Main achievements and directions of scientific research in the field of foundation construction on sites composed of permafrost in the Russian Federation

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Abstract. Construction in the northern construction-climatic zone associated with the solution of complex engineering problems. This is primarily the monitoring of the temperature state of the cryolithozone, which depends on a combination of climatic, engineering-geological, hydrogeological, environmental and technogenic factors. This is even more relevant in connection with the fact of degradation of permafrost. Generalized and classified technical solutions for the construction of foundations of buildings and structures built on the I and II principles. At the same time, technical audit of design solutions and scientific support during the entire life cycle of objects is required. In order to improve and implement the progressive direction in foundation construction, variants of design solutions for self-cooling freestanding columnar foundations of factory production are proposed and the work schedule is detailed.

Permafrost soils in natural conditions are located in the northern regions of the Russian Federation, the United States of America, Canada, partially Scandinavian countries, Greenland, and for high-altitude permafrost island character is located in other countries of the world.

On the territory of Russia, permafrost soils (cryolithozone) occupy 65% of the country's territory.

The temperature of permafrost soils is known to range from -0.5°C to -10°C and depending on this, soils are divided into: low-temperature and high-temperature; hard-frozen (firmly cemented with ice, characterized by brittle fracture and almost incompressible) and plastic-frozen (cemented with ice, but having viscous properties and compressibility under external load).

The temperature state of the cryolithozone is not stable.

Factors that influence the natural environment include: instability of arctic ecosystems, solar radiation, surface albedo, and polar night.

The consequences of human life are influenced on warm-balance characteristics of ground coat layer surface in winter and summer.

The consequences of natural and climatic phenomena characterized by global warming and man-made processes are manifested in the form of degradation of the earth's cryolithozone.

As a result of a comprehensive analysis of data from weather stations and geocryological hospitals, it was found that within a few decades, the border of permafrost can move north by 200-500 km. [1,2]

At the same time, the northern lands (in particular in Russia) contain the main natural resources, the development of which is necessary to ensure the viability of the country's economy.

In all countries, including Russia, two basic principles of the use of permafrost soils as the foundations of buildings and structures are used (in other countries-in a different version and interpretation). [3,4]
I principle-permafrost soils of the base are used in a frozen state, preserved during construction and during the entire period of operation of the structure;

II principle-permafrost soils of the base are used in thawed or thawing condition.

To implement the I principle of construction on permafrost soils (solid-frozen low-temperature soils), the following basic engineering solutions are provided and developed: arrangement of ventilated subfields or cold ground floors of buildings with natural and incentive ventilation; laying in the base of the construction of pipes, boxes with forced ventilation; application of ventilated foundation structures with forced ventilation; the installation of the seasonally operating cooling devices mainly deep action (even in the plastic-frozen soils); the device of heat shields reducing the thermal impact of buildings, structures on the frozen ground.

It is mandatory to take into account the depth of seasonal freezing-thawing of the soil (merging and non-merging permafrost).

The use of the II principle of construction on permafrost soils (and this is usually plastic-frozen high-temperature soils), as well as a fairly complex engineering task and it is connected with indepth termophysical calculation and with observing exact rules of works production.

Technical solutions used in construction practice: preliminary (before the construction of the building) artificial thawing of base soils; replacement of icy soils with thawed non-sedimentary soil (sandy or large-block); increasing the depth of foundations with bear against the rock or other low-compressible soils. [5,6]

Intensive development of the northern regions of Russia has been going on for several decades, and in the last 10-15 years, the state and enterprise investors allocate very large funds for this.

One of the main directions of improving the quality of work in the design, construction and operation of buildings, structures, highways are technical audit of design solutions and scientific support during the entire life cycle of objects. [7,8]

The purpose of the technical audit is to assess the effectiveness of the use of new technologies and equipment in specific conditions for a given production task, competitive evaluation of options for a set of heterogeneous criteria, structural and parametric selection of the best options, assessment of the payback period of investments and risk prediction.

Scientific support includes systematization of scientific research, observations and results of geocryological and geotechnical monitoring, methods of mathematical modeling of thermodynamic and thermal interactions of objects and geotechnical systems with permafrost soils.

A progressive direction for improving construction on permafrost soils is the use of self-cooling support systems-foundations. [9,10]

The thermocouple partially rises above the ground, and there are holes in the structure. Cold air due to convection falls down to the base, transfers the cold to the ground.

The use of self cooling support systems has a number of advantages over other systems:
- combining cooling and supporting structure into a single unit;
- reducing the cost of cooling systems-the absence of special self-cooling devices (SSCD) which are installed separately from the foundations;
- cooling of deep soil layers as opposed to surface cooling;
- higher durability, reliability and aesthetics;
- ecological safety;

In the development of this direction of foundation construction on permafrost soils, the construction of a columnar self-cooling foundation is proposed and is currently being tested.

On Figure 1 the variants of the design solution of self-cooling supports for buildings and structures are given. In this case, it is a free-standing columnar reinforced concrete foundation of factory manufacture. Channels and cavities in the foundation are located in such a way as to provide natural (and if necessary forced) ventilation of the internal surfaces of the structure and mainly the ground surface at the level of the upper boundary of the permafrost layer of the base.
Installation of such foundations in the design position must be performed at certain times of the year and in strict compliance with the rules of work.

Production time is limited. The start time of the excavation works (i.e. development of pits for free-standing foundations) must match the beginning of the period reduction in average daily outdoor temperature below 0°C. During this period, the soil thawed over the entire depth of the active layer, and the top “crust” is already partially frozen soil (if this is the case) is insignificant and does not preclude the development of soil conventional mechanisms. The pit is developed to the full depth to the level of the foundation sole. The base is prepared in the traditional way. The prefabricated foundation with a factory-applied layer of waterproofing is mounted in the design position.

The channel openings are located above ground level. The foundation is installed in such a way that the inlet and outlet openings of the ventilation channels are located taking into account the direction of the prevailing winds. Further, without interruptions in the production of works, it is necessary to perform backfilling of the pit with soil with a layer-by-layer seal.

The work must be performed as soon as possible, providing in advance the availability of the necessary machines, mechanisms, materials, structures and labor resources.

This technology will avoid excessive thermal effects on the permafrost soil and after completion of work to ensure the penetration of cold air inside the foundation to cool the base.

During the construction of both the I and II principles there is a task to improve the system of temperature monitoring of permafrost soils of the base of buildings and structures under construction.

It is necessary to control, and sometime to operate a temperature regime of soils in the course of operation of objects.

A modern measuring system allows monitoring temperature conditions continuously during the operation of objects. The set of equipment includes: thermocos installed in thermometric wells; controllers; loggers; personal computers for recording and processing data. The equipment works continuously for several years.

The measured temperature values from the thermocos sensors are recorded on a MicroSD memory card. Data collection is carried out by copying a data file using a communication line to a personal computer in the form of an archive over a radio signal.

Thus, as a result of many years of fundamental research in the Russian Federation, almost any engineering problems in construction in the northern construction and climate zone are solved. Self-cooling free-standing
columnar foundations of factory manufacture (Pic.1) designed for construction on the principle of I – one of the most effective areas of foundation construction

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