Investigations of damage to the under-rail base on the main routes JSC "Uzbekistan Temir Yullari"

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Abstract. The article presents the results of field surveys of the condition of reinforced concrete sleepers of the BF70 type with different periods of their operation and different missed tonnage on the main tracks of JSC "Uzbekistan Temir yullari". The main types of defects and the causes of the destruction of the sleepers have been identified. They were distributed according to classification numbers. In order to increase the life cycle of the under-rail foundation and the overhaul period, ways to prevent and eliminate defects are recommended.

1 Introduction

Today, targeted measures are being taken in the Republic of Uzbekistan to further develop the transport potential, which contributes to strengthening the political and economic independence of the country, ensures its active integration into the world community [1-3]. One of the key goals of the Development Strategy of New Uzbekistan for 2022-2026 is the development of a unified transport system in conjunction with all modes of transport, including the expansion of "green corridors" and transit opportunities in the transport system for foreign trade, as well as an increase in the volume of transit cargo turnover up to 15 million tons [4-7].

In this regard, in order to increase the efficiency of transport and ensure the safety of train traffic, the operational reliability of the main elements of the railway is necessary. In order to achieve this, proper knowledge of the condition of the superstructure of the track during long-term operation is required. Based on this, it is of great importance to study the aging processes of track elements, including changes in the state of its under-rail bases [8-10].

As everyone knows, sleepers are the traditional and most common type of under-rail foundation. In general, sleepers serve to absorb pressure from the rails and transfer it to the ballast layer; elastic processing of dynamic impacts on the track; ensuring the constancy of the track width and, together with the ballast, the stability of the rail-sleeper lattice in the horizontal and vertical planes [11].

The main materials for the manufacture of sleepers are wood, reinforced concrete and metal. Reinforced concrete sleepers now the most popular in the construction of new and operation (especially high-speed, for Uzbekistan - high-speed) railways.

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The main advantages of reinforced concrete sleepers are high strength, which is achieved due to stressed reinforced concrete, a relatively long service life (40-50 years), uniform elasticity of the track along the length, good stability in ballast against shear, the possibility of giving them an appropriate shape [12, 13] .

On the Uzbek railways, reinforced concrete sleepers of the modern type BF 70 with elastic (elastic) intermediate rail fastening of the Pandrol type Fastclip "(England) have been installed and operated since 2004 [14-16]. The main supplier of sleepers today is the plant of reinforced concrete structures in Uzbekistan LLC "STEEL PROPERTY CONSTRUCTION".

As of January 1, 2022, the total length of railways in the context of the territories in the Republic of Uzbekistan is 6,118.3 kilometers [15], of which 80 percent of the main tracks have BF 70 sleepers. The choice of BF 70 sleepers is justified by a number of their advantages in terms of compared with the previously laid Sh1-1 [14]:

designed and manufactured according to European standard EN 13230 - 1.2 using a quality management system in accordance with the international standard ISO 9001;

in terms of strength and crack resistance , BF 70 sleepers are 25-30% superior to Sh1-1 sleepers, which allows them to be used on main lines of any class , including high-speed and high-speed sections (200-250 km/h) and lines with increased axle loads (30 t/axle);

installation of all elements of elastic fastenings is carried out at the factory, thus, the assembly of the rail grating is carried out fully automated, which reduces labor costs by 8-10 times when assembling the track grid, and also eliminates the possibility of losing fastening elements or their incomplete delivery [17, 18];

Fastclip fastening allows for quick installation / dismantling of the under-rail unit with the help of a special tool (included in the scope of delivery), ensuring protection against unauthorized dismantling; at the same time, the absence of bolted and screw connections in the sleeper and fastenings makes the BF 70 sleeper indispensable, especially in desert conditions, saline soils, as well as in areas with increased snow drift and low temperatures;

minimization of costs for the current maintenance of the track, since during operation there are practically no costs for maintenance of BF 70 sleepers and fasteners [16, 19];

technological advantages of manufacturing BF 70 sleepers: high-precision dosing of concrete components; individual and controlled tension of each wire; the use of special additives that ensure the grade of concrete is not lower than B45; high transfer strength (40 MPa); smooth transfer of prestress to concrete, etc. [16, 20].

Rigid dynamic loads, tangible temperature fluctuations, moistening and drying, freezing and thawing, exposure to an organic-oil environment, and other aggressive factors place exceptionally high demands on the reliability and durability of sleepers [16, 19].

In accordance with this, the sleepers must have sufficient strength, elasticity, good resistance to mechanical wear and movement, be simple in shape, have the longest service life and the lowest cost in manufacturing and maintenance.

In the manufacture of reinforced concrete sleepers, increased requirements are imposed, one of which is the service life [16]. In the process of long-term operation under the influence of rolling stock and climatic conditions, the sleepers age, their strength and other physical and mechanical characteristics decrease, parts fail. The appearance of sleeper defects leads to a decrease in the bearing capacity as a whole, which must be taken into account in the current maintenance of the track and the appointment of its repairs [21, 22]. An exhaustive classification of defects in reinforced concrete sleepers is given in the "Instructions for the current maintenance of the railway track" [19]. The classification by S. Kaevunruen and A. Remennikov [10] is no less remarkable. The fact is that in these works the classification of defects is general for reinforced concrete sleepers . Many of them are not observed on BF 70 sleepers . It is possible that the development of a new classification of defects for BF70 sleepers, recommendations for their elimination and timely repair of damaged sleepers in accordance with the recommendations will increase the standard service life and the missed tonnage of the road, which, according to the Instruction, are 50 years and 500 million gross tons, respectively.

Along with the advantages, reinforced concrete sleepers also have disadvantages: increased sensitivity to the heterogeneity of the ballast layer; sufficiently high loads on the ballast layer with a rigid substructure of the track; higher rigidity of the track (compared to impregnated wooden sleepers), reduced with the help of additional rubber shock absorber pads; small area of the active contact zone [23, 24]. In order to reduce these shortcomings and to use reinforced concrete sleepers for fifty or more years, it is important to diagnose the tracks, including studying their durability and damageability, which will make it possible to identify deformations and breakages.

2 Objects, materials and methods of research

Field surveys of BF 70 sleepers were carried out on sections of the main tracks of JSC "Uzbekistan Temir yullari ". Sections of the continuous track are selected with different lifetimes of sleepers, missed tonnage and traffic density (Table 1).

Surveys of the state of the sleepers during operation were carried out in the following order.

1. Studying the reporting documentation of the distance of the track and the choice of experimental sections of the railway according to the following indicators:

with different missed tonnage with the same service life after overhaul;

with a commensurate missed tonnage at different periods of operation after a major overhaul.

2. Performing visual field surveys of sleepers (inspection of selected sections of the track), detection of defects in sleepers, accounting for their number.

3. Processing inspection results:

exclusion of single types of defects, determination of the number of identical types of defects per 1 km;

on the basis of the existing classification of defects in reinforced concrete sleepers [17], the establishment of the causes of the defect BF 70;

classification of defects according to their causes;

recommendations for the elimination and prevention of the defect.

Table 1. Characteristics of the selected experimental sites

Indicators	Date on	Site indicators				
		1	2	3	4	5
		Tukmachi - Syrdarya, even way			Tukumachi - Hamza, even path	Tukumachi - Angren, even path
		Km 3403	Km 3437	Km 3437	km 0	km 31
Section length, m	01.01.22	920	330	185	561	609
Year of laying	-	2004	2011	2004	1997	2003
Missed tonnage, million gross tons	01/01/19	591.5	270.4	507.0	616.8	651.3
	01.01.20	625.3	303.8	540.8	644.5	685.6
	01.01.21	658.7	337.2	574.2	671.9	719.5
	01.01.22	692.1	370.6	607.6	699.3	752.4
Cargo density, mln. tkm gross/km per year	for 2019	33.8	33.8	33.8	27.7	34.3
	for 2020	33.8	33.8	33.8	27.7	34.3
	for 2021	33.4	33.4	33.4	27.4	33.9
	for 2022	33.4	33.4	33.4	27.4	33.9

3 Results and their discussion

The experiments were carried out in the period from 2019 to 2022. Four sections of the railway of the Tashkent track distance were taken as objects of study. Inspection of the condition of the sleepers at each site was carried out once a year.

Analyzing the results of the experiment, we can say that the sleepers are mostly damaged in the form of longitudinal cracks; breaks and chips at the ends of the sleepers, transverse cracks and fractures in the rail zone of the sleeper ; longitudinal cracks passing through the places where fixed embedded anchors are mounted in the sleepers or next to them . Based on the results of sleeper surveys, a classification of defects was developed (Table 1).

Table 1. Classification of defects in sleepers type BF 70

№	Defects	Cause of defect	Photo	Defect №
1	Longitudinal crack	Impact of a sleeper on a sleeper during loading, transportation, unloading and storage of sleepers .		№1
2		Violations during the laying of the rail grating		
3	Breakage, chipped sleeper at the ends with exposure of reinforcement	Breakage and chipping of the sleeper due to derailment; inaccuracy in ballasting and lack of ballast in maintenance, improper tamping		№2
4				
5	Breaks, transverse - cracks and chips in the under-rail zone, destruction of the sleeper in the lower part	Drawdowns at the joints; stretched - gaps in the joints; vertical steps or saddles at the joints; uneven tamping of the sleeper, lack or loss of elasticity of the under-rail padding made of polymer composite, rail play due to weak pressing of the rail by the terminals that have lost elasticity during long-term operation or destruction of the terminal insulator on the terminal.		№4

Note: The table shows part of the classification.

The destruction of the sleepers in these places is understandable. Defect №1 is a sudden phenomenon that occurs when the sleepers fall on the rails, during a strong earthquake, a sudden impact of the vehicle on the rails, the collision of the sleepers with each other causing local plastic deformation. The reason for the above are violations of the rules for loading, transporting and unloading sleepers. In addition, destruction can occur in any part of the sleeper at the points of impact.

A break, a split of a sleeper at the ends with an exposure of reinforcement (defect №2) appears under the influence of impacts of track repair equipment, when rolling stock derails.

Under the influence of the train load, a horizontal force arises that tends to move the rails forward in the direction of travel. Fastening the rails to the sleeper with intermediate terminals creates a structure that does not allow the rail to be stolen. The authors of [10] noted that the rigid state of the track quickly exacerbates the cracking of concrete sleepers. Apparently, in this design, the weakest element is the sleepers, namely reinforced concrete. As a result, its destruction occurs - a longitudinal crack of the sleeper passing through the places where fixed anchors are mounted, i.e. defect №3 appears.

Defect No. 4 occurs in the under-rail zone. Transverse cracks in the under-rail zone, namely, in the lower part of the sleeper, are caused by positive and negative bending moments of the lower part of the sleeper, which exceed its bearing capacity, respectively. Usually, these cracks are small in width, but depend on the magnitude of the bending moment of the load. If the torque is too high, the crack will develop and the sleeper will fail [8]. This zone of the sleeper is also characterized by destruction of the lower part in the form of fractures. Most likely, these destructions occurred during the performance of track work.

A graphical interpretation of the results of the experiment was performed, equations were obtained for the linear dependence of defects on the missed tonnage (Fig. 1) and defects on the period of operation (Fig. 2).

Defect №1 does not depend on the missed tonnage and the number of defects here is 3. The following expressions show a linear dependence for defects № 2, № 3, № 4, respectively:

$$y = 0.012\,x - 0.1583,\ R^2 = 0.9756 \tag{1}$$
$$y = 0.012x - 0.1583,\ R^2 = 0.9756 \tag{2}$$
$$y = 0.018\,x - 0.5718,\ R^2 = 0.9326 \tag{3}$$

where y is the number of defects, %;

x - the passed tonnage of the road, million gross tons.

Expressions 1-3 will allow you to determine the amount of each type of defect for different values of the missed tonnage. Approximation confidence values greater than 0.93 are a confirmation of the high level of reliability of the trend line. The straight trend line reflects the constant rate of increase in the number of defects with increasing tonnage. It should also be noted that the number of sleeper defects increases in proportion to the increase in the missed tonnage (Fig. 1).

Equations for the dependence of the number of defects on the period of operation, respectively, for defects №2, №3, № 4:

$$y = 0.5x - 0.5,\ R^2 = 0.9303 \tag{4}$$
$$y = 0.3129\,x - 0.2446,\ R^2 = 0.9467 \tag{5}$$
$$y = 0.7871\,x - 0.8554,\ R^2 = 0.9183 \tag{6}$$

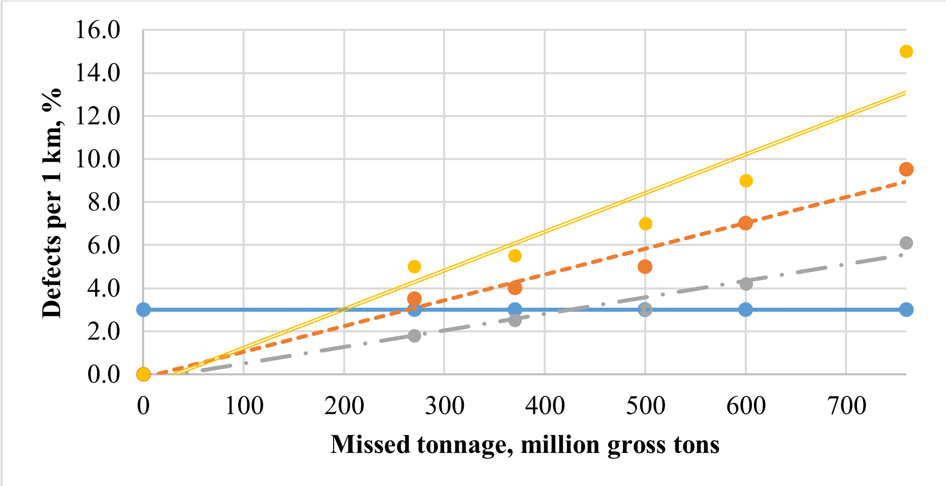

Fig. 1. Dependence of the number of defects on the missed tonnage:
- №1; - 2; - 3; - №4;
- linear (№ 2); - linear (№ 3); - linear (№ 4)

The maximum number of defects of 13% per 1 km of track type No. 4 occurs with a missed tonnage of 750 million gross tons (Fig. 1) for the 18th year of operation of the sleepers (Fig. 2). The minimum amount of 0.5% corresponds to defect No. 3 with a missed tonnage of 100 million gross tons in the third year of operation of the sleepers.

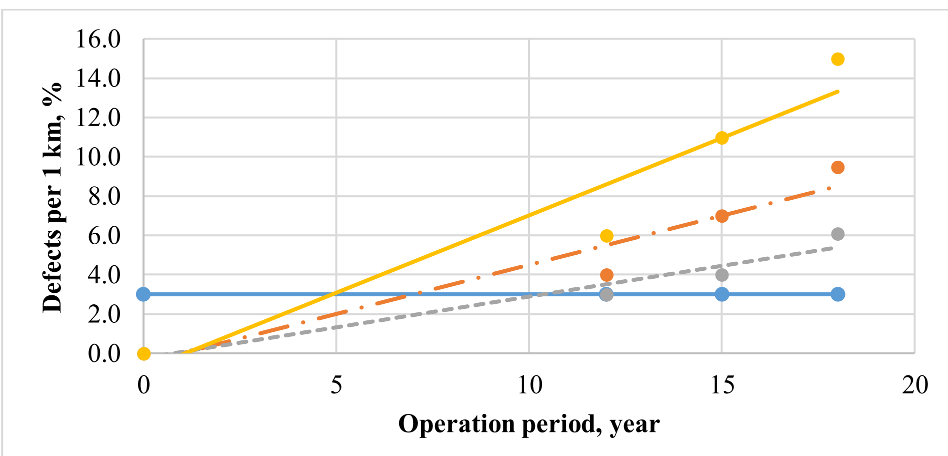

Fig. 2. Dependence of the number of defects on the period of operation:
- №1; - 2; - 3; - №4;
- linear (№ 2); - - linear (№ 3); - linear (№ 4)

4 Recommendations

In order to prevent defects resulting from violation of the rules for loading, transporting and unloading sleepers, it is necessary to comply with the requirements for the correct loading, transportation and unloading of sleepers. If the end of the sleeper breaks more than 300 mm, it must be replaced.

To prevent and eliminate the appearance of transverse cracks in the under-rail part of the sleeper, it is recommended to timely straighten the track at the joints with the tamping of the sleepers; polishing the rail at the place of the step. In the case of a transverse crack in the under-rail part of the sleeper, a break in the sleeper in the under-rail zone, a longitudinal crack passing through the places where fixed embedded parts are installed, the sleeper is replaced in a planned manner.

5 Conclusions

1. Based on the results of the research, a classification of the main defects of BF 70 sleepers was compiled, hypothetical causes of defects were put forward, a graphical interpretation was made, and equations were obtained for the dependence of the number of defects on the missed tonnage and the period of operation of the sleepers.

2. As a result of the experimental work performed, the evidence of the dependence of the condition of reinforced concrete sleepers of the BF70 type on the missed tonnage was confirmed: sleepers with an operating time close to overhaul have the maximum number of defects. The number of defective sleepers is proportional to the increase in the missed tonnage.

3. The most vulnerable places of the sleepers are their under-rail zone and the places where fixed embedded parts are mounted. The resulting defects in the sleepers will lead to destabilization of the gauge and a threat to the safety of train traffic.

4. In order to extend the service life of BF70 sleepers, it is necessary to develop technologies for repairing reinforced concrete sleepers with various types of defects.

5. Defects of type BF70 sleepers and their causes differ from the defects listed in the classification of defects of reinforced concrete sleepers.

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