ASSESSMENT OF RELIABILITY OF DETERMINATION OF THE
LONG-TERM DEFORMATION OF FROZEN SALINE SOILS

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UDC 164.139

The reliability of parametric equations of technical creep theories and the method of strain-time analogy for prediction calculations is demonstrated on the basis of comparison of experimental and computed values of the deformation of frozen saline soils.

Saline permafrosts are, as a rule, found in a plastically frozen state. In conformity with Construction Rule and Regulation 2-02-04-88, beds composed of these soils should be considered with respect to two groups of limiting states — bearing capacity and deformations.

No computed deformation characteristics of frozen saline soils are given in this Construction Rule and Regulation, and their determination is not discussed.

Development of methods of predicting the long-term deformations of frozen saline soils over a period of time comparable to the service life of structures is therefore an extremely important problem.

Above all, it is necessary to establish the applicability of solutions employed in the area of the creep prediction of plastically frozen soils with no readily soluble salts to saline soils.

At the present time, these solutions are based on parametric equations obtained on the basis of creep theories (aging, hardening, flow). In these equations, the relationship between strains, stresses, and time is in explicit form [1]. The equation of the theory of hereditary creep is also used with the vanishing-creep kernel obtained by Zaretskii [2] for plastically frozen soils. Moreover, a number of authors have proposed empirical relationships that include experimental parameters [3]. The possibility of using methods of time analogies to predict the long-term deformation of plastically frozen soils is also demonstrated [4]. Parameters established on the basis of experimental laws governing the deformation obtained during a comparatively short period of the creep testing of frozen soils (hours, days) is used in all of the methods enumerated. These laws are then assumed constant during the course of the entire prediction period, the duration of which exceeds the experimental time by several orders. The accuracy of the prediction depends on to what extent the equation expressing laws governing deformation during the test period is valid for description of the deformation process during the course of the overall prediction time. Assessments of the reliability of long-term strains obtained by computation are also required for frozen saline soils. Test data on the basis of which it is possible to confirm computed strain values are a criterion of such an assessment. For frozen saline soils, research directed toward comparison of predicted and experimental strain values assume particularly critical significance, since the character of the manifestation of the rheological properties differs, by nature, from that for other types of plastically frozen soils (peaty, heavily iced, highly silted). This difference is caused by the fact that the content of unfrozen water is the basic factor determining the increased deformation of saline soils, while creep is also determined by the viscoplastic properties of the solid components — ice and biogenic particles — in peaty, heavily iced, silt-laden soils.

Methods of predicting long-term deformation have been proven on the basis of test data (more than four years) from research on the creep of frozen saline soils in the Yamal Peninsula, and recommendations given for their use. Experiments were conducted in the underground laboratory of the Anderma Scientific-Research Station, in whose compartments a constant temperature of minus 3°C is maintained. Sand, sandy loam, and clayey loam were tested. Sandy loam and sand specimens were removed from deposits of the third Zyryanka-age marine terrace in outcrops of the left bank of the Erkuta-Yakha River 20 km from its mouth. The clayey loam was sampled at a depth of 1-3 m in the central part of Yamal Peninsula at the latitude of the Cape of Kharasavi in marine Kazantsevsk deposits located to the east of Lake Tyurin-To.
The physical properties and results of chemical analysis of aqueous extracts from the undisturbed soils under investigation are presented in Tables 1 and 2.

The tests were conducted on both undisturbed and artificially prepared specimens. The latter were subjected to additional uniform salinization by a marine salt in conformity with the maximum salinity of the types of soil in question on the Yamal Peninsula.

The average values of the basic physical properties of the artificially prepared specimens are presented in Table 3. In that case, the freezing point of the soil moisture (θ_{fp}) was calculated from an equation obtained as applies to frozen saline soils on the basis of the Rayleigh–Van’t Hoff equation [5], and the content of unfrozen water (W_u) from an equation derived on the basis of the generalized relationship W_u/W_t = θ/θ_{fp} (where W_t is the total moisture content, and θ is the temperature of the soil), as established by Roman [4].

The tests were conducted in uniaxial compression under a creep regime with a one-time load application on twin specimens with sixfold repetition at each load value.

Two series of tests were conducted.

In the first series, twin specimens were tested in the stress range (5-7 values) as a result of which a family of creep curves was obtained. The duration of the tests was 9-10 days.

In the second series, we tested the same specimens at one of the stresses assigned in the first series, which had caused vanishing creep or creep at a constant rate. The duration of the tests was more than four years.

The results of the tests were processed by the method of least squares and creep curves were plotted for the average values of the deformations that developed over time (Figs. 1 and 2).