EXPERIENCE ACQUIRED WITH THE OPERATION OF HYDRAULIC STRUCTURES AND EQUIPMENT HOUSED IN HYDROELECTRIC PLANTS

SUBSTANTIATING THE METHOD OF UNDERWATER ASPHALT LININGS FOR THE REPAIR OF HYDRAULIC STRUCTURES

N. F. Shchavelev, V. M. Davidenko, and G. A. Davidenko

Concrete failure can often be observed in operating concrete hydraulic structures; this occurs primarily due to alternate freezing and thawing of the concrete, to the pulsating action of the flow, to the leaching of lime from the concrete, etc. A lowering of the water level in the canal or reservoir is required to restore the sections of the structure that have failed in this manner. In the majority of cases, this is economically inexpedient and occasionally quite impossible. Convenient and reliable methods for performing repair work directly under water are, therefore, sought in hydraulic-construction practice.

The method of underwater lining with sheet asphalt to stabilize banks and the bottoms of pools has come into widespread use in foreign practice. In Holland, e.g., an underwater fine-sand sheet asphalt with an additive of 10% aggregate and 18-20% bitumen was produced to protect the sea floor from erosion. The substance of this lining method is readily understood from Fig. 1.

The successfully completed stabilization of the banks of the Po River near the towns of Messoli and Maleri in Italy by stabilizing rip-rap with an asphaltic lining may serve as another example [1]. Here, the underwater sheet-asphalt lining was produced using a special apparatus. It consisted of pipes 30 cm in diameter with a distributor on the lower end and a container from which the asphaltic mix was gravity fed into the river through a pipeline. Other examples of underwater asphalt-mix linings are also known [2].

In the USSR, an underwater sheet-asphalt lining was placed in 1966-1968 in restoring the imperviousness of the deformation joints of the Kama hydroelectric plant [3]. In this structure, the installation of a new seal by drilling a hole and filling it with asphalt was a uniquely effective measure taken to eliminate the leakage of water through the joints.

Theoretical and experimental investigations of the adhesion of an asphaltic lining mix to a concrete base underwater [4], which indicate that this adhesion depends primarily on the mobility of the mix and the temperature of the medium and mix, as well as on the thickness of the lining, were conducted at the B. E. Vedeneev All-Union Scientific-Research Institute of Hydraulic Engineering in 1973-1974.

The primary objective of the investigations, the results of which are outlined in this paper, was to establish the capacity of the feed pipe for the underwater sheet-asphalt lining. In Fig. 2: \( L_0 \) and \( L \) are the lengths of the upper and lower segments of the feed pipe; \( H_{u0} \), pressure in the upper segment of the pipe at the outset; \( H_{u1} \) and \( H_{u2} \), heads over the pipe and in the section \( l \) at time \( t \); and \( \gamma_w \) and \( \gamma_m \), volumetric weight of the water and asphaltic material, respectively.

The differential equation for charging the feed pipe with asphaltic material, which was derived in conformity with the working scheme shown in Fig. 2a, takes the form

\[
\frac{\gamma_m}{\eta} \frac{L_0 + l (1 - \omega/\gamma_m)}{L_0 + l} \frac{ds}{dt} = \omega dl,
\]

where \( \omega \) is the cross-sectional area of the pipe; \( r \), radius of the pipe; and \( \eta \), viscosity of the asphaltic material.

After integrating Eq. (1) and several transformations, one obtains Eq. (2) for determination of the time required to charge the pipe with asphaltic mix over segment \( l \).

Fig. 1. Unit designed for underwater asphaltic lining. 1) Mixer; 2) container for prepared mix; 3) charging cart; 4) gate; 5) chute; 6) feed pipe; 7) gearing for slide gates; 8) distributor; 9) distributor set pin; 10) opening for asphalt.

Fig. 2. Working diagram showing placement of asphaltic material in water through gravity-feed pipe. a) Filling of delivery pipe; b) flow in filled pipe. 1) Delivery pipe; 2) piezometric line at point in time during charging of pipe; 3) lining surface; 4) piezometric line after charging pipe.

The time required to charge the pipe with asphaltic material over its entire length can be obtained from Eq. (2) when \( L = L_0 \).

According to the working scheme in Fig. 2b, the asphaltic material will move along the feed pipe at a constant velocity under the pressure gradient

\[
J = \frac{1}{L + L_0} [L_0 + L (1 - \gamma / \gamma_m)].
\]

The capacity of the feed pipe will be

\[
Q = \frac{\pi \gamma m^2}{8 \eta (L + L_0)} [L_0 + L (1 - \gamma / \gamma_m)].
\]

From Eq. (4) we can derive a relationship to determine the pipe's radius that is necessary for passing the asphaltic material at a given rate

\[
r = \sqrt{\frac{Q \eta (L + L_0)}{\pi \gamma_m [L_0 + L (1 - \gamma / \gamma_m)]}}.
\]

The analytical relationships derived were used by the authors in developing the basis for the technology of repairing the upstream headwall of the Ust'-Kamenogorsk lock. The volume of the cavity filled with asphaltic material (Fig. 3) was \( V = 4300 \text{ m}^3 \), while the time between lockings allotted for lining with this amount of asphaltic material under water was determined as 15 days. The flow amounted to \( 3.3 \times 10^3 \text{ cm}^3/\text{sec} \) for the initial data. From Eq. (5), we can determine the pipe radius required for passing this flow under the following