ELECTRICAL METHOD FOR DETERMINING TANGENTIAL REACTIONS ALONG THE LATERAL SURFACE OF A LOADED PILE FROZEN INTO SOIL

1957

SovietRxiv

Fig. 1

Figure 1: Fig. 1

Fig. 2

Figure 2: Fig. 2

Abstract

Full Text

MECHANICS

K. E. EGEREV

ELECTRICAL METHOD FOR DETERMINING TANGENTIAL REACTIONS ALONG THE LATERAL SURFACE OF A LOADED PILE FROZEN INTO SOIL

(Presented by Academician D. I. Shcherbakov, 24 XII 1956)

The electrical method for measuring non-electrical quantities has been adopted by the V. A. Obruchev Institute of Permafrost Studies of the Academy of Sciences of the USSR for studying changes in the stressed state of soil near a pile frozen into it. The present work is based on the electrical method of measurement.

Let us consider the behavior of a hollow support in the form of a pile of length H, with cross-section F and lateral surface Π, passed without friction through the thickness of a seasonally frozen layer of depth h_1 and frozen into the soil to a depth h_2. By design measures the occurrence of longitudinal bending is excluded; therefore the pile will undergo simple compression under the load P over the entire length $h_0 + h_1$ (Fig. 1).

Fig. 1. Theoretical outline of the diagrams of $\sigma_{(y)}$ and $\tau_{(y)}$ according to the boundary conditions

Fig. 2. Diagrams of τ_{avg} under loads $P = 50 \div 125$ kg for 5 min. Measurements 10–21 VIII 1954. Compressed measuring tube No. 3, $d = 5$ cm, a–$P = 50$ kg; b –75 kg; v–100 kg; g–125 kg

Let us write the equilibrium conditions for the vertical forces acting on the pile: in sections where $y \leq 0$,

$$F\sigma_{(y)} - P = 0; \tag{1}$$

Fig. 3. Measuring tubes Nos. 1 and 3; $d = 15$ cm

Figure 3: Fig. 3. Measuring tubes Nos. 1 and 3; $d = 15$ cm

in sections where $y \geq 0$, the tangential reactions distributed along the lateral surface of the loaded pile frozen into the soil are added to the sum of the forces of equation (1):

$$F\sigma_{(y)} - P + \Pi \int_0^y \tau_{(y)}\, dy = 0, \tag{2}$$

where $\sigma_{(y)}$ is the normal stress in the pile wall due to the load; $\tau_{(y)}$ is the tangential stress along the lateral surface of the pile frozen into the ground due to the load P.

The unknowns in equation (2) are $\sigma_{(y)}$ and $\tau_{(y)}$, where $\sigma_{(y)}$ is measured by the electrical method, and $\tau_{(y)}$ is determined as a function of the measured $\sigma_{(y)}$ for the given temperature, moisture content, and granulometric composition of the soil. With these data, using the measured $\sigma_{(1,2\ldots)}$, an auxiliary force diagram is constructed,

$$T = \Pi \int_0^y \tau_{(y)}\, dy = P - F\sigma_{(1,2\ldots)}, \tag{3}$$

which makes it possible, with accuracy sufficient for practical purposes, to construct the diagram of $\tau_{(y)}$.

For the experimental investigations, electrical strain gauges in the form of wire resistance sensors and an electronic deformation meter (EID) were selected. The EID manufactured for the Institute of Permafrost Studies of the Academy of Sciences of the USSR was calibrated at a negative temperature of $-10°$ and at a positive temperature of $+20°$. The accuracy of the instrument proved to be equal to $\frac{1}{1.5 \cdot 10^5}$ of relative deformation. From this, knowing the value of the modulus of elasticity of the material, the value of one rheochord division in kg/cm^2 and the measurement range within the accepted conventional values of stresses of various materials were established; these are given in Table 1, from which it is seen that duralumin is most expediently used for experimental pile tubes. This elastic material provides the highest measurement accuracy.

Laboratory investigations had as their aim a preliminary check of the theoretical conclusions; the experiments were carried out with three measuring duralumin tubes 5 cm in diameter, 32–50 cm long, and with a wall thickness of 0.1 cm. Inside the tubes, 4 active and compensating sensors each were glued. The character of the experimental curves obtained for τ_{mean} (Fig. 2) agrees with the theoretical curve $\tau_{(y)}$ (Fig. 1).

Fig. 3. Measuring tubes Nos. 1 and 3; $d = 15$ *cm*

Field investigations were carried out during September–November 1954 in Yakutsk at an experimental site. To place the measuring tubes in the perennially frozen soil mass, a pit 2.65 m deep was dug, equal to the depth of seasonal thawing of the ground. In all, three measuring tubes were made: Nos. 1 and 3 with a diameter of 15 cm (Fig. 3), and No. 2 with a diameter of 20 cm. The measuring tubes were frozen into a soil typical for the city of Yakutsk, consisting of silty quartz sand of average gravimetric moisture content 20-25%. Temperature measurements near the tubes were made with inertial thermometers; in addition, 5 thermistors were installed inside tube No. 3. The duralumin used for making the measuring tubes had an ultimate strength of 3800-4400 kg/cm^2, elongation of 12-20%, and modulus of elasticity $E = 740\,000$ kg/cm^2. On the inner

from 5 to 10 pairs of wire sensors, having ohmic resistances of about 230 ohms and a base of 23 mm, were glued to the surface of the measuring tubes. The sensor wires were mounted on wooden inserts and led out into the room for measurements.

The solution of the problem posed above was accompanied by investigations of the properties of various adhesives for the sensors, and of various types of insulation for the sensors and wires under the action of low temperatures and high humidity.

Table 1

Material	Modulus of elasticity, $E \times 10^6$, kg/cm^2	Conventional elastic limit, kg/cm^2	Cost of measurement of one point, kg/cm^2	Range of measurements, number of divisions
Steel	2.0	1700	13.3	127
Duralumin	0.74	1850	5.0	375
Reinforced concrete	0.2	50	1.3	38
Wood	0.1	100	0.7	150

Measurements were carried out over the course of 10 days. The greatest load reached 8525 kg and was maintained for up to 52 hours, with maximum stresses in the wall of the tube of 1235 kg/cm^2, which is less than the conventional stress limit of 1700 kg/cm^2. The numerous measurement data obtained in three tubes at different load magnitudes confirmed the theoretically established law of distribution of tangential reactions over the depth of the support and refuted N. I. Bykov' s assumption ([1]) of a distribution of freezing forces increasing with depth according to the law of a triangle.

Figure 4 shows the characteristic change in the values of $\sigma_{(y)}$ and τ_{avg} in measuring tube No. 2 under prolonged action of a load of 8525 kg. The excessive

Fig. 4. Epures of $\sigma_{(y)}$ and τ_{avg} with a duration of action of a load of 8525 kg from 1 to 52 hours. Measurements on 31 X, 1 XI and 2 XI 1954. Measuring tube No. 2. I –duration of loading 1 hour; II –23 hours; III –52 hours

Figure 4: Fig. 4. Epures of $\sigma_{(y)}$ and τ_{avg} with a duration of action of a load of 8525 kg from 1 to 52 hours. Measurements on 31 X, 1 XI and 2 XI 1954. Measuring tube No. 2. I –duration of loading 1 hour; II –23 hours; III –52 hours

increase of τ_{avg} to 9.15 kg/cm^2 at the surface of the frozen soil is explained by the deliberate increase of the moisture content of the upper soil layer to 46%, as against an average moisture content of 23%.

Fig. 4. Epures of $\sigma_{(y)}$ and τ_{avg} with a duration of action of a load of 8525 kg from 1 to 52 hours. Measurements on 31 X, 1 XI and 2 XI 1954. Measuring tube No. 2. *I* –duration of loading 1 hour; *II* –23 hours; *III* –52 hours.

Conclusions

1. The electrical method of measuring elastic deformations in metal (duralumin) pile-instruments makes it possible to refine the law of change of the stressed state of perennially frozen soils as a function of their temperature, moisture content, and granulometric composition.
2. From the data of the investigations it follows that in regions where construction based on the principle of preserving perennially frozen soils in the foundation of structures is possible, the use of pile supports is rational. Determining the distribution of tangential reactions along the lateral surface of a pile makes it possible to assign optimal dimensions both for the length and for the cross section of piles.

Institute of Permafrost Studies
Academy of Sciences of the USSR

Received
14 VIII 1956

References

1. N. I. Bykov, P. N. Kapterev, *Permafrost and Construction on It*, Moscow, 1940.

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