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Modelling of Snow Cover Thickness Influence on the Railway Construction Temperature Regime under Variable Weather Conditions

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Abstract

This article presents results of the modelling of temperature regimes of railway construction layers in application of the SV HEAT software. In one case, ambient air temperature affects the railway construction in presence of a snow cover and in another case – without it. Temperature changes in railway construction layers were modelled pursuant to the data of the Lithuanian Hydrometeorological Service of January–February 2015 in Vilnius region and the conducted field experimental studies. Ambient air temperature, moisture content in layers and snow cover thickness were assessed. Properties of the materials used to install railway construction layers were identified in the laboratory. Moisture content and temperature in construction layers were measured using sensors installed in the experimental field stand (DRETM II) set up in Slovakia. Modelling results have shown that the greatest temperature difference with a snow cover layer on the top railway construction and without it is 1.2 °C. These data revealed that a snow cover carried out the function of a thermal insulation layer. The railway construction with a snow cover had a lower freezing depth (difference of 0.5 cm). With increasing distance from the top of the ballast layer, the temperature of construction layers with a snow cover approaches the temperature of the construction without a snow cover, i.e. temperatures tend to approximate.

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Keywords: railway, construction layers, freezing depth, temperature, moisture, experimental stand, DEM method, SV HEAT software

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1. Introduction

In railroad construction one of important elements are ballast and sub-ballast. Railroad ballast has to resist vertical and longitudinal forces, hold the track in position, provide energy absorption for the track, facilitate adjustment of the track geometry, provide immediate drainage of water falling onto the track, reduce pressures on underlying materials by distributing loads, provide energy absorption for the track [1, 2].

Exposed to rail traffic loads, climate and ambient air factors, railway track ballast, sub-ballast and railway bed deform, which in turn leads to the changing track quality index (TQI) [3–5].

The railway sub-ballast layer must ensure an even distribution of rolling stock loads throughout railway sleepers and the ballast layer to the soil bed, prevent ballast rubble and soil from mixing, deformation, drain rain water due to low water permeability, also, prevent it from rising via capillaries and protect the bed soil from frost.

Water occurring in structural layers of the railway track has a major impact not only on the deformation, but also on thermo-technical features of inbuilt construction materials. The moisture content of the track substructure is not constant, but it varies in the course of the year, depending on the amount of downfall (water, snow), temperature and water regime of the body of the track substructure as well as its shape (embankment, cutting, cut) [6, 7].

Considering the increase of train speeds, the determination of the zero isotherm – non-traffic load (climate influence) [8] is a very important task for the railway corridor bodies. The research project, which was done in Slovakia and results presented [9] shows the determination of the position of the zero isotherm in the construction of railway subgrade, where it is possible to state that freezing of a certain construction layer occurs.

In most European countries road weather information systems (RWIS) have been established to reduce the road maintenance costs in winter, to ensure good traffic safety, to inform drivers about poor traffic conditions [10]. The response of permafrost to climate warming differs greatly from that of engineering construction. This difference is mainly caused by permafrost thermal stability [11, 12].

A large amount of research on climate change, its effects on transport and possible solutions has been carried out in different countries (USA [13], Australia [14], Scotland [15], United Kingdom [16]). Canada and other northern countries have not only a problem related to global warming, but also a more frequent freeze-thaw cycle [17]. The assessment of the current effects of extreme weather conditions on transport systems reveals high costs in specific locations [18].

Freezing depth of the railway construction is defined as a distance of zero isotherm (0 °C) from the surface of railway bed. The following factors influence the thermal resistance of the railway construction: temperatures in the winter period characterized most commonly by the frost index (I_m) thermal-insulation features of the railway subgrade structure layers; condition of subgrade surface soil (humidity w, bulk density ρ, granulometric composition, etc.); thickness of snow cover on the railway track.

Maps on the distribution of the depth of frozen ground according to the data of meteorological stations and of RWIS (Road weather information system) show that the deepest zone of frozen ground (120–130 cm) covers the largest part of the territory of Lithuania [19]. Climate of the Baltic region is monitored continuously [20–22]. But the conducted climate change research has shown that at times the ongoing gradual climate warming does not reflect the climate of specific regions [23]. Thus an accurate assessment of each region, or, more accurately, its part, is possible solely by specifically monitoring data of each metrological station. In 1961–2010, the most vivid trend of increasing average air temperature was observed in winter in Lithuania (with the greatest changes being in January). In this time of the year, the highest temperatures were in the Eastern Lithuania. The average annual air temperature also experienced a statistically significant increase throughout the entire territory, while in the fall, just like in the months of May and June, air temperature changed slightly [24].

A snow cover covering the ballast layer in cold climate countries such as Lithuania has a positive impact on thermodynamic processes of railway construction layers. A sufficiently thick snow cover can reduce the freezing depth of construction layers and slow down changes of geothermal parameters of the road.

A snow cover in land transport on roads and railways has a different effect on parameters of vehicle traffic. A snow cover covering the road pavement reduces the wheel grip factor and increases rolling resistance, thus it is either mechanically removed or chemically melted [25]. Snow covering railways is dangerous in northern countries,