Identification Of The Emergency Condition Reasons At Railway Lines That Are In Difficult Geocryological Conditions

Gorobtsov D.N.[1[0000-0002-1232-6652]], Fomenko I.K.[1[0000-0003-2318-6015]], Pendin V.V.[1 [0000-0003-3055-2095]], Nikulina M.E.[1[0000-0003-0796-6839]]

[1] Russian State Geological Prospecting University n. a. Sergo Ordzhonikidze (MSGU), Miklouho-Maklay's street 23, Moscow 117997, Russia
nikulinamari93@mail.ru

Abstract The quantity slope stability assessment organization based on the engineering, geological and geophysical investigations analysis. The geomechanical slope's models creation realized along stability assessment for slopes in natural conditions and in conditions of one estimated geological element soaking and thawing. Morgenstern-Price, Bishops and Janbu methods were the main in stability assessment. The estimation analysis allows concluding that there are two main mechanisms of sliding processes on the slope. In the first case, landslide dislocations occur in the embankment's body. The second mechanism bases on the assumption of one estimated geological element soaking and thawing. In this case, sliding dislocations cover the whole embankment. The embankment's displacement comes along frozen moistening loams (main straining horizon (MSH)). This main straining horizon is the base for made ground. In addition, displacement may occur because of infiltration the surface water along well-filtering macadam in warm period. The main sliding factors at the territory are significant relief energy, low strength properties of soils during it soaking and thawing, artificial cooperation. Fine probability sliding process activation predetermines the necessity of design and engineering protection measurements organization.

Keywords: QUANTITY SLOPE STABILITY ASSESSMENT, GEOMECHANICAL MODELS, MECHANISMS OF SLIDING PROCESSES

1 Introduction

Temperature regime and factors that caused it during engineering surveys in permafrost areas were under much attention. In addition, the observation of the degree of frost heaving, assessment the depth of seasonal thawing and determination the types of cryogenic processes and areas of their distribution is also very important. The aim of engineering and geological investigations is complex study of natural and technogenic conditions [2]. These conditions are necessary and sufficient for the development the main measures for drainage system (as the main factor that influence on temperature regime) and strengthening sustaining capacity of railway tracks soils to the loading rack of petroleum products. The sustaining capacity complex assessment of permafrost soils based on the engineering surveys. The main objectives of investigations were:

1. Organization the quantitative assessment of slope stability.
2. Developing the measures for strengthening and/or sustaining capacity preservation.
3. Composing the recommendations for further safe operation of investigated area.

2 Engineering and geological conditions of the territory

The investigated area situates at the junction of the West Siberian lowland and the middle Siberian highland. The territory is extensive low hilly rolling plain with an average absolute strength altitude about 120-130 m and maximum altitudes about 215 m. In this area various and complex relief and all-round permafrost forms widespread. The oil base locates near the edge of Krasnoyarsk region.

Climate is arctic. It characterizes by abrupt temperature changes along the day and the year. There is also cold winters and short cool summers. The duration of stable frosts is 214 days. The average temperature of the coldest month is - 28,0°C. All year-round strong winds widespread there. The number of them is on average about a week in a month. Night frosts and snowfall are not rare in summer. Precipitation here falls a little (about 380 mm per year). The permafrost and slight evaporation of moisture from the surface cause strong quantity of bogs. The average duration of the frost–free period is 67 days.

Continuous spread of permafrost soils with merging type are typical for this region. The capacity is more than 100 m.

Modern technogenic, quaternary lake-alluvial, as well as quaternary marine and glacial deposits compose the investigated territory to a depth of 40.0 m. Quaternary sediments are represented by plastically frozen loam, with low ice content, icy. Such sediments also consist of medium size sand, frozen, icy.

At this territory, the most distributed geological forms are mounds of swelling, spot medallions, frost-thaw subsidence.

According to thermometric observation in boreholes at the depth from 0 to 5 m the soils temperature was positive (from 7,08°C to 0,01 °C). Above 10 m temperature hesitate from - 0,02 °C to -0,26 °C. Temperature was from - 0,37 °C to -0,93 °C from 10 to 20 m

The soils of the seasonal thawing layer represent by bulk soils. The seasonal thawing and freezing layer depth was from 2,2 to 8 m along the investigations depth.

The processes of permafrost soils degradation may occur within the study area. Frozen soils thawing occurs because of technogenic waters leakage. Permafrost soils degradation appears as:

- formation and increase of technogenic unfrozen pockets;
- activation of dangerous cryogenic processes (especially thermokarst, thermal erosion, rheological processes);

- increasing the seasonal soils thawing depths;
- increasing the temperature in the frozen zone;
- decreasing the bearing capacity of soils;
- activation of cryogenic weathering.

In general, this territory characterizes by:

- high susceptibility of the natural environment to the technogenic impacts;
- widespread of permafrost;
- expand of cryogenic processes.

3 Slope stability assessment

There is a wide range of slope stability methods at present [1]. The choice of the method determines by two factors. The first is the type of landslide process. The second is the mechanism of possible landslide masses displacement [3]. Each method characterizes by original forces system [1]. The last one obtains using one or another assumption. It is associated with the statistical uncertainty of the problem [4-8].

The preferred method of calculations was the class of limit equilibrium methods designed for inhomogeneous slopes [4, 5, 6, 11]. This class include:

- Morgenstern-Price method;
- simplified Bishop method;
- simplified Janbu method.

The geotechnical model for stability calculations bases on the engineering and geological survey's results. The geomechanical models of slopes creation includes construction the geometric model for stability quantifying. Geometric model is schematic representation of the real object structure, its typical division into separate layers and structural elements. The elastic-plastic model of Coulomb-Mohr soil behavior poses an adaptation in the calculations [3].

The slope stability calculations includes the following variants:

1. Slope stability assessment in natural state. Strength properties (table 1) of the calculated geological element (CGE) 3 based on soil section tests on the ground.

Table 1. Soils' properties and the legend for geomechanical scheme (variant 1)

Material Name	Color	Unit Weight (KN/m3)	Cohesion (kPa)	Phi (deg)
1	yellow	19	1	30
2	light green	20	128	34
3	pink	18	14,4	37
4	orange	18	100	

2. Slope stability assessment in forecast state (assuming soaking of CGE). Strength properties (table 2) of the calculated geological element (CGE) 3 based on soil section tests on the moist soil.

Table 2. Soils’ properties and the legend for geomechanical scheme (variant 2)

Material Name	Color	Unit Weight (KN/m3)	Cohesion (kPa)	Phi (deg)
1		19	1	30
2		20	128	34
3		18	31	2,4
4		18	100	

3. Slope stability assessment in forecast state (assuming frost retreat of CGE). Strength properties (table 3) of the calculated geological element (CGE) 3 based on soil section tests on the thawed soil.

Table 3. Soils’ properties and the legend for geomechanical scheme (variant 3)

Material Name	Color	Unit Weight (KN/m3)	Cohesion (kPa)	Phi (deg)
1		19	1	30
2		20	128	34
3		18	6	10
4		18	100	

4 Slope stability assessment results

The considered landslide refers to landslides slip. The analysis of the performed calculations allows making a conclusion that there are two possible mechanisms for activating the landslide process on the slope.

The first mechanism corresponds to the calculation variant 1 (Fig.1). In this case, landslide displacements of soils occur in the embankment body. Calculations performed by the methods of limiting equilibrium in the natural state and with the external load application showed that the slope is in the state of limiting equilibrium ($1,00<S_c<1,25$).

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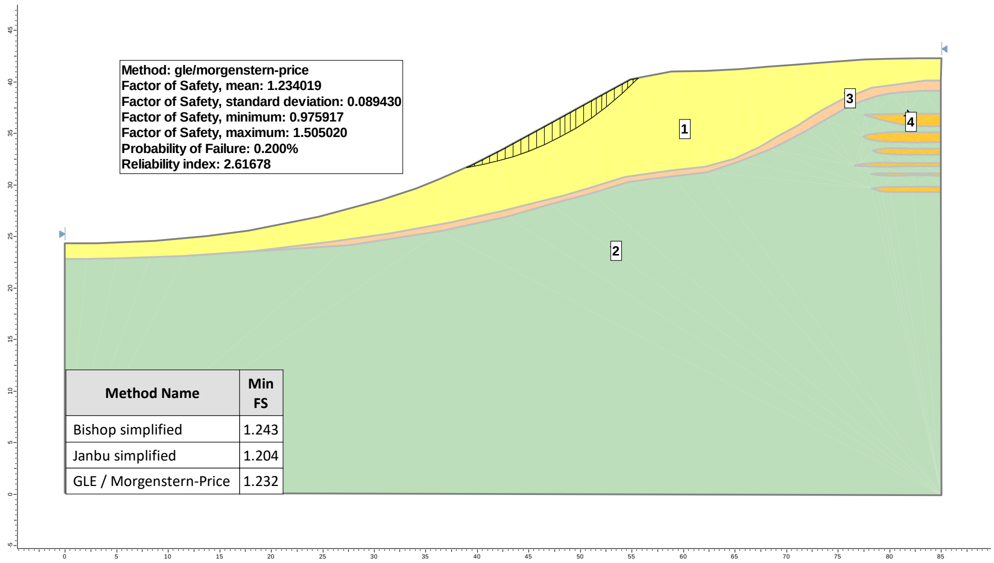

Fig.1. Slope stability assessment with the results of probability analysis made by Morgenstern-Price method (variant 1)

Probability analysis allows assessing the danger of sliding activation [9, 10, 12]. It was 0,2%. Sensitivity analysis of S_c based on the soil heterogeneity in the mound and its strength characteristics [2]. This analysis includes definition of the soil's internal friction angle composing the embankment (Fig. 2). The obtained relation showed that with internal friction angle about 24 degrees the slope becomes unstable (S_c<1.0). The reduction internal friction angle may occur in the case of "clogging" the crushed clayey material. The last one acts, in the case of hydration, as a lubricant. In addition, sensitivity analysis allows assessing the impact of the external load on the calculated S_c. The results showed that the slope loses stability when the external load exceeds 175 kPa.

In this case, the landslide displacement captures the whole embankment. The offset of the mound occurs on the frozen moist loam (main straining horizon (MSH)). This is the underlying bulk soil (option 2). Thawing deformations (in the loams) occur due to penetration the warming surface waters at the well filter gravel in the warm season. The calculations performed on the second variant showed that the slope is in the state of ultimate equilibrium (S_c<1.25). On the third the slope is unstable (S_c<1.0).

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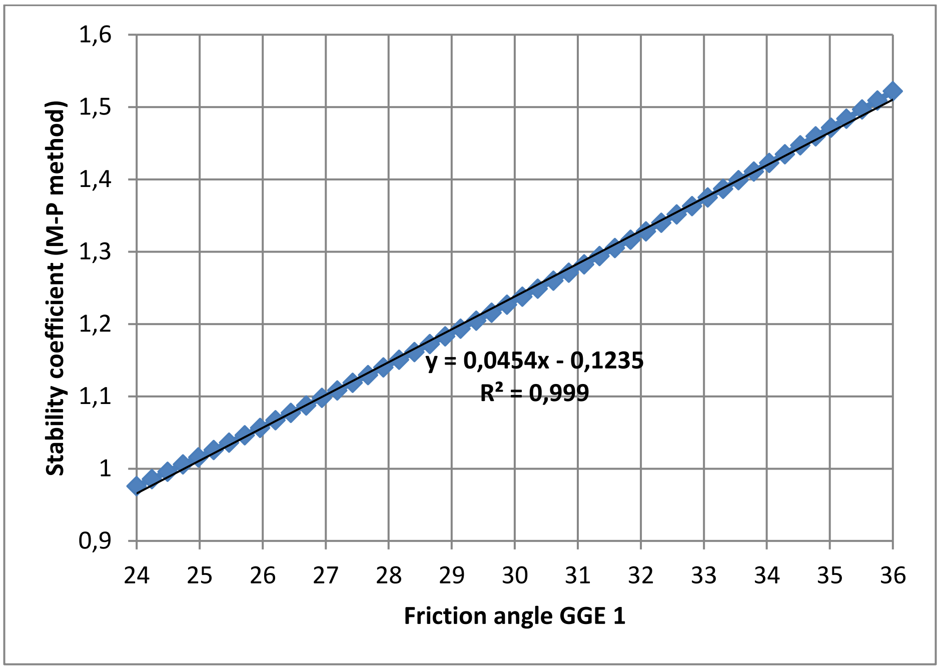

Fig. 2. The relationship between S_c and friction angle of CGE 1

The second mechanism corresponds to variants 2 and 3 (Fig.3, 4).

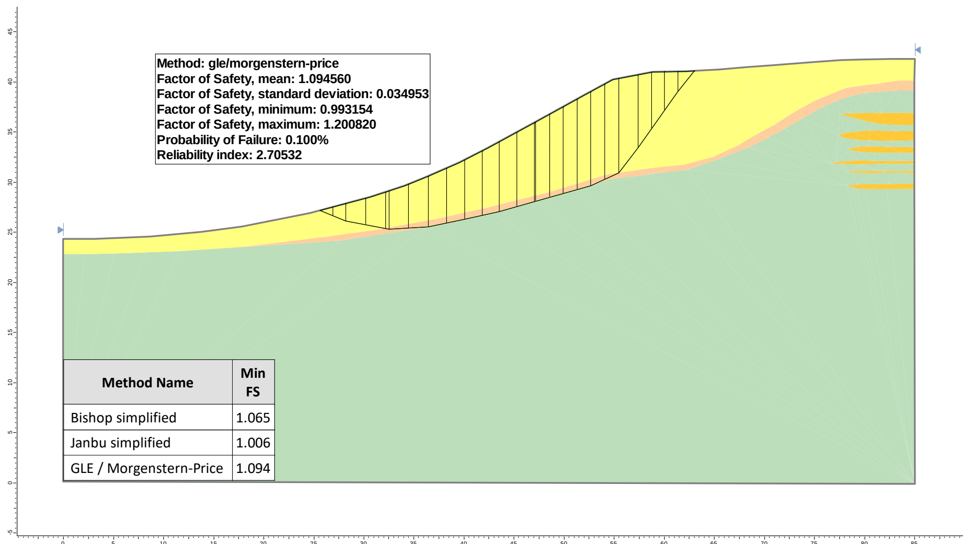

Fig. 3. Slope stability assessment with the results of probability analysis by Morgenstern-Price method (variant 2)

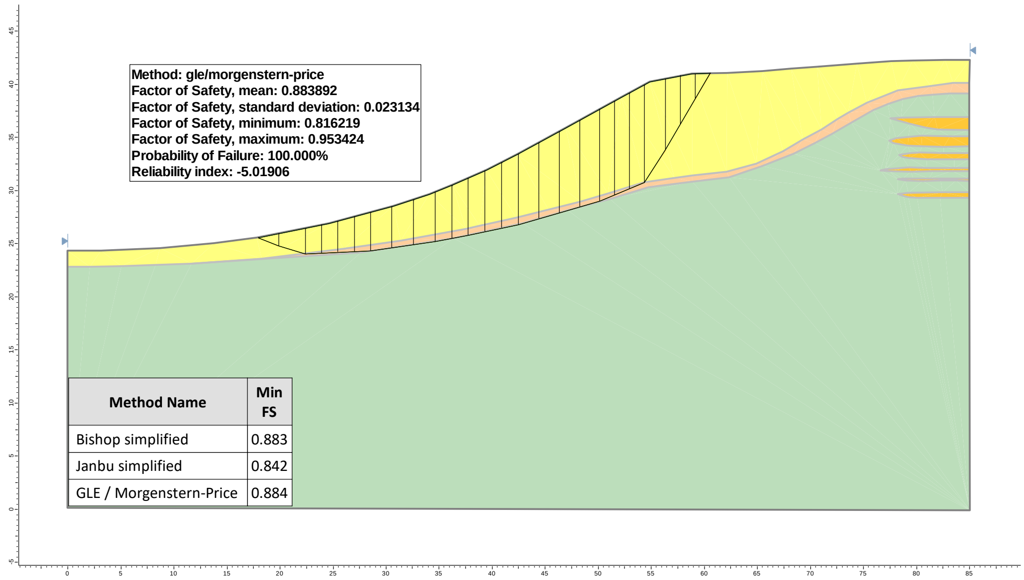

Fig. 4. Slope stability assessment by Morgenstern-Price method (variant 3)

The probability of activation the sliding process for the second variant is 0.1%. Therefore, in spite of the drop in the S_c value sliding hazard has decreased. The probability of activation the sliding process for the third variant is 100%. In case of the third variant slope loses the stability on the base of deterministic and probability analysis.

The estimation results are in the table 4.

Table 4. The results of the calculation by various methods

Estimation methods	Computational methods		
	Morgenstern-Price (M-P)	Bishop	Janbu
Variant 1a	1,23	1,24	1,20
Variant 1b	1,135	1,17	1,11
Variant 2	1,09	1,065	1,01
Variant 3	0,88	0,88	0,84

5 Conclusion

The slope is generally stable (except of the results obtained by the third version of the calculation). This conclusion bases on quantitative assessment the stability by the methods of limit equilibrium.

The main factors of landslide processes activation are:

- significant energy of relief;
- low strength properties of soils during their moistening and thawing;
- artificial interactions.

The high probability of landslide process activation determines the designing and implementation appropriate measures for engineering protection. These measures should be directed to exclude the situation with the third estimation variant. It is necessary to:

1. Organize surface drainage, providing interception of surface runoff at the site and (or) waterproofing of the slope. It happens to prevent the groundwater horizon formation and thawing of MSH soils.

2. Develop the project of pile restraining structure combine with heat stabilizer. This solution will prevent the thawing of MSH soils. It will significantly reduce the risks of sliding process activation on the slope.

The implementation of proposed measures will ensure regular operation without negative engineering and geological processes. It is necessary to create a system of operational monitoring to ensure quality control. The system should monitor for development the negative engineering and geological processes. Thermal logging of soils within the core and measure the level of groundwater in the spring and summer organizes to clarify the calculations and select the optimal solution.

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