Features of the Operation of the Railway Roadbed of the Russian Federation

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Abstract: The railway roadbed is a permanent structure that has been in operation for many years. During this time, under the influence of natural, man-made and operational factors, defects and deformations occur in the roadbed - diseases of the roadbed, which can lead to a decrease in the safety and continuity of train traffic. The article deals with the main defects of the roadbed, the most common on the railway network of the Russian Federation, the analysis of the causes of these deformations. For the Sverdlovsk Railway, data on the condition of the roadbed and drainage structures along the road as a whole and service regions are given, the most obvious causes of the main deformations in each of the regions are noted. It is noted that the presence of defects leads to a decrease in the speed of trains and an increase in operating costs. The data on the measures that are being taken on the road to improve the condition of the roadbed and recommendations for anti-deformation measures are given.

1 INTRODUCTION

The basis for the organization of safe and uninterrupted railway freight and passenger transportation is high-quality maintenance of the railway track and, above all, its base and foundation – the roadbed.

The railway roadbed is a permanent earthwork that has been in operation for tens or even hundreds of years. According to Russian Railways JSC, 56% of the total length of the roadbed has been in operation for over a hundred years (Fig. 1).

There is no doubt that defects and deformations occur at such long-term operated facilities. The statistical data of Russian Railways JSC indicate that about 10% of the roadbed has defects and deformations (Fig. 2, 3), while the dynamics of changes in the length of the "sick" roadbed is negative.

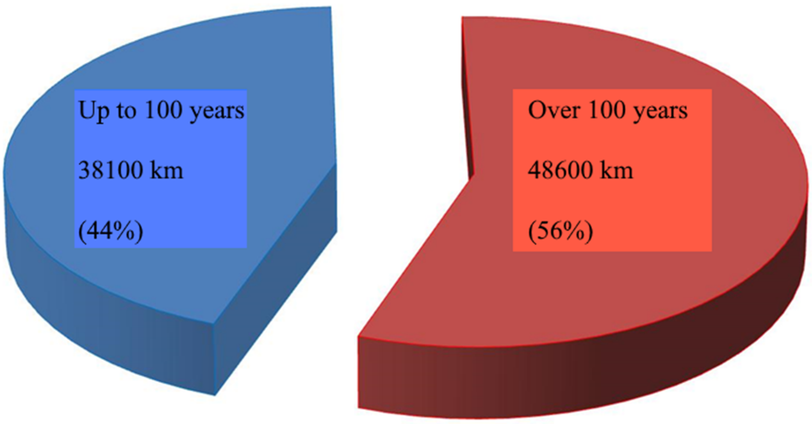

Figure 1: The age structure of the roadbed operated by Russian Railways JSC.

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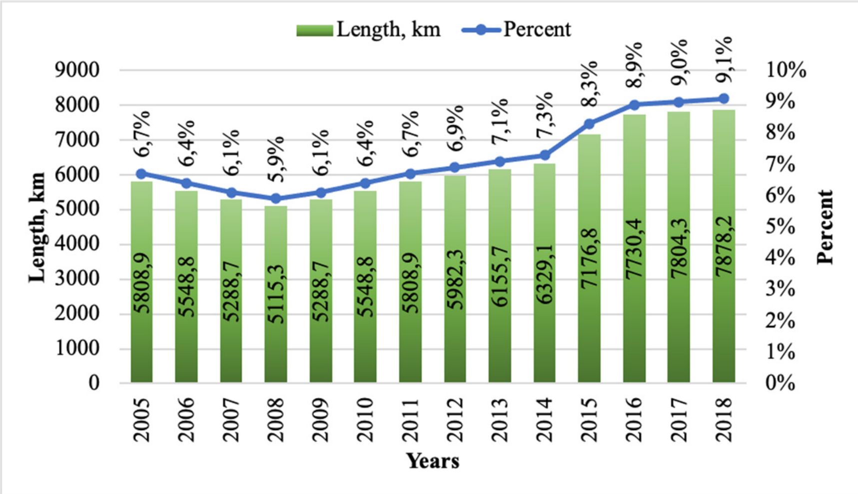


Figure 2: Changing the length of the defective and deformable roadbed on the railway network of the Russian Federation for 2005-2018.

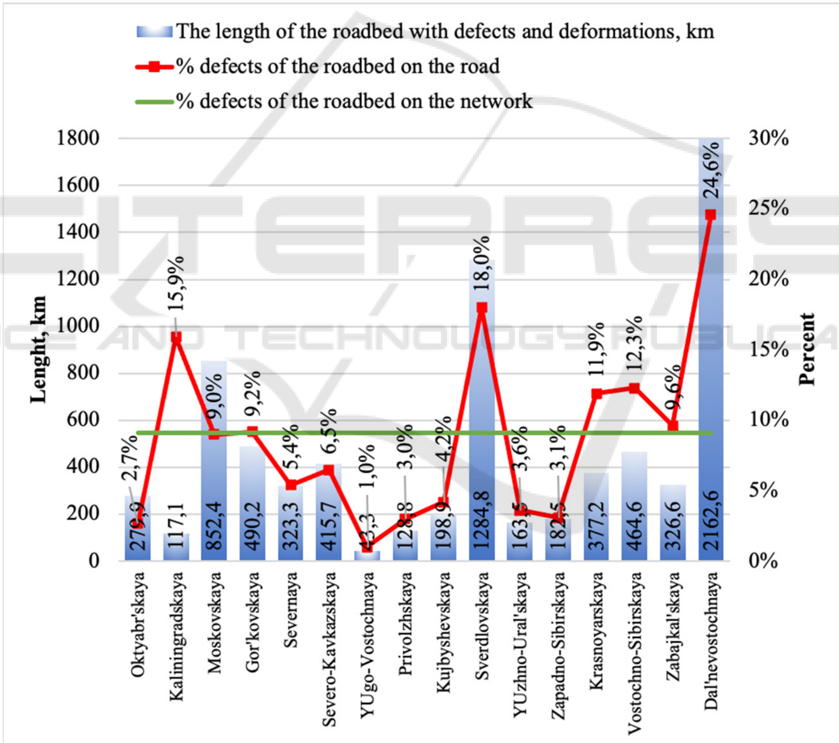


Figure 3: Defectiveness of the roadbed on the railway network of the Russian Federation as of 01.01.2019.

2 MATERIALS AND METHODS

What caused the current situation? This is not necessarily a long service life. The negative factors include the difficult natural and climatic conditions on the territory of the Russian Federation:

- about 60% of the territory are areas with insular or continuous permafrost, the behavior of which is sometimes unpredictable;
- wetlands, landslide and karst-prone areas, slide, avalanche and mudslide-prone areas in mountainous areas;

- significant inter-seasonal, intra-seasonal and daily temperature differences characteristic of the continental climate of most territories of the Russian Federation;
- according to ground conditions, 87% of the roadbed is filled out of cohesive soils with low drainage properties, prone to frost heaving, as well as plastic deformations and shifts.

In addition, the roadbed, designed and built according to the old design standards, does not meet the new requirements and loads. Currently, heavy trains, weighing up to 9,000 tons, and more than 1,500 m long, run along the railway lines. Despite the fact that in such trains the axial loads do not exceed the average value of 20-23 tf/axis, the duration of the impact of such loads on the roadbed increases significantly, and it does not "have time to rest", process and compensate for fatigue stresses arising in it. It should be emphasized that an increase in axial loads will lead to a significant increase in the deformability of the roadbed and an increase in the cost of its treatment. Thus, experimental studies conducted by VNIIZHT in 2018 (Russian Railways JSC, 2019) on the passage of trains with an axial load of 27 tf/axis on the Kachkanar-Smychka section of the Sverdlovsk Railway with a length of 103 km showed an increase in the cost of operating the track by 5.8 million rubles per year (in 2017 prices, excluding VAT), of which 83 thousand rubles – on the roadbed. At the same time, 19.5 million rubles is the cost of preparing the infrastructure before the start of experimental studies.

It should be noted that the causes of deformations of the roadbed may also be ignorance or non-compliance with the technology of work on the filling of the earth, insufficient quantity or lack of necessary construction equipment, especially for compaction of soils.

Unfortunately, we have to talk about insufficient funding for the treatment of diseased areas of the roadbed. It is clear that such work is very material and labor-intensive, lengthy and requires significant financial injections, but you can't do without them, as they say, "a miser pays twice". The roadbed is like a living organism in which the disease can slumber and not manifest itself in any way for many years, but a small push is enough, the consequences of which can be catastrophic.

From the analysis of the condition of the roadbed on the railways of the Russian Federation (Fig. 3), it follows that the Sverdlovsk Railway, unfortunately, is not at the forefront, the defectiveness of the roadbed here is almost twice the average network.

The Sverdlovsk Railway is a powerful transport complex with great technical and intellectual potential. The highway connects the European and Asian parts of Russia, stretches from west to east for fifteen hundred kilometers. The eastern section of the road is located in the swampy West Siberian Lowland, and the western section is located in the mountainous regions of the Perm Territory. In the north direction, the road crosses the Arctic Circle and enters the zone of permafrost soils. This geographical location largely explains the problems of the roadbed existing on the road (Tables 1, 2), (Fig. 4, 5).

The most common deformations of the roadbed on the Sverdlovsk railway are ballast tanks, excessive steepness of slopes, water-bearing pockets (Sverdlovsk Railway, https://svzd.rzd.ru). The occurrence and development of these deformations are caused by several factors.

Firstly, the Sverdlovsk Railway is a landfill of heavy traffic (Skutina, 2020). Hydrocarbon trains

Table 1: Summary table of indicators of the roadbed of the Sverdlovsk railway.

No.	Indicator	UoM	Total	Incl. defective	% defective
1	Embankments, total:	km	4861,411	732,425	15,07
	including height				
	from 6 m (excl.) to 12 m (excl.)	km	159,548	83,4	52,27
	from 12 m (incl.) and more	km	95,31	20,3	21,30
2	Ditch cuts, total:	km	557,701	142,129	25,48
	including depth				
	from 6 m (incl.) to 10 m (excl.)	km	66,032	12,192	18,46
	from 10 m (incl.) and more	km	33,917	7,894	23,27

Table 2: Defects and deformations of the roadbed on the Sverdlovsk railway.

No.	Defects and deformations	Length by service regions, km					Total by Infrastructure Directorate	
		SR 1 (Perm)	SR 2 (Sverdlovsk)	SR 3 (Tyumen)	SR 4 (Nizhny Tagil)	SR 5 (Surgut)	Length, km	Number of sections, pcs.
1	Violation of the outline of the roadbed:							
	– excessive steepness of slopes	167,786	79,169	44,869	5,971	18,908	316,703	3730
	– narrowed width of the subgrade	13,261	6,053	1,120	21,671	4,594	46,7	640
2	Wash-outs	2,297	1,201	0,100	0,042	0,313	3,953	33
3	Sagging	23,378	5,188	0,960	6,872	14,880	51,278	165
4	Water washes	3,650	1,000	-	-	-	4,650	11
5	Rock-fall sections	3,891	5,301	-	-	-	9,192	25
6	Karst	24,920	1,429	-	-	-	26,349	26
7	The length of the track with ballast tanks	265,248	134,605	185,929	191,508	-	777,29	7949
8	The length of the soft spots, total	42,137	24,350	0,000	12,799	-	79,786	443
9	The length of the roadbed with defects and deformations of all kinds	546,568	258,296	232,978	238,863	38,695	1315,901	13022
10	The length of the railway line located on the territory of permafrost distribution, total						14,547	
	– including deformable areas (PU-9)						13,947	
11	The length of the railway line passing through the karst territory						557,475	

move in the North-South meridional direction, coal routes move in the East-West direction. The roadbed is not prepared for increased loads, ballast depressions are formed on the subgrade, in which waterlogging of the soil of the roadbed is possible, and in winter their uneven heaving. The irregularities of the subgrade lead to drawdowns and distortions of the path, which are eliminated by adding ballast. As a result, the ballast bed does not fit on the subgrade, it begins to slide along the slopes, which leads to the formation of ballast plumes, the excessive steepness of the slopes and the narrowed width of the subgrade. In this regard, the Perm and Sverdlovsk service regions are particularly distinguished, through which heavy coal trains move.

Secondly, the roadbed of the Surgut and Tyumen service regions is located on weak, waterlogged, and often swampy grounds. This is associated with hollow spots and bulging of the soil of the base of the roadbed, in some cases, the spreading of embankments and, ultimately, the sediment of the subgrade and lowering the level of the rail head. The alignment of the path is carried out due to the same ballast filling, which leads to the formation of ballast plumes and slope steepening.

Thirdly, the condition of the roadbed is significantly influenced by the presence and condition of drainage structures: slope drains, upland and longitudinal drainage ditches, etc. (Table 3). It should be noted that drainage structures of the roadbed are an integral part of the entire structure as a whole. Their unsatisfactory content leads to the appearance of ballast tanks, heaving of soils, slope splits, sedimentation of the base, wash-out of fills, erosion of slopes. There is an undoubted connection between the presence of ballast depressions on the subgrade and the condition of the ditches (SR-1, SR-2), violations of the outlines of the roadbed and the condition of drainage ditches (SR-3). The main reasons for the faulty condition of drainage devices on the Sverdlovsk railway are: siltation of drainage channels (20%-50%), destruction of upland ditches

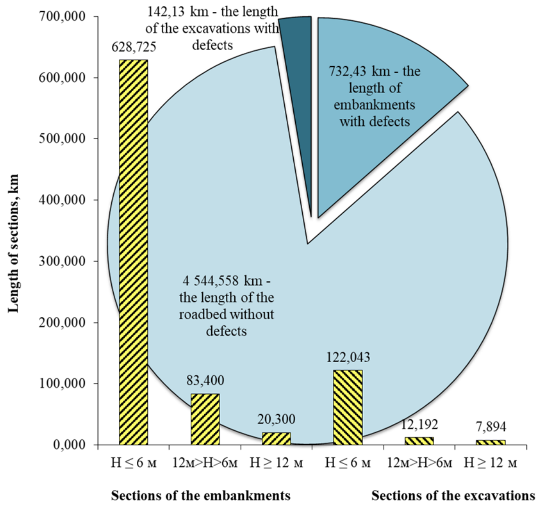


Figure 4: Summary indicators of the condition of the roadbed of the Sverdlovsk railway (as of 1.01.2020)

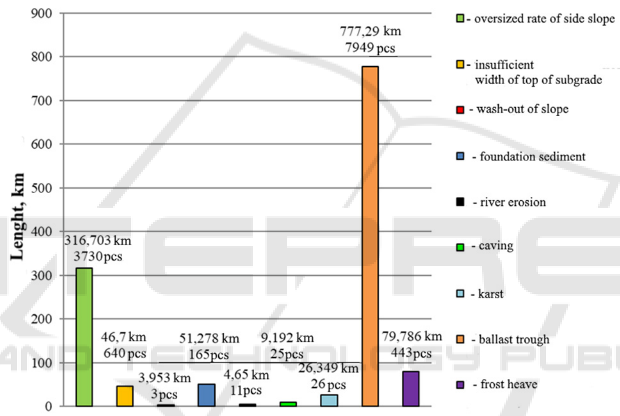
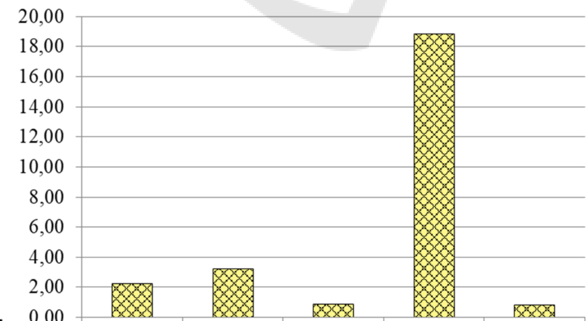


Figure 5: Defects and deformations of the roadbed of the Sverdlovsk railway (as of 1.01.2020)



Limit speed, km/h	< 30	40	50	60	70
Lenght, km	2,23	3,21	0,9	18,8	0,8

Figure 6: The length of sections with limited train speed according to the condition of the roadbed

and trays, overgrowth of drainage ditches with vegetation and clogging with old-year ballast after capital works. The total length of the sections of the roadbed with defects is 916.957 km. At the same time, the length of drainage structures requiring major repairs and restoration is 1,155.230 km. Comparing these data, it can be assumed that further development of defects and deformations is possible.

The presence of defects and deformations of the roadbed entails the issuance of warnings about the speed limit, which leads to a decrease in the capacity of the lines and large interruptions in the train schedule (Fig. 6). The total length of sections with a permanent speed limit on 01.01.2020 is 25.98 km. These speed limits are eliminated, as a rule, according to individual projects as part of the overhaul of the roadbed. The projected date of cancellation of these restrictions is 2025. At the same time, it should be noted that the initial issuance of warnings in some areas is dated more than 40 years ago.

3 RESULTS AND DISCUSSION

It should be noted that the Sverdlovsk Railway is taking the necessary measures to treat and restore the roadbed (Table 4)

At the same time, modern geosynthetic materials and advanced technologies for the treatment of the roadbed are not widely used on the road. The exception is the use of geotextile as a separation layer during major repairs of the track and the installation of thermal insulation coatings made of expanded polystyrene. However, as of 01.01.2020, there were only 19 objects of the roadbed reinforced with reinforced ground and mesh structures with a total length of 4000 m and a volume of 30,000 m^3. Within the Perm and Sverdlovsk service regions, for reasons of dislocations, landslides and collapses of a weathered rock slope, trapping and revetment walls with a total length of 10 km are arranged. As of 01.01.2020, more than 74% of the trapping walls and more than 90% of the revetment walls require major repairs.

The problem of eliminating ballast depressions on the subgrade is acute not only on the Sverdlovsk railway. According to Russian Railways JSC, more than 10% of the deformable roadbed on the railway network are ballast depressions. It is necessary to radically solve the issue of strengthening the subgrade, since laying a reinforcing and separating layer of geotextile is not enough. In this case, it may be proposed to use a volumetric geogrid with filling its cells with a sand-gravel-crushed stone mixture;

Table 4: The main engineering structures for the stabilization of the roadbed on the Sverdlovsk railway.

Ser. No.	Length of sections		Service region					Total on Sverdlovsk Railway
			SR 1	SR 2	SR 3	SR 4	SR 5	
1	Slots and drains, km	total	74,072	35,865	12,938	4,890	-	127,765
		require major repairs	7,597	6,188	3,585	1,009	-	18,379
2	Thermal insulation pillows, l.m.	total	30302	42832	61101	38727	27470	200432
		require major repairs	-	788	-	-	-	788
3	Trapping walls, l.m.	total	3149	-	-	-	-	3149
		require major repairs	2319	-	-	-	-	2319
4	Revetment walls, sq. m	total	59843	19140	-	-	-	78983
		require major repairs	53535	9900	-	-	-	63435
5	Sea walls l.m.	total	309	2500	-	-	25960	28769
		require major repairs	-	1100	-	-	-	1100
6	Counter dams and bulk berms, l.m.	total	21344	108218	27852	20195	363212	540821
		require major repairs	-	310	-	-	-	310
7	Dam dikes, breakwaters, l.m.	total	-	-	3550	-	13601	17151
		require major repairs	-	-	-	-	-	-

laying a geogrid and vibrators; cutting the soil of the subgrade with replacing it with a draining soil of the protective layer; soil reclamation; the use of polyphilizers; arrangement of a sub-ballast layer of asphalt concrete mixture. The use of hot-mix asphalt to strengthen the subgrade allows you to provide the required efficiency of subgrade soil, create a waterproof layer between the ballast and the roadbed, prevent the penetration of moisture and weeds into the roadbed and improve the geometric characteristics of the track. In general, the use of an asphalt layer makes it possible to increase the intervals between the next repair work by 10-20 times.

The length of embankments with an overestimated slope steepness is about 20% of deformable areas. Reinforcement the slopes of such embankments is possible not only with traditional counter dams. Retaining reinforced ground or gabion walls should be widely used in sections of culverts, which will avoid technologically complex and time-consuming work on lengthening the pipe. In areas of weak foundations (Surgut and Tyumen service regions), the filling of counter dams can lead to an increase in the sediment of the base and additional deformation of the roadbed, and in areas of permafrost – to the melting of the foundation soils and the formation of thermokarsts. In such cases, to ensure the stability of slopes with ballast loops, it is advisable to use drill-injection piles, tightening elements, ground anchors or dowel structures.

Embankment pitching, as well as reinforcement of the slopes and the bottom of drainage structures in order to protect them from erosion is possible with concrete-filled mats, concrete canvas, a volumetric geogrid with filling its cells with plant soil, crushed stone, etc. Such means of reinforcement are technological in installation, economical, have a long service life. On rock-fall sites, the revetted wire meshes made of double-braided galvanized wire have proven themselves well. They prevent scree and rock falls from the slopes. Retaining anti-collapse walls are recommended to be made of gabion structures.

The problem of insufficient width of the subgrade (26% of the deformable roadbed) can be solved by using support elements equipped with a geogrid in combination with geotextile, or gabions (Skutina, 2014; Skutina, 2012).

Strengthening of weak bases – vertical drainage of composite geomaterials, the use of polyphilizers, thermal ignition, electrochemical fixing of soils, and on permafrost soils – the use of thermosiphons.

4 CONCLUSIONS

The analysis of the data and recommendations provided allowed us to draw the following conclusions:

- defects and deformations of the roadbed develop in those areas that are designed according to standards that do not meet modern requirements;
- the condition of the roadbed is significantly affected by the quality of work on its construction and maintenance;
- the appearance and development of deformations of the roadbed depends on the terms of its operation, a combination of natural, man-made and operational conditions;
- common deformations of the roadbed on the railway network of the Russian Federation are precipitation, ballast tanks, excessive steepness of slopes, narrowed width of the subgrade;
- unsatisfactory condition of drainage structures has a significant impact on the appearance and development of deformations of the roadbed;
- in order to detect defects and deformations in a timely manner, it is necessary to widely implement the monitoring system of the roadbed (Ashpiz, 2002), comply with the technological regulations for diagnostics and routine observations of the roadbed, use geophysical diagnostic methods, track measuring cars, cars of engineering-geological survey of the condition of soils and railway tracks, etc.;
- when developing measures for the treatment of the roadbed, use advanced methods for calculating and designing its parameters (Skutin, 2014);
- when eliminating defects and deformations of the roadbed, use modern geosynthetic materials and structures (Skutin, 2012; Skutin, 2016; Skutina, 2015).

REFERENCES

The program for the development of heavy traffic on the railway network of Russian Railways JSC. Russian Railways JSC. 2019. http://www.rzd-expo.ru/images/Events-2019/27ts/01.pdf.

The official website of the Sverdlovsk Railway. https://svzd.rzd.ru/ru/4749.

Skutina, O. L., 2020. Peculiarities of operation of the railway track on sections of heavy train traffic. *Modern* *technologies. System analysis. Modeling.* 4 (68). pp. 76-85.

Skutina, O. L., 2014. Design of the roadbed of the railway track. Z.R. Abdulkhasanova, O.L. Skutina // Patent of Russia No. 2557276, 2014.

Skutina, O. L., 2012. Method for the reconstruction of the railway track (options). Karavaeva O.V., Kravchenko Y.M., Skutina O.L. // Patent of Russia No. 2501910, 2012.

Ashpiz, E. S., 2002. Monitoring of the roadbed during the operation of railways. p. 112.

Skutin, A. I., Skutin, D. A., Tabynshchikov, A. I., 2014. Modeling of a roadbed reinforced with geosynthetic materials. *Designing the development of a regional railway network: Collection of scientific papers.* 2. pp. 144-150.

Skutin, A. I., Skutin, D. A., Tabynshchikov, A. I., 2012. Increasing the stability of weak soils. *RSP Expert.* 8. pp. 24-25.

Skutin, A. I., Skutin, D. A., Skutina, O. L, Tabynshchikov, A. I., 2016. Improving the stability of the roadbed using reinforcement with geosynthetic materials. *Designing the development of a regional railway network: coll. of scientific papers.* 4. pp. 351-354.

Skutina, O. L., 2015. A method of strengthening the earthwork of a railway track on a weak foundation Khabibullina E.S., Skutina O.L. // Patent Russia No. 2593282, 2015.