BUILDING A ROCKFILL DAM BY DIRECTIONAL BLASTING

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To protect the city of Alma-Ata from mud-laden flows arising in the basin of the River Malaya Almaatinka (the city is located on its alluvial fan), a dam was designed by the Kazakhsk Branch of Gidroproekt (the S. Ya. Zhuk All-Union Planning and Scientific Research Institute). The site selected is in the middle reach of the river, in a narrow mountain canyon with a width of 60 m in its downstream section. The solid component of the mud flows must be retained in the mud-retention reservoir formed by the dam, and it is planned that the liquid component of the mud and the natural flows of the river be carried through inclined water intakes covered by gratings and a spillway tunnel located in the left bank.

The mud flows formed at the time of intensive melting of ice and cloudbursts (July and August) are the most substantial and hazardous. As it is inadmissible to pass mud flows over the incomplete rockfill dam, the principal work of building the dam and necessary mud-retention reservoir capacity must be completed between the periods of mud flow.

The Kazakhsk Branch of Gidroproekt considered the alternatives of a concrete dam and a rockfill dam built by the conventional mechanized methods. However, these alternatives were not adopted because of time limitations.

Taking the stated circumstances and local conditions into account, the placing of the principal volume of fill in the body of the dam (Fig. 1 and 2) was planned and executed by blasting the banks with two massive directional explosions.

The charges in the right bank were placed on a level with the bottom of the valley, and in the left bank, on a level with the projected dam crest (Fig. 3, and Fig. 1 of the paper by A. N. Romanov and V. V. Garnov in this issue). The location of the right bank charges did not seem to be rational, as the blast increased the width of the valley. However, this location was adopted in the design for a number of reasons. As the results of the first (right bank) blast depended on a number of unexplored factors, which were difficult to evaluate and calculate (cracking, large magnitude of line of least resistance* of the principal charge, and others), the possibility was anticipated that the results would diverge from the plan. Therefore, the second (left bank) blast was not conducted simultaneously with that in the right bank, but five months later. By this time the experience of the first blast had been studied and the plan for the second corrected, as a result of which supplementary drift work had to be carried out in the charge chamber.

The design volume of the dam embankment was 3.6 million m$^3$, and the design height 113 m, which figure for the crest takes into account a settlement of 5 m. It was intended that about 80% of the volume in the dam body be placed by directional blasting (right bank, 1.84 million m$^3$, and left bank, 1.0 million), and the remaining volume be completed by machinery.

As a result of the right bank blast an embankment height of 62 m was attained, a base width of 560 m, and a crest width of 70 m. The right bank blast threw 1.67 million cubic meters of rock, i.e., 44% of the dam volume, into the body of the dam. A disintegration coefficient of 1.26 for granite was obtained during the blast, with an average volumetric embankment weight of 2.1 tons/m$^3$.

With a total weight of 5.3 thousand tons of BB (flaked TNT) exploded in the right bank, 3.18 kg of BB were used per cubic meter of rock placed in the dam profile. The cost per cubic meter of usefully placed rock was about 2.2 rubles, of which 70% is the cost of BB. In addition, there are 300-400 thousand m$^3$ of broken-up soil in the right bank which can be used for finishing the dam construction.

*See the paper by A. N. Romanov and V. V. Garnov—Editor.
†The discrepancy in volumes from data contained in the paper of A. N. Romanov and V. V. Garnov is explained by the fact that the authors of the present paper used a more detailed survey, with cross-sections every 20 m.

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In order to increase the height of the embankment and create the necessary mud-retention capacity, blasting of the left bank was accomplished in 1967.

The expenditure of BB in the right bank blast was 4,000 tons, which accounts for the distance the rock was thrown. Eight million cubic meters of rock were thrown into the embankment by the blast. The rock was distributed in a practically uniform layer 10-20 m thick on the surface of the embankment produced by the first blast. The useful fill (within the boundaries of the dam contour as designed) was about 700,000 m$^3$. A coefficient of disintegration of the granite of about 1.3 was obtained during the left bank blast. The expenditure of BB per cubic meter of usefully placed rock was 5.7 kg; i.e., substantially more than during the right bank blast. This is explained by the insufficiently successful directing of the blast onto the crest of the dam, and by the great distance that the rock was thrown in the directions of the upstream and downstream slopes. The cost per cubic meter of useful embankment is about 3.3 rubles. There was about 1.5 million m$^3$ of rock broken up by the blast in the left bank which is intended for use of finishing the dam. Thus, an embankment height of 70 m was obtained as a result of two massive blasts.

The body of the dam produced by directional blasting consisted of two parts: one part formed by a cumulative jet of rock shattered and expelled by the blast, and the other part formed due to sliding of the sides of the crater, which were unstable after the blast.

It is assumed that the part of the dam body formed from rock which was ejected by the blast and which fell with a rather high terminal velocity should contain a large quantity of fine material and have a relatively high density. The other part of the dam body, formed as a result of sliding of the mass which was unstable as a result of the blast, should contain larger material, with the inclusion of large blocks of rock, and should have a lower average density. In order to study the composition of the dam body, three pits were sunk in the period between blasts.

In view of the great complications of sinking such pits and the time limitations, they penetrated to a depth of up to 20 m from the surface. Each pit was 2 x 2 m. In accordance with safe practice, the pits were sunk with continuous reinforcement by girder. A space of as much as 40 cm in height to allow for inspection and documentation of the embankment composition was made between the faces of the pit and the lower row of the reinforcement.

As is apparent (Fig. 4), the structure of the embankment is nonuniform and the granular distribution is irregular with height. However, as assumed, there proved to be a large content (in the 20-60% range) of fines less than 10 mm in size in this zone. The high volumetric weight (from 2.33 to 2.38 tons/m$^3$, according to separate measurements) was also confirmed.

Inspection and the photographs show that, in places where there is an accumulation of large rock fragments, the voids are filled with shattered rock fines, as though compressed between these fragments. This occurred as a result of the dynamic effect of these fragments having fallen with a high velocity, and because of the superimposed mass.

In this zone, three tests were set up to determine the filtration properties. The coefficient of filtration determined according to the Boldyrev method was 13.9-32.8 m/day. However, to extend these filtration coefficients to the entire investigated zone is inadmissible as, for technical reasons, the tests were conducted in locations where there was an accumulation of large blocks of rock more than 20-30 cm in size. Besides, considering the discrete