Agnieszka JEDUT[1], Zbigniew SUCHORAB[1] and Henryk SOBCZUK[1]

SURFACE PROBES FOR BUILDING MATERIALS MOISTURE MEASUREMENT BY REFLECTOMETRIC METHOD

SONDY POWIERZCHNIOWE DO POMIARÓW WILGOTNOŚCI MATERIAŁÓW BUDOWLANYCH METODĄ REFLEKTOMETRYCZNĄ

Abstract: The problem of building materials moisture, resulting from their porous structure, has a meaningful value for environmental engineering for the sake of its numerous, negative consequences. After breaking the limited states, the negative aspects both for building users' health, mechanical, physical and chemical properties of barriers can be observed. Therefore, the essential matter is to provide the possibility of barriers moisture state evaluation. Among the techniques used for building materials moisture measurement, the TDR method application should be underlined for the sake of its simplicity in use and high precision, especially with the use of surface probes. The construction of probes presented in this paper enables non-invasive and accurate moisture measurements, both in laboratory and in situ conditions. The formulas obtained from conducted investigations make possible the evaluation of selected building materials moisture states.

Keywords: TDR method, surface probes, moisture measurement

The durability of external walls as well as the thermal and moisture processes inside them are dependent on climate conditions, which means temperature, rainfalls, velocity and direction of wind, relative humidity and solar radiation. The similar situation takes place in the case of internal walls, which do not undergo the cycles of congealing and thawing, but they are threatened both with moisture and temperatures creating favorable conditions for the microorganisms growth [1].

According to Witczak et al [2], moisture is the less desired and the most destructive factor in the case of walls, especially in connection with minus temperatures. The presence of water results in decrease of the durability of building materials, among others by the freeze water inside their structure, corrosion of metals, precipitation of soils, biological corrosion etc. Moreover, the rise of moisture content causes deterioration of insulation properties, which can increase the costs of heating in the winter season.

The negative influence of moisture on the building materials, accommodations and their users should be considered from a few different perspectives. Wyrwal i Swirska mention the following results of the building moisture [1]:

- health,
- mechanical and physical,
- chemical,
- biological.

Excessive walls dampness creates the base for the microorganisms and fungus growth, which is harmful for people's health. The lower wall temperature in connection with its high moisture harmfully influences the thermal comfort feelings as well. All these aspects can contribute to the creation of Sick Building Syndrome, which means the situation, when

[1] Faculty of Environmental Engineering, Lublin University of Technology, ul. Nadbystrzycka 40B, 20-618 Lublin, tel. 81 538 44 06, 81 538 43 22, 81 538 44 81, email: A.Jedut@wis.pol.lublin.pl, Z.Suchorab@wis.pol.lublin.pl, H.Sobczuk@wis.pol.lublin.pl

at least 20% of examined group of people can feel the negative influence of microclimate of accommodation.

The physical results of the water presence in the material's structure manifest themselves by the reduction of mechanical durability, which can result in building barriers' deformations. The congealing and thawing processes in the material's structure cause the formation of splits as a result of the volume changes.

The chemical influences include the corrosion caused by acid rains and aggressive groundwater. The biological aspect means both aesthetic as well as connected to people's health results of microorganisms' growth. On the external surfaces, the moss and lichen growth can be observed, which not only spoils the elevation, but also is the reason of crumbling and destruction of materials [1, 3].

The thermal conductivity of porous materials increases with their moisture. It is caused by the fact, that the water filling the pores of material has a thermal conductivity almost 20 times higher than the air. The mentioned influence can be easily observed especially in the range of capillary water dampness. The rise of thermal conductivity of moistened barrier can amount to 15% [4].

All the described problems are the base to search the easy to use and precise method of moisture measurement, which can help to find the reason of water presence in the barrier and to value the range of moistening.

TDR probes

The technique applied in the experimental part of the research is the Time Domain Reflectometry method. This technique bases on the electromagnetic pulse time propagation along the rods of the probe placed in a porous material. The measured time is directly connected to dielectric permittivity of the medium, which in turn is mostly dependent on water content in the material [5-7].

The experimental setup for such measurement includes the PC computer as a controlling appliance, the measuring device and probes connected with device by concentric cable. The primary probes were constructed as the extension of concentric cable, where the core separates from the screening, and they create two or three rods used to put into the material. For the hard building materials, the traditional rod probes are replaced by the new construction of surface probes [8].

Fig. 1. The surface probes applied to the measurement of the aerated autoclaved concrete (left side) and insulated silicate (middle and right side) moisture

For the research carried out, the three types of surface probes with similar construction were used (Fig. 1). The probe called STDR2 has 2 measuring elements in the shape of brass rods placed in the distance of 3 cm. The shelter of rods is built from ertacetal. The rods are connected to concentric cable by the printed plate. The probe called STDR3 has two rods placed in the distance of 7 cm, and the STDR4 probe has three rods separated by 3.5 cm fragments of shelter. Each of the probes has a handle for the proper pressure during the measurement on the vertical barrier [9].

Experiment

In the experimental part of the research, there were 120 measuring series conducted. The aim of experiment was to determine the calibration formulas for three surface probes construction, in application to aerated autoclaved concrete and insulated silicate. The measurements were conducted in April 2009 at the Laboratory of Thermal Technique on Faculty of Environmental Engineering at Lublin University of Technology.

The measurements were conducted by the use of TDR multimeter MTS-1 by EasyTest Lublin (Fig. 2).

Fig. 2. The measuring device, MTS-1 multimeter

The special computer program Surface TDR Calibration v.1.0 was created to ensure the control over whole experiment. The program was used to monitor the MTS-1 multimeter and to interpret the data. Figure 3 presents the window of this program during the research.

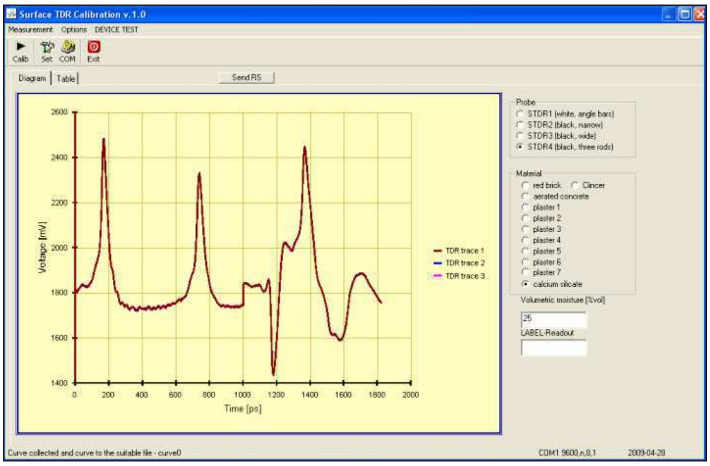

Fig. 3. The window of Surface TDR Calibration v.1.0 program

Results and discussion

On the basis of the obtained results, the dependences between the dielectric permittivity of materials and their moisture were described by the calibration formulas and graphics (Fig. 4).

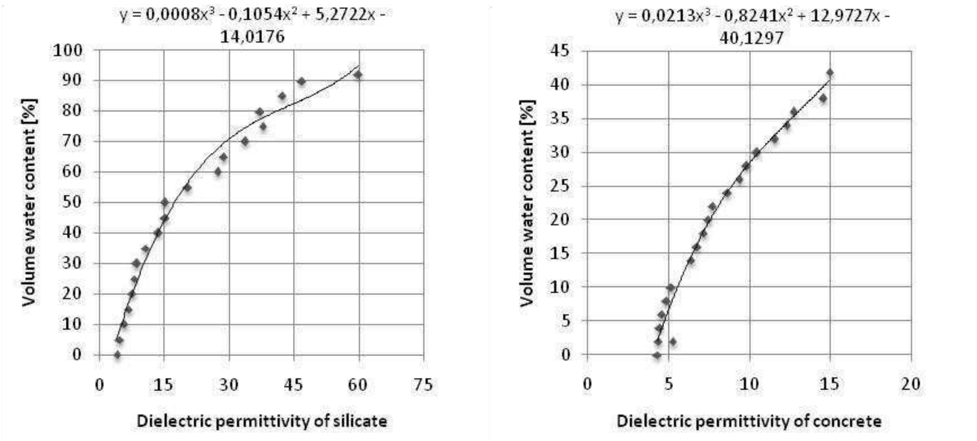

Fig. 4. The dependence between volumetric water content and dielectric permittivity of aerated autoclaved concrete (left) and insulated silicate (right) obtained from the STDR2 probe measurement

To establish the precision of measurement, the obtained TDR results were compared to the gravimetrical measurement results. The comparison is presented in Figure 5.

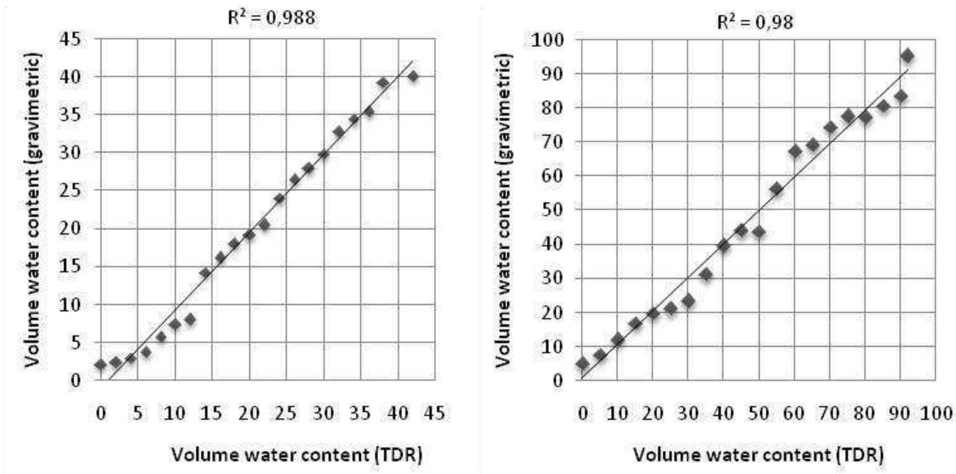

Fig. 5. Comparison of results obtained from TDR and gravimetric measurements for aerated autoclaved concrete (left) and insulated silicate (right)

All the obtained formulas are gathered in Table 1.

At the presented formulas, Θ means volumetric water content, and ε is the dielectric permittivity of material.

Table 1

Calibration formulas and the R factors obtained from executed measurements

Measurement		Calibration formula	R factor
STDR2	Concrete	$\Theta = -0.0213\cdot\varepsilon^3 - 0.8241\cdot\varepsilon^2 + 12.9727\cdot\varepsilon - 40.1297$ (5.1.1)	R = 0.990
	Silicate	$\Theta = 0{,}0008\cdot\varepsilon^3 - 0.1054\cdot\varepsilon^2 + 5{,}2722\cdot\varepsilon - 14{,}0176$ (5.1.2)	R = 0.989
STDR3	Concrete	$\Theta = 0.039\cdot\varepsilon^3 - 1.2887\cdot\varepsilon^2 + 16.8321\cdot\varepsilon - 48.6653$ (5.2.1)	R = 0.997
	Silicate	$\Theta = 0.0013\cdot\varepsilon^3 - 0.1571\cdot\varepsilon^2 + 6.6177\cdot\varepsilon - 20.621$ (5.2.2)	R = 0.996
STDR4	Concrete	$\Theta = 0.0340\cdot\varepsilon^3 - 1.149\cdot\varepsilon^2 + 15.5147\cdot\varepsilon - 44.747$ (5.3.1)	R = 0.993
	Silicate	$\Theta = 0.0012\cdot\varepsilon^3 - 0.1393\cdot\varepsilon^2 + 5.848\cdot\varepsilon - 16.1428$ (5.3.2)	R = 0.992

As it can be seen in the Table, the results obtained by the use of STDR3 probe are characterized by the highest precision. However, all the obtained results are marked out by the values of R factors between 0.990÷0.997. The resolution of measurements amounts from 0.24% to 0.4%.

Conclusions

On the basis of conducted analyze, the usefulness of TDR technique for moisture measurements of building materials was confirmed. Moreover, the high precision of applied method was proved, by the comparison of TDR and gravimetrical results. The calibration formulas obtained from the executed measurements can be applied for evaluation of aerated autoclaved concrete and insulated silicate moisture states.

Lots of advantages of the described method [10-12], like its non-invasive character, insensitivity on salinity and temperature changes, monitoring potential, create a possibility of its implementation on the world market.

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SONDY POWIERZCHNIOWE DO POMIARÓW WILGOTNOŚCI MATERIAŁÓW BUDOWLANYCH METODĄ REFLEKTOMETRYCZNĄ

Wydział Inżynierii Środowiska, Politechnika Lubelska

Abstrakt: Problem zawilgocenia materiałów budowlanych, wynikający z ich porowatej struktury, ma duże znaczenie dla inżynierii środowiska z uwagi na jego liczne, negatywne następstwa. Przy przekroczeniu stanów dopuszczalnych obserwuje się niekorzystne skutki dla zdrowia użytkowników budynku spowodowane wzrostem liczby szkodliwych mikroorganizmów i grzybów oraz obniżeniem parametrów komfortu cieplnego, a także negatywny wpływ wilgoci na właściwości mechaniczne i fizykochemiczne przegrody. Ważną kwestię stanowi zatem możliwość oszacowania stanu wilgotnościowego materiałów budowlanych. Spośród dostępnych technik pomiarowych dużą precyzją oraz prostotą stosowania wyróżnia się metoda reflektometrii w domenie czasowej (*Time Domain Reflectometry*), szczególnie z zastosowaniem sond powierzchniowych. Sondy o konstrukcji przedstawionej w tej pracy umożliwiają bezinwazyjne i dokładne pomiary wilgotności zarówno w warunkach laboratoryjnych, jak i w obiektach rzeczywistych. Równania otrzymane na podstawie przeprowadzonych badań mogą posłużyć do oceny stanów wilgotnościowych wybranych materiałów budowlanych.

Słowa kluczowe: metoda TDR, sondy powierzchniowe, pomiary wilgotności