Assessment of a Possibility of Partial use the Cold Ventilated Spaces under Buildings in the Permafrost Zone

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Abstract. Researches are executed on the example of the existing house in a Permafrost zone. The constructive decision includes the pile bases and the high ventilated spaces under buildings. In work is offered to estimate an opportunity to lower the room for a ladder directly on a planning surface without the ventilated gap. For reduction of thermal influence the insulation device under floor of this room is offered. The possibilities of additional cooling of the frozen basis by means of the cold pile bases with the built-in liquid thermostiphons of coaxial type are considered. Options with the device of cold pile bases and without them are considered. Regularities of formation of temperature condition of frozen soil were carried out by numerical methods by means of the TEMPA program.

1. Introduction

Absolute majority of civil buildings in the cities located in a zone of steady permafrost soil are built by the first principle of the device of the bases - with preservation of a frozen condition of soil of the basis. Here, belongs such, cities as citys Norilsk, Yakutsk, Mirny.

Special constructive decisions of base part of the building are applied to preservation of soil of the basis in a frozen state. The main task to limit thermal influence of the building on basis soil. For this purpose apply air layers under the building, the ventilated adding, the ventilated channels, and also a combination of these constructive decisions. [1,2,3]. Most often under residential multystoried buildings leave free air space the so-called ventilated air spaces (VAS). For this purpose the building is lifted on one and a half - two meters over a planning surface. VAS can be as absolutely open, and with adjustable airing. [4].

Open VAS have the free, not stopping during the whole year message with external air. The main advantage of these undergrounds is an opportunity almost completely to eliminate thermal influence of the building on a surface of soil of the basis both in warm, and in a winter season. Besides in a warm season the building protects a soil surface from solar radiation. And in the winter with a height of undergrounds of 1.5-2 m the free bringing of snow under the building is provided that increases cooling influence of cold air.

In conditions when average annual air temperature is much lower than temperature of soil of the basis, VAS can be arranged with adjustable airing and can be even built partially up with cold rooms [5]. It concerns areas with a temperature in a zone of annual zero amplitudes below -6 °C (Norilsk, Yakutsk, the Arctic coast, etc.). Ventilation of such undergrounds is carried out through openings (pro-spirits) arranged in a building pedestal base.
The main lack of VAS is overcooling overlapping base that adversely affects temperature condition of rooms of the first floor. For residential buildings this factor can turn out so essential that need of the device of a special lock will appear. In case of placement over socle overlapping of a residential zone very strict heatphysical requirements as the protecting design are imposed to this overlapping. But as showed operating experience of residential buildings even observance of these requirements in the north does not provide creation comfortable a microclimate in the first floor of the building. As a result over VAS it is necessary to arrange the technical floor which replaces the cellar in the usual building[6]. Such technical floor over VAS is not only a thermal lock between a residential zone of the building and cold external air, but also the channel for laying of communications. In houses there are two new floors in the form of VAS and the technical floor instead of the cellar in the north. As a result the mark of a floor of the first floor rises over planning the Earth's surface by 4 - 5 m.

To get on the first floor inhabitants of this house should climb the main ladder, the part from which is outside of the building as shown in fig. 1. In the winter at low air temperatures and snowfalls such decision creates discomfort.

![Figure 1. The main ladder, the part from which is outside of the building](image)

Attempts to refuse VAS and to apply the traditional decision with the buried cellar lead to temperature increase of soil of the basis, decrease in the bearing ability of piles and rainfall of the building. Standard constructive it is submitted decisions of base part of the building with VAS and an external ladder in fig. 2.

![Figure 2. Building section fragment with the ventilated air spaces](image)
In this article the possibility of partial building of VAS with the purpose to place there the main ladder of an entrance to the building is considered. For this purpose it is necessary to arrange the warm room with the sizes in respect of 4.5х4.5 m directly under the building. For what it is offered to lower part of the technical floor directly on the planning Earth's surface without the ventilated gap. The fragment of a section and the building plan with the ladder placed under the building is presented to VAS in fig. 3.

![Diagram](image)

**Figure 3.** The fragment of a section and the building plan with the ladder placed under the building is presented to VAS

Technically the task is reduced to calculation of temperature condition of the basis at partial thermal "load" of surfaces. It is possible to carry out cooling of the soil basis in a working zone of a pile both from a surface, and by deep cooling. Soil of the basis is cooled from a surface by means of VP, and at a depth at the expense of the so-called seasonally cooling devices (SCD). As SCD in this work "cold" piles are applied. These piles differ from usual piles in the fact that in them liquid heat exchangers from metal pipes of a coaxial design with natural circulation of the heat carrier are built in. [7,8,9]. Placement of a thermosiphon in a pile promotes fast cooling of soil about a pile at the beginning of the cold period. Such feature increases the bearing ability of the base, and installation of a pipe of the heat exchanger in a reinforced concrete pile increases reliability and durability of the device.

In modern construction on frozen soil it is widely applied two-phase SCD. These devices are effectively used to freezing of soil in emergencies, and also for the bases of buildings and constructions with limited time of operation. This first of all oil and gas and network construction of the high voltage line, and also automobile and railway constructions. [10,11,12]. Liquid SCD are much more expensive, than two-phase SCD which reliability does not correspond to time of settlement operation of residential buildings [13].

The idea to lower part of socle overlapping was considered in work [6], but was not realized in practice. Lack of reliable methods of cooling of soil of the basis not only with top, but also at a depth,
and a method of calculation of temperature condition of the frozen foundations of buildings under various boundary conditions taking into account the deep cooling devices was the main problem.

For the solution of non-stationary problems of heat conductivity with phase transitions of steam moisture there is a wide set of methods of the decision now. The physical problem definition of heat exchange with phase transitions is most developed the so-called task of Stefan is. In this model it is accepted that in soil there are thawed and frozen zones. On limit of the section of these phases there is an allocation or absorption of warmth of phase transitions. The main difference of the existing algorithms is approach to the accounting of heat of phase transitions where the rupture of thermal streams takes place.

Stefan's statement to is applicable to breeds in which phase transition of steam moisture happens at a constant temperature of 0 °C that is characteristic of ice thawing. Actually in disperse breeds steam moisture in soil freezes in a wide range of negative temperatures that gives the chance "to smear" the front of phase transitions and to enter concept of an effective thermal capacity. Such method received the name "enthalpy" a method which is applied as physical model to the solution of a task by numerical methods.

There are many program complexes for calculation of the frozen bases, but they are a little adapted for engineering tasks, with variable boundary conditions, including heatsources in a type of SCD[14-19]. Now most widely use a method of final elements and final differences. With use of a method of final differences several computer programs for calculations of thermal interaction of buildings and constructions with permafrost gruntayom of the bases are developed. HEAT program of department of geocryology of Lomonosov Moscow State University; FROST program of the Siberian office of the Russian Academy of Sciences; KRIOS program of Fundamentproyekt institute. With a regret these programs cannot consider all complex of basic data, when calculating engineering tasks in natural conditions. At present actively systems with the seasonal cooling devices with a vertical and horizontal arrangement of the cooling pipes develop. [20,21]

In this work research of regularities of formation of temperature condition of the cooled soil basis were carried out by means of the program TEMPA complex (the certificate on state. Registration 2016618937). The complex is developed in MGSU - MISI for the solution of non-stationary heatphysical tasks. As physical model the entalpiyny method is accepted. The numerical decision is based on a method of final differences which allows to change heatphysical parameters of any elementary block on any step on time. In a specific objective it is necessary at the accounting of thermal sources in a type of SOU as productivity of SOU depends on temperature of the heat carrier, temperatures settlement and the next blocks and changes on each step on time. The program TEMPA complex was used in real design of the bases of civil and industrial buildings in regions of permafrost soil since 1974 [22].

2. Basic data: problem definition.

Under the building 14 m wide with the VAS height in purity of 2.0 m established the warm room of 4.5х4.5 m with air temperature +20 °C. Piles with SCD settle down with a step of 1.5 m to four rows between which distance 6 - 2 - 6 m. Height of elevated part of SCD of 1.5 m, and underground 4 m. Diameter of a pipe of a thermosiphon of 0.12 m.

Boundary conditions in VP under the building are set by results of natural supervision of 1973 - 1974 taking into account warming by 2050. Temperatures and coefficient of heat exchange are specified to average monthly taking into account lack of snow. Out of a building zone the boundary condition is set in the form of a sinusoid directly on a soil surface. Average annual temperature of a surface is accepted to equal temperature in a zone of annual zero amplitudes taking into account "temperature shift". Distribution of temperatures on depth is set by results of calculation of a kvazistatiosny state. On the lower bound of the massif the constant temperature of \( T_0 = -1,0 \) °C is set. On lateral surfaces of the massif heat exchange is absent.

Numerical modeling was carried out with thickness of thermal insulation from 5 to 20 cm in the form of a layer of rigid extrusive polyfoam with coefficient of heat conductivity of \( \lambda = 0.04 \) of W/m °C.
Resistance to a heat transfer of such layer at a thickness of 10 cm is equivalent to snow thickness in 30-40 cm. In below the given calculations thermal insulation on half of the warm room.

Results of calculations are output for September when average temperature on the working length of a pile is minimum within a year.

In fig. 4, the temperature field created for the fifth year in foundation of the building with the seasonal thermal insulation 10 cm thick laid on VAS without the cooling influence of SCD is presented.

In fig. 5, the temperature field created for the fifth year in foundation of the building with thermal insulation on half of the warm room placed in VAS with the accounting of the cooling influence of SCD is presented.

3. Discussion
Results of calculation show that the temperature field in foundation of the building with the warm room placed in VAS, does not protect soil from heating at the device in a heater floor from polyfoam 10 cm thick. It is connected first of all with that, in the winter soil under the warm room is not cooled. And in the summer warmly gradually collects. In spite of the fact that heating goes from above, by
fifth year in a working zone of piles temperature makes from 0°C to -1°C that does not guarantee the sufficient bearing ability of piles.

At application of cold piles and a heater on half of the warm room cooling of the basis remains. The ventilated underground located around the warm room cools soil of foundation of the building from a surface, and cold piles keep the cold which is saved up during the winter at a depth, in a working zone of a pile. Temperature at a depth of 4 - 6 m at the right time the maximum increase (the middle of October) does not exceed minus of 1.8 °C. In a zone where influence of the warm room affects less, temperatures of soil are lowered to minus 2.4 °C.

Numerical modeling shows that placement of certain warm rooms in VAS directly on a planning surface without the ventilated layer perhaps at the joint device of local thermal insulation and SCD.

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