Peculiarities of protection of railroad tracks from snow drifts in the arctic zone

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Abstract. The natural and climatic conditions of Russia's Arctic zone require special designs and technological solutions for railroad operation, due to the simultaneous presence of permafrost soils and gigantic volumes of snow transport. The article talks about the need for theoretical justification of calculation schemes for permafrost processes.

1 Introduction

The volume of wind snow transport in the Arctic zone reaches 1000-1500 m3/m per year, exceeding by 7-10 times similar values for the central regions of the European territory of the country. The winter period is also characterized by a peculiar wind regime, rare thaws, and a large number of days with snowstorms (Fig. 1).

Fig. 1. Examples of snow drifts on the Yamal Peninsula.

Blizzards are known to have a great impact on the snow-bearing capacity of the track superstructure (rails, sleepers, and ballast). In this case, snow removal equipment will be used for snow removal [1, 2]. Also, rails are greatly affected by low temperatures. The creation of modern varieties of rail steel melting is aimed, among other things, to combat the effects of low temperatures in the track facilities [3].

The construction and operation of railroads in the Arctic zone pose a special challenge to designers and operators: to effectively prevent disruptions in the transportation process, disruption of safety, and uninterrupted train traffic due to snow drifts [4, 5].

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At present, protective afforestation, permanent snow fences of various designs, and portable shields are most commonly used to combat snow drifts on railroads [6].

However, in the Arctic zone, the above methods of snow-fighting are not directly applicable:

First, due to the harsh climate and insignificant active layer over permafrost soils, the tree and shrub vegetation is very sparse [7, 8];

Secondly, the snow collection capacity of two or three rows of snow retardant fences is not enough, a construction of more rows requires significant costs and land acquisition, and is not everywhere possible.

2 Materials and methods

The complex geocryological conditions of the Arctic zone further complicate the task of snowmaking. Permafrost soils of categories III-IV of subsidence are widespread in the area in question, and the ice content of the soils reaches 0.5 d.u. and more. Areas with dangerous geocryological processes require special attention: thermal erosion, thermal karst, solifluction, permafrost frost mounds, and various slope processes.

Highly frosty permafrost soils turn into a liquefied mass during thawing, losing their carrying capacity [9]. One of the factors affecting the thawing of permafrost soils is the increase in snow deposits. They prevent the cold from entering the ground, thus violating the annual heat balance, and the permafrost degrades. In terms of the nature of the impact of snow deposits on the operation of the railroad track, not only their mechanical impact but also the thermal impact should be taken into account. The graph shows the dependence of the ground temperature at the depth of zero amplitudes on the average winter height of the snow cover for different regions of the Arctic zone (Fig. 2) [10].

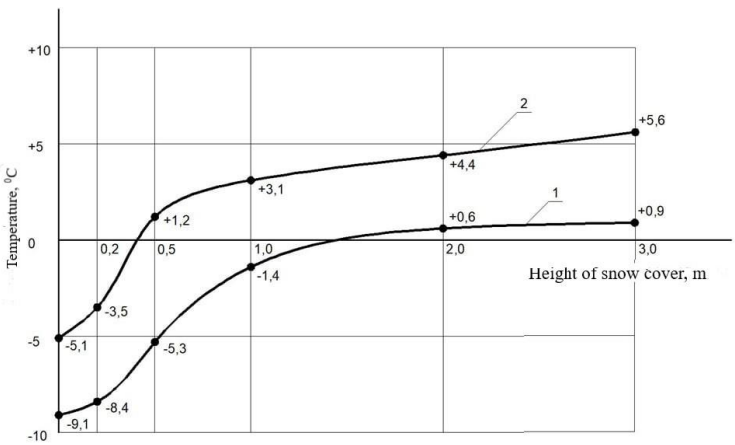

Fig. 2. Dependence of the ground temperature "t" at the zero-amplitude depth on the average winter height "δ" of the snow cover in the steady-state mode.

1-Kharasavey port area, 2-Salekhard city area

It is also necessary to take into account the thermal influence of snow deposits not only on the slopes of the earth bed but also on the adjacent territory. The point is that the temperature of any point in the ground, located at a depth h from the surface, is thermally influenced by a zone located on the surface with radius R, equal to R=2 h, m. In this case, the center of the zone is located above the point of interest. Or the temperature at an arbitrary point "0" will be determined by the sum of thermal influence from the area with radius R=2 h (Fig. 3).

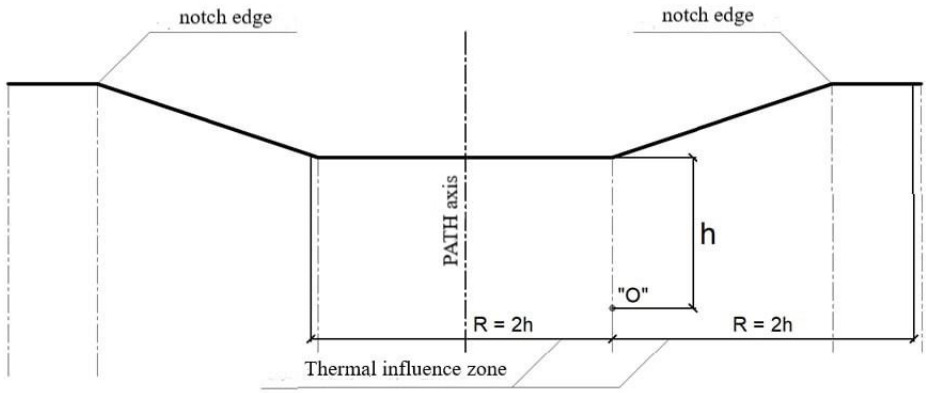

Fig. 3. Zone of thermal influence of the adjacent soil mass.

In the existing standards, according to the principle of operation, all means of protection against snow drifts can be divided into three groups: snow retardant, snow blowing, and snow insulating.

The first group includes protective forest plantations, permanent fences, and portable shields.

The second group includes snow-blowing fences.

The third group includes galleries, tunnels, and tunnel-type excavations.

The groups comply with international norms and standards [11,12].

The disadvantages of the aforementioned means of snow protection, as applied to the Arctic zone, are:

– focus on protection against the mechanical effects of snow, i.e. directly against skidding off the track, the thermal effect of snow is not taken into account;

– does not take into account the thermal impact of snow accumulations within the snow protection means themselves.

An additional negative effect of making the wrong design decisions on the choice of snow protection methods is the violation of the environmental safety of the territory, due to the development of dangerous geocryological processes. Moreover, the Arctic zone is an area where the disturbed natural conditions are very slow to recover.

3 Outcomes

It follows from the above that in the conditions of the Arctic zone snow-retarding structures need new technical solutions.

Thus, snow control on the linear part of the railroad should be implemented already at the design stage, laying, where possible, snow-carrying cross sections that freely let the snow pass by without trapping it. The absence of snow deposits excludes their mechanical and thermal impact on the operation of the track.

As for the wide earth bed, for example, at split points, it is impossible to ensure unobstructed passage of the snow and wind flow [13]. In this case, it is reasonable to develop a new direction of snow protection-snow guiding. The essence of this type of snow protection is not to hold the snow, but to direct it past the object. The snow-stopping fences described above can be used for this purpose. These fences are placed at an angle to the wind direction, allowing the snow stream to flow around the protected object.

For the characteristic conditions of the Arctic zone, a new classification of means of protection against snow deposits is proposed, allowing to take into account the specifics of permafrost soils (Fig. 4).

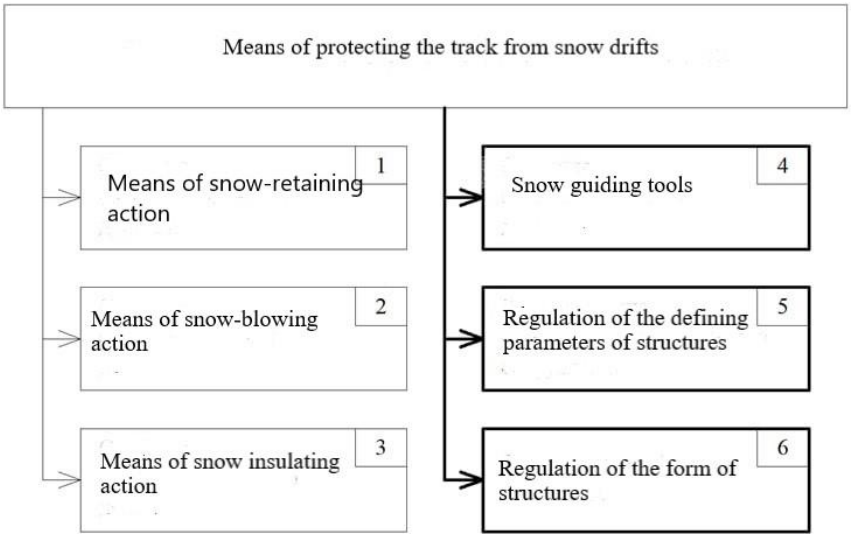

Fig. 4. Classification of track protection against snow drifts.

The first three groups of protective equipment in the classification repeat all three groups given in the current regulatory documents.

The fourth group-means of snow-guiding action.

The fifth group is the adjustment of the defining parameters of the structure.

The construction parameters mean the ratio of the line plan, longitudinal and transverse profiles with the terrain relief, and the snow drift rose. Exclusion of snow-carried areas without overestimating the volume of earthworks.

The current design standards require that the track be protected from snow drifts along all snow-covered sections. For Arctic conditions, at the design stage of the railroad, from the point of view of snowmaking, snow-bound sections, such as the following, should be eliminated as much as possible:

- notches on the curves in the plan;
- excavations in watersheds.

The six groups of means for protecting the track from snow drifts-regulation of the shape of the structure is of particular importance. This means regulating the configuration of the embankment and excavation cross-section, in particular, by changing the slope of the slopes, regulating the shape of the slopes at the bank slopes, regulating the shape of buildings, etc.

For example, changing the steepness of embankment slopes changes the volume of snow deposits. Fig. 5 shows the configuration of snow deposits on the slope and at the bottom of the embankment for slopes of different steepness. This pattern is observed throughout the Arctic zone.

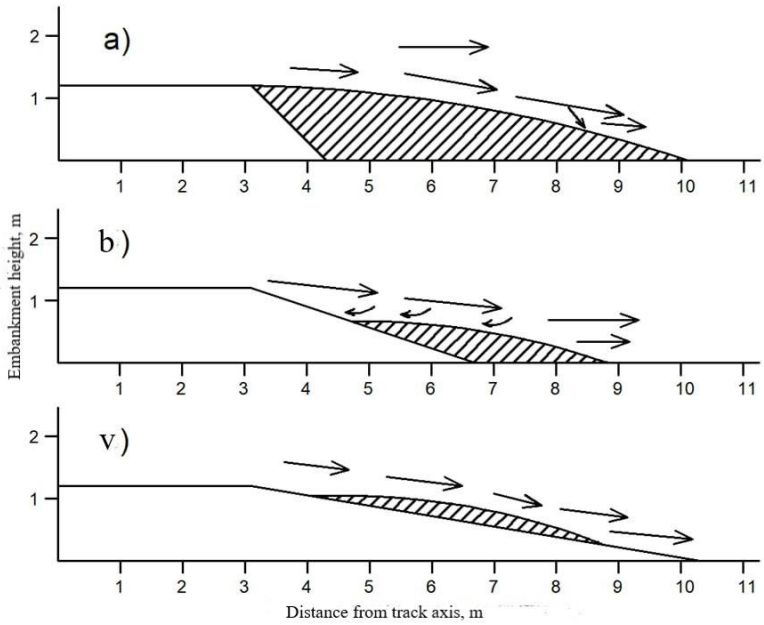

Fig. 5. Effect of obstacle slope on snow carrying capacity. a) slope setting 1:1, b) 1:3, v) 1:6; the bold arrow indicates the wind direction, and the shaded area is the snow-bearing zone.

4 Discussion/ Analysis of Outcomes

Climatic and permafrost and soil conditions of the Arctic zone differ significantly from those of the average strip. Permafrost, the widespread presence of high-gravity soils and buried ice, as well as the need to respect the region's ecology, require special (unique) technical solutions for railroad construction. The development of a new classification of snowmaking methods makes it possible to combine the elements of the ground and snow protection structures into a single system and, at the design stage, to select solutions that meet the requirements of high efficiency and cost-effectiveness of transportation structures when operating in the Arctic zone.

The classification of snow removal methods is based on four classification criteria: time of action; the principle of operation; effect on the state of permafrost soils; and relation to construction objects (Fig. 6).

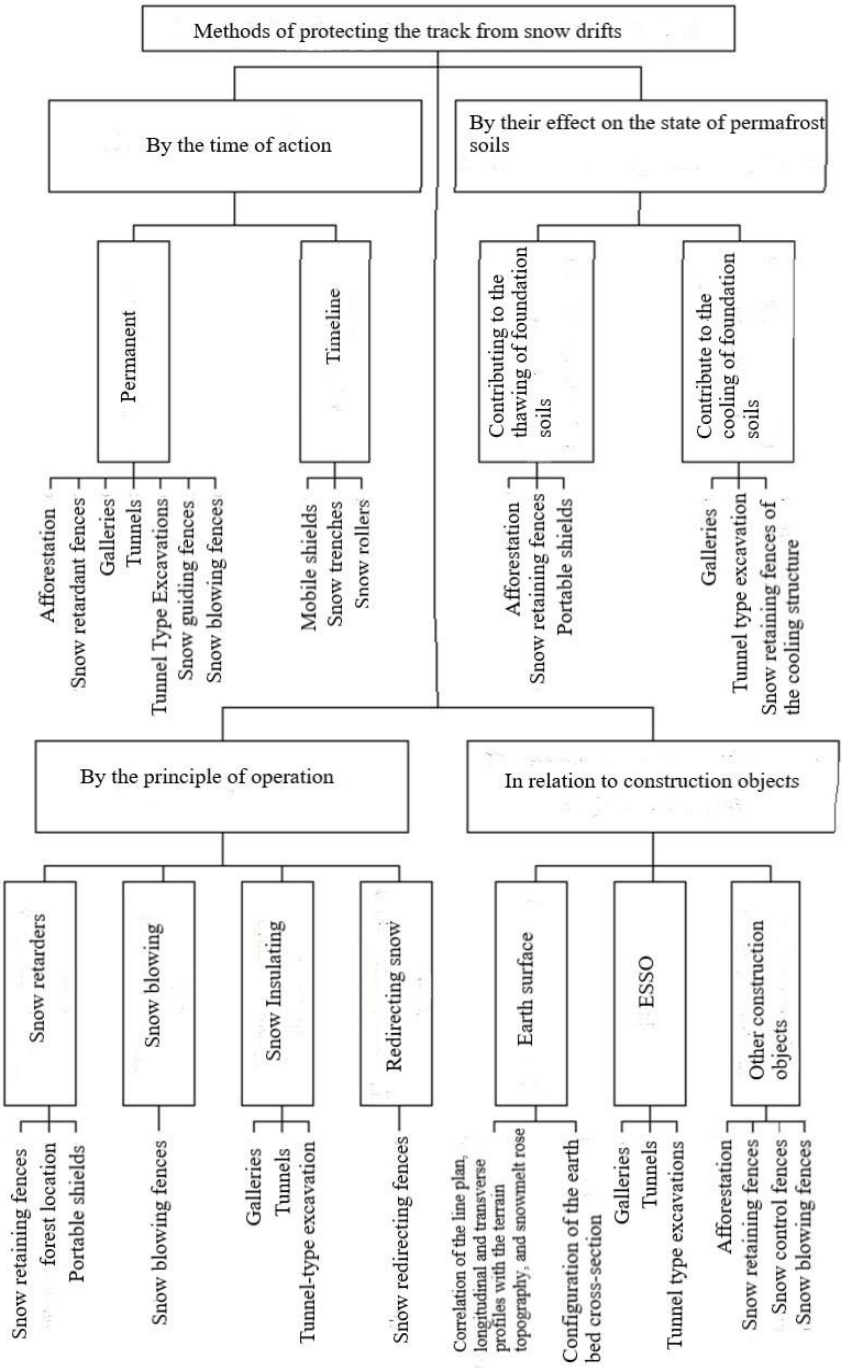

Fig. 6. Classification of track protection methods against snow drifts.

The following should be noted in the proposed classification.

Methods of protection according to the principle of operation are supplemented by the method of redirection of snow (snow-guiding means).

The classification feature-the relation to the objects of construction was singled out. According to this feature, the methods implemented directly in the construction of the earth bed are distinguished:

– correlation of the line plan, longitudinal and transverse profiles with the terrain relief, and the snow drift rose (adjustment of the defining parameters of the structure),

– configuration of the cross-section of the embankment, and excavation (regulation of the shape of the structure).

A classification feature is the effect of snow protection on the state of permafrost soils [14]. According to this feature, snow protection methods are divided into those that promote the thawing of permafrost soils and those that promote the cooling of soils.

The stability of an earthen bed is determined by its design and the influence of the external environment, which affects the state of the soil environment. Thus, when designing a railroad in the Arctic zone, considering the influence of natural and climatic conditions in the area, it is necessary to take into account the melting effect of snow deposits caused by the construction of the earth bed and the implementation of snow protection measures.

It should be noted:

Firstly, measures within the framework of snow protection measures aimed at reducing the mechanical impact of snow (snow drifting off the track) and measures aimed at reducing its thawing impact often contradict each other. For example, increasing the height of the embankment leads to reducing the value of track drifting, but promotes the accumulation of snow deposits at the bottom of the embankment, which contributes to thawing or degradation of permafrost; the creation of snow barriers also promotes permafrost degradation within them, which may lead to serious deformations of ground massifs in the area of the railroad itself in the presence of buried ice [15].

Second, the consequences of thawing of permafrost soils vary (from insignificant to dangerous with an unpredictable outcome) and depend on both the characteristics of the soils and the terrain.

The process of designing railroad track in the Arctic zone requires theoretical justification of calculation schemes of permafrost processes, based on which an engineering and practical method of solving the system "subgrade - snow protection measures" should be implemented

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