EXPERIMENTAL RESEARCH OF THE LUNAR SOIL-ANALOGUE VI-75 UNDER NEGATIVE TEMPERATURE. A. V. Uvarova[1] and I. A. Agapkin[1], [1]Vernadsky Institute of Geochemistry and Analytical Chemistry, Moscow, Kosygina 19, Russia, uvarova@geokhi.ru.

Introduction: Modern studies of the moon are aimed, among other things, at the study of the polar regions. In these areas, ice may be present and, according to various estimates, its content can reach 4% by weight [1]. It greatly affects the mechanical properties of soils [2] and can increase the strength properties by several times. This fact should not be neglected during missions, the purpose of which is drilling and sampling of soil, as well as its sounding. In this regard, the research is aimed at studying the lunar soil analogue with different water contents at low temperatures. The lunar soil analogue VI-75 [3], previously developed by the Laboratory of Geochemistry of the Moon and Planets, was used as an analogue soil, which imitates the physical and mechanical properties of the surface lunar soil.

Research methods: The main strength properties in soil mechanics are the angle of internal friction (φ) and specific cohesion (c). The first parameter characterizes the ratio of normal (σ) and tangential (τ) forces required to destroy the sample, while the second shows the resistance to tangential forces, without the influence of normal forces. These characteristics were determined by a shear test. This method is based on the Mohr-Coulomb theory: the destruction of materials occurs at a certain ratio of normal and shear stresses.

The experiments were carried out at three values of the vertical load according recommendations of Russian standards 12248.1-2020 [4], the minimum stress was taken to be 50 kPa, since it is close to the natural pressure of dense soils at a depth of 60 cm and further. Subsequent stages of loading are chosen as doubled values of the previous stage. The Shear load was set kinematically at a velocity of 2 mm·sec^{-1}. All experiments were done using testing equipment the GEOTEK company.

A sample of VI-75 was mixed evenly with the required amount of water, until the same water content was reached inside the sample. Water content values were set at 5% and 10% by weight. The resulting mixture was placed in cylindrical rings 35 mm high and 71 mm in diameter, these are special forms for preparing samples for shear tests, and compacted to ρ = 1.75 g·cm^{-3}. The rings were pre-lubricated with petroleum jelly to make it easier to push the frozen samples into the test setup.

The prepared samples were placed in a box made of insulating material. Liquid nitrogen was poured into a separate container to quickly freeze the samples. They froze to the lowest possible temperature from –110ºC to –120ºC within 2 hours (Fig. 1).

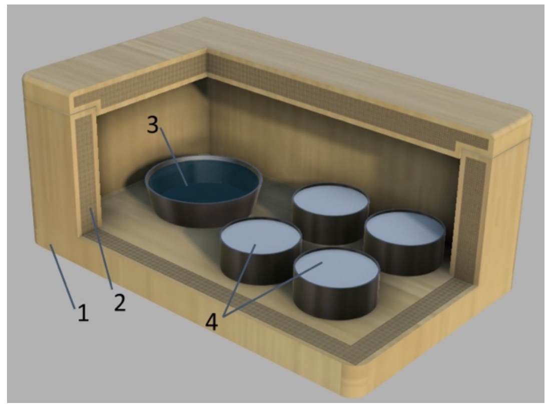

Figure 1. Scheme of preparing samples for testing: 1 - hardboard box, 2 - heat insulator, 3 - liquid nitrogen, 4 - samples in metal rings.

The initial stage of the research did not involve the use of freezers with a large capacity, so that the whole device for a single-plane cut could fit there, besides, it was not designed to work with such low temperatures, so the experiments were carried out at a temperature of +13ºC. Such conditions inevitably led to an increase in the temperature of the samples; therefore, the rate of thawing of the samples was additionally measured. As a result of a large number of experiments (about 20), 9 closest to each other were selected, 3 results for each level of normal load.

Results: Measurement of the thawing rate showed a significant increase in temperature from -120ºC to -50ºC in 5 minutes, then the rate decreases and, when approaching zero, the graph asymptotically approaches zero, which is quite explainable by the beginning of the phase transition of water ice (Fig. 2).

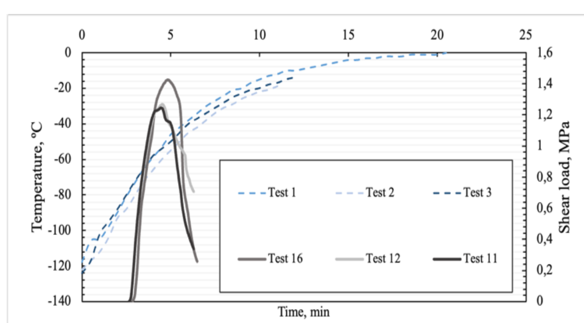

Figure 2. Graph of thawing samples with 10% water

content and test results of 3 samples at a normal load of 0.1 MPa.

Comparison of the results of the cut with the thawing rate graph shows that the peak value of the shear load is reached at the 5th minute of the experiment, while the temperature of the samples is from -45ºC to -55ºC. Shear stress also varies from 1.26 to 1.42 MPa. Samples with a large spread of shear stress values and outside the statistical error were excluded from the total sample. Thus, due to a large number of experiments, it can be assumed that all the selected tests were on samples with a temperature from -45ºC to -55ºC at the time of destruction.

Tests with a one-plane cut of samples with a 5% water content showed that the angle of internal friction is 66.8±0.9º and the specific cohesion is 163.9±28.4 kPa. These characteristics increased to the values φ = 74.9±0.67º and c = 486.2±72.9 kPa with an increase in the total weight moisture to 10% (Fig. 3).

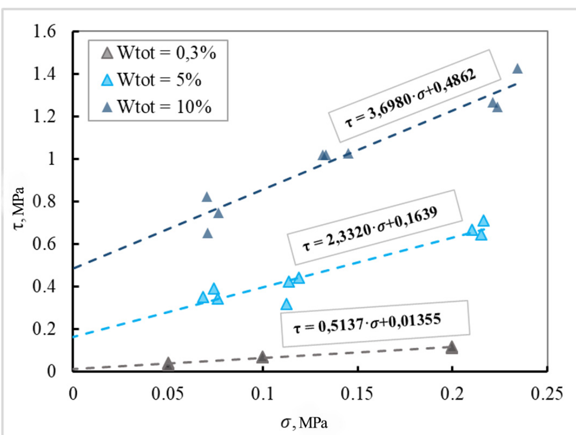

Figure 3. Test results for samples with a density of 1.75 g/cm³ and various water contents.

Conclusion: The experiments carried out with a shear test on the VI-75 frozen soil with 5% and 10% water contents at a temperature from -45ºC to -55ºC, as well as its comparison of the results with a dry sample, the water content of which is not more than 0.3%, showed that the angle of internal friction increased greatly at 5% water content up to 66.8º and up to 74.9º at W=10%. Specific cohesion increased even more and became 163.9 at W=5%, and at 10% water content it is equal to 486.2 kPa. Thus, the presence of ice in the lunar regolith can significantly increase its strength characteristics.

Further research will focus on ways to test samples at constant temperature, as well as to determine other mechanical characteristics.

References: [1] Slyuta E. N. et al., (2023) *LPSC LIV* Abstract #1089. [2] Roman L.T. (2002) *Nauka/Interperiodika*, 425. [3] Slyuta E.N. et al. (2021) *Acta Astronautica, 187*, 447 – 457. [4] Russian standard 12248.1-2020 (2020) *Standartinform*, 20.