DETERMINATION OF MOISTURE CONTENT BY ULTRASONIC METHOD

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Abstract

In this paper, the measurement of moisture content of porous building materials by ultrasonic method is carried out. The experiments are done on the FGD gypsum, lime-cement mortar and cement mortar. These materials are generally non-homogenous with differences in the structure.

Key words: Ultrasonic undulation, ultrasonic scanning, sound reduction, water content

1. Introduction

The ultrasound diagnostic is a non destructive method that is widely used in medicine or mechanical engineering. It serves mainly for diagnostics of homogenous materials like steel [1]. The ultrasonic approaches are usually applied to rail, railway track or other construction and elements inspection.

In this paper the ultrasonic impulse method based on the principle of transmitter and receiver was utilized on inhomogeneous materials. The ultrasonic probe – transmitter emits periodically repeated ultrasonic impulses into the specimens under test. The ultrasonic probe – receiver scans the impulses after they passed through the specimen [2, 3].

2. Measuring system

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For ultrasonic experiment the DIO 2000 device was used. The measuring system of the ultrasonic scanning is described in the scheme in Fig. 1.
For emitting of the ultrasonic waves the piezoelectric element on frequency 200 kHz is used. The special focusing probe makes possible to emit concentric pulses. Probes are fixed on connected arms able to move along both X and Y axes. On the upper arm the transmitter is fixed, and on the lower arm is the receiver. The smooth movement of arms is operated and controlled by servomotors. Arms with probes move parallel with horizontal surfaces on specimen under the test. The maximum distance between probes is 100 mm and it is in dependence on the thickness of specimen. In horizontal direction it is possible to test specimen with total size not exceeding 500 x 700 mm.
The high frequency pulse generator emits the ultrasonic undulation in the transmitter. The pulse amplifier is built in the receiver. The received signal passes through coding device – modulator. The emitted pulse as well as the pulse received is recorded by oscilloscope. Data are next processed in PC. The special software evaluates the time delay of ultrasonic impulse due to transfer through specimen under test.

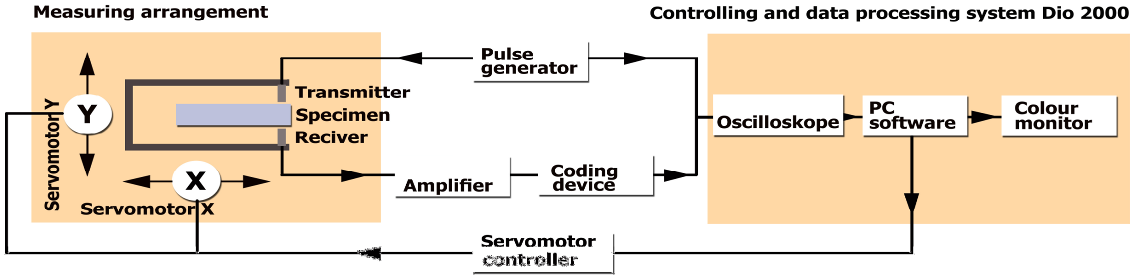

Fig. 1: Measuring system of the ultrasonic scanning

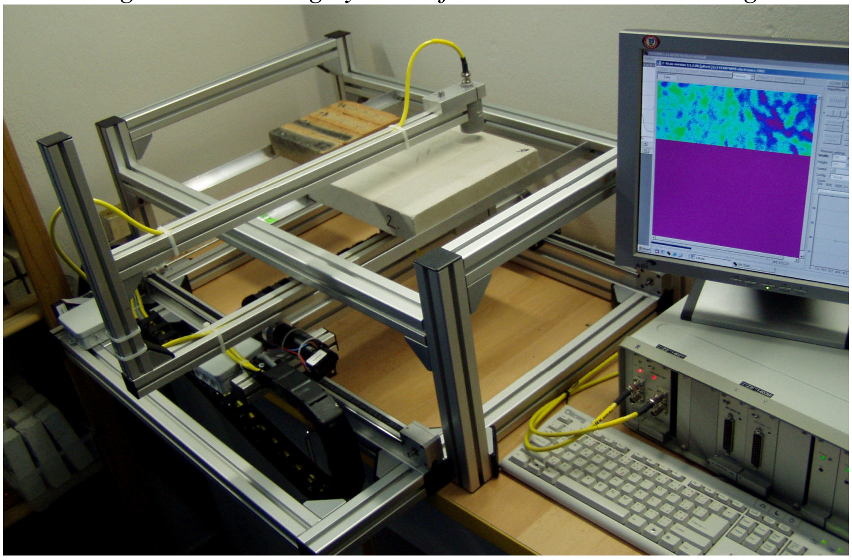

Fig.2: Equipment for ultrasonic testing

3. Tested samples

The tests were done on the FGD gypsum, lime-cement mortar and cement mortar. These materials are non-homogenous with difference in structure, size particles and all other properties. They have also different content of water inside material.
The tested specimens were rectangular parallelepipeds with square cross-section area and their thickness was 15 mm. The distance between probes, (transmitter, receiver), and tested sample was 10 mm.
The basic physical parameters like bulk density, total open porosity and matrix density of tested materials are shown in table 1.

	Bulk density (kg/m^3)	Matrix density (kg/m^3)	Total open porosity (Vol.-%)
Gypsum	981	2090	53,0
Lime-cement mortar	1430	2495	42,6
Cement mortar	1406	2471	42,9

Tab.1. Basic physical properties of studied materials

4. Experiment

For determination of water content in the material by ultrasonic method it is necessary to construct a calibration curves. In the first step, the sound reduction on the dried sample was measured. Then, the samples were fully saturated by water. On the water saturated samples ultrasonic experiments were done. Then the samples were dried in natural way in the laboratory conditions. During the drying process the measurements of sound reduction were done. The sound reduction in dried material is shown in figure 1, on the figure 2 is sound reduction in water saturated sample. On the horizontal axis is the length of sample, on the vertical axis is the width. On the white pixels on the figure is sound reduction 41.6 dB and on the black pixels 49 dB for dried sample and 53.1 dB for water saturated sample.

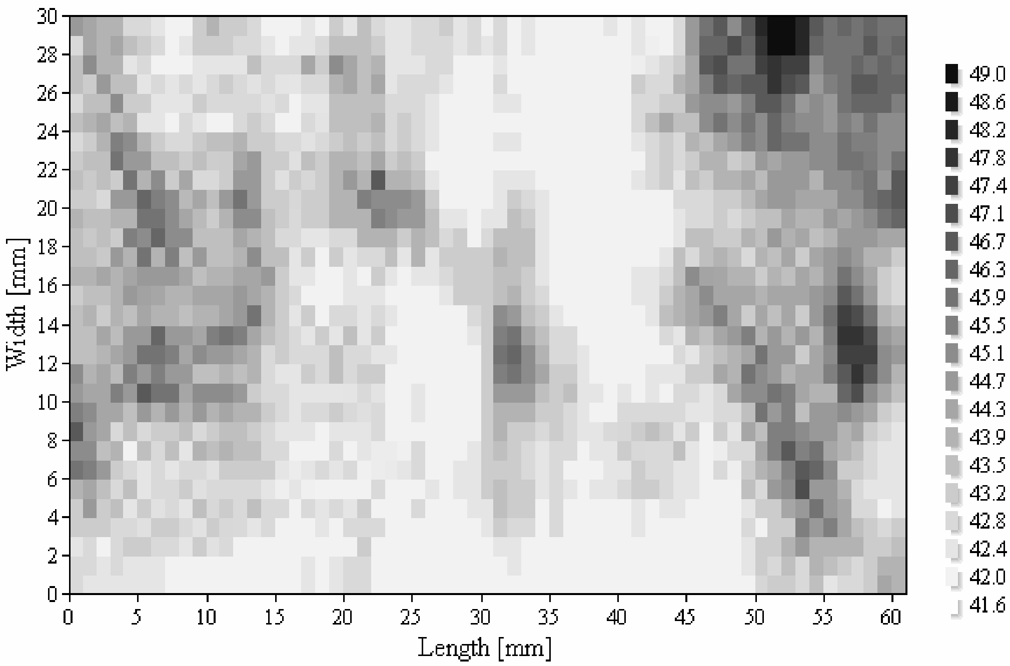

Fig. 1: *Sound reduction in dried material*

On the figure 2 is sound reduction of water saturated sample.

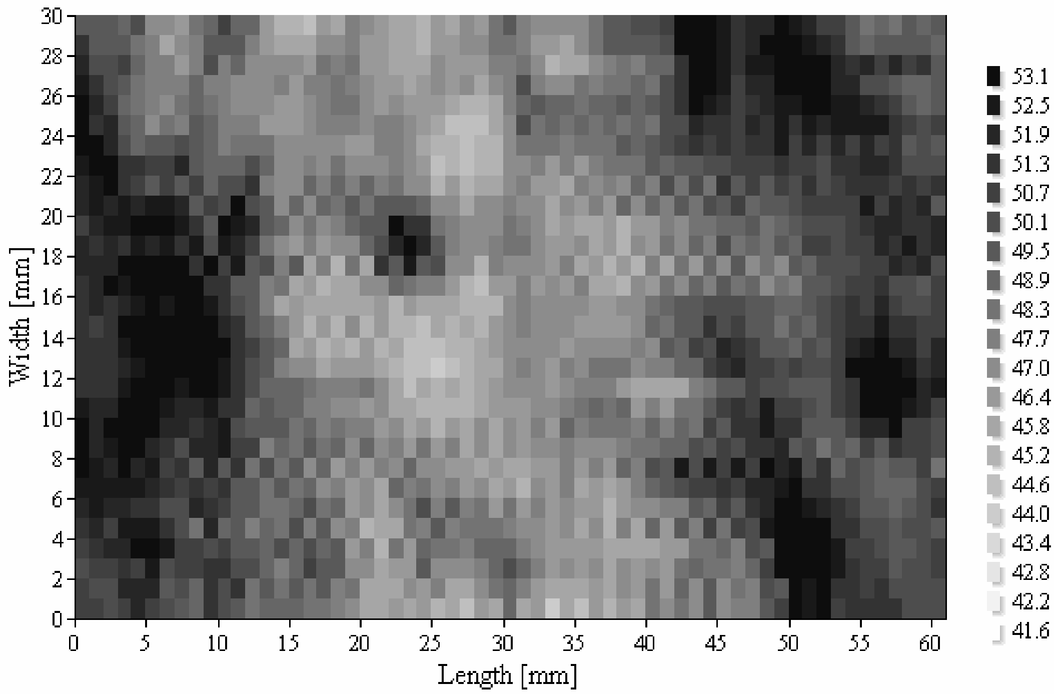

Fig. 2: *Sound reduction in water saturated material*

The results of sound reduction serve for construction of calibration curves.
Then the dried sample was immersed 2 mm into the water. After one hour, the material was scanned and moisture content was determined according to the calibration curve. This is the useful way to describe liquid water transport through porous material. The result of moisture content of lime – cement mortar is shown on the figures 3 and 4. From figures 3 and 4 it is possible to see water penetration into the tested material.
The main disadvantage of this method is necessity to construct a calibration curve for each sample in all pixels.

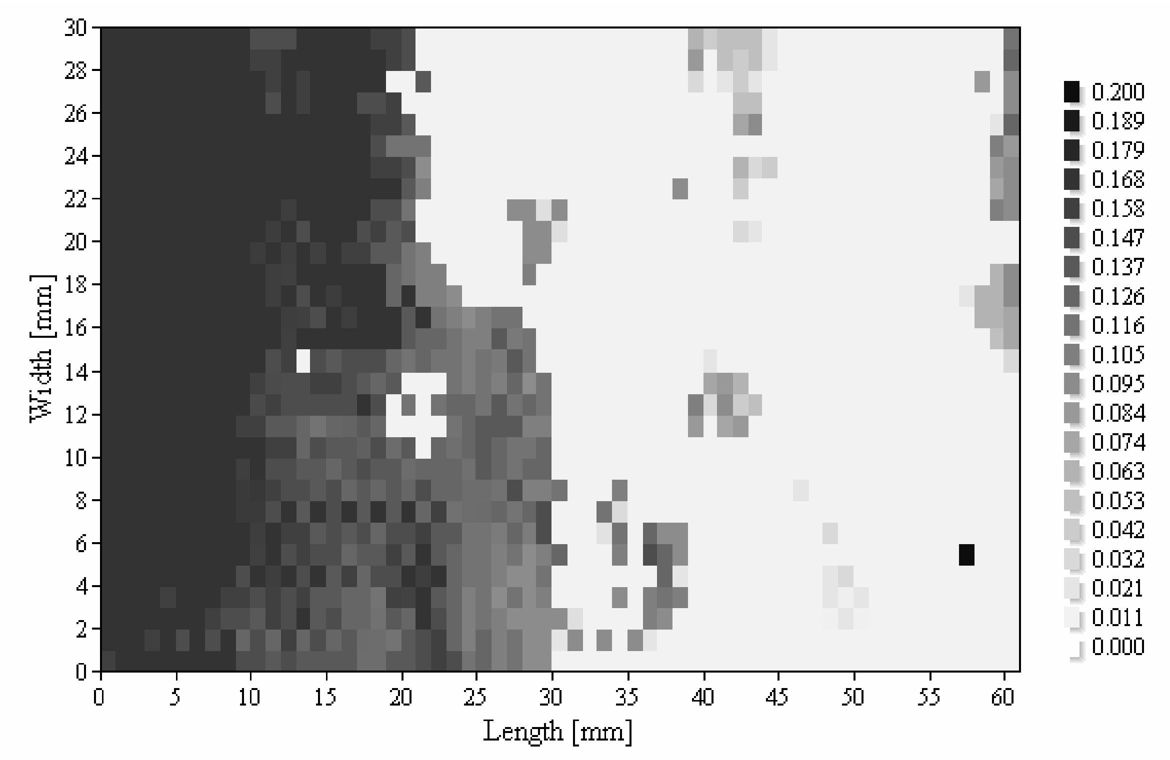

Fig. 3: *The gravimetric moisture content after 1 hour*

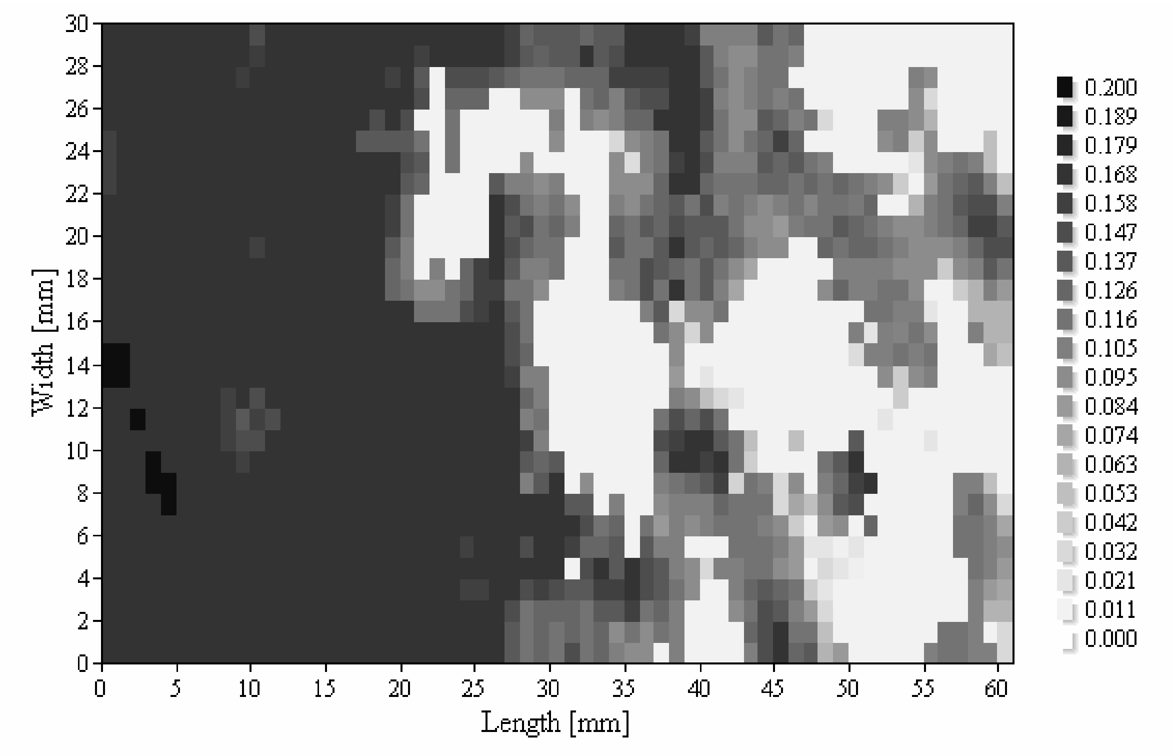

Fig. 4: *The gravimetric moisture content after 2 hours*

5. Conclusion

The results of moisture content measurement in this paper showed that the ultrasonic method can be applied for moisture tomography experiments. These results are the first step for ultrasonic investigation of hygric properties of building materials.

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References

[1] MATINČEK, G.: Nedeštruktívne dynamické metódy skušania stavebných materiálov, Bratislava: SAV, 19621, p.242
[2] Štarman, S.: Ultrasonic Instruments for Material Testing, Prague: Starmans electronic s.r.o., 2005, p. 15
[3] OBRAZ, J.: Zkoušení materiálu ultrazvukem, Prague, SNTL 1989, p.460.

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