The Quality Evaluation of Concrete Structures with the Ultrasonic Low-Frequency Tomograph

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Abstract. The paper presents the research findings obtained as a result of the ultrasonic nondestructive testing of flaw detection in one-sided access confined concrete. The ultrasonic nondestructive testing is applied to detect the size and location of internal defects in confined concrete that allows the accurate taking cores and their mechanical testing. Tomographic images of the scanned internal structure are given herein as well as the results of compressive strength testing of cores taken from defective portions of the concrete one-sided access construction.

1. Introduction
Nowadays, the ultrasonic nondestructive testing is widely used along with other techniques for the quality control and inspection of in-situ reinforced concrete constructions. The ultrasonic nondestructive testing allows the investigation of one-sided access constructions, field applications, non-hazardous and eco-friendly applications, and provides the parameter informativeness. Ultrasonic waves is the only type of radiation which responds to various mechanical defects of the material structure [1–4].
In 2014, the authors conducted research into the flaw detection, namely cracks, voids, cavities, etc. occurred in the reinforced concrete load-bearing structures, that have a negative effect on mechanical conditions of test object. Examination was carried out on ultrasonic nondestructive testing tools.

2. Experimental
The nondestructive testing was carried out on the ultrasonic low-frequency tomograph A1040 POLYGON that performs the echo method for testing, does not require a coupling medium to promote the transfer of sound energy into the test object, and provides the structure visualization of concrete and masonry products and constructions with the one-sided access [5–6].
The following problems should be solved to accomplish the aim of this research.
- Selection of the appropriate portions of the concrete construction and their preparation for the inspection.
- Representation of experimental findings by tomographic imaging B-, C-, and D-scans.
- Laboratory processing of obtained experimental findings.
Analysis of obtained experimental findings and making conclusions in accordance with the aim of research.

Tomographic imaging is a two-dimensional reconstruction of the material structure represented by its three mutually perpendicular cross-sections as shown in figure 1. The screening and evaluation method is used to generate tomographic images of these cross-sections. The screening and evaluation method comprises a plurality of scanning steps in which the scanner assembly performs a successive scanning of an object plane in order to capture a series of tomographic images which can be evaluated. The direction and step of scanning are pre-selected and not changed during the whole procedure as a result of which only preliminary conclusions can be made about test object. We draw parallel lines on the object plane at regular intervals [7] prior to the scanning procedure.

![Figure 1. Scans of tomographic images.](image)

Figures 2–4 contain the fragments of tomographic images of scanned concrete structures. The red colour shows that there are regions (reflecting surfaces) with acoustic properties differing from that of the material of the structure, i.e. concrete [8]. This reflecting surface is the non-homogeneous concrete having voids, cavities, channels, and steel bars.
**Figure 2.** Scans of tomographic images. Test object – confined concrete in strip foundation and basement floor, 400 mm thick.

**Figure 3.** B-scans of tomographic images obtained at different scanning positions. Test object – in-situ concrete floor slab, 250 mm thick.
B- and D-scans of tomographic images presented in figure 4, show the back wall echo the distance from which to the surface comes to 800–900 mm. The thickness of the inspected construction is detected by the location of the back wall echo.

The in-depth analysis of these tomographic images allows the detection of test object regions having supposedly a non-homogeneous structure [9–10]. Cores are then taken from the detected region in order to determine the strength properties of concrete using direct methods.

Thus, two cores are taken from the in-situ base slab during the scanning procedure. The length of the core taken from the first region is 780 mm, while that of the second comes to 930 mm. The quality control and inspection of test object includes the visual examination and compressive strength testing of cores on a test machine.

The visual examination of cores shows that some of them have small single voids and pores distributed over the concrete core as shown in figure 5. Also, single clay inclusions are observed in the core presented in figure 6. The strength testing of the cores was carried out at Tomsk State University of Architecture and Building, Tomsk, Russia in the Laboratory ‘Stromtest’.

**Figure 4.** Scans of tomographic images. Test object – in-situ base slab, 900 mm thick.

**Figure 5.** Small voids in core N 2.
Strength properties of concrete obtained during the compressive strength testing are given in the table below.

| Cores | Specimen number | Ultimate compressive strength (MPa) | Concrete type by compressive strength | Concrete type by design documents |
|-------|-----------------|-----------------------------------|-------------------------------------|----------------------------------|
| Core 1 | 1.1/1           | 30.0                              | B22.5                               |                                  |
|       | 1.1/6           | 18.3                              | B12.5                               |                                  |
|       | 1.2/1           | 29.0                              | B20                                 |                                  |
|       | 1.2/4           | 16.8                              | B12.5                               | B25                              |
| Core 2 | 2.1/1           | 29.7                              | B22.5                               |                                  |
|       | 2.1/5           | 31.9                              | B22.5                               |                                  |
|       | 2.2/1           | 35.2                              | B25                                 |                                  |

3. Conclusions
This research resulted in the generation of tomographic images of the material structure of inspected concrete constructions. Scan imaging was carried out in the real time mode. The flaw detection technique allowed obtaining information about the sizes and locations of defects in the confined concrete structures.

However, the following disadvantages were detected during the application of A1040 POLYGON:
- A relative complexity of data interpretation.
- A rather high degree of the human factor in the quality evaluation of concrete structures.

4. References
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