The moisture transport in the composite building material

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Abstract

The publication introduces technical knowledge of experimental measurements which were carried out by the transport of humidity in porous composite material in non-stationary conditions for description of moisture profiles with the help of measuring apparatus functioning on the non-destructive principle of electromagnetic microwave radiation. The aim is to verify the tested method of measurement for the description of moisture parameters on composite materials.

Mentioned composite material is experimentally made from more substances with different characteristics which together arrange resulting new feature, and which is not any from single composite (like the example composite building material – concrete, stone, cement, wood, ceramics etc). These materials are developed by Institute of Technology of Building Materials by Brno University of Technology and represents insulating building materials with filling masses of specific gravity.

Keywords: electromagnetic microwave radiation (EMWR), composite building material, transport of humidity

Introduction

The moisture in building structures influences physical properties of materials and can cause degradation of structures. Apart from several exceptions, building materials are hardly ever dry. They always contain some moisture in a solid, liquid or gaseous state. Moisture is a variable quality with different effects on thermal and technical properties of substances. To express an anticipated negative effect of moisture on building materials related to building structures it is necessary to accurately determine not only thermal and insulating properties of building materials, but above all their moisture characteristics. A parameter expressing moisture transport through capillary porous materials is referred to as the capillary conductivity coefficient.

Specific instruction

One of the properties of porous materials, which may be decisive for their utilization in a building structure, is their ability to absorb and release water. It is a case of moisture that flows through a material, saturates it, or drains it. The moisture content varies both in space and time. Many properties of a material (insulating value, strength, etc.) depend on its moisture content and therefore material moisture must be taken into account but in particular it must be checked and controlled.

Moisture transport in capillary porous materials is due to diffusion and capillary conductivity. Material moisture is represented by water content in the porous medium of a material and is expressed by the weight or volume parts of water in proportion to the solid phase of a material. Water penetrates a porous material from the environment and the equilibrium between the material moisture and the ambient air moisture is reached under steady temperature and moisture conditions. If the partial pressure of water vapor in a building material is lower than that in the ambient air, then the material absorbs water vapor from the air. Conversely, the material releases water vapor. Equilibrium moisture is characterized by zero increment of weight and temperature in time. An impact of moisture on coefficients of thermal conductivity varies according to the concrete temperature and moisture content of a material.

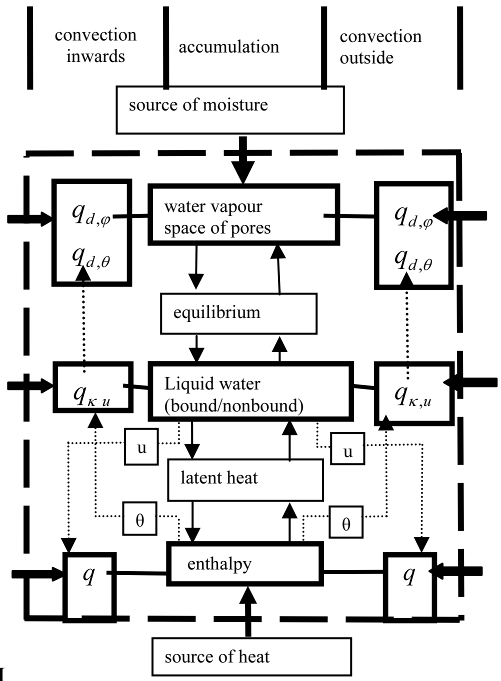


Fig. 1. **Model of impact of external influence on porous. Material [1]**

Fig. 1 shows a model of impact of external influences on porous materials. The moisture conductivity coefficient is a central quantity of transportability depending on water content. Material processes are accelerated by water vapor diffusion driven by temperature gradient, and due to an increased temperature gradient, diffusion is increased as well.

Capillary conductivity coefficient

The capillary conductivity coefficient can be calculated by using the Matan method. For the application of the method it is sufficient to know one wetting curve (see Fig. 2), i.e. time elapsed from the start of the experiment and the coordinates indicating the moisture front profile, which correspond to the given curve. The method employs Boltzmann transformation, which can be used in case of short time intervals, when the boundary condition at the dry end of a specimen does not become evident yet. The solution of the partial differential equation, found by combining the continuity equation and Lykov's equation for flux density, is converted in a common differential equation.

$$\kappa(u(x)) = \frac{1}{2tu'(x)} \cdot \int_x^\infty \xi \cdot u'(\xi) d\xi \quad [\mathrm{m^2.s^{-1}}], \; [3], \qquad (1)$$

where: κ ($u(x)$) is the capillary conductivity coefficient [$\mathrm{m^2.s^{-1}}$], t- the time interval [s], ζ - the substitution of the distance measured along the specimen length from the point on the curve representing wetting front du, x - the coordinate in the length of specimen [m], u' - the derivation of moisture η the transformation denoted as Boltzmann coordinate [$\mathrm{m.s^{-1/2}}$]

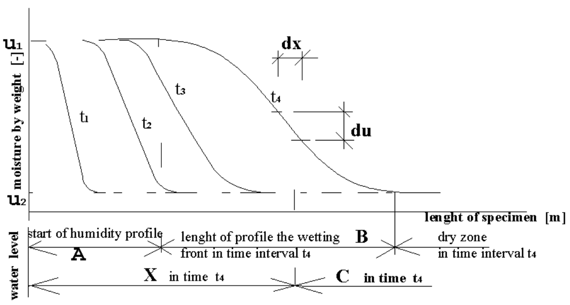


Fig. 2. **Wetting profiles $u(x)$ at time intervals t_x during moistening of the measured specimen marking initial and boundary conditions for determination of the moisture conductivity coefficient [2].**

Fig. 2 demonstrates an anticipated course of wetting curves at time intervals t_1 to t_4 from the start of moistening, and specification of boundary conditions for calculation of the moisture conductivity coefficient κ. Along the x axis are plotted lengths as coordinates at the distance from the point of contact of the measured specimen with free water level: A is the coordinate of start of the moisture front profile and B is the coordinate of the length of the wetting front. C is the coordinate into the dry region → ∞. Along the vertical axis are plotted the values of moisture by weight, u_2 is moisture by weight in the measured specimen and u_1 is moisture by weight in the measured specimen after moistening.

Measurement of wetting profiles by help of EMWR

In order to measure the input data needed for calculation of capillary conductivity coefficient, researchers at the Department of Building Constructions, Brno University of Technology developed the measuring apparatus - Fig.3.

Fig. 3a. **Apparatus experimentally assembled at the Brno University of Technology**

The apparatus utilizes electromagnetic microwave radiation. It measures transmittance of radiation that passes through a specimen with a defined thickness of 20 mm, which depends on the moisture content in a specimen. The apparatus is designed in such a manner that a specimen of porous material is fixed between the transmitting and receiving waveguides. The smallest base of the specimen must be in contact with water level. Water rises up through the specimen and the beam of EMWR passes through the thinnest side of the tested specimen in the direction that is perpendicular to the direction of capillary elevation. The height of the microwave beam from water level can be continuously changed by the motor drive of waveguide travel. To achieve the most efficient monitoring of rising moisture transport in the material, unambiguous and defined initial and boundary conditions have been set.

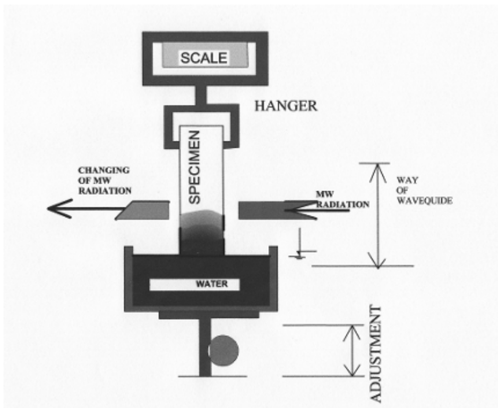


Fig. 3b. **Principle of detection of wetting curves by measuring Apparatus []**

Moisture gradient

Liquid moisture that accumulates in a building construction as a result of water vapor condensation is carried into its surrounding. This movement of liquid moisture depends on the moisture conductivity coefficient, as well as the moisture gradient (du_m / dx):

$$q_{t,1} = -\kappa_m . \rho_s . \frac{du_m}{dx} \quad [\mathrm{kg.m^{-2}.s^{-1}}], \; 3] \qquad (2)$$

where u_m - gravimetric moisture of material [%], ρ_s -dry mass density [kg.m^{-3}], κ_m - capillary conductivity coefficient [m^2.s^{-1}]

The equation in (2) expresses the directly proportional relationship between the density of the mass flow of liquid water with a moisture gradient, the volume mass of the dry material and the moisture drop (which is the negative value of the moisture gradient). The moisture conductivity coefficient with a moisture gradient (κ_m) is in fact a coefficient of proportionality.

Testing materials

We deal with the samples of materials, produced based on the waste products usage. The used samples are marked "R" concrete samples and "H" materials samples. Please check the Fig. 01. The development of such materials is based on the composite materials (i.e. recycle concrete using the natural aggregate).

Material characteristic is porous structure as well as inert homogenous material. The homogenous material includes aggregate gradation in range 0 up to 8 mm. or possible in range 4 up to 8 mm when used porous gravel.

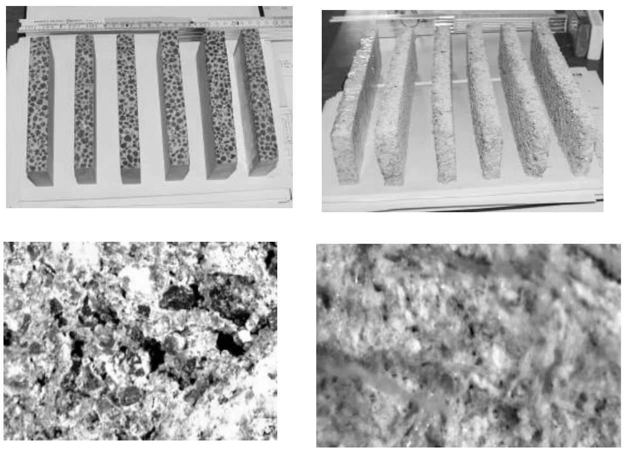


Fig. 4. **Material samples developed at Department of Building Materials University of Technology by Brno – "R" concrete (left), "H" material (right)**

The "H" material represents soft isolative mass with fibrous filling of specific gravity. The usage of the mentioned materials in building activities is based on the material characteristics and attributes. These items are subject for the following examination.

The experimental measurement of the moisture parameters is based on the observation of the liquid moisture transport. It allows us to realize moisture curves, needed for the calculation of the capillary conductivity coefficient using the non-destructive method.

The moisture flow that has been described above may be applied as a concept only in situations where we are able to determine either the moisture values for the different layers of the building construction, or the moisture gradient (either by means of measurement or calculation). If the moisture gradient is effective over time (τ), we are able to calculate the total amount of liquid water that passes through the material:

$$m_v = \kappa_m . S . \frac{du_m}{dx} . \rho_s . \tau \quad [3]. \tag{3}$$

Moisture transport in composite material

For the testing of the mentioned behavior was used measuring instrument built up by experiment. We tested time behavior of moisturize by observing water intake through samples imbibitions. There were used "R" concrete samples and "H" materials samples to record moisture front profile position (Fig. 2). Sample size 150×19×60 mm and specific gravity "R" concrete 2150 kg/m^3 and "H" materials 850 kg/m^3.

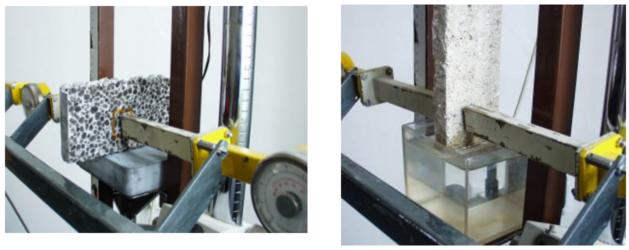


Fig. 5. **"R" concrete and "H" material samples during recording of the moisture front profile position**

Graphical output of the measurement is at the Fig. 6. There is captured position of the moisture front profile in the particular time period from the start of the imbibitions. The process of imbibitions was done by close contact of lower sample's surface (placed in the measuring equipment) with the liquid area.

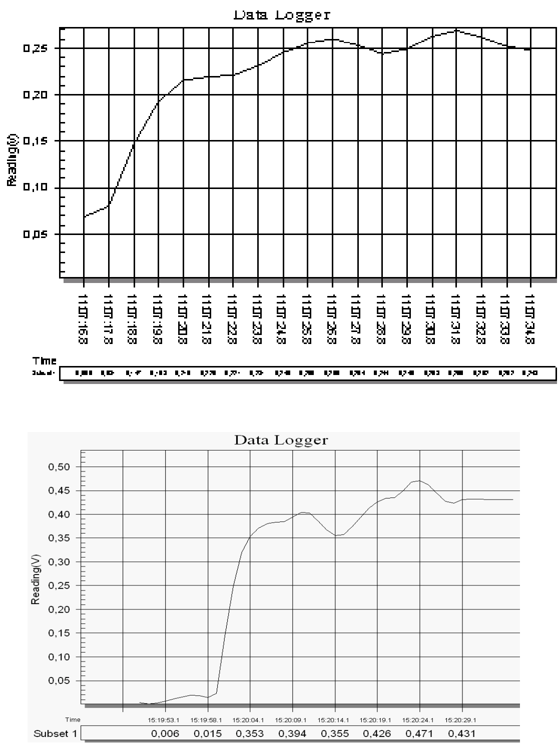


Fig. 6. **Graphical output of measurement "R" concrete and "H" material samples**

Data taken from the graph 6 are set as an input data to determine position of the moisture front profile during the sample moisturize of "H" material. The following step is the calculation of the obtained figures covering intensity EMWR changes dependency according to the specific moisture during the waveguide shift through the observed material's (Fig. 7).

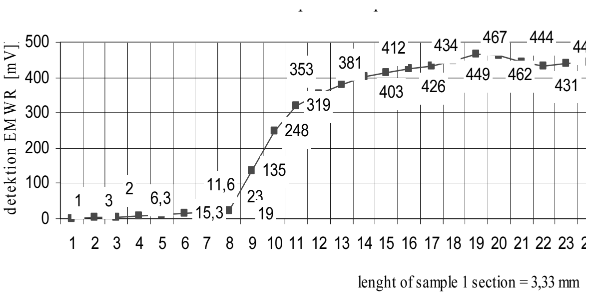


Fig. 7. **Length information from the sample "R" concrete**

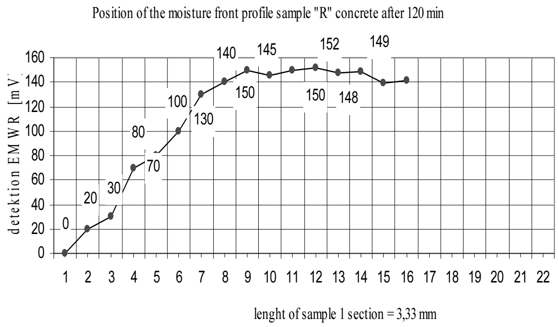
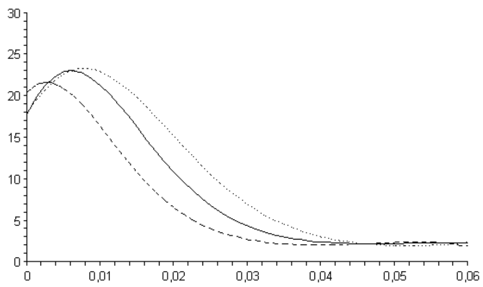


Fig. 8. **Length information from the sample "H" material**

Weting curves

Based on the above mentioned measurements, we are able to express moisture curves (according to the methodology) as a base to calculate capillary conductivity



coefficient κ

Fig. 9. **Wetting curves [5]**

Wetting curves are determined as graphs of complex functions, which are established by combining the functions from previous calculations. Graph plotting of functions expressing dependence of moisture content on the distance from the moisture source.

Conclusion

For practice it is necessary know moisture characteristics of building materials for their assessment in applying in the construction. Manufacturers these data generally show in for materials in dry state.

Standards made reference to moisture problems, but only how informative notice. Explored is only diffusion process without liquid water in porous material and for simple application is useless.

The verification of the electromagnetic microwave radiation usage to detect moisture movement into the porous material, using the measuring instrument built up by experiment, will give us the assumption for the next material characteristic information. Such non-destructive way to define moisture position allow us obtain continuous figures of the continual measurement. We can process the results of the measurement using the well-known mathematical operations.

There were measured tested samples of the composite material to obtain moisture parameters based on the theoretical hypothesis. We deal with the absorption of moisture. The results of the measurement should help us to define the capillary conductivity coefficient, one of the material specific quantities.

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Drėgmės sklidimas kompozicinėse statybinėse medžiagose

Reziumė

Pateiktieji eksperimentiniai matavimų rezultatai gauti tiriant drėgmės sklidimą poringame kompoziciniame betone nestacionariomis sąlygomis. Tam tikslui buvo panaudotas neardomasis metodas, pagrįstas mikrobangine spinduliuote. Tiriamosios medžiagos buvo sukurtos Brno technologijos universiteto .Statybinių medžiagų ir komponentų technologijos institute. Tiriamieji bandiniai buvo atrinkti pagal jų panaudojimą.

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