STRENGTHENING THE SUBMERGED PORTION OF THE UPSTREAM SLOPE OF THE DAM ACROSS THE RIVER CHANNEL AT THE KREMENCHURSK HYDROELECTRIC PLANT

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Closing of the Dnieper River at the site of the Kremenchursk hydroelectric plant by means of a 12-m-high embankment was carried out in October, 1962, by dumping rock fill from a pontoon bridge built across a passage which had been previously narrowed by using the pioneer method to place fill material from both banks at a distance of 172.5 m upstream from the axis of the earth structures. When the flow was diverted through the crest of the overflow dam hydraulic filling of the earth dam across the river channel was initiated (Fig. 1). The lower layers of the dam were placed when the water in front of the downstream embankment had a depth of 4 to 6 m. As demonstrated by full-scale measurements and special investigations carried out in 1959 by the soil mechanics laboratory of the Dnepropetrovsk Institute of Transport Engineers, the lower sand layers placed under the water by the hydraulic-fill method were not sufficiently dense (Table 1).

The commissioning of the first units of the Kremenchursk hydroelectric plant had been scheduled for December, 1959. By that time, the first-stage filling of the reservoir, to El. 8.50 m, should have been completed. Filling of the reservoir took place after the dam was built, and the low-density, underwater portion of the hydraulic-fill dam across the river channel remained unloaded from the upstream side where the water was at El 7.0 m. At this location (the narrow passage), the dam (height 30 m, head 17 m) is one and a half times higher than the adjoining island and flood land zones. In the foundation of the dam across the river channel there is a fine sand layer which has a thickness of from 6 to 18 m (layer 2), and at the lower portion there is a layer of medium and coarse sand (layer 10). The sand is underlain by a 8-10 m thick layer of marly clay belonging to the Kiev formation. Under the clay is a layer of coarse sand. The sedimentary deposits in the area of the dam across the river channel have an average overall thickness of 25 m. These deposits are underlain by solid rock.

Under normal operating conditions, with the protection provided by the downstream rock-fill embankment and the upstream rock-fill surcharge this portion of the dam is stable. Only a strong dynamic action can affect the stability of the low-density submerged slope at the upstream side. Disturbance of the stability of the upstream slope (Fig. 2) was in fact observed in 1959, when experimental blasting was carried out below the berm, at El. 9.0 m.

Fig. 1. Cross section of earth dam across river channel. 1) Upstream embankment; 2) lower limit of protection placed during construction; 3) riprap; 4) reinforced-concrete slabs; 5) sand surcharge; 6) downstream embankment.

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The problem of the dynamic stability of the dam across the river channel had to be solved, inasmuch as at a distance of 1350 m from the axis of the dam, at the Vlasovsk quarry, granite was being excavated by blasting. In order to reduce the vibration effect on the dam from the blasting operations, in February, 1962 it was decided to limit the size of the charges to 10 tons of explosive divided into portions of 1.5-2.0 tons weight, and to use delay blasting. In connection with these measures, field investigations were undertaken to determine the characteristics of the vibrations in the dam under the dynamic action of blasting at the quarry. Of great importance for the solution of this problem was the property of sands of passing into a state of rarefaction which depends upon their density. It was necessary to determine the density of the soils in the dam, after a long period of operation. By applying an electric measuring method (the SEPP method, the Department of Soil Mechanics Investigations of the State Institute for Planning and Design of Hydraulic Structures (Gidroprom) determined the density of the sands in the dam (Table 2, No. 1). By using the dynamic penetration method, the Department of Investigations of the Ukrainian Gidroprom established slightly different values (Table 2, No. 1).

The density increased, apparently, under the dynamic action of the blasting at the quarry, under the weight of trains and vehicles travelling along the crest, and under the pressure of the upper soil layers. However, the density of the lower layers did not reach the required values.

In 1964, the Institute of Soil Physics of the Academy of Sciences of the USSR and the B. E. Vedeneev All-Union Scientific-Research Institute of Hydraulic Engineering carried out field investigations for determining the characteristics of vibration of the foundation and the body of the dam across the river channel, under an extensive series of blasts at the Vlasovsk quarry. During those investigations, preparatory work was also undertaken for studying the conditions governing the passage of the sand into the rarefaction state according to the density, the intensity of the action, and the internal stresses. The data obtained for the vibrations in the surface of the sand soil next to the dam permitted determining the length of the waves travelling along the foundation.

The length of the disturbing wave is determined from the equation

$$\lambda_0 = C_0 \cdot T,$$

in which $C_0 = 1700 \text{ m/sec}$ is the velocity of the elastic longitudinal waves in the sand on the river-channel portion; $T = 0.13-0.20 \text{ sec}$ is the period of the vibration in the sand.

Substituting these values in the equation, we obtain:

$$\lambda_0 = 221-340 \text{ m}.$$  

For a qualitative evaluation of the action of the waves on the structure, we apply the so-called wave length criterium: for $B < \lambda/2$ the wave is long; for $B > \lambda/2$ the wave is relatively short ($B$ = width of the dam at the foundation).

Under the action of a long wave, the stresses in the structure are of a simple nature (either compression or tension). Under the action of a short wave, compression and tension fields are formed in the structure. Within the limits of the width of the dam across the river channel, one wavelength acts which causes compression deformations in one half of the structure, and tension deformations in the other. For this case, the dam is considered as a body resting on a rigid vibrating platform and its dynamic stability is determined by taking into account the inertia forces it develops. According to the data from the investigations, the maximum vibration stresses in the dam and its foundation were considerably lower.

* The distances between the different points and the dam were respectively 50, 120, 170, and 300 m.