A hygroscopic method to measure the adsorption isotherm of porous construction materials

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Abstract

A sorption isotherm is the relationship between the moisture content in a material and the relative humidity of the surrounding atmosphere in an equilibrium situation. Most often, the sorption isotherm is measured with a gravitational method. This work presents a method to measure the adsorption isotherm of a porous construction material (sand-lime) with a hygroscopic method. The set-up of the experiment consists of a glass vessel that contains a humidity and temperature sensor. The measurement starts with drying a sample completely inside the vessel by blowing dry air through the vessel. After injecting a known amount of water into the vessel, the water evaporates and is adsorbed partly by the sample until an equilibrium state is reached. With the known amount of the injected water, the measured humidity inside the vessel and the volume of the vessel, one point of the adsorption isotherm is determined. For measuring the next point, more water is injected into the vessel. The desorption isotherm can also be measured with this technique.

1. Introduction

Measuring the sorption isotherm of a porous construction material is important to understand the water transport properties of materials and through that to improve their durability. Various techniques to measure the sorption isotherm can be found in the literature, such as gravimetric, manometric and hygrometric [1-2]. The present paper describes a hygrometric technique to measure the adsorption isotherm of a porous construction material [3]. Sand-lime of the class CS12 is the material that is examined in this work.

2. Set-up

A glass vessel with a glass cover is used to measure the desorption isotherm, as it is given in Fig.1. In order to prevent leakage in the system, a teflon foil ring is placed between the glass vessel and the cover. The use of rubber rings can disturb the measurements in this set-up, because rubber can absorb or release water, as it is shown in [4]. The glass vessel contains a humidity sensor, a temperature sensor, and a glass plate that serves as a capture of the added water into the vessel. The glass vessel is also provided with an inlet and outlet, for blowing the air into the vessel and letting it escape from the vessel. An additional opening in the glass cover is used to inject water into the vessel in order to obtain a certain relative humidity. Furthermore, the glass vessel is placed in a room with a constant temperature.

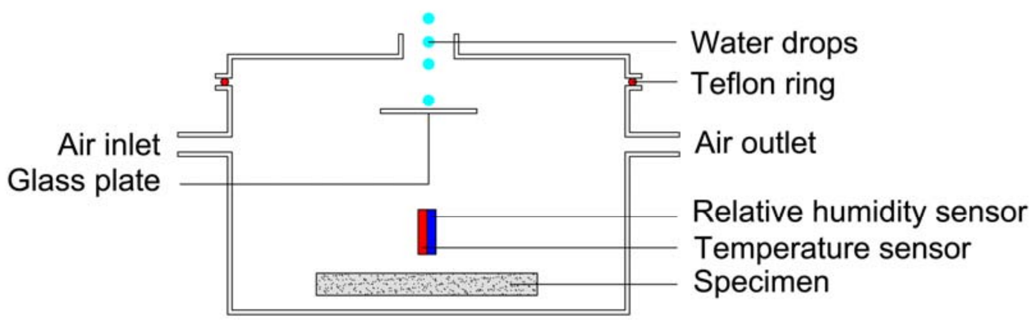

Figure 1. Experiment set-up to measure the adsorption isotherm of sand-lime with a hygroscopic method

3. Method

The measurement starts with placing the sand-lime specimen inside the glass vessel. By blowing dry air through the vessel, the specimen is completely dried. The dry air has a relative humidity of 7.5%, which is the lowest value in the adsorption graph. The drying of the specimen occurs due to the decrease of the humidity in the vessel as a result of the dry air, which leads the specimen to release the water. After establishing the equilibrium inside the vessel, the air inlet and outlet are closed with teflon plugs. A known amount of water (0.1g) is injected on the glass plate in the vessel. The injection opening in the glass cover is closed also with a teflon plug. The injected water evaporates changing the humidity inside the vessel and the water content of the specimen. After a certain time, an equilibrium is reached in the vessel. Fig. 2, gives a characteristic chart of the humidity in the vessel as a function of time. The chart can be divided into three phases; the first phase is the increase of the relative humidity which is the result of the evaporation of the injected water. The second phase is the decrease of the relative humidity that results from the adsorption of the sand-lime specimen. The final phase is the equilibrium state between the relative humidity inside the vessel and the adsorbed water of the specimen.

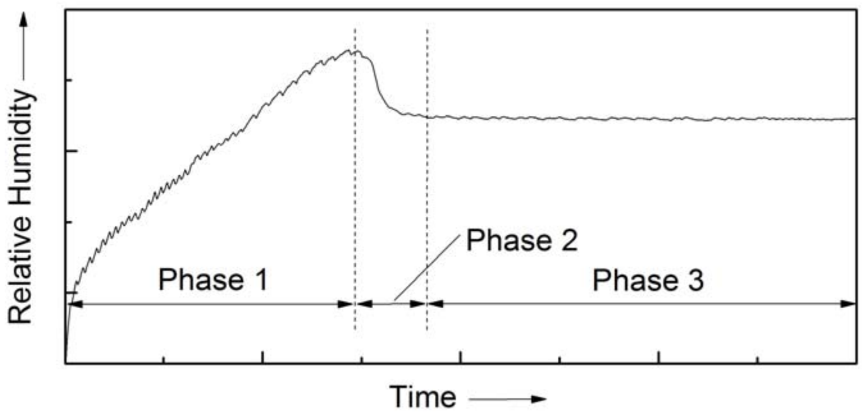

Figure 2. A characteristic chart of the relative humidity in the vessel as a function of time at 21°C

The total amount of water in the vessel is equal to the known amount of injected water. The amount of water in the air in the vessel is also known by calculating from the measurement of equilibrium relative humidity (phase 3). The rest of the total amount of water is in the specimen. By calculating the amount of water in the specimen at a certain relative humidity, a point of the adsorption isotherm is measured.

4. Results

The glass vessel is placed in a climate room with constant temperature. For computing the adsorption isotherm, the water content in the specimen, $m_{specimen}$, is determined at various relative humidities inside the vessel.

$$m_{specimen} = m_{total} - m_{air} \ , \qquad (1)$$

where m_{total} is the total amount of added water and m_{air} the amount of water in the air inside the vessel.

The water amount in the air, is computed with Antoine's law and ideal gas law, as

$$m_{air} = \frac{H \cdot V \cdot M}{R \cdot T \cdot 100} \cdot e^{\left(23.19695 - \frac{3816.44}{-46.13+T}\right)}, \qquad (2)$$

where H (%) is the relative humidity inside the vessel, V (m^3) the volume of the vessel, M (kg/mol) the molar mass of water, R (J/K/mol) the gas constant and T (K) the temperature.
By dividing the water content in the specimen by the volume of the specimen, the moisture content in the specimen w (kg/m^3) at a certain relative humidity is determined. Fig. 3 shows the measured adsorption isotherm of the sand-lime specimen. The moisture content at H=7.5% is defined as zero.

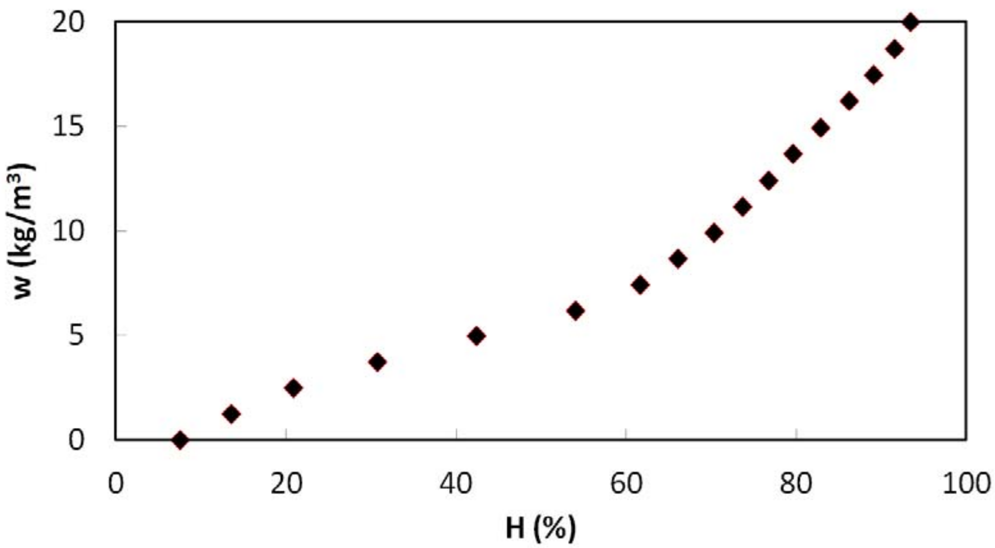

Figure 3. Adsorption isotherm of sand-lime of the class CS12.

5. Conclusions

The adsorption isotherm of sand-lime is measured with a hygroscopic method. With this technique, the desorption of any porous construction material can be measured. The amount of measured points can easily be adjusted, by increasing or decreasing the amount of added water. For instance, by adding 0.05 g of water instead of 0.1 g, which is used in this paper, twice as much measured points can be obtained. Moreover, with this technique the desorption isotherm of any porous construction materials can be measured also. The amount of the measured points can also be adjusted easily.

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