Practical applications of electroosmotic system using electrodes with conductive plastics and advanced osmotic pulse system

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Abstract. Practical applications of the two commonly used electroosmotic systems in Slovakia were monitored and described in the paper. Emerged problems were analysed, to test the relevance of the system used for moisture removal from the object. Own installation of electroosmotic system was done. Porous structure and salt content of treated masonry was analysed and the influence of advanced osmotic pulse technology on salts’ precipitation and moisture field homogenisation was tested. Best results were achieved using electrodes with conductive plastics and the power unit with pulse system.

1. Introduction
The usage of electro osmosis in Civil Engineering has longer data as it is one of the least destructive methods for removing noxious moisture from masonries. Excess moisture in a building is a serious problem that affects the quality of life and the durability of construction. Electro osmotic utilisation can be divided according to the applied power supply, connecting wire and electrode’s shape and material. In the paper experiences with two, in Slovakia often used, electroosmotic systems are described.

2. Experimental
Electrodes with conductive plastics, Kerasan consist of electrical wire- special alloy of titanium Ø 3 mm, resistant to salts, electrically conductive nonpolar plastic (1st layer of the shielding) that ensures that the material does not change its dense structure and so protects the wire and electrically conductive polar plastic (2nd layer of shielding). The 2nd layer loses its closed structure which extends into a slightly larger volume. The resultant porosity of outer layer increases the effective surface area of the electrode.

The electrodes are preferably laid diagonally when the wall is accessible from both sides. If the walls are only accessible from one side, the positive and negative electrodes are placed over each other at a distance of 2 times the wall thickness. Direct current to the electrodes is applied through the control unit. Voltage and the current flow (mA) is set up according to the conditions in masonry. The unit is directly connected to 230 V power source. Power consumption of the unit is up to 0.8 kWh per year per 1 meter of the masonry [1].
2.1. Monitoring practical applications of Kerasan system and troubleshooting

We were monitoring installations in the old part of Bratislava at: Chapel Corpus Christi at Panská Street, Building of the Slovak Philharmonic, Palackého 100/2, Honorary Consulate of the Principality of Monaco in the Slovak Republic at Gorkého 7/A in Bratislava and a family house at Holubyho 10. At the Chapel Corpus Christi, electroosmotic circuit has been functioning since 2010, without any problems and the place is much drier and healthier than ever before. Restoration work at the Building of the Slovak Philharmonic was done by several companies, for one part of the building 6 electroosmotic circuits were installed in 2011. In 2013 problems occurred with one of them. The measurements in situ did not prove problems in the circuit, so the control unit was changed, one anode added and for some time the polarity changed to get the uniform distribution of the water content close to the anode and decrease the value of electrical resistance close to it. No other problems occurred but since the owner has changed we do not have any further information. At the Honorary Consulate of the Principality of Monaco two electroosmotic circuits were built in 2008 to solve moisture problems, one was set into function. The restoration of the building continued. On 29.7.2014 a control was done and moist places and deteriorated masonry with clearly visible salt signs appeared. Twelve control places were specified for the moisture control, but the tests and further inspection revealed that the conductive mortar was replaced with nonconductive, one of the wires was slightly damaged, and conductive material was found in the field of electroosmosis. After replacing of the damaged parts, electroosmotic circuit started to function again. Family house was another example what can happen if there were more companies involved without properly documentation left. While installing the electroosmotic circuit unprofessionally done undercutting was revealed, the outer wall was covered with cement plaster, what meant that water could not get out and all the water was kept in. Because of all these two circuits were installed after putting in order the chaos done before.

2.2. Own installation at Beblavého street

The installation procedure at Beblavého Street, in the cellar of a company house.

| Figure 2.2.1. | Figure 2.2.2. |
| Wall with rising moisture. | Cathode’s positioning. Opening for inserting the cathode (length 40 cm, angle 45°). The distance between the electrodes is 80 - 100 cm, the diameter of the drilled hole is 16 mm. |
| Source: (Author) | Source: (Author) |
The device started to operate on 27.8.2015. Although the measurements have shown that electroosmosis improved the condition in the wall we spotted other problems that needed understanding and solving. We observed salts’ precipitation and wet mortar in the anode vicinity so material testing and salt analysis were done. See Figures 2.2.5 and 2.2.6).

2.2.1. **Testing the material characteristics and salt content.** Thermogravimetric Analysis TGA and Differential Scanning Calorimetry DSC of historical brick and plaster was performed by Mettler Toledo TGA/DSC 2 at the heating rate 10°C per minute from room temperature to 1000 °C. DSC and TGA curves of brick and plaster looked very similar. Until 300 °C it was possible to see evaporation of physically bounded water. This was represented by the decrease of both pairs of curves. From about 400 to 800°C removing of chemically bounded water (dehydration) was present which was represented by the further decreasing of TGA curves and “plateau” of DSC curves. This meant that fired brick and plaster were certainly historical once because in the middle ages it was not possible to achieve higher temperatures than 700 °C because the firing was made by wood and therefore only part of dehydroxylation process occurred. At 800 °C the calcination was present which was represented by...
the at DSC curves. The fact that both TGA curves and both DSC curves were very similar lead to the conclusion that probably some portion of this brick was added into the plaster.

![DSC curves](image)

**Figure 2.2.1.1.** Thermogravimetric Analysis TGA and Differential Scanning Calorimetry DSC.

Pore size distribution of historical brick and plaster was performed by the porosimeter Pascal 140 Series Thermo Scientific. The maximum number of pores was at 1 µm. This also added to our presumption that part of the brick was added into the plaster and they were manufactured by the same process from similar types of materials with very similar pore size distribution.

![Pore size distribution](image)

**Figure 2.2.1.2.** Pore size distribution of historical brick and plaster.

The studies of salt taken from the vicinity of electrodes were carried out by means of the scanning electron microscope Vega 3 from Tescan company (SE Detector, 30 kV, high vacuum 9×10⁻³ Pa) working with EDX Link 300 ISIS from Oxford Instruments (Detector Au(Pd), 30 kV, low vacuum 100 Pa, resolution 128 eV). The samples were prepared by fixing the powder particles to microscope holder, using a conducting carbon strip.

From the point of morphology the microstructure was formed by polyhedral grains in all cases. The structure of salts close to the anode showed also calcium phosphate (most probably gypsum) crystals. The spectra obtained during EDX studies were used for carrying out the quantitative analysis. Quantitative analysis showed that the elements with the highest percentage were oxygen: 47.55 mw. %, sodium: 28.89 mw. % and sulphur present in amount: 17.07 mw. %.
We tested the salts in the area of the fifth cathode.

The elements with the highest percentage were oxygen: (49.98 - 64.63) mw. %, sodium: (1.94 - 14.16) mw. %, calcium: (13.71 - 34.01) mw. %, carbon: (4.67 - 8.65) mw. %, and other elements like Mg, Al, Si, Cl, K and Fe were within the range (0.13 - 5.16) mw. %.
From the results it was not clear, what kind of salts we were dealing with. In the old part of Bratislava the level of groundwater is high and the building is just under the castle hill, which means the influence of heavy rains, as well. In the last years increasing temperature of ground water was documented [2] - a new factor, that appeared recently. We decided to ask the company working with AOP (advanced osmotic pulse) technology [3], whether we could test their control unit consisting of a power supply and main controller board connected to a rectifier output stage. AOP also uses titanium wire for anodes, but without plastics and cathodes are regular copper clad ground spears The control unit (AKJI ECBS) works through administering a series of low voltage pulsating charges, which means technology uses pulses of electricity to reverse the flow of water seepage. Removal of moisture decreases the conductivity of materials, especially in the area closest to the anode. Eventually it comes to the point when no more dewatering is possible since the passage of current is hindered by this dry area. By changing the direction of flow more uniform water profile during dewatering can be achieved. The technology was invented and tested in the old USA military premises and some old concrete dam chambers [4, 5]. The power unit was used from January 2018 to January 2019. The current increased 4 times, from the average 102 mA to the average 419 mA (see Fig. 2.2.1.7 – 2.2.1.10). For the better resolution the current values in the plot have been divided by 5. The unit of the current is therefor in the plot presented as [mA/5], so the value of the current in the plot represented by 20 units was in the reality current with the value 100 mA. Precipitation of the salts was only in the vicinity of the cathodes and the mortar in the area of anode dried. The moisture amount decreased as well. Now the previous power unit is used and so far without changes. As mentioned in [4, 6] the reason was not only higher current, but changing the direction as well. We did not change the electrodes, it would mean drilling in the walls again and from experiences we believed that electrodes with conductive plastics were the better choice. We do not sell electroosmotic systems, so we are completely free to choose the best from both mentioned systems. The combination of the electrodes with conductive plastic and AOP control unit provided so far the best results.

![Figure 2.2.1.7. Moisture measurement in the vicinity of the anodes n. 1-4.](image-url)
**Figure 2.2.1.8.** Moisture measurement in the vicinity of the anodes n. 5-8.

**Figure 2.2.1.9.** Moisture measurement in the vicinity of the cathodes n. 1-4.
3. Conclusion
Unwanted moisture in buildings is a big problem mainly for historical buildings. Electroosmosis is for sure a solution because of its least destructive application; however its popularity decreased, mainly because of many systems of passive electroosmosis that are on the market. Companies claim that the system works without any external source. They have always been a controversial issue. On theoretical grounds, there is no evidence that they can work, we have done research in this field [6], but there are many ways they use to persuade the customer and they enlarge their mistrust even to the functioning systems. We should also keep in mind that electroosmosis does not stop water entering the capillaries from the ground, but it keeps the amount entering the wall in acceptable amount. Another important thing is that masonry is complicated porous structure and there are always many factors involved, so before choosing the final decision on how to deal with moisture thorough inspection and analysis should be done.

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