EXPERIMENT IN CONTROLLING STABILITY OF SCARPMENT BENCHES IN DEEP-PIT NORTHERN MINES BY MEANS OF FOAMED PLASTIC HEAT-INSULATING SHIELDS

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In mining, roadbuilding, and hydrotechnical construction, experimental studies were initiated in the 1960s with the aim of controlling the thermal regime of the ground by the use of high-porosity synthetic materials with thermal conductivities very little higher than that of air [1-4].

Deformation of benches in open-pit mining of diamond deposits in Yakutia can be attributed mainly to cryogenic processes (regelation, sublimation, frost heaving, settling, cracking, disintegration, and so on) [5]; these processes are related to the formation of a seasonally thawed layer during the summer. The most widely encountered type of deformation, characteristic for all enclosing and overlying rock, is the formation of talus and erosion of the upper lip of the benches. Talus is formed as a consequence of loss of strength of the frozen rock when it is heated, with thawing of the ice that plays the role of a cementing composition in the cracks and pores. Important roles in the formation of talus are also played by physical weathering of the escarpment surfaces as a consequence of the changing temperatures (from -10°C to +10°C daily, from +40°C to -60°C yearly), the presence of moisture and its migration, and repetitive freezing and thawing. The rate of crumbling is the highest in the first two or three years after the bench is fixed in its final position, after which the rate drops off. On the average, the crumbling of the upper lips of benches made up of limestones and dolomites is 5-10 cm per year; in weak rocks, the rate may be an order of magnitude higher [6].

One of the methods used to preserve the stability and strength of frozen rock is the use of heat-shielding [1, 7, 8]. Thermal insulation of exposed frozen rock reduces the rate and amplitude of changes in the temperature field of the rock, thus reducing the depth of thawing and preventing the development of weathering processes, and hence mitigating to a great degree the effect of cryogenic processes on the stability of the exposed rock.

In 1981, the authors of the present article carried out the first experimental studies on heat-shielding the benches in the pit of the Mir diamond pipe of the Yakutalmaz Production–Scientific Association.

Three sections were prepared for the subsequent program of temperature measurements:
- No thermal insulation.
- Insulated with polystyrene foam blocks on metal mesh (length 10 m, height 6 m).
- Insulated with auto tires, chained together and filled with granulated polystyrene (length 15 m, height 6 m).

The temperature measurements indicated the following:
- Heat-shielding the surface of the bench at 265 m lowered the temperature of the rock mass during the warm period of the first year by 1.3-3.5°C in the section insulated with auto tires, and 0.5-5.7°C in the section insulated with foam blocks; in the second year, the corresponding temperatures were lowered by 1.5-8.8°C and 3.0-11.3°C.
- During the winter, the temperature of the rock in the thermally insulated sections was slightly higher than in the uninsulated sections.

The experiment showed that the heat-insulating coating curtails the thawing and greatly reduces the temperature effect of the atmosphere on the rock; however, the experiments revealed certain shortcomings in the technology of constructing the heat-insulating shields.
Fig. 1. Placement of boreholes for temperature measurement in experimental section: 1) metal mesh; 2) heat-insulating coating.

†As in Russian original; in Fig. 2 and in the text, the borehole in the uninsulated section is identified as borehole 2 — Translator.

Analysis of studies of the stability of pit banks in the Yakutalmaz Production—Scientific Association provides a basis for formulating the distinctive features of technology in the application of foamed plastics to pit escarpments:

• Performance of the operation in the early spring, hence with low temperatures of the rock and air.
• The brief time window for the operations — limited on the one hand by the need for the benches to be free of snow, frost, and ice, and on the other hand by the need for maximum retention of the cold accumulated in the rock during the winter.
• The need for performing operations with hoisting equipment on surfaces with a 60-80° slope.
• The need for maintaining reliability and integrity of foamed plastic heat shields during the entire course of mining operations in the pit.
• The high level of hazard in performing operations on pit benches with hoisting equipment.

In 1991, field experiments were performed on thermal protection of pit benches by polyurethane foam heat shields. The pit banks selected for these experiments consisted of interlayered, highly fissured dolomites and limestones. With a bench height of 28 m and an angle of 75-80°C, the dimensions of the thermally insulated section were 30 × 20 m (30 m along the bench). The material used for the thermal insulation was Ripor-6TN polyurethane foam, thickness 5-10 cm.

Boreholes were drilled in the experimental section (Fig. 1) for the installation of temperature sensors at depths of 0, 1, 2, 3, 4, 6, 8, 10, and 12 m. After positioning the chain of temperature sensors, the boreholes were riffled with clayey sand — a measure that gave a significant improvement in the accuracy of the measurements.

From the temperature measurements and visual observations of the experimental section, we can draw the following conclusions.

1. With the thermal insulation (Fig. 2a), the depth of thawing on the berm was no greater than 3 m; i.e., this depth was reduced by a factor of 2. The rock temperature along the entire line of the bench, at a depth of 2 m, had a stable subfreezing temperature (−0.9°C during the summer).
2. Without heat-shielding (Fig. 2b), the depth of thawing on the berm reached 6 m, and the rock temperature at a depth of 2 m approached 0°C along the entire line of the bench. This sort of situation should be classed as critical, since it creates conditions for rock cave-in, and the upper part of the bench is the most dangerous.
3. An analysis of the distribution of the temperature field among the boreholes shows that the thermal insulation acts as a barrier to the passage of not only heat but also cold during the winter (Fig. 2, a-c); this is a restraining factor in the application of foamed-plastic heat-insulating coatings on large areas.