A Transient method for determination of water diffusion coefficient of building materials as function of relative humidity

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Introduction

- Commonly used methods

  - Steady state method

    - time consuming

    - single value of water vapour properties

      diffusion resistance factor

      diffusion permeability

      diffusion coefficient

European standard EN ISO 12571 (2001)

- Requires measurement using traditional cup method with three pairs of relative humidity, 0/50%, 0/80% and 50/93%
- Similar procedure can be foun in American standard

- American standards ASTM E96 (1995)

    - Specific 2 relative humidity conditions, 25% and 75 %

This method can be recommended for manufactor's testing.

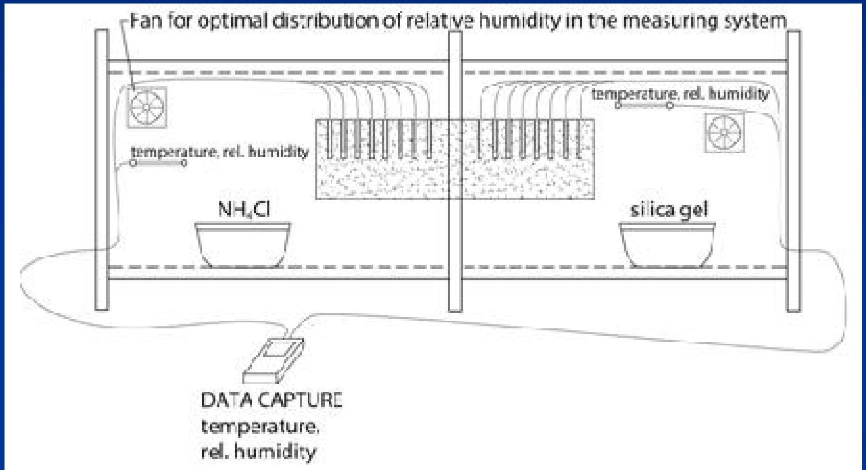
This information are inadequate for detailed hygrothermal analysis of building component.

Water vapour diffusion properties are parameters depending on the relative humidity in material

Therefore, new transient method for determination of water vapour transport parameters is developed and tested

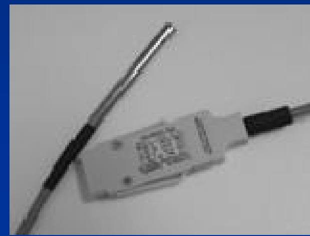
Description of developted transient method

- Exposing a material specimen to the difference climate conditions
- Monitoring the relative humidity field in the specimen
- Isothermal conditions



Measuring device

- Two airtight plexiglass chambers
- Separated by a sample
- First chamber RH close to 0%



- Basic advantage:
  - Relative humidity profiles, use inverse analysis of heat and liquid moisture transport
  - Boltzmann-Matano treatment was used

Computational evalution of transient diffusion experiment

- Boltzmann-Matano treatment

$$\frac{\partial \rho_v}{\partial t} = \frac{\partial}{\partial x}\left(D(\rho_v) \frac{\partial \rho_v}{\partial x} \right)$$

- with the boundary condition

$$\rho_v(0,t) = \rho_{v1} \qquad (3)$$

- and the initial condition

$$\rho_v(x,0) = \rho_{v2} \qquad (4)$$

Where

ρv	partial water vapour density (kg/m3),
x	distance along the longitudinal sample axis (m),
D	water vapour diffusion coefficient (m2/s),
t	time (s).

- Using the Boltzmann transformation
- $$\rho_v(x,t) = \varpi(\eta), \qquad (5)$$
- $$\eta = \frac{x}{2\sqrt{t}} \qquad (6)$$
- equation (1) can be converted into the ordinary differential equation with the new parameter η
- $$\frac{d}{d\eta}\left(D(\varpi)\frac{d\varpi}{d\eta}\right) + 2\eta\frac{d\varpi}{d\eta} = 0 \qquad (7)$$
- with the boundary conditions
- $$\varpi(0) = \rho_{v1} \qquad \varpi(\infty) = \rho_{v2}$$

If the partial water vapour density distribution is known at the time t = t0, i.e., we know the function ϱv(x,t0), then using the integration of equation (7) and assuming the zero water vapour flux for $\eta \rightarrow \infty$, we arrive at the water vapour diffusion coefficient as a function of the partial water vapour density in the form

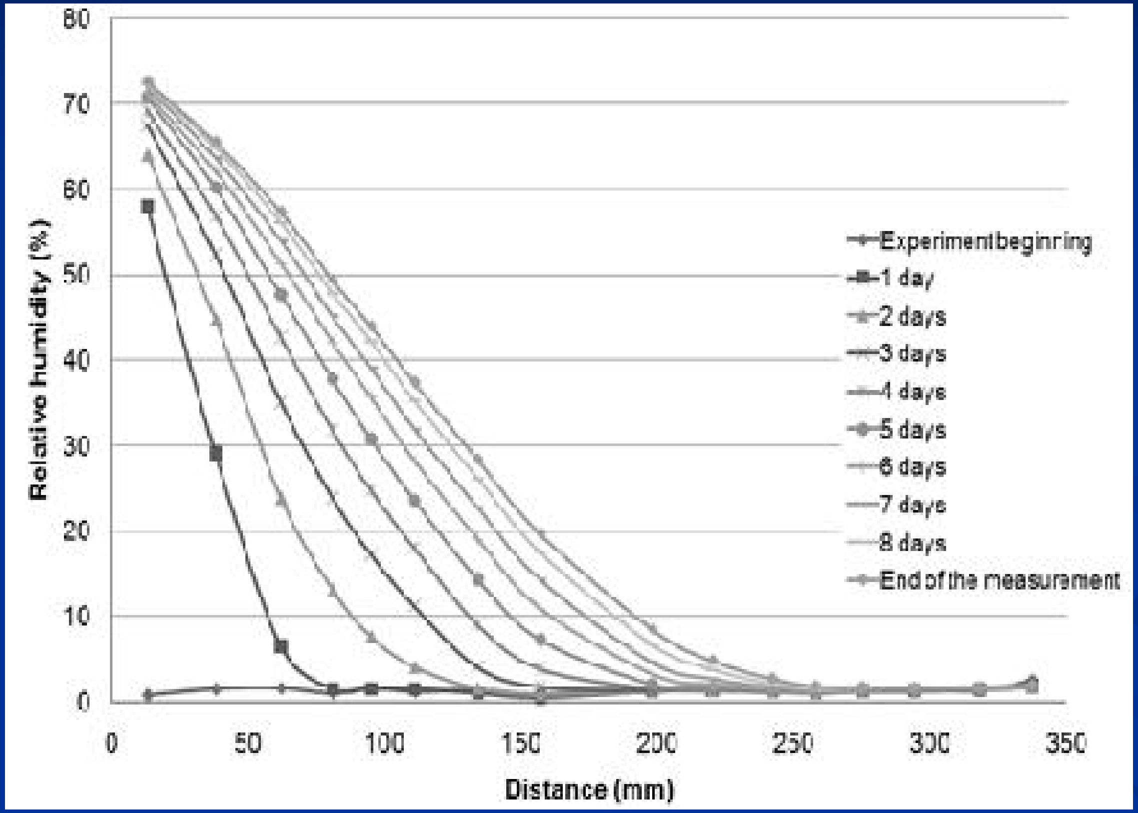
$$D(\rho_v(x_0,t_0)) = \frac{1}{2t_0\left(\frac{d\rho_v}{dx}\right)_{x_0}} \int_{x_0}^{\infty} x \frac{d\rho_v}{dx} dx$$

As there is an explicit relation between the partial water vapour density and relative humidity which can be easily derived using the equation of state of an ideal gas and the definition relation for relative humidity, under isothermal conditions we can write the final formula for the calculation of water vapour diffusion coefficient as

$$D(\varphi(x_0,t_0)) = \frac{1}{2t_0\left(\frac{d\varphi}{dx}\right)_{x_0}} \int_{x_0}^{\infty} x \frac{d\varphi}{dx} dx$$

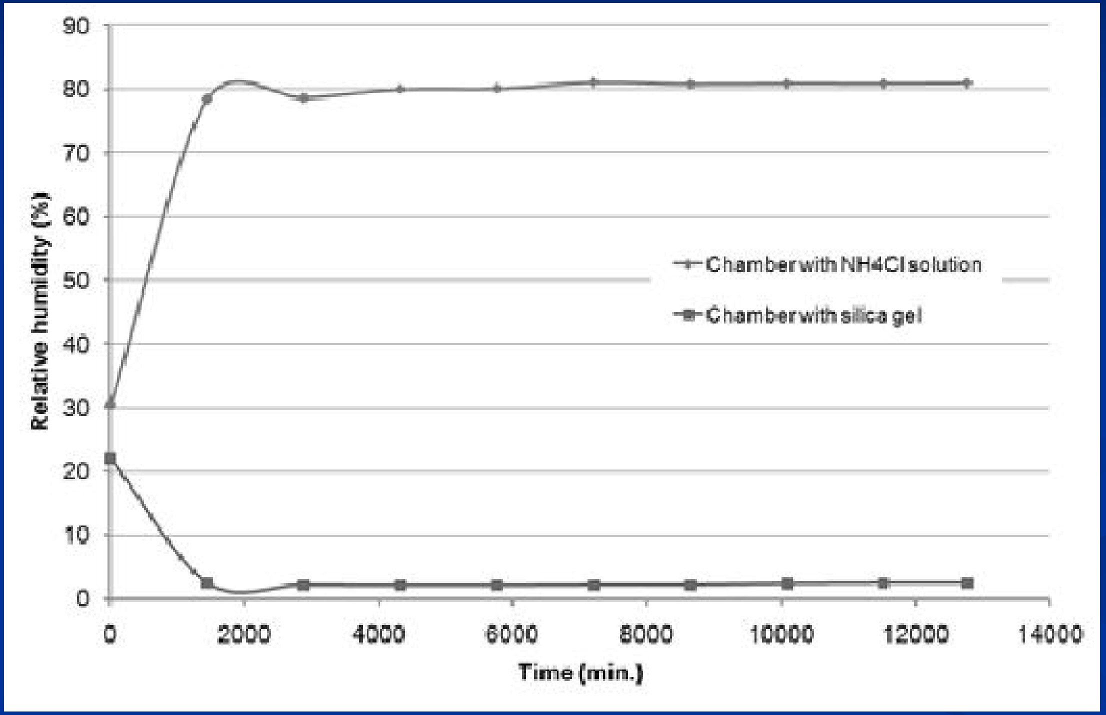
Experimental results

Relative humidity distribution



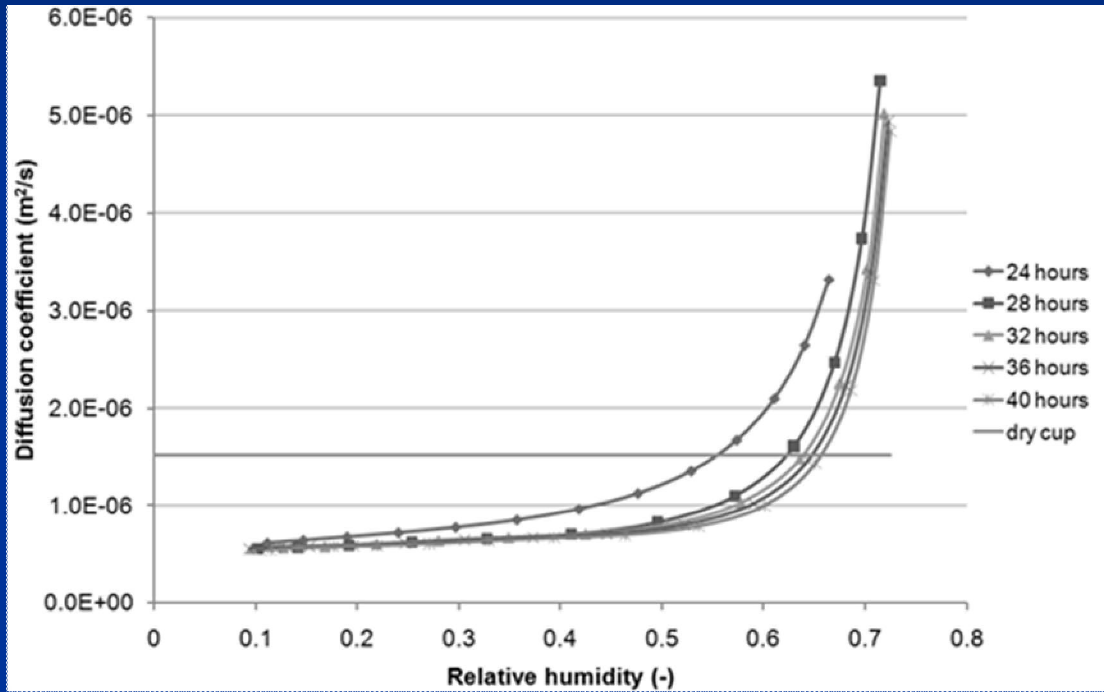
In figure, there are presented relative humidity fields measured within the transient experiment. We can see relative humidity distribution along the sample length caused by difference conditions of simulated environments.

Relative humidity in separated chambers



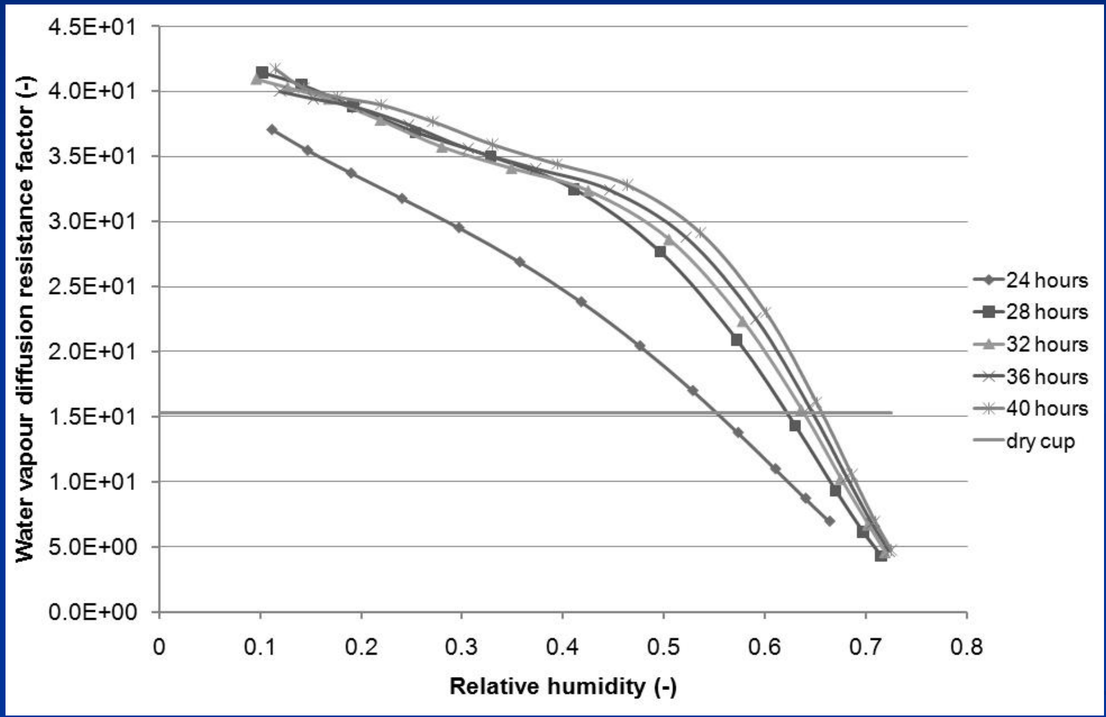
We can see that the distribution of relative humidity in the separated chambers simulated by specific saturated salt solutions was after certain time from the experiment beginning (typically after 16 hours) relatively well constant. This is very important finding, because it validates the proper conditions of the experiment.

Water vapour diffusion coefficient



there are presented results of water vapour diffusion coefficient and resistance factor calculated using inverse analysis of measured relative humidity fields. Here, the data accessed using standard dry cup method is given as well.

Water vapour diffusion resistance factor



Conslusion

- Newly developed transient method for determination of water vapour transport properties of porous building materials was introduced and tested.
- The method allows determination of water vapour transport properties as function of relative humidity what is necessary for practical application of building materials in real conditions of buildings, where they are exposed to changes of climatic conditions.
- However, one must take into account that the presented transient method was tested on one material only, which makes the obtained data merely preliminary. For drawing more decisive conclusions, experiments for a wide class of materials have to be done.
- On the other hand, one can assume good perspectives of the developed method in building physics research.

- Thank you for your attention