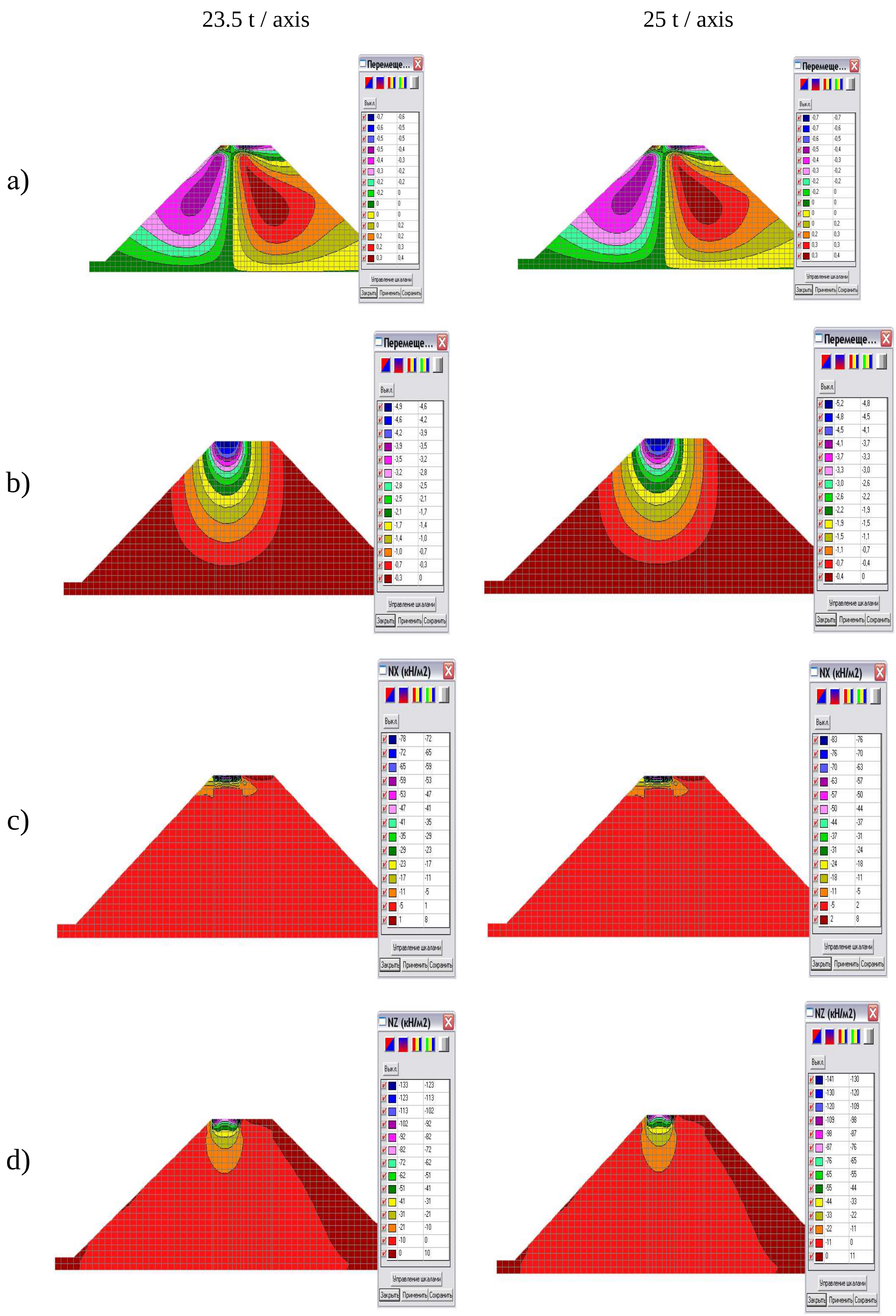

Figure 5. Results of the calculation of the formation (1 scheme of loading): a) movement along the X axis; b) movement along the Z axis; c) voltage along the X axis; d) the voltage along the Z axis

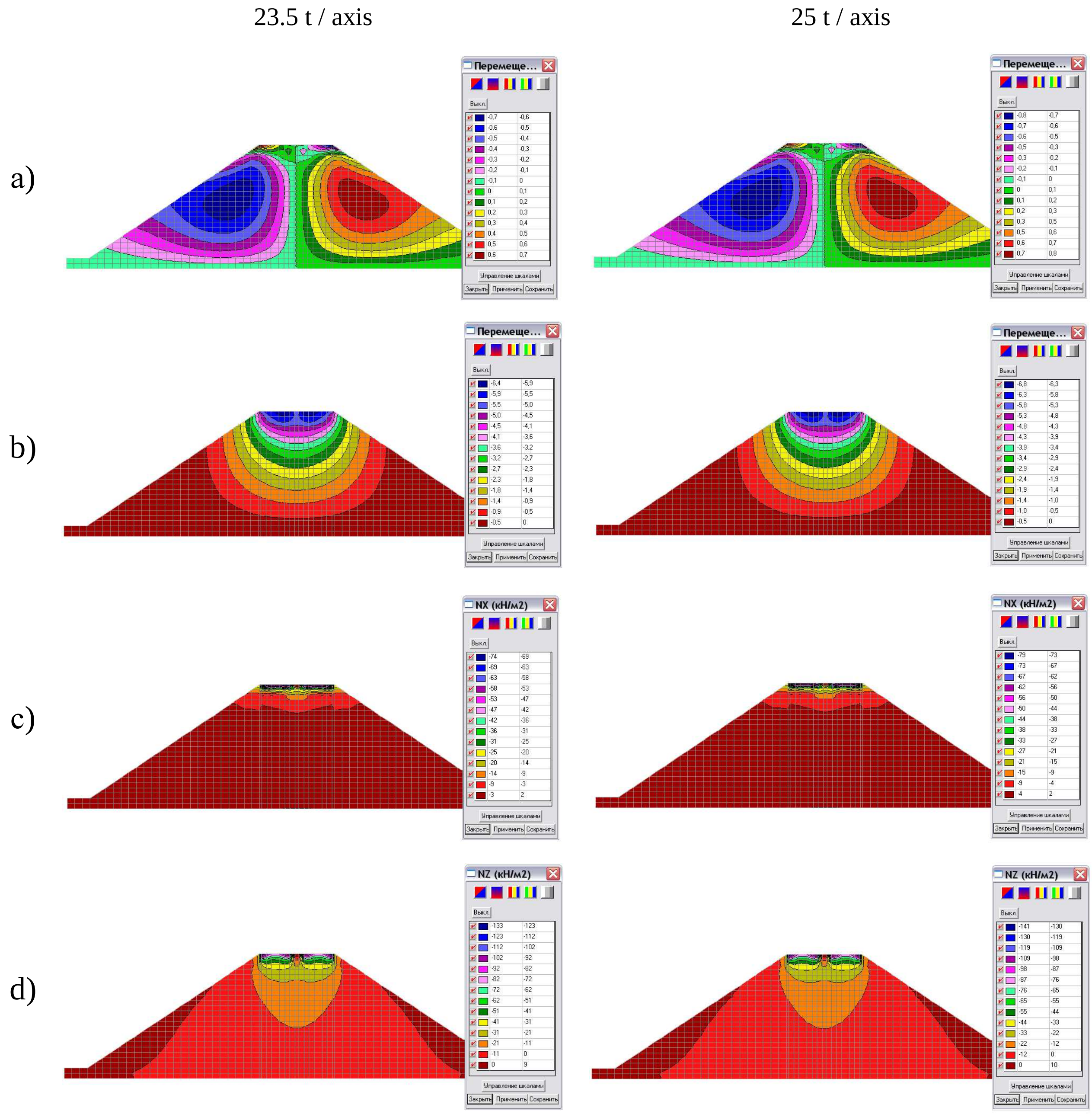

Figure 6. The results of the calculation of formation (2 scheme of loading):
a) movement along the X axis; b) movement along the Z axis;
c) voltage along the X axis; d) the voltage along the Z axis

The analysis of movements along the X-axis makes it possible to conclude that in the case of loading in accordance with the 1st scheme (one gondola), this parameter is distributed non-uniformly, which is characterized by soil displacement on the surface of the ballast layer. Quantitatively this displacement is -0.7 mm for the existing (Figure 5) and perspective (Figure 6) loads. The maximum displacements along the X axis according to the 2nd scheme (two gondola cars) are homogeneous and quantitatively amount to the 2nd scheme -0.7 mm for the existing and -0.8 mm for the perspective loads, that is, the increase during the transition to the enlarged axial load up to 25 t / axis is 12.5%.

The analysis of movements along the Z axis also indicates some heterogeneity of this factor in the case of asymmetrical application of train load according to the 1st scheme. The maximum displacements on the Z axis according to the 1st scheme (one gondola) are quantitatively -4.9 mm for the existing and -5.2 mm for the perspective loads, ie, the increase in the transition to the enlarged axial load up to 25 t / axis is 5.77% . The maximal displacement along the Z axis in accordance with the 2nd scheme (two gondola cars) is homogeneous and quantitatively represents -6.4 mm for the existing and -6.8 mm for the perspective loads, ie increase in the transition to the enlarged axial load up to 25 t / axis is 5.88%

The stress distribution along the X and Z axes in the case of the 1st and 2nd load circuits indicates that the stress assignment changes slightly: the horizontal stress along the X axis according to the 1st load circuit -0.078 MPa (78 kN / m^2) and -0.083 MPa (78 kN / m^2), respectively; according to the 2nd load scheme -0.074 MPa (74 kN / m^2) and -0,079 MPa (79 kN / m^2) respectively; vertical voltage along the Z axis according to the 1st and 2nd load schemes -0,133 MPa (133 kN / m^2) and -0,141 MPa (141 kN / m^2) respectively, what corresponds to the strength of the base under the upper railway structure (0.16 MPa) / 160 kN / m^2), although the margin of safety in the case of prospective loading is some smaller.

3 Conclusions

The ITU train load calculus makes it possible to obtain all the factors of VAT in it, which is the main purpose of the study of the strength of the earth cloth, and allows to forecast their development in the future. Preliminary analysis with the average values of deformation characteristics of the earth fabric allows to come to the following conclusions:

1.The model developed in the professional complex SCAD made it possible to perform a numerical analysis of the stress-strain state of the formation for the existing and perspective loads on the axle of the wagon with a high level of accuracy and to obtain the results of stresses and displacements, which indicate their increase in the case of perspective (25 t / axis) load. However, in the preliminary analysis of a particular embankment with an accepted height of 3 m, it is not possible to definitely determine the intensity of this increase for embankments with a different height, since the results of the specific analysis are incorrectly extrapolated to other cases. Therefore, it is necessary to outline a complex of studies of the formation with different heights in the interaction of existing and perspective loads in the future.

2.The results of movements in the developed finite element model make it possible to conclude that for perspective loading on the axle of the wagon, unlike the existing one, they increased in 1.2 and 1.3 times respectively for the horizontal and vertical components. The values obtained indicate that the increase of the load on the axis to the value of the perspective (25 t / axis) for a specific value of the formation (modulus of elasticity of 25 MPa) is not significant, but for other values it is, what does not meet the norms of subsidence of the upper structure of the path. Therefore, in the future, it is necessary to outline a complex of studies of formation with different modules of elasticity, in particular for sites under construction or under reconstruction.

3. The results of the stresses in the developed finite element model make it possible to conclude that for the perspective load on the axle of the wagon, unlike the existing one, they change insignificantly: the horizontal stress along the X axis in accordance to the 1st load scheme -0.078 MPa (78 kN / m^2) and -0.083 MPa (78 kN / m^2) respectively; according to the 2nd load scheme -0.074 MPa (74 kN / m^2) and -0.079 MPa (79 kN / m^2) respectively; vertical voltage along the Z axis according to the 1st and 2nd load schemes -0.133 MPa (133 kN / m^2) and – 0.141 MPa (141 kN / m^2) respectively, which corresponds to the strength of the base under the upper railway structure (0.16 MPa) / 160 kN / m^2), although the margin of safety in the case of prospective loading is some smaller. The obtained values indicate that the increase of the load on the axis to the value of the perspective is not significant, but for other conditions it can differ more, that does not meet the norms of subsidence of the upper structure of the path and the strength of the base under the upper structure of the railway. Therefore, in the future, it is necessary to outline a complex of studies of earth formation with different variations of properties, in particular for sites under construction or under reconstruction, including strengthenings.

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