Impact of contact surface on accuracy of humidity distribution measurements in autoclaved aerated concrete constructions by EIS

Sanita Rubene, Martins Vilnitis, Juris Noviks

Abstract**—**Humidity distribution throughout the cross section of autoclaved aerated concrete masonry constructions has significant impact on its performance of heat resistivity properties. An application of electrical impedance spectrometry (EIS) method for determination of humidity distribution throughout the cross section of autoclaved aerated concrete constructions has been a subject of research recently. The EIS method seems to be a useful and convenient method for detection of the humidity distribution throughout the cross section of a construction. Impact of contact surface between the measurement probe and the testing concrete sample is a subject of this research.

Keywords**—**EIS, non-destructive testing, humidity distribution, aerated concrete.

I. Introduction

ENERGY efficiency is one of the most actual and significant topics of research. As autoclaved aerated concrete masonry blocks are a construction material that combines load bearing properties as well as high heat insulation properties it is very suitable for use as a load bearing construction material in building where high heat insulation performance is required. The most common problem in use of autoclaved aerated concrete constructions is neglected drying period of freshly manufactured material and lack of useful non-destructive test methods for easy detection of humidity distribution throughout the cross section of the masonry construction.

EIS is a relatively new method for non-destructive measurements of humidity distribution in aerated concrete constructions but it has already displayed acceptable results in field of relative measurements for humidity distribution. Therefore it allows to control the drying process of the masonry construction in order to reach as high heat insulation parameters of the material as it is possible. As the measurements are performed with a pair of probes which are inserted in the construction then the question of impact of contact surface between the measurement probe and the testing concrete sample arises. This is a subject of the research described in this paper.

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II. Methods

For particular research electrical impedance spectrometry method using Z-meter III device was used.

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 [1-2]. This method ranks among indirect electrical methods and it is used in measuring properties of organic and inorganic substances. So far, EIS is widely used in medicine as one of the most common testing methods in diagnostics where any kind of tissues are involved. 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) [3]. In particular case the measurement results were obtained as a value of real part and imaginary part of electrical impedance. It made easier to determine which changes of impedance were caused by the changes of humidity ratio and which were caused by the changes of materials' porous structure during its drying process. For further measurements the real part of electrical impedance is used.

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 characterisation 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 [4-5].

The initial application of the device was for determination of humidity distribution changes and monitoring of moisture migration in earth-filled dams and other similar constructions [6-8].

This far application of the EIS method is credible for measurements of relative changes in humidity distribution throughout the cross section of the autoclaved aerated concrete constructions and further researches are performed in order to develop the method for wide use of non-destructive humidity distribution measurements.

The measurements are performed by inserting a pair of measurement probes in bores made in the construction. The measurements are taken in area between the measurement probes. In the particular case the measurements are performed using 4 (four) or 5 (five) measurement channels (Fig.1) of the probes depending on thickness of the construction. The channels are counted starting from the furthest channel of the probe.

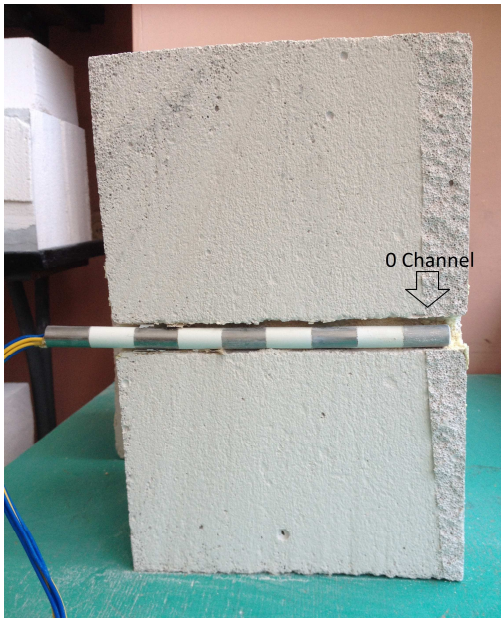

Fig.1. Cross section of autoclaved aerated concrete block used for the experiment with measurement probe

The measurements are performed between the stainless steel elements in both probes which are inserted in the construction within a distance (Fig.2).

III. PREVIOUS RESEARCH IN FIELD OF APPLICATION OF EIS FOR HUMIDITY DISTRIBUTION MEASUREMENTS IN AERATED CONCRETE CONSTRUCTIONS

A series of research have been performed to determine the possibilities to apply EIS method and particularly Z-meter III device for humidity distribution measurements throughout the cross section of autoclaved aerated concrete constructions.

The first research about the possibilities of application of EIS method for humidity distribution measurements in autoclaved aerated concrete constructions by Z-meter III device was performed by authors in 2013 in Brno university of Technology [5]. The tests were performed with different types of measurement probes and proved that humidity distribution changes throughout the cross section of autoclaved aerated concrete masonry block sample correlate with changes of its electrical resistivity measurements. All of the tests were performed as surveillance of changes in resistivity measurements while one side of the block was exposed to direct impact of water. The experiment proved that the EIS method was applicable for detection of humidity distribution changes in relative means.

The second part of the research about the application of EIS method on humidity distribution changes was performed by authors in Riga Technical university [9]. The subject of this research was to ascertain that the results obtained in the experiments performed in the Brno university of Technology [5] were credible as well as to determine the impact of cracks or masonry joints on the EIS measurement results.

Series of tests performed during the previous researches proved that the results of EIS measurement tests in field of humidity distribution throughout the cross section of the masonry block are credible and confirmed the previous results – by the increasing of the humidity ratio in the area of the monitored cross section its electrical resistivity values decreased. As for the second part of the research, it showed that large cracks or masonry joints between the measurement points have significant impact on measurement results in absolute values. It means that measurements performed in masonry construction area without significant cracks or masonry joints cannot be compared with the results that are obtained in areas where the masonry joints or significant cracks are present.

As all previous researches [5,9] were performed on single autoclaved aerated concrete blocks or combinations of two such blocks then the next step of the research was to monitor the drying process of an aerated concrete block masonry wall segment [10]. The results of the research displayed a humidity migration process throughout the cross section of the wall segment and its correlation to the EIS measurements. The obtained data allow visualizing the speed and character of the humidity migration process in the wall segment after its construction until the moment when the air-dry state of the construction is reached in the laboratorial environment. The test approved authors' assumption that the aerated concrete

drying properties are efficient in case of the construction which is not covered with finishing layers.

In additional research the impact of masonry joints on the values of the EIS measurements were performed [11-12]. The research allows assuming that there exists linear correlation between the results obtained in the areas where are no masonry joints between measurement points and the results, which are obtained in areas, including masonry joints between the measurement points. The determined correlation indicates that the impact of joints can be described with a linear equation (1) where a quotient is in range of 0,67 to 0,96 but the value of C is depending on the width and filling material (mortar, special glue etc.) of the masonry joint.

$$y = ax + C \quad (1)$$

IV. Experiments

For this research autoclaved aerated concrete masonry blocks with density of 375kg/m^3 were used (Fig.2). [13]

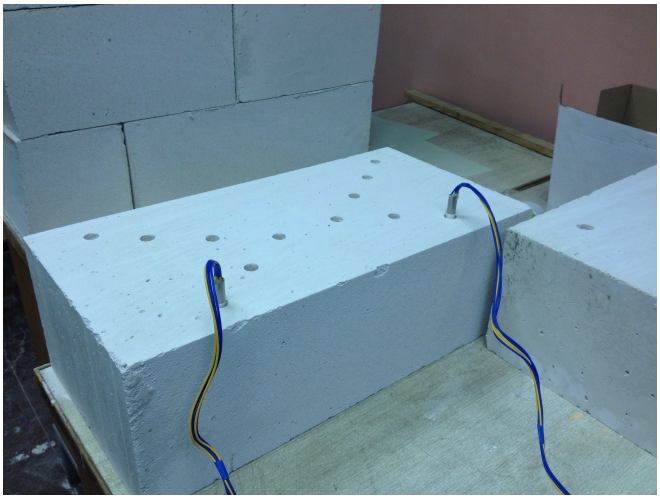

Fig.2. Autoclaved aerated concrete block with one pair of measurement probes

The experiment included usage of three measurement series where in each set different type of contact surface improvements were performed. To increase the credibility of obtained results each of the series consist of measurements performed on three blocks which are exposed to identical conditions.

For the first set of the blocks the measurement bore was made with the maximal accuracy for the bore diameter to comply with the diameter of the measurement probe and it was maximally close to the probe diameter. The difference between the probe radius and the radius of the bore was approx. 1mm (Fig.3).

Fig.3. Autoclaved aerated concrete block used for the experiment

Although such precision causes certain inconveniences in measurement process due to difficult insertion of the measurement probe the contact surface in this case was very tight (Fig.3, 4).

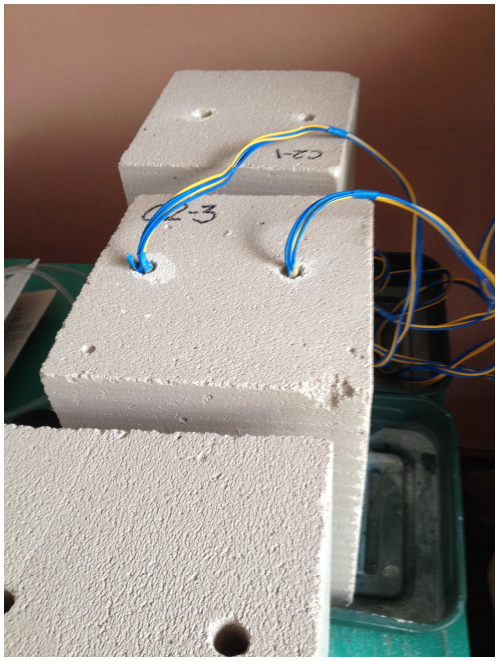

Fig.4. Autoclaved aerated concrete blocks with liquid silicone filling in bores and bores with no filling

In measurement process arises a problem of extensive drying process due to additional ventilation of the blocks through the measurement bores and a solution for this problem was researched during this experiment as well as the problem of contact surface's influence on the precision of measurement results.

In the second set of experiment in order to prevent fast drying of the block due to additional ventilation of the structure in the measurement bores the bore surface was covered with liquid silicone and the influence of this material on measurement results was also assessed.

In the third set of the experiment blocks the space in the measurement bore between the probe and the surface of the aerated concrete block was filled with universal silicone. The silicone fills all free space between the measurement probe and the aerated concrete so that ideal contact surface between the probe and the block is established. Although a problem arises during the drying process of the block. As the block dries the small particles of aerated concrete which were displaced in the pores of the material during the drilling process separates from the block and in such way decrease adhesion between the silicone and the block. As the measurement process assumes cyclic insertion and withdrawal of the measurement probe then the decreased adhesion between the materials cause separation of the silicone from the block surface and in such way the integrity of the measurement process is terminated.

The obtained results were compared within each of the measurement sets and afterwards the results were compared between the sets.

All blocks were monitored for period of three months during summer of 2014. The average temperature of the surrounding environment during the monitoring process was +22°C and average air humidity rate was 70%.

V. RESULTS

A. *Impact of the bore diameter on the measurement results*

For all following results the measurement result which was obtained from the EIS measurements from autoclaved aerated concrete blocks with no filling between the block surface and measurement probe is considered as a reference result.

The reference chart is displayed in Fig.5.

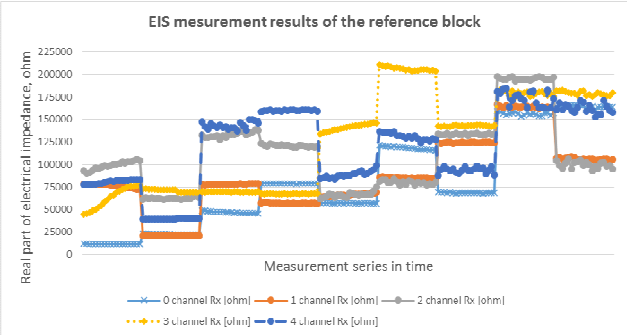

Fig.5 EIS measurements during the drying process of the reference block

During the blocks` drying process its` electrical resistivity changes. Fig.5 displays that the changes of the electrical resistivity are not equal in all areas of the block and tendencies of humidity migration throughout the cross section of the block can be monitored through the EIS measurement results. From the measurement results it can be concluded that each sector of the block show different speed of drying and moisture transfer. The resistivity measurements of separate channels can change significantly in time from high values (aka relatively low humidity rate) to low values (aka relatively high humidity rate) but the tendency of overall increase of the resistivity can be correlated to overall decrease of the materials' relative humidity rate.

B. *Impact of the silicone filling on the measurement results*

As the application of universal silicone significantly improves contact surface between the measurement probe and the surface of aerated concrete block this material was used in the second set of measurements (Fig.6).

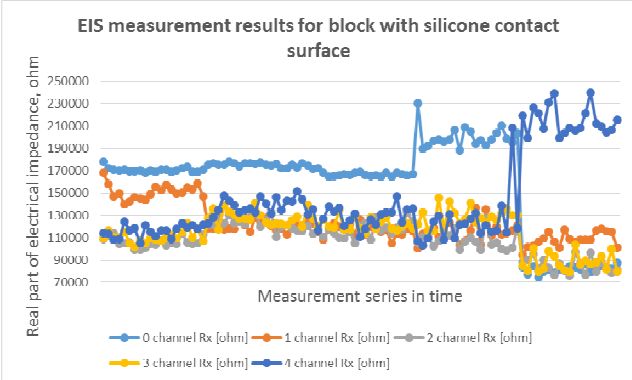

Fig.6 EIS measurements during the drying process of the block with silicone filling between the measurement probe and the surface of the aerated concrete block

After comparing results of Fig.5 and Fig.6 it can be stated that the results for the measurements where silicone was used as filling material of space between the probe and the block surface the overall trend of the charts is similar but the later measurements are more even and do not show significant differences between the measurement series which are taken in different time. In case of not using silicone the differences between the measurement series are obvious (Fig.5).

Comparison of absolute measurement values between the measurements made without any filling material and using silicone as filling show that the silicone filling works as insulation material which does not allow to monitor detailed changes of moisture migration through the cross section of the material in real time (Fig.7).

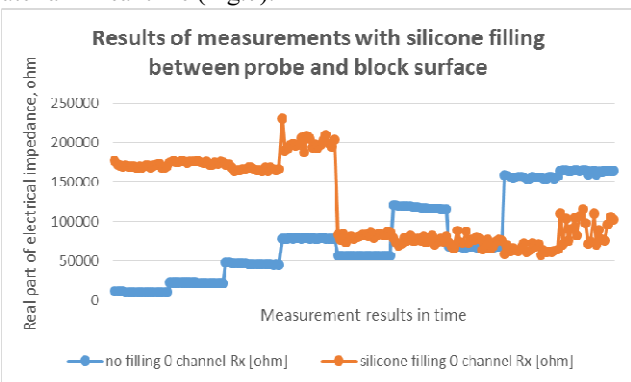

Fig.7 EIS measurements during the drying process of the reference block and block with silicone filling between the probe and the measurement surface

These results also show significant differences in absolute values of measurement data which does not allow to correlate data obtained during different measurement sessions. In fact the measurement results prove that during the drying process

silicone layer loses its' adhesion to the measurement surface and then a leap of measurement values can be observed. This brings to a conclusion that due to difficult application of silicone in measurement bores and to the fact that silicone affects measurement results it is not the most suitable material for prevention of measurement surfaces' accelerated drying process or for improvement of the contact surface between the measurement surface and the probe.

C. *Impact of the liquid silicone on the measurement results*

The experiment with application of universal silicone in order to prevent accelerated drying processed of the measurement areas due to additional ventilation and exposed drying surfaces showed that universal silicone is not suitable for such purpose.

As an alternative a liquid silicone spray was chosen. After the preparation and cleaning of the measurement bores with compressed air a layer of liquid silicone spray was applied on all surface of the measurement bores. The liquid silicone infiltrated into the aerated concrete for approx.1cm (Fig.4, the block with the measurement probes inserted). After the blocks were infiltrated with water the area which was exposed to liquid silicone spray became clearly visible and in such way it can be stated that liquid silicone had covered all area of contact surface between the measurement probe and the aerated concrete material.

Although liquid silicone spray infiltrates into the aerated concrete and thus does not improve the contact surface, it prevents the measurement bore surface from accelerated drying. In such way, these results can provide more precise data about moisture migration processes throughout the cross section of the construction.

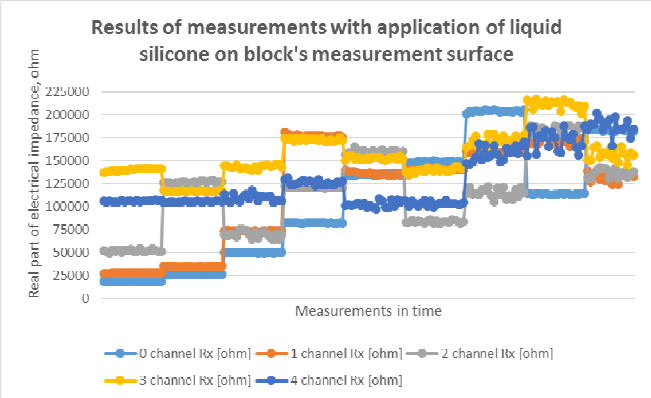

Fig.8 EIS measurements during the drying process of block with liquid silicone spray filling between the probe and the measurement surface

The overall character of the measurement results for the reference block and for the block with liquid silicone application of measurement contact surface is similar (Fig.5 and Fig.8). Exact division into measurement series can be seen in the chart which allow to assume that liquid silicone does not have significant impact on sensitivity of measurement tool as universal silicones does.

Comparing the absolute values of the measurement results (Fig.9) from the reference block and the block with liquid silicone filling on measurement bores it can be stated that liquid silicone spray does not have significant impact on absolute values of EIS measurement results.

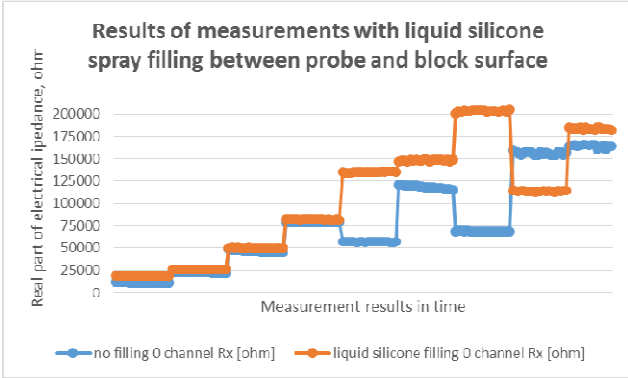

Fig.9 EIS measurements during the drying process of the reference block and block with liquid silicone spray filling between the probe and the measurement surface

Furthermore, it can be stated that application of liquid silicone spray on measurement bore surface excludes some influence of surrounding area to the results of the experiment. The barrier which is made by the silicone covering prevents measurement surface from accelerated drying in warm and dry conditions and increased absorption of air humidity in case of high humidity rate of surrounding environment.

VI. CONCLUSION

Electrical impedance spectrometry is a convenient method for non-destructive determination of humidity distribution throughout the cross section on autoclaved aerated masonry constructions. This research proved that the contact surface between measurement probe and the measurement surface of the masonry block has significant influence on measurement results. If the filling material for improvement of the contact surface is chosen wrongfully then it can lead to misinterpretation of the measurement data or even for obtaining of wrongful data. The example with universal silicone proved that there exist such materials which can reduce accuracy of the obtained results and contrary to expected result that it will improve the accuracy of obtained data it had an opposite effect.

Experiment proved that from the three types of contact surface measurements were performed on the most precise results can be obtained from the contact surface on which liquid silicone spray is applied. The liquid silicone penetrates into the porous structure of autoclaved aerated concrete material for approx.1cm and establishes a layer within the contact surface that prevents excessive drying of the measurement area though the surface of measurement bores and in separate cases prevents recurrent absorption of humidity from the surrounding environment. The measurement values on these measurements almost do not differ from the measurement values of the reference block. It means that in

cases when it is important to establish correlation between the electrical impedance spectrometry measurements and absolute values of relative humidity rate in the material standard correlations can be applied for the interpretation of the results. It is important for correct interpretation of the obtained results because standard correlations are prepared with blocks where no contact surface improvement is used.

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