formed during the 20th, but during the 17th century. His "group 3" is not from A.D. 1750–1800, but is rather 5 000 to 7 000 years old, according to the offset of Cordillera Blanca great fault.

This contribution is published in full as three papers in *Journal of Glaciology*, Vol. 18, No. 79.

EXPERIMENTS ON THE HEAVING FORCE OF FREEZING SOIL

By Seiiti Kinosita

(Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan 060)

Abstract. Frost heaving of soil is accompanied by a force which often causes severe damage to structures. It was suggested by Everett that this so-called "heaving force" can be attributed to the coexistence of ice and water in micropores among soil particles which characterize the soil type and can be computed thermodynamically. However, the actual heaving force changes in a complicated manner depending on various factors including freezing speed, constraining condition for a soil block, and, of course, soil type.

Measurements of heaving force were carried out on various soil samples (sand, sandy loam, sandy clay loam, and two kinds of clays) under various freezing conditions: freezing speed in a range from 0.10 cm/h to 0.35 cm/h, presence or absence of water supply, complete or loose axial constraint applied to a soil block. In each experiment, soil was packed in a cylindrical container with a diameter of 11 cm and a height of 10 cm. A disk was placed on top of the soil contained in the container to constrain the sample either rigidly (a complete axial constraint) or less rigidly through a spring (a loose axial constraint). Main results of the measurements were as follows:

(1) Under complete axial constraint, the heaving force decreased with decrease in the freezing speed and with the increase in the size of soil particles (from 6 bars to 1 bar for clay; from 4 bars to 1 bar for sandy clay loam; from 4 bars to 0.8 bar for sandy loam; from 1.5 bars to 0.6 bar for sand).

(2) Without the constraint, the heave amount was almost independent of the freezing speed when there was no water supply (8 mm for clay; 6.5 mm for sandy clay loam; 3.5 mm for sandy loam; 1 mm for sand).

(3) The heaving force decreased very rapidly with the loosening of the axial constraint by weakening the spring.

The results indicate that it is practical to treat the heaving force phenomenologically as a kind of resistive force exerted by freezing soil on a container holding the soil. Because of a volumetric increase due to the transformation of water into ice at the freezing front, both unfrozen and frozen parts of the soil suffer some strain if the soil is somehow constrained by the container. The strains cause stresses which appear as the heaving force. A formula for the heaving force is given in which both the frozen and the unfrozen soil are treated as visco-elastic bodies.

DISCUSSION

R. List: What is the porosity of the soil or the saturated water content? Do you get rid of all the air when you let the water into the sample? If you do not, or at least do not vary the air content of the sample, what is the meaning of the experiment?

S. Kinosita: Referring to our clay samples the water content by weight was 60% to 70%. We did not remove the air from any of our samples before saturating them.

D. BRUCE: What defences may be used to prevent frost heaving, in particular for highways with asphalt pavement?

KINOSITA: Soil which is susceptible to strong frost-heaving action is replaced by other materials which have a coarse grain (e.g. sand). The depth of such replacement is 80% of maximum frost penetration. Furthermore replacement is limited only to 40 cm below the pavement surface. Under the 40 cm level a board of thermal insulation, such as polystyrene is placed. The thickness of the insulation depends on the severity of the frost.

CHARACTERISTICS OF PROCESSES OF ELECTRICAL RELAXATION IN FROZEN SOILS

By A. D. FROLOV *and* B. V. GUSEV
(Moscow Geological Prospecting Institute, Moscow, U.S.S.R.)

ABSTRACT. The results of measurements of dielectric properties of frozen soils are analysed on the basis of modified theory of dielectrics. The relaxational character of frequency and temperature dependence is shown and the basic equations are derived. The characteristics of distribution of relaxation times and effective relaxation times as depending on the temperatures are discussed. The values of activation energy are estimated.

https://doi.org/10.3189/S0022143000029622 Published online by Cambridge University Press