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Ground heat stabilizer work research in year-round operation mode

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Abstract

The aim of the study is to preserve state of permafrost in northern constructions. To keep the permafrost ground heat stabilizers are used. This work is dedicated to research the dynamics of ground temperature around the heat stabilizer in winter and summer modes of operation for the climatic zone of the south of Western Siberia. There are experimentally obtained temperature fields around the earth heat-stabilizers. The calculated results are confirmed by experimental studies. There are designed promising combined devices for frozen ground.

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Keywords: ground heat stabilization; temperature fields; seasonal cooling unit (SCU); frozen ground

1. Introduction

The danger of permafrost degradation is to reduce the carrying capacity of the ground, as the temperature rises and there is their stability loss during thawing. All this requires the development and application of new technical solutions to offset the negative impact of global warming existing under constructions and planned facilities.

Currently, the most effective technical solutions that can compensate the anthropogenic influence on the bearing capacity of permafrost ground is the use of heat-stabilizers (HS) of the ground.

The current state of the HS use in the northern building can be characterized by the following features:

- there is an advanced search of vapor-liquid and liquid coaxial HS designs for ground freezing, and preference is given to the first in view of more effective structure and at less metal consumption;
- to preserve negative temperature is promoted with ice- ground mass insulation from summer heat inputs, and so the protection of external heat exchangers (HE) from solar radiation with assistance screens;

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- using HS in combination with tanks for the winter cold accumulation (so-called frozen brine cartridge) helps to extend HS active period;
- there is not enough data for calculation of operating experience and new technical solutions of HS designed for special conditions (change the operation of the facility, global climate change, etc.).

Common to all seasonal cooling units (SCU) is that there is formed post of frozen ground around its embedded part of the cooling unit, its diameter increases with time. The growth rate is dependent on the magnitude of the heat flux in the exhaust heat exchanger and the air flow coming from the cooling (freezing) to SCU primer. In periods of SCU shutdown there is an increase in frozen mass temperature, and even its partial thawing [1,2]. The study of the SCU thermal modes usually solves the following tasks:

- the problem of determining non-stationary temperature field in the surrounding ground at a given intensity of heat removal (the direct problem);
- thermal ground management, providing stabilization of ground temperatures in a given volume (the inverse problem).

To meet these challenges there is required a mathematical model describing the processes of the thermodynamic system: air - SCU - ground. However, the reliability of the results of the use of mathematical modeling requires their adjustment according to full-scale testing of new technical solutions.

2. Study subject

There was a task to carry out pilot SCU studies with the possibility of frozen ground zone [3]; its construction has been developed at "Refrigerating compressor equipment and technology" Department of OmSTU. Zonal ground freezing allows using this type of SCU for temperature ground stabilization in areas including the infiltration area where the serial structures are ineffective. Introduction of zone transporting coolant [3] allows keeping the bearing capacity of the ground to the above conditions with the same metal consumption of SCU. For comparison the experiment results, there was serially applied the sample of individual soil thermo-stabilizer HS 32/6M5 A-01.

3. Research methods

Test stand for the study of the two HS characteristics (production model and with the possibility of freezing zone) is shown in Fig.1.

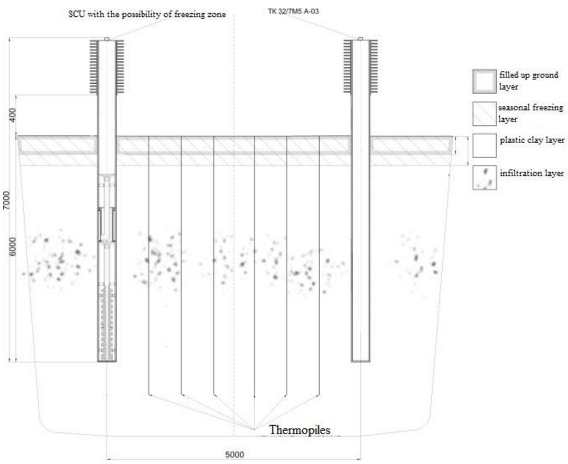


Fig. 1. The test stand scheme.

Changes in the ground and thermopiles temperature were detected by direct measurement via sensors disposed outside of the housing thermopiles and measuring rods.

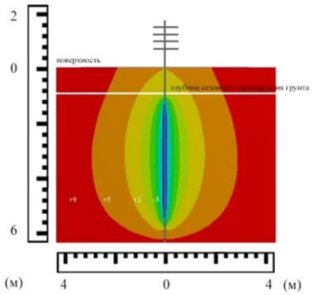
An analysis of heat inputs dynamics was implemented by an indirect method based on temperature measurements at the heat flows control points.

Radius of frozen ground around the individual heat stabilizer is determined to justify the diameter of the evaporation of the heat stabilizer for a particular area. Due to this calculation results the selection of the HS number is determined.

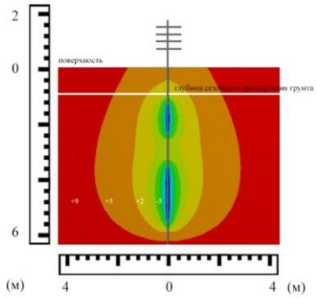
As the initial data for the solution of the direct problem using a mathematical model there are accepted climatic characteristics of the construction area (air temperature, wind speed, solar radiation), the initial temperature of the ground, its thermal parameters, the structural characteristics of the SCU. The difficulty is that essentially there are two interconnected processes: the freezing (thawing) of ground by reacting with the cooling unit and the atmosphere (external task) and heat transfer in the SCU (internal). Thus, it is necessary to consider the problem as a common ground for the system: ground - SCU - the atmosphere. [4]

4. Results

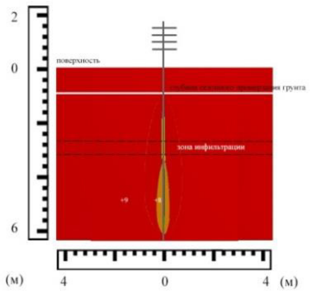
The results of experimental and numerical tests are given in Figure 2.



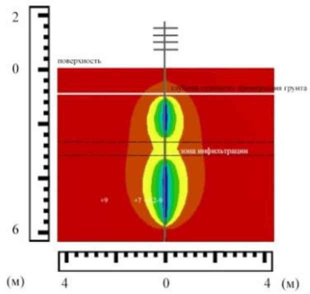
Calculated ground temperature field around the TS 32 / 6M5 A-01 with the duration of the active period 180 days, with αc=52 W/m^{2K} in the zone of infiltration



Calculated ground temperature field SCU around with the possibility of freezing zone with a duration of the active period of 180 days, with αc=52 W/ m^2K in the area of infiltration



Calculated ground temperature field around the TS 32 / 6M5 A-01 with the duration of the active period 180 days, with αc=104 W/m^{2K}, in the zone of infiltration



Calculated ground temperature field SCU around with the possibility of freezing zone with duration of the active period of 180 days, with αc=104 W/ m^2K in the area of infiltration

Experimental ground temperature field around TK 32 / 6M5 A-01 with the duration of the active period 180 days.

xperimental ground temperature field around SCU with the ossibility of freezing zone with duration of the active period of 30 days.

Fig. 2.The isothermal soil layers along the length of HS.

Fig.3 shows the dependence of the frozen ground radius at 4 meters depth from the time of active SCU period. These dependences show that the time to freeze a predetermined radius (in this case, Rz = 100cm) in HS with freezing zone is reduced by 25-28% (ΔT=T2-T1). It means more effective work near HS bearing pad of building structures.

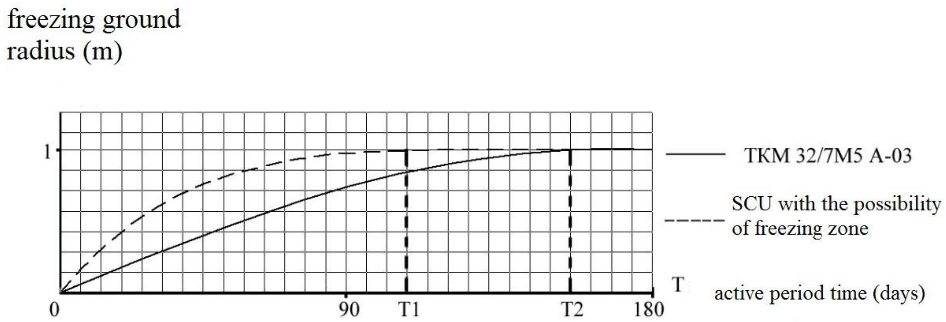


Fig. 3. Experimental dependence of the radius from the ground freezing time of SCU.

The results of experimental and numerical studies make following conclusions:

- There are tested SCU samples with the possibility of freezing zone in the ground in the climate area of South and West Siberia.
- Changes of ground isotherms were determined using software ANSYS, and they correspond with the nature of their changes at testing full-scale samples. It proves the adequacy of results of numerical modeling and opportunities of numerical experiment in software ANSYS.
- Experimental data and numerical experiment results show that SCU structure with opportunity of zonal freezing ground allows reach the determined radius in the near the bearing pad of building structures for less time period than when using the operation model. When there is a layer of ground infiltration with high values of heat transfer factor serial structure of SCU are ineffective; the same time SCU design with zonal freezing with the same metal consumption allows reach and save specified temperature mode of ground.

5. Conclusion

There is designed and studied the device for frozen ground, which has a number of advantages, such as adaptation of the device for zonal frozen ground areas; providing frozen ground during the whole period of operation; increase in the rate frozen ground; decrease of metal consumption. The tests of the prototype were carried out.

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