Zbigniew SUCHORAB[1], Henryk SOBCZUK[1] and Zbyšek PAVLIK[2]

EXAMINATION OF CAPILLARY RISE PHENOMENON IN AERATED CONCRETE BLOCK USING THE SURFACE TDR PROBE

BADANIE ZJAWISKA PODCIĄGANIA KAPILARNEGO W BLOCZKU Z BETONU KOMÓRKOWEGO Z ZASTOSOWANIEM POWIERZCHNIOWEJ SONDY TDR

Abstract: Aerated concrete is the basic building material applied in traditional building industry. It is mainly caused by its thermal parameters - heat conductivity coefficient λ for lighter brands of this material is many times lower than other traditional materials like brick etc. Low value of heat conductivity coefficient is mainly caused by the material structure which is highly porous. This porosity causes capillary forces which are the reason of so called capillary rise phenomenon being the reason of many buildings destruction. This article presents the possibility of monitoring and quantitative valuation of moisture increase in building barriers due to capillary rise with the application of the TDR surface probes enabling quick and noninvasive moisture determination in porous building materials. The analyses conducted using surface TDR probes will be compared with the examinations made using other electrical methods and the results will be presented in the form of moisture profiles changing in time.

Keywords: capillary rise, aerated concrete, surface probes TDR

Aerated concrete is the one of the most popular building materials in the Polish market [1]. It is the artificial material with specific cellular structure which was intentionally designed to obtain suitable bearing and thermal parameters. The structure of aerated concrete consists of the air gaps called pores which can differ in volume and shape within a single sample of the material [2].

With its porous structure the aerated concrete is a very good building material. Especially its thermal properties make it a particularly interesting option from the point of view of ecology and Environmental Engineering. Many literature sources [3-5] and normatives (PN-EN ISO 6946) inform that the value of thermal conductivity λ of aerated concrete varies between 0.1 and 0.25 W/mK depending on apparent density and moisture which makes it even 10 times better than the other materials like red ceramic brick or stones.

It should be also underlined that many of its production technologies utilize ashes from power plants [6] which satisfies the idea of Sustainable Building [7] in two most important fields:

- building materials production,
- building exploitation.

On the other hand, this complicated porous structure of aerated concrete strongly influences its water parameters because the empty pores attract water molecules to fill the air gaps. This phenomenon called capillary rise is a serious reason of many objects

[1] Faculty of Environmental Engineering, Lublin University of Technology, ul. Nadbystrzycka 40B, 20-618 Lublin, phone 81 538 43 22, email: Z.Suchorab@wis.pol.lublin.pl, H.Sobczuk@wis.pol.lublin.pl
[2] Faculty of Civil Engineering, Czech Technical University, Thákurova 7, 166 29 Praha, Czech Republic, phone +420 224 354 371, email: pavlikz@fsv.cvut.cz

destruction. Porous building materials like aerated concrete absorb water from the ground, waterfalls, floodwater or sanitary installations fails in the common phenomenon called capillary rise.

All above-mentioned parameters and problems connected with the aerated concrete are the reason to develop a handy method of water presence detection which could enable quantitative moisture determination in building barriers. Determination of moisture and its changes monitoring in particular periods may enable easier finding of the problem source and may give the indications how to remove the problem.

Traditionally used direct, gravimetric methods, despite their accuracy are not perspective in this branch because they are invasive, require sampling and, what is perhaps the biggest problem, are significantly time-consuming. That is why, especially for monitoring and *in-situ* measurements, they are successfully being replaced by the indirect methods which offer less accuracy, but otherwise provide quick results and in some cases give the possibility of constant monitoring of moisture changes phenomena.

Among the indirect methods two electric ones are presented in this paper. They measure one of the the electric parameters of the material which is dependent on water content - dielectric permittivity. Dielectric permittivity of the moist material can be measured in *Frequency Domain* (FD) and *Time Domain* (TD) methods. FD method [8] is a capacitance method, which relies on the determination of condenser capacity. This method enables quick moisture determination with simple, user friendly mobile devices - Figure 1a which are noninvasive and do not require samples preparations. Among the Time Domain methods the most popular is the TDR method, which was successfully used for moisture determination of the soils [9-11] and building materials [12-17]. Until now, application of the TDR method with building materials was problematic due to the necessity of probes internal installation which was only possible to apply in laboratory conditions and rather for soft building materials [18, 19].

Since several years the surface TDR probe is developed which seems to be perspective for noninvasive moisture determination in building materials. The idea and parameters of the presented surface TDR probe are presented in the following papers [20-23]. Figure 1b presents the example of the surface TDR probe manufactured at Lublin University of Technology.

a) b)

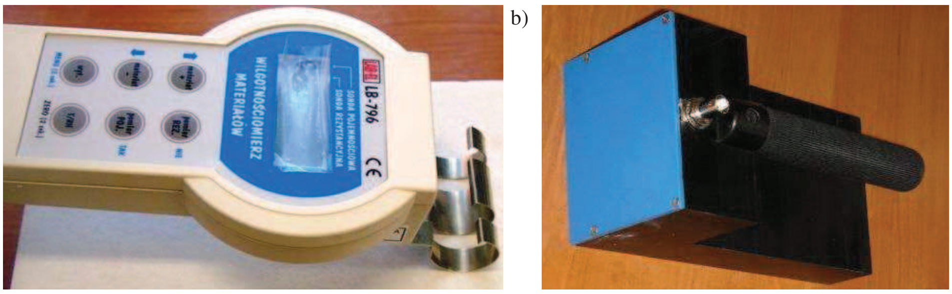

Fig. 1. Probes applied in described experiment: a) capacitance moisture probe, b) surface TDR probe

In this article we present the possibility of monitoring of capillary rise phenomenon using the capacitance and surface TDR probes in blocks of aerated concrete.

Materials and methods

The experimental setup consisted of:

- TDR surface probe presented in Figure 1,
- TDR Soil Multimeter (Easy Test),
- PC computer controlling the TDR device,
- LB-796 capacitance moisture meter (Label, Figure 1),
- aerated concrete sample (SOLBET Lubartow).

As a sample we used the block of aerated concrete produced by the local manufacturer SOLBET Lubartow. The sample dimensions were the following: 240×240×240 mm and its density in dry was about 700 kg/m^3. First the sample was dried in 105°C and put into the water container. The bottom of the sample was one centimeter under water level which was kept constant by the specially prepared device. The reference points were signed every 5 centimetres above water level and during the experiment they shown the measuring points (5, 10, 15 and 20 cm).

The measurements were conducted manually in period of 16 days with the irregular time steps (in most cases three measuring series per day).

Results

The experimental results are presented in Figures 2 and 3 in the form of the process diagrams at the particular heights. The diagram 2 presents readouts obtained with capacitance probe and Figure 3 shows the readouts obtained with TDR device. Water content increase at each altitude is expressed by increased value at the ordinate axis.

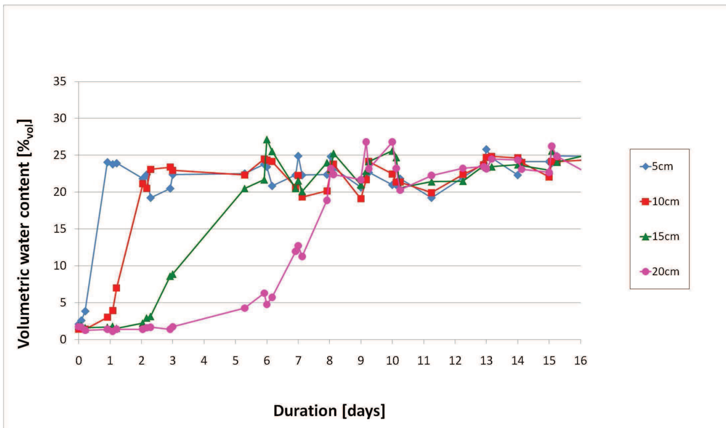

Fig. 2. Moisture changes in aerated concrete determined using capacitance method

The experiment confirms the phenomenon of capillary rise in aerated concrete and enables quantitative determination of its progress. In both diagrams the initial value of moisture is equal 0 which is the result of drying during sample preparations. Both probes show quick moisture increase at 5 cm reference point, the slope of the increase is very steep which proves high capillary forces of the material. After one day of the experiment it reaches the maximum water content value. At higher altitudes moisture increase is shifted in time but also very quick. At 10 cm the first water presence is noticed after one day of the experiment but from that moment it increases quickly and after the next day it reaches the maximal value possible for this material. The rate of water content increase at 15 cm is slower than before. The first readouts are observed after 3 days of the process and the maximal value is noticed about 4 days later. Fourth, the highest reference point, placed at the height of 20 cm shows water presence after the period of 6 days and then it gently rises to reach high values after the next 4 days but its maximum value was noticed at the end of the whole presented experiment.

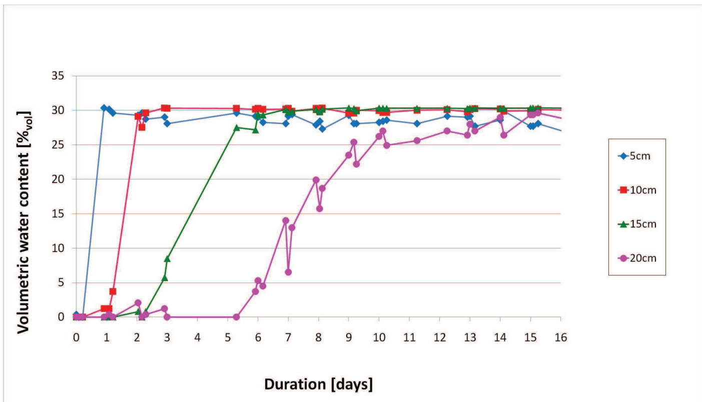

Fig. 3. Moisture changes in aerated concrete sample determined using surface TDR probe

Both experiments show very similar process progress. The major noticed differences are the following:

- Maximum water content read by the capacitance probe was less than TDR surface probe.
- In high water states moisture readouts by the capacitance probe were less stable than TDR readouts.
- In low water content and intermediate states the process readouts determined with capacitance and TDR probe were comparable.

Conclusions

- The experiment confirms the potential of TDR technique for moisture processes monitoring in building materials. Application of the surface TDR probes enables quantitative determination of moisture changes in the material profile without the necessity of invasive probes installation which may be successfully used in *in situ* experiments.
- Comparing with the traditional invasive TDR experiments of capillary rise, surface TDR probes show greater results dispersion which is compensated by the simplicity of application and no drilling is required.
- The reasons of this increased dispersion are the smaller resolution of surface probes and the increased influence of other factors connected with permanent probe

repositioning. In case of traditional TDR measurements the probes are buried inside the material. In the described experiment the probes position was permanently moved from one to other reference point which could increase the readouts dispersion.

- Capacitance probe readouts showed underestimated values of maximum water content. Also the readouts dispersion was greater than in presented TDR measurements. This can be explained by the salinity influence on capacitance measurement - especially in high water content states.

References

[1] Siejko J. and Babiński Z.: Co to jest beton komórkowy? Budowanie z betonu komórkowego. Poradnik-Katalog, Stowarzyszenie Producentów Betonów SBPB, 2005, 11-59 (in Polish).

[2] Roels S., Sermijn J. and Carmeliet J.: *Modelling unsaturated moisture transport in autoclaved aerated concrete: microstructural approach*. Proc. 6th Symposium on Building Phys. Nordic Countries, Norwegian Univ. Sci. Technol., Trondheim, Norway, 2002, 167-174.

[3] Gawin D., Kosny J. and Desjarlais A.: *Effect of moisture on thermal performance and energy efficiency of buildings with lightweight concrete walls*. Proc. Summer Study on Energy Efficiency in Buildings Efficiency & Sustainability. Pacific Grove, California, USA, 2000, 149-160.

[4] Grunewald J., Plagge R. and Haupl P.: *A two-leveled hygrotermal material database for the numerical simulation program DELPHIN4*. Proc. 6th Symposium on Building Phys. Nordic Countries, Norwegian Univ. Sci. Technol., Trondheim, Norway, 2002, 39-46.

[5] Klemm P. (red.): Budownictwo ogólne. Tom 2 (Fizyka budowli). Arkady, Warszawa 2005 (in Polish).

[6] Narayanan N. and Ramamurthy K.: *Structure and properties of aerated concrete: a review*. Cement & Concrete Composit., 2000, **22**, 321-329.

[7] Adamczyk J. and Dylewski R.: *Recykling odpadów budowlanych w kontekście budownictwa zrównoważonego*. Problemy Ekorozwoju - Problems of Sustainable Development, 2010, **5**(2), 125-131 (in Polish).

[8] Łobzowski A., Opęchowski A. i Szkolnikowski W.: *Wilgotność materiałów stałych, sypkich i gleby*. Pomiar, 2008, **4**.

[9] Topp G.C., Davis J.L. and Annan A.P.: *Electromagnetic determination of soil water content: Measurements in coaxial transmission lines*. Water Resour. Res., 1980, **16**, 574-582.

[10] Malicki M., Plagge R. and Roth C.H.: *Improving the calibration of dielectric TDR soil moisture determination taking into account the solid soil*. Eur. J. Soil Sci., 1996, **47**, 357-366.

[11] Skierucha W. and Malicki M.A.: TDR method for the measurement of water content and salinity of porous media. Institute of Agrophysics, Polish Academy of Sciences, Lublin 2004.

[12] Suchorab Z., Sobczuk H., Łagód G., Pavlik Z. and Cerny R.: Zastosowanie metody TDR do pomiaru wilgotności materiałów budowlanych. Materiały, tom 2, Monografie Komitetu Inżynierii Środowiska PAN, 2005, **33**, 1063-1070 (in Polish).

[13] Pavlík Z., Pavlíková M., Fiala L., Černý R., Sobczuk H. and Suchorab Z.: *Application of time-domain reflectometry method for measuring moisture content in porous building materials*. Trends in Applied Sciences Research, 2007, **2**(3), 188-200.

[14] Sobczuk H. and Plagge R.: Time domain reflectometry method in environmental measurements. Monografie Komitetu Inżynierii Środowiska Polskiej Akademii Nauk, Vol. 39, Lublin 2007.

[15] Hansen E.J. de P. and Hansen M.H.: *TDR measurement of moisture content in aerated concrete*. Proc. 6th Symp. Building Phys. Nordic Countries, Norwegian Univ. Sci. Technol., Trondheim, Norway, 2002, 381-388.

[16] Suchorab Z., Barnat-Hunek D. and Sobczuk H.: *Adaptation of reflectometric techniques for moisture measurement of rock walls on the example of Janowiec Castle*. City of Tomorrow and Cultural Heritage, Pomerania Outlook, Int. Workshop, December 08-09, 2005, Gdańsk, Poland, Volume I, 71-74.

[17] Suchorab Z., Barnat-Hunek D. and Sobczuk H.: *Monitoring parametrów wilgotnościowych murów z kazimierskiej opoki wapnistej przy wykorzystaniu technik reflektometrycznych TDR*. Proc. of Renovation Problems in Buildings and Historical Monuments, Wrocław 2006, 184-191 (in Polish).

[18] Cerny R., Pavlikova M., Pavlik Z., Suchorab Z. and Sobczuk H.: *Effect of sensor installation method on the applicalibity of TDR moisture measurement technique*. Proc. 8th Int. Conf. Electromagnetic Wave Interact. Water and Moist Substan., June 1-5, Espoo, Finland, 113-117.

[19] Pavlik Z., Suchorab Z. and Sobczuk H.: *Two-rods sensor installation method and its effect on applicalibity of TDR method for moisture and salt concentration measurement*. 18th Annual CTU University-Wide Seminar, Special Issue, Part A, Vol. 13, February 2009, 58-59.
[20] Suchorab Z., Jedut A. and Sobczuk H.: *Water content measurement in building barriers and materials using surface TDR probe*. Proc. ECOpole, 2008, **2**(1), 123-127.
[21] Suchorab Z., Sobczuk H., Černý R., Pavlík Z. and Sevillano de Miguel R.: *Sensitivity range determination of surface TDR probes*. Environ. Protect. Eng., 2009, **35**(3), 179-189.
[22] Suchorab Z., Barnat-Hunek D. and Sobczuk H.: *Zastosowanie powierzchniowej sondy TDR do bezinwazyjnych pomiarów wilgotności materiałów budowlanych*. Materiały Budowlane, Wyd. Uczel. Uniwersytetu Technologiczno-Przyrodniczego w Bydgoszczy, Bydgoszcz 2009, 65-74 (in Polish).
[23] Suchorab Z., Sobczuk H., Cerny R., Pavlik Z. and Plagge R.: *Noninvasive moisture measurement of building materials using TDR method*. Proc. 8th Internat. Conf. Electromagn. Wave Interact. Water Moist Subst., June 1-5, Espoo, Finland, 147-155.

BADANIE ZJAWISKA PODCIĄGANIA KAPILARNEGO W BLOCZKU Z BETONU KOMÓRKOWEGO Z ZASTOSOWANIEM POWIERZCHNIOWEJ SONDY TDR

[1] Wydział Inżynierii Środowiska, Politechnika Lubelska
[2] Wydział Inżynierii Budowlanej, Czeski Uniwersytet Techniczny, Praga, Czechy

Abstrakt: Beton komórkowy jest podstawowym materiałem budowlanym stosowanym w budownictwie tradycyjnym. Wynika to głównie z jego właściwości termoizolacyjnych - współczynnik przewodzenia ciepła λ dla lżejszych jego odmian jest wielokrotnie niższy od wartości tego współczynnika takich materiałów, jak cegła itp. Niska wartość współczynnika przewodzenia ciepła wynika głównie ze struktury materiału, która charakteryzuje się dużą porowatością. Z właściwością tą wiąże się fakt występowania sił kapilarnych, które są przyczyną zjawiska podciągania kapilarnego będącego przyczyną destrukcji wielu budynków dotkniętych nadmiernym zawilgoceniem. Artykuł przedstawia możliwość monitoringu i ilościowej oceny wzrostu wilgotności w przegrodach budowlanych wskutek procesu podciągania kapilarnego przy wykorzystaniu powierzchniowych sond TDR umożliwiających szybkie i bezinwazyjne wyznaczanie wilgoci w porowatych materiałach budowlanych. Analizy wykonane za pomocą sond powierzchniowych porównano z wynikami z innych metod elektrycznych i przedstawiono w postaci profili wilgotnościowych zmieniających się w czasie.

Słowa kluczowe: podciąganie kapilarne, beton komórkowy, powierzchniowe sondy TDR