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Abstract

Full Text

MECHANICS

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RELAXATION OF SHEAR STRESSES ALONG THE LATERAL SURFACE OF A LOADED PILE FROZEN INTO SOIL

(Presented by Academician D. I. Shcherbakov, September 2, 1957)

In 1954 the author applied an electrical method for determining the shear reactions along the lateral surface of a loaded pile frozen into soil ⁽¹⁾. On the basis of the results of measuring the normal stresses $\sigma_{(y)}$ in the elastic material of the pile, the shear stresses $\tau_{(y)}$ were determined from the equation:

$$F\sigma_{(y)} - P + \Pi \int_0^y \tau_{(y)} dy = 0,$$

where F is the cross-sectional area of the pile, P is the external load, and Π is the perimeter of the pile.

As a result of the measurements it was established that, for a constant value of a briefly acting external load, the greatest values of $\tau_{(y)}$ were observed in the upper part of the pile, decreasing sharply in the lower part of the pile. In addition, it was noted that, owing to the creep of frozen soils, with the passage of time stress relaxation occurred in the upper part of the pile, while lower down the stresses increased.

Such a redistribution of stresses was accompanied by an increase in the length of the stressed upper part of the pile and a decrease in the length of the unstressed lower part of the pile, where $\sigma_{(y)} = 0$ and $\tau_{(y)} = 0$. A phenomenon occurred which the author called "zero creep."

Subsequently, as measurements continued at the open experimental site of the Yakutsk Scientific-Research Permafrost Station of the Academy of Sciences of the USSR, their duration was extended to 460 hours. During this period, damping of changes in shear stresses under stepwise increasing loads was recorded, and it was possible to establish, under the experimental conditions, the long-term freezing strength of the soil to the lateral surface of the loaded pile under a nonuniform distribution of shear stresses along its length. For technical reasons, the experimental investigations were limited in pile No. 2 to measurements of $\sigma_{(y)}$ at the places where sensors Nos. 2 and 3 were glued, and in pile No. 3 to sensors Nos. 3-5. The ohmic resistances of the listed sensors under zero pile

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

load did not change during the period 1954–1955. The normal stresses in the pile were measured with an electronic strain-measuring instrument powered by direct current and with a socket-type decade switch. Pile displacements were measured by clock-type indicators, and soil temperatures by thermometers and thermistors*.

Pile No. 3, 200 cm long and 15 cm in diameter, was under the action of a tensile, stepwise increasing load for 460 hours. In the section between sensors Nos. 3 and 4, i.e., at a depth from 0.55 to 1.05 m from the surface of the frozen soil, at negative temperatures from -2.1 to -3.1° , the instantaneous values of τ varied from 0.50 kg/cm^2 at $P = 2450 \text{ kg}$ to

* Measurements were carried out by A. A. Zhigulskii.

2.49 kg/cm^2 at $P = 13250 \text{ kg}$. Under the action of this latter load, over the course of 6 days the value of τ reached $2.30\text{--}2.40 \text{ kg/cm}^2$, and at this point the decrease stopped.

Thus, the long-term adfreezing strength of the soil with the lateral surface of the pile, at temperatures from -2.1 to -3.1° , proved to be $\tau = 2.3\text{--}2.4 \text{ kg/cm}^2$ (Fig. 1). Relaxation of stresses proceeded intensively only during the first days, and thereafter the fall of τ gradually died out.

Fig. 1. Changes with time in shear stresses in frozen soil along the lateral surface of the measuring tube of pile No. 3 between sensors Nos. 3 and 4

In the section between sensors Nos. 4 and 5 of the same pile No. 3, at a depth of 1.05 to 1.55 m from the surface of the frozen soil, at temperatures from -3.1 to -3.5° , an increase in shear stresses occurred. Here τ changed from 0.03 kg/cm^2 at $P = 2450 \text{ kg}$ to 1.48 kg/cm^2 at $P = 13250 \text{ kg}$

Fig. 2. Changes with time in shear stresses in frozen soil along the lateral surface of the measuring tube of pile No. 3 between sensors Nos. 4 and 5

(Fig. 2). The rate of increase of τ in this section of the pile corresponded to the rate of decrease of τ in section No. 3–No. 4. On the fourth day of loading the pile with a load of $13,250 \text{ kg}$, the shear stresses between sensors Nos. 4 and 5 decreased to 1.29 kg/cm^2 , with a clear tendency toward further decrease. Increasing the load to $14,000 \text{ kg}$ caused an increase in shear stress to $\tau = 1.79 \text{ kg/cm}^2$, followed by a very rapid fall to $\tau = 0.93 \text{ kg/cm}^2$. Under this load, pile

Fig. 3. Vertical displacement over time of the head of the measuring tube of pile No. 2

Figure 3: Fig. 3. Vertical displacement over time of the head of the measuring tube of pile No. 2

No. 3 was pulled out of the frozen stratum; the failure was preceded by the formation, in the frozen soil, of a crack around the pile.

Since the granulometric composition and moisture content of the soils in the section from 0.55 to 1.55 m were almost unchanged, while the temperature decreased with depth, the reduction of shear stresses to 1.29 kg/cm^2 between sensors Nos. 4 and 5, as against $\tau = 2.3\text{-}2.4 \text{ kg/cm}^2$ in the section between sensors Nos. 3 and 4, is not associated with relaxation. Apparently, already under a load of 13,250 kg, after three days from the moment of its application, the transformation of adfreezing forces into friction forces began. After a slight increase of the load to 14,000 kg, the transformation process was instantaneously completed, and the external load was opposed only by friction forces, which proved insufficient to resist the external load, as a result of which the pile was pulled out of the frozen stratum.

Pile No. 2, 200 cm long and 20 cm in diameter, was subjected to a compressive, stepwise increasing load for 430 hours. When the load was increased to 11,010 kgf, the pile head lost stability and the measurements were discontinued. The measurement results show that relaxation of shear stresses at $\tau = 1.5 \text{ kgf/cm}^2$ was not observed.

Measurements of the displacements λ were also made under stepwise increasing tensile and compressive loads on the piles. The displacements of pile No. 2, measured by indicators under a load of 9640 kgf over 430 hours, are shown in Fig. 3. After 8 days the displacements began to die out and no longer increased.

Fig. 3. Vertical displacement over time of the head of the measuring tube of pile No. 2

Thus, piles of the indicated dimensions, frozen into the soil to a depth of 175 cm in a soil characteristic of Yakutsk—silty quartz sand with 20% moisture content and with a naturally established subzero temperature in the ground—were fully used in additional investigations, as a result of which some data were obtained on the relaxation of shear stresses at the contact with frozen soil.

On the basis of the measurements performed, the following conclusions may be drawn:

1. Redistribution of shear stresses, for known ratios of load and pile length, occurs with a decrease in stresses due to their relaxation in the upper part of the pile and with some increase in stresses without relaxation in its lower part.

2. The long-term freezing strength of sandy loam with duralumin at soil temperatures from -2.1 to -3.1° reached the value $\tau_{\text{lt}} = 2.40 \text{ kgf/cm}^2$.
3. The long-term freezing strength of the same soil, at the same temperatures and moisture content, with a reinforced-concrete pile should have larger values, since the surface of reinforced concrete has greater roughness than the surface of the duralumin measuring tube.

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CITED LITERATURE

1. K. E. Egerev, DAN, **114**, No. 1 (1957).

Note: Figure translations are in progress. See original paper for figures.

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