COMPARATIVE ANALYSIS OF DESORPTIVE METHODS USED FOR MASS DIFFUSIVITY ESTIMATION

Halina Garbalińska

Szczecin University of Technology

Abstract. The paper provides a comparative analysis of three methods used to determine D_m diffusivity, which were tested for non-stationary desorption process and referred to various stages of its course. These are: the $\sqrt{t}$-type method – linked to the initial phase; the logarithmic procedure – for the advanced phase of the process, and the half-time method – referring to the point of time when 50% of mass has been exchanges. The article presents results of desorption process research carried out in the temperature of 20°C and encompassed three mortars characterized by the following water-cement ratios $w/c = 0.50, 0.65$ and 0.80. Samples of these mortars were conditioned for several months under air relative humidity $\varphi = 97\%$ until the time of reaching moisture equilibrium, and then they were placed in humidity conditions of $\varphi \approx 0\%$. The values $D_m(\sqrt{t})$, $D_m(\ln)$, $D_m(t_{0.5})$, obtained through the analyzed desorption process ($T = 20°C$, $\varphi = 97\% \rightarrow 0\%$), presented a good conformity of all the three tested methods in the case of all the mortars – from the fully identical results: $D_m(t_{0,5})/D_m(\ln) = 1.00$ with $w/c = 0.80$ to the most diversified ones: $D_m(t_{0,5})/D_m(\sqrt{t}) = 1.23$ with $w/c = 0.65$.

Key words: mass diffusivity, desorption, non-stationary measurements

INTRODUCTION

The mass diffusivity is necessary for calculation of moisture fields that are developed within a building element during the exchange of water with the environment.

A review of basic mathematical models, which are appropriate for describing thermal-moisture processes that take place in building elements, can be found in the work [Gawin and Klemm 1993]. Several typical models were confronted there – from the first ones, prepared by Philip and de Vries, Łykow, Krischer – to those of 1980's, by Kiessel, Kohonen and others. The list is closed by equations of the Gawin's model, which were

Corresponding author – Adres do korespondencji: Halina Garbalińska, Szczecin University of Technology, Faculty of Civil Engineering and Architecture, al. Piastów 50, 70-311 Szczecin, Poland, e-mail: Halina.Garbalinska@ps.pl

formulated with the use of space averaging theory. This issue was developed in the work Gawin [2000]. Space averaging method was also used in the monograph [Wyrwał 1989]. In the work Wyrwał and Świrska [1998], a description of a complex process of gas and liquid phases moisture flow was proposed. A description of the software and examples of implementation of the developed model by the means of "Humidity" computer program were included. Moreover, the authors presented analysis of the actual status of research (in Poland and in the world) on moisture in building partitions. In the work Kubik [2000] one can find thermomechanic descriptions of thermodynamic, diffusive-convective, phase transformation and other processes. Additionally, opposite tasks, making it possible to identify humidity transfer coefficient, were presented in the work. The term of effective flow, being a sum of different form of transport, was introduced. The method described in the work Kubik [2000] was confronted in Garbalińska [2002a] with non-stationary methods tested by the author.

This paper deals with the use of non-stationary desorptive measurement methods for determining the mass diffusivity of porous building materials. These methods are also based on the moisture summary flow. A distinction between molecular transport of water and transport of liquid phase is not made. The methods were as follows: $\sqrt{t}$ -type method, logarithmic method and half-time method.

Examples of practical application of these techniques for defining the mass diffusivity from non-stationary desorption processes were given. Cement mortars were chosen as a model environment for testing the usability of the a/m techniques. The experiment covered series of cement mortars of different water-cement ratios (w/c = 0.50; 0.65; 0.80). The paper presents the use of the three a/m calculation procedures for desorptive measurements of the mass diffusivity of three cement mortars in one of 15 cycles carried out in Garbalińska [2000]. The cycle covered the temperature of T = 20°C and almost the whole range of hygroscopic humidity (0–97%).

Subject of the research presented in this paper was a suitability assessment of the tested methods for defining diffusivity based on desorption measurements and a conformity assessment of averaged diffusivity values obtained by the means of different methods and referred to the humidity range discussed. However, the article did not focus on determining the dependence of the coefficient D_m on humidity, as this requires quite a different arrangement of the experiment, which would have to be carried out within narrow, adjacent humidity intervals. Desorption measurements of this type, taken in five humidity intervals φ: 30% → 12%, 50% → 30%, 75% → 50%, 85% → 75%, 97% → 85% are described in the article [Garbalińska 2006]. Functional courses that are presented therein indicate a vital quantitative and qualitative influence of humidity on diffusivity D_m of cement mortars.

THEORETICAL DESCRIPTION OF DESORPTION

General assumptions

Desorption of water within a plane sheet $0 \leq x \leq$ d is subject to the analysis. It has been assumed that at the initial moisture c_{m1} is distributed uniformly within the sample. Such

a condition may result from the dampness, due to the process conditions or storage of the material in the environment of humidity c_1. The process concerned is initiated by placing the sample in the environment of humidity by volume $c_2 < c_1$. It was assumed that upon the commencement of the process the surface concentration c_{m2} stabilizes immediately and then remains at the same level over the entire duration of the experiment. With time, the process develops gradually and covers deeper and deeper leyers of the plane sheet and finally affects the concentration in the innermost layers, which was kept at c_{m1} so far. The whole system reaches the new equilibrium as soon as the concentration within the sample has been stabilized at c_{m2}.

Mathematical description of initial phase of process

The plane sheet could be represented by a model of a 1-D constrained body along axis x as long as the moisture concentration within the deepest layers of the material is kept at the initial value. In Bagda [1988b], to describe mass changes in the initial phase of sorption and desorption in a layer that borders surroundings (aluminum film based layer) a linear model was applied:

$$M_t = \frac{2M_\infty}{d}\sqrt{\frac{D_m t}{\pi}} \qquad (1)$$

where: D_m – mass diffusivity of water vapor $[m^2 \cdot h^{-1}]$, referred to material concentration of moisture c_m $[g \cdot m^{-3}]$,
d – plane sheet thickness [m],
t – process duration [h].

Additional symbols designate the following: $M_t = \Delta m_t/F$ and $M_\infty = \Delta m_{max}/F$, where as Δm_t represents changes in sample mass during process [g] and Δm_{max} is the total sample mass change [g], as found after the completion of the process, i.e. after the moisture equilibrium with the environment has been reached.

If the mass exchange involves two external surfaces of a sheet $\dfrac{\Delta m_t}{2F} = \dfrac{2M_\infty}{d}\sqrt{\dfrac{D_m t}{\pi}}$, it is two times quicker:

$$M_t = \frac{4M_\infty}{d}\sqrt{\frac{D_m t}{\pi}} = 4\frac{\Delta m_{max}}{Fd}\sqrt{\frac{D_m t}{\pi}} \qquad (2)$$

In the process in study, the total change in mass is caused by a change in concentration within the sample in range c_{m1}–c_{m2}. Thus, formula (2) could be given as follows:

$$M_t = \frac{4}{\sqrt{\pi}}(c_{m2} - c_{m1})\sqrt{D_m t} \qquad (3)$$

Künzel and Kiessl, that deal with porous building materials, give a formula describing the initial changes in mass Δm_t of disc-shaped samples of thickness d with their side surface insulated. The exchange of moisture is then carried out through two faces 2F. After unification of symbols to follows the a/m formulas, the one concerned is as follows:

$$\Delta m_t = \frac{4}{\sqrt{\pi}} F(c_2 - c_1) \sqrt{\frac{D_L \sigma}{\mu}} \sqrt{t} \qquad (4)$$

where: D_L – mass diffusivity of water vapor in air [m^2·h^{-1}],
  μ – diffusion resistance value of a given material [–],
  σ – sorption factor [–].

Taking the following relation of water vapor transfer under consideration:

$$\frac{D_L}{\mu} = D \qquad (5)$$

formula (4) could be given as follows:

$$\frac{\Delta m_t}{F} = M_t = \frac{4}{\sqrt{\pi}} (c_2 - c_1)\sqrt{D\sigma t} \qquad (6)$$

Since Garbalińska [2000]:

$$\frac{D}{\sigma} = D_m \qquad (7)$$

then formula (6) is turned to:

$$M_t = \frac{4}{\sqrt{\pi}} (c_2 - c_1)\sigma\sqrt{D_m t} \qquad (8)$$

and D [m^2·h^{-1}] represents the transfer coefficient in a given material – related to humidity of air c [g·m^{-3}]. After taking the definition formula of the so called sorption (desorption) factor adopted in Garbalińska [2000] as given below into consideration (compare Künzel and Kiessl [1990]).

$$\sigma = \frac{c_{m2} - c_{m1}}{c_2 - c_1} \qquad (9)$$

formula (8) is transformed into a form identical to the one given in formula (3), produced on the basis of Bagda [1988b].

Mathematical description of advanced phase of process

With time, the changes resulting from desorption begin to reach the sample core, violating its initial humidity equilibrium. Crank suggests using the following formula to describe changes in mass during more advanced sorption or desorption within a plane sheet of a porous material [Crank 1989]:

$$\frac{M_t}{M_\infty} = 1 - \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp[-D(2n+1)^2 \pi^2 t / d^2] \tag{10}$$

where: M_t – changes in mass of a sample during the process referred to a surface that borders surroundings $[g \cdot m^{-2}]$,

M_∞ – total change in mass of a sample after completion of the process, i.e. after achieving the moisture equilibrium with surroundings $[g \cdot m^{-2}]$.

This formula concerns processes of sorption or desorption of any substance by a porous medium in which diffusing molecules occupy only the volume of pores or, optionally, form an extra adsorption layer on the surface of the pores.

In Künzel and Kiessl [1990] the above formula is slightly modified for such materials, i.e.:

$$M_t = M_\infty \left\{ 1 - \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(-\frac{(2n+1)^2 \pi^2 D_L}{\mu \sigma d^2} t \right) \right\} \tag{11}$$

Taking formulas (5) and (7) and definition (9) into consideration, the above formula can be given as follows:

$$\frac{M_t}{M_\infty} = 1 - \frac{8}{\pi^2} \sum_{n=0}^{\infty} \frac{1}{(2n+1)^2} \exp\left(-\frac{D_m (2n+1)^2 \pi^2 t}{d^2} \right) \tag{12}$$

The above considerations form theoretical assumptions for the experiment described below.

ESTIMATING D_m ON THE BASIS OF DESORPTION STUDY

Experiment

The experiment carried out by Garbalińska [2000] involved three cement mortars of different w/c ratio ($w/c = 0.50; 0.65; 0.80$). Nilsson's research [Nilsson 1980] confirmed that, among different factors, the w/c ratio affects transportation properties of cement-based materials to the highest degree. The study on desorption was carried out at three temperatures and the process was observed in five humidity ranges for each temperature. Consequently, the experiment totaled 15 cycles that differed either with temperature or humidity. Each cycle covered nine disc samples (three of each mortar) with the insulated side surface.

Results of one out of 15 completed cycles are presented in Figures 1–3, namely cycle *Vd*, in which the study was carried out at $T = 20°C$ and covered almost entire range of sorptive humidity ($97\% \rightarrow 0\%$). Before commencement of the desorption measurements,

the samples were placed above the saturated aqueous solution of K_2SO_4 at $T = 20°C$ and stored in such conditions for some months in order to obtain a uniform distribution of moisture within the samples that represents the moisture equilibrium with the environment of the relative humidity of air $\varphi = 97\%$, i.e. $c_1 = 17.29$ g·m^{-3}. The desorption measurements were taken as soon as the samples were placed above some silica gel. The latter was chosen from among other sorbents, according to DIN 52 615 [1987], which states that the sorbent concerned should maintain the relative humidity at 0–3%.

Practical application of $\sqrt{t}$-type rule to define D_m

In the presented study, the surroundings of the damp samples showed the humidity at the zero level. The sample of constant thickness d and insulated side surface released its moisture to the surroundings through two faces (each of area F). In the initial phase of desorption, decrements of mass in the sample of initial concentration c_{m1} and placed in the environment of humidity by volume $c_2 = 0$ are represented by the following formula [Garbalińska 2002a]:

$$M_t = \frac{\Delta m_t}{2F} = -2c_{m1}\sqrt{\frac{D_m t}{\pi}} \tag{13}$$

Changes in mass in the initial phase of desorption (as well as of sorption) are proportional to the square root of time [Bagda 1988b, Künzel and Kiessl 1990]. In some cases, the rectilinear course is observed (acc. to Künzel and Kiessl [1990]) until the sample has released 70% of the moisture content. The inclination of the curve that describes relation $\Delta m_t = f(\sqrt{t})$ allows to identify mass diffusivity D_m on the basis of the desorption process in study. To do so, formula (13) is converted to:

$$\frac{\Delta m_t}{\sqrt{t}} = -\frac{4}{\sqrt{\pi}} F c_{m1}\sqrt{D_m} \tag{14}$$

Having adopted the designation:

$$\frac{\Delta m_t}{\sqrt{t}} = a_{\sqrt{t}} \tag{15}$$

the formula for defining mass diffusivity is obtained:

$$D_m = a_{\sqrt{t}}^2 \frac{\pi}{16 F^2 c_{m1}^2} \tag{16}$$

The formula can be converted to a more convenient form for practical applications:

$$D_m = a_{\sqrt{t}}^2 \frac{\pi d^2}{16 \Delta m_{\max}^2} \tag{17}$$

since:

$$c_{m1} = \frac{\Delta m_{\max}}{V} = \frac{\Delta m_{\max}}{Fd} \tag{18}$$

Results are shown in Figure 1, after processing them according to the $\sqrt{t}$ -type procedure.

It was found that after plotting changes in mass Δm_t, observed during the beginning of the desorption versus square root of time $\sqrt{t}$, the approximately rectilinear curve could be obtained for the initial phase of the process and, after crossing a certain point, the curve starts getting closer and closer to the extreme value of $\Delta m_{\max}$.
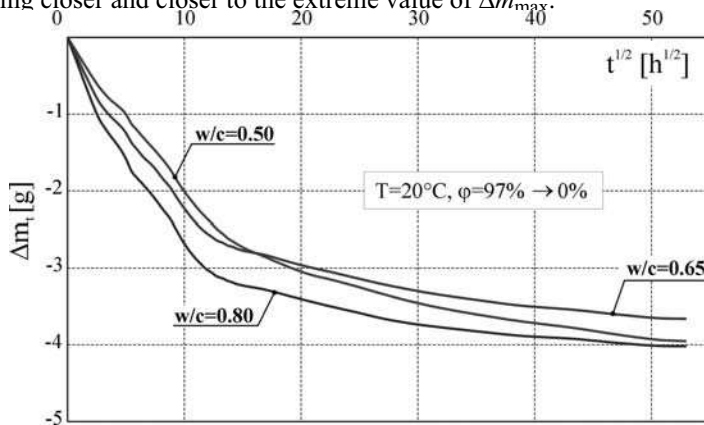

Fig. 1.   Functions $\Delta m_t = f(\sqrt{t})$ for mortars 0.50; 0.65; 0.80 at $T = 20°C$ and $\varphi = 97\% \rightarrow 0\%$

Rys. 1.   Funkcje $\Delta m_t = f(\sqrt{t})$ dla zapraw 0,50; 0,65; 0,80 w $T = 20°C$ i $\varphi = 97\% \rightarrow 0\%$

Mass diffusivity $D_{mi}(\sqrt{t})$ was found in [Garbalińska 2000] for each sample in study, after identifying of the inclination of each rectilinear component of certain curves representing relation $\Delta m_t = f(\sqrt{t})$. The values of $D_{mi}(\sqrt{t})$ obtained for three samples of the mortar were then used to calculate the average of $D_m(\sqrt{t})$ for each mortar in study (see Fig. 4).

Defining D_m by means of logarithmic method

According to Künzel and Kiessl [1990], terms of equation (12) for $n > 0$ are neglectible if the formula concerned describes the process that occurs after absorbing (in the case of sorption) or releasing (in the case of desorption) 40% of the gain or loss of the mass observed in the process accordingly. Having assumed that this formula is to be used for description of the more advanced phase of the phenomenon, just the first term of the series can be taken into consideration:

$$\frac{M_t}{M_\infty} = 1 - \frac{8}{\pi^2} \exp\left[-D_m \pi^2 t / d^2 \right] \tag{19}$$

After logarithmic transformation, the linear equation with respect to time t is obtained:

$$\ln\left(1-\frac{M_t}{M_\infty}\right) = -0.21 - D_m\pi^2 t/d^2 \tag{20}$$

and the argument of the logarithmic function remains within range (0–1).

If the curve representing relation $\ln(1 - M_t/M_\infty) = f(t)$ is rectilinear in certain interval t, then the value of inclination factor $a_{\ln}$ of the straight line could be used to determine the mass diffusivity according to the following formula:

$$D_m = -a_{\ln}\frac{d^2}{\pi^2} \tag{21}$$

whereas:

$$a_{\ln} = \frac{\ln\left(1-\dfrac{M_t}{M_\infty}\right)+0.21}{t} \tag{22}$$

Recorded changes in mass Δm_t, related to the surface that takes part in the exchange of moisture (2F), produced the variable in time M_t and M_∞. The latter obtained upon the termination of the measurements. The collected results are shown in Figure 2 as diagrams of $\ln(1 - M_t/M_\infty)$ versus time. The reproduction of changes in mass that occur during the desorption in a form of relation $\ln(1 - M_t/M_\infty) = f(t)$, leads (already below ordinate approx. –0.4) to a rectilinear curve of $\text{tg}\alpha = a_{\ln}$. Values of $D_{m,i}(\ln)$ corresponding to certain samples of mortars in study could be found by means of formula (21) after determining inclination factors $a_{\ln}$ for each reproduced diagram. Average values of $D_m(\ln)$, obtained in the a/m manner, and average values for mortars in study, determined on the basis of the former, are shown in Garbalińska [2000]. The graphic lists of average $D_m(\ln)$ are shown in Figure 4.

Application of half-time method

Decrement of moisture in the initial phase of desorption within a plane sheet (having the initial concentration c_{m1}) that releases the moisture to surroundings, exhibiting the naught concentration through two faces, is described by formula (13). The latter could be given as follows:

$$\frac{\Delta m_t}{\Delta m_\infty} = \frac{4}{\sqrt{\pi}}\sqrt{D_m}\sqrt{\frac{t}{d^2}} \tag{23}$$

Changes in mass in the initial phase of desorption are proportional to the square root of time as confirmed by the author's research and data given in, e.g. Bagda [1988b], Künzel and Kiessl [1990]. After introducing the term of the so called half-time $t_{0.5}$ (see Crank [1989]) that corresponds to "the half" change in mass, i.e. $\Delta m_t = 0.5\,\Delta m_\infty$, formula (23) could be given as follows:
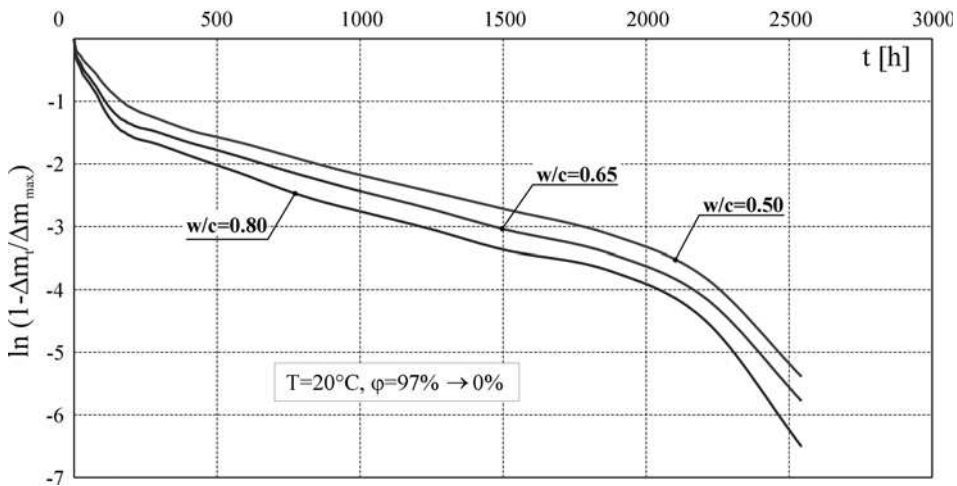
Fig. 2. Functions $\ln(1 - \Delta m_t/\Delta m_{max}) = f(t)$ for mortars 0.50; 0.65; 0.80 at $T = 20°C$ and $\varphi = 97\% \rightarrow 0\%$

Rys. 2. Funkcje $\ln(1- \Delta m_t/\Delta m_{max}) = f(t)$ dla zapraw 0,50; 0,65; 0,80 w $T = 20°C$ i $\varphi = 97\% \rightarrow 0\%$

$$\frac{1}{2} = \frac{4}{\sqrt{\pi}} \sqrt{D_m} \sqrt{t_{0.5}/d^2} \tag{24}$$

Thus:

$$D_m = \frac{0.483}{\pi^2} / \frac{t_{0.5}}{d^2} = 0.049 \frac{d^2}{t_{0.5}} \tag{25}$$

Such a simple formula could be used for determining mass diffusivity D_m of the process concerned provided the above assumptions have been met.

The identical equation is also obtained from the advanced phase of the process. Assuming that the reproduced curve representing relation $\ln(1-M_t/M_\infty) = f(t)$ and described by formula (20) remains linear at least until $M_t/M_\infty = 0.5$, then:

$$\ln \frac{1}{2} = -0.21 - D_m \pi^2 t_{0.5}/d^2 \tag{26}$$

After transforming the above equation, the following formula identical to the one given in (25) is obtained:

$$D_m = 0.049 \frac{d^2}{t_{0.5}} \tag{27}$$

An attempt to use the half-time method for the description of the desorption study is presented below. Before defining D_m values by means of the „$t_{0.5}$" method, the detailed

analysis of curves shown in Figure 1 was carried out. The curves represent the course of changes in mass Δm_t versus the square root of time. The condition of using the simplified half-time method is the linear character of relation $\Delta m_t = f(\sqrt{t})$ at least until $t = t_{0.5}$. Such an approximate linear relation in the samples in study was maintained for the first 140 hours of the experiment. In that time, the samples of mortar 0.50 released 50–65% of the total moisture content, the samples of mortar 0.65 released 63–76% and the samples of mortar 0.80 released 70–77% of the total moisture content accordingly. The process in study met theoretical assumptions of the „$t_{0.5}$" method and therefore could be covered by formula (25) that made it possible to determine the approximate value of mass diffusivity on the basis of time $t_{0.5}$ that corresponded to mass decrement $\Delta m_t = \frac{1}{2}\,\Delta m_{max}$.

Desorption that leads to a mass stabilization is a long process. The presented study included measurements that were taken within the period of about 4 months until the relative stabilization of the mass of samples. It should be noted, however, that the samples released half the total moisture during the first few days of the process. The graphic representation of relative decrements of mass $\Delta m_t/\Delta m_\infty$ of certain mortars in time t of the cycle Vd is shown in Figure 3. Having collected values of d and determined exact values of $t_{0.5}$ mass diffusivity $D_{mi}(t_{0.5})$, was calculated in Garbalińska [2000] for each sample, according to formula (25), and then the arithmetic average $D_m(t_{0.5})$, for each mortar was found. Values of $D_m(t_{0.5})$ are shown in Figure 4.
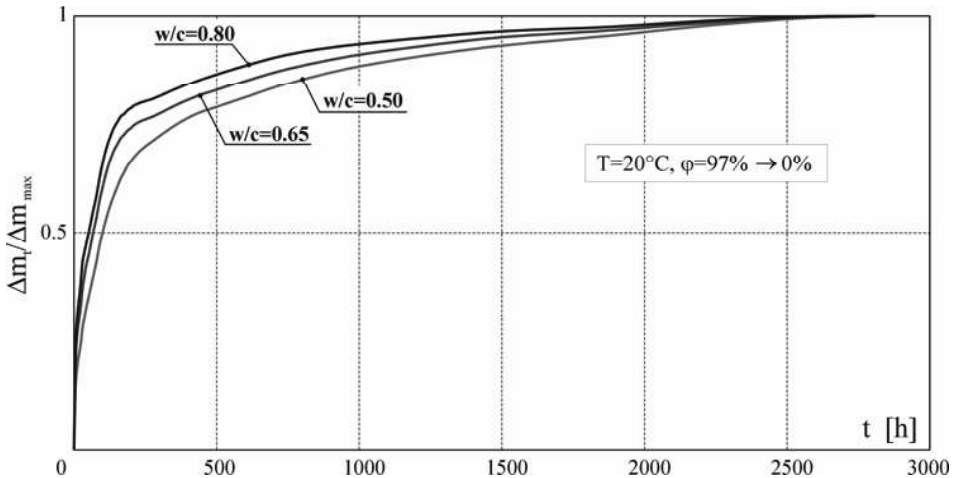

Fig. 3.   Functions $\Delta m_t/\Delta m_{max} = f(t)$ for mortars 0.50; 0.65; 0.80 at $T = 20°C$ and $\varphi = 97\% \rightarrow 0\%$
Rys. 3.   Funkcje $\Delta m_t/\Delta m_{max} = f(t)$ dla zapraw 0,50; 0,65; 0,80 w $T = 20°C$ i $\varphi = 97\% \rightarrow 0\%$

CONCLUSIONS

Figure 4 presents the comparison illustrating the divergences between mass diffusivity D_m of mortars found independently for the same process by means of different techniques (see Garbalińska [2002a]). There are following relations between the mass diffusivity found by means of the analysed methods:
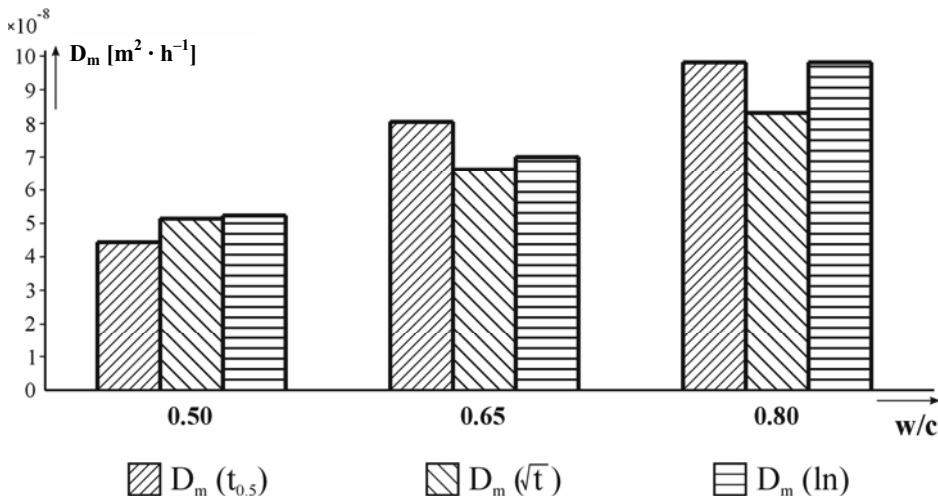
Fig. 4. Average values of mass diffusivity (D_m) of mortars 0.50; 0.65; 0.80 found for the desorption in study be means of three different methods

Rys. 4. Średnie współczynniki dyfuzji (D_m) zapraw 0,50; 0,65; 0,80 wyznaczane w badanym procesie desorpcji za pomocą trzech różnych metod

- mortar 0.50: $D_m(\sqrt{t})/D_m(\ln) = 0.99$; $D_m(t_{0.5})/D_m(\sqrt{t}) = 0.86$; $D_m(t_{0.5})/D_m(\ln) = 0.85$;
- mortar 0.65: $D_m(\sqrt{t})/D_m(\ln) = 0.94$; $D_m(t_{0.5})/D_m(\sqrt{t}) = 1.23$; $D_m(t_{0.5})/D_m(\ln) = 1.15$;
- mortar 0.80: $D_m(\sqrt{t})/D_m(\ln) = 0.84$; $D_m(t_{0.5})/D_m(\sqrt{t}) = 1.19$; $D_m(t_{0.5})/D_m(\ln) = 1.00$.

Differences between results of the methods vary within 0 to 23%, so they are rather alike as far as moisture measurements are concerned. Consequently, all the techniques could be regarded as practically useful. Each of them enables to determine the mass diffusivity in non-stationary desorption processes and the said factor characterizes transfer properties of the material in study at the given temperature and within the adopted range of humidity.

The mass diffusivity D_m values, found in the study for individual mortars, prove a significant influence of the differentiated structure of porosity on the results obtained. The more porous structure is, the greater mass diffusivity. The ranges of variation were as follows:

- ($\sqrt{t}$) procedure: $D_m(0.65)/D_m(0.50) = 1.27$; $D_m(0.80)/D_m(0.50) = 1.60$,
- logarithmic procedure: $D_m(0.65)/D_m(0.50) = 1.34$; $D_m(0.80)/D_m(0.50) = 1.88$,
- $t_{0.5}$ procedure: $D_m(0.65)/D_m(0.50) = 1.81$; $D_m(0.80)/D_m(0.50) = 2.21$.

In each of the methods a change in *w/c* may influence diffusivity, and that means a possibility of modeling the material structure and setting D_m in desired direction.

The desorption measurements presented in Garbalińska [2000] (partly discussed in this paper) were regarded as a pilot study to set out guidelines for further researches, the same may refer to the adsorption study described in Garbalińska [2002b, 2004]. Today the desorption and adsorption measurements of the mass diffusivity in cement based materials are being continued for more narrow adjacent ranges of humidity, along with stimulation of non-zero concentrations c_{m1} and c_{m2} (see Garbalińska [2006]).

ACKNOWLEDGMENTS

REFERENCES

Bagda E., 1988a. Zum Feuchtehaushalt von Beschichtungsstoffen. Teil 1. Die Wasser-dampfdurch-lässigkeit und die Bestimmung der Permeationskoeffizienten. Farbe+Lack 1, 15–18.

Bagda E., 1988b. Zum Feuchtehaushalt von Beschichtungsstoffen. Teil 2. Bestimmung des Diffu-sionskoeffizienten aus Absorptions-Desorptions-Messungen. Farbe+Lack 4, 270–272.

Crank J., 1989. The Mathematics of Diffusion. Oxford Science Publications, New York.

DIN 52 615, 1987. Wärmeschutztechnische Prüfungen. Bestimmung der Wasserdampf-durchläs-sigkeit von Bau- und Dämmstoffen.

Garbalińska H., 2000. Examination of isothermal coefficients of moisture transfer of porous buil-ding material [in Polish]. Report of Research Project KBN Nr 7 T07E 011 14, Szczecin.

Garbalińska H., 2002a. Isothermal coefficients of moisture transport of porous building material [in Polish]. Prace Naukowe Politechniki Szczecińskiej 571.

Garbalińska H., 2002b. Measurement of the mass diffusivity in cement mortar: use of initial rates of water absorption. International Journal of Heat and Mass Transfer 45, 1353–1357.

Garbalińska H., 2004. Application of the logarithmic procedure to absorption measurements of mass diffusivity for cement mortars. Heat and Mass Transfer 40, 963–972.

Garbalińska H., 2006. Application of $\sqrt{t}$ -type, logarithmic and half-time methods in desorptive measurements of diffusivity in narrow humidity ranges. Cement and Concrete Research 36, 1294–1303.

Gawin D., 2000. Modelling of associated thermal-moisture phenomena in building materials and structures [in Polish]. Zeszyty Naukowe Politechniki Łódzkiej 853.

Gawin D., Klemm P., 1993. A review of literature concerning associated processes of mass and energy transfer in capillary-porous centers [in Polish]. Fizyka materiałów i konstrukcji budowlanych 1, 4–33.

Kubik J., 2000. Moisture transfers in building materials [in Polish]. Politechnika Opolska.

Künzel H.M., Kiessl K., 1990. Bestimmung des Wasserdampfdiffusions-widerstandes von minera-lischen Baustoffen aus Sorptionsversuchen. Bauphysik 5, 140–144.

Nilsson L.O., 1980. Hygroscopic moisture in concrete – drying, measurements and related material properties. Lund, Report TVBM-1003.

Wyrwał J., 1989. Movement of moisture in porous building materials and partitions [in Polish]. Studia i Monografie. Wyższa Szkoła Inżynierska w Opolu 31.

Wyrwał J., Świrska J., 1998. Rising damp problem in buliding partitions [in Polish]. PAN KILiW, Studia z Zakresu Inżynierii 44.

ANALIZA PORÓWNAWCZA DESORPCYJNYCH METOD WYZNACZANIA WSPÓŁCZYNNIKA DYFUZJI WILGOCI

Streszczenie. W artykule poddano analizie porównawczej trzy metody wyznaczania dyfuzyjności (D_m), przetestowane w odniesieniu do niestacjonarnego procesu desorpcji, a dotyczące różnych etapów w jego przebiegu. Są to: metoda typu $\sqrt{t}$ – dotycząca wstępnej fazy procesu, procedura logarytmiczna – dotycząca zaawansowanej fazy procesu, oraz

metoda czasu połówkowego – odnosząca się do punktu czasowego odpowiadającego 50--procentowej wymianie masy. W artykule przedstawiono wyniki badań procesu desorpcji przeprowadzonych w temperaturze 20°C, a dotyczących trzech zapraw o wskaźnikach wodno-cementowych (w/c = 0,50, 0,65, 0,80). Próbki tych zapraw były kondycjonowane przez okres kilku miesięcy w wilgotności względnej powietrza φ = 97%, aż do czasu uzyskania równowagi wilgotnościowej, a następnie lokowane były w wilgotności $\varphi \approx$ 0%. Uzyskane w badanym procesie desorpcji (T = 20°C, φ = 97% → 0%) wartości $D_m(\sqrt{t})$, $D_m(\ln)$, $D_m(t_{0,5})$ wykazywały w przypadku wszystkich zapraw dość dobrą zgodność testowanych trzech metod – od w pełni zgodnych wyników: $D_m(t_{0,5})/ D_m(\ln)$ = 1,00 przy w/c = 0,80 do wyników najsilniej zróżnicowanych: $D_m(t_{0,5})/D_m(\sqrt{t})$ = 1,23 przy w/c = 0,65.