REPAIR WORK ON A FROZEN DAM

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A 21.4-m-high frozen earth dam was constructed as a part of the structures for a city's water supply; the storage capacity of the reservoir is 1.2 million m³. The climate in the region of the dam is characterized by a long and cold winter and short and overcast summer with snowfalls and frosts; the mean annual air temperature is -10.8°C.

The dam is located in a permafrost zone. Its thickness at the dam site is about 230 m. The temperature of the rock at the depth of zero annual change is -7°C. The stream valley at the dam site is composed of Triassic and Lower Jurassic sedimentary rocks. Loose Quaternary deposits from 2 to 30 m thick lie on the surface. On the left, flatter slope of the valley the bedrock, composed of clay shales, occurs at a depth of 2-8 m, and on the right slope, at a depth of 8-30 m. Its upper layer, from 4 to 8 m thick, is severely fractured. The Quaternary deposits at the dam site are deluvial and alluvial formations. The surface of the left slope is composed of comparatively coarse material — rubble and grus-rubble deposits with sandy loam. The ground contains ice bodies in the form of pockets and interlayers 10-20 cm thick.

On the right-bank slope the composition of the loose deposits is more heterogeneous. In addition to the grus-rubble soil, interlayers of sandy loam from 3 to 6 m thick are found here at a depth of 4-6 m. The content of ice in the sandy loam reaches 40%, and here and there pockets and lenses of ice up to 2-3 cm thick are found.

The content of fine earth in the rubble-grus soils, which are the foundation of the dam, ranges from 15 to 30%, of which the sand fractions account for 45% on the average, the silt particles account for another 45%, the clay fractions is 10%. The water content (as ice) of the loose deposits varies from 13 to 97%, averaging 44%. It should be noted that a high ice content is traced to a depth of 15 m, ice lenses up to 1.1 m thick being found in the 2-15-m depth interval.

Construction of the dam was begun in 1960. Originally the dam was to be constructed with a central core having a top width of 3 m and slope of 0.15. Since the characteristics of the loam for filling the core differed little from the properties of the material sought for filling the upstream and downstream shoulders, the dam was made homogeneous. A shoulder of 20-30-cm rock was placed in the downstream slope. The work of placing the earth in the dam was completed in August, 1968. An air-freezing system, consisting of 214 freezing columns with a diameter of 159 mm and depth of 12-29 m, was not installed, owing to delay in delivering the pipes.

Fig. 1. Crevasse formed on breaching of the dam (view from lower pool).

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Despite the indicated circumstances, because of the extremely unfavorable water-supply conditions of the city the reservoir was placed in temporary operation in 1967 without freezing-through of the dam's body and foundation. The freezing system was partially installed and began to operate in the central part in March, 1969. As a consequence of operating the dam with an incomplete freezing system, on August 14, 1970, the dam was breached in a stretch of the left-bank abutment at the site of the intake pipes. At the time of breaching the reservoir was filled to the 46.3-m level (normal pool level 49 m); the volume of water before breaching was 0.8 million m³; 0.37 million m³ flowed through the breach before the crevasse was dammed by a temporary earth cofferdam within the course of 16 h.

An ellipsoidal tunnel washout with a cross-sectional area of 40 m² (Fig. 1) formed in the dam.

Reconstruction work began with clearing of the crevasse and construction of a temporary pumping station behind the temporary cofferdam (Fig. 2). The purpose of the initial earth work was to clear the crevasse to the bottom of the intake pipes, remove the liquefied earth, and flatten the slopes of the crevasse. The earth of the dam above the tunnel was frozen through during the period of construction and operation. The work was carried out in steps with loosening of the ground by small dynamite charges. Hole charges weighing 2-3 kg were used in the central part. Two NKR-100 drilling rigs and two cable drills were installeld on the dam crest for drilling the shot holes. The loosened ground was removed from the crevasse by bulldozer. Then the ground was moved by a dragline excavator to a dump located in the lower pool of the dam.

In the initial stage of operations a 15-m-wide, vertical-wall trench, which uncovered the crevasse, was excavated. The walls were then flattened to a slope of 0.5. The ground was caved into the bottom of the trench, then moved by bulldozer to the excavator's operating zone. During excavation in the crevasse a protective layer 0.3-0.5 m thick was left on the slopes, which was subsequently removed manually by pneumatic drills. The lips of frozen ground were also removed in order to obtain a sufficiently even slope. The volume of excavated earth in the crevasse between August 16 and September 20 was 8000 m³. The slopes and bottom of the trench in the rocky ground were cleared by a monitor. The muck was removed by gravity along a drainage ditch into the lower pool.

Since the concrete prism sealing the intake pipes was not made over the entire width of the trench (1.2 m in instead of 5 m), the repair work called for concreting the trench with the intake pipes flush with the rock flanks. The thickness of the new layer of concrete above the previously made prism was 1.5 m. The loam was placed in the crevasse in layers 30-35 cm thick and compacted by loaded dump trucks. On the slopes the earth was compacted manually by tampers.