EXPERIMENTAL RESEARCH OF FOAM GYPSUM DRYING PROCESS

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Abstract: *The theoretical model of porous materials drying process is developed. It is large importance of accurate modeling in order to bring together experimental results and theoretical prediction. A number of experimental investigations of drying process of different volume density foam gypsum samples are given. Theoretical model was tested using these experimental data. Model parameters are estimated.*
Dependence of these parameters on volume density is adequate physical processes.

Keywords: drying process, porous materials, foam gypsum, moisture diffusion coefficient.

Introduction

Foam gypsum is a suitable material for different building constructive solutions (Skujans et al., 2007). According to the requirements for the technological process of foam gypsum, the initial moisture content should be very high (Iljins et al., 2009). The drying of these products is obligatory requirement to obtain material with sufficient mechanical and heat conductivity properties. In the case of porous materials drying is time and energy consuming process. Drying process is a complex phenomena with simultaneous mass and heat transfer mechanisms taking place. Understanding its physical phenomena is of great practical importance. There is a need for simple models verified by experimental data that will provide optimum conditions for drying. A complete drying profile generally consists of two drying stages – a constant drying speed period and falling drying speed period (Mujamdar, 1987). In first stage drying speed is determined not by the properties of sample material, but depends on temperature, relative humidity and flow speed of ambient air (Tang and Etzion, 2004; Dincer and Dost, 1995; Musielak and Kieca, 2009). In second stage drying speed is determined by the physical properties of the sample material. Now it decreases depending on the time and is lower than initial constant drying speed of the first stage.

The constant-rate and falling-rate stages are separated by critical point (Iljins et al., 2009) The critical moisture content is a significant design parameter since at this point the drying mechanism change from one controlled externally to one controlled internally.

One of most important material parameters in drying theory of capillary-porous materials is the moisture diffusion coefficient. In most cases moisture drying theoretical models are based on the solution of a simple diffusion equation (Fotzing, 2004; Jurendič et al., 2011; Kaya et al., 2010; Chemki and Zagruoba, 2005; Avci and Can, 1999). However, they cannot describe the changes of moisture in the material in time accurately enough. Limited data on moisture diffusion in porous materials are available in literature. Moisture diffusion coefficient experimentally determination was performed for wood material (Simpson, 1993; Fotsing, 2004), baby food (Jurendič and Tripalo, 2011), vegetables (Kaya at al., 2010), clay material (Chemkhi and Zagruoba, 2005). There is no data about moisture diffusion coefficient dependence on porous material volume density.

Matherials and methods

The aim of this work was experimentally determine drying process parameters in porous material. In order to test the obtained theoretical results (Iljins et al., 2009), a range of foam gypsum samples were made with the different final density in the dry condition of approximately 270 - 1100 kg/m^3 and the research on their drying at room temperature 20 - 22 °C and relative air humidity 30- 40%. The following description presents the physical data of one of the most typical sample. The moisture content of foam gypsum was calculated according to the following formula

$$W = \frac{m}{V}, \tag{1}$$

where m – water mass in the sample, kg; V –volume of foam gypsum sample, m$^{3.}$ Usually the initial moisture content is high W = 200 – 350 kg/m^3 or (45 – 50%) in relation to a dry sample.Experimentally the drying speed of the sample is determined by the following formula

$$\varphi = \frac{1}{S} \cdot \frac{\Delta m}{\Delta t}, \tag{2}$$

where ϕ – drying speed of the sample, kg/(m^2 s); Δm – change of mass, kg; Δt – interval of time, s; S – surface area of the sample, m^2.

According to our theoretical calculations, the drying time of the sample is inversely
proportional to the thickness squared . Therefore, the thickness of the sample was chosen d = 2 cm, so that the drying time would be within 1 week. All the surfaces of the sample, except the top surface through which the

moisture evaporates , are covered with a vapour barrier. During the process of drying the average moisture content in the sample was determined by weighing the sample with the scales manufactured by the company KERN, the maximum allowable weight of which is 16100.0 g, but sensitivity ± 0.2 g. The surface area of the sample was chosen 0.1 m^2 in order not to exceed the maximum allowable weight value. To check the temperature on sample surface and inside termocouples were inserted. On the surface of sample heat flow sensors were replaced.

Experimentally when weighing the samples, the average moisture <W> was determined depending on time (fig. 1). Thus, the moisture experimental measurements depending on time should be theoretically compared with the integral (Iljins, at al., 2009):

$$< W(t) >= \begin{cases} \frac{1}{d}\int_0^d W_I(t;z)dz = W_s - \frac{\varphi \cdot t}{d}, & \text{if } t < t_{cr}; \\ \frac{1}{d}\int_0^d W_{II}(t;z)dz = W_0 + \frac{2}{\pi}\sum_{n=0}^{\infty}\frac{(-1)^n A_n}{2n+1}\cdot\exp\left(-\frac{\pi^2(2n+1)^2}{4d^2}D(t-t_{cr})\right), & \text{if } t > t_{cr}. \end{cases} \quad (3)$$

where W_s- initial moisture of the sample kg/m^3; t – drying time, s; D- diffusion coefficient, m^2/s. W_0 – equilibrium moisture kg/m^3. In the course of time, the sample dries and after a certain time t_{cr}, when the first stage of drying period is completed, on the surface of the sample z=d, the moisture has reached the equilibrium moisture W_0.

From this time on, the sample t_{cr}, has entered the second stage of drying.

Using this comparison, it is possible to calculate the unknown values W_{cr}, ϕ, D by means of the least square method (Iljins, et al., 2007).

Results and discussion

The experimental moisture measurements for different volume density samples were performed. In Fig. 1 typical drying curve is represented.

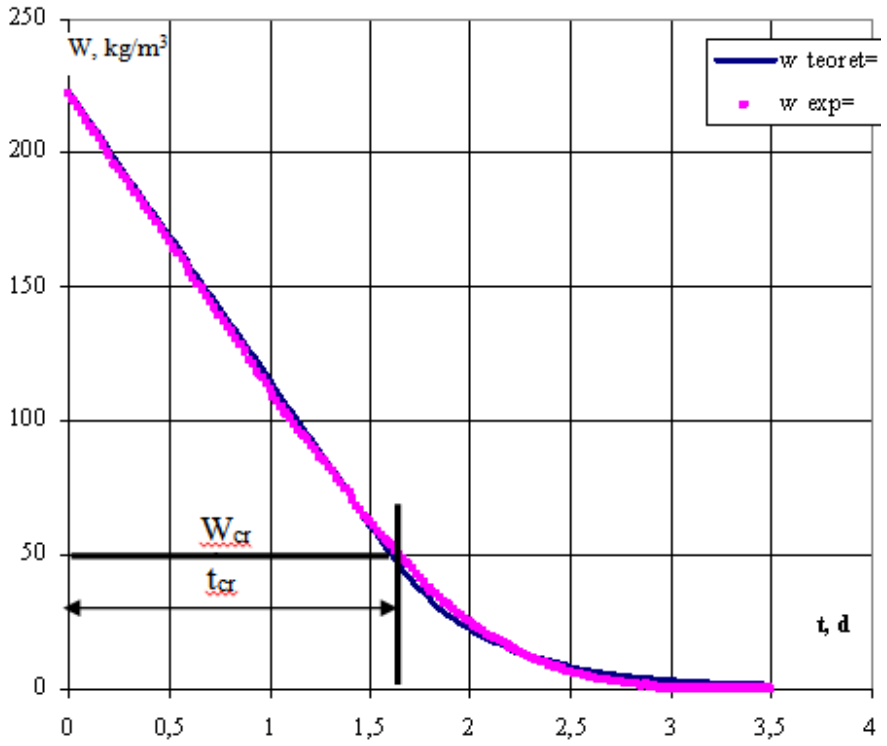

Fig.1.**Theoretical and experimental comparison of the sample's average moisture depending on the drying time. Sample volume density was 311kg/m.**

On the basis of experimental drying process data, we calculated theoretical model parameters that are summarized in the following table. It is worth to note that moisture diffusion coefficient in foam gypsum is the same order as in clay materials (Chemkhi and Zagruoba, 2005).

Table 1.

Calculated model parameters for foam gypsum samples with different volume density

ρ, kg/m3	$D \cdot 10^9$ m^2/s	$\varphi \cdot 10^5$ kg/(m^2 s)	W_{cr} kg/m3
276	6,02	2,7	30
311	4,95	2,85	44,2
661	2,61	3,07	74

Conclusion

Drying model (Iljins, et al., 2009) physical aspects predicts that moisture diffusion coefficient decreases on increasing volume density. On the other hand drying speed should remain constant as it is determed by ambient air properties. Obtained results provide a satisfactory coincidence with the theoretical model predictions.
Ii is nesessary to provide experiment for different ambient air conditions – temperature and relative humidity.

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