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MODIFICATION OF THE MEASUREMENT METHOD OF RELATIVE MOISTURE DETERMINATION USING PELTIER PROBE

MODYFIKACJA TECHNIKI POMIAROWEJ DO WYZNACZANIA WILGOTNOŚCI WZGLĘDNEJ ZA POMOCĄ SONDY PSYCHROMETRYCZNEJ PELTIERA

Abstract: Psychrometric probes are used for porous materials potential determination which can be easily recalculated into the relative moisture. They can be also applied for building materials moisture parameters determination. They enable relative moisture readout in the narrow range between 94 and 99.9%. Water film evaporating from the thermocouple causes temperature decrease and generation of a voltage in a range of microvolts. Due to external heat flux influence on the applied sensors (Wescor PST-55 probes) the measurement must be conducted in the stabilized conditions. Non-stable heat flows and thus the decrease of measurement results repeatability. This is especially important during measurement of porous material samples with small dimensions. To increase the measurement accuracy the probes were equipped with metal sleeves having the external diameter of 12 mm and wall thickness 1 mm. The aim of the sleeve is to stabilize the instantaneous temperature variations and bridge the heat flow around the psychrometric Peltier probe.

Keywords: psychrometric probe, sleeves

Psychrometric Peltier probe enables water potential determination in the range about –7÷–0.2 MPa which is valid for the 95÷99.9% relative moisture of the air inside pores [1]. Water potential can be described as the specific energy of bond the water in the porous material [2]. The idea of water potential and the idea of Peltier probe measurement were described in [3]. The relative humidity of air in material pores develops in equilibrium with the water in a material pores. In the equilibrium state, bond energy of water in any state, liquid or vapor, is the same, so the moisture potential of water vapor is a good measure of moisture potential of pore water. With the psychrometric Peltier probe and TDR method [4] water retention curves were determined for calcium silicate. The psychrometric probes were equipped with copper sleeves in order to diminish the influence of external heat flux onto the measurement results.

Inside the barriers made of porous building materials water can appear during building works or later during objects exploitation. Building moisture evaporates during the years and mostly it can be noticed in newly built objects.

Moisture from groundwater occurs because of the capillary rise phenomenon which relies on adsorption of water by the capillars and pores walls and depends mostly on ground conditions, capillars diameter and water chemical compound [5].

The amount of moisture which is caused by rainfalls depends mainly on capillary rise by the materials. The quicker the process the larger amount of water is absorbed comparing with water falling by the walls surface.

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Water vapor absorption from the external air by the dried material with hydrophilic properties is called moisture sorption. Moisture sorption strongly influences building barriers moisture and the materials which form them. Due to materials sorption they always contain some moisture even if not used in barriers, but only stored in the magazines.

Building barriers can also be moistened by the water vapor condensation on the surface or the internal layers. Surface condensation occurs when the air flowing close to cold surface is cooled below the dewpoint temperature and water condenses. Such a condensed water causes moisture entering the barrier material in the form of capillary water [6].

Reasons of high water content

Among the building materials threats due to water presence we can distinguish the following items:

- Physical: temperature changes and insulation parameters decrease, heat loses, scratches, material changes, wet barriers surfaces, destruction due to congealing;
- Chemical: salinity splashes, material destruction due to volume increase, structure changes, glue chemical reactions, calcium loses, rust splashes, chemical corrosion [7];
- Biological: microorganisms development, algae, moss, lichens, biocides, fungi and mould development, pollution [8].

Scheme of measurement installation

Voltage readouts from psychrometric probes PST-55 is measured by multimeter PS/1, which enables voltage measurements with the sensitivity of several microvolts [9]. Together with water potential measurement, TDR moisture measurements were done with the application of two-rod sensor and the MTS-1 measuring device (Fig. 1). Measuring device is controlled by the computer program which enables readouts synchronization. For the experiment 8 silicate samples were used with the following dimensions: 5×5×13 cm. In each sample a central hole was drilled which was used as a place to install the psychrometric probe and from the other side the TDR probes were mounted.

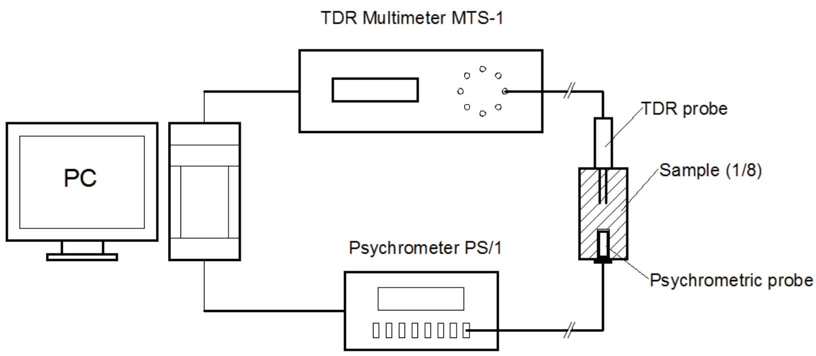

Fig. 1. Scheme of measurement installation

Psychrometric probes were placed in copper sleeves with the diameter of 10 mm and 30 mm long to stabilize heat parameters during measurement (Fig. 2). The aim of the sleeve was to equal the heat flow q results caused by the small sample walls temperature. It is mainly caused by the different exposition of radiation.

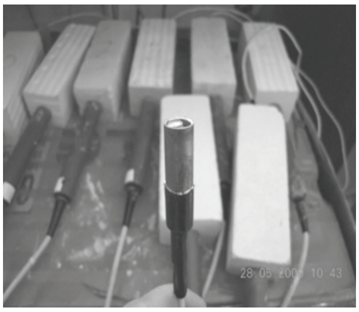

Fig. 2. Psychrometric probe with copper sleeve

Materials and methods

Measurement of water potential was released on the samples of autoclaved calcium silicate. It is the mineral material with microporous solid phase. Billions of micro-pores are joined together and with the external air which enables high capillary parameters. This is a material enabling flow of water vapor, insulating and natural environment friendly, non flammable and preventing mould development.

Small dimensions of samples allowed to obtain a homogenous moisture in the whole volume of the sample. The process of moisturizing was released by putting the sample into the water until the maximum water content was achieved, which was determined using the TDR sensors. After this stage, psychrometric probes were mounted and the holes were insulated. Then the samples were under the process of desorption which was monitored using the measurement equipment. The first experiment series were conducted with the psychrometric probes without sleeves. In the second series the probes were armed with extra copper sleeves. Uncovered silicate samples were threatened with external parameters like daily temperature fluctuations, infrared radiation from the stuff and electrical devices. It was to compare two measurement techniques. The point of the experiment finish was constant water content value showed by the TDR device. With this information the stable state of moisture was noticed and the measurements were finished.

Results

From the diagrams presented in Figure 3 it can be concluded that the application of a copper sleeve for water potential determination using psychrometric probe positively influenced the readouts. Dispersion of measuring points was smaller which is mainly visible in the confidence band 95%. This makes the readouts more precise. This comparison is presented in Table 1. The average confidence band for measurements without sleeves was 2.0 and with the sleeves - 1.33. The copper sleeve increases the heat inertia of the direct probe environment and absorbs flowing heat which would flow through the probe. On the diagram it can be also observed the influence of daily fluctuations of external conditions where the samples were placed.

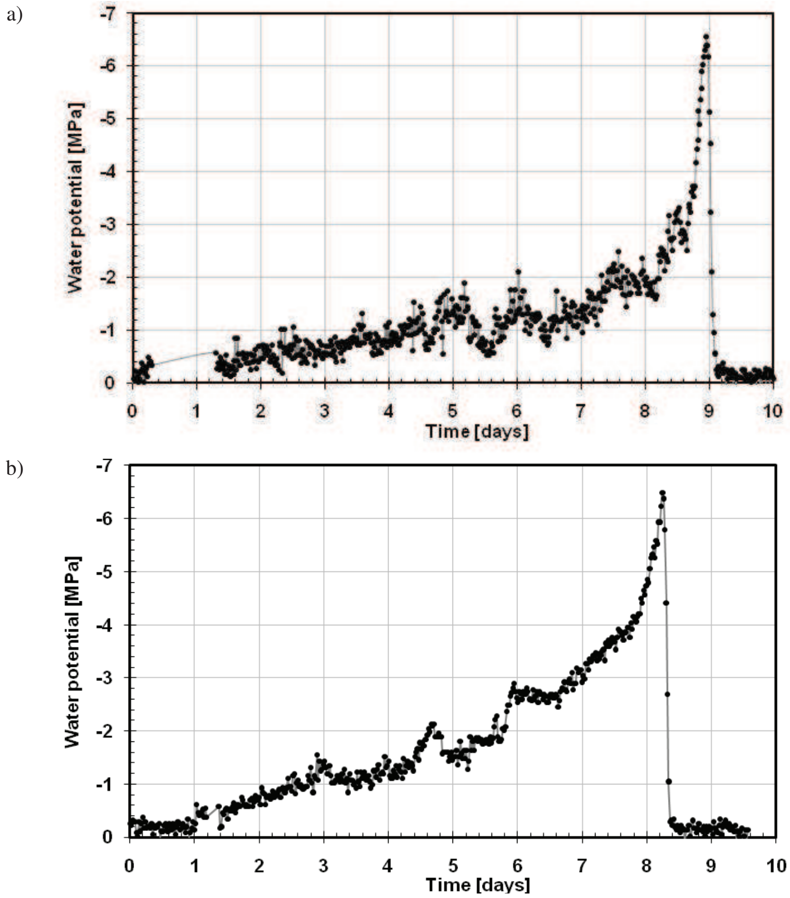

Fig. 3. Water potential in samples measured with psychrometric probes measurements: a) without sleeves, b) with sleeves

Table 1

Confidence band (0.95) of results of psychrometric probe with and without sleeve

Probe number	**1**		**2**		**3**		**4**	
Confidence band [MPa]	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve
	1.0	1.7	1.1	1.6	1.4	2.3	1.2	2.1
Probe number	**5**		**6**		**7**		**8**	
Confidence band [MPa]	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve	With sleeve	Without sleeve
	2.5	3.0	1.1	1.3	1.0	2.1	1.3	1.9

Combining the above-presented results with the TDR probes readouts the water retention curves were elaborated in the range between –1 and –7 MPa of water potential (Fig. 4).

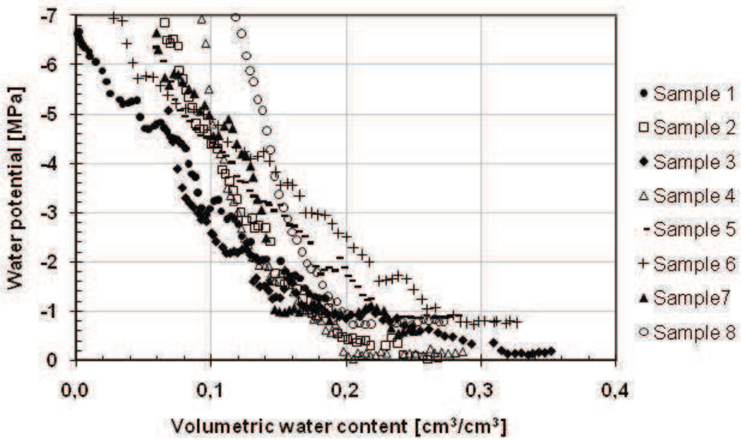

Fig. 4. Water retention curve determined through conjugation of psychrometric and TDR technique

Conclusions

Applied copper sleeves for psychrometric probes cause that in laboratory conditions the readouts are more stable which enables more precise elaboration of water retention curves of building materials.

Water retention curve elaborated with the combined TDR and psychrometric probe enables determination of pF curves in the range –1÷–7MPa, which is caused by the psychrometric probe sensivity.

Acknowledgment

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Abstrakt: Sondy psychrometryczne służą do pomiaru potencjału wody materiałów porowatych, którą można przeliczyć na wilgotność względną. Stosowane są od lat w agrotechnice i mogą również być zastosowane do pomiarów parametrów wilgotnościowych materiałów budowlanych. Umożliwiają odczyt wilgotności względnej w wąskim zakresie około 94÷99,9%. Jest to możliwe dzięki zjawisku Seebecka, odparowujący film wody z termopary powoduje obniżenie jej temperatury i wygenerowanie mikrowoltowego napięcia. Z uwagi na niską wartość mikrowoltowego napięcia generowanego na sondach Wescor PST-55, użytych podczas badań, pomiary muszą odbywać się w ustabilizowanych warunkach. Nieustabilizowane przepływy strumienia ciepła lub skoki temperatury powodują zmniejszenie powtarzalności wyników pomiarów. Ma to szczególne znaczenie podczas pomiarów próbek materiałów porowatych o niewielkich wymiarach geometrycznych. W celu zwiększenia dokładności pomiarów sondy zostały osłonięte metalowymi tulejami o średnicy 10 mm i grubości ścianki 1 mm. Zadaniem takiej tulei jest stabilizowanie nagłych wahań temperatury i regulowanie przepływów strumienia ciepła wokół sondy psychrometrycznej Peltiera.

Słowa kluczowe: sondy psychrometryczne, tuleje