EVALUATION OF CONCRETE HOMOGENEITY IN MASSIVE WALL OF HYDROTECHNICAL STRUCTURE BY MEANS OF ULTRASONIC TOMOGRAPHY METHOD

Tomasz GORZELAŃCZYK, Jerzy HOŁA, Łukasz SADOWSKI, Krzysztof SCHABOWICZ
Institute of Building Engineering, Wroclaw University of Technology
Contact e-mail: t.gorzelanczyk@pwr.wroc.pl

Abstract
This paper presents the results of nondestructive tests of concrete inhomogeneity in a massive wall of a communication gallery in a hydroelectric power plant located on one of the largest rivers in Poland. The tests were carried out using the ultrasonic tomography method. An analysis of the test results showed that in most of the selected measuring places the quality of the concrete is satisfactory. Concrete inhomogeneity, probably in the form of large air voids which had formed as a result of improper concrete compaction or because large aggregate particles had not been properly enveloped in concrete, was detected in only a few places. In such places the microstructure of concrete is inhomogeneous and loose, whereby they are susceptible to water leaks through the wall. The investigations have shown that the ultrasonic tomography method can be successfully used for this purpose. It enables one to quickly detect concrete zones with a different degree of compaction and larger air voids formed as a result of, e.g., improper concrete compaction.

Key words: acoustic methods, ultrasonic tomograph, nondestructive testing, concrete

1. Introduction
Nondestructive methods are currently increasingly often used to diagnose various building structures, including massive hydrotechnical structures [2-4, 7, 8]. The advantage of such methods is their noninvasiveness, which in some situations is simply irreplaceable. Acoustic methods belong to commonly used nondestructive methods. One of the latest acoustic methods is ultrasonic tomography [4] which was employed in this research to evaluate the homogeneity of concrete in the wall of a communication gallery in a hydroelectric power plant.

The investigated object is a hydroelectric power plant (built in the 1970s) located on one of the largest rivers in Poland. It consists of three power generation units separated by isolation joints. Each of the units includes two turbine-generator sets forming two sections called hydroelectric sets. The underground part of the hydroelectric set consists of the following major parts: an inlet scroll, a suction pipe and galleries connecting all the hydroelectric sets. Since they are located below the water level these components should be watertight. Despite repeated waterproofing and sealing, leaks continue to appear on the walls of the structure, also on the walls of the communication gallery tested in this research. The leaks occur not only in the expansion joints,
but also in places where the structure of the concrete is probably inhomogeneous and loose. These may be zones of improperly compacted concrete (honeycombing). There is a problem with such invisible defects occurring inside structural elements, since they become apparent only in the course of service, and then require repairs to remove them.

Figure 1 shows a general view of the investigated communication gallery and a water leak on the gallery wall is shown in fig. 2.

Fig. 1. General view of investigated gallery. Fig. 2. Water leaking through gallery wall.

This paper presents investigations of concrete homogeneity in a structural element constituting the concrete wall of the hydroelectric power plant communication gallery by means of the ultrasonic tomography method.

2. Description of tests
As mentioned above, an ultrasonic tomograph, shown in figs 3 and 4, was used to investigate the concrete wall of the communication gallery.

The tomograph includes a special multihead ultrasonic antenna and a laptop with dedicated software for recording graphical images. The antenna, having 40 independent heads (probes) with dry point contact, is used to excite, receive and process ultrasonic signals. The tomograph has been adapted for testing unilaterally accessible (up to 2500 mm thick) structural elements in order to detect air voids and other places which may be empty or filled with liquid [1, 3-8].

The communication gallery wall was tested by means of the ultrasonic tomograph in 30 measuring places shown in fig. 5. About 500 mm wide and 1500 mm long measuring zones were tested in each of the measuring places. In the course of the test, in a given band the ultrasonic tomograph antenna was continuously moved at every 100 mm in one direction. The total number of measuring points amounted to about
Images of the cross sections in each position were stored in a three-dimensional matrix table and three mutually intersecting cross sections of the investigated object (images B, C and D) were obtained on the basis of the matrix table. Figure 6 shows the names of the cross sections (images) of the investigated object and the tomograph antenna coordinate system.

**Fig. 3. View of ultrasonic tomograph.**

**Fig. 4. Testing by means of ultrasonic tomograph.**

**Fig. 5. Location of measuring places on communication gallery wall.**

**Fig. 6. Names of investigated object’s cross sections, and tomograph antenna coordinate system [4,6].**
3. Test results and their analysis
Exemplary results of the nondestructive ultrasonic tomography tests, showing images of type B and D, are presented in figs 7 and 8. The images were obtained in measuring places 19 and 23. It should be mentioned measuring place 23 was situated close to a water leak through the gallery wall. In the right upper corner there is a scale showing correspondence between the ultrasonic dispersion level in the tested point of the gallery wall and the colour representing it. The ultrasonic dispersion level indicates that the physical characteristics of the media vary in the tested area. The arrows point to the identified areas of concrete inhomogeneity.

Fig. 7. Measuring place 19: a) image D, b) image B.
The results of the ultrasonic tomography tests carried out in the 30 measuring places showed no significant concrete quality problems in 25 of them. An example here is measuring place 19. It appears from the images in figure 7 that there are two small concrete inhomogeneity zones at a depth of about 2200 mm.

However, in five of the 30 measuring places there occur zones of concrete characterized by high inhomogeneity. One of such areas is place 23 where water leaked through the gallery wall. When examining the images in fig. 8 one should notice ten to twenty places located at different depths, where probably large air voids occur. In such places the structure of concrete may be inhomogeneous and loose, which results in leaks. One should suppose that the existing situation is due to the improper compaction of the concrete mixture during construction or to the use of too large aggregate particles (with a diameter larger than 70 mm) which were not properly enveloped with cement grout. Unfortunately the test results could not be verified by taking drill cores since the owner of the investigated object did not give permission for destructive testing.
4. Conclusions
Thanks to the ultrasonic tomography tests it was possible to evaluate the homogeneity of concrete in the wall of the hydroelectric power plant communication gallery. An analysis of the test results showed that the quality of the concrete in most of the selected places is satisfactory. Concrete inhomogeneity, probably in the form of large air voids which had formed as a result of improper concrete compaction or because large aggregate particles had not been properly enveloped with concrete, was detected in only a few places. In such places the microstructure of concrete is inhomogeneous and loose, which has a significant bearing on the durability of the structure since such places are susceptible to water leaks through the wall.

Moreover, the investigations showed that the ultrasonic tomography method is useful for evaluating concrete homogeneity in a massive structural element to which a destructive test method cannot be applied. It would be advisable to confirm the nondestructively obtained results by taking drill cores from randomly selected places.

The authors also note the lack of standard images obtained by the ultrasonic tomography method in laboratory conditions from structural elements with modelled defects. Such standard images assigned to the particular defects would be very useful in the interpretation of results obtained from real objects.

References