

Original article

UDC 625.1

doi: 10.46684/2026.2.4

EDN: BXYGEB

Unconventional solutions for exploiting harsh Arctic conditions in railway construction

Alexey V. Seleznev¹, Lyudmila S. Blazhko²

^{1,2} Emperor Alexander I St. Petersburg State Transport University; Saint-Petersburg, Russian Federation

¹ seleznev_alrxei@mail.ru; <https://orcid.org/0009-0005-6653-5184>

² lydmila.blazhko@gmail.com; <https://orcid.org/0000-0001-5209-6778>

ABSTRACT Railway construction in the adverse climate and environmental conditions of the Arctic Zone in Russia is characterized, on the one hand, by a shortage of local soils of suitable quality due to the prevalence of ice-rich soils in the area, and on the other hand, by a significant increase in requirements for soil material as a result of levelling off the terrain along the route on permafrost soils by building embankments, almost without excavations. All these are factors that make construction significantly more expensive. The authors offer engineering solutions for a significant reduction in the amount of excavation work and requirements for local soil material when building the subgrade.

The primary features of the climate and environmental conditions in the Arctic Zone include huge amounts of snow transport and severe geocryological conditions. The selection of a route location for a project is heavily complicated by the highly developed destructive geocryological processes, with one of them being the downslope viscoplastic flow of waterlogged fine-grained soils in the conditions where they alternately freeze and thaw and are influenced by gravity (solifluction).

The paper presents a technology for modifying the terrain by means of artificial solifluction in areas where a line crosses terrain obstacles, and describes the solutions for both inducing and halting solifluction within the desired limits. The authors discuss the most promising applications of artificial solifluction, such as local terrain obstacles and approaches to bridges crossing non-navigable rivers.

The study puts forward a hypothesis that soils in the base of railway embankments are thermally stabilized by snow deposits as they accumulate in winter and persist through the warm season, and proposes solutions for long-term preservation of snow deposits at the toe of embankments.

KEYWORDS: permafrost soils; soil thaw; solifluction; railway design; construction site preparation; icy soils; snow deposits; snow melting; snow preservation

For citation: A.V. Seleznev, L.S. Blazhko. Unconventional solutions for exploiting harsh Arctic conditions in railway construction. *BRICS Transport*. 2026; 5(2):4. <https://doi.org/10.46684/2026.2.4>. EDN: BXYGEB.

Научная статья

Нетривиальные решения использования суровых условий Арктической зоны в железнодорожном строительстве

А.В. Селезнев¹, Л.С. Блажко²

^{1,2} Петербургский государственный университет путей сообщения Императора Александра I; г. Санкт-Петербург, Россия

¹ seleznev_alrxei@mail.ru; <https://orcid.org/0009-0005-6653-5184>

² lydmila.blazhko@gmail.com; <https://orcid.org/0000-0001-5209-6778>

АННОТАЦИЯ Строительство железных дорог в неблагоприятных природно-климатических условиях Арктической зоны России характеризуется, с одной стороны, дефицитом кондиционных местных грунтов, вызванным широким распространением высокольдистых грунтов; с другой стороны, значительным увеличением потребности в грунтах,

© Alexey V. Seleznev, Lyudmila S. Blazhko, 2026

© Translation into English. *BRICS Transport*, 2026

вследствии спрямления рельефа трассы на многолетнемерзлых грунтах за счет сооружения насыпей, практически исключая выемки. Все это факторы значительного удорожания строительства. Предложены технические решения, позволяющие значительно сократить объемы земляных работ и потребности в местных грунтах при строительстве земляного полотна. К особенностям природно-климатических условий Арктической зоны прежде всего следует отнести гигантские объемы снеготранспорта и сложные геокриологические условия. Сильно развитые деструктивные геокриологическими процессами, одним из которых является вязкопластическое течение переувлажненных тонкодисперсных грунтов на склонах в условиях их попеременного промерзания, протаивания и действия силы тяжести (солифлюкция), значительно усложняют выбор трассы объекта.

Изложена технология изменения рельефа на участках пересечения трассой рельефных препятствий путем искусственной солифлюкции. Описаны решения, как провоцирования процесса солифлюкции, так и его остановки в требуемых границах. Рассмотрены наиболее перспективные области применения искусственной солифлюкции: локальные рельефные препятствия и подходы к мостам через несудоходные реки.

Выдвинута гипотеза о термостабилизации грунтов оснований железнодорожных насыпей снежными отложениями, за счет их накопления зимой и сохранения при наступлении теплого периода. Предложены решения по длительной консервации снежных отложений у подошвы насыпей.

КЛЮЧЕВЫЕ СЛОВА: многолетнемерзлые грунты; растепление грунтов; солифлюкция; проектирование железных дорог; подготовка территории строительства; льдистые грунты; снежные отложения; таяние снега; сохранение снега

Для цитирования: Селезнев А.В., Блажко Л.С. Нетривиальные решения использования суровых условий Арктической зоны в железнодорожном строительстве // Транспорт БРИКС. 2026. Т. 5. Вып. 2. Ст. 4. <https://doi.org/10.46684/2026.2.4>. EDN: BXYGEB.

INTRODUCTION

The strategy of the Russian Federation for the development of railway transport puts a major focus on the construction of railway corridors to link ports in the Pacific and Indian Oceans with destinations along the Northern Sea Route¹. A considerable number of these routes run through the Arctic Zone.

The region in question features thaw-weakened permafrost soils; therefore, a guiding principle in designing the subgrade on these soils is to level off the terrain by building embankments and using almost no excavations. This approach requires a significant amount of excavation work. A shortage of local soils of suitable quality for building the subgrade is a substantial factor affecting the cost and length of construction projects in the Arctic region. It is even more challenging when a railway line extends further to the north where ice-rich permafrost soils are more prevalent.

Due to the shortage of local soils of suitable quality, the distances from the quarry to the construction site are significantly longer. Construction of railway lines in high altitudes is significantly more expensive because there is almost no road infrastructure in the area of construction, soils can only be delivered by winter snow roads (in the warm season, dump trucking in the tundra zone is prohibited), and building on-site storage areas for the soil material is very costly.

The following should be addressed in order to reduce the amount of excavation work and require-

ments for the local soil material to build the subgrade when constructing railways in the Arctic Zone:

- Reduce the route development ratio by bypassing terrain obstacles while lowering the embankment height;
- Lower the embankment height on approaches to bridges over non-navigable rivers; and
- Switch to subgrade transverse profiles with steeper slopes.

When addressing the above objectives, it is, first of all, necessary to take into account the adverse climate and environmental conditions in Russia's Arctic Zone, such as collapsible ice-rich permafrost soils in combination with huge snow transport volumes, which can reach as much as 1,000–1,500 m³/m per year. The former requires engineering solutions to keep the base soils frozen both during the project construction period and throughout its operation period and to prevent any destructive geocryological processes, such as thermokarst development [2, 3]. The latter requires both engineering and operational solutions to effectively prevent disruptions in the transportation process, safety failures, and interruptions in train traffic due to snowdrifts.

Below, we describe possible solutions for integrating some of the adverse climate and environmental conditions in the Arctic Zone into construction and operation of railway lines in order to improve their reliability and reduce the cost of building the subgrade.

¹ Transport Strategy of the Russian Federation until 2030 with a Forecast until 2035, approved by Order of the Government of the Russian Federation No. 3363-r dated November 27, 2021. URL: <http://static.government.ru/media/files/7enYF2uL5kFZlOOpQhLlOnUT91RjCbeR.pdf>.

ARTIFICIAL SOLIFLUCTION FOR PRE-CONSTRUCTION MODIFICATION OF TERRAIN

As it is obvious that the flatter the railway area, the lower the line's route development ratio is and the lower the embankment heights are, the question is, how can we modify the existing terrain and reduce the number of local terrain obstacles? The answer was obtained from years of observation over construction projects in the permafrost zone. The analysis reviewed cases when construction operations triggered the flow of fine-grained soils on slopes as they thawed, the time it took to stabilize the slopes, and final construction outcomes. It has been found that it is possible to level off the terrain during the preparation for the construction phase.

It is proposed to level off the terrain along the construction project's route at sections comprised of

thaw-weakened icy and ice-rich permafrost soils by activating or triggering solifluction, that is the flow of fine-grained soils on slopes (with an angle of 2–3 grades or more) in the conditions where they alternately freeze and thaw and are influenced by gravity. The plastic flow of fine-grained soils occurs on the not-yet-thawed, slippery surface of the frozen lower layer. Where the topsoil is not available or destroyed and the thawed layer, particularly its lower part, is strongly moistened due to the ice it contains and filtration of moisture from above, the solifluction process turns into the downslope runoff of soil in thin layers [4].

Inducing solifluction on predetermined sections during the pre-construction phase involves full or partial removal of the topsoil and activation of horizontal thawing. This significantly accelerates the formation of a flowing thawed layer during the warm season (Fig. 1).

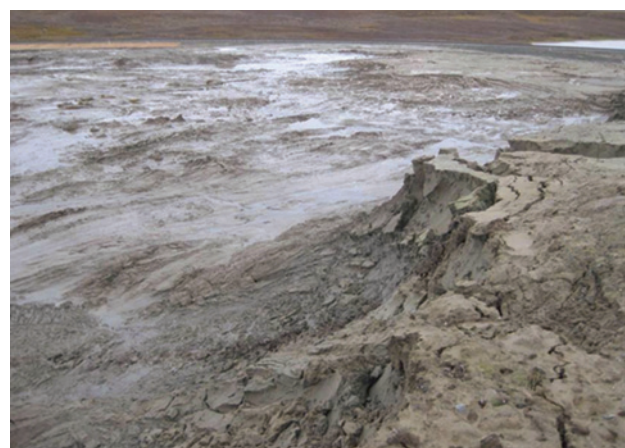


Fig. 1. Run-off of the thawed-out soil after the topsoil removal

The technology for railway construction in the Arctic Zone was developed by employees of the Railway Track Department of the Emperor Alexander I St. Petersburg State Transport University in cooperation with the Laboratory of Engineering Thermophysics and is known as “Artificial solifluction” [5].

Thaw-weakened soils of the elevation flow down the slope, leaving the surface without any thermal resistance to environmental factors (wind, solar radiation, and

rain). This creates a vertical surface (bench) that soon begins to move horizontally. The vertical size of the bench depends on the soil characteristics and the configuration of the rise. The thawed-out soil or ice flows downslope and, where the slope of the terrain at the foot of the elevation is longitudinal, towards lower elevations (Fig. 2). The natural grade of the slope resulting from the soil flow is much more gentle than the original one because the upper part of the slope has flowed down.

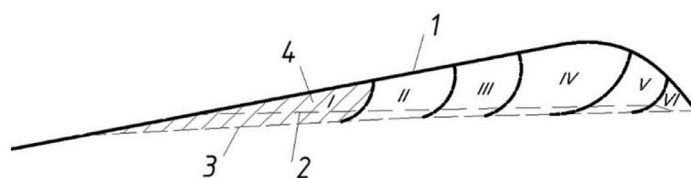


Fig. 2. Changes in the slope of an elevation comprised of thaw-weakened soils as a result of slope cutting:
1 – natural slope surface; 2 – stabilized slope surface after the deformations; 3 – design slope;
4 – original area of slope cutting with flattening; I–VI – deformation development stages

Artificial solifluction is effective as it requires minimal labour costs for excavation operations as the terrain levels off “automatically”.

In a construction project, the amount of artificial solifluction should be predictable. During the artificial solifluction, a terrain obstacle is eliminated/destroyed

either to the point where the flowing soil body reaches a balanced state, or after the elimination of thawing conditions on a gentle slope by covering the exposed vertical surface (bench) to provide a thermal shield.

The thermal shield at the border of the artificial solifluction area is provided in advance [6]. To this end, a solution for protecting the adjacent area has been developed (Patent No. 2769793 C1) [7]. A protection block with estimated height h and breadth b is built from suitable local soil at the upper border of the area where the profile is created (Fig. 3).

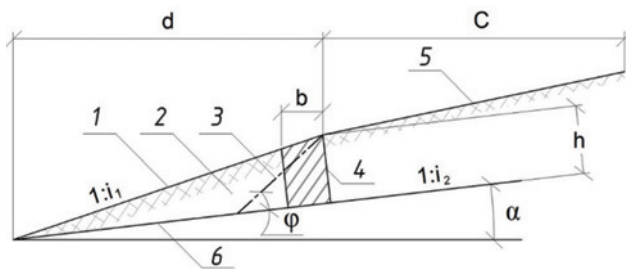


Fig. 3. Structure diagram of the thermal shield at the border of the artificial solifluction area: d – the area with moss and vegetation removed; C – the area with undisturbed natural conditions; b and h – the breadth and height of the protection block, respectively; $1:i_1$ – the original slope; $1:i_2$ – the resulting slope; 1 – the original slope surface; 2 – the flowing soil body; 3 – the slope of the protection block after the slope stabilization work; 4 – the protection block; 5 – the natural slope surface; 6 – the slope surface after artificial solifluction; ϕ – the slope angle of the protection block; α – the angle of the resulting slope

The resulting profile is stabilized either naturally or by implementing other engineering solutions, such as installing thermal insulation or anti-erosion structures on the slope. It is also possible to use a combination of these solutions.

ARTIFICIAL SOLIFLUCTION ON APPROACHES TO BRIDGES

Artificial solifluction on approaches to bridges where the river valley is narrow, the slopes of the terrace above the floodplain are steep, and the difference between the water line and the valley-side edge is large provides an additional technical and economic effect due to a significant reduction of the bridge length and abutment height, which is of great relevance for crossing non-navigable rivers in the Arctic Zone.

In terms of preserving the ecology of the riverbed by the withdrawal of soils through the artificial solifluction of the slopes of the terrace above the floodplain, it should be noted that the process is similar to the formation of a riverbed (channel meandering) through the river development cycles.

HYPOTHESIS FOR THERMAL STABILIZATION OF EMBANKMENT BASE SOILS BY SNOW DEPOSITS

On railways in the Arctic Zone, a snow-resistant subgrade is built to prevent the accumulation of snow. The transverse profiles of such a subgrade are built with gentle slopes (steepness of 1:3 to 1:5 or gentler). Flattening the subgrade slopes is not only an effective means of snow control, but it also minimizes deposits of snow at the toe and on the slopes of the embankment. Fig. 4 shows how snow deposits depend on the slope grade². Field observations over excavations with beach slopes on the Obskaya–Bovanenkovo–Karskaya railway line confirm that snow deposits follow this pattern (Fig. 4, c).

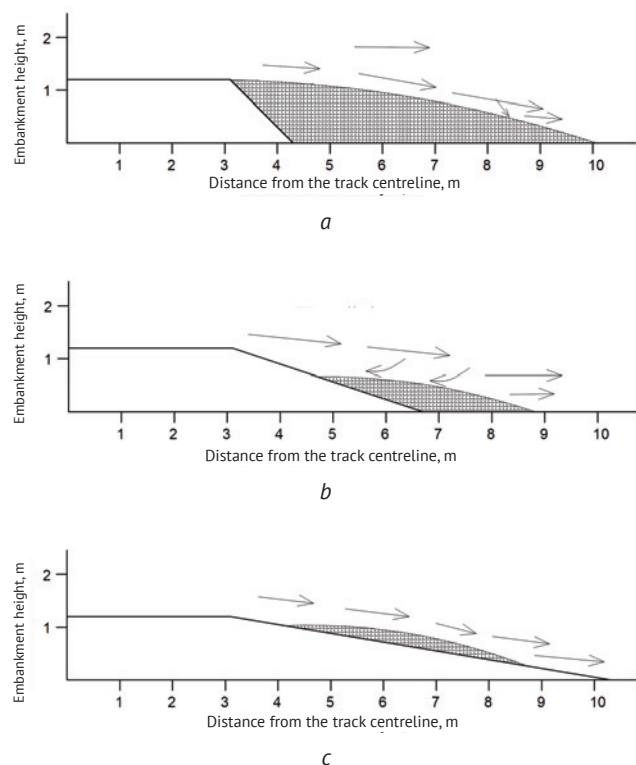


Fig. 4. Influence of obstacle / slope grade on snow accumulation: a – 1:1 slope, b – 1:3 slope, c – 1:6 slope; the arrows show wind direction; the shaded area indicates the area of snow deposits

Increasing snow deposits at the toe and on the slopes of the embankment disturbs the heat balance of the base soils, making them thaw, promoting thermokarst activity and, hence, deformation of the subgrade. Fig. 5 shows how the temperature of permafrost soils changes with an increase in snow deposits. Depending on the air temperature, snow accumulation patterns, and snow cover density, the graphs of soil temperature behaviour have different numerical parameters, but similar profiles.

² Snow. Handbook. Leningrad. Gidrometeoizdat. 1986:607.

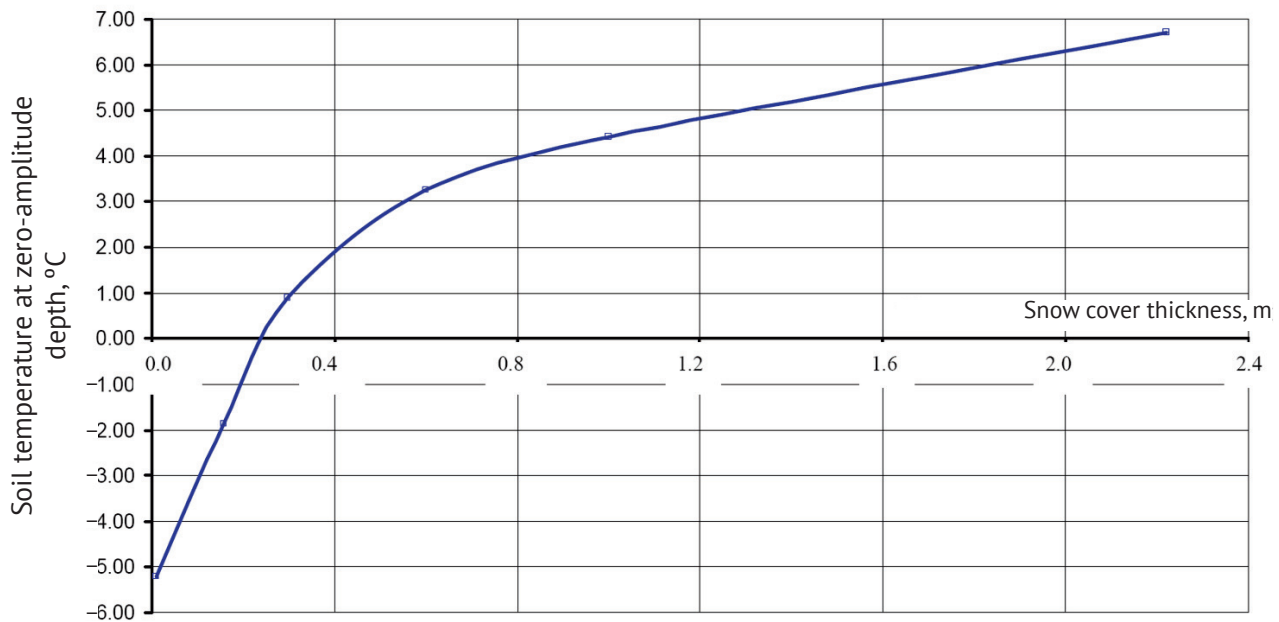


Fig. 5. Dependence of soil temperature at the zero-amplitude depth in a steady state on snow cover thickness

Observations over transport facilities and terrain irregularities on the Yamal Peninsula show that in this region, the slope grade of snow deposits ranges between 1:5 and 1:10 and gentler. Besides, the further north a site is located, the lower the grade of snow accumulation at an obstacle is. A combination of the factors such as extending railways to the north of the permafrost soil area and global climate warming will require subgrades with even gentler slopes for a streamlined transverse profile.

The increasing flatness of subgrade slopes leads to a significant increase in the width of the embankment toe which is comprised of the subgrade width (the distance between the shoulder lines) and two slope projections on the earth surface, i.e. to an increase in the area with the disturbed natural

ground surface and to an increase in the area where the thermal balance of base soils and hydrological conditions are disturbed.

Fig. 6 presents a comparison of the subgrade's transverse profile with slopes of varying steepness and Table 1 lists requirements for the soil material for the embankment (excluding the fill volume for the protective layer which, in the areas in question, is only built using the off-site sand, crushed stone and gravel mix) and the area of the embankment toe. An analysis of these data shows that flattening the embankment slopes increases the amount of excavation work several times. As a result, in high altitudes, railway construction becomes increasingly costly and, given the shortage of suitable local soils, hard to implement.

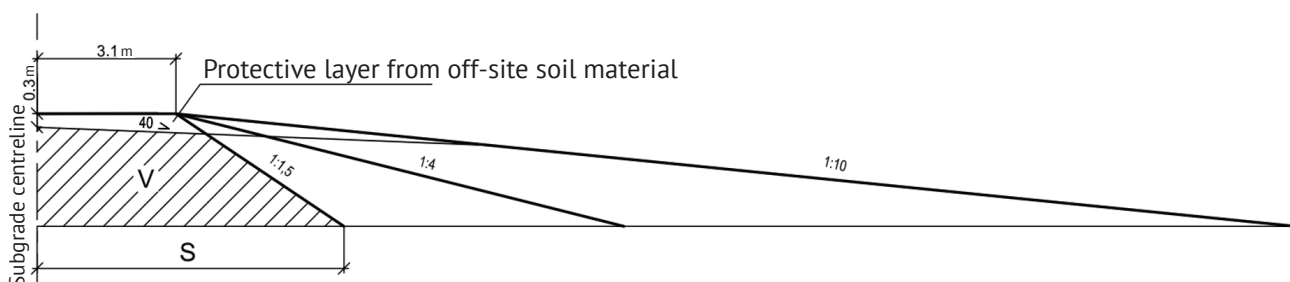


Fig. 6. Transverse profile of the subgrade with slopes of varying steepness

Switching to transverse profiles of the subgrade with steeper slopes will require addressing the earlier mentioned issue of thermokarst development at the toe of the embankment. At present, to prevent thermokarst activity, foam polystyrene heat insulating shields are installed both within the subgrade and in the adjacent area³. A shortcoming of this engineering solution is that

heat insulation not only prevents heat from getting to the subgrade body during the warm season, but also prevents soil freezing during the cold season. Worth mentioning are two conditions typical of the Arctic Zone: First, the average annual air temperature is negative, and second, the beginning of the cold season does not always coincide with significant snowfalls and snow transport.

Table 1

Requirements for soil material (V) for building the subgrade (without a protective layer) and the toe area of the embankment

Slope steepness, 1:m	Embankment height, m					
	1.5		2.5		3.5	
	V, m ³	S, m ²	V, m ³	S, m ²	V, m ³	S, m ²
1:1.5	10.14 (100 %)	10.6 (100 %)	22.34 (100 %)	13.6 (100 %)	37.54 (100 %)	16.6 (100 %)
1:4	15.2 (150 %)	18.2 (172 %)	37.4 (167 %)	26.2 (193 %)	67.6 (180 %)	34.2 (206 %)
1:10	26.54 (262 %)	36.2 (342 %)	72.73 (326 %)	56.2 (413 %)	138.92 (370 %)	76.2 (459 %)

Studying the process of spare snow accumulation for skiing tracks in case of a dry winter enables us to put forward a hypothesis that soils at the base of railway embankments are thermally stabilized by snow deposits, and this prevents the thermokarst development when subgrade slopes are steeper.

In the cold season, the increasing amount of snow deposits contributes to thawing of the permafrost as this prevents the heat exchange between the warm soil and the cold environment. However, if we preserve the snow cover during the warm period, it will serve as a cooling factor, as it will shield the soil from the environmental heat.

Melting of the snow cover is a complex combination of heat-and-moisture exchange between the atmosphere and snow, snow and soil, and a number of processes that take place in the snow mass, such as evaporation and crystallization, consolidation and deconsolidation, formation of firn and ice, and so on [8]. Snow melting is influenced by a variety of local conditions, such as snow stratigraphy, density, availability of a vegetation cover, snow surface pollutants, topographies, etc. But the primary meteorological factors affecting snow melting are the average daily air temperature, average daily vapour pressure in snow layers, wind velocity, and total solar radiation.

When elements of the complete heat balance of the snow surface are explicitly used in the snow melting model, it is considered as a physical energy balance model [9]. The general formula for the energy balance model in a snow melting environment looks as follows:

$$L_s \cdot M_s = R_s + Q_E + Q_s + Q_G + Q_p, \quad (1)$$

where L_s is the specific heat of snow melting; M_s is the amount of melting snow; R_s is the radiation balance of the snow surface; Q_E is the latent heat flux from evaporation from snow; Q_s is the sensible turbulent heat flux; Q_G is the heat flux from the soil; and Q_p is the heat transferred to the snow mass by rain.

Snowdrifts are highly thick and dense. The density of snow in snowdrifts is usually 0.25 to 0.35 g/cm³, but after a long exposure to strong winds, which is typical of the Arctic Zone, the density of snowdrifts reaches 0.40 to 0.50 g/cm³. These snow deposits can support the weight of

a human or a Trekol all-terrain vehicle. It is important to note that the left-hand side of equation (1) increases with the increase in the density of snow deposits. Therefore, all other things being equal, their melting time increases, too.

The temporal and spatial variability of snowmelt characteristics are mainly determined by variations in meteorological variables, such as air humidity, air temperature, precipitation, wind speed, and radiation absorption. While construction solutions and railway operation cannot influence air temperature alone, the other meteorological variables involved in snowmelt can be influenced by engineering solutions. By reducing wind blowing over the snow surface, ensuring that the snow surface is dense and even, reducing the absorption of radiation energy by the snow, and reducing rainfall on the snow, it is possible to significantly extend the duration of the snow cover at the embankment toe during the warm season, thereby improving the temperature balance in the permafrost soils of the base.

The influence of precipitation (rain) and wind (heat flux and evaporation) on snow deposits is reduced by creating a wind- and waterproof coating on the snow surface.

In addition to its immediate function, the snow surface coating should meet the following requirements: it should be inexpensive, easy to install in a given environment, be temporary (with a service life within the warm season), and leave no environmentally unfriendly residues when decomposing.

Materials with the required functions (temporary waterproofing and wind protection coatings) exist and are widely used in agricultural engineering, landscape architecture, and construction-related conservation. These include roll materials and liquid compounds (membrane forming spray materials).

When unrolled and watered, roll materials stick together with the base or substrate to create a monolithic coating. These include starch- or polylactic acid (PLA)-based mulch films with a water-activated layer and non-woven viscose/cellulose fabrics impregnated with polyvinyl alcohol or an environmentally friendly binder.

Advantages of roll materials: They are completely biodegradable, the degradation period (two to six months)

³ Organization Standard STO 72746455-4.6.6-2025. Road Embankments in Permafrost Zones. Using TECHNONICOL XPS Thermal Insulation to Stabilize the Temperature Regime of Soils in Embankment Base and Body // TekhnoNICOL – Construction Systems Limited Liability Company. Moscow: (sine nomine), 2025. URL: https://nav.tn.ru/documents/sto/ast_72746455_4_6_6_2025.

can be set during production; they provide perfect wind protection; and they are waterproof. Drawbacks: The surface for laying must be flat; installation requires relatively high manpower efforts.

A more general way to build a protective coating is to use liquid compounds. When sprayed and contacting with water/a wet surface, they polymerize to form an elastic membrane. These materials can be made from polyvinyl alcohol (PVOH) with plasticizers; chitosan (obtained from crustacean shells); or acrylic copolymers with a programmable life cycle.

The placement technology for these compounds is as follows:

- Powder or liquid concentrate is mixed with water and applied with a spray diffuser;
- Upon drying, a durable, biodegradable, water- and wind-impermeable film is formed.
- The film is decomposed by microorganisms and moisture. The rate of decomposition (three to four months) can be controlled by the degree of polymerization, layer thickness, and additives.

It should be noted that a cost-effective material/compound that will meet both its intended purpose and the installation and operation conditions of the protective coating is still to be developed on the basis of the above-mentioned materials.

As for solar radiation, snow has a high (up to 0.9) albedo, which means that it reflects almost all solar radiation energy that falls on it. The snow surface within the right-of-way of a railway line is certainly contaminated and its albedo is lower, but it can be increased by reducing the amount of pollutants on the surface by switching to gas turbine locomotives or electric traction.

The following design solutions reduce the influence of radiation fluxes on snowmelt:

- Subgrade orientation to cardinal directions;

- Shading the embankment toe and the lower part of its slopes with sun shields and sunshades.
- The feasibility of these solutions is limited, because in many respects they depend on the line route location and the height of the subgrade.

Albedo can be increased using temporary protective wind- and waterproof membranes to be formed on the snow surface. These can be either transparent or in a given colour. To extend the life of snow deposits, the protective membrane on the surface must ensure that it reflects the entire spectrum of solar radiation wavelengths, from short-wave violet rays to long-wave red rays, including the ultraviolet and infrared regions.

Accumulated snow can be preserved (in terms of volume and quality) provided a wind- and waterproof coating is installed on its surface in due time.

CONCLUSIONS

1. Specific climate and environmental conditions in the Arctic Zone, including permafrost soils, require unconventional solutions for reducing construction costs and providing a reliable and durable railway subgrade. The paper presents solutions designed to reduce the amount of excavation work.

2. Based on the amount of observations of solifluction and horizontal thawing, we find it possible to recommend the practical application of artificial solifluction.

3. The hypothesis of thermal stabilization of soils in the embankment base by snow deposits requires comprehensive testing. In the first instance, mathematical modelling of the proposed processes and adaptation of the materials to form a protective film to snow should be completed. Positive findings of the priority studies will be instrumental in launching experimental operation on existing transport facilities.

REFERENCES

1. Gorodishcheva E. An Iron Web: Russia is thinking about a new megaproject that will require trillions of rubles. *Lenta.ru*. 2020 Apr 2. URL: https://lenta.ru/articles/2020/04/25/novuy_megaproekt/. (In Russ.).
2. Ashpiz E.S. Subgrade in the conditions of permafrost soils of the Northern Latitudinal Railway. *Railway Track and Facilities*. 2021;(3):22-25. EDN: PVTRAW. (In Russ.).
3. Passek V.V., Vorobiev S.S., Poz G.M., Passek V.V. System of surface cooling of the embankment in the permafrost zone. *Railway Track and Facilities*. 2024;(1):2-6. EDN: NLTQVZ. (In Russ.).
4. Voskresensky K.S. Modern relief-forming processes on the plains of the North of Russia [doctoral dissertation]. Moscow; 1999. 360 p. EDN: QCZRIV. (In Russ.).
5. Seleznev A.V., Blazhko L.S., Passek V.V., Gerasimov V.A. New technology of railway construction in the polar tundra. *Railway Track and Facilities*. 2026;(2):22-25. EDN: KTCREO. (In Russ.).
6. Passek Vad. V., Seleznev A.V., Vorobyov S.S., Andreev V.S., Passek Vyach.V. Environment protection when constructing engineering structures on ice-rich permafrost soils. *Hydrotehnika*. 2022;(2):47-51. EDN: WLEHIL. (In Russ.).
7. Passek Vad.V., Seleznev A.V., Vorobiev S.S., Andreev V.S., Passek Viach.V., inventors; JSC Zheldorproekt, assignee. Earth structure on permafrost with a transverse slope of the terrain. Russian patent RU 2769793 C1. 2022 Apr 06.
8. Dyunin A.K. *In the Realm of Snow*. Melnikov P.I. (Ed.-in-chief). Novosibirsk. Nauka. 1983:161 p. (Man and the Environment series). (In Russ.).
9. Lavrov S.A. The influence of meteorological factors, snow properties and climate changes on the snow cover melting processes. *Water Sector of Russia: Problems, Technologies, Management*. 2024; 1:46-70. DOI: 10.35567/19994508-2024-1-46-70. EDN: NZVXXY. (In Russ.).

ЛИТЕРАТУРА

1. Городищева Е. Железная паутина В России задумались над новым мегапроектом. На него нужны триллионы рублей // Lenta.ru. 25.04.2025. URL: https://lenta.ru/articles/2020/04/25/novuy_megaproekt/.
2. Ашпиз Е.С. Земляное полотно в условиях многолетнемерзлых грунтов Северного Широтного Хода // Путь и путевое хозяйство. 2021. № 3. с. 22–25. EDN: PVTRAW.
3. Пассек В.В., Воробьев С.С., Поз Г.М., Пассек В.В. Система поверхностного охлаждения насыпи в зоне вечной мерзлоты // Путь и путевое хозяйство. 2024. № 1. С. 2–6. EDN: NLTQVZ.
4. Воскресенский К.С. Современные рельефообразующие процессы на равнинах севера России : дис. ... д-ра географ. наук. М., 1999. 360 с. EDN: QCZRIV.
5. Селезнев А.В., Блашко Л.С., Пассек В.В., Герасимов В.А. Новая технология строительства железных дорог в заполярной тундре. // Путь и путевое хозяйство. 2026. № 2. С. 22–25. EDN: KTCREO.
6. Пассек Вад. В., Селезнев А.В., Воробьев С.С., Андреев В.С., Пассек Вяч. В. Способ защиты окружающей территории при строительстве сооружений на высокольдистых вечномёрзлых грунтах // Гидротехника. 2022. № 2. С. 47–51. DOI: 10.55326/22278400_2022_2_47. EDN: WLEHIL.
7. Пат. № 2769793 РФ, E02D 17/18. Земляное сооружение на вечной мерзлоте при поперечном уклоне местности / Вад. В. Пассек, А.В. Селезнев, С.С. Воробьев, В.С. Андреев, Вяч. В. Пассек. № 2021124083; заявл. 13.08.2021; опубл. 06.04.2022, Бюл. № 10.
8. Дюнин А.К. В царстве снега / отв. ред. П. И. Мельников. Новосибирск: Наука : Сиб. отд-ние, 1983. 161 с. (Сер. «Человек и окружающая среда»).
9. Лавров С.А. Влияние метеофакторов, свойств снега и климатических изменений на процессы таяния снежного покрова // Водное хозяйство России: проблемы, технологии, управление. 2024. № 1. С. 46–70. DOI: 10.35567/19994508-2024-1-46-70. EDN: NZVXXY.

Bionotes

Alexey V. Seleznev – Associate Professor; **Emperor Alexander I St. Petersburg State Transport University (PGUPS)**; 9 Moskovsky ave., Saint-Petersburg, 190031, Russian Federation; RSCI ID: 3320-5735; ORCID: 0009-0005-6653-5184; seleznev_alrxei@mail.ru;

Lyudmila S. Blazhko – Professor; **Emperor Alexander I St. Petersburg State Transport University (PGUPS)**; 9 Moskovsky ave., Saint-Petersburg, 190031, Russian Federation; RSCI ID: 275525, SPIN-code: 8522-5224; Scopus: 57190230361; ResearcherID: AAC-3455-2022; ORCID: 0000-0001-5209-6778; lydmila.blazhko@gmail.com.

Об авторах

Алексей Викторович Селезнев – доцент; **Петербургский государственный университет путей сообщения Императора Александра I (ПГУПС)**; 190031, Санкт-Петербург, Московский пр., 9; РИНЦ ID: 3320-5735; ORCID: 0009-0005-6653-5184; seleznev_alrxei@mail.ru;

Людмила Сергеевна Блашко – профессор; **Петербургский государственный университет путей сообщения Императора Александра I (ПГУПС)**; 190031, Санкт-Петербург, Московский пр., 9; РИНЦ ID: 275525, SPIN-код: 8522-5224; Scopus: 57190230361; ResearcherID: AAC-3455-2022; ORCID: 0000-0001-5209-6778; lydmila.blazhko@gmail.com.

Contribution of the authors: the authors contributed equally to this article.

The authors declare no conflicts of interests.

Заявленный вклад авторов: все авторы сделали эквивалентный вклад в подготовку публикации.

Авторы заявляют об отсутствии конфликта интересов.

Corresponding author: Alexey V. Seleznev, seleznev_alrxei@mail.ru.

Автор, ответственный за переписку: Алексей Викторович Селезнев, seleznev_alrxei@mail.ru.

The article was submitted 02.05.2026; approved after reviewing. 22.05.2026; accepted for publication 11.06.2026.

Статья поступила в редакцию 02.05.2026; одобрена после рецензирования 22.05.2026; принята к публикации 11.06.2026.