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TECHNICAL AND ECONOMIC SUBSTANTIATION CONSTRUCTION METHODS ON FROZEN SOILS IN THE FACE OF GLOBAL WARMING

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Abstract. The article is devoted to the substantiation of construction methods on frozen soils in the face of global warming. In the article, we analyze with the help of modern computer methods the principles of the use of soils as foundation structures, and propose a methodology for technical and economic substantiation of the choice of the most appropriate and effective of construction methods.

1. Actuality

The actuality of the problem is determined by intensive development of the Russian arctic territories and other regions with permafrost where the consequences of climate changes are to be carefully forecasted [1]. Also the new methods of forecasting and prevention of the permafrost deterioration under various man-caused influences and the global warming are to be worked out. It is very important due to the fact that the permafrost melting may substantially influence the functionality of the already existing buildings and those under construction [2, 3]. Below the climatic impact on the permafrost soils under various climate conditions is considered.

2. Goals and tasks of the research

While during the global warming the processes of permafrost deterioration are intensifying, one needs a complex approach to substantiate the construction process. This approach includes the following stages:

- a special program of engineering-geological survey;
- a forecast of basement condition of the projected object with respect of all possible types of impact (solving of a climatic problem);
- value analysis of new and existing construction methods;

On the every stage of construction substantiation, the modern computer methods are to be used

Figure 1 shows the flow chart for creation of new and improvement of the existing construction methods (CNCM) on the permafrost soils.

3. The results of the research. The climatic problem

For solving of the climatic problem, the model of the active soil layer is used [4]. The latter is represented with the vertical soil pillar of 10 m height (*H=10 m*, Fig. 2). For modeling of the semi-infinite space this value is automatically incremented by 3 m (*ΔH=3 m*) in the ***FSTM*** software. Because of all processes are conducted in the upper part of the pillar, the temperature fields are applied for the depth of 2 m ($H_{VIS}=2$ *m*).

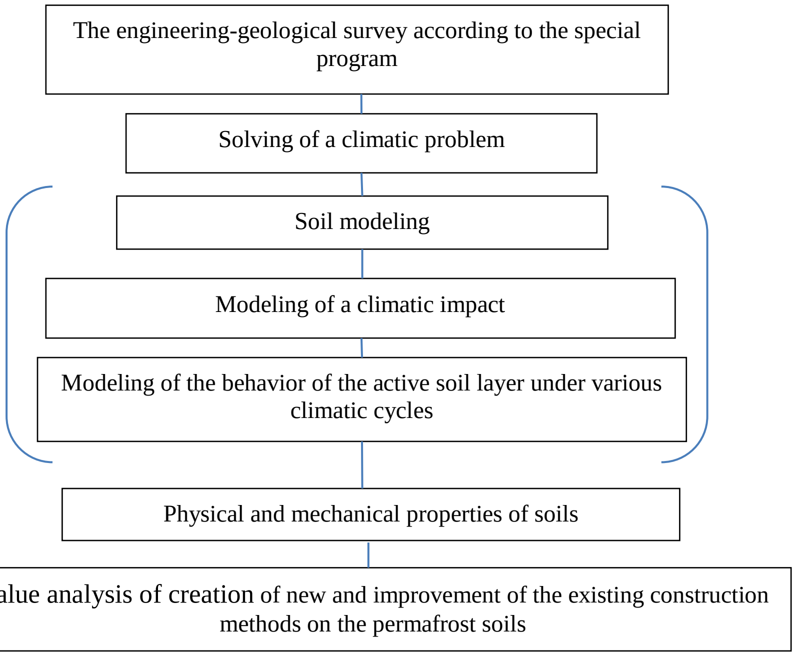

Fig. 1. The flow chart for creation of new and improvement of the existing construction methods (CNCM) on the permafrost soils.

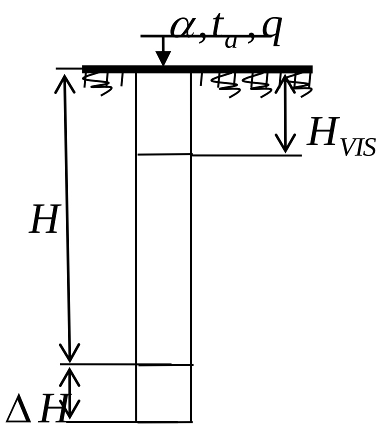

Fig. 2. The active soil layer model.

The pillar is divided into cells of 0.05 m (*Δz =0.05 m*) each. Here the time unit is about 0.04 of an hour. On the upper surface, the mixed boundary conditions are set. The boundary conditions of the third type mean the atmospheric heat transfer, while the heat flow describes the solar radiation heat transfer. The presence of the snow layer is taken into consideration through adjusting of the atmospheric heat transfer ratio. The total thermal resistance is made up by the two components: the atmospheric heat transfer to the snow layer and the resistance of the snow layer itself:

$\frac{1}{\alpha}=\frac{1}{\alpha_a}+\frac{h_{sn}}{\lambda_{sn}}$. Here is the heat transfer ratio: $\alpha=\frac{\alpha_a}{1+\frac{\alpha_a h_{sn}}{\lambda_{sn}}}=\frac{\alpha_a}{\kappa_\alpha}$.

Because of the snow thermal conductivity $\lambda_{sn} = 0.1\text{-}0.4\ W/mK$, the coefficient $k_\alpha = 1.0\text{-}10.0$. The condition of soil at any time and any point is characterized by temperature and the parameter θ, which shows the quantity of free frozen water (Fig. 3).

For climatic cycles modeling the ***FTSM*** software uses the month and year cycles. The region of Nadym with the permafrost layer up to 300 m thick is taken as an example.

While modeling the behavior of the active soil layer in various climatic cycles the maximal thawing depth of the permafrost during the summertime serves an important climate property. Sometimes an important climate property is the position of the permafrost upper surface. (*PUS*) which is roofing the frozen grounds. The pace of downward moving of the *PUS* enables forecasting of further permafrost thawing. The speediest uptrend for the average temperature of the Earth is $0.1\ ^oC$ per year. That means that in a century temperature may rise by $10\ ^oC$.

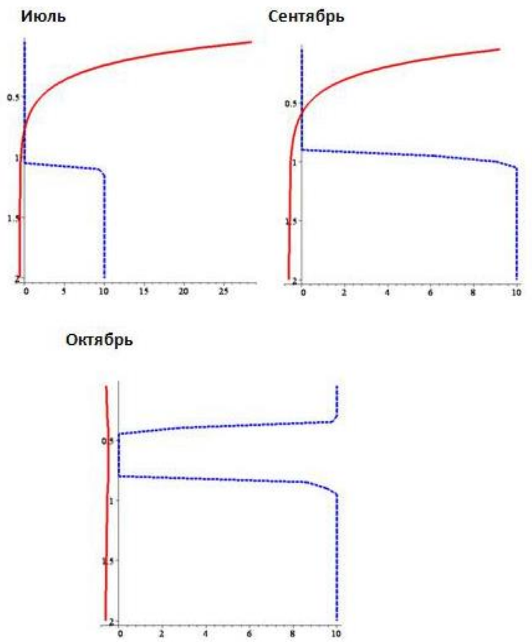

Fig. 3. The temperature distribution (the solid line) and the parameter $\theta x10$ (the dashed line) versus the depth of the active soil layer.

We will consider the up-to-date climate condition with the average yearly temperature $t_{av}=-6.65\ ^oC$ along with the speediest global warming up to the average yearly temperature $t_{av+10}=3.35\ ^oC$. For comparison we consider three variants: A - the normal up-to-date condition; B - the equal increase of the temperature during the whole year by $10\ ^oC$; C - the increase of the temperature by $20\ ^oC$ during only the warm period of the year (from May till October). In all the variants total freezing of the active soil layer during the winter months (from November till March) takes place.

The modeling results show that, in all the cases these cycles are stable: the soil temperature and the thawing depth are the same during the same periods of each year.

4. The value analysis

On the finishing stage, the value analysis is applied for the construction on the frozen soils. The method of value analysis - is a method of systematic research of the functionality of the object which is aimed on cost minimizing on the stages of projecting, production and operation while the quality and the utility of the object remains constant or even improves. The spheres of implementation of value analysis during the construction on frozen grounds is shown on Fig. 4.

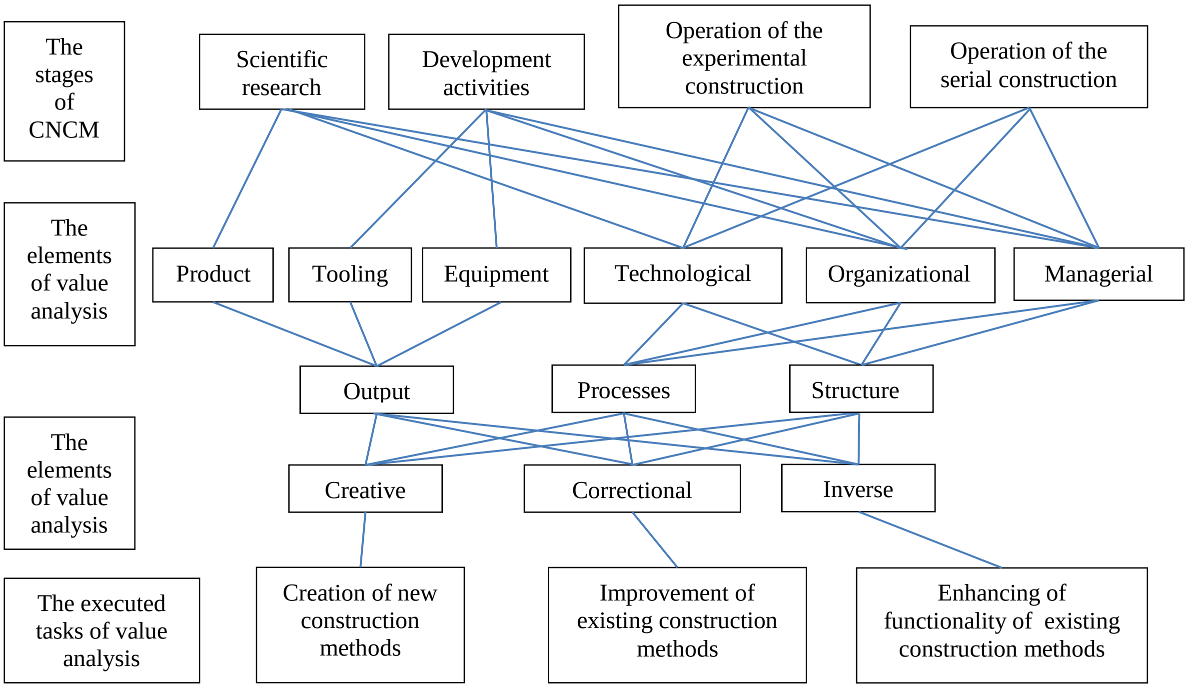

Fig. 4. The objects, forms and spheres of implementation of value analysis while creating new or improving the existing construction methods on the frozen soils.

5. Conclusion

In the regions with insulated frozen areas, the climate warming brings the most permafrost deteriorating effect. The south boundary of the frozen area usually moves with climate warming. These shifts are to be considered during projecting. The projecting should be done keeping in mind the permafrost condition up to its total disappearance, while deterioration of the permafrost upper layers may lead to emergency condition of buildings and constructions.

Intensive development of the Russian Arctic zone and possible climate changes make creation of new construction methods and improving the existing ones an increasingly significant task of construction on the frozen soils.

Acknowledgements

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