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PRINCIPLES AND METHOD OF DETERMINING THE THERMAL DIFFUSIVITY OF HOMOGENEOUS AND ISOTROPIC MATERIALS

Dan CONSTANTINESCU,[a*] Mariella CONSTANTINESCU,[b] Constanța MARIN-PERIANU,[a] Horia PETRAN,[a] Cristian PETCU,[a] Angela-Gabriela CARACAŞ[a] and Elena Maria ANGHEL[b]

[a] National Building Research Institute (INCERC), 266 Sos. Pantelimon, Bucharest, 021652, Roumania
[b] Institute of Physical Chemistry "Ilie Murgulescu" of Roumanian Academy, 202 Spl. Independentei, Bucharest, 060021, Roumania

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This article introduces the principles and the method of determining the *a* value of thermal diffusivity in terms of the solutions specific to the analysis of the transient thermal conditions of the heat transfer through infinite flat plates. The mathematical models are presented as well as the measured data processing results, the acceptability criteria, the deviations from the catalogue values, the sensitivity analysis of the analytical solutions, the laboratory equipment used and the applications of the building materials thermal diffusivity with reference to the assessment of the energy and environmental performances of new and existing buildings.

INTRODUCTION

The thermal response of the opaque or transparent envelope closing components of buildings which is defined by the specific thermal flow variation in time, at the closing component boundaries, but also by the variation of the inside energy of the whole building component subjected to random thermal load specific to the climatic parameters and to the subjective thermal load resulted from the thermodynamic processes specific to the occupied space (modifications of the built environment temperature and of the fluids enthalpy). The closing structures are of the composite type, made of materials characterized by different thermo-physical properties. The thermal response may be determined if the thermo-physical properties of the component materials are known; of these, the most important are thermal conductivity λ (used in determining the closing components thermal resistance in steady-state heat transfer processes) and thermal diffusivity a (a composed parameter used in determining the variation of the temperature range in heat transfer processes in real conditions, variable in time). The materials thermal diffusivity belongs to the category of materials transport properties. The building materials thermo-physical parameters are experimentally determined; harmonized standards are used for most of them. Thermal diffusivity is an exception from the standardized procedures as it is a derived parameter. The building materials have some characteristics both in terms of their structure (fibers or granules) and of the significant non-linearity of some of their thermo-physical properties in terms of temperature (mainly the heat-insulating materials). In such cases, the thermal diffusivity determination by calculation generates errors that may significantly alter the structures thermal response. The classical method, known and used since 1961 in determining the homogeneous solid materials thermal diffusivity is the "laser flash" method[1] based on the thermal response analysis related to the application of the laser flash on one of the surfaces of the tested sample. The "laser flash" method raises a number of difficulties in the case of fibrous materials (*e.g.* mineral wool) or granular materials (*e.g.* expanded polystyrene), extensively used in the constructions technique.[2] The use of a Heaviside step function

[*] Coresponding author: dan_const_home@yahoo.com

type load as thermal excitation function for a material sample is an alternative experimental method in determining the thermal diffusivity of the materials in terms of the laser flash method.[1] The methods proposed in this article are based on the thermal response as a temperature variation at an adiabatic surface[6,8] (Method 1) and as a variation of the specific heat flow at the contact boundary of the sample with the heat/cold sources[7,8] (Method 2). Method 2 has the advantage of the simultaneous determination of the thermal diffusivity and of the thermal conductivity of the solid respectively liquid materials (including the phase change materials) on the condition of abolishing, by the sample layout, the complementary effect of the natural convection in enclosed spaces. The third method, of reference in terms of the two previously examined, actually performed in practice of material properties assessment, uses the lumped capacitated method,[9,10] which may be used with geometric and procedural restrictions. These three methods belong to the classes specific to the laboratory assessments, namely calorimetry with the sample excitation and thermal response source based on reaching the thermodynamic balance between the sample and the adjacent fluid environment.[3-5] In terms of conduction heat transfer process modeling, two classes of boundary conditions are to be remembered, namely symmetrical boundary conditions of Dirichlet and von Neumann type[6,7] (Method 1), where the temperature of the flat plate boundary areas is preserved constant at a known value ϑ_{P_0} and asymmetric boundary conditions of Dirichlet type[6] (Method 2) where the temperatures of the flat plate boundary surfaces are different but constant. The first experimental method uses the Dirichlet symmetrical thermal excitation at the boundaries geometrically defining the flat plate, as a Heaviside function (identical temperature sudden leap on the areas geometrically defining the material plate the initial temperature of which is uniform). The second method uses the asymmetric load by applying the Heaviside excitation on one of the boundaries and by preserving the constant value of the initial temperature at the other boundary. The first method is used together temperatures measurement in the flat plate central zone and the second method in measuring the heat flows at the level $x = 0$. The solutions of the heat transfer equations in transient conditions, in the form of the temperature variation in time at the level $x = 0$ (Method 1) or of the thermal flow-rate variation at level $x = 0$ (Method 2) are presented according to the material thermal diffusivity and the identification of the calculated parameters with the measured values generates the procedure of determining the thermal diffusivity value (also by verifying the statistic criterion of errors acceptability). Method 3 – the calorimetric method was used with the methodological restrictions required by the calculation model as the "classical" reference method compared to the two ones presented in the article. The accurate determination of the thermal diffusivity, within the limits resulted from the sensitivity analysis is a necessary condition in determining the Unitary Thermal Response of the intelligent buildings envelope structures,[8] useful in assessing the heat and mass transfer in variable conditions of the components subjected to the random loads of the natural and anthropic environments.[9,10] The two methods presented in the article are easily applied in laboratory activities in order to determine the thermal diffusivity of building materials at the same time with the thermal conductivity determination. Methods 1 and 2 may be the object of the harmonized procedures specific to building products certification, in which case the laser flash method is subjected to certain inaccuracies caused by the building materials physical structure.[2] The experiments presented in this article are doubly targeted: to validate the mathematical models substantiating the building materials thermal diffusivity assessment methods and to describe the recommended procedures, with reference to the necessary equipments, test samples preparation (graded plate method), the measured thermodynamic parameters, the measured data processing methods and the accuracy rate of the results obtained, by comparison to the currently used method, namely the lumped capacitated method.[9,10]

EXPERIMENTAL

Laboratory equipments

The device used is specific to determining the materials thermal conductivity. Two methods of measuring in laboratory the building materials thermal conductivity are used, namely:

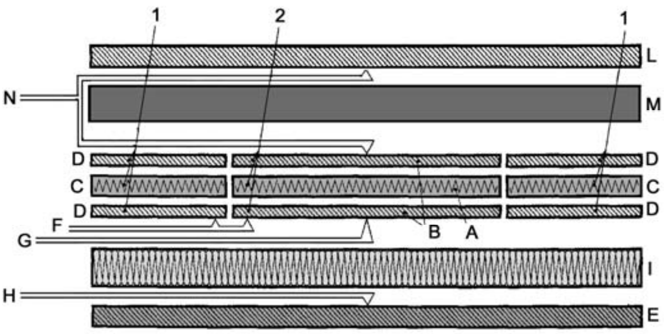
The guarded hot plate method (Method 1): the temperature values, measured by means of thermocouples fixed on $x = \delta$ and $x = -\delta$ plane.

The thermo-flux-meter method (Method 2): the heat flow is measured by means of a thermo-flux-meter plate or two such plates, fixed on the test sample(s) surfaces.

The device consists of the following components: a heating unit (hot plate), one or two thermo-flux-meter plate(s), one test sample, a cooling unit (cold plate). The device used is of single sample type, namely UNITHERM. It consists of a central square flat plate which is the heating unit (including an electric heater) and an insulated plate, called guard plate. The sample to be measured is placed between the plates. The guard plate is meant to insulate the sample from the device inactive zones; therefore the heat transfer is performed only between the sample and the heating plate. The heating unit has a 100 × 100 mm central zone called measuring zone, where a one-direction, constant and uniform heat flow can be reached. The central measuring zone is surrounded by an insulated zone called "guard zone". The device is equipped with additional insulated plates (additional guard zone) on the four sides (front, back, left, right) of the assembly consisting in heating unit – sample – guard plate, in order to avoid the heat transfer between the device and the environment. The device plates (central and guard) are hydraulically operated in order to provide a close contact between them and the sample under testing during the whole experiment; this is one of the essential conditions for obtaining accurate results. The device also has the function of measuring the thickness of the sample fixed between the two plates. The conductivity-meter with guarded hot plate with a single sample unit, allowing measurements at different temperatures (within the range 10°C-500°C), owned by INCERC Bucharest is presented in Fig. 1 and Fig. 2.

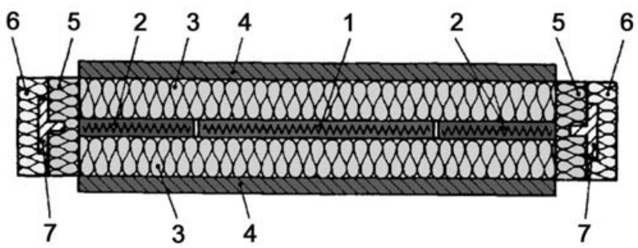
The calorimeter method (Method 3)

In order to determine the thermal diffusivity, the calorimetric method was used in parallel for determining the cooling/heating pace of the PCM (Phase Change Material) sample which is placed in an environment (air) with a constant monitored temperature. Copper – constantan thermocouples were used for temperatures measurement; for recording the evolution in time of the temperature of the samples subjected to the cooling / heating processes as well as the environment temperature, a Data Taker system connected to a PC for collecting data on thermocouples, was used. The use of air as an environment with controlled and constant temperature is required by the low value of number Bi_δ which meets the condition of minimizing the error generated by the "lumped capacitance method" model associated to the determination of the test sample temperature variation (13).



A – Cross-section of the heater in the measurement zone
B – Cross-section of the heating unit plates in the measurement zone
C – Cross-section of the heater in the guard zone
D – Cross-section of the heating unit plates in the guard zone
E – Cooling unit
F – Differential thermocouples
G – Thermocouples on the heating unit surface
H – Thermocouples on the cooling unit surface
I – Test specimen
L – Guard plate
M – Guard plate insulation
N – Differential thermocouples in the guard plate
1 – Cross section of the guard zone heating unit
2 – Cross-section of the measurement zone heating unit

Fig. 1 – Graded plate conductivity-meter – test specimen.



1 – Cross-section of the central hot plate in the measurement zone
2 – Cross-section of the guard hot plate
3 – Test specimen
4 – Cooling plate
5 – Border insulation (the spots represent the temperature sensors location)
6 – Additional guard insulation on the outside
7 – T shaped additional insulation on the outside

Fig. 2 – Details of the additional guard zone preparation.

RESULTS AND DISCUSSION

1. Validated mathematical models and experimental methods

Coefficient *a*, thermal diffusivity is a composed coefficient equally reflecting the heat transfer property and the balance state by values λ and ρc respectively and its mathematical generation suggests no possibility of "direct" measurement. Taking into account the transient nature specific to the conduction heat transfer through a flat plate, the heat transfer basic primary problem may be expressed as follows:

Consider a homogeneous flat plate at the initial temperature ϑ_0. It is strained by the symmetric/ asymmetric modification of the temperature (Heaviside step function) on the flat surfaces defining the plate. The request is to determine the space-time variation of the flat plate temperature field, $\vartheta\,(x, \tau)$.

According to the expression of the problem, it results that it is associated to certain boundary conditions itemizing, at the plate boundaries, the interaction between the plate and the environment. Two classes of boundary conditions are reminded, namely:

A. Symmetric boundary conditions of Dirichlet type where the boundary temperature is preserved constant at a known value, $\vartheta_{P0} \neq \vartheta_0$, where ϑ_0 is the plate uniform temperature at moment $\tau = 0$ – **Method 1.**

The determination of the thermal diffusivity implies a special equipping of the material plate with temperature sensors inside it, placed in the coordinate plane $\dot{x} = 0$. Actually, considering the symmetrical loading, the thermocouples are fixed on one of the flat areas that border the flat plate and this area is thermally insulated so that it becomes an adiabatic area. The other surface is placed in contact with the constant temperature hot source. The flat plate made of solid P15E includes thermocouples fixed between the area adjoining the hot plate (level $x = \delta$) and the adiabatic plane at level $x = 0$. The thermocouples are equidistantly fixed at 0.01 m on the plate thickness. The temperatures measured according to the experiment of Method 1 are presented in the diagram in Fig. 3 with the triangle symbol.

B. Asymmetric boundary conditions of Dirichlet type where the fluid temperature is preserved constant at value ϑ_{P0} at level $x = 0$ and at value ϑ_0 at level $x = \delta$ where ϑ_0 is the plate uniform temperature at moment $\tau = 0$ – M**ethod 2**.

This method is based on the determination of the heat flow at level $x = 0$ (the plane on which the temperature lap from the initial value ϑ_0 to value ϑ_{P0}). The experimental determination is performed using thermo-flux-meter small plates perfectly adjoining the flat plate surface, $x = 0$.

We mention that the environment adjoining the flat plate representing the test sample is not the natural environment subjected to complex property (heat and mass) transfer processes, difficult to quantify (an aspect specific to the “laser flash” method). The environment consists of the hot plate and the guarded flat plate in order to obtain, at the level $x = 0$, a theoretically adiabatic area if Method 1 is used and the hot plate and the cold plate of the equipment presented in Fig. 1 and Fig. 2 if Method 2 is used; the temperatures of these plates are controlled and the plates are in perfect thermal contact (hydraulically controlled) with the test specimen.

1.1. Method 1

The problem is expressed as the one-dimension conduction heat transfer through a flat plate initially at the uniform temperature $\tau = 0$ it is **symmetrically thermally loaded** by Dirichlet boundary conditions, at moments $\tau > 0$. The geometrical definition range is $x \in [-\delta, \delta]$.

The solution of problem has the following form:

$$u(\dot{x},\mathrm{Fo}) = 1 - \frac{4}{\pi}\cdot\sum_{k=0}^{\infty}\left\{(-1)^k \frac{1}{2k+1}\cdot\exp\left[-(2k+1)^2\cdot\left(\frac{\pi}{2}\right)^2\cdot\mathrm{Fo}\right]\cdot\cos\left[(2k+1)\cdot\frac{\pi}{2}\cdot\dot{x}\right]\right\} \tag{1}$$

where:

$$u(\dot{x},\mathrm{Fo}) = \frac{\vartheta(\dot{x},\mathrm{Fo})-\vartheta_0}{\vartheta_{P0}-\vartheta_0} \tag{2}$$

$$\dot{x} = \frac{x}{\delta} \tag{3}$$

$$\mathrm{Fo} = \frac{a\cdot\tau}{\delta^2} \tag{4}$$

Based on the measured temperature variation at the level $\dot{x} = 0$ (the plate plane at level $x = 0$ – the adiabatic surface), $\vartheta_{M,j}(\dot{x}=0,\mathrm{Fo}_j)$, the following equation is generated for each moment τ_j (namely for a value Fo_j):

$$1-\frac{4}{\pi}\cdot\sum_{k=0}^{\infty}\left\{(-1)^k\frac{1}{2k+1}\cdot\exp\left[-(2k+1)^2\cdot\left(\frac{\pi}{2}\right)^2\cdot \mathrm{Fo}_j\right]\right\}=\frac{\vartheta_{M,j}(\dot{x}=0,\mathrm{Fo}_j)-\vartheta_0}{\vartheta_{P0}-\vartheta_0} \quad (5)$$

which is solved in terms of number Fo_j. The relation defining the Fo_j dimensionless number provides the a_j thermal diffusivity value:

$$a_j=\frac{\mathrm{Fo}_j\cdot\delta^2}{\tau_j} \quad (6)$$

The result is that each of the equations (6_1), (6_2) … (6_n) will provide a value $a_1, a_2 \dots a_n$.

Based on the variation function of the root mean standard deviation of the values provided by equations (6_1)....(6_n) in terms of thermal diffusivity, considered as an independent parameter, the thermal diffusivity value which corresponds to the minimum value of the function (by solving equation $\frac{\mathrm{d}\sigma(a)}{\mathrm{d}a}=0$ which represents the necessity condition associated to the mathematical model), is determined, further called the representative thermal diffusivity specific to the experiment and marked by $\bar{a}$.

The root mean standard deviation of values a_j around the $\bar{a}$ representative value, is determined by the following relation:

$$\text{RMSD} = \sigma\{a\}=\sqrt{\frac{\sum_{j=1}^{n}(a_j-\bar{a})^2}{n\cdot(n-1)}} \quad (7)$$

The following condition (representing the sufficient condition associated to the mathematical model) should be met so that value $\bar{a}$ should represent the thermal diffusivity of the tested material:

$$\text{CV (RMSD)} =\frac{\sigma\{a\}}{\bar{a}}\le 0,05 \quad (8)$$

The diagram in Fig. 3 presents the variation of the root mean standard deviation in terms of thermal diffusivity, considered an independent parameter. The use of the condition of the minimum leads for each of the analyzed methods, namely Method 1 (proposed in the article) and Method 3 (currently used) to the values $\bar{a}.met.1 = 8.24466\cdot10^{-8}$ m²/s and $\bar{a}.met.3 = 8.27483\cdot10^{-8}$ m²/s respectively; these values are very close and do not prove the necessity of adopting a new method. It is noticed that when criterion (8) is input, it clearly emphasizes the superiority of Method 1 over Method 3, even if the representative thermal diffusivity values are close (Table 1).

Table 1 and the diagram in Fig. 4 present the results of the processing of the data measured according to the mathematical model (based on P 15E PCM experiments). The correlation curves for moments τ = 3600 s and τ = 10800 were marked out as functions $\vartheta_m(\dot{x},\tau_j)$; here, indicator m symbolizes the source of the function, namely the material temperature measured values at $\dot{x}$ dimensionless levels, together with the curves provided by relations (1) and (2) by using the single value $\bar{a}.met.1 = 8.24466\cdot10^{-8}$ m²/s, resulted from minimizing function $\sigma(a)$ – diagram in Fig. 3. The overlapping of the experimental and the theoretical curves is noticed.

Table 1

P 15E PCM – Measurement results synthesis

Time [s]	a – Met. 1 [m²/s]	a – Met. 3 (catalogue) [m²/s]
3600	7.99341E-08	8.55100E-08
5400	8.41206E-08	8.35206E-08
7200	8.37853E-08	1.27468E-07
9000	8.19432E-08	5.66132E-08
10800	8.24498E-08	6.01980E-08
	$\bar{a}.met.1$	$\bar{a}.met.3$
	8.24466E-08	**8.27483E-08**
	CV (RMSD)	CV (RMSD)
	0.00906051	**0.15306**

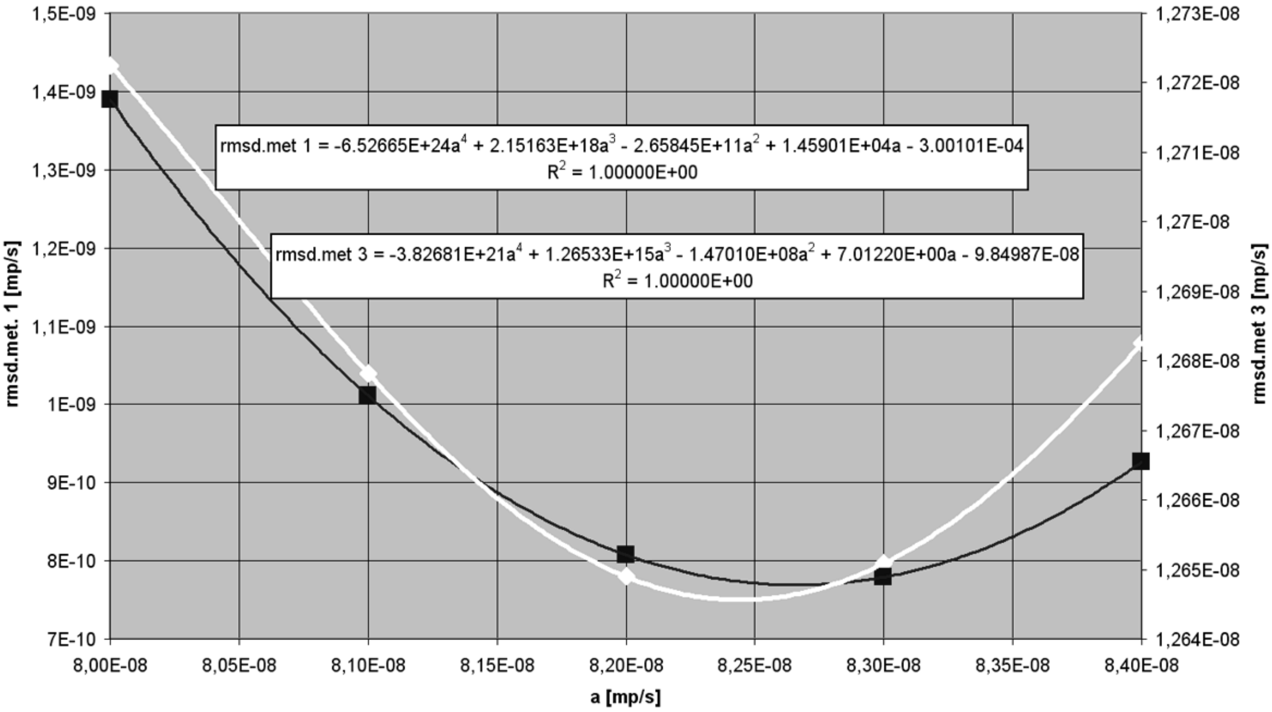


Fig. 3 – Root mean square deviation in terms of thermal diffusivity – P 15E PCM – solid state.

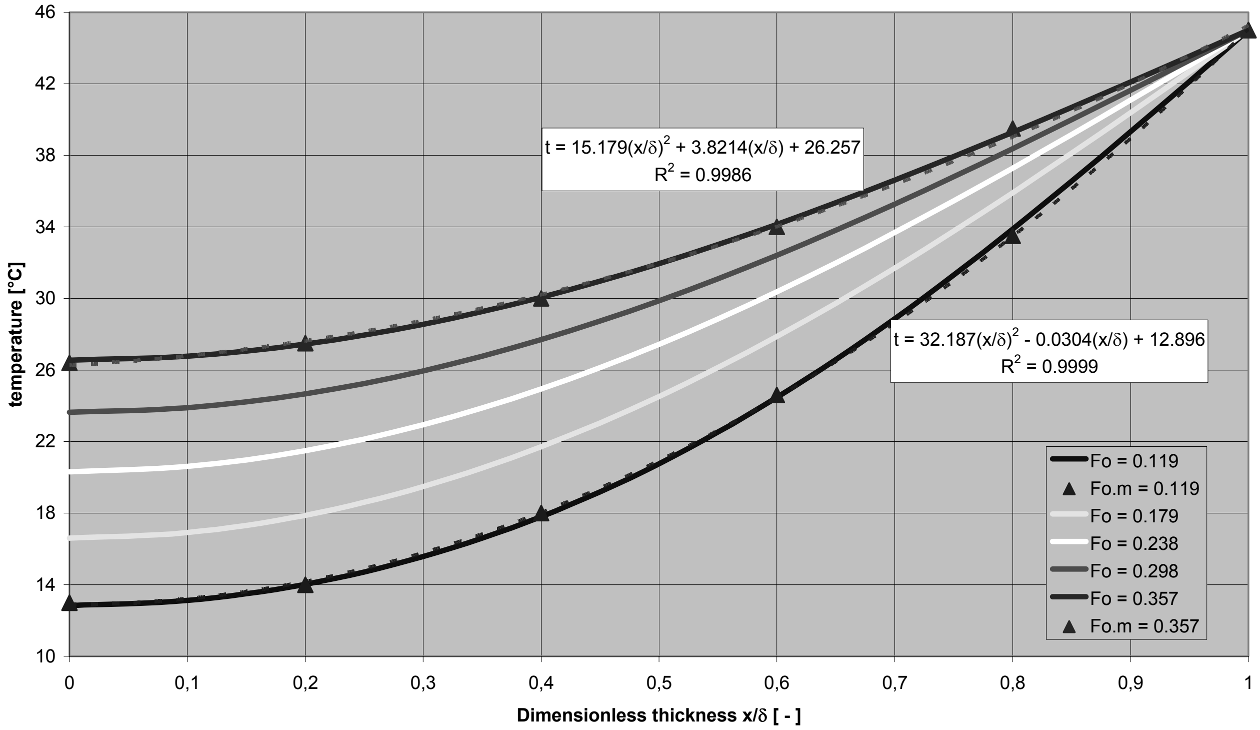


Fig. 4 – Temperature variation in terms of dimensionless thickness – PCM, P15 E solid state, $\delta = 0.05$ m – Method 1 – calculated and measured values.

1.2. Method 2

The problem is expressed as the one-dimension heat transfer through a flat plate, the initial uniform temperature of which is ϑ_0, asymmetrically thermally loaded by Dirichlet boundary conditions at moments $\tau > 0$. The solution of the problem is the following, as the dimensionless temperature (2) is provided by the following relation:

$$u(\dot{x},\mathrm{Fo}_j)=1-\dot{x}+2\cdot\sum_{k=1}^{\infty}(-1^k)\cdot\frac{\sin\left[k\cdot\pi\cdot(1-\dot{x})\right]}{k\cdot\pi}\cdot\exp[-(k\cdot\pi)^2\cdot\mathrm{Fo}_j] \quad (9)$$

The expression of the heat flow density (specific heat flow) is provided by relation:

$$q(\dot{x},\mathrm{Fo}_j)=q_0\cdot\left\{1+2\cdot\sum_{k=0}^{\infty}(-1)^k\cdot\cos\left[k\cdot\pi\cdot(1-\dot{x})\right]\cdot\exp[-(k\cdot\pi)^2\cdot\mathrm{Fo}_j]\right\} \quad (10)$$

The dimensionless specific heat flow at level $x = 0$ is determined by equation:

$$\frac{q(\dot{x}=0,\mathrm{Fo}_j)}{q_0}=1+2\cdot\sum_{k=0}^{\infty}\exp\left[-(k\cdot\pi)\cdot\mathrm{Fo}_j\right] \quad (11)$$

where q_0 represents the value of the specific heat flow in heat transfer steady-state conditions determined according to the thermal conductivity (known) of the plate material, the flat plate thickness and the values of the two temperatures of the flat plate surfaces. The value of the thermal diffusivity is determined as a solution of equation (11), where the thermal flow-rate density values $q(\dot{x}=0,\mathrm{Fo}_j)$ are those provided by the experiment, for different τ_j moments. The representative value $\overline{a}.met.2$ is determined by relations (6)...(8). The diagram in Fig. 5 presents the results of the measurements and processing of the data measured on burnt brick. The values of the specific thermal flow-rate measured at different moments at level $\dot{x} = 0$ are in the diagram, marked by the rhomb symbol and are figured using the I[st] bisector of the Cartesian coordinate system which represents the highest possible exigency of the experiment, namely the identity between the measured values and the values theoretically determined by relation (11). The regression straight line equation based on the measured values (represented by the interrupted line) is in fact identical to the I[st] bisector equation, which proves the accuracy of the method presented in this article.

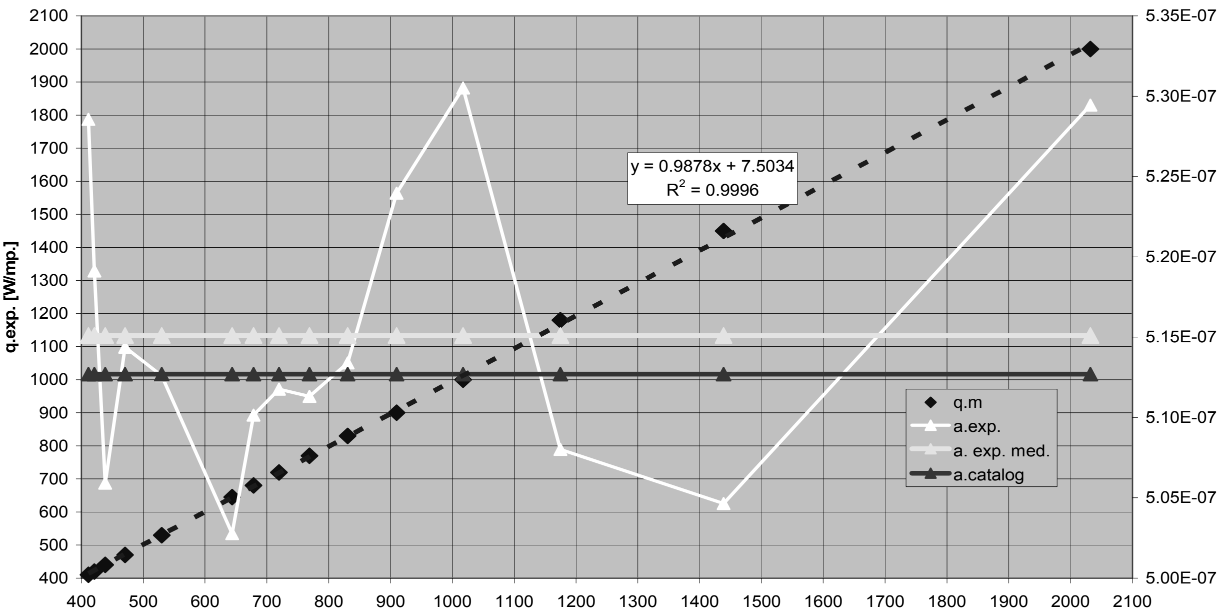


Fig. 5 – Thermal diffusivity in terms of flow-rate – Method 2 – burnt brick.

1.3. Method 3

The calorimetric method based on the lumped capacitance method improperly extrapolated for energy efficient constructions materials. The dimensionless temperature provided by solving the conduction equation[8] in Newton type boundary conditions, for level $\dot{x}=1$ specific to the plate outside plane has the following expression:

$$u(\dot{x}=1,\mathrm{Fo}_j)=2\cdot\sum_{k=0}^{\infty}(-1)^k\cdot\frac{\sqrt{\mathrm{Bi}_\delta^2+z_k^2}}{\sqrt{\mathrm{Bi}_\delta^2+\mathrm{Bi}_\delta+z_k^2}}\cdot\cos(z_k)\cdot\exp(z_k\cdot\mathrm{Fo}_j) \quad (12)$$

where z_k are the solutions of the following eigenvalues equation: $z_k\cdot\mathrm{tg}(z_k)-\mathrm{Bi}_\delta=0$

The dimensionless temperature resulted from the lumped capacitance method is expressed as follows:

$$\overline{u}(\mathrm{Fo}_j)=\exp(-\mathrm{Bi}_\delta\cdot\mathrm{Fo}_j) \quad (13)$$

The condition of minimizing the error of the integral method solution (13) compared to the accurate solution (12), generates the applicability range of Method 3 for $\tau > 1800$ s and $\mathrm{Bi}_\delta < 0.20$ (a severe condition, asociated with the use of air as an isothermal environment). The additional condition is generated by the necessity of using the compound heat transfer surface coefficient (natural convection and radiation) as a function depending on the sample surface temperature and on the fluid adjacent to the sample. The surface coefficient of the heat transfer between the fluid (air) and the test specimen surface is a non-linear function of the temperature difference between the fluid and the test specimen outside surface. The determination of this function is a source of errors because it is based on the dimensionless criterion-related equations specific to natural convection in open spaces the accuracy of which ranges within $\pm 25\%$ compared to the accurate value of coefficient α_{cv}.[8]

2. Sensitivity analysis

The sensitivity analysis includes the determination of the admissible error range for the values of the building material thermal diffusivity as a result of the impact on the assessment of the heat flow specific to the surface adjoining the occupied spaces. The diagram in Fig. 6 presents in the case of brick – a traditional building material – the dependency of specific heat flow specific deviation from the true value in terms of the variation of the thermal diffusivity values. The true value is the value determined by using one of the Methods 1 or 2 of this article and using the **catalogue material** as a support (example: a newly obtained material according to the standard material recipe). Other materials belonging to the same class or materials taken from existing buildings affected by the impact of the natural and anthropic environment will be characterized by thermal diffusivity values different from that specific to the standard material. The conclusion of the sensitivity analysis refers to the impact of the environment on the energy performance of an existing building envelope. Therefore, in the case of the burnt brick, a deviation of over 12% of the *a* value compared to the catalogue value causes an assessment error of the thermal flow density which exceeds 5% compared to the basic value (based on the thermal diffusivity catalogue value).

It results that the new methods presented ensure a high accuracy in assessing an intensity of the heat transfer at random climatic loads – transient conditions.

3. Heat transfer through building components subjected to random climatic and anthropic loads

The thermal response of the building components adjoining the natural outdoor environment is represented the heat flow specific to the surface adjoining the built (occupied) environment. The heat flow rates vary according to the random outside and anthropic loads. The values resulted are necessary in designing the buildings energy-related layout according to their target and to the energy performance of the structural components as well as of the entire building. The analysis of the dynamic thermal response is based on the Unitary Thermal Response of the homogeneous and non-homogeneous structures, linear and non-linear, in terms of the temperature[8]. UTR (Unitary Thermal Response) is determined in terms of the known values of the thermal diffusivity of the building components forming the closing structures.

Expressions of the heat flow rates on the inside / outside surfaces of a randomly loaded flat building component – loading functions $\varphi_1(\tau)$ and $\varphi_2(\tau)$:

$$\begin{pmatrix}\{q_i(\tau)\}\\ \{q_e(\tau)\}\end{pmatrix}=\begin{pmatrix}\{X(\tau)\}^T & \{Y(\tau)\}^T\\ \{Y(\tau)\}^T & \{X(\tau)\}^T\end{pmatrix}\cdot\begin{pmatrix}\{\varphi_1(\tau)\}\\ \{\varphi_2(\tau)\}\end{pmatrix} \quad (15)$$

where: $\{X(\tau)\}^T$, $\{Y(\tau)\}^T$ – row vectors, are UTR components; { } – column vector.

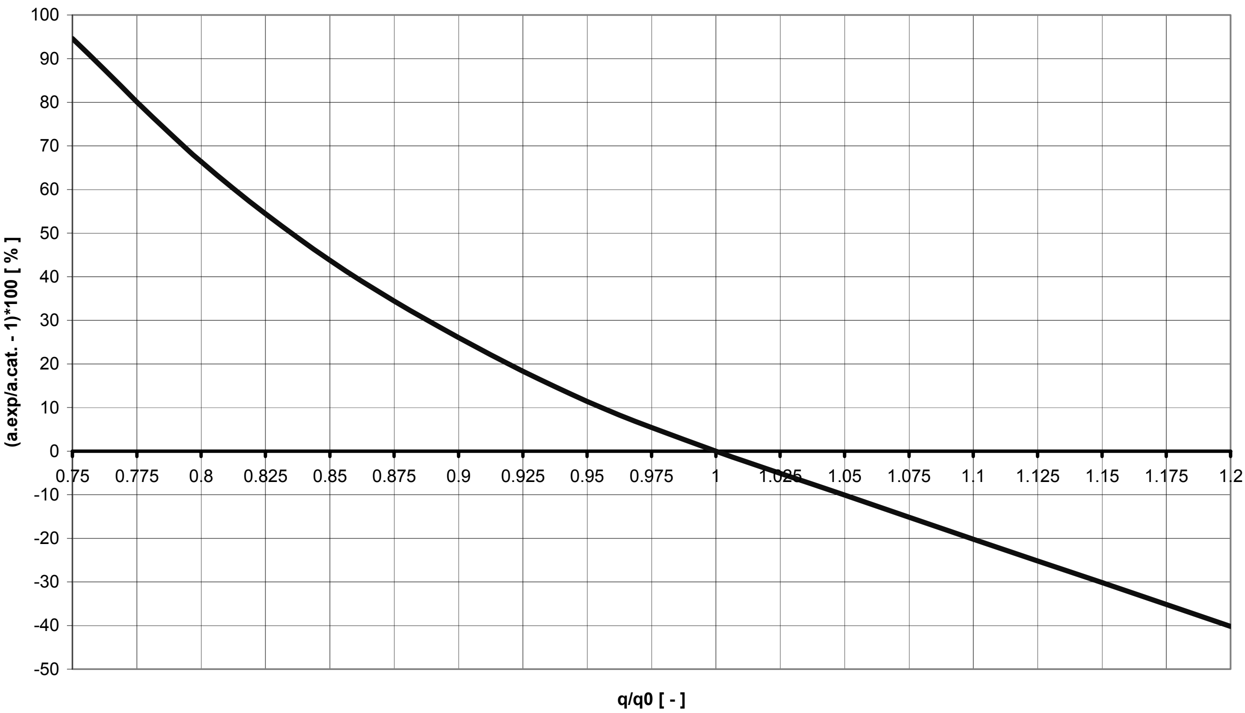


Fig. 6 – Sensitivity analysis – burnt brick.

The Unitary Thermal Response $\{X(\tau)\}$, $\{Y(\tau)\}$ is expressed according to the building material thermal diffusivity by means of the Fourier number and allows the characterization of the Buildings Energy Performance in terms of the climatic parameters specific to the climatic zones and of the energy profile of the occupied spaces energy-related equipments (indoor air relative temperature and humidity).[8]

CONCLUSIONS

This article presents two new methods of experimentally determining the building materials thermal diffusivity. The methods of processing the measured data based on easily used mathematical models are described. The advantage of using these methods is that the experiment necessary in determining the building materials thermal conductivity based on the guarded plate method provides the data necessary and sufficient in determining the thermal diffusivity of the tested material. The methods used in determining the building materials thermal diffusivity proposed in this article are based on the thermal response of the test specimen as a temperature variation at an adiabatic surface (Method 1) and as a variation of the specific heat flow at the contact boundary of the sample with the heat/cold sources (Method 2). The third method, of reference in terms of the two previously examined, uses the lumped capacitated method, which may be used with geometric and procedural restrictions. Both sets of thermodynamic parameters (intensive and extensive respectively) generate equations the solutions of which are components of the thermal diffusivity values set. The experimental results based on first and 2nd methods and the possible errors resulting from the use of the calorimetric method (third Method), extensively used in the constructions materials technique as well as the method of minimizing the possible errors by a proper dimensioning of the material samples under measurement, are presented.

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REFERENCES

1. W.J. Parker, R.J. Jenkins, C.P. Butter and G.L. Abbot, *J. Appl. Phys*., **1961**, *32*, 1679-1684.
2. K. Shinzato and T. Baba, *J. Therm. Anal. Calorimetry*, **2001**, *64*, 413-422.
3. V. Bohac, M.K. Gustavsson, L. Kubicar and S.E. Gustavsson, *Rev. Scient. Inst.*, **2000**, *71*, 2452-2455.

4. Y. Takahashi, *Pure & Appl. Chem*, **1976**, *47*, 323-331.
5. S.E. Gustavsson, *Rev. Scient. Inst.*, **1991**, *62,3*, 797-804.
6. L. Hamburger, "Conducţia căldurii", Ed. Academiei R.P.R., Bucharest, 1956.
7. F. Incropera and D.P. De Witt, "Fundamentals of Heat Transfer", John Wiley & Sons, 1981.
8. D. Constantinescu, "Tratat de inginerie termică. Termotehnica în construcţii", vol. 1, Ed. AGIR, Bucharest, 2008.
9. D. Constantinescu, H. Petran and C. Petcu, "Performanţa energetică a clădirilor noi şi existente – Fundamentare teoretică", Ed. UAUIM, Bucharest, 2009.
10. D. Constantinescu, H. Petran and C. Petcu, "Aplicaţii ale indicatorului performanţa energetică a clădirilor", Ed. UAUIM, Bucharest, 2009.