MEASURING OF WATER VAPOUR DIFFUSION OF NANOFIBRE TEXTILES

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Abstract

Properties related to moisture vapor transmission rate through membrane are important in many branches also in building constructions. This article deals with comparison two methods of measurement water vapour diffusion flow through nanofiber textiles. One of the parameters for comparison of different sheet materials for its ability to brake the water vapour is an equivalent air layer thickness value S_d. The equivalent air layer thickness S_d [m] expresses the thickness of the air layer, which would have the same diffusion resistance as the measured material in certain thickness. It is necessary to choose the appropriate measurement method for determining the value S_d with diffusion open materials such as nanofiber materials. This article compares the outcomes of two measurement methods - Dry Cup Method according to EN ISO 12 572 and Tube Method. The measurements were carried out on a sample from nanofiber textiles based on PUR.

Keywords: Nanofiber textiles, moisture vapor transmission rate, PUR, dry cup method

1. INTRODUCTION

Nanofiber textile is an interesting material for building structures primarily because of the low water vapour resistance and because of its chemical properties, which can be in curtain range modified [1, 2]. We premise nanofiber textiles have low diffusion resistance due to their structure and therefore is this material suitable for special application - pitched roof underlay, wood protection, restoration material [3]. Equivalent air layer thickness is in construction mostly determined by „Wet Cup Method" or „Dry Cup Method" according to EN ISO 12 572. This method is suitable for building materials with higher value of equivalent air layer thickness S_d (>10 cm). The S_d value is higher if water vapour penetrates more difficult through the material. It is possible to eliminate some measurement inaccuracy by adjusting the measuring method. The modified methods are suitable for materials with low value of diffusion resistance. This modified method should be used also for more accurate measuring and monitoring the differences between materials with small differences in their properties (basis weight, base material, production parameters etc.).

2. METHODOLOGY

2.1. The Dry Cup Method and the Wet Cup Method.

These methods are based on natural water vapour flow through the sheet material placed on the neck dish which is placed in a desiccator. There is maintained approximately the constant environment in the desiccator and in the dish (relative humidity). Diffusion flow is calculated from the weight gain (the Dry Cup Method) or weight loss (The Wet Cup Method) of agent in the dish. The Dry Cup Method is shown in **Figure 1**. It appears several influences which cause inaccuracies in measurements in this measuring method. For example, inhomogeneity environment in the desiccator, uncertainty parameters of the environment in the cup or in the desiccator (when it's not measured), resistance to water vapour transfer on both sides of the sample, changes of environment in desiccator during weighing the dish, the diffusion flow between the dish and the surrounding environment during the weighing. Dry Cup Method is suitable for testing of multiple samples simultaneously, which leads to time saving [4].

2.2. The Tube Method.

This method is based on the utility model "Device for experimental non-stationary determination of material parameters describing transportation of water vapour in porous building materials" (hereinafter Tube Method) [5]. Modification of this method compared with standardized method involves changing weighing system, continuous monitoring and homogenization the environment on both sides of the sample. The laboratory balances are placed directly below the bowls with humectant and desiccant. This allows continuous monitoring of weight gain and weight loss on both bowls. This modification eliminates the uncertainty caused changing defined environment during the weighing and inaccuracy caused by diffusion flow between the environment in the dish and the surrounding environment during the weighing. Placing of continuous temperature and relative humidity gauges in each environment enables accurate quantification of partial water vapour pressure between the two environments. Homogenization of environment on both sides of the sample is achieved by placing the circulating fans. The measuring device is shown in **Figure 2**.

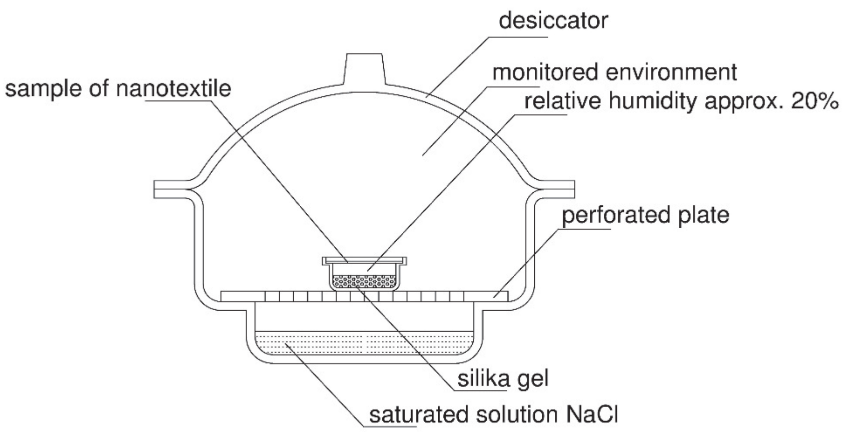

Figure 1 Dry Cup Method according to EN ISO 12572

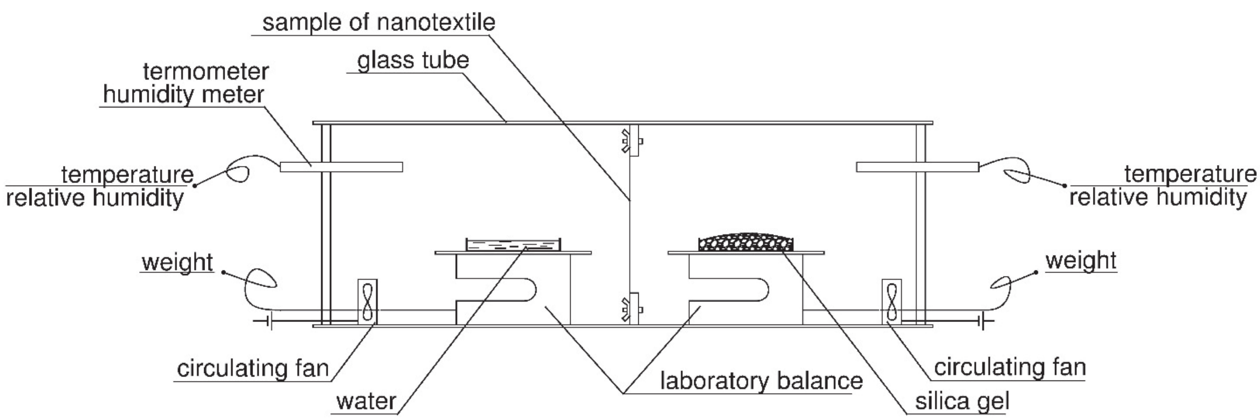

Figure 2 Tube method

2.3. Calculation.

Calculation of the equivalent air layer thickness is derived from Fick's law of diffusion. Measurement provides us parameters of the internal environment, weight gain respectively weight loss on the laboratory balances, the interval of time between two readings of values and the area of the sample. Then we can calculate the water vapour flow and consequently the equivalent air layer thickness according to the Equation 1.

$$S_d = A \cdot \tau \cdot \Delta p \cdot \delta_a \cdot \Delta m^{-1} \tag{1}$$

Where S_d is equivalent air layer thickness [m]; A is area of the sample [m²]; τ is time interval between two readings of values [s]; Δp is difference of partial water vapour pressure [Pa]; δ_a is diffusivity of water vapour in air [kg/(m.s.Pa)]; Δm_i is weight difference (1 - weight gain, 2 - weight loss) [kg].

3. RESULTS

Measurement was carried out on a nanofiber textile made by electrostatic spinning of PUR polymer solution on the Nanospider™ - NS 4S1000U (manufacturer Elmarco s.r.o., Czech Republic). The basis weight of the textile was determined gravimetric and is 17.7 ± 0.5 g/m2. Equivalent air layer thickness was calculated from the measured values from measurement by the Dry Cup Method and the Tube Method. In the case Dry Cup Method was used as the wetting agent a saturated aqueous solution of sodium chloride, in case of the Tube Method it was used distilled water. In both cases it was used silica gel as a desiccant agent. It was measured relative humidity and temperature on wet side of the sample, on the second side of the sample we presume relative humidity up to 20% based on previous experiments. It was monitored both internal environments around the sample by Tube Method. Two samples were measured together by the Dry Cup Method. It was measured only weight gain of desiccant agent by the Dry Cup Method (no loss of wetting agent). In this experiment there were collected 9 values. One sample was measured by the Tube Method. Totally it was collected 22 values of weight gain of desiccant and 22 values of weight loss of wetting agent by measuring by the Tube Method.

The results of the first and second measuring methods are shown at the **Figure 3** and **Figure 4** below.

Measurements showed a very low value of equivalent air layer thickness of the PUR nanofiber textile. Equivalent air layer thickness of the textile with a basis weight 17.7 ± 0.5 g/m², including water vapor transfer coefficients on both sides, was 0.003 m by the Tube Method. The flux of water vapour was stabilized circa after 2 hours by this method. Equivalent air layer thickness of the same sample using Dry Cup Method was approximately 0.03 meters. The water vapour flux was stabilized after approximately 2 hours and it decreased in time. Accuracy of carried out measurement is shown in **Figure 5** below.

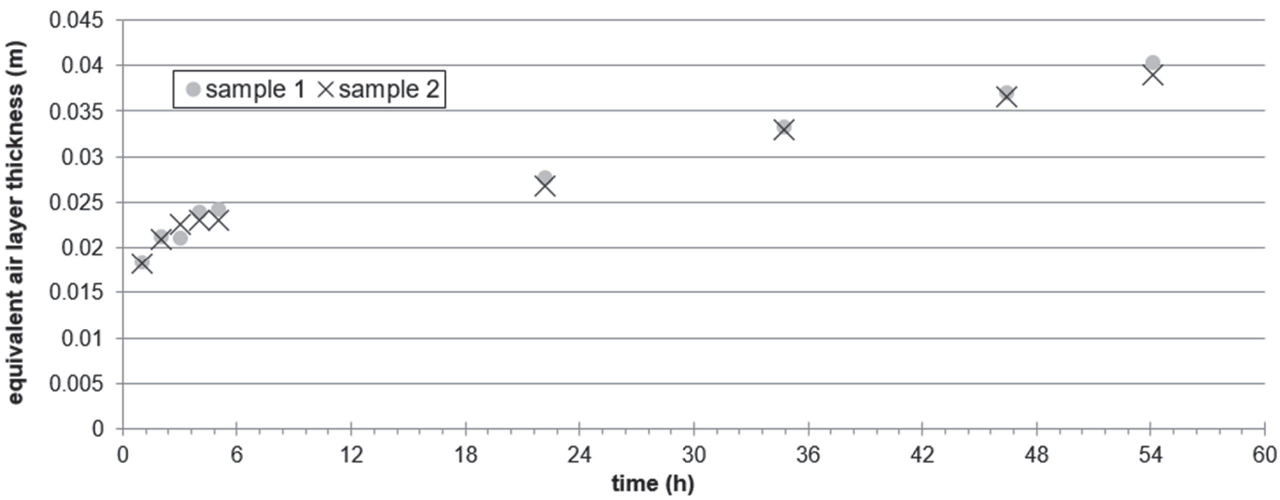

Figure 3 Measured values of equivalent air layer thickness [m] of PUR nanofiber textile by Dry Cup Method

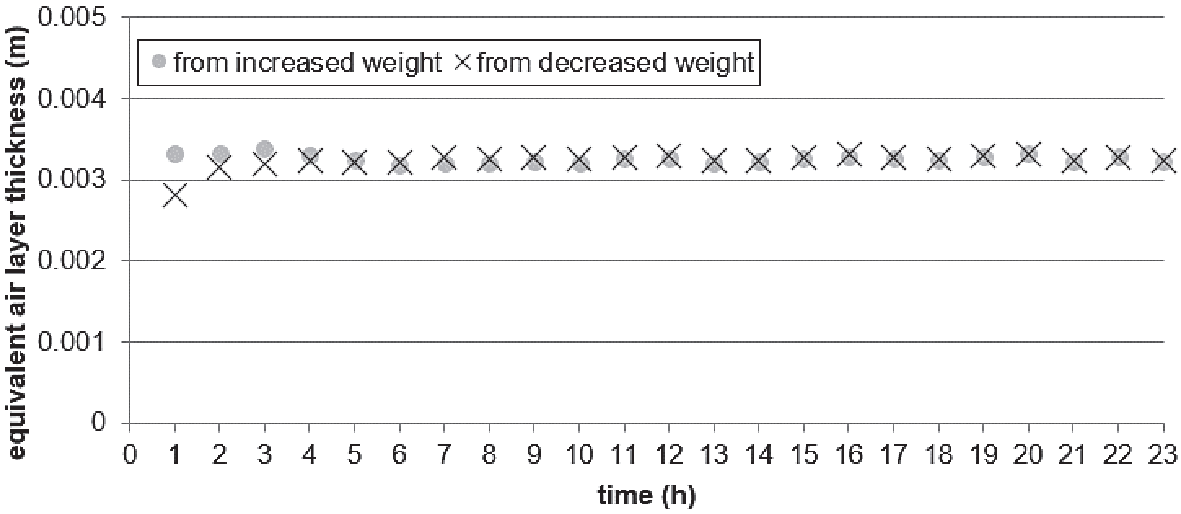

Figure 4 Measured values of equivalent air layer thickness [m] of PUR nanofiber textile by Tube Method

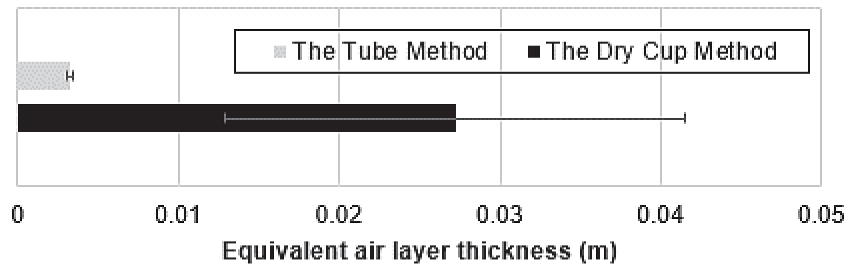

Figure 5 Measured values of equivalent air layer thickness, comparison of two methods

4. CONCLUSION

These measurements by two methods showed huge large differences in measured values. The discrepancy between the measured equivalent air layer thickness values comes probably from different water vapour transfer resistances on both sides of the sample (different speed of air flow around the sample) and from an uncertainty in relative humidity of environment on the dry side with desiccant agent by Dry Cup Method (parameters of the dry environment were measured only by Tube Method). Water vapour can be also transfers by convection (not only by diffusion) due to ventilation fans placed in the chamber by the Tube Method. The measured values are in agreement with the measurement of Hlaváč R. et al. [6] where are measured very low value of diffusion resistance of nanofiber textiles. Their measured values equal approximately to the measurement uncertainty.

Tube Method shows consistent results and it can accurately measure the water vapour flow over time. Water vapour transport by convection can be excluded this measuring method. When the first set of test measurements carried out, it was found that it is essential to seal both chambers of the measuring device, including all cables and probes penetrating through the water vapour-tight envelope of the chambers.

Results of the Tube Method have higher scattering of values and there enters the uncertain values in the calculation of the equivalent air layer thickness (relative humidity on both sides of the sample, uncontrolled transfers of water vapour during weighing etc.).

The Tube Method is suitable for measuring the water vapour transport of a diffusion open materials. It requires a more precise determination of material properties about spreading of water vapour. Accuracy of the equivalent air layer thickness by this method is likely to grow with increasing airtightness of measured material (water vapour transfer by convection is limited). Influence on the equivalent air layer thickness values of water vapour transfer resistance by both sides of the sample is higher by Dry Cup Method.

It is suitable to use a Tube Method with monitoring environmental parameters on both sides of sample, continuous weighing and homogenizing environment that does not cause higher air speed close to the measured sample for more accurate measurement of equivalent air layer thickness of nanofiber textiles.

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REFERENCES

[1] TEREBESYOVÁ, M., RYPAROVÁ, P., KUKLÍK, P. Biocidal Properties of Nanotextiles Doped with Fungicides against Dry Rot Fungus Serpula Lacrymans. In *PROCEEDINGS OF THE 6TH INTERNATIONAL CONFERENCE ON MECHANICS AND MATERIALS IN DESIGN*, *6th International Conference on Mechanics and Materials in Design*. Porto: Universidade de Porto. 2015, pp.1327-1334.

[2] HAVRLÍK, M., SVESHNIKOV, A., KLICMANOVÁ, I., Determination of Structure of Polymer Nanotextiles. In *DEVELOPMENT OF MATERIALS SCIENCE IN RESEARCH AND EDUCATION*, *Development of Materials Science in Research and Education - DMSRE 25*. Prague: Czechoslovak Association for Crystal Growth. 2015, pp. 33.

[3] RÁCOVÁ, Z., HLAVÁČ, R, MUKAŘOVSKÝ, J., NEŽERKA, V., RYPAROVÁ, P., TESÁREK, P. The Use of Nanomaterials as Protection of External Surfaces of Porous Building Materials. In *CESB 13 - CENTRAL EUROPE TOWARDS SUSTAINABLE BUILDING 2013*, *Central Europe towards Sustainable Building 2013.* Prague: GRADA PUBLISHING. 2013, pp.441-444.

[4] STANĚK, K., KOPECKÝ, P. Apparatus for laboratory measurement of water vapor diffusion resistance factor of building materials by the cup method, Functional Sample. 2012.

[5] PAVLÍK, Z., PAVLÍKOVÁ, M., ČERNÝ, Z. Utility model 21744, Device for experimental non-stationary determination of material parameters describing transportation of water vapor in porous building materials, writted on 10.2.2011.

[6] HLAVÁČ, R., SOUČEK, J., TICHÁ, P., BENDOVÁ, T. Moisture-vapour Permeable Surface Treatment Used on Wooden Construction, Dřevostavby 2014 (2014) 225-230.