Electroosmosis – a method applied for handling of moisture in foundations

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Abstract. Electroosmosis is an electrokinetic phenomena which is applied in some technical fields. It is also applied large scale for transport of moisture out of basements. We see the method of electroosmosis as an opportunity for solving moisture problems in basements. However, there is a need to develop both the technology for the method and the understanding about what to expect out of it. Better methods are needed to predict whether the method will work in a particular case.

1 About use of electroosmosis in foundations

This report will tell about electroosmosis applied for handling moisture in foundations. It will discuss three questions:

- Why is electroosmosis used?
- How are the installations designed today?
- Why is it difficult to say whether the installations are working or not?

The origin of this work was that we became involved in a controversy regarding whether the electroosmosis could be considered a serious method of reducing problems with moisture in basements.

We received funding for collecting knowledge about this which resulted in a literature study, a field study where we visited a number of buildings where electroosmosis had been used for solving moisture problems and also a study where modelling of the processes was done. The full report about this is available in ref [1].

The kind of the controversy is also summarised in the Wikipedia entry for Electroosmosis [2] mentioning "The controversial use of electro-osmotic systems is the control of rising damp in the walls of buildings".

1.1 Reasons for a basement being damp

The reasons behind damp in basements may be well know, still they are worth mentioning here:

They become damp either because moisture penetrates through the basement walls or because condensation happens in the basement [3].

If water happen to enter through the basement wall, the drainage of the building may require maintenance by cleaning or replacing drainage pipes. Any rainwater or other stormwater must be diverted. To dig deeper drainage and make a pump pit may also be needed.

The water in the ground is not easy to control and it is no guarantee that measures done for hindering water to enter a basement will really be successful. It is also very costly to dig around a building and sometimes it is almost impossible because of different obstacles in the environment such as conduits in the ground for water and sewer, district heating or gas and wirings for electricity, or to sidewalks and streets impractical to shut down. So, a facility owner is not to blame for searching for alternative ways to solve problems with water and damp in foundations and basements.

In plenty of cases the ground water level is not possible to reduce. So, the foundation must be waterproof, which requires building the basement with concrete of waterproof quality without cracks and with waterproof joints. In practice, this is sometimes difficult to accomplish.

It is common to prepare for grouting with sealing compounds in waterproof basement walls in order to be able to seal cracks that may come in the future.

1.2 Moisture transport mechanisms through a concrete wall

A common sign of moisture transport in a wall is that crystallized products from the concrete pore solution are visible on the inside. The crystallization product usually consists of $Ca(OH)_2$ which is rapidly carbonated to $CaCO_3$. This may occur with some flaking of the surface because of a salt blasting effect.

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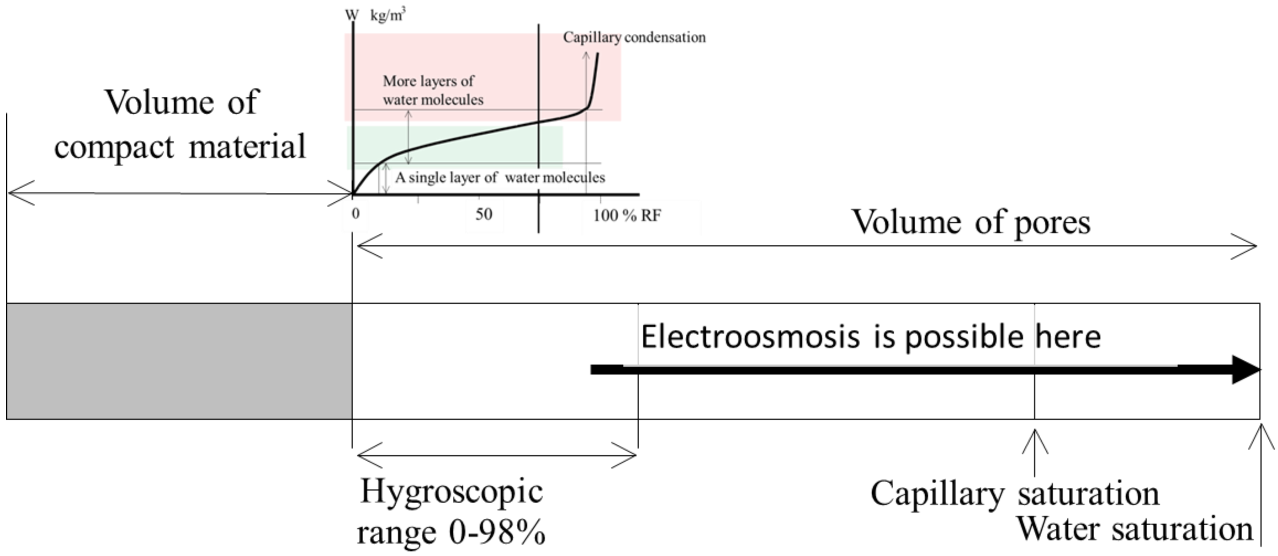

Fig 1. Hygroscopic range, capillary saturation and water saturation in a material

The flow of moisture through pores in concrete being in contact with soil (as in basement walls) follow different mechanisms:

1: Vapor phase diffusion occurs mainly in the pores of concrete when the material has a moisture content in the concrete low enough to be in equilibrium with air having a relative humidity below 60%.

2: Capillary transport of moisture in liquid phase through diffusion or capillary suction. This happens mainly in concrete with a moisture content high enough to be in equilibrium with air having a relative humidity above about 80%. Capillary suction occurs in non-saturated concrete in contact with free water. Evaporation happens on the indoor side of the concrete wall.

3: A combination of 1 and 2. The surface of the concrete is in contact with soil saturated by water. The capillary transport in liquid phase may proceed up to a certain distance in the concrete and then transfers to vapor phase transport towards the inner side of the wall where evaporation happens. This is possible in a concrete that has a moisture content that brings air to have a relative humidity between 60 and about 80%.

1.3 The process of electroosmosis

The development of the understanding about electrokinetic phenomena is reviewed by Staffan Wall [4]. The first notations about the phenomena known as electroosmosis was reported by F.F. Reuss in 1809.

Electroosmosis is an electrokinetic effect which means phenomena when a liquid moves along a charged surface.

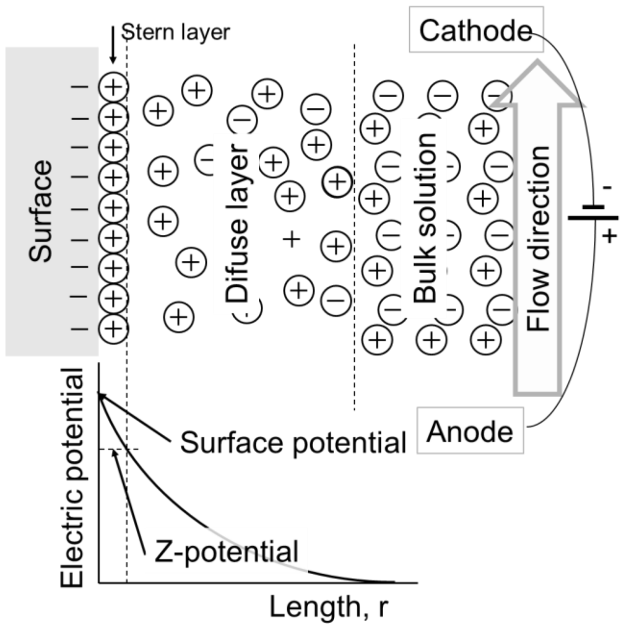

Fig 2. Electric double layer in a negatively charged soil particle. According to Camselle [3].

Examples of other electrokinetic effects are electrophoresis and capillary osmosis. The “double layer” or is fundamental for the electroosmosis. These double layers are formed near the interface between a solid surface and an electrolyte solution. In this case water with dissolved ions is the electrolyte. The ions are hydrated which means that a number of water molecules are attached in a complex with each ion. This happens because water is a dipole and easily binds one of its polar sides to a charged ion. This double layer is shown in figure 2.

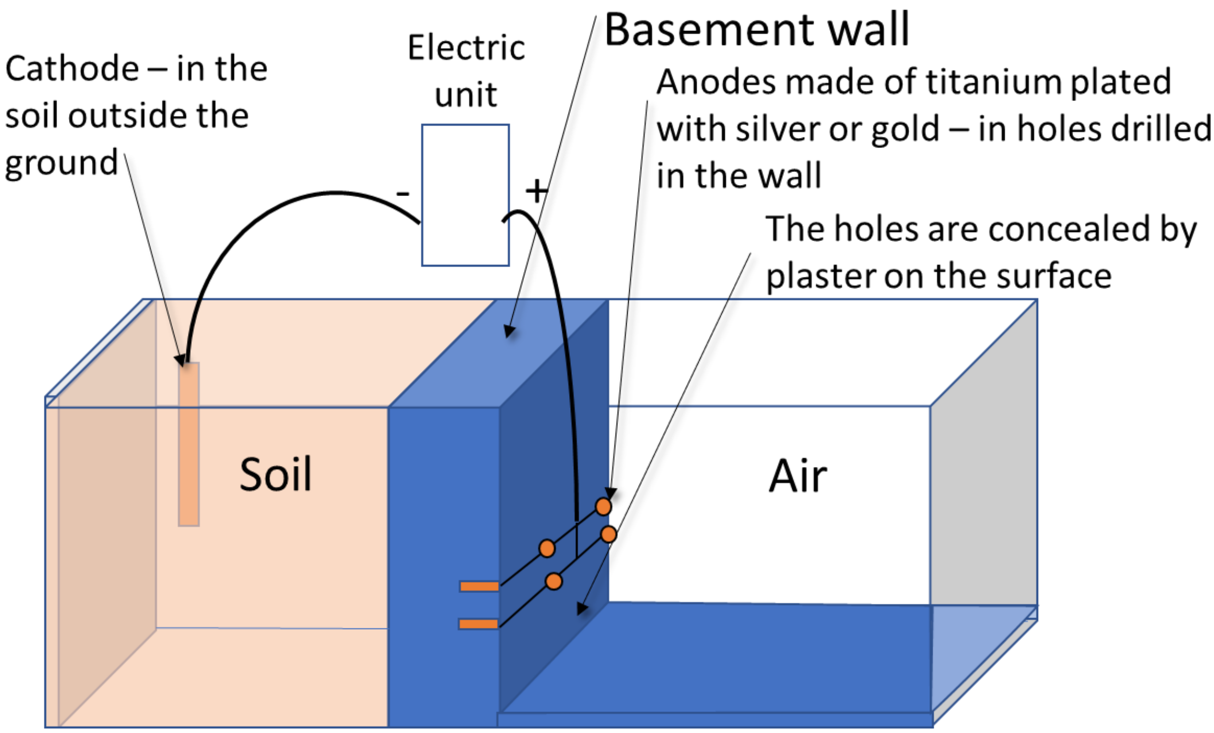

Fig 3. The principle for installation of electroosmosis equipment in a basement.

The solid part could be a porous material, a capillary tube, a membrane, a microchannel or some other type of fluid conduit. When an electric field is applied over the material the resulting Columb force induces a movement where the ions with their complex of water molecules will start to move in the pores of a material [5]. This will go from the positive anode to the negative cathode. This transport is also indicated in Figure 2.

Electrokinetic methods are used as a chemical separation technique in a multitude of applications. There are also examples on application of the method for dewatering of clay [6].

1.4 What is necessary to make the method work in a concrete wall?

Some prerequisites have to be met for the electroosmotic process to work. A closed electrical circuit is required. The resistance between the electrodes have to be low enough to allow enough current output to occur. There must be moisture in the capillaries all through the material. Figure 2 illustrates all the water that a material can absorb. The hygroscopic range corresponds to a portion of water uptake that comes because of the equilibrium between damp in the air and moisture in a material.

The capillaries in the concrete must be more or less water filled for electroosmosis to function.

Capillary condensation occurs when the concrete is in equilibrium with damp air. This also refers to case 2 in section 1.2. when relative humidity is above 80%. Therefore, if relative humidity in the concrete is lower than that, there are hardly no possibility for electroosmosis to happen.

2 Experience of electroosmosis

2.1 Study visits

We made study visits to five places where electroosmosis equipment was installed to get rid of moisture problems [1].

In a basement with an installation for electroosmosis there are anodes inserted in the wall that are connected to an electronic device that serves the electrodes with an electric voltage, Figure 3.

We saw several different examples of the cathode's location in the objects we visited. In some cases, the grounding of the electrical system was used as a cathode and in one case the lightning arrestor was used. In other cases, one or more copper rods were piled down outside the building to be cathodes.

The electric unit served the systems with a pulsating voltage that for about 30 seconds gave about 20V in the anticipated direction, then it was reversed for about 3 seconds and relaxed for about 10 seconds. This program is explained by the experience that the process of moisture transport proceeds much better in this way. The current varied but could be around 200 mA.

Most of the house owners were satisfied with the function of the systems. They could report about improvements in indoor environment or less damage on belongings stored in the buildings.

The use of the grounding of the electrical system for the cathode is regarded as worrying because it feeds a constant direct current into a conductor that should normally be powerless. We see that a better understanding of how the cathode is to be placed is needed.

3 Discussion

3.1 Why is electroosmosis used?

Electroosmosis is used although it is still under controversy. From a facility owner perspective, it may come up as an attractive alternative when other traditional or established methods are not available because of economical or other reasons. The presence of customers who are satisfied is a good marketing tool and also one reason not to discard the method. Still, this is not a reliable proof of the effect of the method in real life.

3.2 How are installations designed today?

There are certain conditions that have to be met for the electroosmotic process to work. A closed electrical circuit is required. There must therefore be moisture in the capillaries of the material. Electroosmosis requires high levels of moisture to function. Drying down to lower moisture levels requires supplementation with other drying methods.

When talking to people who market and install equipment for electroosmosis, it is often pointed out that the design of the details in their installations is something they have learned gradually. This, they explain, is a secret of business because it took a lot of development work to come up with the solutions they have. This makes them reluctant to tell everything in detail about their technology because they do not want it to be copied.

The installations are done with anodes drilled into the walls and the cathodes designed in different ways. The electric voltage is pulsating and around 20V. The installation is also combined with the sealing of all cracks in the ground.

Based on earlier experiences of cathodic corrosion protection, it is important to ensure that the current is evenly distributed throughout the structure. It is reasonable to think the same about an electroosmosis installation.

Another question to be asked is whether these installations may give harm to the buildings structure. In concrete, the cations capacity to bind water molecules is limited which in theory reduces moisture transport out from concrete walls. Therefore, we do not believe that electroosmosis will affect, or damage, the properties of the concrete in the long term

3.3 Why is it difficult to say whether the installations are working or not?

The electroosmosis installations are supposed to give a positive effect when the basement is exposed to moisture from the outside and the walls (of concrete or bricks) are damp enough to make the capillaries of the material more or less filled with water. Drying down to lower moisture levels requires supplementation with other drying methods. The electroosmosis process cannot prevent water flow in any crack. The construction must therefore be sealed against hydraulic water transport. The groundwater level varies during the year, which means that there may be water in contact with the basement during certain periods, although it is generally well drained.

It is very difficult to verify that there really are changes in moisture levels after an electroosmosis installation has started to operate. The case studies reports about use of RH-meters inside the walls [3, 7, 8, 9], moisture ratio in pieces of wood that are inserted in the wall [3]. Electrical conductance in the walls [10] was used in one case and in another one moisture indicators on the materials surfaces [9]. In one case it was not clear the how level of dampness was measured [11] although the installation was reported to give improvements.

With the help of a moisture indicator using the dielectricity/radio frequency principle, the process can be studied on a shallow level directly under the surface of the concrete, but what happens in the inner fabric of the wall is much more difficult to evaluate. Measurement of capillary saturation in a sample chiselled out of the wall could be a possibility, but this is a destructive test. Thus, development of a non-destructive test method is needed to verify that an installation of electroosmosis works as intended. Resistivity measurements with electrodes that are inserted into the depth of the concrete wall could give a relative value of the change. Calibration in each case is then required to obtain an absolute measure.

4 Conclusions

We see the method of electroosmosis as an opportunity for solving moisture problems in basements. However, there is a need to develop both the technology for the method and the understanding about what can be expected of it.

Better tools are needed to predict whether or not the method will work in a particular case.

Development of measurement methods are needed to verify that an installation of electroosmosis works as intended.

Electroosmosis requires high levels of moisture to function. To go down to moisture levels below those critical for mould and rot other supplementary drying methods are required. It is a need for clarity on how to solve this.

A better understanding of how the electrodes should be placed for the best function is needed.

The issue about how moisture moves in the soil might be of great importance for the process in practice. It is an idea to investigate whether this can be used to develop the method. Perhaps it is better to design the systems to deal with moisture transport in the soil close to the building and so reduce the moisture loads on the basement walls.

Clear rules are needed regarding how the electrical installation should be designed in a safe way.

Finally, it can be argued that electroosmosis is a strange thing that is hard to understand. There are a number of reports from case studies where electroosmosis has been applied in basements. Some of them reports successful results while other reports failing results.

Still other measures for protecting basements from damp do also have their problems and uncertainties. For this reason, the possibility for using electroosmosis should also be notified and evaluated.

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