

Experimental Comparison of Construction Material Vapor Permeability in Case of Horizontal or Vertical Sample Position

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Abstract. The paper proposes a device for vapor permeability coefficient determination in case of vertical sample position. The device is a L-type section capacity with a window in upper part of long side of the capacity. A test sample of construction material is positioned vertically and sealed in the window. The capacity has built-in relative air humidity sensors distributed along capacity height. These sensors allow measuring height-average relative air humidity. Experimental vapor permeability coefficient values, obtained by means of the proposed device and by means of well-known wet cup method, have been compared. Rock wool has been used as a test material. As a result, wet cup method has been confirmed for vapor permeability coefficient determination for vertical enclosing structures.

1. Introduction

Enclosing structure moisture regime studies are actual at present. There are both theoretical researches concerned with moisture regime calculation for various enclosing structures [1,2,3,4,5,6], and experimental studies of moisture diffusion coefficients [7,8]. Correct assessment of enclosing structure moisture state allows to determine building heat losses during operation [9,10,11,12,13,14], and moisture effect on life of the building [15,16,17,18,19]. Results of theoretical and experimental studies are controlled by means of field moisture measurement of constructed buildings [20,21] using various devices [22,23,24].

Vapor permeability coefficient determination under service conditions is one of the most important issues in enclosing structure moisture state study. Vapor permeability coefficient determination methods - wet cup method and dry cup method –are the most popular methods at present [25].

There are researches studying vapor permeability coefficient dependence on temperature [26]. Vapor permeability kinetics under different temperature during unsteady sample moistening with water vapor has been studied in the paper [27] using gamma-radiation and infrared thermography methods. An interesting approach has been proposed in papers [28,29]. Vapor permeability coefficients have been measured in a special device under reduced atmospheric pressure, thus, experiment time has reduced considerably.



The work [30] has carried out several experiments on vapor permeability coefficient under air flow directed along construction material surface. Dependencies between vapor permeability coefficient and air flow ambient velocity have been obtained. Work results can be useful for moisture regime calculation of suspended facade systems.

2. Problem

The test sample is positioned horizontally in almost all vapor permeability coefficient studies at present. But enclosing structures positioned vertically (for example, building walls) are used in construction. Vapor permeability coefficient of such structures is considered to be equal to the coefficient for horizontal structures in moisture regime calculation.

This work aims to carry out experimental studies to find out vapor permeability coefficient variation for horizontal and vertical sample position.

3. Materials and methods

An experimental device [Fig. 1, Fig. 2] has been built. The device is a L-type section capacity with a window in upper part of long side of the capacity. A test sample of construction material is positioned vertically and sealed in the window.

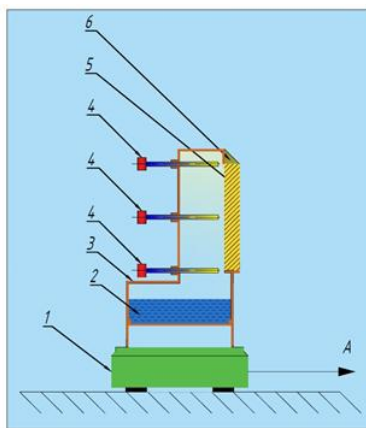


Figure 1. Scheme of vapour permeability coefficient measuring device in case of horizontal test sample position (1 – electronic scales, 2 – water, 3 – device case, 4 – relative air humidity sensors, 5 – test sample, 6 – sealing compound, A – link between electronic scales and computer).

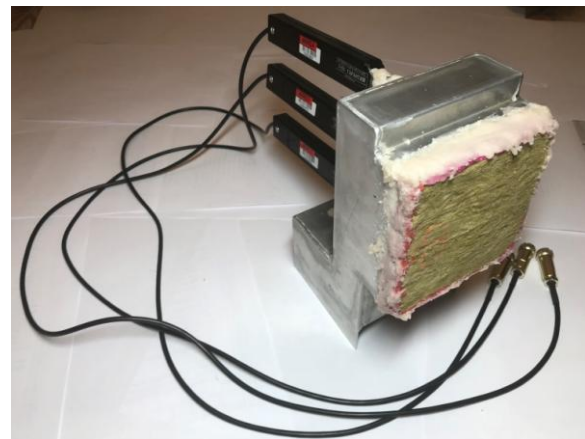


Figure 2. Device for vapor permeability coefficient measurement in case of horizontal test sample position (rock wool sample is in the device).

The capacity has built-in relative air humidity sensors distributed along capacity height. Thus, vertical sample position, i.e. position, corresponding to actual construction material position in building wall, allows test air flow influence simulation similar to building service conditions. Built-in relative air humidity sensors distributed along capacity height allow measuring average relative air humidity along the sample height. As a result, it is possible to measure construction material vapor permeability in case of vertical sample position.

The device is installed on electronic scales connected to computer. Three relative air humidity sensors located inside the experimental device, and one temperature and relative air humidity sensor located outside the device, are also connected to computer. The computer in automatic mode records mass variation of the device with a sample received from scales, and also records temperature and relative air humidity readings received from sensors [Fig. 3].



Figure 3. General view of the device connected to computers.

Material vapor permeability coefficient is defined by well-known relation:

$$\mu = \frac{\delta}{R}. \quad (1)$$

where δ – test sample thickness, m ; R – vapor permeability resistance, $Pa \cdot s \cdot m^2/kg$.

Vapor permeability resistance is determined by formula:

$$R = \frac{e_{in} - e_{ext}}{g} - \frac{d_{air}}{\mu_{air}}. \quad (2)$$

where e_{in} – water vapor partial pressure inside the device, Pa ; e_{ext} – water vapor partial pressure outside the device, Pa ; g – moisture flow through the sample registered by scales, $kg/s \cdot m^2$; d_{air} – air gap thickness between relative air humidity sensors and the test sample, m ; μ_{air} – vapor permeability of the air gap between relative air humidity sensors and the test sample, $kg/m \cdot s \cdot Pa$.

As the distance between relative air humidity sensors and the sample d_{air} is low, the expression can be written as:

$$R = \frac{e_{in} - e_{ext}}{g}. \quad (3)$$

Water vapor partial pressure inside and outside the device is determined by relation:

$$e_{ext} = \varphi_{ext} \cdot E_t. \quad (4)$$

where E_t – saturated water vapor pressure under experimental temperature, Pa ; φ_{ext} – relative air humidity outside the device.

$$e_{in} = \varphi_{in} \cdot E_t. \quad (5)$$

where φ_{in} – relative air humidity inside the device.

Relative air humidity inside the device is defined as the average relative air humidity along the sample height determined by relative air humidity sensors distributed along the sample height:

$$\varphi_{in} = \frac{1}{h} \cdot \int_0^h f(x) dx. \quad (6)$$

where h – sample height, m . $f(x)$ – sensor reading dependence function on height, m .

Integral in equation (6) is determined by trapezoidal method.

Taking equations (3) – (6) into account, vapor permeability coefficient (1) is definitely determined by formula:

$$\mu = \frac{\delta \cdot g}{E_t \cdot \left(\frac{1}{h} \cdot \int_0^h f(x) dx - \varphi_{ext} \right)}. \quad (7)$$

4. Results and discussion

Vapor permeability coefficients, one obtained experimentally in case of vertical sample position in the proposed device, and the other obtained by wet cup method in case of horizontal sample position, have been compared.

160 kg/m³ density rock wool samples have been used for testing. Five samples have been used for testing by wet cup method, and five samples have been used for vapor permeability coefficient determination experiment.

Experiment results show that vapor permeability coefficient obtained by the new device is similar to vapor permeability coefficient obtained by wet cup method, and is equal to $8.6 \cdot 10^{-11} \text{ kg/m} \cdot \text{s} \cdot \text{Pa}$.

Thus, vapor permeability coefficient obtained by wet cup method has been confirmed for vertical enclosing structures.

5. Conclusion

Device for vapor permeability coefficient determination in case of vertical test sample position has been developed.

Vapor permeability calculation method for the device in case of vertical sample position has been proposed.

Wet cup method for vapor permeability coefficient definition for vertical enclosing structures has been confirmed.

6. References

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