AN EXPERIMENTAL ROCK-SAND DAM

O. B. Pyshkin

In 1966, in one of the flumes of the Dneprodzerzhinsk Branch of the B. E. Vedeneev VNIIG, an experimental rock-sand dam was constructed (Fig. 1) with the following dimensions: height 7.5 m, width on the crest 2 m, width at the base 23.6 m, length 4 m (width of the flume), upstream face slope 1: 1.25, downstream face slope 1: 1.5, volume 400 m³. The large-scale experiment described in this article is only a part of the investigations devoted to the development of a new design of rock-sand dam without the antiseepage elements in the form of cutoff walls and central cores inherent in rock-fill dams of the classical type. The impervious element in the rock-sand dam is the sand washed into the voids of the rock fill.

The design of the experimental dam was based on results of studies of properties of the rock-sand medium carried out on special large-scale installations built for various purposes on the site of the Dneprodzerzhinsk Branch of VNIIG. The flume in which the dam was erected is 114 m long, 4 m wide, and 7.5 m deep. A new technique of underwater sluicing-in of the voids of a rock fill of large volume (the fill volume was 400 m³) was studied by testing for imperviousness and seepage stability a rock-sand dam, the impervious element of which is the sand in the voids of the fill.

The dam was built in the following manner. First a prism of sorted rock with side slopes of 1: 1.25 and 1: 1.5 was placed in the flume. Then sand was washed into the prism by a method developed at Dneprodzerzhinsk Branch of VNIIG [1]. Sorted rock with fractions from 80 to 600 mm was used in the fill. Dnieper sand with a mean diameter of 0.21 mm, effective diameter of 0.11 mm, controlling diameter of 0.25 mm, average volume weight of 1.44-1.46 g/cm³ for a limiting-porosity structure and of 1.84-1.87 g/cm³ for a maximum-dense structure, and a specific gravity of 2.65 g/cm³ was used for sluicing-in the voids of the fill. The rock was delivered to the storage site and placed in the flume by a K-2K 20-ton gantry crane with a 3 m³ bucket. As the rock filling progressed, piezometers were installed in the body of the dam. Piezometers were placed at the wall of the flume shaft and in the bottom.

The sluicing-in of the fill with sand was done with the aid of a hydromechanical installation developed at VNIIG with which a slurry of high consistency (1:1 by weight) was obtained and transported in the slurry conduits. The installation operates on a strict regime of consistency and velocity of the slurry from the outlet of the slurry conduit.


Fig. 1. Experimental rock-sand dam 7.5 m high. Sand (1); crushed rock 1-10 mm fraction (2); crushed rock 5-20 mm (3).
Fig. 2. Sluicing-in a rock fill with sand.

The sluicing-in was carried out from bottom to top in sloping layers, beginning with the footing of the dam. The formation of cavern under the stones, which is unavoidable when, for instance, the slurry is placed on the crest (gravity sluicing), is completely excluded. Sluicing in the fill from its slopes by the method shown in Fig. 1, leads to the formation in the center of the dam of a zone of maximum content of fine sand fraction, which in turn can be considered as a kind of core. The thickness of the sluiced-in layer was computed by the following formula, obtained in the process of development of the technology of forming the rock-sand medium:

\[ \Delta l = 6D_{av} \sqrt{\frac{H_m}{H_{max}}} \]  

(1)

where \( \Delta l \) is the spacing of sluicing, i.e., the thickness of the sluiced-in layer; \( D_{av} \) is the average size of rock used in the fill; \( H_m \) is the height of the model prism; and \( H_{max} \) is the maximum height according to the formula, equal to 15 m.

The sluicing points, i.e., the places where the slurry conduits were set up at the surface of the slope of the treated fill, were arranged in checkerboard fashion. The distance between sluicing points was determined by the formula

\[ b = \frac{2m \Delta l}{\sqrt{m^2 + 1}} \]  

(2)

where \( b \) is the distance between sluicing points, \( m_0 \) is the angle of repose of the sand within the fill, \( \Delta l \) is the spacing of the sluicing, and \( m \) is the angle of repose of the rock-fill.

With points of slurry discharge on the slope spaced as determined by Eq. (2) there are formed within the fill, as a result of intersection of the cones of sluiced-in sand, triangular-shaped channels running from the surface of the slope down into the fill. By placing the sluicing points of the succeeding layer (sluicing-in horizon) between the sluicing points of the preceding layer, i.e., along the axes of the channels formed within the fill, conditions are created for the movement of the slurry along the channels within the fill which enhanced the quality of the sluicing.

Before beginning the sluicing-in of sand into the rock skeleton of the experimental dam, the flume was filled with water to the 2.5 m level, and the tips of the slurry conduits were attached on the slope under the water at the level of the first sluicing horizon, i.e., at the 2.0 m level. The tips of the slurry conduits were attached perpendicular to the slope and flush with it. After the end of sluicing in the first layer (Fig. 1) the sluicing conduits were moved from the lower slope to the upper slope and were installed there as on the lower slope. The water level in the flume during the sluicing-in of the first horizon was kept constant by discharging through a spillway arrangement the water entering the flume.

Sluicing-in the dam on subsequent horizons was done in the same manner. The water level in the flume was raised every time at the completion of the sluicing-in of the dam at the next horizon. This was done to enable visual inspection of the progress of sluicing-in, which would have been difficult had the flume been filled to the 7.5 m level. Under field conditions, observation of sluicing at great depth can be accomplished with underwater television [2, 3].

Sluicing-in of the experimental dam (Fig. 2) was done simultaneously through three slurry conduits. The three conduits installed next to the last sluicing horizon are seen on the slope. The consistency of the slurry was 1:2. The output of the hydromechanical slurry installation was 24 m³/h, the velocity of the slurry out of the tip of the conduit was 2 m/sec. Sluicing from beginning to end proceeded without any complication in the operation of the hydromechanical installation.