ESTIMATION OF FOUNDATION SETTLEMENT ON WEAK BASE SECTIONS

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ABSTRACT

In the development of embankment projects on a weak base (water-logged clay soils), the correct estimation of the size of the embankment settlement and broadening of the main site of the roadbed are of current importance. The article offers the author's analysis of the condition of the roadbed of the Naryn–Lugokan railway line, taking into account the presence of island permafrost, the specified operational characteristics, the geodetic survey data and the scientific and theoretical substantiations of the project.

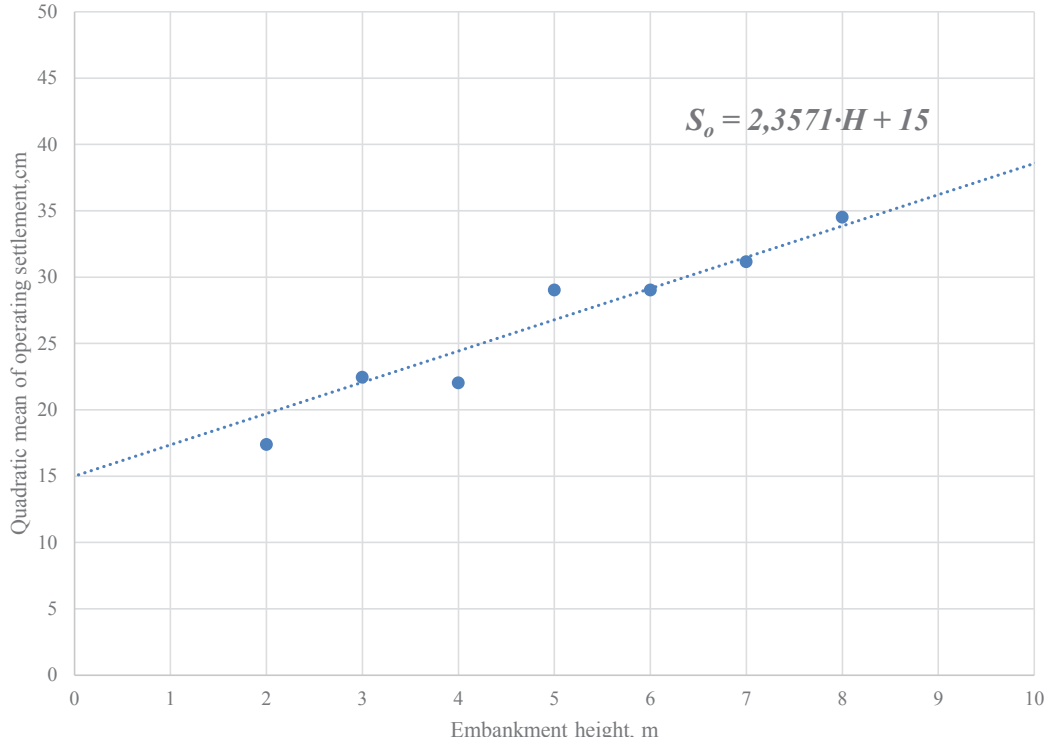
Keywords: railway, operating settlement, building settlement, weak foundation soils, permafrost, operational problems, site broadening.

Background. *The construction of railways on areas of weak bases requires a careful approach to the design of individual structures of the roadbed. When performing the calculations, it is necessary to ensure not only the general and local stability of embankment slopes, but also to provide measures for preserving the project marks of the rail head after completion of the settlement of the base.*

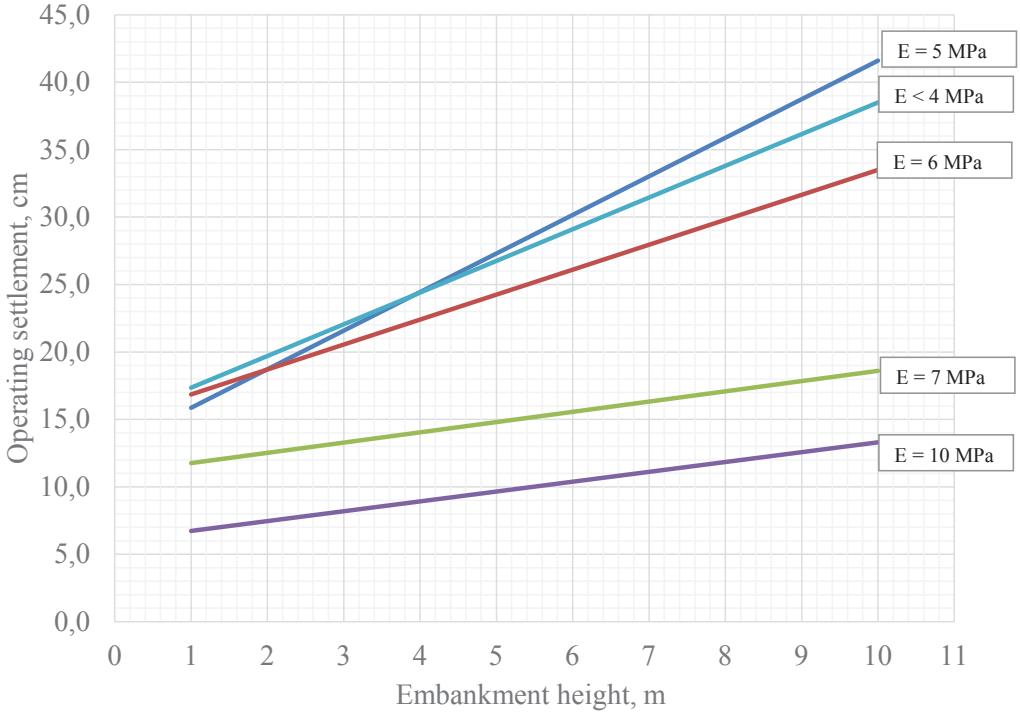
The modern normative and technical documentation describes the methods of designing the roadbed on peat, saprel marshes and mud. At the same time, there are practically no calculations and typical design solutions for the design of embankments of railways and highways on water-logged clay soils. The lack of attention to this issue leads to serious problems in the operation of the constructed facilities. Underestimation of the size of the settlement of the embankment and the absence of broadening of the main site of the roadbed lead to deformation of the roadsides and the formation of ballast trails.

As it is known, the total settlement of the embankments is formed by building and operating settlement. Building settlement is achieved due to the compaction of the foundation soils during the erection of the embankment. Operating settlement arises due to the addition compaction of the body and the foundation of the embankment under the influence of the train load. Calculation of the total settlement of the base of embankments is recommended to be carried out using compression curves of soils. The relationship between settlements occurring during the construction period and after putting the embankment into operation is established by SP 32–104–98 as $S_b = S_o = 0{,}5S$.

That is, the building settlement is conditionally equal to the operating one. The actual amount of settlement during the operational period is not always equal to the calculated values of the building settlement. This is especially evident in areas of weak bases and during the filling of the embankment during the winter period. Thus, incorrect design decisions are laid in the design of the roadbed designs: insufficient width of the main platform for lifting the track onto the ballast after the completion of the



Pic. 1. Dependences of S_o ***on H for soils with*** $E < 4$ ***MPa.***



Pic. 2. Dependences of S_o on H for soils with different modulus of deformation.

settlement, or, conversely, an excessive stock of the embankment for the settlement in height.

Objective. *The objective of the author is to consider estimation of roadbed settlement on weak base sections.*

Methods. *The author uses general scientific and engineering methods, graph construction, comparative analysis, evaluation approach.*

Results.

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To assess the value of the operating settlement for the new railways commissioned, an analysis was made of the condition of the roadbed of the line Naryn–Lugokan 220 km long, located in Zabaikalsky region. The construction area is characterized by the presence of island permafrost, high groundwater level and, as a consequence, the predominance of water-logged clay soils in the active layer.

In considering the characteristic areas, it was found that the greatest operating settlements occur when clay soils with loamy water-logged soils are present in the base of the roadbed: sandy loam and loam from a flowing to a turgid consistency with a deformation modulus from 5 to 10 MPa with a power of 1,0 to 5,5 m, and peat with a deformation modulus of less than 4 MPa. The roadbed is represented by embankments with a height of 1 to 9 meters.

The filling of embankments is made of rocky slightly weathered soils – granites, porphyrites and sandstones with a density of 2,48–2,62 g/cm^3. Construction was carried out all the year round. The embankments were compacted layer-by-layer by vibrating rollers with a mass of 15 tons, 9–12 passes along a 0,4-meter layer. Excavations were carried out from 2008 to 2011, and the superstructure was laid from 2011 to 2013. The interval between the completion of the construction of the roadbed and the beginning of the laying of the superstructure averaged two years, that is four seasons of freeze-thawing of the soil. Based on this, it can be concluded that at the time of laying the superstructure the embankment was consolidated, the building settlement was completed.

Before the laying of assembled rails and sleepers, the main site of the roadbed was subjected to instrumental geodetic inspection, if the actual marks were deviated from the designed ones by more than 5 cm, the rocky ground was filled with compacting and profiling the top of the roadbed with a grader.

In the autumn of 2013, after laying the superstructure and opening the main traffic operation, the leveling of the edges of the roadbed and rails heads was made. The data obtained were the starting points for the subsequent analysis.

The obtained measurements confirmed the theoretical knowledge about the settlements of railway embankments. The greatest settlement was confined to the places of the culvert assembly, to the sites with disturbed drainage, and also to the thawing areas of the permafrost soils of the III–IV thermal deposition category (some settlements exceeded 100 cm). Similar areas with settlements over 60 cm were filtered out and excluded as gross errors or particular cases. A total of 23 sections with weak soils totaling 10,6 km were identified for further processing. The filtered data array was grouped according to the main distinguishing feature – the ground deformation module. Soil characteristics were taken based on the results of engineering and geological surveys carried out by design institutes in 2008–2010.

In total, five groups were obtained for the classification of soils with deformation modules of

Table 1

Recommended values of broadening of the main site of the roadbed for the possibility of mounting the track on to the ballast

No.	Embankment height, m	Foundation soil with a deformation module, MPa				
		Magnitude of broadening at E < 4 MPa	Magnitude of broadening at E = 5 MPa	Magnitude of broadening at E = 6 MPa	Magnitude of broadening at E = 7 MPa	Magnitude of broadening at E = 10 MPa
1	1	0,5	0,5	0,5	0,4	0,2
2	2	0,6	0,6	0,6	0,4	0,2
3	3	0,7	0,6	0,6	0,4	0,2
4	4	0,7	0,7	0,7	0,4	0,3
5	5	0,8	0,8	0,7	0,4	0,3
6	6	0,9	0,9	0,8	0,5	0,3
7	7	0,9	1,0	0,8	0,5	0,3
8	8	1,0	1,1	0,9	0,5	0,4
9	9	1,1	1,2	0,9	0,5	0,4
10	10	1,2	1,2	1,0	0,6	0,4

10, 7, 6, 5 and less than 4 MPa. Further, the arithmetic mean and mean square data sets were determined for different settlement heights from 1 to 10 meters. The average quadratic deviation of the results of the changes did not exceed 25 %.

Based on the obtained average values, a graphical dependence of the actual operating settlement on the height of the embankment was constructed. Using the data approximation, the functions $S_o = f(H)$ were defined.

An example of the graphical dependence of the mean quadratic data of the actual operating settlement on the height of the embankment with the modulus of deformation of the foundation soil less than 4M Pa is shown in Pic. 1.

The analysis of the example shows that the dependence of operating settlement on height of the embankment is linear and, in a particular case, can be described by the formula:

$$S_o = 2{,}3571 \cdot H + 15. \quad (1)$$

Similar dependencies were revealed for each of the five groups under consideration (Pic. 2).

As a result, the linear dependence of the value of operating settlement of the railway embankment under the influence of the train load on height of the embankment on weak water-logged foundation soils was determined. The obtained graphs can be used in calculating the final value of the settlement of the embankment. Intermediate values are found by linear interpolation.

When designing embankments on a weak base, it is recommended to widen the main site of the roadbed to allow the track to be lifted onto the ballast after completion of the settlements. To determine the broadening values, the empirical data presented in the article should be used. In addition, it should be noted that the magnitude of broadening of the main site of the roadbed should be influenced only by the value of the operating settlement, while building settlements should be completed by the time the superstructure is laid. The recommended values of the broadening of the main site on weak soils are presented in Table 1, the values are rounded to within 0,1 m.

Conclusions. *The obtained values of operating settlement and recommended values of broadening of the main site of the roadbed can be used in the development of individual projects of the roadbed of railways on weak water-logged foundation soils. They are quite applicable to determine the empirical relationship between the building and operating settlements, the improvement of calculation methods and the regulatory framework for the design of the roadbed.*

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