

Investigation of the influence of the railroad track on the stress state of the tunnel lining

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Abstract. Tunnel lining takes significant loads from moving vehicles. The consequences of their impact depend on the design of the railway track and the deformation characteristics of its elements. For their study, a numerical model of a circular tunnel has been developed. As a result of the model calculation, the values of the main vertical stresses in the main tunnel structures were obtained. It is established that with increasing loads from the wheel to the rail from 100 to 200 kN, the voltage on average increases by 50%. The stress distribution is affected by the rigidity of the elastic layer. When it increases, the vertical stresses in the sub-rail support decrease nonlinearly, while in traveling concrete they increase nonlinearly.

1 Introduction

Currently, worldwide, there is a constant increase in the speed of the railway transport, the volume of freight and passenger transfers. The most important role in the development of a network of railways is played by transport tunnels that ensure the intersection of mountain and water barriers, densely built-up urban areas.

Thus, the relative length of tunnel crossings in the railroad network of Russia does not exceed 0.1%, but they can significantly limit the operational characteristics of both individual sections of the track and the direction as a whole [1].

These problems are especially acute as high-speed highways develop. Currently, in Europe, the speed of freight trains in tunnels reaches 160 km/h, passenger speeds - 250 km/h or more. The corresponding established speed of trains in tunnels in Russia does not exceed 65 km/h [1].

The task of increasing the carrying capacity of the railway is also solved by putting into operation trains with axial loads of up to 300 kN, which necessitates an increase in the carrying capacity and reliability of the railway track construction.

A comprehensive analysis of studies of the stressed state of the ballast prism during the movement of trains with increased axial loads was carried out in [2,3]. It is established that the stresses in the ballast layer increase linearly with increasing train speed and axial load.

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For example, an increase in the axial load from 230 to 250 kN/axis leads to an increase in stresses on the main track by 6.8%, from 230 to 270 kN/axis - by 15.3%.

With increasing loads on railroads, ballastless track designs are becoming increasingly widespread, allowing a significant increase in the reliability of the section of the railway line, reducing noise, vibration and operating costs for track maintenance [2,3].

At the same time, experimental studies of stresses in the elements of the design of the ballastless path show that using a ballast-free design, the attenuation of vertical stresses occurs less intensively than in a conventional ballast design. An increase in the speed of the train from 70 to 200 km/h causes an increase in vertical stresses on the main site of the roadbed to 20%. [4].

In the tunnel, temporary loads from the rolling stock will be transferred to road concrete and lining. The stress-strain state of tunnel structures when using the ballastless path and large axial loads requires further study.

2 Statement of the problem

At present, two designs of the ballastless path are recommended for use in tunnels in Russia (Instruction for the application of the upper track structure in tunnels.) Ordinance No. 2607r of Russian Railways of December 18, 2012):

1. A ballastless track with sub-rail supports that are homogenized in track concrete through an elastic layer with calculated (reduced) rigidity (Fig Tunnel lining takes significant loads from moving vehicles. The consequences of their impact depend on ure 1.a).
2. The ballastless track of the "mass-spring" system with calculated (reduced) rigidity (Figure 1.b).

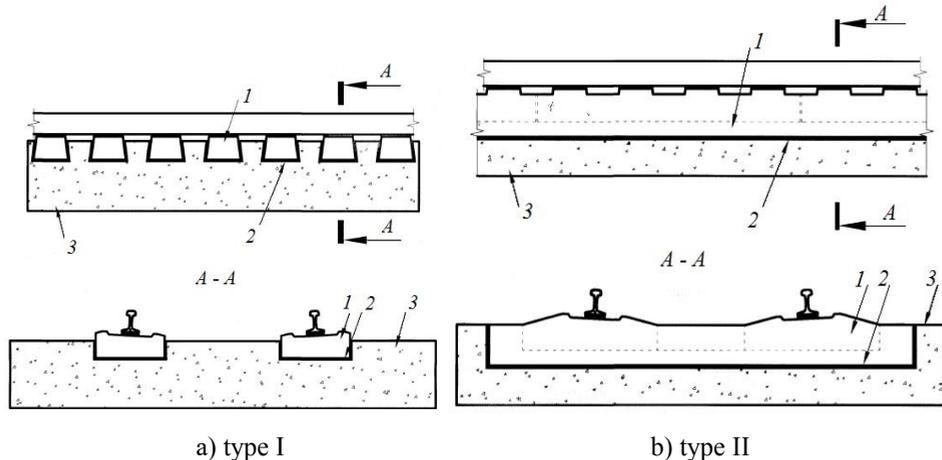


Fig.1. Ballast-free track.

An example of a type 1 ballast-free track is LVT (Low Vibration Track) system (Figure 3), which includes rails, rail fasteners, reinforced concrete half-sleeves with rubber covers and cushioning pads, supporting the construction of the track base from unreinforced concrete.

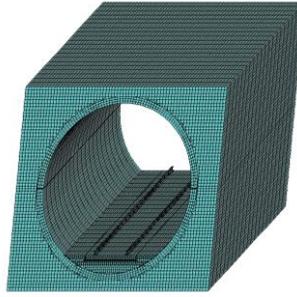


Fig. 5. Fragment of the volume finite element model of the railway tunnel.

As the upper structure of the path, a type II ballastless path was adopted (Fig. 1b). The physical and mechanical characteristics of the materials of the model are presented in Table. 1.

Table 1. Physical and mechanical characteristics of the materials of the model.

Type of feature	Initial modulus of elasticity, MPa·10 ⁻³	Specific volumetric weight, kN/m ³	The coefficient of transverse deformation
Rail P65	210	78	0,3
Sub-rail support B40	36	25	0,2
The elastic laye	2	18	0,4
Track concrete B15	24	25	0,2
Lining (concrete B35)	34,5	25	0,2
Rock mass	15	27	0,3

To assess the impact of temporary loads on the rolling stock on the stress state of the tunnel structures, the model was loaded only with concentrated loads from the wagon wheels to the rail.

The vertical dynamic load of the wheel on the rail was from expression

$$P_{\text{dun}}^{\text{max}} = P_{\text{cp}} + \lambda S, \quad (1)$$

where λ is a normalized factor determining the probability of occurrence of a dynamic load; S is the mean square deviation of dynamic wheel dynamic stress on the rail;

P_{cp} - average value of the vertical load on the rail, kN:

$$P_{\text{cp}} = P_{\text{cr}} + 0,75P_{\text{p}}^{\text{max}}, \quad (2)$$

Here P_{cr} - static load of a wheel on a rail, kH;

$P_{\text{p}}^{\text{max}}$ is the dynamic maximum load of the wheel on the rail, which arises from the oscillation of the body on the springs, kN.

3 Results

As a result of calculations for various axial loads, the values of the main vertical stresses in the main elements of the tunnel structures were obtained. In Fig. 6 shows an example of a section of a tunnel with isopolis of principal vertical stresses. Data on the calculated values of the maximum vertical stresses in the main tunnel structures are presented in Table. 2.

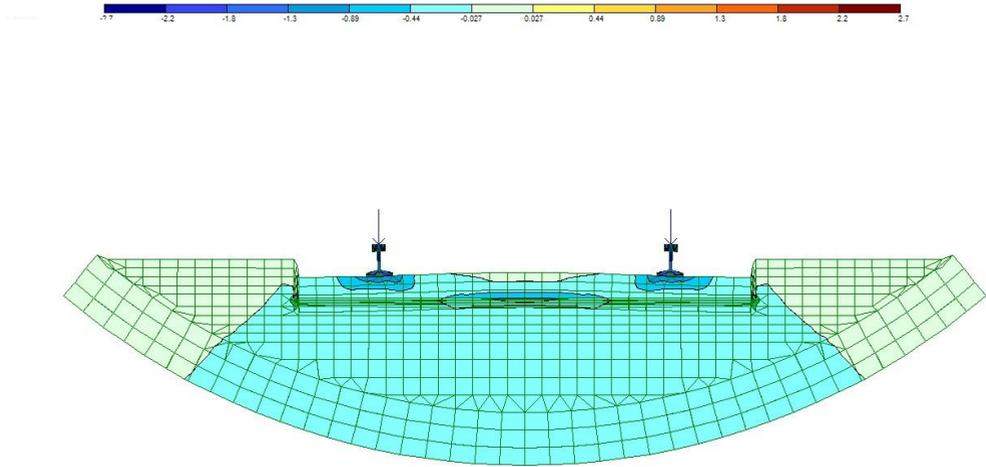


Fig. 6. Fragment of the section of the model with isopolines of principal vertical stresses.

Table 2. Results of calculation of vertical stresses in tunnel structures

Type of feature	The main vertical stresses, kPa, with the value of the vertical dynamic load of the wheel on the rail, kN				
	100	125	150	175	200
Under-rail support	932,5	1170,0	1339,0	1631,9	1865,0
Track concrete B15	80,3	100,3	120,4	140,5	160,5
Lining (concrete B35)	65,6	82,0	98,4	114,9	131,3

The results of the calculations show that with an increase in the vertical load from 100 to 200 kN, the vertical stresses in tunnel structures increase by an average of 50%. At the elastic stage of the deformation of materials, the dependence of the stresses on the load is linear.

Of particular interest is the investigation of the influence of the rigidity of the elastic layer on the stresses in the constructions of the ballastless path. The stiffness of the elastic layer can be determined from expression

$$H = E \frac{A}{h}, \quad (3)$$

where E is the modulus of elasticity of the layer, GPa;

A is the area of the elastic layer in terms of 1 p.m. of path, m²;

h is the thickness of the elastic layer, m.

In Fig. 7a shows the dependence of the main vertical stresses in the subbase rail on the rigidity of the elastic layer. In Fig. 8a shows a similar dependence. 7 - Dependences of the main vertical stresses on the rigidity of the elastic layer:

a - in the subbase rail; b - in track concrete

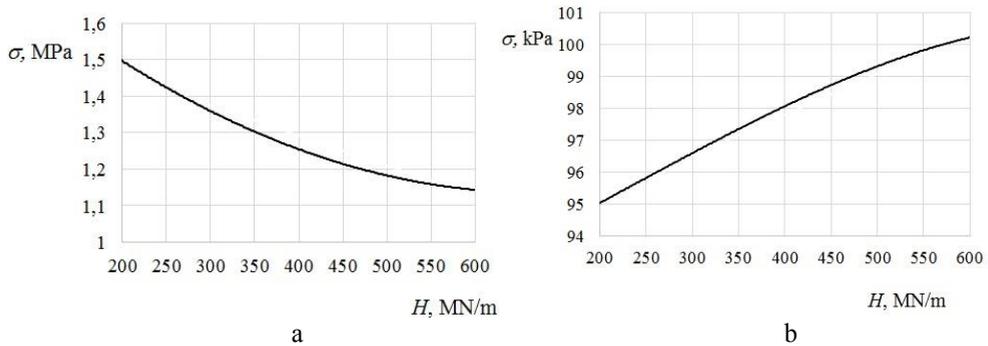


Fig. 7. Dependences of the main vertical stresses on the rigidity of the elastic layer: a - in the subgrade rail; b - in track concrete.

4 Conclusions

The received results testify expediency at designing of designs of a railway tunnel of carrying out of the analysis of a multicomponent system «a mobile structure - a rail way - the road concrete - a lining - a ground». Its analysis under the action of calculated combinations of permanent, temporary and special loads will allow to determine the required strength and deformation parameters of structures and to increase the technical and economic indicators of design solutions. The rigidity of the elastic layer can be considered as one of the regulating elements for achieving optimal parameters of the system interaction under severe operating conditions.

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