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MONITORING OF CAPILLARY RISE PHENOMENON IN CALCIUM SILICATE BOARD USING THE SURFACE TDR PROBES SET

MONITORING PROCESU PODCIĄGANIA KAPILARNEGO W SILIKACIE WAPIENNYM ZA POMOCĄ POWIERZCHNIOWYCH SOND TDR

Abstract: Capillary rise phenomenon is a process threatening many building objects. It is mainly caused by the capillary structure of most building materials. The described phenomenon relies on water flow against gravity forces and hydrostatic pressure. The problem of capillary uptake is especially visible in case of lack of horizontal or vertical water isolation layers, their damage or natural wear during long time exploitation. The sufficient condition for capillary rise phenomenon appearance is constant contact of the building barriers to the moist ground. Described phenomenon is dangerous because the range of its influence can reach even 2.5 m or more above ground level, depending on building material. Capillary uptake is a dangerous process, because it runs to barriers destruction and decrease of its strength and heat parameters. Excessive water is the reason of biological strokes of the buildings, mainly caused by mould. The article presents the experimental research of capillary rise phenomenon in a sample of autoclaved calcium silicate. For the experiment it is applied the setup of TDR sensors prototypes which enable constant monitoring of the described phenomenon in non-invasive way.

Keywords: capillary rise, calcium silicate, surface probes TDR, monitoring

Introduction

This article is devoted to the capillary rise phenomenon and the possibility of its monitoring in autoclaved calcium silicate being an insulating material.

Capillary rise is one of the most threatening problems observed in many buildings [1, 2]. It causes the damage of external barriers, funds and runs to many exploitation problems like biological corrosion [3, 4], decrease of indoor air parameters and the decrease of thermal parameters of the materials [5-8].

A very interesting building material is autoclaved calcium silicate sold in Polish market as Renovario/Calsitherm and distributed by Ecovario Ltd Company [9]. It was elaborated in Germany by Häupl [10] at the end of the previous Century. Autoclaved calcium silicate is produced in form of plates with the dimensions of 1250 · 1000 mm and 25, 30 or 50 mm thickness [9]. The plates are made of calcium silicate being the mineral based material. Crystals of calcium silicate form the microporous shell, which provides the great capillarity of the ready material [11]. The most important parameters of Calsitherm plates, influencing their application are bulk density, porosity, compression strength and heat conductivity coefficient. All of them are set together in the Table 1, following the distributor webpage [9].

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Table 1

Technical data of autoclaved calcium silicate plates [9]

Parameter	Unit	Value
Bulk density	[kg/m^3]	200-240
Porosity	[%]	over 90
Compression strength	[MPa]	1
Heat conductivity coefficient (dry plate)	[W/(m · K)]	0.060
Heat conductivity coefficient (wet plate)	[W/(m · K)]	0.059

From the technical data presented in the table above it is visible that Calsitherm plates can be considered as insulation material with average insulating parameters (significantly lower, comparing to the other common materials like mineral wool or polystyrene). On the other hand their great porosity, exceeding 90% and microporous structure (Fig. 1) causes that they can be applied for internal insulation of the walls which should not be insulated from the outside. This is especially applicable for the old historical objects.

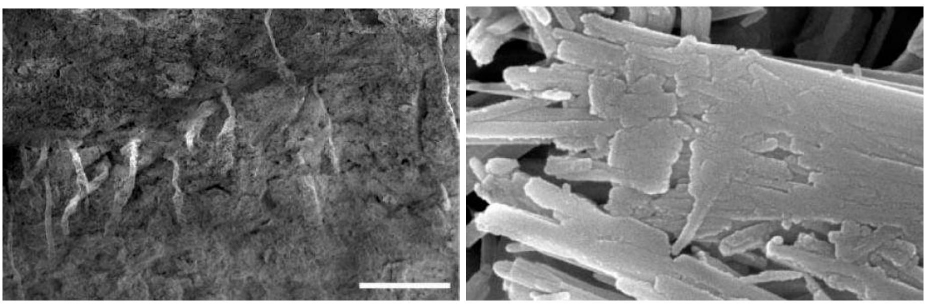

Fig. 1. SEM photography of autoclaved calcium silicate structure [12]

Indoor insulation layer, comparing to the traditional external insulation techniques does not provide suitable temperature distribution inside the building envelopes. In most cases this runs to water vapor condensation inside of them. It must be underlined here, that great porosity and water absorptivity of calcium silicate forces the wall to transfer condensed water into the insulation material which can be safely removed to the indoor air during dry periods of the year [2].

Materials and methods

As it was underlined in the above chapter, autoclaved calcium silicate is characterized by strong capillary forces and great water absorptivity. This paper presents research of water absorptivity of autoclaved calcium silicate.

For the experiment, the autoclaved calcium silicate (Calsitherm plate) sample was put to the container with constant water level and exposed to water uptake process (Fig. 2). Dimensions of the sample (Fig. 3) were the following: 580 mm (height) × 280 mm (width) × 50 mm (thickness). Bottom 20 mm of the sample was submerged into water, and moisture sensors were placed at the following heights over water level: 100 mm (probe 00), 200 mm (probe 16), 300 mm (probe 32), 400 mm (probe 48), 500 mm (probe 64).

For the experiment it was applied the TDR (Time Domain Reflectometry) methodology, previously applied by the author of this paper for moisture determination in soils [13] and building materials and envelopes [14-17]. The application of the TDR methodology was strongly limited to soils and light building materials due to its invasive character and the necessity to install the measuring elements into the structure of measured barrier. This ran to measured material destruction and readouts falsification because of the steel elements internal installation.

To obtain the possibility of noninvasive, constant monitoring of the described phenomenon it was used an unique system of modified TDR probes (Figs. 2-4). The traditional TDR probes were reduced to measuring bars, which were separated with plastic dielectric material, that enabled to keep constant, parallel bars distribution and made it easier to attach the measuring elements to the sample. Measuring elements were made of brass angle-bars with the following dimensions: 200 mm (length), 10 mm (sides of the bars). Space between the bars was 40 mm and the total width of the probe was 60 mm. The terminations of the angle bars were connected to the concentric cable which distributed the electromagnetic signal from the described sensors to the TDR multimeter presented at Figure 2. Such prepared probes attached to the material sample and the whole measuring setup are presented at Figures 2 and 3.

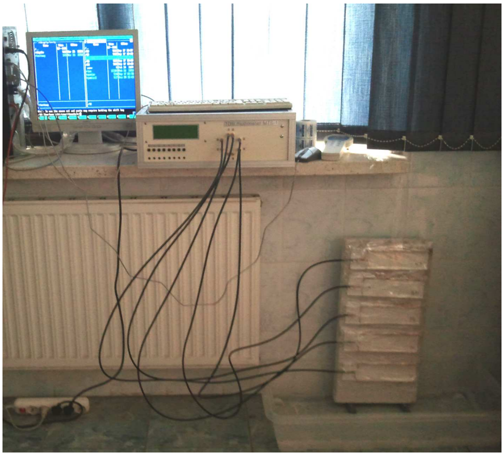

Fig. 2. Measuring setup during experiment

To avoid any influence of the external conditions on the sample and uptake process, the sample, together with the probes was covered with insulating foil. Sensors were connected to the typical TDR multimeter (EasyTest/Lublin/Poland) which was controlled by PC computer. Measurement sequence was repeated every 15 minutes and the readouts were made at each attitude (every probe). Modified system of the TDR probes required to elaborate special software which enabled to control the device and interpret the obtained results. The redouts from the multimeter were obtained as the TDR reflectograms, that, after suitable postprocessing (location of signal peaks and calculation of time intervals) and empirical calibration (Fig. 2) enabled to monitor moisture changes at each level of the examined sample.

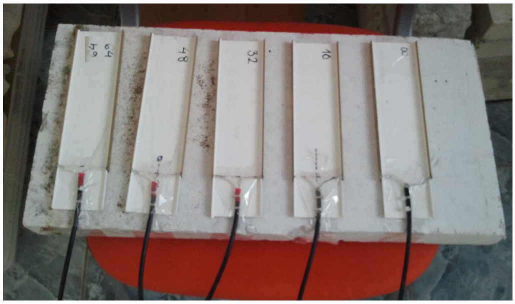

Fig. 3. Probes attached to the examined material

Results

Before the experiment started all probes were calibrated for moisture. Probe during calibration procedure is presented at Figure 4.

Fig. 4. Surface probe calibration for autoclaved calcium silicate

Calibration experiment of surface TDR probes is presented in the following paper [18]. After calibration procedure was conducted, the equation (1) was elaborated, which was then applied to recalculate moisture from the TDR readouts:

$$\Theta = -0.0023 \cdot t^2 + 1.4227 \cdot t - 127.74 \quad (1)$$

where: t - signal travel time along the angle bar of the sensor [ps], Θ - volumetric water content [% vol.].

The diagram presented at Figure 5 represents the progress of the water uptake phenomenon in Calsitherm sample. It is clearly visible that water quickly appears at Probe 00 placed 100 mm above water level. Rate of the moisture increase is very high and after 2 hours a state near maximum water content is reached. Moisture increase read by the above probes is postponed for average period of 5 hours but still is very rapid and quickly after water appears, maximum moisture is reached. Moisture increases appear after 4 hours at Probe 16, after 9 hours at Probe 32, after 13 hours at Probe 48 and finally after 20 hours at Probe 64.

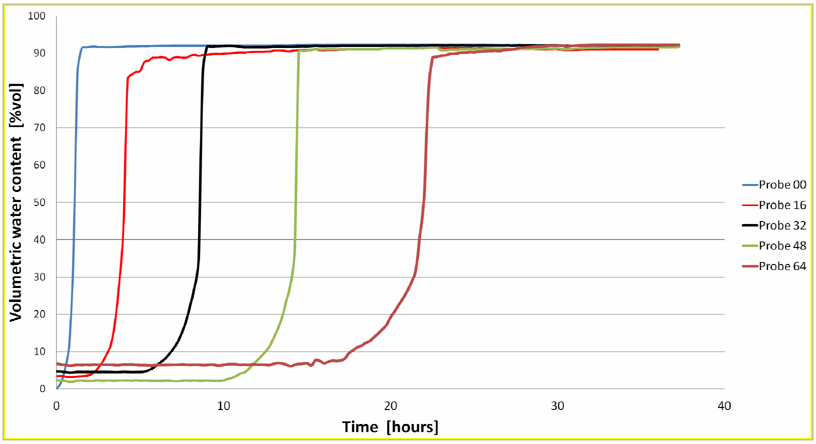

Fig. 5. Water uptake process determined in calcium silicate

Presented research confirms high water absorptivity of autoclaved calcium silicate (Calsitherm plates) declared by the producers and distributors. Modified TDR sensors confirmed that maximum water content for the described material exceeds 90% and maximum moisture states are achieved quickly after water appears. This confirms high capillary forces and unique capillary structure of the discussed material.

Conclusions

Basing on the conducted experiment the following conclusions may be drawn:

- described experiment proved high potential of the TDR method for monitoring of moisture changes phenomena in building materials,
- setup applied for the described experiment is unique and its application required modification of applied probes construction and special software,
- conducted research confirmed high water absorptivity of autoclaved calcium silicate,
- uniform porous structure causes a predictive water uptake process which runs rapidly and quickly after water appears, maximum water content is reached.

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MONITORING PROCESU PODCIĄGANIA KAPILARNEGO W SILIKACIE WAPIENNYM ZA POMOCĄ POWIERZCHNIOWYCH SOND TDR

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Abstrakt: Podciąganie kapilarne jest procesem dotykającym wiele obiektów budowlanych. Przyczyną jego występowania jest kapilarna struktura większości materiałów budowlanych. Zjawisko to polega na przepływie wody w kierunku niezgodnym z siłami grawitacji, wbrew ciśnieniu hydrostatycznemu. Omawiany problem podciągania kapilarnego jest szczególnie widoczny w przypadku braku poziomych i pionowych izolacji przeciwwilgociowych, ich uszkodzenia lub przy naturalnym ich zużyciu w czasie wieloletniej eksploatacji. Warunkiem wystarczającym do rozpoczęcia procesu podciągania kapilarnego wody do wyższych partii ścian jest styczność przegród budowlanych z gruntem o naturalnej wilgotności. Zjawisko to jest niezwykle niebezpieczne, ponieważ zasięg jego oddziaływania może osiągać nawet wysokość do 2,5 m od poziomu gruntu lub więcej w zależności od materiału budowlanego. Podciąganie kapilarne jest procesem szkodliwym, ponieważ prowadzi do degradacji przegrody, obniża jej właściwości konstrukcyjne oraz cieplne. Nadmierna ilość wody w przegrodzie jest przyczyną porażeń biologicznych budynków, z których najczęściej spotykanym problemem jest zagrzybienie. W artykule przedstawiono badania eksperymentalne procesu podciągania kapilarnego w próbce z autoklawizowanego silikatu wapiennego. Do badań zastosowano zestaw prototypowych czujników TDR, dzięki którym możliwy jest ciągły monitoring zjawiska w sposób bezinwazyjny.

Słowa kluczowe: podciąganie kapilarne, autoklawizowany silikat wapienny, powierzchniowe sondy TDR, monitoring