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Problems Associated with Ensuring the Stability of the Roadbed in Difficult Conditions and Options to Solve Them

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Abstract. The article refers to the problems of operating the earth in difficult conditions. Railways in difficult conditions, especially in areas of permafrost and deep seasonal freezing of soils, need constant supervision over the operational performance of the track superstructure in plan and profile, as well as the state of the subgrade from the adverse and destructive leverage of external factors of a natural and technogenic nature. Sections of the roadbed, being deformed for long periods of time, require significant operating costs and capital investments to ensure the stability of these sections.

1. Introduction

The modernization of the infrastructure of the Baikal-Amur and Trans-Siberian railways is carried out in pursuance of the presidential decree of May 7, 2018 "On national goals and strategic objectives of the development of the Russian Federation for the period up to 2024" in order to increase their traffic capacity by 1-1.5 times. By that time, it is planned to develop transport corridors "West - East" and "North - South", to increase the level of economic connectivity of the territory of the Russian Federation, including the modernization of the railway infrastructure. The freight containers traffic should increase by 4 times, and the time of their transportation from the Far East to the western border of the Russian Federation will reach seven days [1,2].

2. General information

This year, plans have been corrected - Russian Railways will build additional tracks ahead of schedule and expand railway stations on 212 priority sections. At the same time, an increase in capacity through the building of additional stations, sidings and double-track inserts requires preliminary research of the roadbed condition of the existing track, which has not acquired stability over many decades, but on the contrary, its deformability is growing and will continue to grow in the process of increasing traffic density [3,4]. In addition, the base of the additional track will deform on permafrost soils due to cross section conditions difference.

It is obvious that the deformations of different regions associated with regional climatic, engineering-geological, hydrogeological, permafrost-ground and hydrological conditions of the Far East have a specific nature. In the southern regions (Primorye), mainly gravitational phenomena occur as a result of the loss of stability of slopes under the influence of natural phenomena (typhoons, tsunamis, etc.), shrinkage and displacement of the roadbed on soft soils.



In the central regions (Trans-Siberian railway), deformations prevail in the form of subsidence phenomena in the western part, and in the east - heap, deep-subsidence and cryogenic (permafrost) phenomena [5]. In areas of high-temperature permafrost soils (eastern testing area of the Far Eastern Railway) - degradation of permafrost, shrinking, sinkholes, cryogenic deformations, effervescence, pressure-mechanical suffusion, etc. [6]. Deformations caused by thawing of permafrost soils and underground ice, as well as deformations of a cryogenic nature, prevail in the northern regions of Sakha (Yakutia) [7].

One of the examples on the Trans-Baikal Railway of the Trans-Siberian Railway, is the "golden" kilometre - a section 6277-6278 km, where systematic deformations of the roadbed and rail and sleepers have been observed since 1949, and the constant train speed limit goes down to 40, sometimes 15 km/hour introduced since 1969 and where every year it is necessary to straighten and raise the track several times during the warm season. In some places, the crib material has already fallen by 5–7 m, but the track shrinking does not stop. According to preliminary estimation, the shrinking can continue for another 100–150 years, since at the base of the path there are places with ice-rich permafrost rocks 25–30 m thick, especially in the areas of tectonic faults [8, 9].

2.1. Available information on the problems of operation on railways located in permafrost conditions

There is not a single constructed railway track in the world that would not experience deformations due to sediment during thawing of icy soils or heaving during freezing of wet dispersed soils of the base. These problems are typical for all railways, regardless of their service life, for example: on the Trans-Baikal railway, which has been in operation for more than a hundred years, Baikal-Amur Mainline (45 yrs) and Amur-Yakutia mainline (more than 30 yrs), access roads Chara-China and Ulak- Elga - several years old - and recently built Qinghai-Tibet railway [9,10].

Due to that reason, there is an opinion that deformations can be prevented by keeping the base soils in a permanent frozen state or by preemptively melting icy soils and replacing them. These technical solutions were tested by a number of scientists, including TMS, Far Eastern State Transport University and representatives of the railway in the projects of the Amur-Yakutia railway, on the Trans-Baikal railway, on sections of the Qinghai-Tibet railway in China. The Qinghai-Tibet Railway from Golmud to Lhasa passes through the territory with absolute height over 4000 m and 50% of its length passes through permafrost with an average annual temperature of -0.5 to -3.6 °C and a thickness of 5-130 m and more.

To stabilize the roadbed, sun and rain shelters were used, which increase the average annual air temperature to 3-5 °C in areas of highly icy permafrost. In addition, transverse cooling pipes with automatic dampers and thermosiphons in embankments were tested; 5 million of them were installed. In addition, a flyover was tested by Chinese specialists [11].

The disadvantages of such an expensive structure are associated with the bulging of the overpass supports, the destruction of their heads in the seasonally thawed layer with constantly alternating processes of freezing and thawing. The main deformations of the subgrade: thermokarst, thermal erosion, frost heaving, precipitation and melting during thawing.

A positive aspect is the large amount of experimental work during the construction and operation of the road. In addition, rock placement, thermosiphons, and cross-ventilated pipes were tested. For the most part, rock placement, thermosiphons, thermal insulation, as constructive solutions in mass execution, did not materialize, which confirms again the need to develop fundamentally different technical solutions and technological methods based on the regulation of natural and man-made heating and cooling factors in specific natural climatic and permafrost conditions.

Another example. The well-known object of the East Siberian Railway is located in the Kazankan junction area on the BAM, the roadbed of which has being deformed for more than 35 years and the plan and profile of the railway track are distorted, the speed of movement is constantly limited to 15–25 km / h. The section of the road is electrified, and it is also necessary to constantly repair the contact system. Such cases are often associated with tectonic and karst (thermokarst) phenomena [8,9].

Another example, on the East Siberian Railway, where in 2001 the construction of the Chara-Chin access railway was basically completed, going through an area with extremely difficult engineering and geocryological conditions, caused, in particular, by the spread of permafrost highly ice-rich rocks, often with underground ice up to 5-10 m thick. Today, this line has being destroyed by geological, including cryogenic processes, and measures to ensure the trains traffic until recently were limited to permanent alignment of the track and backfilling of drawdowns. After 2008, track repairs and train traffic ceased.

It is possible to build local structures (buildings) on areas of icy permafrost soils without condemning them to permanent repair, in two fundamentally different ways: keeping the base soils frozen throughout the entire operation of the road or, if it is impossible to cut them out, by preventive thawing of icy soils and replacing them. them. Linear structures (railways) can be built in this way, but it is practically impossible to operate them. The experience of operating railways - BAM, AYaM, Qinghai-Tibet Railway - has shown that. The drainage system on permafrost is currently being tested at BAM (fig.1).

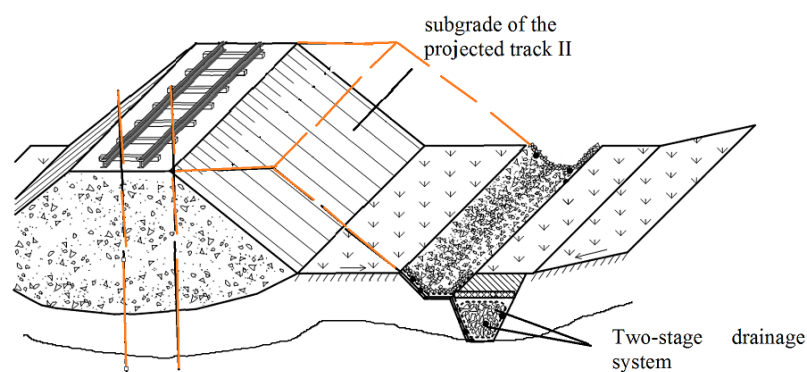


Figure 1. Two-stage drainage system in permafrost.

2.2. Solving the problems of the operation of the subgrade in especially difficult conditions

Mostly, the reasons for the deformation of the subgrade are [12]:

- Self-compaction (soil consolidation);
- Plastic slides from vibrodynamic factor;
- Cryolithogenesis (pressurized groundwaters, soil destruction, soil dustiness, etc.);
- Water-thermal erosion, disturbance of surface runoff;
- Weathering and destruction of rocks;
- Accumulation of weathering products - gravitational processes;
- Processes of thawing, leaching of soils - karst (thermokarst).

In drainage areas with underground ice, deformations are practically unpredictable, therefore, to make the right decisions to ensure the stability of the existing subgrade and its strengthening, a methodological approach based on the diagnosis of a deforming subgrade can be applied.

The following approach can be recommended as one of the methods for diagnosing the state of the roadbed during design [13]:

1. On the topographic plan to make the grid with the position of the longitudinal profiles for every 10 - 20 m from the bottom of the subgrade at the site of the proposed design solutions for strengthening the subgrade (drainage systems, tail slopes, berms) and analyze them in detail;
2. Compare the topographic conditions with the natural position of the ground level before filling the subgrade;
3. Analyze the data of engineering surveys: engineering-geodetic, engineering-geological, hydro-geological and geophysical works;

4. Select the most appropriate structural and technological solutions for draining the adjacent territory and the base of the subgrade, and protective and fortifying structures to strengthen it.

Currently, there are several recommendations on the choice of technical solutions for stabilizing soil structures in deforming areas.

The anti-deformation measures tested in real conditions, justified by calculation, theoretical, economic means, are the following [14]:

1. Drainage of subsoil zones of the subgrade: with the help of longitudinal insulated drains, drains, drainage of ground and surface water using the device of "rock clips", water-squeezing berms, transverse drainage slots, geosynthetics, reinforcing compounds, etc.

2. Armored-drainage in the bottom-slope zones: tail slopes of variable cross-section, "rock clips", "Setkon" technology, etc.;

3. Injection using natural components and reinforcing compounds (cementation), concreting, soil strengthening;

4. Small bypasses with the help of preliminary ensuring the stability of the foundation with modern materials, flexible flyovers, the use of the Setkon technology;

5. Backfilling of sinkholes. Flattening of unflattened rocky and uneven slopes with fine-dispersed soils, unloading of slopes, installation of retaining and protective structures.

With a competent approach to the choice of anti-deformation measures and a detailed analysis of topographic conditions, the measures and technologies used give a high result, which is manifested in the long-term stabilization and stability of the roadbed.

2.3. Increasing the throughput of the eastern range of the Far Eastern Railway

Recently, Russian Railways has done a lot to support the coal industry, including the identifying areas that require mainline-accelerated modernization. The problem is that the countries of the Asia-Pacific region remain the most priority destination for coal exporters, and the BAM and Transsib are not yet able to meet the growing demand for transportation.

The increasing the modernization speed of the mainlines of the Eastern range pertains the BAM and Transsib. The mainlines will be modernized both in the direction of the border crossings of the Far East and in the direction of seaports.

The first stage of the reconstruction of the BAM and Transsib, estimated to be finished in 2020, has been practically completed. It is aimed at solving the primary task - the elimination of the so-called "bottlenecks" of these mainlines, which seriously slowed down the process of cargo transportation on the territory of Transbaikalia and the Far East.

Additional tracks and stations were built where necessary in the first place. Outmoded tunnels did not allow trains to reach required speed. This problem has been solved through the reconstruction of the Kiparisovsky, Obluchensky and Vladivostoksky tunnels, which meet all modern requirements.

To increase the traffic capacity, it is necessary to stabilize the subgrade. Technical solutions to ensure the stability of the track superstructure on the existing deforming roadbed will also require large expenses. For the eastern BAM mainline, the length of the deforming places causes significant costs [15].

The subgrade of the Eastern BAM from Khani to Postyshevo with the BAM - Tynda - Berkakit and Izvestkovaya - Urgal lines (from Tynda) is mainly in high-temperature permafrost conditions [10].

3. Conclusion

Many issues have not yet been fully investigated and agreed upon, which affects the stability indicators of the roadbed. Problems of construction and operation in these conditions affect the balanced development of the transport network of the region, which is currently characterized by the lowest road density among developed countries in the world (5 km of railways per 1000 sq. Km).

Since 1961 FESTU has been engaged in the construction and operation of the subgrade of permafrost soils: studies of the state of the subgrade have been carried out and technical solutions have been developed that ensure the stabilization of the railway track in conditions of permafrost soils.

To strengthen the subgrade, it is suggested to provide the following measures:

- Arrangement of armored drainage systems;
- Dumping of tail slopes of variable cross-section, from rocky soil at the intersection with local logs;
- Filling the embankment to the value determined by the project, reinforcing the base to prevent shrinkage (usually more than 5 mm) of the embankment on a weak base, causing overstress in the elements of the superstructure of the track;
- Improvement of drainage systems and drainage structures;
- Arrangement of a two-stage drainage system.

As supporting structures, the most widespread are tail slopes - soil prisms piled up at the slopes of the embankments. Tail slopes can be stone, crushed stone, pebble, gravel, crushed stone waste, sand, or local soil (depending on local conditions).

They can be used to increase the stability of the roadbed, to strengthen landslide and unstable slopes. Tail slopes are widely used on the roads; they are mainly filled with soil delivered by dump car trains. The disadvantages of tail slopes are their large volume, the impossibility of using in cramped conditions, the need in some cases to lengthen culverts, remove communications, the need for many "windows" in the performance of work on their construction.

Taking into account the complex soil conditions of the base of the exploited deforming section of the roadbed, the project provides the stabilization of places of shrinkage, filtration of groundwater, which cause heaving-subsidence deformations of soils during their seasonal freezing-thawing, listed above, using the device of a new design of the drainage and drainage system (Fig. 1). The design of a two-stage drainage system was previously developed by the Far Eastern State Transport University to stabilize such areas and a patent for an invention was obtained [16].

Various drainage structures are used to drain the subgrade, but according to the conditions of humidification, the design of a closed horizontal insulated drainage is the most acceptable. A drawing and a description of the structure are shown below. The design allows to improve the technology of development of the drainage trench. Due to the depth, the longitudinal slope can be increased, and the presence of thermal insulation will allow the area near the roadbed in the late autumn period to be drained from groundwater.

To solve this problem, the drainage system on permafrost consists of the upper, lower longitudinal trenches, made along the roadbed of the railway track within the drained area, filled with large-porous fractional drainage material and a waterproof screen, with the upper longitudinal trench located directly behind the lower longitudinal trench above the slope of the upland parts of the relief with the formation of a single stepped trench. The waterproof screen is laid on the side-stepped edge of a single trench, on top of which, along its entire perimeter, a reinforcing screen is laid. The large-pore drainage material of the upper longitudinal trench is wrapped with a reinforcing screen to form a drain. A waterproof geosynthetic material was chosen as a waterproof screen, and a synthetic non-woven material was chosen as a reinforcing screen.

The lower longitudinal trench is made above the depth of the seasonal freezing layer, and the upper longitudinal trench is made in the seasonal freezing layer and at the level of the step of a single stepped trench is covered with a heat-insulating screen, above which a waterproof layer is laid to the level of the relief, forming the side wall of the upper drainage trench.

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