Roadbed for Ballastless Track

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Abstract: The comparative tests of four types of ballastless constructions completed on the JSC VNIIZHT Test Loop, located near Scherbinka railway station. The tests had been carried out from 2014 to 2018. The tonnage amounted to 1.1 mio. tons gross. Tonnage volumes accomplishing had been reached with a test train composed of 85 cars having 230.3 kN axle load. The speed reached 80 km/h.

Index Terms: Axle load, Ballastless track, Roadbed, Service life, Speed, Tonnage.

I. INTRODUCTION

The comparative tests of four types of ballastless constructions completed on the JSC VNIIZHT Test Loop, located near Scherbinka railway station. The tests had been carried out from 2014 to 2018. The tonnage amounted to 1.1 mio. tons gross. Tonnage volumes accomplishing had been reached with a test train composed of 85 cars having 230.3 kN axle load. The speed reached 80 km/h [1]-[5].

A test track section was located on a straight track. Each ballastless construction was 75 m long, plus two transitional sections.

LVT ballastless track (Low Vibration Track) produced by JSC "RZDstroy" (Russia) features prefabricated separable concrete blocks cased in rubber. They are embedded into the track concrete.

FFB ballastless track (Feste FahrbahnBoegl) produced by MaxBögl (Germany) is prefabricated prestressed concrete plates, which are put on the track and tied up to each other.

NBT ballastless track (New Ballastless Track) by Alstom company (France) represents the plates that are manufactured on a track construction site and have mounted-in joints of rail fastenings.

EBS ballastless track (Embedded Block System) by Tines (Poland) represent prefabricated non-separable concrete plates having a damping layer. The plates are embedded into the track concrete.

Roadbed for all four constructions was built using the same technology with the use of a layer of chemically stabilized soil.

From the viewpoint of vertical settlement of track, the construction of roadbed and technology of its building are of the ultimate interest, as particularly vertical settlement is a major risk during operation [6]-[9].

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II. PROPOSED METHODOLOGY

A. Roadbed Construction Technology

Before laying of test ballastless track construction much attention was paid to the roadbed construction, which had identical structure for all four test constructions(LVT, MaxBögl, Alstom, Tines) and was executed by one contractor [10], [11].

A design of a stabilized layer is standardized by the Instruction on stabilization of railway track by stabilizing chemical additives.

The soil mixture is stabilized by adding of liquid and powder additives. A concentrate "Konsolid 44" is blended with water; "Solidray" concentrate is a mixture of surface acting agents, concrete, lime, cinder slag and other components – they are added to the soil as a ready-made powder mixture.

The roadbeds for the four ballastless constructions (LVT, MaxBögl, Alstom and Tines) that were laid in the 2nd track of the Test Loop consist of layer chemically stabilized by active polymeric materials, and a layer composed of a mixture of subgrade, gravel and sand (SGS). Thickness of the layers is 0.5 and 0.7 m respectively. Their width is 7 m; surface slope in square section is 0.04. Fig. 1 demonstrates the transverse profile.

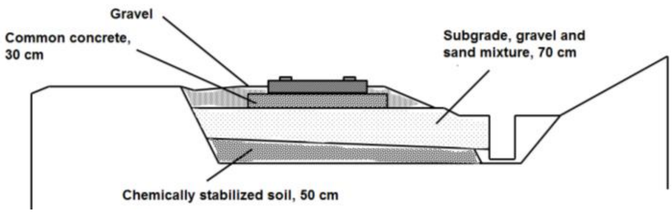

Fig. 1. Transverse profile

After chemical stabilization of the soil it was tested in a laboratory for evaluation of uniaxial compression strength R_{COM} in dry condition and after capillary water saturation. Average values of physical and mechanical characteristics of stabilized soil are presented in Table I.

Table I. Average values of physical and mechanical characteristics of stabilized soil

R_{COM} of dry samples, MPa	Water saturation, % of the mass of dry soil	R_{COM} of water saturated samples, MPa	Water resistance coefficient, K, unit fraction
2.08	1.47	1.32	0.63

During static tests a device for evaluation of soil bearing capacity InfraTest was

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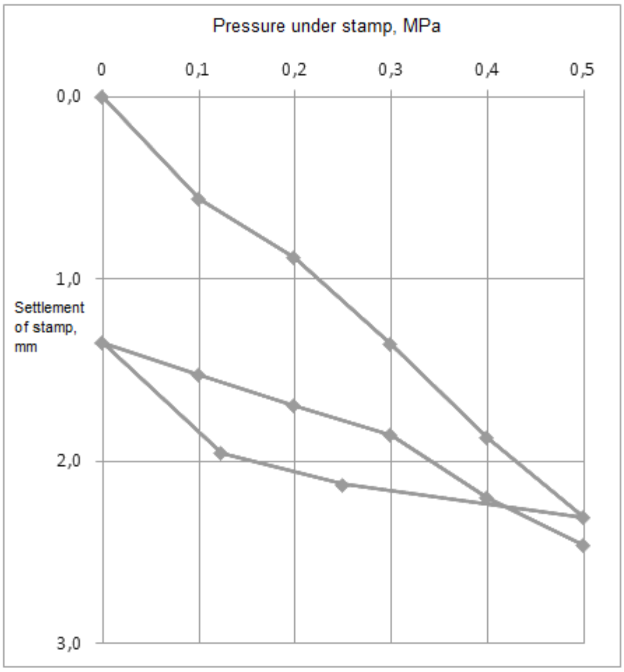
applied (according to DIN 18134-2001). Diameter of a stamp was 300 mm. Pressure under stamp was gradually increasing with a step of 0.1 MPa up to O.5 MPa. Fig. 2 shows the graph of stamp settlement depending on the pressure.



Deformation modulus as to DIN 18134-2001, MPa					
First loading branch			Second loading branch		
a_0	a_1	a_2	a_0	a_1	a_2
0,184	3,333	1,929	1,422	0,817	2,571
Ev_1			Ev_2		
52,4			**107,0**		
Ev_2/Ev_1 = 2,0					

Fig. 2. Graph of stamp settlement depending on the pressure, soil stabilized by active polymeric materials

Average value of deformation modulus on the second load branch with regard to the additional portion of active polymeric materials in the soil amount to $\bar{E}v_2$ = 146 MPa. Design values of deformation modulus $E^n_{v_2}$ of stabilized soil shall be no less than 80 MPa.

During tests of deformation modulus TERRATEST 3000 and INSPECTOR 2 were used. 23 readings of TERRATEST 3000 showed average value of deformation modulus $\bar{E}^T_{v_d}$ = 147 MPa (range of variation $E^T_{v_d}$ makes 118...221 MPa). Specified average value fixed by INSPECTOR 2 device providing the above-mentioned quantity of definitions makes $\bar{E}^I_{v_d}$ = 178 MPa (range of variation $E^I_{v_d}$ makes 99...289 MPa). The data is presented in Table II.

Table II. Deformation modulus of chemically stabilized soil

Location, km, 100+	Values a_0, a_1, a_2 and deformation modulus, MPa								$\frac{E_{v_2}}{E_{v_1}}$
	first loading branch				second loading branch				
	a_0	a_1	a_2	E_{v_1}	a_0	a_1	a_2	E_{v_2}	
2, 8+50	0,018	2,237	1,571	74,4	0,358	2,761	-0,786	95,0	1,3
2, 9+98	0,144	3,44	2,00	50,7	1,39	1,52	1,21	105,7	2,1
3, 0+84	0,938	-2,37	19,71	30,0	3,32	2,90	5,21	40,8*	1,4
3, 1+14	0,184	3,333	1,929	52,4	1,422	0,817	2,571	107,0	2,0
3, 1+21	-0,210	5,710	-1,500	45,4	0,980	3,064	0,643	66,5*	1,5
3, 1+25	0,192	4,763	2,429	37,6	2,160	0,670	3,500	93,0	2,5
3, 1+26	0,032	2,347	0,071	94,4	0,494	1,573	-0,071	146,4	1,6
3, 2+8	-0,086	1,190	0,500	156,3	0,164	0,879	-0,214	291,7	1,9
3, 2+23	0,094	3,11	-1,14	88,8	1,192	1,00	0,21	203,0	2,3
3, 2+81	0,152	4,974	-0,857	49,5	1,594	1,524	0,643	121,9	2,5

Note: * The soil was additionally treated by active polymeric materials on the section 40 m long.

Consequently, the derived data of static and dynamic tests of deformation modulus (resilience) of the soil stabilized by the active polymeric materials are favorably in line with each other.

After completion of laying of stabilized soil, layer-by-layer heaping and tamping of a layer of the subgrade, gravel and sand

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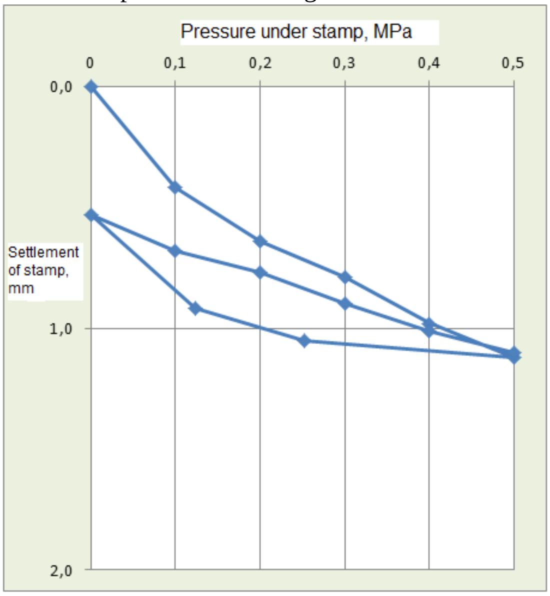
mixture was executed.

Results of static tests of this layer with the use of InfraTest device are presented in Table III. Average value of deformation modulus on the second loading branch makes $\bar{E}_{V_2}$= 181,7 MPa.

Table III. Deformation of subgrade, gravel and sand mixture

Location, km, 100+	Value a_0, a_1, a_2 and deformation modulus, MPa								$\frac{E_{v_2}}{E_{v_1}}$
	first loading branch				second loading branch				
	a_0	a_1	a_2	E_{v_1}	a_0	a_1	a_2	E_{v_2}	
2, 8+82	0,162	2,953	-1,071	93,1	0,750	1,603	-0,571	170,8	1,84
2, 9+25	0,022	6,157	-3,429	50,6	1,600	1,427	0,071	153,8	3,04
2, 9+83	0,138	2,427	-0,929	114,6	0,624	0,599	0,786	226,9	1,98
3, 0+5	0,386	4,196	-2,643	78,3	1,270	1,180	0,000	190,7	2,44
3, 0+15	0,614	0,130	3,500	119,7	0,978	-0,643	3,571	196,9	1,64
3, 1+48	0,210	4,571	-2,286	65,6	1,434	1,271	-0,286	199,4	3,04
3, 1+58	0,208	2,254	-0,857	123,2	0,558	1,166	-0,143	205,6	1,67
3, 2+73	0,180	5,474	-2,857	55,6	1,596	1,301	0,214	159,7	2,87

According to the project settings, the deformation modulus of subgrade, gravel and send mixture in ballastless constructions should make no less than 120 MPa. ActualvaluesarepresentedontheFig.3.



Deformation modulus as to DIN 18134-2001, MPa					
First loading branch			Second loading branch		
a_0	a_1	a_2	a_0	a_1	a_2
0,208	2,254	-0,857	0,558	1,166	-0,143
Ev_1			Ev_2		
123,2			**205,6**		

Fig. 3. Dependency graphs of stamp settlement in relation to pressure on subgrade, gravel and send mixture

Analysis of international experience concerning the normative documentation is presented in Table IV.

Table IV. Norms of compaction of soils of the roadbed for high-speed traffic on the ballastless construction

Standard title	Values				
	Compaction ratio	Compaction ratio as to Proctor	E_{V2} MPa	E_{V2}/E_{V1} MPa	E_{Vd} MPa
Top protective layer					
UIC 719R (UIC) [319]	-	1.00-1,03	>120	<2,2	-
Ril836.0501 (Germany) [320]	-	1,00	120	-	50
TB 10621- 2009/J 971- 2009 (China) [321]	> 0.97		>120	<2,3	-
Bottom protective layer					
UIC 719R (UIC)	-	>1,00	>80	<2,2	-
Ril836.0501 (Germany)	-	1,00	60	-	35
TB 10621- 2009/J 971- 2009 (China)	> 0,95		>80	<2,5	>40
Back of ballastbed					
UIC 719R (UIC)	-	>0,95	>45 * / >60	<2,2	-
Ril836.0501 (Germany)		0,97-1,00 (**)	-	-	-
TB 10621- 2009/J 971- 2009 (China)	>0,92		>45	<2,6	-

* Numerator – powder soils, clay; denominator - sands, gravel;

**value fluctuates depending on the soils used (value 1.00 is admitted for draining soils)

III. RESULTS AND DISCUSSION

A. Subsiding Rate of The Roadbed

According to the test procedure for ballastless track constructions on the Test Loop, primary measurements of the rail level (RL), as well as its measurements after each 100 mio. tons gross were taken (see Fig. 4).

Not only the value of subsiding itself, but also its unevenness – when the sections of the plate subside on different depth – are of vital importance.

Dependencies of the subsidings of ballastless constructions on Fig. 5 are approximated by the functions from the Table 4.

Graphs on Fig. 6 show, that subsiding of all ballastless constructions is substantially fewer than subsiding of the track laying on the ballast. In cases of Alstom and MaxBögl constructions, their values exceed the permitted subsiding values for 15 mm.

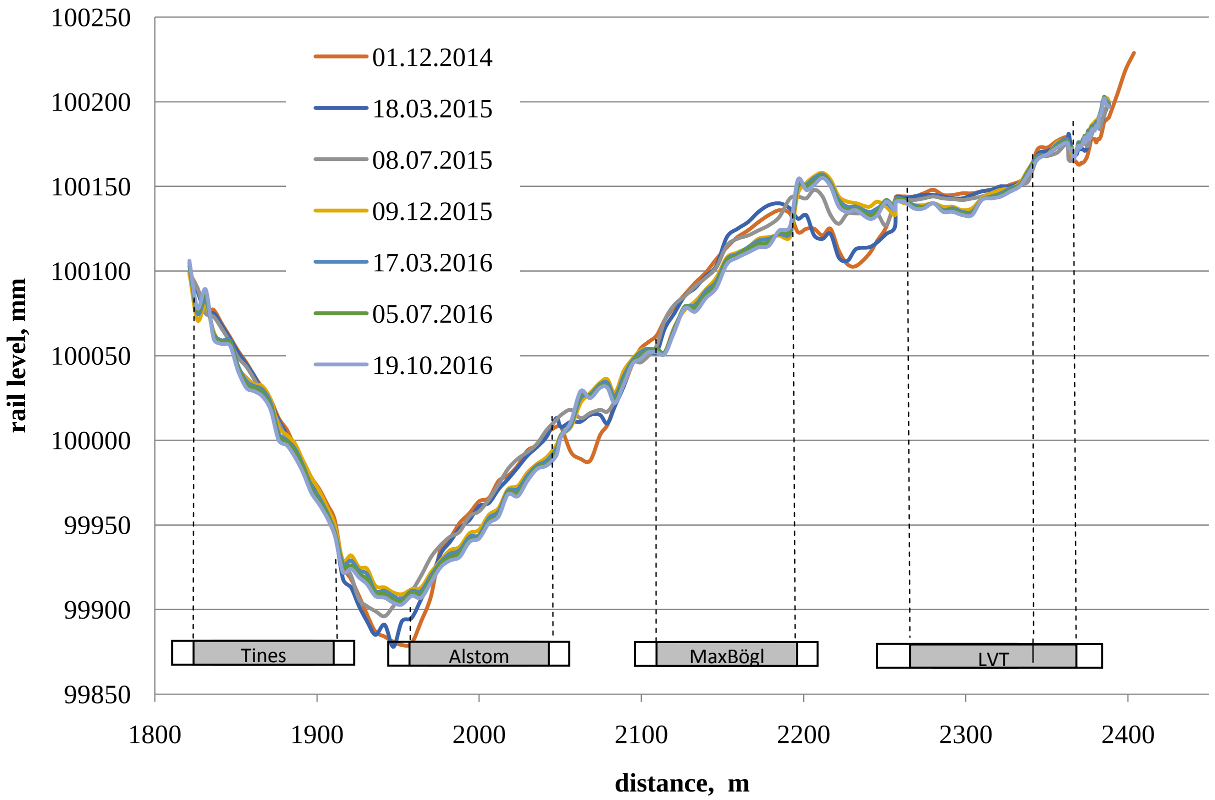


Fig. 4. Rail level

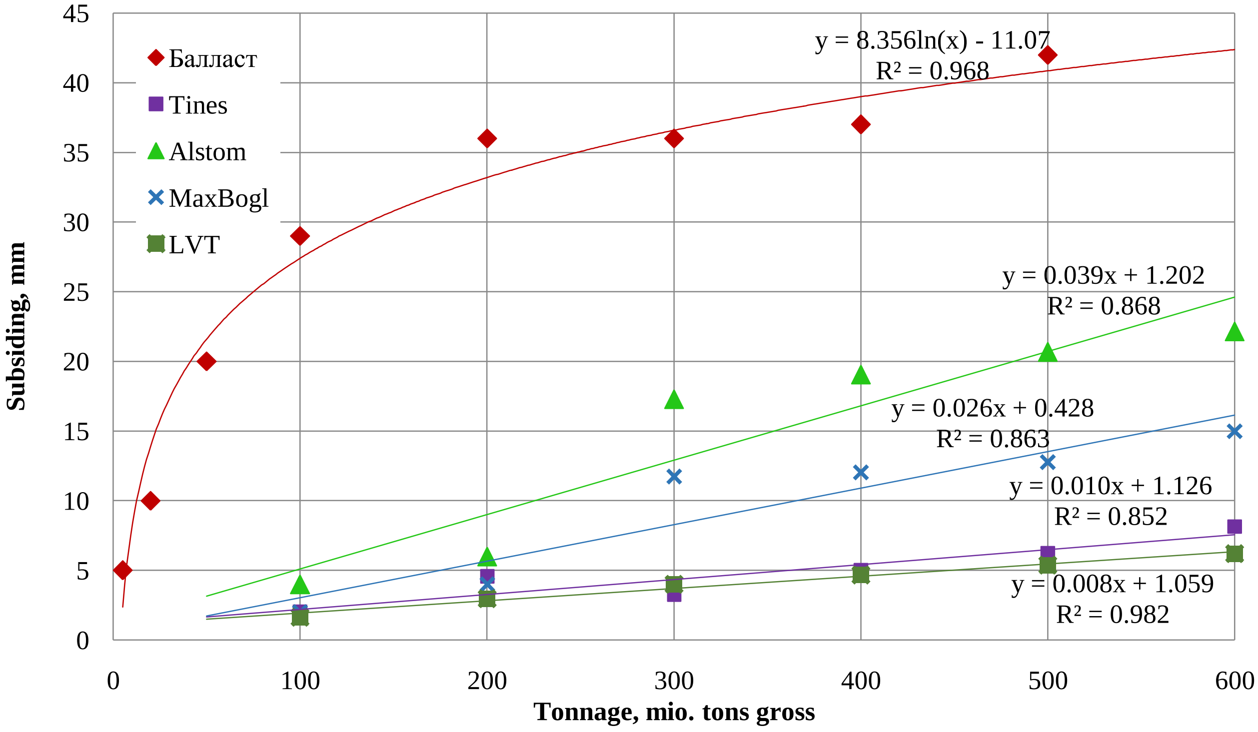


Fig. 5. Dependence of subsiding from the tonnage

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Table IV. Approximating functions of subsidings of the tonnage

Construction name	Tonnage, mio. tones gross	Approximating function	Certainty of approximation R^2
Track on ballast	750	y = 8,3563ln(x) - 11,074	R^2 = 0,9686
Tines	750	y = 0,0107x + 1,1263	R^2 = 0,8528
Alstom	750	y = 0,039x + 1,202	R^2 = 0,8682
MaxBögl	750	y = 0,0262x + 0,4283	R^2 = 0,8638
LVT	750	y = 0,0088x + 1,0593	R^2 = 0,9828

Subsiding of all ballastless constructions is uneven enough. The difference between the initial rail level and after tonnage 600 mio. tons gross revealed prominent vertical unevennesses generated by the subsiding. Their length makes from 10 to 25 m. Slopes generated by the subsiding are about 0 to 2,1 ‰. In line with "Special Technical Regulations for Roadbed of Moscow-Kazan section of the High-Speed Line Moscow-Kazan-Yekaterinburg", the value of residual deformation of the roadbed shall be equal in the longitudinal direction: a slope generated by the subsiding shall not exceed 0.25‰. Therefore, slopes of unevennesses generated by the subsiding significantly exceed the permitted values; herewith, the track construction is still functionally operative. The occasion of such unevenness slopes is the inequality of deformation modulus of chemically stabilized soil and the SGS layer along the length of the test section. Along 500 m the deformation modulus values of the chemically stabilized soil fluctuate from 93.0 to 291.7 MPa. As for the SGS layer, the deformation modulus values are from 153.8 to 226.9 MPa.

IV. CONCLUSION

On the ground of the conducted research technical requirements to the roadbed of the ballastless track can be defined.

Depth of the roadbed that required special preparation makes 1.5–2 m. Herewith it is efficient to carry out geological survey every 50 m for the depth of 3 m. Bearing strata comprise the following combination: concrete or asphalt-concrete bearing stratum, hydraulically bound layer, frost blanket, layer of natural stabilized soil.

A core requirement to the roadbed is a gradual increase of deformation modulus from the bottom layers to the top $E_1>E_2>E_3$.

On the top of the roadbed of the new tracks a deformation modulus of the second loading branch is required $E_{v2} \geq 60$ L/mm^2, and for modernized tracks – $E_{v2} \geq 45$ L/mm^2. These indicators of bearing capacity to be reached by consolidation of the roadbed and soil stabilization with the help of lime, concrete and other chemical additives.

Bearing strata on the Test Loop during laying of the ballastless track sections were constructed as follows. As the soil basement served the layer of a tamped sand or a layer of chemically stabilized natural soil. As frost blanket served the SGS mixture. Hydraulically bound layer was the layer of common concrete.

For reaching of the stated parameters during construction, a need in additional vibrotamping of the layers by 2–2.5 times comparing to the work execution plan arose.

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