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MONITORING OF THE AERATED CONCRETE CONSTRUCTION DRYING PROCESS BY ELECTRICAL IMPEDANCE SPECTROMETRY

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In the time of energy saving different methods of thermo insulation have been developed and one of them besides the comprehensive use of thermo insulation materials is use of masonry consisting of aerated concrete blocks. In order to determine the contribution of aerated concrete in total scope of heat insulation it is important to determine the distribution of humidity in the wall construction itself. One of non-destructive methods for determination of humidity level and its distribution throughout the aerated concrete constructions is application of electrical impedance spectrometry. In laboratorial test series it is detected that within increasing of the humidity level in aerated concrete block the electrical impedance of the construction decreases. Using this method it is possible to detect the distribution of humidity throughout the construction in relative means. If absolute means are important, then calibration work must be performed prior field testing. In order to increase accuracy of the results obtained, the frequency analysis must be performed for every type of testing material. In this paper non destructive testing of a wall segment from aerated concrete blocks is described in order to determine the distribution of humidity level throughout the section of the blocks during the drying process of the construction. The frequency analysis and impact of irregularities in structure for aerated concrete blocks is described as well.

Keywords: *aerated concrete, non destructive testing, electrical impedance spectrometry.*

1. Introduction

In time of energy saving it is important to monitor humidity travelling process through the wall constructions. Aerated concreted is considered to be one of the most efficient load bearing construction materials in aspect of thermo insulation. For aerated concrete it is important to determine the distribution of humidity throughout the section of the construction because it influences the thermic resistance of the construction. This aim can be reached by a non destructive testing methods which are easily applicable on inhabited buildings as well as on buildings which are in construction phase.

Application of electrical impedance spectrometry on different materials in order to monitor humidity distribution is one of the methods which are tested by scientists recently [4.,5.,6.,.7.,11.]. In laboratorial test series it is detected that within increasing of the humidity level in aerated concrete block the electrical impedance of the construction decreases. Using this method it is possible to detect the distribution of humidity throughout the construction in relative means. If absolute means are important, then calibration work must be performed prior field testing. In order to increase accuracy of the results obtained, the frequency analysis has to be performed for every type of testing material. Method of electrical impedance spectrometry (EIS) enables detection of the distribution of impedance or other electrical variables (such as resistivity, conductivity etc.) inside a monitored object, and thus the observation of its inner structure and its changes [3.,1.]. This method ranks among indirect electrical methods and it is used in measuring properties of organic and inorganic substances. It constitutes a very sensitive tool for monitoring phenomena that take place in objects (e.g. changes occurring in earth filled dams when loaded by water, in wet masonry sediments etc.), electrokinetic phenomena at boundaries (e.g. electrode/soil grain, between soil grains) or for describing basic ideas about the structure of an inter phase boundary (e.g. electrode/water) [12.].

The EIS is based on the periodic driving signal – the alternating signal. If low amplitude of the alternating signal is used, concentration changes of charge are minimal at the surface of an electrode connected with the measured surface, which is very important in systems sensitive to so called concentration polarization. The range of frequencies used for the driving signal enables the characterization of systems comprising more interconnected processes with different kinetics.

In the Laboratory of Water – Management Research of the Institute of Water Structures at the Civil Engineering Faculty of Brno University of Technology, a measuring instrument with a Z-meter III device has been developed within the solution of an international project E!4981 of programme EUREKA. This instrument is verified in laboratory experiments and measurements on objects in situ [5.].

In this paper laboratory research results for a segment of aerated concrete block wall are presented. [10.] For further experiments device called "Z-meter III" will be used [6.] This device was invented in framework of EUREKA E!4981 project in the Czech Republic.

Previous researches [9., 10.] have proved that it is possible to use electrical impedance spectrometry (EIS) method to determine relative means of humidity distribution throughout aerated concrete blocks. It is important to choose correct frequency (Hz) for each material so it is necessary to perform frequency analysis of each material prior the main tests on humidity distribution.

2. Methods

In the particular research measurements were performed on a aerated concrete wall segment which consists of 6 (six) aerated concrete blocks [2.] with dimensions of 300mm (width) x 200 mm (height) x up to 600 mm (length which varies depending on place in masonry construction). The wall fragment is shown in Fig. 1.

Fig. 1. *Wall segment of aerated concrete blocks*

In order to perform measurements on the wall the frequency analysis had to be performed on the blocks to determine the most suitable frequency for the measurements.[8.]

Frequency analysis was performed on the wall construction block.

As the distance between measurement points changes in the range of 174 to 348mm (exact distance between measure points in table 1 according to Fig.2.) it was important to find a frequency which can provide reliable results in the range of distances which were previously mentioned.

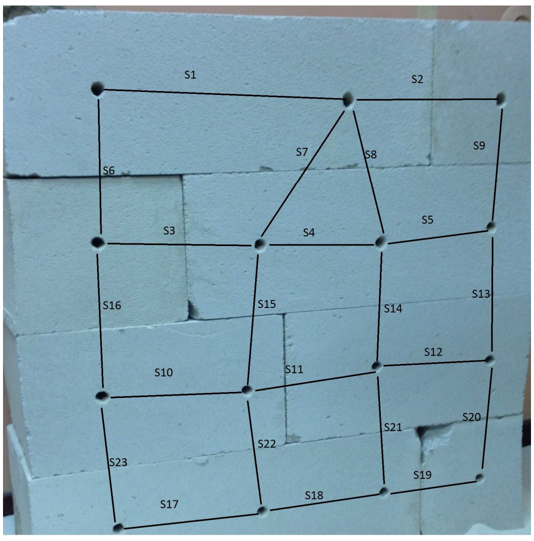

Fig. 2. *Marking of the measurement points on wall segment*

Table 1. *Distance between measurement points*

Marking of the measurement point (according to Fig.2.)	Distance between measurement points, mm
S1	348
S2	258
S3	232
S4	188
S5	186
S6	196
S7	237
S8	215
S9	185
S10	221
S11	208
S12	200
S13	206
S14	187
S15	215
S17	212
S18	215
S19	203
S20	174
S21	198
S22	171
S23	195

Previous researches show that by decreasing distance between measurement points the most suitable measurement frequency also decreases. [8.] In this particular case frequency analysis was performed within a range from 1000Hz to 20 000Hz with 10 repetitions. Each test repetition was performed with 1000Hz step and with 100ms settling time between the measurements. Z-meter III gives the output of the test results separately for real part of electrical impedance (Rx) and imaginary part of electrical impedance (Xx). Previous researches [9.] have shown that for frequency analysis the imaginary part of impedance is most important because it considers the properties of material structure which are crucial in this case. [8.]

An example of frequency analysis graph is given in Fig.3.

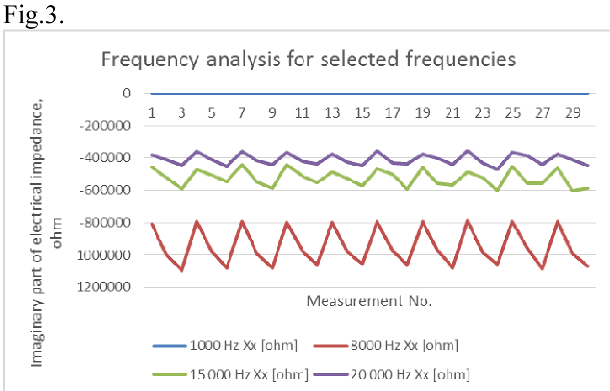

Fig. 3. *Frequency analysis example for measurement distance of 368mm*

Optimal frequency for the measurements is the one that give the most deviation of the obtained results (the amplitude of the graph is the largest if the other conditions are the same). The frequency analysis show that the most suitable frequency the used aerated concrete material is 8000 Hz that can be used in all testing distances. Detailed frequency analysis results are shown in table 2. [8.]

Table 2. Results of frequency analysis

Testing distance, mm	Optimal range of testing frequency, ohm
368	5000 - 10000
233	4000 - 9000
98	3000 - 5000

Actually, results for 98mm testing distance are informative because there are not such testing distance on the wall segment but the result shows the tendency of the optimal test frequency to decrease if the distance between measurement points decreases.

3. Results

The aim of the research was to monitor movement of the humidity throughout the cross section of the aerated concrete wall [Fig.1.]. Measurements were performed in 23 (twenty-three) points all over the wall and all measurement results displayed the same correlations between the drying time and the humidity movement from the centre of the cross section to the side parts of the aerated concrete block. The indications of the measurement places are displayed in Fig.2.

It was important to consider the influence of joints between the aerated concrete blocks to the results of the EIS measurements. Joints have different structure and resistivity to the measurement frequency, which causes irregularities in results. The results of the wall drying process within the boundaries of one block show clearly how the humidity move outside from the centre of the block. Fig.4. displays the drying process of the first block in the wall construction (measurement marking s1 [Fig.2.]).

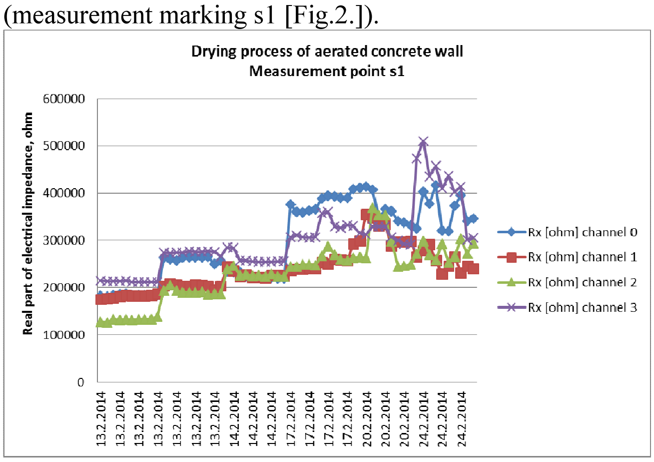

Fig.4. *Drying process of the aerated concrete wall fragment*

As the channels 0 and 3 were located on the sides of the block's cross section while the channel 1 and 2 were located in the middle part of the block it can be seen from the Fig.4. that initially the side parts of the cross section have higher electrical impedance than the middle channels which mean that there is a higher humidity rate in the middle of the cross section.

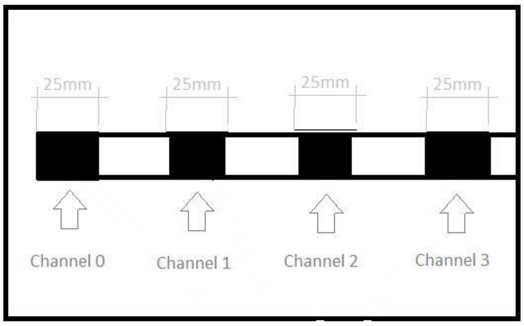

Fig.5. *Cross section of the aerated concrete wall fragment with measurement probe*

The results change during the time of the drying process. In the second day of the experiment, humidity rate in all measurement points of the cross section becomes similar but in another three days, the humidity rate of the side sensors decreases while the humidity rate of the cross section's centre still is higher. In Fig.4. information about humidity distribution throughout the cross section of an aerated concrete block can be found. The general humidity rate of the block decreases but the centre of the block has higher humidity rate.

If the results of measurements performed within one block show clear results, then the results obtained by measurements between two blocks are more complicated. Results that are obtained from the measurement point s2 [Fig.2.] show the same character of the charts but if the absolute values are compared then it is obvious that there is large difference between them. [see Fig.6.]

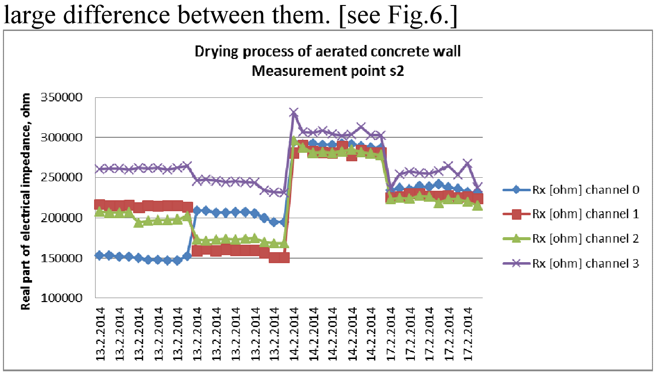

Fig.6. *Drying process of the aerated concrete wall fragment with joint between measurement points*

By comparing the absolute values of measurement data from Fig.4 and Fig.6. then it can be seen that absolute values of the measurement data become approximately twice higher if a joint is located between measurement point. Such effect of joints to the measurement results narrows the application of the EIS method if it is necessary to correlate measurement values to absolute values of humidity level in the block.

4. Discussion

Test results prove that previous assumptions about humidity distribution in aerated concrete blocks are correct. The blocks concentrate the humidity Drying process begins after masonry construction is completed and the humidity travels from the centre of the cross section towards the sides of the block which are in connection with surrounding environment (usually air, not towards other blocks and masonry joints).

If measurements are performed on habitable buildings where the masonry construction is covered by the finishing works it is important to detect the masonry joints prior the EIS testing. Otherwise, it may lead to misinterpretation of the test results.

The experiment proves that if the aerated concrete masonry construction is placed in dry and warm conditions (or such conditions are provided around the construction) then the average drying time for the aerated concrete blocks that are delivered from the manufacturer compiles 11 days. In this case air dry stat of the masonry wall segment was reached on the 11th day of the experiment.

5. Conclusions

EIS method can be applied for non destructive detection humidity level throughout aerated concrete constructions. It is easily applicable for testing of relative changes of humidity level in construction. In such cases no prior calibration of the Z-meter III device is necessary. As there are several types of probes which can be used as sensors for fully non destructive testing and probes which require prior drilling of holes in construction in order to make accurate measurements the method gives opportunity to apply it for different constructions and situations.

It is also possible to determine the distribution of absolute humidity rate within construction with the EIS method. In such case calibration work in laboratory must be done before the in situ testing in order to determine the correlation of the electric impedance value and absolute humidity rate of the construction. The advantage of EIS method against commonly used method of determination the material humidity rate by weight differences in dry and saturated conditions is that EIS can show the distribution of the humidity throughout the section of the construction. Other commonly used methods do not allow obtaining such data.

The research shows several conditions which must be taken into consideration when using EIS method for humidity distribution in aerated concrete construction.

As stated above EIS method can be applied on tests where it is important to determine exact humidity distribution throughout the cross section of the construction. In order to obtain credible results in absolute means several preparation works have to be done. It is mandatory to perform frequency analysis test prior beginning of the main test series. Masonry joints influence the absolute values of the measurement results so it is necessary to locate the joints and avoid them during the tests. If these conditions are not met then the measurement results can be inaccurate or misinterpreted.

Concerning the drying process of the aerate concrete block masonry construction it can be stated that the material if it is placed in dry and warm conditions reaches its air-dry state in time of one week which is confirmed by the experiment results described above (see Fig.4 and Fig.6.). Researches about influence of the measurement hole filling materials and influence of weather conditions on the drying process of the aerated concrete and its monitoring by EIS is a subject of further research.

Acknowledgment

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