When calculating the bearing capacity of foundations working under conditions of thawing of the frozen ground surrounding them it is necessary to take into account the negative friction forces caused by settlement of the thawing layer. This is especially important when calculating the bearing capacity of deep large-diameter piles (supports) as a consequence of the large area of the side surface of these foundations.

In the construction specifications [1, 2] and handbook [3] it is recommended to assume the negative friction force to be equal to 0.01 MPa regardless of the soil conditions, depth, thawing rate, and other factors.

The results of field investigations of the settlement of experimental piles under the effect of negative friction forces developing during layer-by-layer thawing of the enclosed frozen soils and forces causing these deformations, which permit refining these data, are given below.

The first cycle of the experiment consisted in studying the behavior of two unloaded 35-cm-diameter reinforced-concrete piles 1 and 2 driven directly into permafrost to a depth of 6.9 and 7.5 m, respectively, with a distance of 4 m between them (Fig. 1). The soils at the site were represented by silty loams with a unit weight of 2.03 g/cm$^3$, density 2.67 g/cm$^3$, water content at the liquid limit $W_L = 27.1\%$ and at the plastic limit $W_p = 16.9\%$, whose cryogenic structure was characterized mainly by a stratified structure. The ice content was distributed nonuniformly over the section: in the upper part to a depth of 6.5-7 m the 1-2-cm-thick ice interlayers were arranged every 20-35 cm and deeper, more rarely. The total water content was determined from the core of the two boreholes and averaged $W = 21.4\%$ to a depth of 6.5-7 m and $W = 17.2\%$ deeper. The temperature of the frozen ground at the depth of annual variations of 10 m was $-1^\circ C$

The frozen ground around the piles was thawed by electric heaters - tubular electric water heaters 2. Layer-by-layer thawing was achieved by moving the central electrode of the heater. The temperature of the heaters during the work was kept at the 85-90°C level by regulating the voltage. At first the electrodes were lowered to a depth of 2 m and the upper 2-m soil layer was thawed. Then soil layers 5 were thawed layerwise every 1 m to a depth of 10 m by successive lowering of the electrodes. The boundary of the frozen ground is denoted by 6.

Settlement of the surface of the experimental plot in the soil-thawing zone was fixed by a level and settlement of the piles was measured by deflectometers 4.

We see from Fig. 2, which shows graphs of the course of thawing of the permafrost, settlement of the ground surface, and settlement of the piles in time, that settlement of the ground surface began immediately after the start of thawing. Settlement of the piles began 40-50 days later, when thawing reached a depth of 4.5-5 m. At first the rate of pile settlement was insignificant and amounted to 0.01 mm/day. With further advance of the thawing front the rate increased to 0.45-0.67 mm/day. With respect to absolute values the settlement of the ground surface exceeded the pile settlement by several tens of times and only when the thawing front reached the end of the piles did the settlement rates become equal and amount to 1 mm/day.

The negative friction forces in the experiment were established by calculation and experimentally. The calculation method was based on the assumption that the start of settlement of the unloaded piles corresponds to the limit value of their bearing capacity, i.e., the latter is equal to the negative friction forces. Under conditions of the described experiment this moment corresponded to a thawing depth of 4.5-5 m, i.e., when the lower part of the pile was still 2 m in the frozen ground.

In this case the bearing capacity of the experimental piles, determined by instructions RSN 41-72 [2], was 124 kN. Assigning this value of the bearing capacity to the area of the skin surface of the piles within the thaw-
ing depth, we obtain the average specific value of the negative skin friction of the thawed soil, which amounted
to 0.023 MPa.

The experimental ultimate strength of the thawed soil was established by a pull-out test of pile No. 1 by
gradual loading. The tests were conducted after thawing of the ground within the depth of the pile. The ultimate
pull-out resistance of the pile was 175 kN, which corresponds to an average ultimate skin friction of the
thawed soil of 0.023 MPa.

In addition to the investigations described above we also conducted field experiments on the direct mea-
surement of the negative friction forces. Such tests were conducted for the first time by Pchelintsev [4] and
consisted in thawing the soil around a metal pipe lowered into a predrilled large-diameter hole. Pchelintsev
established that for the given soil conditions the negative friction forces were 0.005 MPa. He suggested that a
negative friction force acts on a pile driven into frozen ground in the case of its thawing which is close in mag-
nitude to the standard shear strength of this soil with respect to the skin surface of the pile.