Preparation of frozen rock samples for shear tests

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Abstract. The paper presents the method to prepare frozen rock samples structurally consistent with blasted rock mass for shear tests at a laboratory scale. The proposed method makes it possible to assess strength characteristics of blasted rock mass.

1. Introduction
Investigation of the physical and mechanical properties of rocks is very important in mining and construction. The physical and mechanical properties of rocks and soil have been comprehensively investigated in Russia and abroad [1–4]. One of the main state standards for the determination of strength and deformation characteristics of materials in Russia is GOST-12248-2010. This standard is applicable to half-rock, fine and frozen soil. Deformability and strength of frozen rocks can be determined at a laboratory scale using such methods as ball-point pressing, single-plane shearing along frozen surface, uniaxial compression, three-axial compression and single-plane shearing of defrosting soil.

The adfreezing strength of rocks and soil is mainly determined in single-plane shearing along the frozen surface. This test allows estimating the shear strength of frozen soil, interstitial water and ice on the surface of their adfreezing with an understructure material or some solid; the shear strength of frozen soil at the adfreezing interface with other ground or interstitial water; the shear strength of ice at the adfreezing surface with soil or interstitial water [5]. This method is applicable to sand (except for granular–frozen) and clay soil. Frozen soil tests are carried out at the temperatures below the freeze point by 0.5°C for nonsaline soil and by 1°C for saline soil. The samples of soil can have disturbed and undisturbed structure. The samples are made as cylinders with a diameter not less than 70 mm and height of 1/2 to 1/3 of the diameter.

2. Test procedures and results
According to Russia’s GOST-12248-2010, the manufacturing procedure of test samples is:
—undisturbed structure soil: the sample in due form of the operating ring of the shear tool is cut from a monolith block and is placed in the operating ring;
—disturbed structure soil: the operating ring of the shear tool is filled with prepared soil of assigned composition and moisture content at the required density of the fill, then soil is frozen via the top or bottom face;
—frozen soil in the operating ring of the shear tool is placed in the carrier ring of the matrix. Atop of this operating ring, the same operating ring is put, and a buffer ring of the matrix is placed on it. The upper operating ring is filled with interstitial water preliminary refrigerated to the freeze point, or
with soil of the preset composition and moisture content. Then, the sample is subjected to freezing via
the top or bottom face.

For the shear tests of undisturbed soil samples, a sample with a height to match the sizes of the
frozen rings in the special matrixes is cut from a monolith block. The samples is placed in the
operating rings and is put in the shear tool. Then, the sample is cured at the testing temperature for 12
or 24 h depending on the sample diameter. All tests are carried out in a room at the negative
temperature.

During freezing, the temperature is measured in the check soil sample placed in the heat-sensing
device. Freezing is terminated when the temperature in the check sample reaches the temperature in
the room. After that, the sample is removed from the matrix, sealed and kept until testing.

The advantage of the single-plane shear along the adfreezing interface is impossibility to
determine strength characteristics in samples of nonuniform structure.

For this reason, the Institute of Mining of the North, SB RAS has proposed the manufacturing
method of disturbed structure samples and the Procedure for Shear Strength Testing of Frozen
Overburden Rocks [6]. The procedure provides manufacturing of samples structurally consistent with
blasted rock mass, with preset moisture content, size of inclusions and compaction. A dedicated test
bench composed of a frame, basement and stiffener booms is designed (Figure 1). The main
components of the test bench are the shear box, hydraulic jack and the manual pump meant to create
the horizontal shearing load. The shear box consists of the movable and fixed shells.

![Figure 1. Drawing of shear strength test bench for frozen overburden rocks: 1—frame; 2—basement; 3—boom; 4—fixed shell of shear box; 5—mobile shell of shear box; 6—sliding member; 7—dynamometer; 8—hydraulic jack; 9—manual pump; 10—digital pressure gauge.](image)

First, on a special grille tray, cubic inclusions are manufactured and compacted under vibration.
After compaction, the inclusions are frozen down to the preset temperature. Then, the tray is
disassembled, the inclusions are removed and cured at the room temperature for some time until
condensation appears, for better cohesion with overburden. After that, the inclusions and overburden
are mixed together and placed in a special collapsible cylinder (cartridge). Later on, the cartridge is put
in the climate shell and frozen to the temperature of rock mass in different seasons and cured in the
freezing plant until the temperature in the middle of the sample equals the preset temperature
according to the readings of the heat sensing device.

After freezing, the cartridge is torn down, and the prepared sample is subjected to the shearing
tests on the special test bench.

The advantage of this approach to manufacturing test samples, against the above mentioned
GOST, is possibility of shear strength test of samples structurally consistent with blasted rock mass in
the conditions of secondary freezing. The samples (Figure 2) are subjected to lab-scale shear strength tests as per the developed procedure.

![Figure 2](image)

**Figure 2.** Top view of frozen sample structurally similar to blasted rock mass: 1—inclusions; 2—overburden.

The sizes of samples, the inclusions/overburden ratio and the size of inclusions are determined from practice and from the similarity theory which assumes geometrical similarity of samples and natural objects, geometrical similarity of grain size compositions and equality of bulk densities [7, 8].

For instance, with regard to fragmentation in blasted rocks in Kangalass lignite field, with average particle size of 300 mm, based on the similarity theory and at a geometrical scale of 1:1000, the average size of inclusions is 30×30×30 mm. Then the test sample is to be 350 mm in diameter and 175 mm in height. The volume of the sample is 16828.4 cm³. In order to manufacture such sample, it is required to have 26.9 kg of rocks at the bulk density of 1.6 g/cm³.

### 3. Conclusions

The proposed method to manufacture samples structurally comparable with blasted rock mass enables determination of strength characteristics of frozen rocks depending on temperature, moisture content, lumpiness and density of the sample.

### References

[1] Votyakov IN 1975 *Physico-Mechanical Properties of Frozen and Thawing Soils of Yakutia* Novosibirsk: Nauka (in Russian)

[2] Van Pin, Tsimbelman NYa and Kuznetsov IG 2013 *Studies of strength properties of soil by the methods of triaxial compression and straight cut* *Vestn. Inzh. Shk. DVFU* No 4(17) pp 67–75

[3] Yuanming Lai, Xiangtian Xu, Yuanhong Dong and Shuangyang Li 2013 *Present situation and prospect of mechanical research on frozen soil* *Cold Regions Science and Technology* Vol 87 pp 6–18

[4] Kodama J, Goto T, Fujii Y and Hagan P 2013 *The effects of water content, temperature and loading rate on strength and failure process of frozen rocks* *International Journal of Rock Mechanics and Mining Sciences* Vol 63 pp 1–13

[5] RF State Standard GOST 12248-2010 *Soils. Laboratory Methods for Determining Strength and Deformability* Moscow: MNTKS 2010

[6] Alkova EL, Panishev SV, Kozlov DS and Maksimov MS 2016 *Experimental studies of shear strength of frozen rocks on large specimens* *Uspekhi Sovr. Estestvozn.* No 8 pp 145–149

[7] Yamshchikov VS 1982 *Investigation and Control of Rocks and Processes: Methods and Equipment* Moscow: Nedra (in Russian)

[8] Taibashiev VN 1973 *Physical and Mechanical Properties of Frozen Coarse-Fragmented Rocks* Moscow: VNII-1 (in Russian)