NONDESTRUCTIVE TESTING OF HEAT PIPE CARRYING TUNNEL WALL THICKNESS BY MEANS OF ULTRASONIC TOMOGRAPH

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Abstract
The paper presents the results of nondestructive tests aimed at determining the thickness of the walls of a tunnel carrying heat pipes under a river. Ultrasonic tomography was used for this purpose. An analysis of the obtained results showed that because of the way the tunnel had been constructed the wall thickness varies along its length. Moreover, the tests have demonstrated that the ultrasonic tomography method is suitable for determining the thickness of concrete elements which cannot be tested by any conventional destructive method.

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

1. Introduction
Today nondestructive methods are more universally used to diagnose all kinds of building structures [1-3]. Owing to their noninvasiveness they are irreplaceable in some cases. Most often nondestructive acoustic methods are used. One of such methods is ultrasonic tomography [4, 5]. It was used in this study to test the thickness of a heat pipe carrying tunnel.

The investigated heat pipe carrying tunnel runs under one of the large rivers in Poland, at a depth of ten-twenty meters below the water level. The tunnel was built, using the caisson method and manual tunnelling, in the 1950s. The tunnel was bored simultaneously from two sides. The tunnel walls are made of concrete. The tunnel is 930 m long and has an inside diameter of about 3.5 m. The location of the tunnel and its general view are shown in respectively fig. 1 and fig. 2.

Currently, in the tunnel there are two pipes (each 900 mm in cross section) carrying hot water from a heat and power plant to households, and a service platform for getting from one side to the other.

Recently, because of the planned repair of the tunnel it became necessary to assess the load-bearing capacity of its concrete walls. Therefore not only the thickness of the walls (accessible from one side only), but also the variation in their thickness along the tunnel had to be determined. Because of the peculiar location of the tunnel, destructive tests (consisting in drilling through the wall) could be carried out only sporadically. Since the tunnel had been built using the caisson method one could expect that the actual tunnel wall thickness would considerably differ from the design thick-
ness of 400 mm. It was decided to carry out nondestructive tests by means of an ultrasonic tomograph.

**Fig. 1. Location of investigated tunnel under river**

**Fig. 2. General view of investigated tunnel**

2. **Description of tests**

The ultrasonic tomography set shown in action in figure 3 was used to test the tunnel’s concrete walls. The set includes a special multihead antenna and a laptop with dedicated software enabling the recording of graphic images. The antenna with 40 independent dry-contact heads is used to excite, receive and process ultrasonic signals. The tomograph can be used to test concrete elements in order determine their thickness (when they are accessible from only one side) and to detect cracks, inclusions, voids and other places which may be empty or filled with liquid or material whose density is different than that of the surrounding concrete or which has different physical and mechanical properties.

Tests by means of the ultrasonic tomograph were carried out in twenty measuring sites. A measuring band, about 500 mm wide and 1500 mm long, was covered in each measuring site. During a wall test the ultrasonic tomograph’s antenna was continuously moved (in 100 mm long steps) in one direction. In total there were 400 measuring points. The images of the cross section in each position were collected in a three-dimensional matrix table. Three mutually intersecting cross sections (images B, C and D) of the investigated object would be obtained on the basis of the matrix table. Figure 4 shows the names of the cross sections (images) of the investigated object and the coordinate system fixed to the tomograph’s antenna. Image B is on the right while images C and D are respectively at the top and the bottom. The measuring sites in the tunnel are marked in fig. 5.
Fig. 3. Ultrasonic tomography set in action

Fig. 4. Names of cross sections of investigated object, and coordinate system fixed to tomo-graph's antenna

Fig. 5. Measuring sites in tested tunnel

3. Test results and their analysis

Typical results (in the form of images B, C and D) of the nondestructive ultrasonic tomography tests are shown in figs 6-8. For example, figure 6 shows images B, C and D obtained in measuring sites no. 7, 14 and 19. Figure 6b shows an image of the cross section of the examined concrete wall while the solid line and the arrows mark the wall thickness. In the top right corner in figure 6 there is a scale showing the correspondence between the ultrasonic dispersion level in a point of the examined tunnel concrete wall and the colour representing this level. The ultrasonic dispersion level represents changes whose physical characteristics are different than the characteristic of the concrete in the investigated area, indicating the presence of voids, large inclusions, zones of concrete of different density and so on.

An analysis of the particular images in 20 investigated sites showed that the tunnel concrete wall thickness was close to its design value. As expected, because of the way in which the tunnel was constructed, the tunnel wall thickness is not the same along the tunnel length, ranging from 385 mm to 420 mm. Moreover, at the depth of about 90-140 mm there is probably a reinforcement layer, represented as places with a high dispersion level (red colour), in the images. It should be also noted that the analysis did not indicate any significant cracks, intrusion or voids in the concrete.

In order to verify the obtained results random destructive tests (drillings through) in several selected places were carried out.
Fig. 6. Band in measuring site no. 7: a) image C, b) image D, c) image B

Fig. 7. Band in measuring site no. 14: a) image C, b) image D, c) image B
4. Conclusion

Thanks to the ultrasonic tomography investigations the thickness of the unilaterally accessible concrete walls of the under-river heat pipe carrying tunnel was determined. The wall thickness was found to vary along the tunnel length (due to the way the tunnel had been constructed), ranging from 385 mm to 420 mm. This was confirmed by random drillings through. The thickness is close to its design value of 400 mm. Moreover, the tests have demonstrated the suitability of the ultrasonic tomography method for determining the thickness of concrete elements which cannot be tested by any conventional destructive method.

References


