Analysis of the Type of the Sorption Isotherm Curves of Different Materials

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Abstract— In this paper the analysis of the shape of the sorption isotherm curves of different materials that were carried out from the result of measurement is presented. The investigation of the behaviour of the construction and building materials against water and humidity is highly important from the point of view of thermal sizing of the buildings. Since the sorped amount of water can cause changes in the good physical properties of the materials. As a result, foamed concrete, mineral wool, extruded and expanded polystyrene samples were subjected to wetting in a climatic chamber after desiccating in a drying apparatus. After drying the samples in a Venticell 111 type drying equipment they were treated with a Climacell 111 type climate chamber, where the relative humidity (RH) was varied from 25 to 95 at 293 K for 240 minutes. The reached sorption isotherms were compared to the available Hungarian standard.

Keywords— **S**orption isotherms. construction materials. polystyrene. mineral wool.

I. Introduction

FIRST of all, it is important to mention that, the measurement of the sorption isotherms is one of the most important problems by building materials and thermal insulators. Since water can cause undesirable changes in the physical, chemical and mechanical properties of the solid materials [1]-[10]. Thus, the investigation of water taking up of the solid materials e.g. thermal insulators is important because the sorped amount of water can increase their thermal conductivity, therefore can increase the Overall Heat transfer coefficients; furthermore their specific heat can be raised up. Besides, the complex measurement of equilibrium moisture content values is very important for vapor diffusion calculations. Since, as a result of this the increasing thermal conductivity issues in the decreasing thermal resistance of the building envelope. Thus the thermal efficiency of the buildings can be reduced. In The available Hungarian (HST) data is proved be outdated (1991) [11], because the manufacturing techniques have undergone rapid evolution therefore better and better materials have been put on the market.

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II. Materials and Methods

Please submit your manuscript electronically for review as e-mail attachments. When you submit your initial full paper version, prepare it in two-column format, including figures and tables In order to achieve the sorption curves individual new materials and slabs were used. [12], [13] So as to present this the Polystyrene probes, both the extruded and the expanded were with 30 x 30 x 5 cm geometries, the mineral wool sample and the foamed concrete had 30 x 30 x 3 cm and 10 x 9 x 6 cm geometries respectively. Furthermore, the densities of the materials are indicated in Table I. The samples were dried in the VentiCell equipment at 363 K to changeless weight, according to Hungarian Standard MSZ 21470-2:1981 [14]. It works with hot air circulation by an inbuilt ventilator. After the heat treatment the mass of the samples were measured with a milligram preciseness electronic balance. This mass value gives the dried amount of the samples. Then the samples were taken in the Climacell (CLC) climatic chamber as soon as it was possible. CLC is a temperature cabinet with a chamber either heated with electric heating bodies or cooled by means of a compressor system with the coolant. The objects in the chamber can be heated within the range of 273 to 372.9 K. Besides, air circulation in the chamber is forced by a ventilator. The relative humidity (RH) and the temperature are controlled by a microprocessor. The humidity can be varied at fixed temperature ranging from 25% to 95%. The dried samples were RH treated in the CLC at 293 K and 25, 50, 63, 75 and 95 % for 240 minutes. After this treatment the mass of the wet samples were measured by a balance. From the mass of the dried as well as from the wet samples one can reach the net dried (m_d) and net wet mass (m_w) respectively. From these values the moisture content for the adsorption (ω %) can be calculated at a given temperature and at an optional relative humidity using the following equation:

$$\omega = \frac{m_w - m_d}{m_d} \times 100 \tag{1}$$

III. Results and Discussion

A. The sorption isotherm curves of the measured samples.

With the above mentioned method sorption isotherm curves of five materials was created. In Table 1 the moisture content

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values in function of the fixed relative humilities can be seen. Continuously increasing data is observable in function of rh's.

TABLE I
THE MEASURED MOISTURE CONTENT VALUES OF THE MATERIALS

	Moisture content (%)				
RH %	Concrete (500 kg/m^3)	Yellow XPS (29 kg/m^3)	Pink XPS (30.5 kg/m^3)	EPS 100 (20 kg/m^3)	Mineral Wool (40 kg/m^3)
0	0	0	0	0	0
25	0.34	0.126	0.5	0.78	0.294
50	0.5	0.13	0.55	0.85	0.326
63	0.606	0.138	0.582	0.86	0.343
75	0.77	0.172	0.615	0.89	0.459
95	0.922	0.194	0.636	0.97	0.8

B. The analysis of concrete

In Figure 1a and 1b the available curve taken from the Hungarian standard [10] and the measured sorption isotherm curve of the foamed concrete can be found. Significant difference can be observed. A great difference in the water contents as well as in the shapes marks out from the Figures. The shape of the curve (see Fig 1a) represents Langmuir isotherms initially then continues in a pure Brunauer Type II isotherm. It describes adsorption on macroporous adsorbents with strong adsorbate-adsorbent interactions. In contrast to the isotherm curve on Figure 1b, because it describes only Brunauer Type II isotherms, and much smaller quantity of sorped amount of water [15], [16]. Therefore concrete has lots of small pores and relatively great amount of free surface for the adsorption.

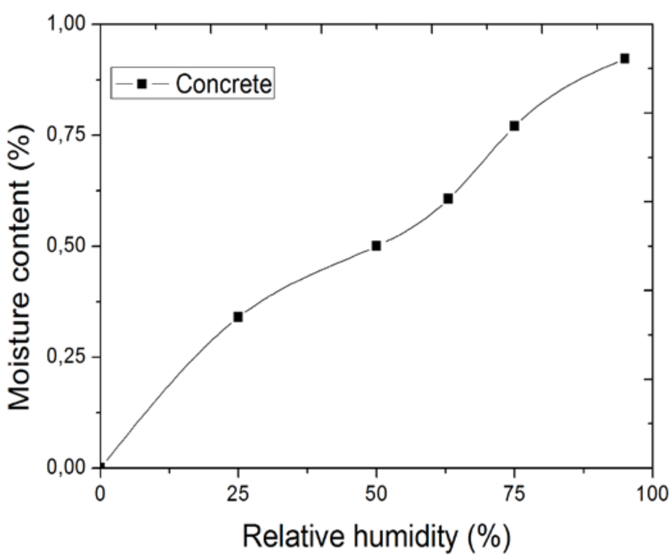

Fig. 1a.:The sorption isotherm curves of the Concrete taken from the standard

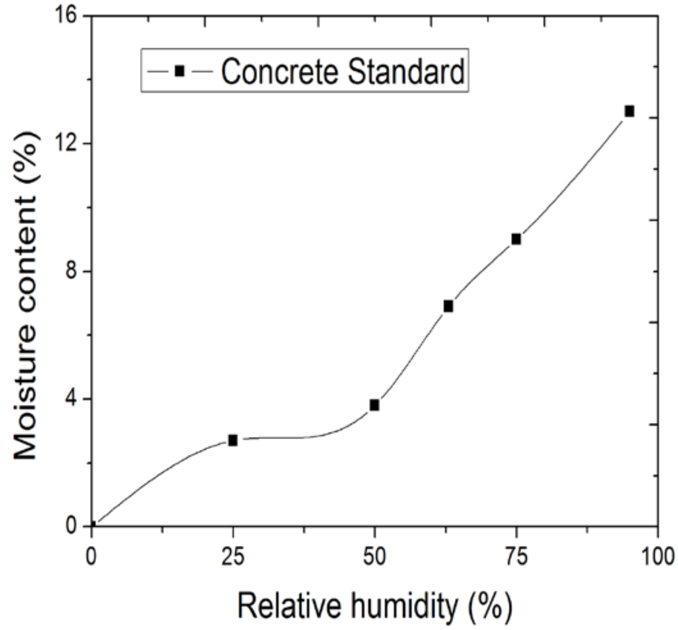

Fig.1b The measured sorption isotherm curves of the Concrete

C. Analysis of polystyrene samples.

In this part the comparison of the measured isotherm profiles with the literature data is presented. In order to demonstrate Two different types of Extruded Polystyrene (Yellow and Pink XPS) and an Expanded Polystyrene (EPS 100) were tested. In the available literature data, the Hungarian standard makes no difference between the expanded and extruded polystyrene. The difference between them can be found in their manufacturing process. The macrostructure of the pores are completely different. Extruded polystyrene foam (XPS) consists of closed cells, offers improved surface roughness and higher stiffness and reduced thermal conductivity. As a result of the extrusion manufacturing process, XPS does not require facers to maintain its thermal or physical property performance, while EPS is produced from the solid beads of polystyrene. Expansion is achieved by virtue of small amounts of pentane gas dissolved into the polystyrene base material during production. The gas expands either under the action of heat or applied as steam, to form closed cells of EPS. These cells occupy approximately 40 times the volume of the original polystyrene bead. The beads can be molded to specifications to form insulation boards, blocks or customized shapes for the building insulation or packaging industries. XPS foam begins with solid polystyrene crystals. The crystals, along with special additives and a blowing agent, are fed into an extruder. Within the extruder the mixture is combined and melted, under controlled conditions of high temperature and pressure, into a viscous plastic fluid. After that the hot, thick liquid is then forced in a continuous process through a die.

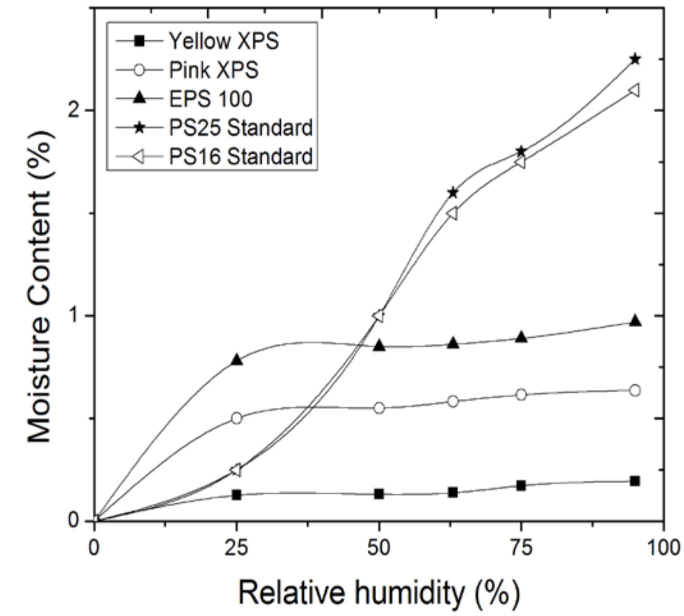

Fig. 2 The sorption isotherms of the PS samples (measured and standard)

As it emerges from the die it expands to foam, is shaped, cooled, and trimmed to dimension. As a result XPS is proved to be a better insulator than the EPS because it has closed cells, while the EPS has open cells. Water can diffuse harder into the XPS, slab so these are mainly used as floor insulators. Although EPS has relatively lower price but it depends on its type. In Figure 2, one can see the curves of the measured two XPS and one EPS materials. In this figure two types of the polystyrene materials taken from the HST are represented as well. The measured PS profiles are showing the similar shapes irrespectively of their types (EPS or XPS) but the curves taken from the standard are showing one another. After executing the Brunauer's analysis one we can observe that our measured profiles are suitable for Brunauer Type I isotherm. It describes microporous adsorbents. However, the basic curves from the standard fits to be BDDT type II or IV isotherms, as macro- or mesoporous materials.

D. Analysis of the mineral wool.

In this section we intend to discuss the shape of the sorption isotherm of a mineral wool insulating slab (see Figure 3). Here we found the most correspondences between our measurement results and the literature data in [10]. In our standard we found three different types of mineral wools to compare with our measured profile. Moreover our measured profile shows BDDT Type IV isotherms with a significant plateau from 25 to 75 % relative humidities. One (MWST148) of the curves taken from the HST shows BDDT Type VI, MWST56 and MWST 103 are showing BDDT type III, describing macroporous adsorbents with weak adsorbate-adsorbent interactions, furthermore MWST 103 fits the most. 56, 103 and 148 means the mass densities in kg/m3 of the given mineral wool materials.

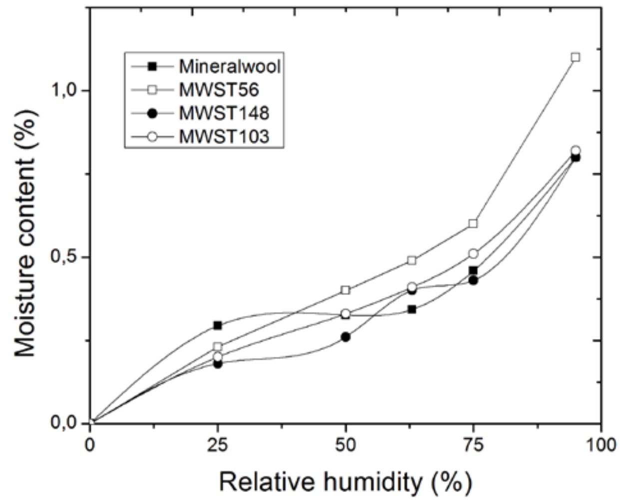

Fig.3 The sorption isotherms of the mineral wools, measured and standard values

E. Moisture content in function of densities.

Through Figure 4 we present the dependencies of the moisture contents of the materials in function of mass densities, taken up at a given relative humidity. Previously in Ref. 2 we reported for EPS materials with different densities, that the PS samples, having low densities, can absorb the most quantity of water from the air. For different insulators we have to modify this since, the EPS 100, the Pink XPS as well as the mineral wool follows this theory, however the yellow XPS is out of the line. The results for concrete are presented as well.

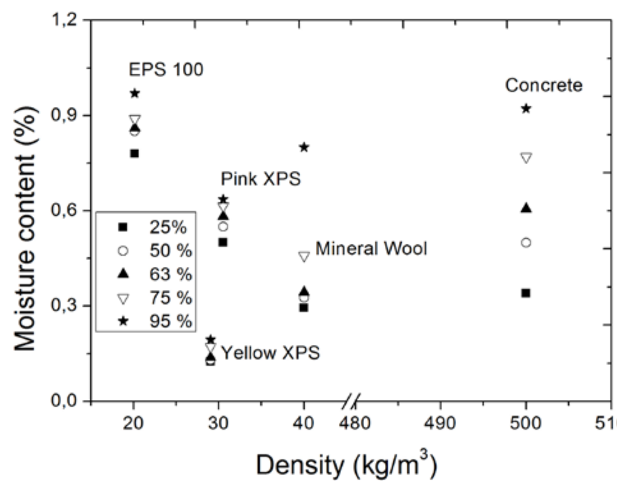

Fig. 4 The sorped amount of water in function of the mass densities

IV. Conclusion

In this paper the investigations of the sorption behavior of different insulator materials can be found. We tested five different materials created and analyzed their sorption curves. In Hungary, the available data for sorption curves is proved to be poor and outdated, thus these measurements are very important from the point of view of building technology. We created and measured new isotherms for well known building materials, besides we defined that the PS materials, the mineral wool and the concrete follow BDDT type I, II and IV isotherms respectively. As a result we concluded that our theory for different types of materials is working only with assumptions, but as we previously showed, it works for the EPS materials.

Acknowledgment

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