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Publisher's version / Version de l'éditeur:

Canadian Journal of Soil Science, 41, pp. 160-163, 1961-12-01

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ALTERNATE FREEZING AND THAWING NOT A REQUIREMENT
FOR FROST HEAVING IN SOILS

BY

E. PENNER

REPRINTED FROM
CANADIAN JOURNAL OF SOIL SCIENCE, VOL. 41,
AUGUST 1961, P. 160 - 163.

RESEARCH PAPER NO. 143
OF THE
DIVISION OF BUILDING RESEARCH

OTTAWA

DECEMBER 1961

PRICE 10 CENTS

NRC 6439

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E. PENNER

National Research Council, Ottawa, Ontario

Reprinted from Canadian Journal of Soil Science 41: 160-163, August, 1961

N.R.C. 6439

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ALTERNATE FREEZING AND THAWING NOT A REQUIREMENT FOR FROST HEAVING IN SOILS

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[Received for publication December 19, 1960]

ABSTRACT

Field measurements of frost heaving beneath a cold storage plant and laboratory soil freezing experiments in "open" and "closed" systems support the view that both a freezing and thawing cycle are *not* required for frost heaving as has been suggested in a recent paper (2).

INTRODUCTION

In a recent paper (2), giving results from heaving experiments in the field, it was intimated that freezing and thawing are "required" for frost heaving, whereas in the summary the suggestion was made that freezing and thawing "favour" frost heaving in field plots.

These statements appear to be contradictory and are not consistent with well-established facts in the literature about the frost action process (3). The writer is not so much concerned with the contradiction, however, as with the statement about the "requirement" for frost heaving. The purpose of this paper is to present evidence to show that the frost heaving process is not contingent on the presence of a thawing cycle either in laboratory experiments or in the field.

THEORY OF FROST HEAVING

Frost heaving in soils is the result of ice lensing. An ice lens obtains water for growth by drying the soil in its vicinity, thereby creating a suction gradient in the water of the unfrozen soil. At the same time, sufficient additional energy is made available in the water-ice phase change to lift the frozen soil. Frost heaving will only occur, however, if sufficient water is available, the soil temperature is below 0°C., and the soil is frost susceptible, i.e., a soil which supports ice lens growth.

Another condition must also be met. During the water-ice phase change the latent heat of crystallization must be removed in order to sustain heaving. This provides a convenient means of following the progress of ice formation. In the particular case of a stationary freezing front the amount of heave may be computed from the net heat extraction.

To a large extent, the rate of heat removal determines the rate of heaving. This has been shown to hold for soils of widely different characteristics in laboratory experiments (4); when heat removal becomes excessive, however, the permeability of soil may limit the rate of frost heaving.

RESULTS AND DISCUSSION

Laboratory Experiments

The results of a laboratory freezing experiment with Leda clay at two rates of heat extraction are shown in Figure 1. In particular it should be noted that the heat flow was in one direction in both stages 1 and 2 of the experiment, i.e., there was no thawing cycle. The rate of heaving

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FIGURE 1. Cumulative values of net heat flow and moisture flow *vs.* time.

FIGURE 2. Net difference between heat out and heat in as a function of time in a closed system as measured by heat meters.

during stage 1 was about 1.5 inches per day; during stage 2 it was 2 inches per day. Calibrated heat flow meters, 6 inches in diameter, were placed at each end of the 3-inch-high soil specimen to measure the heat flow. Water was supplied from an automatic balance arrangement at a suction equivalent to 1 foot of water. Both heat and water flow were continuously recorded on a millivolt recorder.

The results (Figure 1) show that a steady rate of heat flow in an "open system" can produce very substantial frost heaving. This is also true if the system is allowed to desaturate, "closed system". The heat removed during freezing can be accounted for in terms of the latent heat of fusion of the water frozen and the cooling of the sample. Figure 2 gives net heat flow

FIGURE 3. Temperature distribution at equilibrium in closed system.

measured by heat flow meters as a function of time for a closed system. Figure 3 shows the temperature gradient before heaving began and after heaving ceased. The sample was saturated before freezing commenced and no further water was supplied during the freezing period. Again, a smooth and continuous heat flow in one direction during the experiment may be noted.

In the unfrozen portion, the water content had been reduced from the saturated state of 8.4 per cent to 3.9 per cent. From the known unfrozen water-temperature relationship for the soil, the amount of ice in the frozen portion could be estimated. The difference between heat in and heat out measured by the heat meters was 49.8 B.t.u. Freezing of the water took 47.6 B.t.u. and cooling the soil, water and ice took 4.8 B.t.u. This leaves only 5 per cent of the heat extracted unaccounted for, a good balance when the difficulties in doing the many experiments to permit such a computation are considered.

Field Measurements

Level surveys carried out on the floor of a cold storage plant at Cornwall, which was subjected to extensive frost heaving damage after 8 years of continuous operation, showed frost heaving was still in progress (1). For the period February to June, the frost line penetrated from 8 to 9 feet, resulting in some 2½ inches of heaving in the centre of the building. This situation represents frost heaving in the field but compares, in its steady unidirectional heat removal, to the laboratory experiments described.

CONCLUSION

It is believed that sufficient experimental evidence has been provided to conclude that alternating freezing and thawing is not a "requirement" for frost heaving.

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