Determination of the modulus of elasticity of railway track with BF70 sleepers

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Abstract. The purpose of this work is to determine the modulus of elasticity of the under-rail base, which are the main elastic characteristics that determine the stresses in the elements of the track structure under the dynamic load from the train. Traditionally, the modulus of elasticity of the track is determined on the basis of experimental studies. In this paper, the modulus of elasticity of the under-rail base is determined by calculation. For this purpose, a finite element model of the railway track was created in the Femap with NX Nastran software package, and the deflections of the rails from different forces transmitted from the wheel were determined by means of modelling. Values of the elastic modulus of the sub-rail base for the track with BF70 sleepers were obtained. The results make it possible to carry out a set of calculations of the railway track with BF70 sleepers for strength and stability.

1 Introduction

In recent years, the network of high-speed and high-speed railways has been expanding in Uzbekistan [1, 2, 3]. In order to realise high train speeds and ensure guaranteed safety and comfort, it is necessary to widely introduce reliable, low-maintenance and cost-effective structures of the railway track superstructure. At the railways of Uzbekistan as a sub-rail base since 2004, the laying of sleepers of BF70 (BF70S) type with Pandrol Fastclip fasteners has been massively started during new construction and capital repairs [4, 5]. The use of such a track design makes it possible to create a smooth track width diversion in curves of small radius [6]. Sleepers of BF70 (BF70S) type are produced by a local manufacturer in accordance with the requirements [7]. Figure 1 shows BF70 (BF70S) type sleeper and Table 1 shows the technical characteristics of the sleeper.

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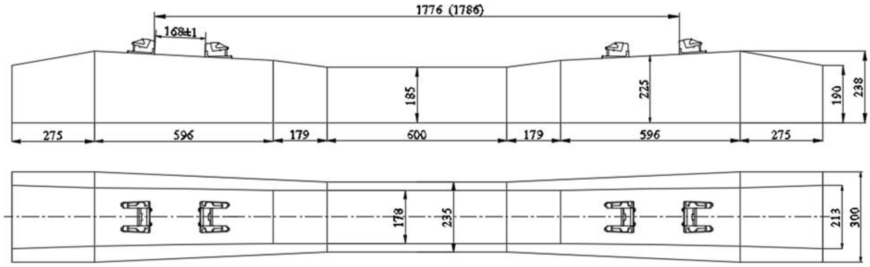

Fig. 1. Caption of the Figure 1. Below the figure.

The track structure with BF70 sleepers and Pandrol Fastclip resilient fasteners has demonstrated its high reliability. However, technical literature and periodicals in very limited volumes reflect technical parameters and characteristics of the track design with BF70 sleepers, which in recent years have become the main ones for the main tracks of JSC "Uzbekistan Railways". In this regard, it becomes relevant to study the performance of railway track with sleepers BF70 in the conditions of the Republic of Uzbekistan. The main indicator of railway track characteristics is the deformability of the track, in turn, the main parameter of railway track deformability is the modulus of elasticity of the sub-rail base. To study the railway track it is necessary to determine the characteristics associated with ensuring the stability of this track in the process of its long-term operation.

Table 1. Technical parameters of sleeper type BF70

№	Parameter name	Magnitude
1	Length, mm	2700
2	Height, mm: - at the end - in under rail section - in the middle	 190 225 185
3	Footprint of the bottom bed, m²	0,72
4	Weight, kg	330±16,5
5	Type of intermediate rail coupling	Pandrol Fastclip
6	Travelling speeds: km/h - passenger trains - goods trains	 up to 250 up to 100
7	Maximum axle load, tonnes/axle	25
8	Estimated service life	at least 50 years

2 Materials and Methods

The modulus of elasticity of the under-rail base of the railway track is determined by the formula [8]:

$$U = \sqrt[3]{\left(\frac{P}{y}\right)^2 \cdot \frac{1}{64EJ}} \tag{1}$$

where: U - vertical modulus of elasticity of the rail base, kg/cm2;
P - wheel load on the rail, kg;
y - deflection of the rail string, mm;

E - modulus of elasticity of rail steel, kg/cm2;

J - moment of inertia of the rail in the vertical plane, cm4.

In turn, the deflection of the rail string from given loads is determined experimentally using mobile diagnostic complexes. Currently, two types of such loading complexes SPM-18 and SM-460 are in operation [9], besides, there are loading devices of VNIIZhT [10] and DIIT [11]. The paper [12] presents a methodology for determining the elastic characteristics of the under-rail base of a ballastless railway track experimentally through the edge stresses of the rail sole.

In addition, scientists have proposed calculation methods to determine the modulus of elasticity of the under-rail base [13-17]. Of particular interest is the method of determining the modulus of elasticity of the under-rail base of the railway track by the finite element method proposed by the scientists of SamGUPS [17]. The method [17] makes it possible to determine the modulus of elasticity of the under-rail base at different parameters of the ballast layer using different types of intermediate rail fasteners, as well as to take into account the characteristics of the subgrade.

In this work, the modulus of elasticity of the track with BF70 sleepers and Pandrol Fastlip fasteners will be determined according to the method [17].

In order to solve this problem, we have developed three-dimensional models of the railway track section, which fully repeat the configuration of the real operating track with BF70 sleepers and Pandrol Fastlip fasteners, Figure 2.

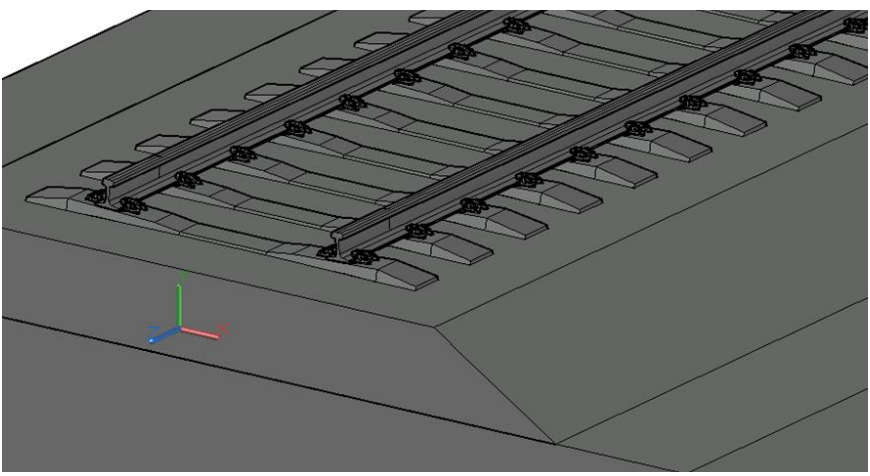

Fig. 2. Three-dimensional model of a track section with BF70 sleepers and Pandrol Fastlip fasteners.

On the basis of three-dimensional models, finite element models with a capacity of more than 1 million nodes were designed in the Femap with NX Nastran software package. Femap with NX Nastran has wide enough possibilities for creating geometric and finite element models of the most diverse structures and allows to perform almost any type of analysis. A finite element model with boundary conditions and analysis conditions is prepared in the Femap environment. The required analysis is then performed in NX Nastran and the results are visualised and documented in Femap [18, 19]. An example of a finite element model of a track with BF70 sleepers and Pandrol Fastlip fasteners is shown in Figure 3.

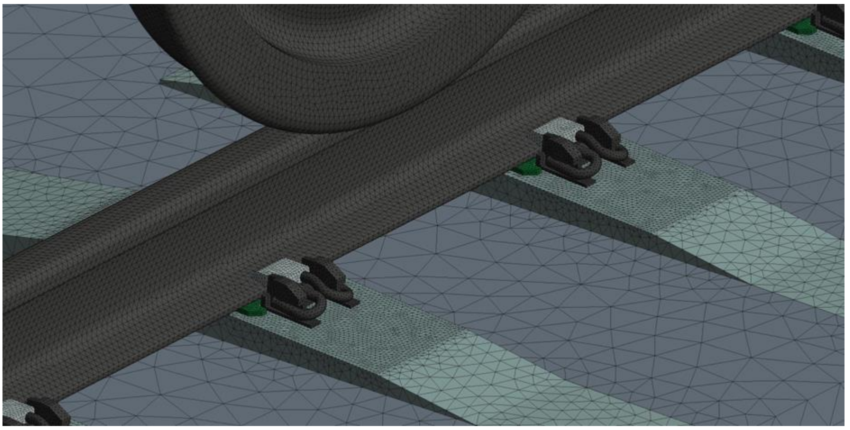

Fig. 3. Finite element model of a track section with BF70 sleepers and Pandrol Fastlip fasteners.

The input data for the modelling are:

1. The force transmitted from the wheel is 5, 10 and 15 tonnes;
2. The clamping force of the fastener terminals is normative [20];
3. Loading is carried out in several stages: taking into account the own weight of the track elements, then applying the load from the rolling stock;
4. Properties of soil materials are accepted according to the researches [21-24]. Physical and mechanical characteristics of the soil and ballast layer are presented in Table 2.

Table 2. Soil characteristics of the subgrade and ballast layer

Parameter	**Soil**	**Ballast**
Density, kg/m^3	2150	1650
Modulus of elasticity, MPa	85	230
Poisson coefficient	0,35	0,275
Angle of internal friction, deg.	30	41,5
Clutch, kPa	16,3	16,5
Dilatancy angle, deg	5	5

3 Results and Discussion

As a result of the modelling, the deformation values of the railway track structure depending on the rolling stock load were obtained. An example of the deformation contour at an axial load of 30 tonnes for a track structure with BF70 sleepers and Pandrol Fastlip fasteners is shown in Figure 4.

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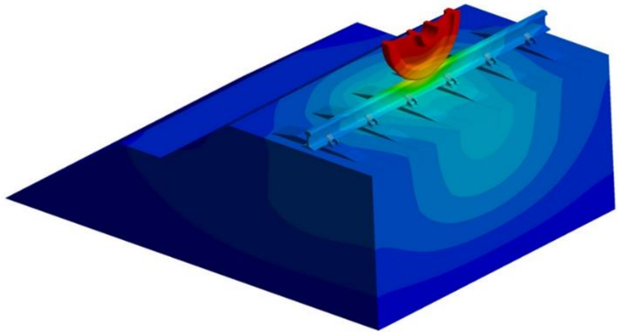

Fig. 4. Deformations at 30 tonnes axial load for track section with BF70 sleepers and Pandrol Fastlip fasteners

Using the modelling results, we determine the modulus of elasticity of the under-rail base of the railway track by formula (1). The values of the obtained average values of the vertical modulus of elasticity of the rail base depending on the characteristics of the subgrade and ballast layer are presented in tabular (Table 3) and graphical form (Figure 5).

Table 3. Values of the vertical modulus of elasticity of the rail foundation

Sleepers epyure, pcs/km	Ballast thickness, cm	Modulus of elasticity of under-rail base, MPa
1840	40	710,2
2000	40	987,6
1720	40	541,7
1600	40	404,5
1840	25	537,1
2000	25	747,1
1720	25	409,7
1600	25	306,38

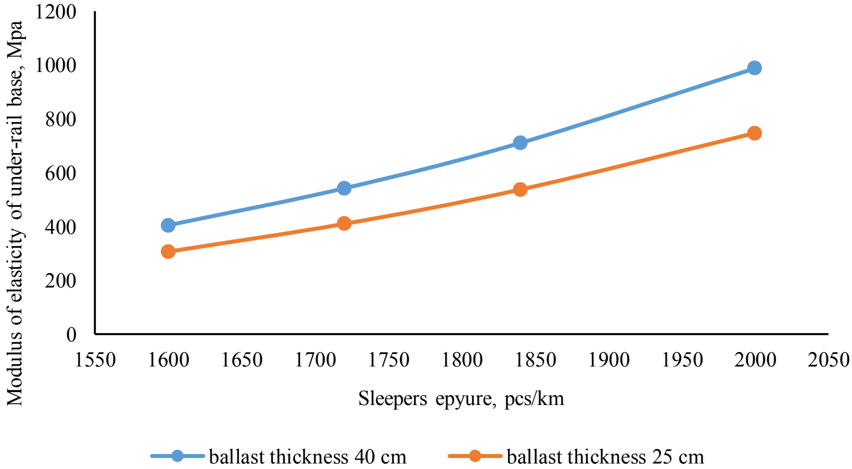

Fig. 5. Graph of dependence of modulus of elasticity of track on sleepers epyure.

The analysis of the table and the graph shows that at a ballast thickness of 40 cm the modulus of elasticity of the track for the sleepers' 1600 pcs./km is equal to 404.5 MPa, with the increase of the sleepers' epature the modulus of elasticity of the track increases and at the sleepers' epature 2000 pcs./km reaches 987.6 MPa. At a ballast thickness of 25 cm these indices are respectively equal to: 306.38 MPa and 747.1 MPa. With the reduction of ballast thickness from 40 cm to 25 cm the modulus of elasticity of the track decreases by 25%.

4 Conclusion

The obtained values of the elastic moduli of the under-rail base completely coincide with the parameters given in the methodology for assessing the impact of rolling stock on the track under the conditions of ensuring its reliability [8] and they can be used in further calculations of railway track strength and stability.

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