**Research on the Stability of a Continuous Track with Improved Methods for Calculating Track Stiffness**

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**Abstract.** The article discusses theoretical and experimental studies of the operation of a joint-less track on reinforced concrete sleepers, developed and improved methods for calculating track stiffness depending on the deformative characteristics of its elements and new designs of track supports with improved stiffness characteristics in modern conditions, making a significant contribution to accelerating scientific and technological progress in railway transport. The issues of determining the influence of the speed of rolling stock on the deformations of a joint-less track are also considered, rail defects at high-speed sections of railway track are considered, and an analysis with different temperatures is made. The spheres of distribution of the main types of the joint-less track base according to the degree of deformability and the volume of accumulation of residual deformations of the railway track under the same conditions and structures in summer and winter are determined. The values of the residual deformations of the track with different structures are compared.

**Keywords:** train movement, safety, seamless track, reinforced concrete sleeper, track stiffness, deformations, rail defects.

**INTRODUCTION**

In the conditions of a market economy in the modern world, the volume of transported goods and passengers is growing, as well as train speeds and safety requirements are rapidly increasing. In the process of formation and development of railways, there is a tendency to increase the length of rails, since the longer the rail, the fewer joints, the lower the dynamic load, and, consequently, less wear on both the railway track and the wheel sets. Thus, the most rational is the construction of a joint-less railway track.

One of the main goals of railway operation is to create a solid and reliable track structure. Studies have been conducted on various railways around the world on the influence of track structures and conditions of its maintenance on the occurrence and development of track emissions, shifts and hijackings, and to determine the influence of various structural and operational factors on the values of the maximum allowable whip temperature, exceeding which relative to the anchoring temperature leads to hijackings, shifts and track emissions [3, 4, 5, 6].

The lateral stability against transverse shear under the train of the link and joint-less tracks has been investigated by domestic [1, 2, 6, 7, 8, 9, 10, 11] and other scientists. An essential role in ensuring the stable operation of the railway track and the safety of train movement is played by rail fasteners, which should ensure reliable connection of rails with sleepers. The stability of the rail track largely depends on the quality and reliability of the rail fasteners and their elements, especially when trains are moving at high speeds and axial loads.

**RESEARCH METHODOLOGY**

If the railway track was perfectly level, and the wheels of the rolling stock were perfectly round (without bumps) and balanced, then it would be advisable to increase the rigidity of the track indefinitely. At the same time, the resistance to movement decreases, which leads to a reduction in fuel costs, an increase in the technical speed and weight of trains and, as a result, to an increase in the capacity and carrying capacity of railways [12, 14].

However, in the presence of uneven rolling, sliders, piles, dents and unbalanced masses on the wheels of rolling stock, track irregularities in the areas of rail joints and rail welding sites, as well as corks, saddles, undulating wear and other irregularities on the rails and the track as a whole, the dynamic forces of interaction between wheels and rails increase significantly with increasing track stiffness.

The increase in dynamic forces is explained by the increase in the inertial forces of the masses of various parts of the moving rolling stock. In modern calculation methods, only the inertia forces of the unsprung masses of the rolling stock are taken into account (as they depend on the stiffness of the track). At the same time, they are subdivided, depending on the cause of the oscillation disturbance, into inertia forces due to the presence of [13, 15]:

- isolated unevenness of the joint-less track due to the uneven elasticity of the rail base;

- isolated irregularities on the rolling surface of the wheels;

- continuous rolling unevenness on wheels.

Lysyuk V.S. recommends evaluating the effect of joint-less track stiffness on these forces using the formulas [15]:

(1)

(2)

(3)

In formulas (1-3):

*l* is the distance between the axes of adjacent sleepers;

*J* is the moment of inertia of the rail section;

*U* is the modulus of elasticity of the path;

*mk* and *mп* are, respectively, the mass of the wheel and the mass of the track, brought to the point of contact between the wheel and the rail;

*Ymax* is the largest additional deflection of the rail due to force;

inertia of unsprung masses due to isolated unevenness on the wheel;

*q* is the mass of unsprung parts of rolling stock attributed to a single wheel.

It follows from the above formulas that the stiffness of the joint-free track significantly affects the dynamic additions of the forces exerted by the wheels on the rails, especially in the presence of isolated irregularities on the wheels. Therefore, there is a natural process of gradual increase in the rigidity of the track, due to an increase in its strength (increased bending stiffness of rails and sleepers, the density of the sleepers, the thickness of the layer and the density of crushed stone, etc.) should be accompanied by a corresponding reduction in the size of the permissible bumps on the track and, first of all, on the wheels, as well as a reduction in the rigidity of the "railway track - rolling stock" system due to rolling stock.

**RESULTS OF THE RESEARCH**

During prolonged operation, the tightening of the terminal and mounting bolts is weakened and the longitudinal forces of the rolling stock cause the longitudinal displacement of the whip points. To determine the effect of the modulus of elasticity of the track on the hijacking of the track, experimental studies were conducted on a jointless track. The experiments were conducted on the Tashkent route. The selected experimental sites had the following characteristics.

Section №1: seamless track with 800 m long R65 rails, reinforced concrete sleepers in the amount of 1,840 pieces/km and intermediate fasteners of the KB type. In plan, this section was located on a straight line, and in profile - on a slope with a steepness of 4.7%. Trains formed from gondola cars with an axial load of up to 250 kN, with electric locomotives O'z-Y-0119 in the head, were moving along the section. The trains were braked by pneumatic car brakes. 390 million tons of cargo were passed through the site. The under-rail gaskets are rubber, worn out and smudged.

Section №2: a link track with R65 rails 25 m long, reinforced concrete sleepers in the amount of 1,840 pieces/km and intermediate fasteners of the KB type. In plan, this section was located on a straight line, and in profile - on a slope with a steepness of 1,2. Trains formed of gondola cars with an axial load of up to 230 kN, with diesel locomotives O'z-Y-0119 in the head, were moving along the section. The trains were braked by pneumatic car brakes. 370 million tons of cargo were passed through the site. The under-rail gaskets are rubber, worn out and smudged.

Observations of the longitudinal displacements of the rail weaves were carried out according to a standard procedure for the valves and marks on the rails. The supports of the contact network were used as shutters. When laying the test section, a cord was stretched between the supports and a solid 10 mm thick line was applied with oil paint on the inner surface of the rail with access to the head and sole of the rail. Measurements of the theft values in the rail lashes were carried out in winter (in late January and early February) when the embankment was frozen by about 1.5 - 2.0 m, and in summer measurements were made (in late June and early July), when the ground had the lowest humidity value. During the measurements, the distances between the cord and the edge of the label were determined. Before the start of the experiment, standard tightening of the terminal and mounting bolts was installed on the test sites using a torque wrench. The results of observations of the longitudinal movements of the rail weaves are shown in Table 1.

**Table 1.** Longitudinal movements of the rail weaves of the seamless track depending on the modulus of elasticity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Plot number | Longitudinal movements of rails in (mm) depending on the modulus of elasticity after passing (MPa) | | | | | |
| summer | | | winter | | |
| 400 | 405 | 415 | 400 | 405 | 415 |
| 1 | 2,0 | 2,9 | 4,4 | 1,3 | 1,9 | 2,3 |
| 2 | 1,5 | 2,2 | 2,9 | 0,9 | 1,2 | 1,7 |

From the data in Table 1, it can be seen that in all experimental sections in the summer, the amount of track theft is higher than in winter. For example, on section N ° 1 where trains with increased axial load operate, track theft in the summer is 1.5 - 1.9 times higher than in winter. This pattern is also observed at site No. 2. When the axial load increases to 250 kN, the hijacking of the track also increases.

Experimental sections were laid to determine the amount of accumulation of residual deformations of the railway track. For comparison, experimental sections with different elasticity modules were laid. The main characteristics of the experimental plots are given in Table 2.

**Table 2.** Characteristics of the experimental sites

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Plot number | Elements of the upper structure of the path | | | Load capacity, million tkm/km per year | | |
| rails | sleepers | ballast | |  |
| 1 | R65 (s.t.) | Sh1-1 | crushed stone | | 25 |
| 2 | R65 (25) | Sh1-1 | crushed stone | | 25 |

The alignment of the empirical series of the distribution of the values of the position of the rail threads in the vertical plane y has shown that they are described by curves obeying the normal law. Verification of the correctness of the theoretical conclusion about the type of function and the values of its parameters based on the experimental results was carried out according to the Pearson x criterion.

The results of statistical processing of the values of the position of the rail threads in the vertical plane as the passed tonnage increases are given in Table 3.

**Table 3.** Statistical parameters of accumulation of residual deformations of rail threads in the profile

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Plot number | Longitudinal movements of rails in (mm) depending on the modulus of elasticity after passing (MPa) | | | | | | | |
| summer | | | | winter | | | |
| 2024 | | | | 2024 | | | |
| y | Sy | y | Sy | y | Sy | y | Sy |
| 1 | 4,72 | 0,83 | 4,95 | 0,96 | 5,67 | 1,28 | 5,54 | 1,58 |
| 2 | 5,15 | 1,03 | 5,47 | 1,10 | 6,33 | 1,62 | 6,88 | 1,70 |

Note: *y* is the arithmetic mean, mm;

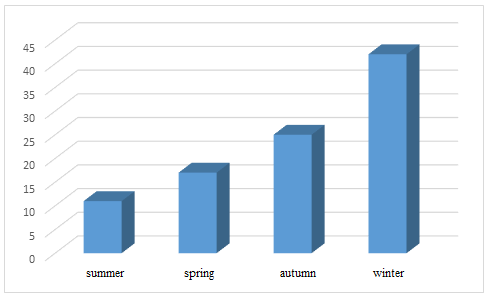
*Sy* is the arithmetic mean deviation of the accumulation of residual deformations, mm.

Analysis of the table data shows that in all experimental areas, residual deformations accumulate faster in the summer. For example, in experimental section 1 (a seamless track with reinforced concrete sleepers), the amount of residual deformation in summer is 1.2 times greater than in winter. In experimental section 2 (link track with reinforced concrete sleepers), the residual deformation in summer is 1.24 times greater than in winter. If we compare the values of the residual deformations of the track with various structures (for example, experimental sections 1 and 2), it can be seen that in the experimental section with reinforced concrete sleepers this value is 1.1 -1.11 times less than in the section with reinforced concrete sleepers. In winter, the standard deviation of the residual deformation is also lower, that is, the path is more equally rigid.

The unevenness of deformations in the vertical plane is estimated by the local slopes of the path. Analysis of local slopes has shown that as the modulus of elasticity increases, the steepness of local slopes decreases. For example, in experimental section 1 (seamless track), when measuring slopes in winter, the slopes from 0 to 1% were 63%, from 1 to 2%: 29%, from 2 to 3% - 6%, from 3 to 4% - 1%. When measuring slopes in summer, the slope steepness from 0 to 1% is 57%, from 1 to 2% is 32%, from 2 to 3% is 8%, and from 3 to 4% is 3%.. These data show that the slope steepness is influenced by the modulus of elasticity of the sub-rail base of the railway track. The steepness of the slopes increases, especially on sections of railway track with reinforced concrete sleepers.

The operation of the rails of the joint-free track differs from the operation of the rails of the link track. The output of defective rails increases in winter, that is, with increasing track stiffness.

Figure 1 shows a diagram of the distribution of detected defects in the rail weaves of a seamless track by time of year.



**FIGURE 1.** Diagram of the distribution of detected defects in the rail weaves of a seamless track over an annual cycle

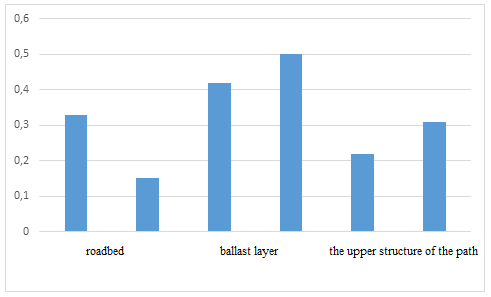
As can be seen from the diagram, most of the defects and damages appear in the rail weaves of the seamless track in winter (43%). This means that in winter, in order to increase the reliability of the railway track and ensure the safety of train traffic during the cold season, it is necessary to take into account the tensile temperature stresses in the rails.

The magnitude of the residual deformations of the ballast layer and the roadbed depends on many factors. These include: constant compaction of the ballast and the ground of the roadbed due to the repacking of particles under the influence of a train vibration load; different support on the ballast of adjacent sleepers and each sleeper in its different sections, a different combination of loads transmitted to the ballast layer, etc. The nature of the seal depends on the initial voidness, grain composition and shape of the ballast grains, on the strength and other physical and mechanical properties of the rock.

The experimental sections not only have the same upper structure of the track, but also have the same missed tonnage, which gives an identical start to the experiments. In order to take into account climatic factors for the accumulation of residual deformations in the above-mentioned areas, precipitation observations and the duration of winter and summer periods were carried out.

Figure 2 shows diagrams of precipitation distribution between track elements in experimental sections with different track designs.

It follows from the above graphs that the proportion of precipitation generated by one or another element of the path largely depends on the design of the upper structure of the path. Thus, for reinforced concrete sleepers, the proportion of precipitation formed due to wear of rails, sleepers, fasteners, reduction of backlashes and gaps between the elements of the upper structure and more dense pressing of the rail to the sleeper is in the range of 23.5%. For reinforced concrete sleepers, this proportion is higher than for reinforced concrete sleepers and is in the range of 30.9%. The proportion of precipitation of the earth bed and ballast prism in reinforced concrete sleepers is greater than in reinforced concrete sleepers.



**FIGURE 2.** The proportion of precipitation of railway track elements.

**CONCLUSIONS**

1. The bending of the rail is greatly influenced by the rigidity of the track. With the same track design, but with different elastic modules, the amount of deflection of the rail under the wheel is different. The maximum deflection in reinforced concrete sleepers at a speed of V = 150 km / h reaches up to 1.44 cm, and at the same speed in winter conditions - 0.38 cm, that is, the deflection of the rail in summer conditions on reinforced concrete sleepers is 3.8 times greater than in winter conditions. The maximum deflection in summer conditions with reinforced concrete sleepers and a speed of V = 150 km / h reaches up to 0.63 cm, and at the same speed in winter conditions - 0.35 cm, that is, the deflection of the rail in summer conditions on iron-concrete sleepers is 1.8 times greater than in winter conditions.

2. The accumulation of residual deformations of the railway track in the same conditions and structures in the summer is 1.2 times greater than in winter. If we compare the values of the residual deformations of the track with various structures, it can be seen that in the experimental section with reinforced concrete sleepers this value is   
1.1 -1.1 times less than in the section with reinforced concrete sleepers. In winter, the standard deviation of the residual deformation is also lower, that is, the path is more equally rigid.

3. The operation of the rails of the joint-free track is different from the rails of the link track. The output of defective rails increases in winter, that is, with increasing track stiffness.

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