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Impact of External Heat Insulation on Drying Process of Autoclaved Aerated Concrete Masonry Constructions

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Abstract. In the time when sustainable construction as well as cost saving on heating and cooling of buildings is one of the most important construction trends, it is important to acknowledge the possibilities of application of construction materials with high heat insulation parameters and the ways in which these parameters can be obtained. Autoclaved aerated concrete (AAC) is a load bearing construction material, which has high heat insulation parameters, although it has one significant disadvantage. If the AAC masonry construction has high moisture content, it loses its heat insulation properties. This is the reason why it is important to detect the humidity distribution throughout the cross section of the masonry elements in order to conduct the drying process of the AAC construction. Therefore, the question about non-destructive detection of humidity distribution throughout the cross section of the material arises. Humidity distribution throughout the cross section of AAC masonry constructions has a significant impact on its heat resistivity properties. Application of electrical impedance spectrometry (EIS) method for determination of humidity distribution throughout the cross section of AAC constructions has been a subject of research recently. The EIS method is an easily applicable non-destructive testing method for detection of the humidity distribution throughout the cross section of a construction. Research on the impact of the external heat insulation layer on the speed of humidity distribution changes is described in this paper.

1. Introduction

Autoclaved aerated concrete (AAC) is a load bearing construction material, which has high heat insulation parameters. However, as the AAC is a porous material, the moisture content of the material can reach high values and therefore the heat resistivity values of the material can decrease significantly. Such situations may lead to misinterpretation of the design data in the field of energy efficiency of the buildings.

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Therefore, testing methods that allow credible determination of the moisture distribution throughout the cross section of the AAC masonry construction as well as moisture migration throughout the cross section of the construction have to be developed. The drying process of the masonry is a long process, therefore, it is preferable to use non-destructive testing methods because a number of measurement series have to be performed in order to provide credible data on the changes in moisture content throughout the cross section of the masonry construction.

In order to increase the heat resistivity properties of AAC masonry constructions, additional heat insulation layer from mineral wool or polystyrene is applied on the construction. Although the additional layer of insulation increases the heat resistive performance of the construction in design, it can result in quite opposite effect on construction site if it is applied on AAC construction with high moisture content. If AAC masonry blocks with high moisture content are covered with insulation layer, the moisture is locked in the masonry and the heat resistivity values drop significantly.

AAC masonry constructions are porous, composed of solid matrix and pores. In porous materials heat transfer is often coupled strongly with moisture transfer [1]. Accurate prediction of heat and moisture transfer in porous material is essential for optimization of building envelope with respect to energy consumption, hydrothermal performance, and indoor environment [2, 3]. It is important to detect not only the overall moisture content of the construction material but also to detect its distribution throughout the cross section of the respective element. Moisture distribution throughout the cross section of the element has a significant impact on its heat conductive properties.

2. Methods

Electric methods have become popular in characterizing different material properties. Electrical impedance spectrometry (EIS) is one of the most popular methods for detection of moisture content in construction materials. EIS can be applied through a number of different devices where each of them focuses on slightly different aspect of the material properties.

The possibility of application of this method on concrete based materials has been researched by McCarter and Garvin [4] and Rajabipour [5], Weiss et al. [6-8]. Barsoukov and McDonald [9] have introduced EIS as an optimal method for characterizing the electrical behavior of systems in which the overall system behavior is determined by a number of strongly coupled processes, each proceeding at a different rate. EIS can be applied for monitoring processes that take place in objects (e.g. changes caused by moisture in wet masonry sediments etc.), electrokinetic phenomena at boundaries or for describing basic ideas about the structure of an inter phase boundary (e.g. electrode/water or solid electrode to solid electrode boundary) [10-12].

The EIS is based on the periodic driving signal – the alternating signal. Its main measurement value is the impedance of AC circuit, which consists of electrodes (measurement device), and the solid electrolyte (in particular case AAC masonry construction).

For the particular research, a Z-meter III device (figure 1) with one pair of measurement probes (five channels in each probe) will be used for EIS measurements. For the measurements, the 0 channel measures the data closest to the external side of the wall construction.

This instrument has been verified in laboratory experiments and measurements on AAC constructions by the authors [13-18]. Correlations between the EIS measurement values on AAC masonry constructions and the moisture content of the respective AAC material samples have been established [18].

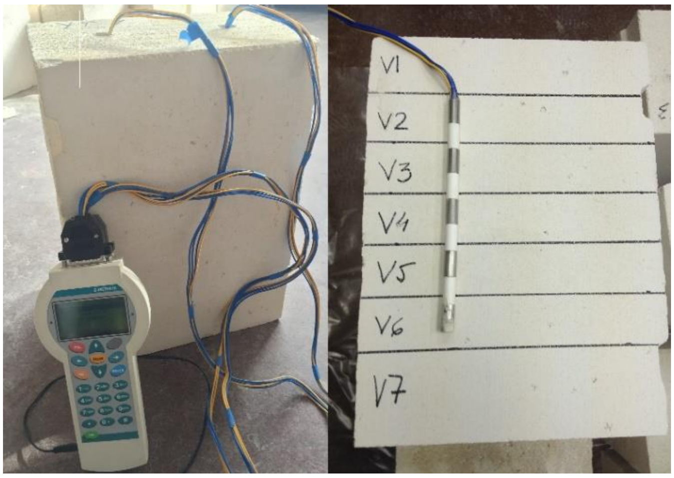


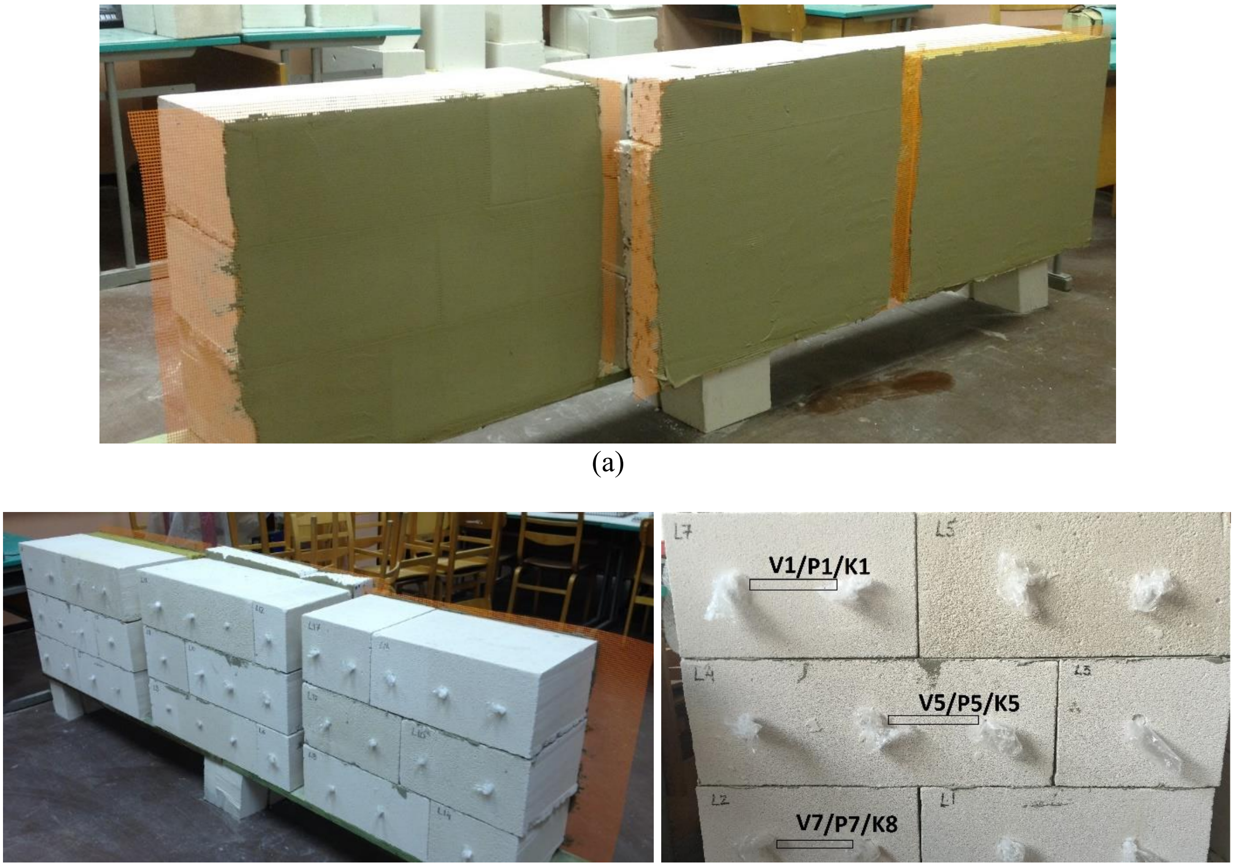
Figure 1. Z-meter III device with measurement probe.

Z-meter III device consists of an electronic and detachable measurement probes. The probes allow taking simultaneous EIS measurements in five different segments of the cross section in the sample. It allows determining the moisture content throughout the cross section of AAC masonry construction. This approach was used in the particular research to determine the differences in drying process of AAC masonry constructions with different heat insulation materials.

3. Description of the experiment

For the particular experiment three samples of AAC masonry wall construction were prepared with dimensions 1200x600x250mm (length x height x thickness). AAC with 375 kg/m^3 density was used [19] and an additional layer of heat insulation was attached to two samples. Most popular heat insulation materials which are usually used in Latvia were used – one of the samples was insulated with 100mm thick layer of mineral wool [20] (sample A) and the second sample was insulated with 100mm thick polystyrene insulation (sample B) [21]. The third sample was left without additional heat insulation layer in order to use it as a reference sample (sample C). Afterwards, both insulated samples and the third sample, which was left without any additional insulation, were covered with plaster from the external side of the insulation (e.g. the external side of the wall construction). Thus a model of construction phase when the cladding of the masonry construction had been finished and the external finishing of the wall had been finished was simulated (figure 2 (a) and (b)).

In each sample 17 bores were made in order to monitor the moisture migration in all directions of the sample by EIS. The monitoring of the drying process was performed for 12 weeks in laboratory conditions with air Rh in the range of 60-80% and the average temperature in the range from 18 to 25°C. Such conditions comply with the average weather conditions on construction site in Northern European summers when the building envelope is not fully closed and heating of the building has not started. The same drying conditions were maintained for all samples.



(a)

(b) (c)

Figure 2. (a) Sample constructions on stand; (b) Sample constructions on stand; (c) Measurement points on the sample.

4. Results

4.1. Initial moisture distribution throughout the cross section of the sample constructions

After the samples were constructed, the initial moisture distribution was determined by EIS. As the EIS measures the resistance values, the determination of the moisture content in the AAC material can be detected by application of correlation equations. Such correlation equation (1) between the electrical resistivity values of the respective AAC material and its moisture content has been developed by the authors [23] and tested in laboratory conditions.

$$y = -0{,}236\ln(x) + 3{,}1507 \quad (1)$$

The EIS measurement results provided information about the initial moisture distribution throughout the cross section of the sample constructions (figure 3 to figure 5)

The average moisture content of the AAC blocks at the beginning of the experiment was 25% of AAC dry mass. The moisture distribution throughout the cross section of all samples is even with the exception of channel 4, where the least moisture content is observed in all samples. This fact can be explained with the least impact of humid processes (e.g. finishing mortar on sample C or insulation installation mortar on samples A and B) on the internal side of the sample construction.

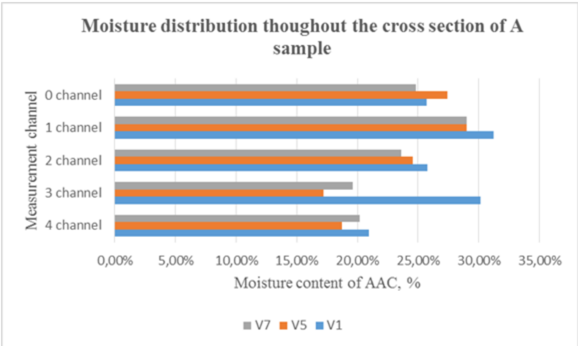


Figure 3. Moisture distribution throughout the cross section of sample A measurement points at the beginning of the experiment.

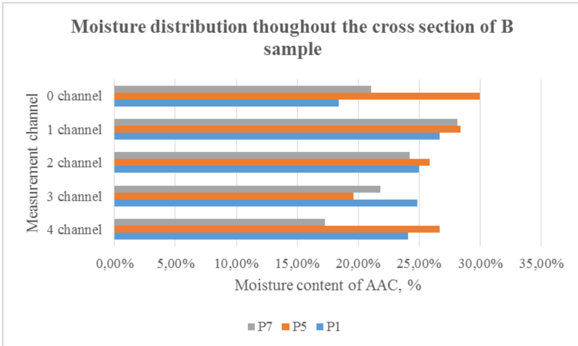


Figure 4. Moisture distribution throughout the cross section of sample B measurement points at the beginning of the experiment.

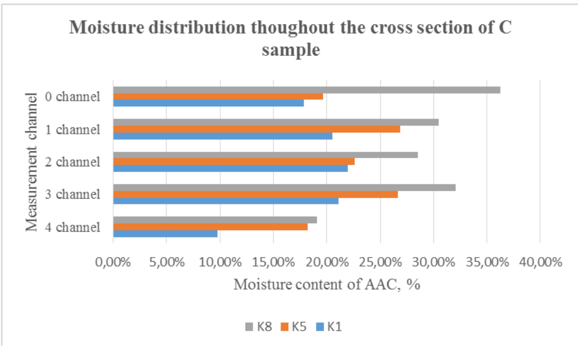


Figure 5. Moisture distribution throughout the cross section of sample C measurement points at the beginning of the experiment.

Further moisture distribution changes throughout the cross section of the samples were monitored by application of EIS measurements three times a week and certain dynamics of drying process were established for each sample construction. Figure 6 to figure 8 display the changes of moisture distribution throughout the cross section of the AAC samples with different external finishing. The obtained data were merged in one surface graph for each sample and the division of the data on x axis allows following the changes of moisture distribution throughout the cross section of the sample during the whole period of the experiment.

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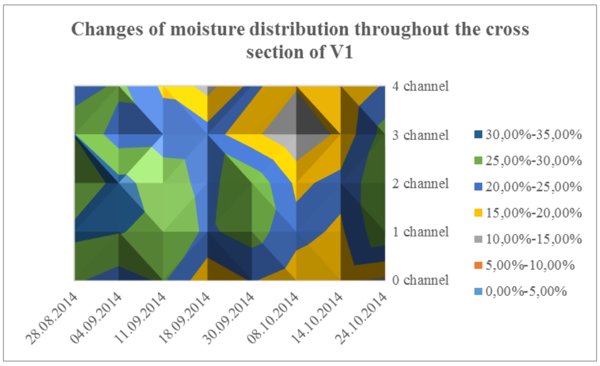

Figure 6. Changes of moisture distribution throughout the cross section V1 of sample A construction during the experiment.

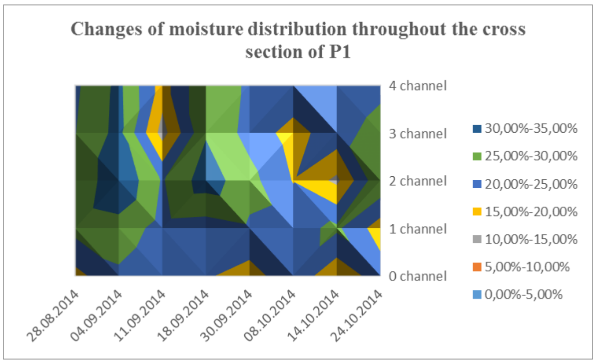

Figure 7. Changes of moisture distribution throughout the cross section P1 of sample B construction during the experiment.

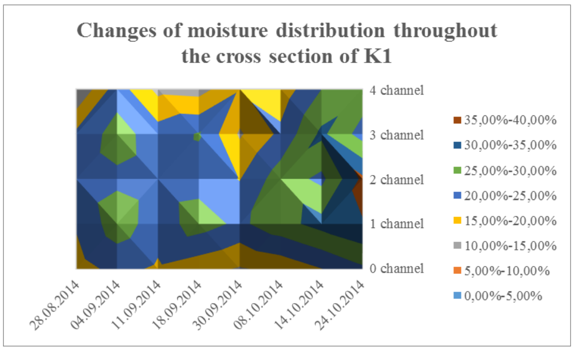

Figure 8. Changes of moisture distribution throughout the cross section K1 of sample C construction during the experiment.

The sample construction A displayed the fastest drying speed in comparison with sample constructions B and C. The slowest drying speed was observed for sample construction B. Therefore the assumption that the insulation material has significant influence on the drying speed of the wall construction has proved to be valid. Sample B attests that the vapor diffusion coefficient of the insulation materials has high impact on the drying speed of the AAC wall construction.

Table 1. Drying speed of the samples.

Sample	Average moisture content of the cross section at the beginning of the experiment, %	Average moisture content of the cross section at the end of the experiment, %	Drying speed (% of moisture lost/obtained in 12 weeks)
Sample A	26.82%	24.07%	-2.75%
Sample B	23.79%	24.04%	0.24%
Sample C	18.24%	29.24%	11.00%

The difference in drying speed of the respective samples varies by 12.75%. The results prove that the only type of insulation which allows decreasing AAC masonry construction's moisture rate is mineral wool as in sample A. Such performance depends on two factors. Firstly, the mineral wool insulation decreases the amount of moisture which is absorbed by the masonry construction and, secondly, allows the moisture to migrate through itself due to high value of the vapor diffusion coefficient. Sample B displayed a minimal increase of the average moisture content due to the fact that the low vapor diffusion coefficient of the polystyrene did not allow the moisture to migrate freely through the insulation layer and all moisture from the installation mortar was absorbed by the AAC masonry construction. The reference block (sample C) displayed the highest absorption of moisture which can be based on the amount of the moisture absorber from the finishing mortar and the fact that all surfaces of the reference construction were exposed to the external humidity of the premise while the other two samples had one covered surface. The fact that the changes of construction's moisture content are caused by the changes of the Rh rate in the premise has been proved by figures 7,8, which clearly indicate the increase of moisture rate in external layers of the construction starting from 30 September 2014, when the Rh rate of the premise increased as well.

5. Conclusions

The finishing and insulation material of the AAC masonry constructions have significant impact on the drying performance and therefore on the humidity distribution throughout the cross section of the wall construction. Furthermore, it influences the heat resistivity properties of the wall construction, therefore it should be considered during the design phase in order to avoid situations when buildings are not able to reach the designed insulation parameters.

The research proves that an insulation material with high vapor diffusion coefficient allows the construction to dry faster. Therefore, application of such materials is recommended for AAC masonry constructions in order to reach the designed insulation parameters as soon as possible after construction.

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