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TESTING WIRELESS ELECTRO-OSMOSIS USED FOR DEHUMIDIFICATION IN CIVIL ENGINEERING

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1. Introduction

Electro osmosis is one of the electro kinetic phenomena where liquid phase is in movement in porous material under the influence of applied electric field. It was observed for the first time in 1809, when F. F. Reuss originally described an experiment demonstrating that water could be forced to flow through a clay-water system when an external electric field was applied to it (Fig. 1).

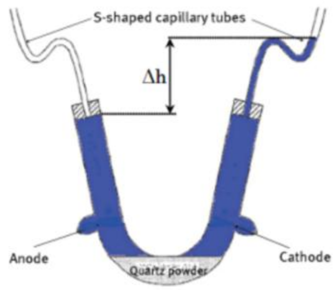

Fig. 1. Reuss' classical experiment on electro osmosis. Water is driven to the cathode.

The porous materials have charged surfaces, (mostly negatively). To obtain chemical equilibrium the surfaces attract charges with an opposite sign from the solution (counter-ions) and the electric double layer is formed. Ions in the solution with the same sign as the charged surface are called co-ions. The co-ions are represented to a much lesser extent in the electric double layers than the counter-ions. In the presence of electric field counter-ions, cations and co-ions – anions will start to move towards the electrode of opposite sign. As there are more cations a net-flow of cations across the electrode of opposite sign will occur and the water molecules around the cations are pushed or dragged towards the electrode together with them. The electric circuit in the masonry is ensured by electrodes drilled into the masonry, connected to the power unit by wires and the wet masonry represents the electrolyte. Presently there are many companies offering electro-osmosis for dehumidification (of historic buildings mostly) they differ in material and shape of electrodes they use, as well as material of connecting wires and power unit. Beneficial effects of electro-osmosis on the moisture elimination of porous materials have been studied and documented in scholarly articles and works [2].

However in the last decades there has been an increase in electro osmotic methods without the necessity of installing wires connecting anodes and cathodes to the power unit and even without the necessity of using electrodes and power unit. We call it wireless electro-osmosis. It is often questioned because of the lack of the scholarly works focused on the physical principles of the method.

Wireless systems for dehumidification can be divided into two main groups: without external power supply and applying electromagnetic field with various frequencies.

Table 1. Wireless electro-osmosis methods.

Without external power supply	With external power supply – electromagnetic field of various frequencies
Using physically not defined source of energy	Using electrodes in masonry
Using electric field arising in masonry	Without electrodes in masonry

The big amount of wireless electro-osmotic methods leads us to do the testing in following steps as to cover the majority of devices:

- site visits with installed devices using different kind of fields, even the ones not recognized by contemporary science,
- site visits with installed devices using electromagnetic fields of different frequencies,
- analysis of theoretical knowledge of inhomogeneous electric and magnetic fields influence on the water movement in porous material,
- construction of the test equipment using electromagnetic field and its testing in the cellar of Notre Dame Convent and in the laboratory.

2. Experiment

Testing commercial devices using different kind of "known and unknown fields"

Inspection made by the authors at the places using commercial dehumidification systems without external power supply using different kinds of "known and unknown fields", according to the companies that produce them and which are well known to the people familiar with the practical problems of dehumidification of monumental buildings, did not show any influence on the moisture content in the masonry.

We also tested the magnetic field in the vicinity of one of such devices using Xtrinsic MAG3110 Three–Axis, Digital Magnetometer MAG3110, for magnetic fields up to 80 [Hz], full-scale range ±1000 [μT], sensitivity of 0.10 [μT], noise down to 0.25 [μT] rms. The results are in Fig. 2. We concluded that the claim of magnetic field at work against the moisture content in the masonry was wrong.

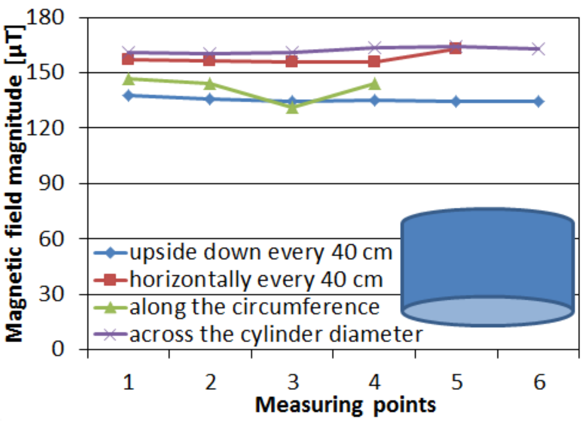

Fig. 2. Magnetic field measurement in the vicinity of the tested device.

Testing devices using electromagnetic fields of different frequencies

Theoretical analysis of inhomogeneous electromagnetic fields influence on the water movement in porous material can be found e.g. in works [1-7]. The result of theoretical analysis is that the inhomogeneous field does not affect the final state of water content of the system.

Our own testing device was an inductive coil emitter wound from enamelled copper wire of 0.5 [mm] diameter. The coil was circular in shape without any core, its outer diameter was 10 [cm], inner diameter 3 [cm] and the height 8 [cm]. Frequency pulses were set at about 100 [kHz] and the output was about 2.5 [W].

Measurements were done in the Sisters of Notre Dame convent from the 18th century and in the laboratory.

Fig. 3. The tested device and its placement in the cellar.

– *Measurements in the convent cellar*
  Data were recorded from September 19, 2012 to January 28, 2014. In this time measurements were done at four different points on the wall – h1 (36 [cm] above the floor level), h2 (80 [cm] above the floor level), h3 (113 [cm] above the floor level), h4 (150 [cm] above the floor level). The first year MC-7825PS moisture meter was used and from June 4, 2013 the moisture meter Trotec T 600, detecting distributions of moisture content at a depth of up to 300 [mm] was used. The data of RH and temperature in the cellar and outside were taken as well and processed.
– *Laboratory test.*
  Free water intake was tested in the laboratory on three samples. The sorptivity plots were done for the measurements in the field of the tested device and then the samples were tested without the influence of the field. First the samples were dried at 105°C to constant mass in a hot-air oven and its dry mass noted. After cooling to the room temperature, the samples were immersed in a tray of water. Samples rested on a grid to allow free access of water to the inflow surface. The water level was not higher than 5 mm above the base of the specimen. The quantity of water absorbed was measured at time intervals, by weighing the specimen. The sorptivity was determined from the straight line obtained by plotting the cumulative mass of water absorbed per unit area against the square root of time.

Tested samples were (Table 2):

- historic brick (30x30x247 mm),
- AAC - Autoclaved aerated concrete (28x24x120 mm),
- CLC Fly Ash based Cellular - Lightweight Concrete Fly Ash based (40x20x220 mm).

Fig. 4. Water intake test.

Table 2. Basic material's characteristics.

Material	Bulk density (kg/ m^3)	Matrix density (kg/ m^3)	Total porosity (-)
Historic brick	1510	2396	0.37
AAC	469	1859	0.74
CLC - Fly Ash based	557	2123	0.78

3. Results

Test in the convent cellar. To find out whether the reason for the moisture in the cellar was the capillary intake we compared the water partial pressure outside and in the cellar. The results in the figure proved it. There were also clearly visible maps from the capillary rising damp on the cellar walls. In the time range: from December, 2012 to January, 2014 measurements were done at four points on the wall. In this time no influence of the testing device on the moisture content was observed.

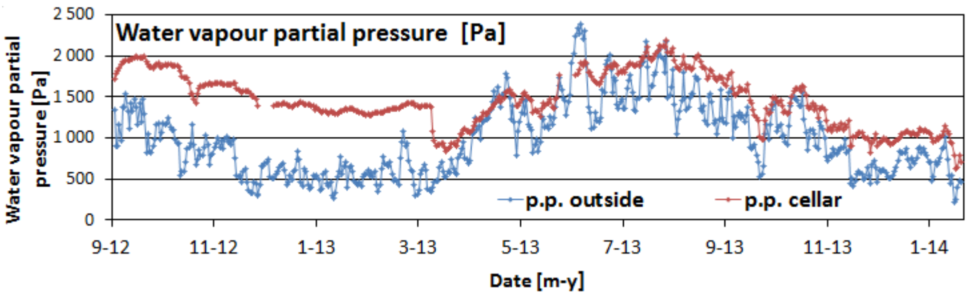

Fig. 5. Water vapour partial pressure of the air outside and in the cellar.

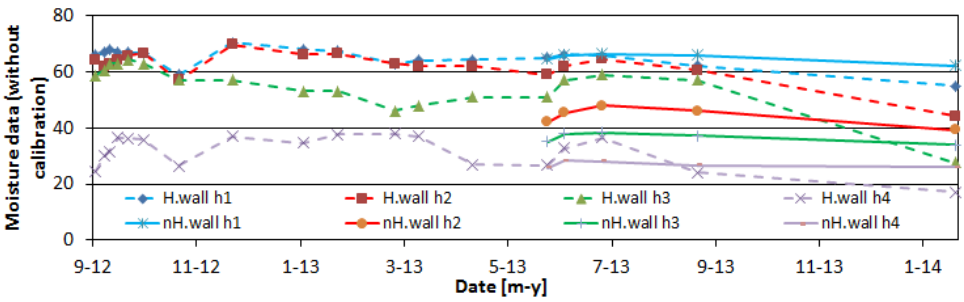

Fig. 6. Moisture content at the four different heights of the wall measured with MC-7825PS moisture meter H. wall 1-4 and moisture meter Trotec T 600 nH. wall 1-4.

Laboratory test. Three samples from different building materials were prepared and free water intake was tested. The sorptivity plots in the figures bellow did not show influence of the tested field on the water absorption coefficient.

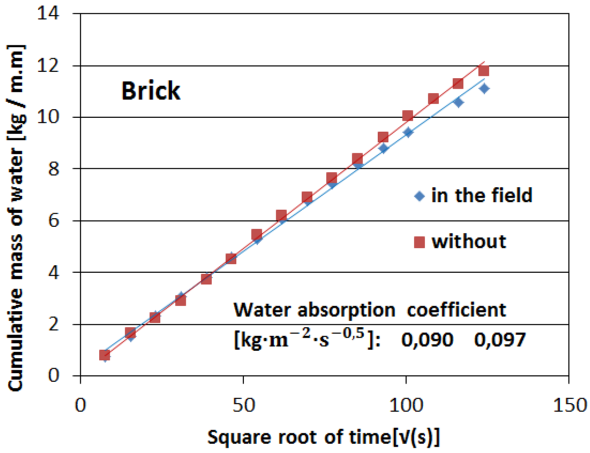

Fig. 7. Sorptivity plot for historic brick.

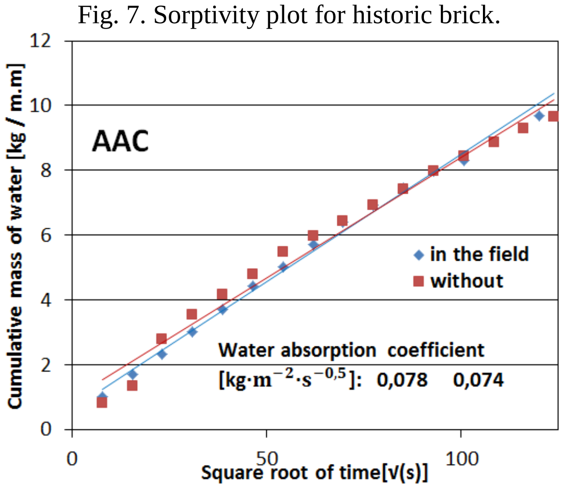

Fig. 8. Sorptivity plot for AAC.

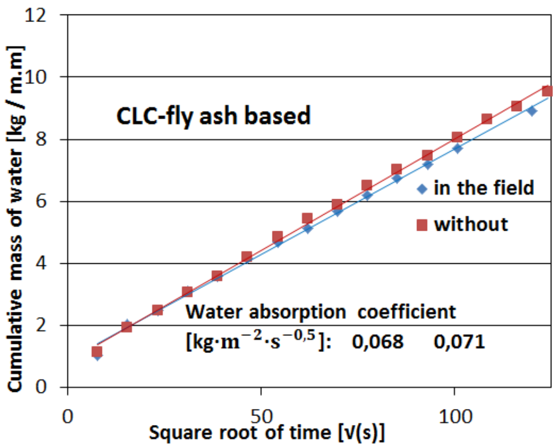

Fig. 9. Sorptivity plot for CLC- fly ash based.

4. Conclusions

Results of the testing the device using electromagnetic field in both cases (dewatering of masonry in the convent and free water intake into the samples) did not show any influence of the field either on the moisture content in the masonry nor there were no significant differences in water absorption coefficient for all three samples.

Our inspection on places using devices without external power supply also did not prove the influence of mentioned devices on the moisture content in the masonry. In the case when also magnetic field should act we did not measure any magnetic field produced by the device. Other sources of energy are not known in contemporary science and principles given by companies are contradictory to known and proved results of science.

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Summary

Paper presents and explains the differences between non wireless and wireless electro-osmosis. Based on information provided by companies that use electromagnetic fields of different frequencies, the device was designed, built and tested in the basement of a historic building and in the laboratory. The experiments confirmed (in all evaluated tests) that the wireless electro-osmosis does not affect the amount of water in porous materials.