CALCULATION OF THE OPTIMAL THICKNESS OF A SANDY-GRAVEL CUSHION IN BED SOILS PRONE TO FROST HEAVING BENEATH THE SHALLOW FOUNDATIONS OF LOW-RISE BUILDINGS

V. O. Orlov

A method of calculating the optimal thickness of the cushion beneath shallow foundations installed on bed soils subject to various degrees of heaving is cited for low-rise construction. Design parameters are given for the frost heaving of soils; they take into account the load due to the building, the moisture conditions of the soils, and the heaving-deformation diagrams.

The construction of a shallow foundation on a sand cushion formed from a nonheaving sandy or sandy-gravel soil is one of the effective methods of installing the foundations of low-rise buildings and structures on heaving soils.

Experience gained with the similar construction of graded sandy-gravel cushions up to 0.3-0.4 m thick and the construction of walls with structural reinforcement on these cushions was brought to light at the outset of the 1960s as applies to conditions prevalent in the Khabarov and Primor’ye Krays, Siberia, and the Far East. As a result of research conducted in Chita by the Scientific-Research Institute of Foundations and Underground Structures in conjunction with the Chita Polytechnic Institute, new data have been obtained on the performance of individual types of three-dimensional shallow foundations on heaving soils in the southern zone of permafrost expansion, which is referred to the northern climatic belt with a mean-annual temperature below minus 2°C (−3.1°C). The results of this research have permitted closer examination of notions concerning the nature of processes that occur in the “foundation/cushion/heaving-bed-soil” system.

The problem of assigning the thickness of the cushion beneath the foundations as a function of the extent to which the freezing bed soil may heave, the depth of its freezing beneath the cushion, the stiffness of the latter in the frozen state and its effect on the rate of development of frost-heaving deformations of the soil with frost depth, as well as the effect of the stiffness of the foundation and superstructure on the nonuniformity of frost-heaving deformations, however, is still not well understood.

In contrast to shallow and normal “traditional” foundations that are installed below the computed depth of seasonal frost in heaving soils, the performance of foundations on sandy cushions has its own advantages:

1) the frost depth and rate of heaving is reduced beneath the building; this makes it possible to lower the design heaving deformation of the soil as compared with the freezing the open surface;

2) an additional resistance to deformations induced by frost heaving is manifested, stresses are dispersed into the soil, and the nonuniformity of its heaving is reduced in the plan of the foundation layout; and,

3) during the spring thaw of seasonally frozen soils, the permeability and compressibility of the thawing soil are reduced, the bearing capacity of the bed is increased, and nonuniformity of building settlement is lowered.


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All this dictates the need for the development of computational models of soil deformations throughout the depth of the freezing layer, which determine the computed thickness of the cushion, the depth of freezing, and the integral amount of heaving.

Using the procedure developed by the author for the calculation of deformations, which is presented in the "Recommendations for the design and calculations of shallow foundations on heaving soil," (Scientific-Research Institute of Foundations and Underground Structures, Moscow, 1985), and the frost-heaving forces, let us determine the thickness of the sandy-gravel cushion for the design of shallow foundations with allowance for the soil's frost deformation throughout the depth of the freezing layer. There are currently no research data on the effect of the stiffness of the cushion on the rate and nonuniformity of frost heaving. As a basic assumption, therefore, let us consider that the assigned thickness of the cushion, which ensures a heaving deformation permissible for the building (structure) in question, will also provide for a reduction in nonuniformity of heaving in the plan of the building.

As we know, the moisture regime and the conditions under which the soils are wetted prior to and during freezing are some of the basic factors affecting the frost-heaving process and its magnitude.

Maximum heaving rate is achieved when ground water exists within the limits of the layer of seasonal thaw or when it is situated near the frost boundary. Characteristic curves of the heaving rate of a soil are presented in Fig. 1 as a function of the distribution of prewinter moisture.

Analysis and generalization of data derived from multiyear research on the effect of the moisture regime of soils on frost heaving makes it possible to select three typical models for the calculation of heaving deformations, which generalize all fundamental cases of the influence exerted by moisture content on the heaving rate of soils throughout the depth of the seasonally freezing layer: