possibility of origin, activity, intensity, reversibility, geographical distribution, formation of paragenetic chains and other features of cryogenic processes differ considerably from natural conditions or are unprecedented at all. Peculiar natural-technogenic geocryological complices (NTGC) are formed in the urban territories, which are remarkable by the vector of permafrost evolution, by the set of cryogenic processes, by temperature trends and the other characteristics. NTGC types depend on initial natural settings and on kinds, intensity and duration of technogenic pressure. For instance, field reconnaissance of permafrost and geological conditions resulted in 17 NTGC types in Norilsk industrial area, 11 types in Yamburg gas condensate field, Taz Peninsula, and 32 types along overground and underground gas and oil pipelines in the north of Western Siberia. NTGC dynamics, depending on the scale of urban system, on the set of its elements and on duration of impact upon nature as well as on degree of stability of natural permafrost, attracts the particular interest. A key point here is assessing the direction of climate change (in terms of influence on the engineering of the permafrost environment) in different areas of the cryolithozone.

Computationally Efficient Numerical Method for Heat Transfer Problems in the Engineering of Foundations Construction on Permafrost Soils

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The long-standing problem of constructions engineering on permafrost soils is reviewed and the relations between effects accompanying the seasons of thawing and freezing of active layer are revealed. The fact that temperature is the most actively changing physical parameter leads to the necessity of determination of temperature field around the constructions foundation for the whole period of exploitation. In practice, this determination is realized via calculations and requires the use of sophisticated scientific software, where appropriate numerical methods are implemented.

We have both developed and implemented an alternating directions implicit method (ADI method) that permits to solve the Stefan problem and to take into account convective heat transfer in large-scale 3D systems – i.e. in permafrost soils. The stable calculation algorithm is constructed and successfully applied to the nonlinear transient heat equation solution in typical three-dimensional domains of permafrost soils. The physical properties (such as thermal conductivity and heat capacity) are assigned separately for the thawed and frozen phases of different soil structures, thus permitting to consider sets of soils layers with purely thawed, frozen or intermediate, so-called frozen fringe, states.

The proofs of convergence of the developed numerical algorithm are obtained by using both generalized Galerkin's method and Brezis theorem for maximally monotone operators. The stability criterion (constraint on the relation between the values of time step, space discretization steps and the values of physical properties of soil) is derived using Samarskiy's and Gulin's approach to the study of stability of difference schemes. The estimated computational complexity of the developed algorithm is O(N), where N is the number of nodes in a mesh. We argue that our numerical ADI method specially designed for permafrost soil heat transfer problems shows good performance in terms of time consumption and accuracy. The numerical results will be presented for some typical configurations of initial-boundary values and soil domains.

Mass Exchange in the System of Atmosphere – Snow cover - Ground

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The input of the sublimation to the snow cover balance was estimated. The relation of snow and ice sublimation intensity on snow density and heat conductivity was experimentally established (from 42•10-8 kg/m^2s for ice and 40•10-8 kg/m^2s for snow with density 500 kg/m^3 to 32•10-8 kg/m^2s for snow with density 160 kg/m^3). The moisture distribution in the pore space of snow and soil and the possibility of vapor migration from snow to ground was considered (relative concentration of water vapor in snow pore space Csnow/Cover_ice varies from 1.,14 at temperature -20°C to 1,06 at -5°C). The experimental results on mass transfer under isothermal condition and with the temperature gradient are presented. The combinations of temperature and temperature gradients, which allows water vapor migration from ground to snow, thermo dynamical equilibrium or migration from snow to ground was characterized. The water vapor flow from snow to ground had the rate 1-

2,5•10-8 kg/m^{2}s on the contact snow/sand at temperature -13 or -4°C and zero temperature gradient. The water vapor flow from ground to snow had the rate 8-39.3•10-8 kg/ m^{2}s on the contact snow/sand or snow/clay at temperature -5 - -8,3°C and temperature gradient 24-91 K/m.

Detecting Changes in Frozen Ground Condition by Radiowave Surface Impedance Measurements

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The results of surface impedance observations in the frequency range from 20 to 900 kHz on experimental sites near Yakutsk, consisting from sandy frozen grounds, are presented. The observations revealed that in the study area the surface impedance of frozen soils is most closely correlated with upper 4-m temperature, structure and strength properties in the frequency range of 500 to 900 kHz.

The period of ground seasonal cooling detected by the surface impedance of the active layer is subdivided into the freezing zone (November - February) and the zone of stable frozen condition (March - April). The period of seasonal warming of the active layer is subdivided into zones of intensive thawing, moderate thawing and stable thawed condition. The sizes of these zones differ in time between forested and open sites. Changes in the periods and zones can be used as a measure of permafrost response to climatic changes.

The temperature dependence of effective electrical resistance of frozen soils has been determined experimentally which is obtained from surface impedance. The lowering of frozen ground temperature from -5 to -8oC has resulted in an over four-fold increase in effective resistance. The variations in mean effective electrical resistance of frozen soils correspond well to the variations in mean annual temperature data from meteorological observations for the same year.

The module of surface impedance at the forested site can decrease in summer more than twice as a result of the increased conductivity of frozen soils of the active layer caused by melting of ice and occurrence of thawed water. The phase angle of surface impedance in the forest can decrease by 45o in the 864 kHz frequency due to the formation of a thawed layer on the surface (active layer, intrapermafrost taliks) and increase by 20o for the 171 kHz frequency due to the formation of an additional thawed layer at depth (intrapermafrost taliks).

The study indicates that joint observation of surface impedance and its phase angle provides a non-contact means for detecting changes in structure of frozen ground caused by the formation of a seasonally thawed layer, as well as suprapermafrost and intrapermafrost taliks.

Moreover, surface impedance parameters can be used to detect variations in moisture content and volumetric ice content of frozen soils.

Impact of Cryogenic Textures on the Deformation Properties

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Deformability of clayey soils during thawing varies widely, because it depends on many factors. Most important ones are density, moisture content, strength structural bounds and type of contacts between the particles, mineral and grain size, the nature of the pore space, the orientation of the structural elements, etc. But the effect of cryogenic structure of clay soils is poorly studied.

The research aims to the investigation the effect of cryogenic structure of clayey soils on their deformation and physical properties under compression tests. Studies were conducted to silt (a IIIkr) and clayey silt (la IIIkz). Soils were selected near pipeline from Pyakyakhinskoye field (Russia, Yamal-Nenets Autonomous District). These soils can be thawed at surface and subsurface pipelining.

Deformation characteristics of clayey soils are determined by various field and laboratory methods. But the field method is quite time-consuming and costly, so soil tests are conducted primarily in the laboratory.

Average values of density and moisture content were obtained by field studies. Then we prepared artificial clayey soils (height 35 mm and diameter 71 mm) with a massive cryogenic and layered texture. Cryogenic texture had two versions. The first was with a one layer of ice (the size of ice layer - 2,1 mm), and the second - with three layers of ice (the size of one ice layer – 0,7 mm). But all soil had the same physical properties (density and moisture content).