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LABORATORY MEASUREMENTS OF MOISTURE IN A MODEL RED-BRICK WALL USING THE SURFACE TDR PROBE

LABORATORYJNE POMIARY WILGOTNOŚCI W MODELOWEJ ŚCIANCE Z CEGŁY CERAMICZNEJ PEŁNEJ ZA POMOCĄ POWIERZCHNIOWEJ SONDY TDR

Abstract: The article presents the non-invasive attempt to moisture determination using the electric methods. The first part of the article describes the problem of moisture in the building barriers and the possibilities of its determination. The special attention is put on the electric methods of moisture determination. Second part of paper is experimental. For the experiment a model red-brick wall was built and prepared for water uptake process. The experiment was monitored by the capacitance and surface TDR probes which enabled to avoid the necessity of sampling or material destruction. Conducted experiments show the progress of water uptake phenomenon in the model wall and prove the potential of the non-invasive measurements using the surface TDR probes.

Keywords: capillary rise, red brick, surface TDR probes

Introduction

Water is one of the most important chemical compounds on Earth. It determines functioning of all living organisms. On the other hand its presence may lead to several problems, also connected to building objects functioning. Water presence in building materials is a common phenomenon. It occurs both in older buildings but also in modern objects, being the consequence of improper building works.

In the building barriers water may occur in three phases - solid, liquid and gaseous. Water presence in newly built objects is always connected to technology of materials production and building works. During their exploitation, the buildings may run dry or get wet, depending on external and internal conditions, but also the properties of the applied materials.

It has been noticed that chemically bound water does not influence moisture properties of the building barriers [1]. Also, water vapor presence is less influencing, comparing with the other types of water present in the building envelopes. The most meaningful is sorption and capillary water. The problem of water migration in building barriers is quite difficult to be described, mostly due to inhomogeneous structure of the materials and barriers, but also the fact that the particular elements like bricks or blocks are combined with mortar having completely different parameters from the main material. All above-mentioned problems cause serious problems for theoretical and experimental description of the mentioned phenomenon.

This paper is sacrificed to capillary rise phenomenon monitoring, which is considered to be a major cause of building destruction. One of the most popular building materials on Polish market is red ceramic brick which is especially popular in masonries and

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substructures of many buildings. As a very popular building material it was used to build the model building barrier and then investigated for capillary uptake susceptibility.

For monitoring of moisture changes in the model barriers there were applied the FD (*Frequency Domain*) and modified TDR (*Time Domain Reflectometry*) methods, which enabled non-invasive moisture measurement in the porous materials.

FD method is a capacitance technique, which relies on the determination of condenser capacity. This method enables quick moisture determination with simple, user friendly mobile devices - Figure 1 which are non-invasive and do not require samples preparations.

The TDR method is a reflectometric technique which estimates dielectric permittivity of measured material by determining the velocity of signal propagation. The TDR which was successfully used for moisture determination of the soils [2-5] and building materials [6-8]. Until now the application of the TDR method for building materials was problematic due to the necessity of probes internal installation and was only possible to be applied in laboratory conditions mainly for soft building materials.

Since several years the surface TDR sensors are being developed and they seem to be perspective for non-invasive moisture determination in building materials and walls. Figure 2 presents the example of the surface TDR probe manufactured at Lublin University of Technology. Construction of the described sensor is presented in the following paper [9].

Fig. 1. Frequency Domain (capacitance) moisture meter (LAB-EL, Poland)

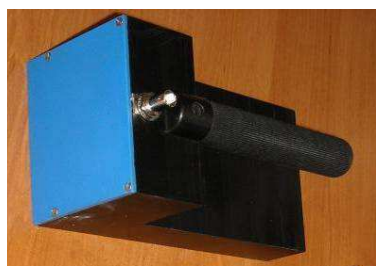

Fig. 2. Surface Time Domain Reflectometry probe (Lublin University of Technology)

Materials and methods

Capillary rise phenomenon was examined in the model wall (Fig. 3) made of red ceramic brick with bulk density of 1600 kg/m^3. Bricks of the masonry were combined with cement mortar 10 mm wide. Particular bricks dimensions are the following: 250 × 120 × 65 mm. For the experiment it was applied the capacitance sensor and the

modified TDR probe which enabled non-invasive measurements of moisture processes inside the walls.

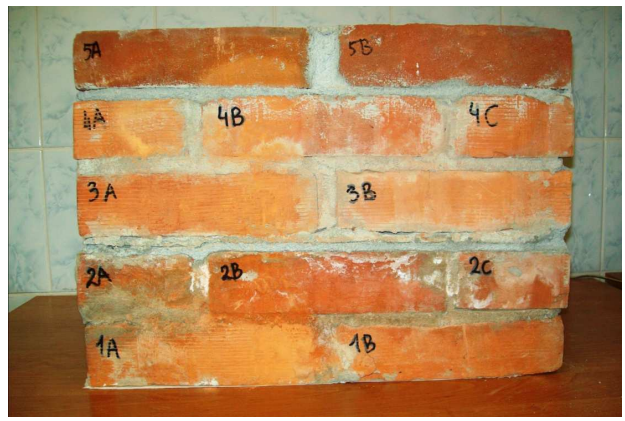

Fig. 3. Model wall made of red ceramic brick

Measuring setup, presented on Figure 4 consisted of:

- model wall placed in the water container,
- TDR multimeter (LOM/EasyTest, Lublin, Poland),
- surface TDR probe (Lublin University of Technology, Poland),
- PC computer as control station,
- LB-796 capacitance moisture meter (LAB-EL, Poland).

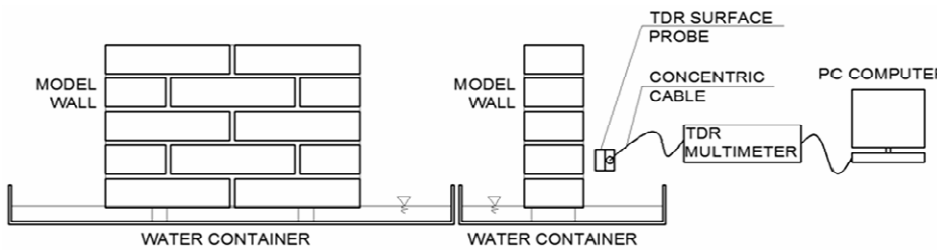

Fig. 4. Measuring setup

In such a prepared model wall, particular bricks were marked with the following symbols 1A, 1B, 2A, 2B, 2C, etc., where digit meant particular layer of the bricks. Such prepared wall was dried in 105°C and put into the water container with constant water level 10 mm above bottom edge of the measured wall. The wall was monitored for moisture changes by capacitance and the surface TDR sensors for period of 30 days with 24 hour intervals. The TDR instrumentation applied for the experiment enabled readouts of electromagnetic pulse propagation along the measuring elements of the surface probe, which were used for effective dielectric permittivity calculation (depending on surface sensor construction) and thus moisture. Calibration experiments were presented in [9, 10].

Capacitance probe was pre-calibrated by the device producer (LAB-EL, Poland) for most of typical building materials and enabled quick moisture measurement without the necessity to calibrate the sensor.

Results

Basing on moisture readouts obtained by the capacitance and the surface TDR probe it was determined the dynamics of moisture increase due to capillary rise phenomenon in the model wall made of red ceramic brick. The process is presented at the below diagrams. Figure 5 represents the average data obtained by capacitance measurements, Figure 6 represents average data obtained by the TDR equipment with the application of the non-invasive, surface TDR sensor presented on Figure 2.

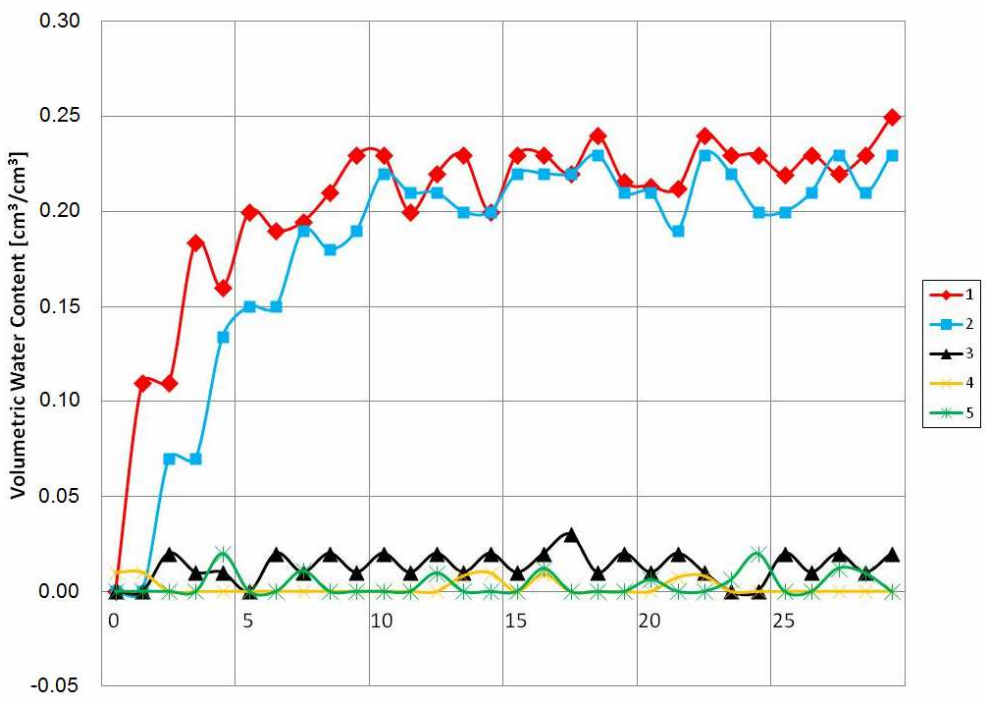

Fig. 5. Capillary rise phenomenon determined with capacitance probe

As a result of the conducted research it was confirmed high absorptivity of water by the red ceramic brick. At the bottom layer of the bricks water appeared soon after the experiment had started. Water content quickly risen, which is clearly visible at the lowest bricks. At bricks 2A, 2B and 2C of the second level, water appeared about one or two days later and after 8 days of process reached more than 20% vol., which was close to saturation. It must be underlined that no increase of water content was observed at layers 3, 4 and 5. This may be caused by several reasons. One of them is low permeability of cement mortar for water, which prevents water from rising to the higher layers. Another reason for that

phenomenon may be the drying process. Comparing with the other experiments [7], model wall was not insulated from external environment, and higher layers of the wall could be not available for water due to its desorption processes.

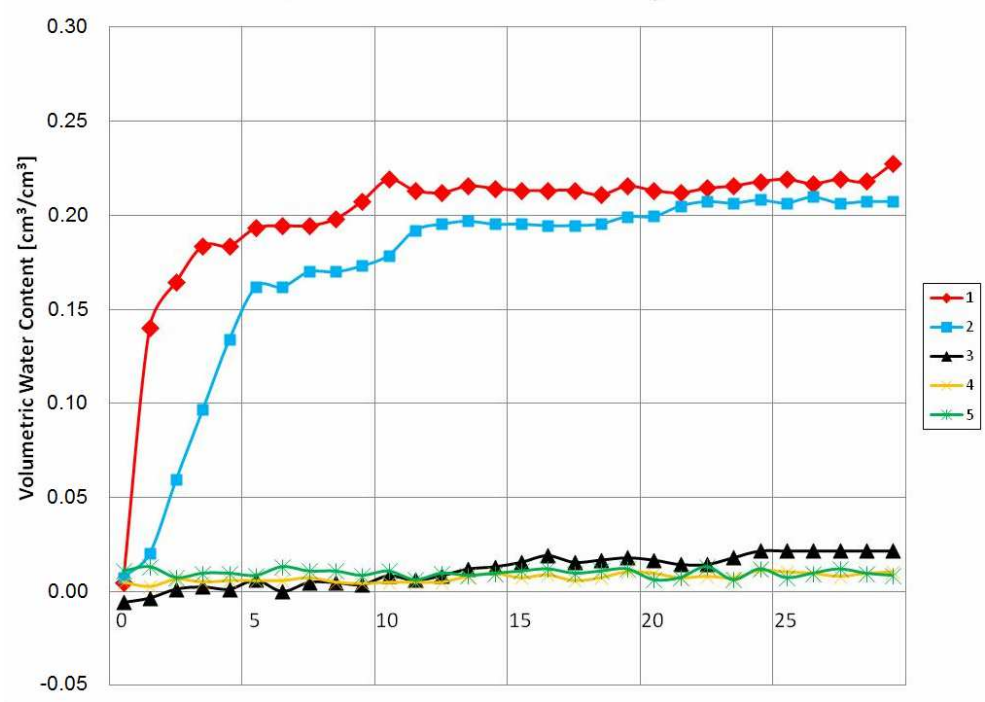

Fig. 6. Capillary rise phenomenon determined with surface TDR probe

Data obtained using the TDR technique comparing with capacitance results seems to be more stable. Capacitance readouts are fluctuating for about 4% vol. and the TDR readouts fluctuations do not exceed 2% vol. On the other side, it is possible that TDR moisture readouts may be underestimated for that material which maximum moisture, according to the producer, may reach 25% vol.

Conclusions

- The experiment confirms the potential of the TDR technique for moisture processes monitoring in building materials. Application of the surface TDR probes enables quantitative determination of moisture changes in the material without the necessity of invasive probes installation, which may be successfully used *in in-situ* experiments.
- For capacitance probe readouts the dispersion was greater than in presented TDR measurements, which can be explained by the salinity influence on capacitance measurement.

- According to both methods, water uptake process was confirmed, especially in bottom layers of the wall, strongly exposed on water presence.

References

[1] Rokiel M. Hydroizolacje w budownictwie. Warszawa: Wyd Medium; 2006.
[2] Topp GC, Davis JL, Annan AP. Electromagnetic determination of soil water content: Measurements in coaxial transmission lines. Water Resour Res. 1980;16:574-582. DOI: 10.1029/WR016i003p00574
[3] Malicki MA, Plagge R, Roth CH. Improving the calibration of dielectric TDR soil moisture determination taking into account the solid soil. Eur J Soil Sci. 1996;47:357-366. DOI: 10.1111/j.1365-2389.1996.tb01409.x
[4] Skierucha W, Malicki MA. TDR Method for the Measurement of Water Content and Salinity of Porous Media, Institute of Agrophysics. Lublin: Polish Academy of Sciences; 2004.
[5] Suchorab Z, Sobczuk H, Rożej A, Łagód G. Comparison of Reflectometric and Gravimetric Methods for Examination of Sewage Sludge Additions Influence on Water Properties of Reclamated Soils. Ecol Chem Eng. 2009;16(4):257-264.
[6] Cerny R. Time-domain reflectometry method and its application for measuring moisture content in porous materials: A review. Measurement. 2009;42:329-336. DOI: 10.1016/j.measurement.2008.08.011
[7] Suchorab Z, Jarmuła M, Sobczuk H, Pavlík Z, Černý R. Zastosowanie metody TDR do pomiaru podciągania kapilarnego w ściance modelowej z cegły ceramicznej pełnej (In Polish). Proc EcOpole. 2009;3(1):207-213.
[8] Guz Ł, Suchorab Z, Alcobia B, Sobczuk H. Wyznaczanie krzywej retencji wody materiałów porowatych za pomocą sond psychrometrycznych i TDR (In Polish). Proc of ECOpole. 2010;4(2):371-375.
[9] Suchorab Z, Sobczuk H, Cerny R, Pavlik Z, Plagge R. Non-invasive moisture measurement of building materials using TDR method. Proc. of the 8th International Conference on Electromagnetic Wave Interaction with Water and Moist Substances, June 1-5, Espoo, Finland; 147-155.
[10] Suchorab Z, Jedut A, Sobczuk H. Water content measurement in building barriers and materials using surface TDR probe. Proc of ECOpole. 2008;2(1):123-127.

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Abstrakt: Artykuł przedstawia bezinwazyjny sposób pomiaru wilgotności z wykorzystaniem metod elektrycznych. W pierwszej części artykułu omówiono problem nadmiernego zawilgocenia przegród budowlanych i sposoby pomiaru tego zjawiska. Druga część pracy ma charakter eksperymentalny. Przygotowano modelową ściankę z cegły ceramicznej pełnej w celu zbadania zjawiska podciągania kapilarnego. Omawiany proces był monitorowany za pomocą czujników pojemnościowych oraz powierzchniowych sond TDR, co umożliwiło bezinwazyjne pomiary, niewymagające pobrania fragmentów muru lub innych ingerencji w badany materiał. Uzyskane wyniki pozwalają na śledzenie procesu podciągania kapilarnego w modelowej ściance z cegły ceramicznej pełnej i potwierdzają możliwości sondy powierzchniowej TDR w pomiarach wilgotnościowych murów.

Słowa kluczowe: podciąganie kapilarne, cegła ceramiczna pełna, powierzchniowe sondy TDR