Impact of porous structure of the AAC material on moisture distribution throughout the cross section of the AAC masonry blocks

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Abstract: - Autoclaved aerated concrete (AAC) is known to be a construction material with high heat insulation parameters. Therefore, it is widely used in construction where high heat insulation parameters of external delimiting constructions have to be met. However, there is a factor that has significant impact of the insulation properties of AAC. This factor is moisture content of the AAC material and its distribution throughout the cross section of the AAC masonry blocks. The moisture distribution and transfer processes depend on the pore distribution throughout the volume of the material and differ in different directions of the material volume. Therefore, the drying process of the AAC has to monitored in order to make sure that the material has reached air dry state and can reach its optimal heat insulation properties.

Key-Words: - moisture distribution, autoclaved aerated concrete, EIS measurements, non-destructive testing.

1 Introduction

Autoclaved aerated concrete (AAC) is a load bearing construction material, which has high heat insulation parameters. The most common problem for AAC heat insulation properties is the excessive moisture content in the AAC materials as well as its distribution throughout the cross section of the masonry elements. Therefore, the drying process of the AAC masonry constructions shall be monitored in order to avoid application of finishing layers on the construction before it has dried to the state it can reach the heat insulation parametres stated at the design stage.

Electrical impedance spectrometry (EIS) is applied for monitoring of drying process of the masonry constructions and detection of moisture distribution throughout the cross section of AAC masonry constructions.

This research describes monitoring of water infiltration in autoclaved aerated concrete masonry construction blocks by electrical impedance spectrometry.

2 Problem Formulation

Construction process is performed in short terms and several significant problems are affecting the quality of the building envelope and its heat insulation parameters. It is the main reason why monitoring of heat and moisture transfer processes as well as the monitoring of the drying process itself is so important. Non-destructive monitoring (NDM) of these processes is the best option for long term data obtaining and comparison of the obtained information. NDM can be used in habitable buildings and influence of different aspects on constructions` drying processes can be considered in the results.

That is the reason why non-destructive monitoring method – electrical impedance spectrometry (EIS) is chosen for monitoring of the water infiltration process in AAC masonry constructions. The method has proven itself as useful and applicable as a relative measurement method as well as a method, which can grant credible absolute measurement values of moisture content in AAC when respective correlation equations are used. It means that the measurement results are obtained as electrical resistivity values, which change as the moisture content in the construction changes. In case it is necessary to obtain absolute values of moisture content in the construction the correlation equations between the moisture content in AAC upon its dry mass and electrical impedance measurements should be used. One of the problems for this measurement method is the anisotropy of the AAC, therefore, drying process as well as water infiltration process should be monitored separately for each direction of AAC material.

The research of Barsotelli et.al [1] provides information that the porosity of the construction material has impact on its hygrometric properties and the research shows a low absorption velocity as a consequence of the large amount of macropores that slow down the capillary forces. Water vapour permeability is enhanced by the degree of connection among the pores and by the absence of condensation phenomena, which are favoured by the presence of micropores. Therefore, a higher quantity of micropores should be envisaged favouring the condensation phenomena and hindering the water vapour diffusion.

In a case of drying the diffusivity is smaller (Kuenzel [2]). A detailed study on drying diffusivity and its determination is given by Pel et al. [3-4]; Pel and Landman [5], which present the approaches to diffusivity determination at the absorption and at the drying during different drying phases. Vu [6] realised the simulation experiments of drying process considering the variability of pore structure parameters expressed by theoretical pore size distributions and modelling the water transport coefficients of building materials represented as a bundle of capillaries, size distribution of which is based on their pore structure [7].

2.1 Methods for measurements of moisture distribution in construction materials

Methods, which are applied on detection of moisture distribution and detection of moisture content of the construction materials in relative means, can be divided into two general subgroups – destructive methods and non-destructive methods.

As the most popular destructive testing method can be stated the gravimetric method. Gravimetric method consist on determining water content through weighting samples upon oven drying, encompassing absorbed and chemically bound water. It can provide data about average moisture content of the construction material if the weight or density of the material in dry state is known. The negative aspect of this method is the fact that for each measurement a sample must be taken from the construction and it means that long term monitoring by this method is problematic if the monitoring is performed in building in the construction phase or in already habitable building.

Different non-destructive testing methods for moisture content measurements of the construction materials can be applied as well.

One of the most common non-destructive testing methods for detection of moisture content in construction materials is application of electrical measurements. The measurement results can be interpreted as moisture distribution quantitative values. One of such electrical methods is electrical impedance spectrometry (EIS).

The EIS is based on the periodic driving signal – the alternating signal.

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 [8-9]. The Z-meter III device is used for non-destructive measurements of water infiltration in AAC masonry blocks.

Experiments with EIS method for the detection of moisture content throughout cross section of AAC masonry constructions have been performed in Riga Technical university by Z-meter III device and methodology for measurement process is being developed [10-12].

2.2 Previous research on moisture distribution measurements in aerated concrete constructions by EIS method

Previous research in field of application this method on detection of moisture distribution throughout the cross section of AAC masonry constructions have been performed at Riga Technical university [10].

These researches show that in relative means the EIS provide credible results of moisture distribution changes throughout the cross section of AAC masonry blocks. The relative nature of these measurements is based on the fact that the direct measurement is based on electrical resistivity measurements and the changes of the electrical resistivity can be correlated with changes of the relative humidity in the construction.

Authors [11-12] have developed the correlation equations between the EIS measurement results in AAC masonry blocks and moisture content in % of the respective material.

The correlation has logarithmic character and the equation depends on the type of the AAC, its density and pore size and distribution.

The correlation equation (1) between the EIS measurements of the AAC masonry blocks used in this research and their moisture content has been developed in previous researches [13].

$$y = -0{,}207\ln(x)+2{,}7074 \quad [14] \qquad (1)$$

and

$$y = -0{,}236\ln(x)+3{,}1507 \quad [15] \qquad (2)$$

3 Monitoring of water infiltration in autoclaved aerated concrete masonry construction blocks by electrical impedance spectrometry

Moisture infiltration in AAC masonry blocks during the construction phase of the buildings is one of the most important problems of application of AAC masonry blocks in construction of delimiting masonry constructions with high heat insulation parametres. As the construction of the building is performed in situ then the weather conditions have direct impact on the construction materials during the construction stage and it is important not only to preserve the materials from direct exposure to the precipitation but also to avoid excessive moisture infiltration from other wet construction processes, which are performed on construction site.

Therefore, non-destructive monitoring of water infiltration in AAC masonry blocks by EIS can be an answer to this emerging issue.

In the particular experiment the impact of the uneven distribution of pores throughout the volume of AAC masonry blocks on the speed of water infiltration in the respective blocks has been researched. Correlation between the porous structure of different AAC specimen and the water infiltration in the ACC masonry blocks has been researched as well.

3.1 Description of the experiment

The experiment there were divided in three parts: firstly, the infiltration of water was monitored in situation when the blocks were inserted in water as in fig.1 and water infiltration occured due to capillary forces.

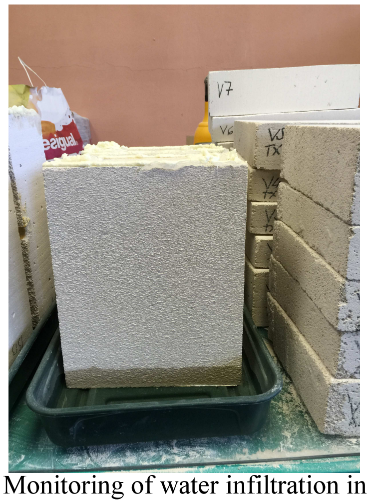

Fig.1. Monitoring of water infiltration in AAC masonry block

In the particular part of the experiment there were used two sets of AAC masonry blocks [14-15] with three blocks in each set. Each set of the AAC masonry blocks was taken from different manufacturer in order to compare the porous structure of different types of AAC.

Both sets of the blocks were used for monitoring of water infiltration in direction, which is parallel to the manufacturing direction of the AAC and perpendicular to the manufacturing direction of the respective AAC masonry blocks due to the uneven distribution of the pores in the AAC material.

For the measurements of moisture distribution a Z-meter III device with one pair of measurement probes with five active channels was used. The probes were inserted into the drilled holes as in example on Fig.2.

Fig.2. Example of measurement insertion in aerated concrete block fragment

The active channel of the probe is the metallic element on the probe (see Fig.2). Measurements were performed between corresponding channels of two probes, which allow to measure resistivity in different layers of the construction within the same measurement. In particular case two to all five channels of the probe were used for the measurements in the construction depending on the dimensions of the specimen.

In order to monitor the water infiltration speed in different directions of AAC masonry blocks (relatively to the manufacturing direction of AAC) a constant amount of water was applied on the blocks hourly. The EIS measurements were taken every hour as well as scaling of the samples in order to determine the average increase of the moisture content in the samples.

For the second part of the experiment, the water was applied evenly on the top surface of the AAC samples as in fig.3 and the water infiltration from the top of the AAC masonry block due to gravitation forces was monitored.

Fig.3. Samples with application of water on the top of the samples

In the third part of the experiment there was monitored the water infiltration in the AAC masonry blocks if the water is applied on the top surface of the sample constantly in a condition of a water droplets as in stand in fig.4.

Fig.4. Stand of the water application on the AAC masonry blocks in condition of water droplets

3.2 Results of the experiment

As a result of the experiment information about the infiltration of water in different directions of AAC masonry blocks was obtained.

For the first part of the experiment, following results were obtained:

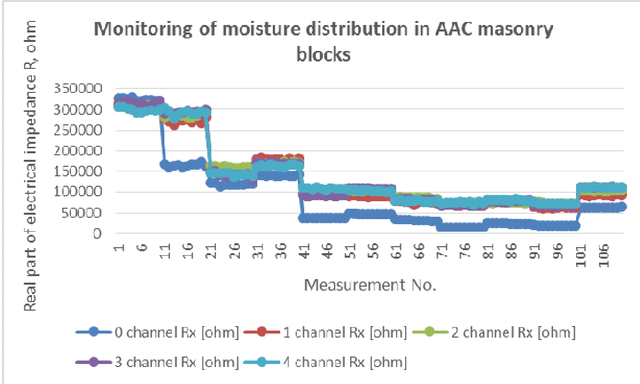

Fig.5 EIS measurement results of water infiltration in the first set of the samples [14]

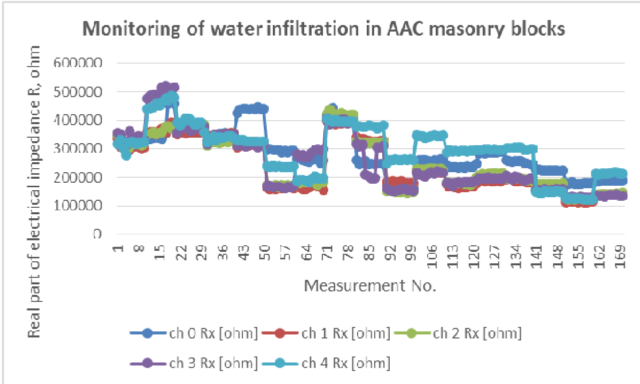

Fig.6 EIS measurement results of water infiltration in the first set of the samples [15]

From the obtained results it can be concluded that the moisture infiltration and distribution throughout its cross section of AAC material with higher porosity is more uneven that in the one with lower porosity (Fig.5 and Fig.6).

The obtained results were compared with the information about pore distribution in the relevant sections of the AAC used for the experiment (fig.7 and fig.8).

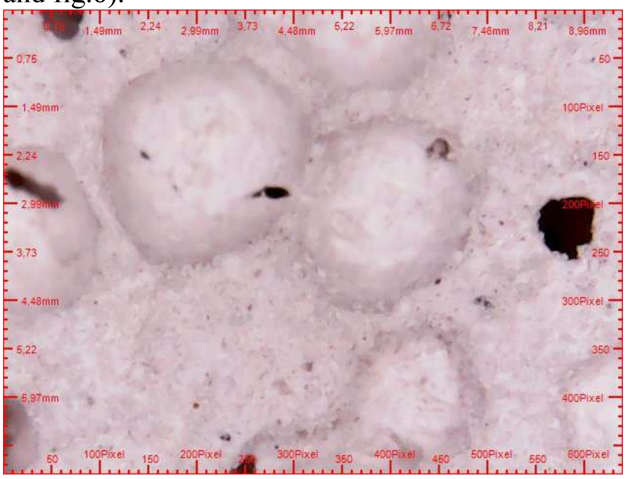

Fig.7. Macropore distribution throughout the cross section of the AAC sample (parallel to the manufacturing direction) [15]

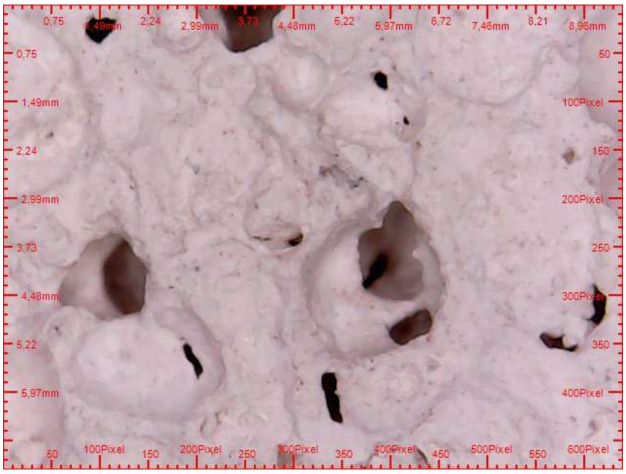

Fig.8. Macropore distribution throughout the cross section of the AAC sample (parallel to the manufacturing direction) [14]

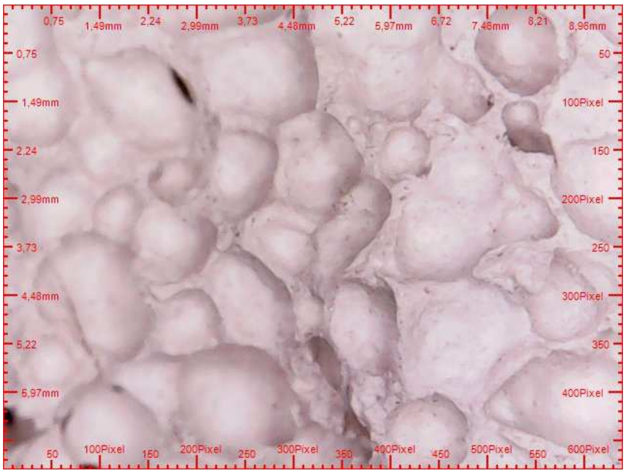

Fig.10. Macropore distribution throughout the cross section of the AAC sample (perpendicular to the manufacturing direction) [14]

In fig.7 and fig.8 it can be seen that the AAC material in the direction which is parallel to its manufacturing direction has a number of interconnected pores. Such phenomena is much less typical for the AAC material in the direction, which is perpendicular to the manufacturing direction of the material (fig.9 and fig.10).

Therefore, it can be stated that the AAC material forms layers of different density within its volume if the material is researched in the direction, which is parallel to its manufacturing direction due to the features of the manufacturing process of AAC.

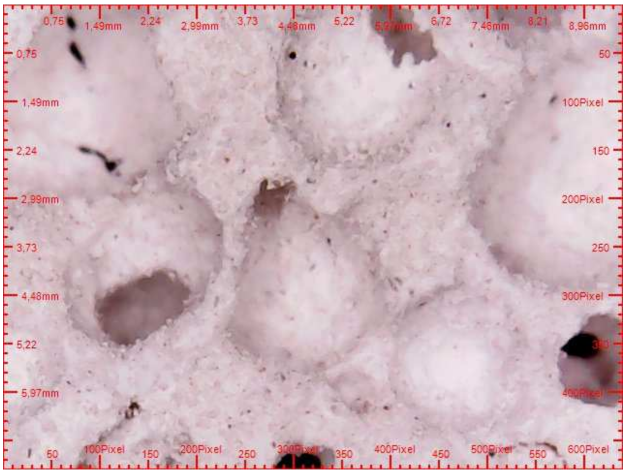

Fig.9. Macropore distribution throughout the cross section of the AAC sample (perpendicular to the manufacturing direction) [15]

However, AAC has more even pore distribution in the direction which is perpendicular to its manufacturing direction with large number of closed pores.

The second part of the experiment displays the impact of the porous structure of the AAC on moisture migration throughout its cross volume.

From the second part of the experiment there were obtained four different result graphs. Fig. 11 and Fig.12 display the results for the type 1 AAC [14] while Fig.13 and Fig.14 display the results for type 2 AAC [15].

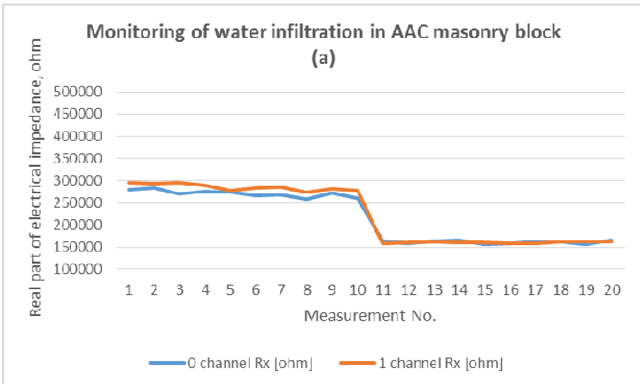

Fig.11. EIS measurement results of water infiltration in the second set of the samples, measurements taken parallel to the manufacturing direction of AAC [14]

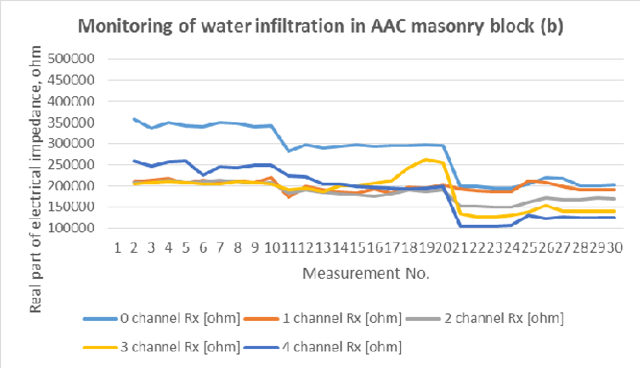

Fig.12. EIS measurement results of water infiltration in the second set of the samples, measurements taken perpendicular to the manufacturing direction of AAC [14]

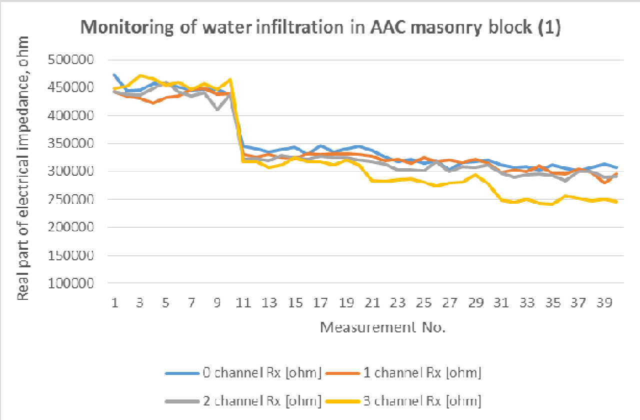

Fig.13. EIS measurement results of water infiltration in the second set of the samples, measurements taken parallel to the manufacturing direction of AAC [15]

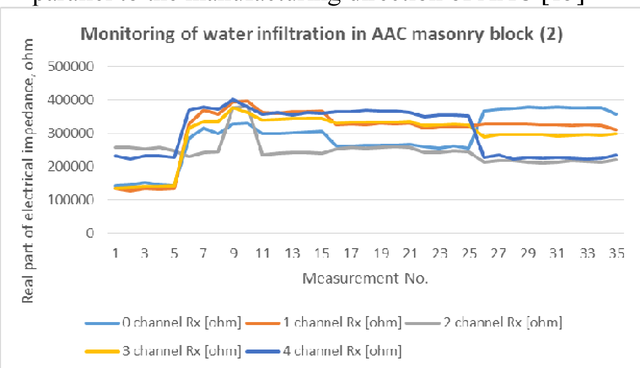

Fig.14. EIS measurement results of water infiltration in the second set of the samples, measurements taken perpendicular to the manufacturing direction of AAC [15]

The obtained results display correlation between the diversity of porous structure in AAC material and the EIS measurement results of moisture distribution changes in the respective specimen. In both cases of the AAC the measurements results in the samples where the EIS measurement probes were inserted parallel to the manufacturing direction (in such case moisture migration is perpendicular to the manufacturing direction) of the AAC, the measurement results display more even distribution of EIS measurement results during the changes of moisture content in the sample. Therefore, it can be concluded that the porous structure itself has significant impact on the speed of moisture infiltration in AAC material.

These conclusions are approved by results of the third part of the experiment where the results obtained from the samples with parallel probe placement to the manufacturing direction of AAC display more even distribution of EIS measurement results than the ones, which were performed with perpendicular probe placement.

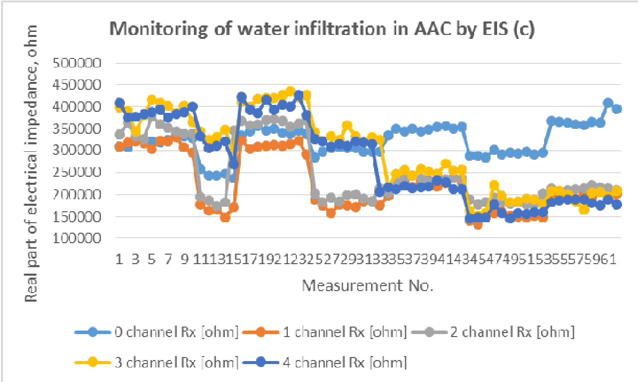

Fig.15. EIS measurement results of water infiltration in the third set of the samples, measurements taken perpendicular to the manufacturing direction of AAC [14]

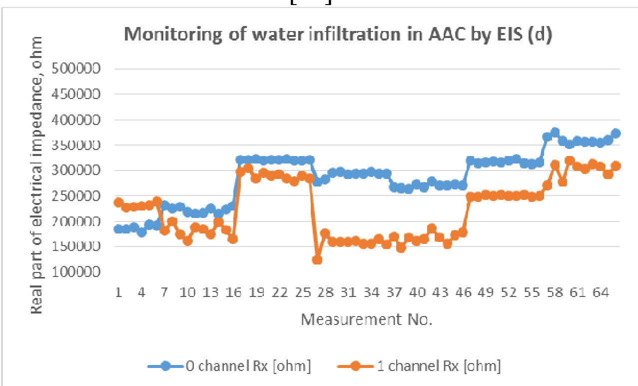

Fig.16. EIS measurement results of water infiltration in the third set of the samples, measurements taken parallel to the manufacturing direction of AAC [14]

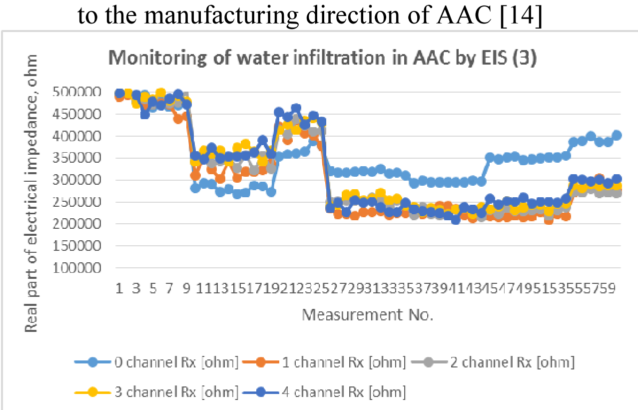

Fig.17. EIS measurement results of water infiltration in the third set of the samples, measurements taken

perpendicular to the manufacturing direction of AAC [15]

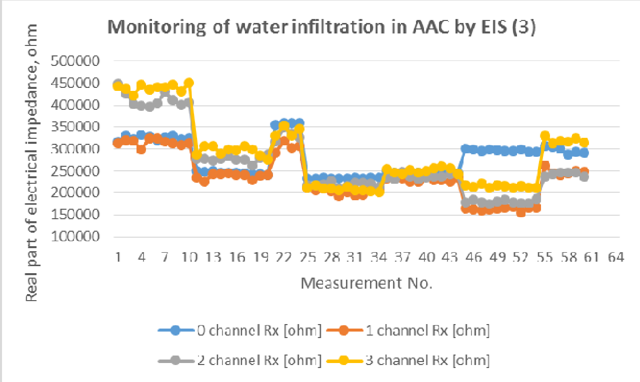

Fig.18. EIS measurement results of water infiltration in the third set of the samples, measurements taken parallel to the manufacturing direction of AAC [15]

4 Conclusion

Moisture infiltration in AAC masonry construction is strongly dependent on the orientation of the AAC masonry blocks. The research proves, that the water infiltration in all three types of water infiltration used in this research is lower when the water is applied on the AAC masonry block in direction, which is parallel to its manufacturing direction. This phenomena can be explained with the fact that AAC has uneven pore distribution throughout its volume and the distribution of pores depend on the manufacturing direction of the material.

Therefore, this property of the AAC masonry blocks should be used in situ for better avoiding them excessive moisture accumulation in AAC masonry constructions during the construction stage of the delimiting constructions.

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