

# Effective Design Solutions in the Design of Shallow Foundations

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**Abstract.** The article presents the main directions related to constructive solutions and methods of calculation of shallow foundations. The analysis of the method of calculation of these foundations Institute NIIOSP (Research, design and survey and design-technological Institute of foundations and underground structures N. M. Gersevanova) associated with the choice of the calculation scheme. To take into account the spatial stiffness of shallow foundations, it is proposed to use the numerical method of calculation. An example of a numerical method for calculating shallow foundations for the action of normal forces of frost heaving for a one-story building is given.

## 1. Introduction

On the territory of the Russian Federation, the phenomenon of frost heaving is almost ubiquitous, which is facilitated by the features of natural and climatic conditions. The use of heaving of soils as grounds cause the necessity of taking into account the negative impact of these soils on foundations of buildings. It manifests itself in the development of additional deformations in the process of freezing and thawing of the soil base. Until the late eighties, this account was provided by the fact that the depth of the Foundation was taken at least the calculated depth of freezing. Engineering practice has shown that for one-storey (lung) demon of buildings, including for agricultural purposes, it is economically inefficient. For this category of buildings, Foundation structures with a depth less than the calculated freezing depth were proposed. Such designs are called shallow foundations (SF). The method of their calculation was developed at the Institute of NIIOSP under The leadership of V. A. Orlov and published as a Recommendation [1]. Currently, the normative documents [2], with appropriate justification, allow the use of these foundations.

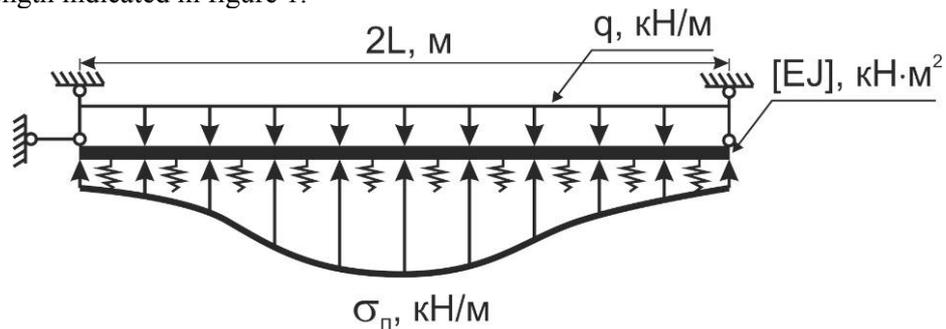
The proposed calculation methods and design solutions provide the stability on heaving soil base for the group II limit state (deformations). Shallow foundations normally is a frame structure, located at subgrade adopted in design schemes resilient. The method of calculation is associated with the selection of longitudinal reinforcement, providing stability of the structure in the II group of limit states.

Subsequently implemented two other methods for sustainability SF on heaving soils. The first one includes the device insulated blind area for heated buildings, excluding the freezing of the soil under the sole Foundation. When implementing this method, the heat engineering calculation of the design under consideration is performed using typical computer software systems. Information about the use of this method, including in foreign practice, is given in [3].



The second method is associated with the device of sand fillings and pillows, ensuring the stability of structures during freezing and thawing of soils bases. Constructive solutions in this direction are outlined in [4].

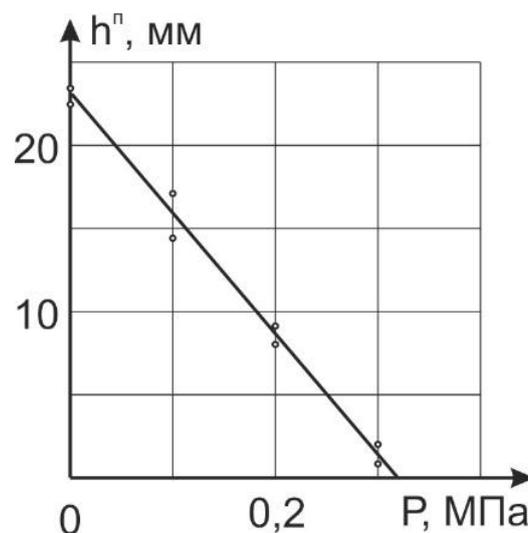
This article is devoted to the issue of improving the method of calculation of the shallow foundations proposed by the Institute NIIOSP. As follows from the work of one of the authors of this technique [5] as a calculation scheme of this technique is not accepted spatial frame structure, and the Foundation beam on two extreme supports, lying on an elastic Foundation (figure 1). The type of support fixings was taken depending on the design features of the Foundation. The exact analytical solution for this scheme was obtained for the pattern of distribution of normal forces of frost heaving along the beam length indicated in figure 1.



**Figure 1.** Scheme to the calculation of the shallow foundations (SF)

The calculation of the frame structure can be performed using the numerical method of calculation, implemented with the help of standard software systems for computers, for example, "PC-Lira" (lira-soft.com).

In the implementation of the proposed method the materials of experimental studies described in [5] were used. These studies established a linear relationship between the normal forces of frost heaving and the depth of freezing of the soil base. The nature of this dependence on one of the objects in the Vologda oblast is shown in figure 2. The ground of the base is represented by loam, which is classified as medium-hard by the degree of frost heaving, and the depth of freezing was 128 cm.



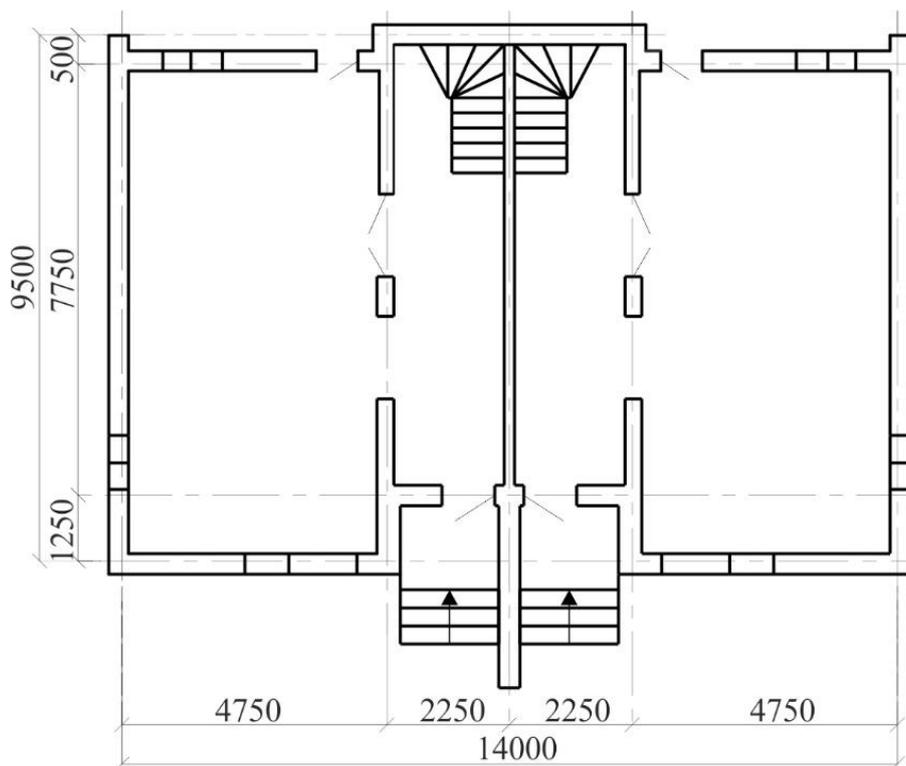
**Figure 2.** Dependence of lift of the Foundation pressure on the ground

The established regularity allowed to determine further at the calculated depth of soil freezing of the base, including taking into account the sand cushion, the normal forces of frost heaving, depending on the magnitude of the beam.

The value of the soil stiffness coefficients in the permafrost (Cm) and melt (CT) state was taken in accordance with the recommendations of VA Florin [6].

As an example, we give the calculation of the SF for a light low-rise heated building. The reference data for the structure and the geotechnical conditions in this example include:

- the plan of the building (figure 3);
- linear load, applied to the edges of the Foundation, it is assumed to be constant for all walls of the building and is  $2.1 \cdot 10^4 \text{H/m}$ , respectively, the pressure on the sole of the SF is equal to  $0,53 \cdot 10^5 \text{Pa}$ ;
- base soil-silty loam, according to the results of laboratory tests, the relative deformation of frost heaving is 7%.



**Figure 3.** Building plan

In this example, adopted SF belt, solid frame construction with a rectangular cross section with width of soles and a depth of 0.4 m. the Foundation Material is the concrete class B15. This Foundation provides calculations for two groups of limit States without taking into account the action of frost heaving forces.

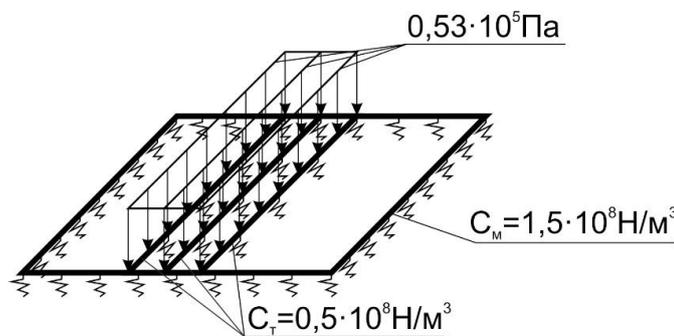
The first stage of the calculation included the determination of the value of the normal forces of frost heaving applied to the sole of the SF. The following design steps included determining the internal forces in the frame structure of the SF from the action of these forces. This definition was made using the numerical method of calculation implemented with the help of the program complex "PC-LIRA". When forming in this complex of the settlement scheme considered in this example tape SF, it was broken down into finite square elements with dimensions of 0,4 m.

Since the building is heated, we assume that the ground under the foundations of the outer walls of the building is in a frozen state, and under the inner walls – in melt. This means that the foundations for the outer walls will be further affected by the normal forces of frost heaving, which are taken in calculation equal to  $3.5 \cdot 10^5$  Pa. The definition of internal efforts made for settlement of the case when all exterior walls have been freezing ground, and deformation of frost heaving was absent.

When performing the calculation, additional source data were taken:

- module of elasticity of the material SF and  $1.7 \cdot 10^{10}$  Pa;
- soil stiffness coefficients in the frozen state  $1.5 \cdot 10^8$  N/m<sup>3</sup>, in the melt –  $0.5 \cdot 10^8$  N/m<sup>3</sup>;
- total pressure plots applied to the sole of the SF, both for internal and external walls, were found by summing the loads applied to the sole of the SF from the overfunding structure and the normal forces of frost heaving.

The calculated value of the deformation of the frost beam was 2.5 cm, and after its completion, the calculation scheme of the SF is shown in figure 4.



**Figure 4.** Calculation scheme shallow foundations

For the accepted design scheme with the use of "PC-LIRA", the values of internal forces in the frame structure were determined. Their maximum values were for the bending moment  $M_{\max} = 5,22 \cdot 10^4$  N\*m, for the transverse force  $Q_{\max} = 5,95 \cdot 10^4$  N. Such an unfavourable loading scheme could only be implemented using the numerical calculation method.

## Conclusion

Thus, the considered example will allow to state that in comparison with the analytical method, the numerical method of calculation has advantages:

1. Taking into account the spatial stiffness of the frame structure shallow foundations.
2. The ability to perform calculations for a variety of adverse loading schemes shallow foundations.

## References

- [1] *Recommendations for the design and calculation shallow foundations on heaving soils*. M.: NIOSP 1985 65
- [2] SP 22.13330.2011. *Bases of buildings and constructions. Updated version of SNIP 2.02.01-83\** [Text]. 2011-05-20. The Ministry Of Regional Development. - M.: OAO "TSPP" publ. p 160
- [3] Nevzorov A 2000 *Foundations on seasonally freezing soils. Textbook*. M.: Ed. ABC p 152
- [4] Simakin V 2002 *Effective foundations for light buildings on heaving soils. Textbook*. Petrozavodsk
- [5] Sazhin V 1988 *Design and construction of foundations of structures on heaving soils [Text] / B. S. Sazhin, V I Shishkin, A S Volokh*. - Saratov: Sarat publishing house. UN-TA p 235
- [6] Florin V A 1959 *Fundamentals of soil mechanics (vol. 1)*. L., M.: Gosstroizdat p 325