Ultrasonic testing of the strength and homogeneity of concrete structures of the turbine compartment of a hydroelectric power plant

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Abstract. At one of the Latvian hydroelectric power plants, according to the project, it was envisaged to replace the turbines and at the same time renovate the concrete of the turbine compartment structures. For this purpose, the old damaged concrete was removed (to a depth of 60 cm), reinforcement was laid and concreted with new concrete. This object is important for the national economy, so it was necessary to ensure quality control of construction work and materials used. To control the strength of concrete, usually at the same time as concreting the structure, cube specimens are made from the same concrete mixture. This method cannot fully guarantee an objective control, since the manufacturing technology and hardening conditions of the control samples differ from real conditions. To obtain more objective results, it would be necessary to drill core samples from the hardened concrete for their subsequent testing. Drilling out a large number of samples is laborious and undesirable, since reinforcing bars can be damaged due to the dense reinforcement of the structure. Investigation the concrete mechanical properties have been performed non-destruction method applying ultrasound equipment.
Therefore, a non-destructive ultrasonic pulse method was chosen to control the quality of concrete. From literary sources [1-7] it is known that there are correlations between the speed of ultrasound in concrete, on the one hand, and the density of the material, its porosity, strength and modulus of elasticity, on the other hand. Having determined the speed of propagation of ultrasound in a structure, using the correlation dependences, it is possible to determine the strength of concrete, heterogeneity and other properties of the material.

For more than 40 years, the Riga Technical University has been conducting research on the use of ultrasound to control various materials: aerated concrete, asphalt concrete, building ceramics, and others [5].

Often real concrete structures are reinforced with metal rods or meshes. It is known that the speed of propagation of ultrasound in metal is greater than in concrete. If the protective layer of concrete is greater than or equal to the diameter of the metal rod, this has practically no effect on the speed of propagation of ultrasound in concrete [4].

An ultrasonic tester UK 1402, was used to control the concrete in the draft tube of the hydraulic turbine. With this device, applying contact sensors to the concrete surface, within a few seconds, the scale automatically records the ultrasound propagation velocity or the transit time of the ultrasonic signal in the material (at the option of the operator). This device has an advantage with other ultrasonic devices:

- you can control elements and products of various configurations;
- measurements can be carried out on a very rough surface of the material, due to the good point contact of the sensors;
- measurement with this device takes little time;
- the device is portative, it can be held with one hand, which is very important when working in hard-to-reach areas of the structure.

To obtain a correlation dependence, 45 concrete cubes with dimensions of 150x150x150 mm were tested in the laboratory, which were made at different times from the same composition. The samples were made from the same concrete that was put into the structure in order to obtain a more accurate correlation between the "ultrasound propagation velocity - concrete compressive strength". Control cubes were checked at the age of 3, 7, 28 and 90 days. The ultrasound speed was determined on the top of the sample at 6 locations, and on the lateral planes at 6 locations, after which the sample was subjected to a compression test. The average velocity of ultrasound propagation on the top of the cube and on the lateral planes of the sample was determined on each sample.

Studies on control cubes in the laboratory have shown that the speed of ultrasound propagation on the lateral planes of the sample (formed by the walls of the mold) is higher than on the open surface of the cube, which is due to the layering of concrete, which is formed during the manufacture of samples in molds. Therefore, for the correlation dependence "the speed of propagation of ultrasound - the strength of concrete", two curves were built, which were later used to determine the quality of concrete directly in the structure itself (figure 1).

To determine the quality and homogeneity of concrete, at different times, measurements were carried out directly on the structure according to the diagrams shown in figures 2, 3 and 4. The selected control method made it possible to control the quality of concrete during the entire construction, as well as to determine the increase in concrete strength over time. With the help of this method, it was possible to identify a case of using low-quality concrete and take appropriate measures in a timely manner.
Figure 1. Correlation curve "Ultrasound propagation velocity - concrete strength".

Figure 2. Diagram of the change in the velocities of propagation of ultrasound on the right wall of the suction pipe.

Figure 3. Diagram of the change in the velocities of propagation of ultrasound on the left wall of the suction pipe.
Figure 4. Diagram of the change in the velocities of propagation of ultrasound on the basement of the suction pipe.

The results obtained in the laboratory indicate the high accuracy of measuring the ultrasound propagation velocity using the UK 1402 device. Thus, the obtained correlation coefficient between the ultrasound velocity and the compressive strength of concrete averages from 0.96 to 0.97.

With the help of this control method, it is possible to fully trace the quality of concreting, as well as to determine the increase in concrete strength over time (with repeated sounding of concrete after a certain time).

With the help of the chosen method and using an ultrasonic control device, it was possible to identify the case of using low-quality concrete and take appropriate measures.

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