Impact of the stationary thermal field on cryogenic processes in road embankments

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Currently there are more than several thousands of kilometers of roads constructed within the cryolithosphere. Many of these undergo deformations, which are the output to the cryogenic processes, happening in the embankment and underneath. Cryogenic processes become more active during the construction and service life of roads. The key reason to that are the changes in the stationary thermal field of the embankment and in that of the natural grounds underneath it. The thermal changes could be both seasonal or long-standing.

Quantitative modeling for 11 study sites, located within Russian cryolithozone [Isakov, 2015], showed the thermal field in the embankments and underneath it undergoes the transformations, resulting in the formation of the four types of the quasi stationary thermal field states: stable, transitory low temperature, transitory high temperature, non-stable (Fig. 1). The quasi stationary thermal field state (QSTF) here means the steady long term thermal state of frozen grounds without accounting for seasonal fluctuations.

Thermal conditions underneath the road embankment result from the long term dynamics (50 years as in the model). They shape significantly the dynamics of cryogenic processes which might get problematic to the engineering stability of the embankment. Among the key hazardous processes are thermokarst, frost heave, ground flows, and frost cracking. Below we consider how the cryogenic process dynamics differ from one QSTF type to another.

Thermokarst. The stable QSTF type implies there is no ground temperature increase so the thermokarst does not appear. For the two transitory types of QSTF we observe the temperature increase over 0°what makes the thermokarst appearance highly probable. Non-stable type of QSTF implies the active layer goes deeper than 5 m underneath the road embankment so the thermokarst would be practically inevitable.

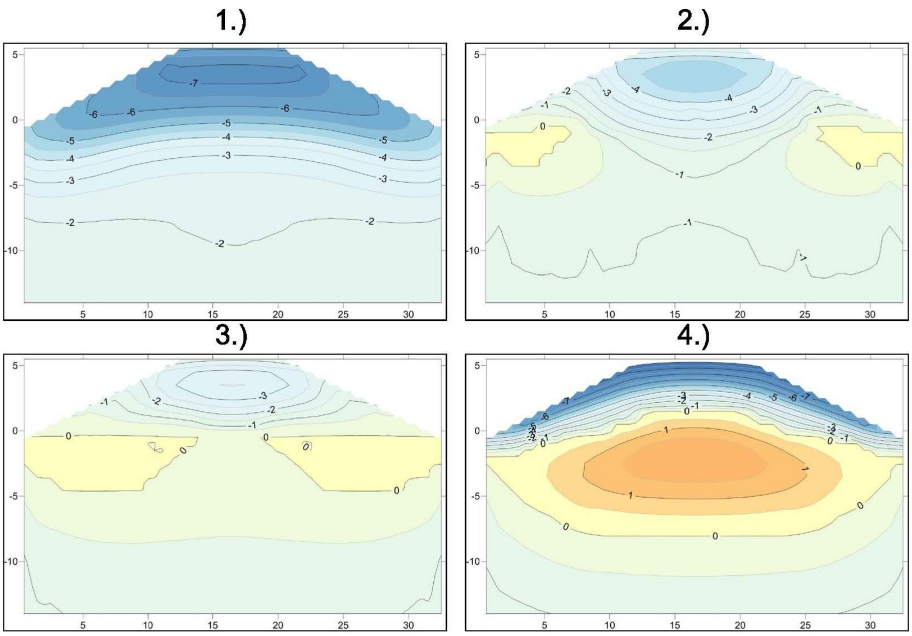

Figure 1: Types of the quasi stationary thermal field state in road embankment and underneath: 1) stable (Amderma); 2) transitory low temperature (Vorkuta); 3) transitory high temperature (Salekhard); 4) non-stable (Chita). Temperature values are given for the end

Frost heave. The stable QSTF types would have a limited potential for the frost heave development since there would be no significant moisture migration happening. The transitory QSTF types are featured with the increased frost heave action in the embankment top. The non-stable QSTF type would be featured with the increased frost heave action all over the embankment body.

Ground flows appear when the pressure on the embankment body exceeds the cohesive resistance of the frozen grounds, constituting the embankment body. The cohesive resistances of the frozen grounds depend on the ground temperatures. The stable QSTF type would keep the low potential for grounds to start flowing. The most intense ground flows would appear for the transitory high temperature QSTF.

Frost cracking damages road pavement and promotes the increased moisture flows into the embankment, hence causing the ice wedge formation. The frost cracking would appear for all the QSTF types. However, these are the stable and low temperature QSTF types, which would have the ice wedges to stay in the embankment.

Generally speaking, each type of the quasi stationary thermal field state (QSTF) is featured with the specific cryogenic dynamics. The intensity and the characteristics of the cryogenic dynamics depend on the QSTF type, which would be featured with specific deformations, appearing in the road embankment.

Thermokarst activation in the embankment basements causes subsidence in the upper filled grounds. The transitional QSTF types are typical of the subsidence at the embankment slopes, while the unstable type would express the subsidence at the subgrade [Isakov, 2012].

Cryogenic heaving in case of the stable QSTF appears as restricted to some small heaves. The transitional QSTFs are featured with the embankment slope deformations and bond-failure crack formations. The unstable QSTF would result in the seasonal heaving all over the embankment.

Plastic deformations of the frozen grounds would result in the uneven subsidence of the top of subgrade, where the pressure on the underlying fill grounds is at maximum.

Frost cracking would cause the road pavement break, the erosion on slopes and uneven subsidence of the subgrade. That is typical of the stable and transitional QSTFs.

Accounting for the type of quasi stationary thermal field state (QSTF) at the road embankment basement allows minimizing deformations by localizing road design solutions to each particular QSTF specific.

References

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