

# Design of track structure for corridors of heavy-train traffic

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**Abstract.** The topical issues of the development of heavy-train traffic along the Central Siberian Main from the “Altayskaya” station to the “Irtyskoe” station of the West Siberian Railway are considered in this paper. For this purpose, the rational design of the track structure for increased axial loads and side forces was selected and analyzed, and measures to expand the operating domain of the continuous welded rail track by improving the design of sleepers and intermediate rail fasteners without changing the plan and profile of the track were considered. Adjusting the track gauge by surface and line is a critical task. The paper discusses the issues of ensuring the widening of the track gauge in curved sections with a radius of less than 350 m as one of the constraints to the development of the operating domain of the continuous welded rail track on the railways of JSC “Russian Railways” and on the West Siberian Railway. Two main ways of ensuring the widening of the track gauge are considered: by changing the structure of sleepers and by means of additional structural elements of intermediate rail fastenings, or a combination of both. This ensures the smoothness when guiding the rolling stock in the curve section of the track, improves the interaction in the wheel-rail system, reduces wear, and complies with requirements of existing regulatory documents. All this reduces the dynamic load on the track, including the subgrade, and extends the service life of the track structure in conditions of heavy-train traffic.

## 1 Introduction

The development of heavy-train traffic on the entire operating domain of the railways of JSC “Russian Railway” is a target problem, the solution of which on the network will lead to an increase in the carrying and traffic capacity, a reduction in the material costs of freight transportation and a reduction in their prime cost.

The purpose of this work is to select the rational designs of the track structure (TS) for the development of heavy-train traffic on the West Siberian Railway (ZSZD), the total length of which is about 9000 km. Among them, about 7,400 km (82%) of a continuous welded rail track on reinforced concrete sleepers. Jointed track on wooden sleepers is 1600 km (18%). At the same time, 9.4% of curves have a small radius from 250 m to 350 m.

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With a radius of 299 m and less - 6.915 km; with a radius of more than 299 m and less than 350 m - 66,264 km.

In addition, an increase in axle loads of up to 25 tons/axle also requires the modernization of existing railroad switches to ensure traffic safety and guaranteed service life.

Jointed track and curves of small radii are the constraining factors for the development of the operating domain of a continuous welded rail track, as the only possible for heavy-train traffic.

Studies have shown that the development of the operating domain of a continuous welded rail track through the improvement of existing track structures designs is economically, technically, and practically more rational than an expensive reorganization of the plan and profile of the track.

## **2 Methods of research**

At the first stage, the introduction of heavy-train traffic at ZSZD is supposed to take place on the Central Siberian Railway from “Altaiskaya” station to the “Irtyshskoe” station with a length of 637 km of a two-way track.

The climate in the design area is continental and extremely continental. The absolute annual amplitude of air temperature reaches 90-95 °C. The average annual temperatures are positive, from +0.5 to + 2.1 °C. Average maximum temperatures in July are + 26 ... + 28 °C, extreme temperatures reach + 40 ... + 42 °C. The average minimum temperature in January is -20 ... -24 °C, the absolute winter minimum is -50 ... -55 °C. The frost-free period lasts about 120 days. The most dry and hot part is the western plains. The climate here is extremely continental in some places. The average amount of precipitation is from 230 mm to 400-500 mm per year.

The composition of the soil is heterogeneous: it's represented by loess, which lie in the form of superposed layers of loess loam, sandy loam, and loess from 1-2 m to 10-20 m thick, separated by interlayers of sand and loam.

## **3 Performance characteristic of the design section**

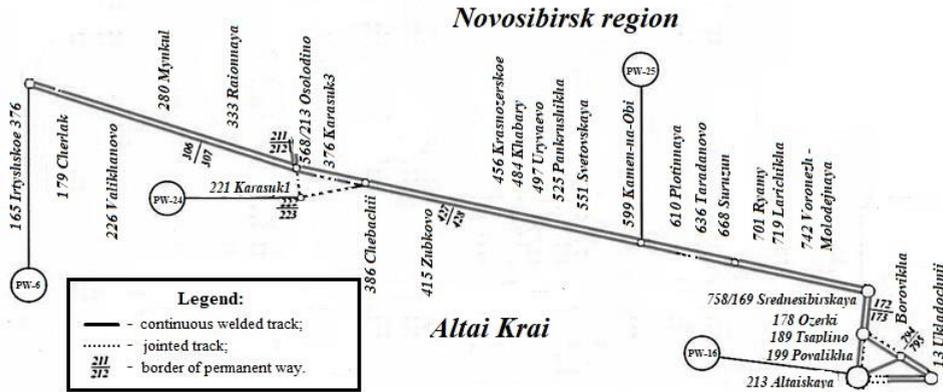
Throughout the section, the speed for freight trains is 80 km/h, for passenger trains - 100-120 km/h. The load on the design sections is:

- on the route Novosibirsk – Barnaul, for the first track is 59.5 million tons km br./km per year, for the second - 133.4 million tons km br./km per year;
- on the route Irtyshskoe – Sredneibirskaya, for the first track is 127.2 million tons km br./km per year, for the second is 46.7 million tons km br./km per year.

The sections have the following track formulas:

- on the route Novosibirsk – Barnaul, the first track is 2V3 and 2B3, the second track is 1A3 and 1B3;
- on the route Irtyshskoe – Sredneibirskaya, the first track is 1A2 and 1A3, the second track is 2V2 and 2V3.

The scheme of design section is shown in Figure 1.



**Fig. 1.** The scheme of design section.

The operational length of the design section is 637 km.

Traction service for freight trains is carried out by electric locomotives of VL80S series, passenger trains - VL80S series with axle load of 24 tons/axle and EP1.

The whole section is electrified, the current is alternating, the voltage in the contact network is 27000 V.

The section between the stations “Altaiskaya” and “Irtyskoe” of Central Siberian Main has a favorable plan (minimum radii of up to 600 m) and track profile (preferably less than 4 %).

## 4 Technical characteristics of the design section

The current maintenance is provided by four distances: Altaiskaya, Kamen, Karasukskaya, Irtyskaya, which are structural subdivisions of the West Siberian Directorate of Infrastructure - a structural subdivision of the West Siberian Railway - a branch of the open joint-stock company “Russian Railways”. Distances of the route are located within the Altai Krai, the Novosibirsk and Omsk regions. The significant part of the distance mileage is the continuous welded rail track. The mileage on the first main track is 543,998 km, on the second main track is 526,162 km. Jointed track on the first main track is 93,002 km, on the second main track is 110,838 km.

Rail facility on the main tracks is represented by rails of the type R65 (92%) and R75 (8%). The base under sleepers is represented by crushed stone (92%) and asbestos ballast (8%). There are 1249 sets of switches at the distance. The main types on the main tracks is R65 1/11, projects 2768 (39%), 2769 (18%), 2764 (8%), 2750 (8%) of the total amount.

Used intermediate fasteners on the main and station tracks KB-65 (49%), ZBR-65, Sh (45%), KN-65 (5.8%), D0 (0.2%).

## 5 Results of the study: Selection of the track structure design

In accordance with an increase in axle loads of up to 25 tons/axis for the passage of trains with the weight of 14200 tons, it is necessary to select the optimal design of the track structure.

### 5.1 Rails

The climate of the design region is extremely continental and the annual temperature

amplitude reaches 95 °C or more, which increases the requirements for the quality of rail steel [1]. In straight lines and curves along the first main track, it is expedient to lay the rails OT370 IK and DT370 IK, which have increased wear resistance and contact fatigue strength [1]. This allows using them in areas of heavy-train traffic and with increased axial loads, including curves of small radii, elevations and descents, where the wear of railway track elements occurs most intensively. The wear resistance of rails OT370 IK and DT370 IK is 30-40% higher than for railway rails of general purpose OT350 and DT350, which are cheaper and can be used for less heavily loaded second main track.

## 5.2 Intermediate rail fasteners

For the traffic of trains with the weight of 14,200 tons at the design section between stations “Altaiskaya” and “Irtyskoe”, strengthening of the first main track is required. At present, the following types of intermediate rail fasteners (IRF) are laid on it:

- KB-65 – 314,485 km;
- ZBR-65Sh – 285,784 km;
- KN – 34,48 km;
- DO - 1,444 km.

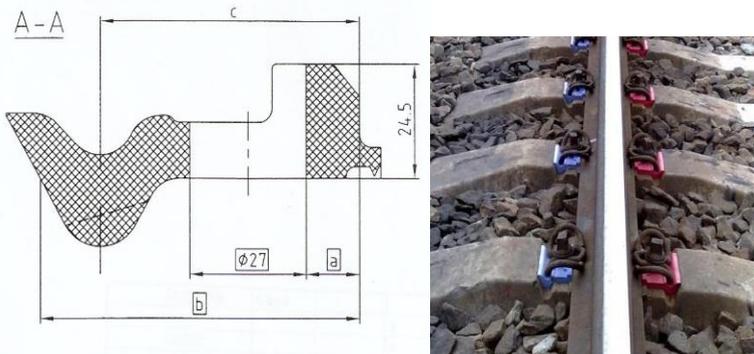
In the future development of heavy-train traffic on the railway network of JSC “Russian Railways”, including on the Trans-Siberian Railway, it is necessary to ensure the adjustment of the track gauge in curves of small radii. For such curves, the widening of the track gauge is provided by normative standards [2]. There are various ways that provide a smooth widening or narrowing of the track gauge within the curves. These methods are carried out either due to the construction of sleepers or due to the design of the IRF.

In conditions of heavy-train traffic, higher requirements are applied to the reliability of the track structure design. Not all IRF currently used by JSC “Russian Railways”, including at the design section, can ensure stable and trouble-free operation of the railway track when passing trains with an axle load of 25 tons/axis.

Therefore, the problem arises of choosing the IRF that is optimum for the given conditions, which at an optimal cost would also provide rational costs for the current maintenance and the variability of the track gauge geometry.

The fastenings Vossloh W30, ZBR-65 Sh, CM-1, ZBR-65 PSh, ZBR-65 PShM, which are used by JSC “RZD”, can be considered as options for the application.

The intermediate rail fastening Vossloh W30 (Figure 2) ensures constant maintenance of the specified track parameters due to elastic fastenings, and with the introduction of the angle guide plate Wfp-14k (Figure 2) in the fastening structure, it is possible to adjust the track gauge ( $\pm 10$  mm) using the angle guide plates of different configuration.



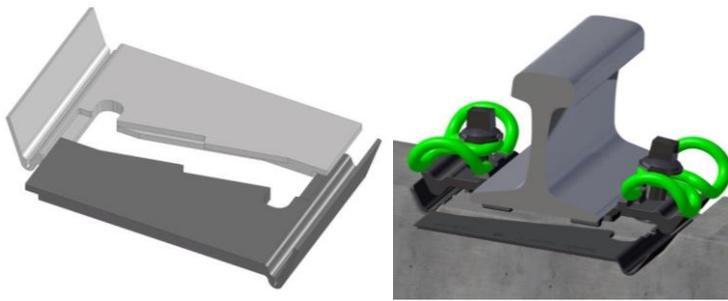
**Fig. 2.** The intermediate rail fastening Vossloh W30 with the angle guide plate Wfp-14k.

Such design features of fastening system Vossloh W 30 allow using it in curves with a radius of more than 300 m, the length of which on the West Siberian Railway is 2042,38 km. In addition, fastening system Vossloh W 30 can be used in sections with different operating conditions due to the possibility of height adjustment up to 15 mm with a standard length screw by plastic plates with thickness of 3 mm, 5 mm and 10 mm with a lock (figure 3).

It should be noted that JSC “Russian Railways” does not yet use this complete set of fastening system Vossloh W 30 on its railways because of higher cost.

In the same way, the track gauge can be adjusted by the ZBR-65 Sh and CM-1 fasteners, the construction of which is similar to the Vossloh W 30.

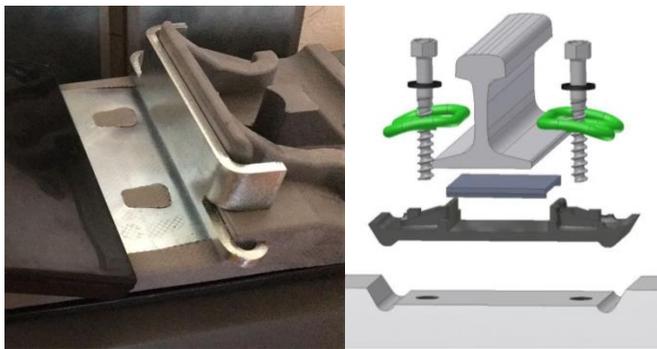
Such a method of widening the track gauge on fastenings without tie plates is acceptable mainly for passenger traffic and small axle loads as an alternative to laying wooden sleepers in curves.



**Fig. 3.** Height adjustment up to 15 mm with a standard length screw.

To increase the amount of clamping of the clip, and therefore anti-creeping forces during heavy-train traffic, it is possible to apply the rotation of the ZBR-65Sh clip fastening by 180° with the screw axis approaching the rail [5].

The design of the ZBR-65PSh fastening (Fig. 4) is a modification of the ZHB-65 Sh and provides fastening of the rails with a polymeric tie plate, screws with washers, and rod spring clips.



**Fig. 4.** Design of fastening ZBR-65 PSh.

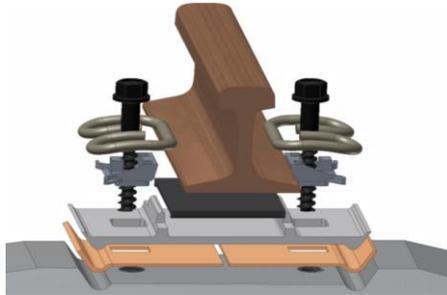
In the modernized version of the fastening of ZBR-65 PSh, the tie plate is reinforced with a special metal insert (Figure 4). The track gauge can be adjusted using side metal plates of various thicknesses.

For high axial loads, the polymer tie plate will be the weak point for the fastening ZBR-65 PSh. Therefore, the rational sphere of application of the ZBR-65PSh fastening can be, basically, the passenger traffic with small axial loads.

For heavy-train traffic, the most reliable is the design of ZBR-65 PShM fastening with a metal plate with rod spring clips and a screw and dowel fastening of the rail, which has a guiding insert for securing the fixation of the screw and the clip in the working position (Figure 5).

Metal tie plate significantly increases the reliability of fastening and ensures the stability of the rail in the curves. Reducing the rigidity of the track is achieved by two damping pads.

Considering the large reserve of the bearing capacity of the rail seats of reinforced concrete sleepers, it is possible to use shortened metal pads in the KZF-07 fastening [6]. In this fastening, it is also possible to adjust the level up to + 15 mm due to the higher flanges of the pads.



**Fig. 5.** Design of ZBR-65PShM fastening.

The basic cost of reinforced concrete sleeper equipped with two nodes of IRF is (prices of 2017):

- Vossloh W30 - 3007 rubles;
- ZBR-65Sh - 2327 rubles;
- ZBR-65PSh - 2704 rubles;
- ZBR-65PShM - 3052 rubles.

Thus, for reconstruction of the IRF of heavy-train traffic on the design section Altaiskaya - Irtyshskoe for the first main track is necessary:

- priority replacement of the spike fastening DO (1,444 km) on the ZBR-65PShM;
- after the passage of the standard tonnage, the replacement of fastenings ZBR-65Sh (285.784 km), KB-65 (314.485 km), KN-65 (34.48 km) for ZBR-65PShM on a regular basis;

On the second main track, reconstruction of IRF is not required due to the lack of heavy-train traffic with a weight of 14200 tons and lower volume of traffic. Therefore, the intermediate fastenings used on JSC "RZD" can be used.

Also, there are the following curves on the design section:

- direction Irtyshskoe - Suzun, 756 km,  $R = 600$  m;
- direction Novosibirsk - Barnaul, 192 km,  $R = 638$  m.

Within these curves, a priority replacement of intermediate rail fastenings is necessary after passing the standard tonnage for the ZBR-65PShM, because with axial loads of 25 tons/axis, considerable side forces occur in the curves of small radii, especially in the braking mode. Therefore, it is necessary to use ZHB-65PShM fastening with a metal tie plate, which will ensure the joint and long-term operation of all fastening points in the straight and curved sections of the track.

In conditions of heavy-train traffic with an axial load of 25 tons/axis, the widening of the track gauge only by the side insulators does not ensure the reliability and stability of the track gauge, so it is more expedient to ensure a smooth track gauge widening in curves of small radii by laying special sleepers with a variable size of the rail seat.

Adjustment of track gauge by the design of sleepers is made using sleepers with different sizes [4]. The step of changing of these dimensions is 2 mm. Curves with a radius of less than 350 m allow using of special reinforced concrete sleepers with a variable size of the rail seat, which determines the track gauge. These sleepers are designated by the index K and the last two digits of the nominal track gauge.

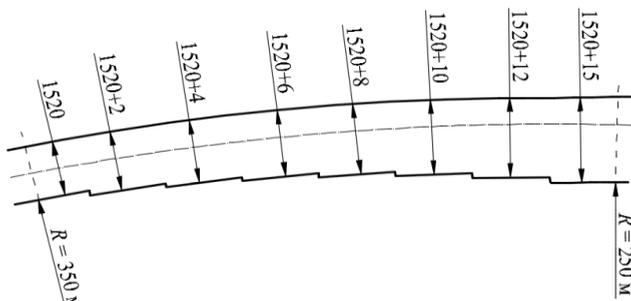
In the circular curves with a radius of 349 m to 300 m inclusive and with a nominal track gauge of 1530 mm, sleepers of the type K30 are used, with a radius of the circular curve of 299 m or less and with a nominal track gauge of 1535 mm, sleepers of the type K35 should be used.

In the transitional curves with variable track gauge, depending on the radius and length of the widening, special sleepers of the types K22, K24, K26, K28, K30, and K32 are laid one after another. For all parameters and dimensions, apart from the distance determining the track gauge, the sleepers for curves of smaller radius are completely identical to typical reinforced concrete sleepers.

Variants of track gauge widening up to 1530 mm are possible with the use of sleepers of the types K22, K24, K26, K28, K30 (Figure 6) and up to 1535 mm with the use of sleepers of the types K22, K24, K26, K28, K30, K32, K35 (Figure 7). This widening is sufficient for laying a continuous welded rail track in curves with a minimum possible radius of 250 m.

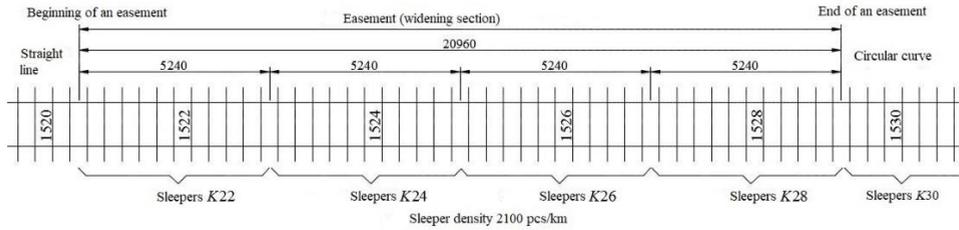


**Fig. 6.** One-sided widening of the track gauge up to 1520+10 mm

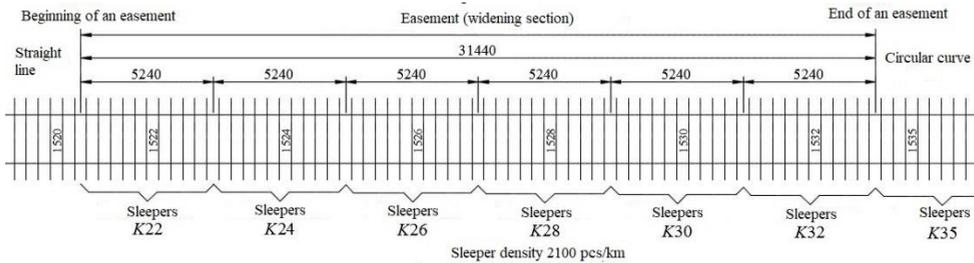


**Fig. 7.** One-sided widening of the track gauge up to 1520+15 mm.

Depending on the radius of the curve, a gauge widening scheme is chosen: in curves with a radius of 349 to 300 m, providing a smooth widening of the track gauge from 1520 to 1530 mm (Figure 8), and in curves with a radius of 299 to 250 m, providing a smooth widening of the track gauge from 1520 to 1535 mm (Figure 9).



**Fig. 8.** The scheme of widening of the track gauge from 1520 to 1530 mm.



**Fig. 9.** The scheme of widening of the track gauge from 1520 to 1535 mm.

Such a method of widening the track gauge in curves with a radius of 299 m to 350 m will make it possible to increase the operating domain of the continuous welded rail track on the West Siberian Railway by 66,264 km.

### 5.3 Sleepers

For the design section, taking into account the selected type of intermediate rail fastening, the reinforced concrete sleepers S3-D (Fig. 10) of the first service life are used as the rail seat [4].



**Fig. 10.** Reinforced concrete sleeper of S3-D type.

When reorganizing the first main track, it is necessary to replace 1,444 km of track with wooden sleepers for reinforced concrete ones of S3-D type.

For the continuous welded rail track in conditions of heavy-train traffic, according to the results of calculations of the continuous welded rail track in curves, sleepers III-DB 44x3 with increased shear resistance in the curves can be used [7] (Figure 11).



**Fig. 11.** Reinforced concrete sleeper III-DB 44x3 with increased shear resistance.

#### **5.4 The ballast layer**

In accordance with the GOST [8] requirements, it is necessary to use crushed stone from hard rocks of the 1st category and of fraction 30-60 mm as a ballast layer for the organization of heavy-train traffic on the section Altaiskaya - Irtyshskoe.

The use of the considered IRF for ballast structures of TS on reinforced concrete sleepers, as well as sleepers of different sizes along the track gauge, will allow to significantly extend the service life of TS elements [9-12] when operating under conditions of heavy-train traffic with the necessarily high quality of assembled rails and sleepers [13-14], and also improve the technological maintenance of the continuous welded rail track under conditions of increased axial loads and extend the service life of the rails [15-17].

#### **5.5 Switches**

For the given axle loads (25 tons/axis), the switches of the Novosibirsk switch plant (NSP) of the projects N01.001 and N01.004 are optimal. The geometric dimensions of the switches of projects 2750, N01.001 and N01.004 are identical, which allows in the future modernization of the project 2750 to the projects N01.001 or N01.004, for heavy-train traffic with an increase in axle load up to 25 tons/axis and 27 tons/axis. The general view of the switches N01.001 and N01.004 is presented in Figures 12 and 13.

The design features of the switch of the project H01.001 are:

- crossing with wing rail of untrailable configuration and welded rail ends;
- widened cast wind rails;
- optimized crossing tread;
- additional connecting strips to ensure a constant track gauge;
- reinforced tie plates with pads;
- roller devices;
- equal elastic fastening of the crossing rail to the tie plate is carried out by clips SKL 12-32 on both sides.



**Fig. 12.** Switch of the project N01.001.



**Fig. 13.** Switch of the project N01.004 with plain sleepers.

The design features of the switch of the project N01.004 are:

- screw and dowel fastening of the tie plate to the concrete base;
- high stability and strength, increased service life and rigidity due to the small number of parts;
- polyamide inserts in connected strips;
- rail pads with increased rigidity of the sides;
- possibility of welding all the junctions of the switch and welding into a continuous string of rails;
- rolling surface is optimized in the same way as the rail crossing with a widened surface of cast wind rails;
- flat construction of switch tie;
- possibility of operation with high axial loads due to an increase in the support surface.

The main technical characteristics of switches are presented in Table 1.

**Table 1.** Technical characteristics of switches of the projects 2750, N01.001 and N01.004.

Switch	2750.00.000	N01.001 и N01.004
Track gauge, mm	1520	1520
Total length of the switch on the straight track, mm	34858	34858
Radius of the side track (along the working face of the outer rail), mm	300000	300000
Step of switch points on the axis of the working rod, mm	154	154
Maximum static load on the rail	245	270
Maximum speed of passenger trains along a straight track, km/h	140	160
Maximum speed of passenger train along the side track, km/h	50	50
Maximum length of the loading place, mm	18770	18770
Maximum weight of the loading place, tons	3,5	3,5
Weight without switch ties, tons, not more than	16	16
Design of switch ties	VNIIZHT 2005-02	VNIIZHT 2005-02

To reduce the dynamic impact on the track, it is also necessary to use trucks with improved spring suspension of the project 18-9855 with a permissible axle load of 25 tons/axle. As a separating layer and to reduce pressure on the subgrade, it is possible to use expanded polystyrene on the blow-up areas and geotextile elsewhere.

## 6 Conclusions

The design of curves of small radii on the continuous welded rail track is possible using modern track structures that provide high stability of the track and possibility of adjusting the track gauge, as well as a number of measures including the use of sleepers with increased shear resistance and grouting of ballast. This will allow expanding the operating domain of the continuous welded rail track without expensive reorganization of the plan and profile.

The considered section between the stations Altaiskaya – Irtyshskoe of Central Siberian Railway has a favorable plan (minimum radii up to 600 m) and profile of the track (mainly less than 4 ‰). Taking into account the passing of trains with an excessive weight up to 14,200 tons and axle loads up to 25 tons/axle, the following design of the track structure for the first main track was chosen:

- rails of category DT370 IK and OT370 IK on all extent of straight and curve sections of the track;
- intermediate rail fasteners ZBR-65 PShM with priority replacement of fastening DO on wooden sleepers and all other IRF on a regular basis of replacement (ZBR-65 Sh, KB-65, KN-65), starting with curves with radii less than 650 m, and further in all other curves and straight sections of the track;
- sleepers III3-B of the first service life and, according to the results of calculations of a continuous welded rail track in the curves, if necessary, sleepers with increased shear resistance III-DB, or an increase in the typical sleeper density up to 2100 pcs/km;
- ballast layer - crushed stone from hard rocks of the 1st category of fraction 30-60 mm;
- the NSP switches of the projects N01.001 and N01.004, which can be installed in place of switches of the project 2750 without the reconstruction of the yard neck;
- using of trucks with improved spring suspension of the project 18-9855 with a permissible axle load of 25 tons/axle;
- separating layer of expanded polystyrene on the blow-up areas and geotextile elsewhere.

On the second main track, reconstruction of TS is not required due to the lack of heavy-train traffic and lower volume of traffic. Therefore, typical structures of TS used on JSC “RZD” can be used.

The conducted research is based on normative and technical documents of JSC “Russian Railways” [1-8], has significant theoretical and practical significance and interrelation with previously published works [9-17]. It showed the technical possibility of widening the operating domain of the continuous welded rail track on the West Siberian Railway as the only possible design for heavy-train traffic. This will significantly reduce the operational costs of maintaining the infrastructure (up to 30%).

According to the results of the study, at the first stage, the trains with an excessive weight up to 14,200 tons and axle loads up to 25 tons/axle can be driven in the considered section between the stations “Altaiskaya” and “Irtyshskoe” of Central Siberian Railway during the reconstruction of the TS. This will significantly reduce the prime cost of freight transportation.

A further line of study will be the development of the track infrastructure to ensure the formation and stop-offs of long trains at the stations.

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