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THERMAL CONDUCTIVITY DETERMINATION FOR AUTOCLAVED AERATED CONCRETE ELEMENTS USED IN ENCLOSURE MASONRY WALLS

BY

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Abstract. In the current context, where the climate changes effects are developing continuously, with a permanent intensification, the energy efficiency of buildings became a starting point in current building design. The energy efficiency of a building is directly influenced by the thermal performances of the envelope. Therefore, desingning of envelope elements whose global thermal resistance exceed the required minimum values, is a mandatory measure. Increasing thermal performances of enclosure mansonry walls; it can be made by thermal insulating or by using masonry blocks with low thermal conductivity. In this category of building materials it can be found also autoclaved aerated concrete blocks.

The paper presents some experimental determination of thermal conductivity for AAC blocks manufactured in our country. The measurements ware made in the Laboratory of Building Physics within Faculty of Civil Engineering and Building Services from Iaşi. Furthermore, the equivalent thermal conductivity of an AAC masonry was determined by using an FEM software and mathematical calculus.

Key words: energy performance; AAC masonry blocks; thermal conductivity; climate chamber.

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1. Introduction

In cold season, the indoor hygrothermal comfort conditions are accomplished with high fossil fuels consumption and with a negative environmental impact, trough GHG emissions (ADENE 2013).

Decreasing the residential energy consumption and raising energy efficient buildings are strategic objectives of the European politics (http://eur-lex.europa.eu/). The EU legislation presents a set of pecularities regarding this class of buildings, according to the specific climate conditions and to the building type, establishing an annual heating energy consumption between zero and 50...75 kW.h/m^2/year (C107 – 1997… 2011).

Designing this type of buildings assumes using of building materials with low thermal conductivity (lower than 0.1 W/m.K) or very thick thermal insulations.

Using external walls with distribute thermal resistance can be an alternative for increasing the envelope level of thermal protection and decreasing the thickness of required thermal insulation.

2. AAC Blocks and Walls

The autoclaved aerated concrete (AAC) masonry is used for external walls due to the material advantages, referred to its low density, to the voluminous character of the blocks, thereby higher building speed, and to its favourable water vapour permeability.

Tabel 1
Termotechnics Characteriscs of Buildings Materials (C107 – 1997… 2011)

No.	Material	Bulk density, ρ	Rated thermal conductivity, λ	Thermal assimilation coefficient, s	Water vapour permeability resistance factor, μ_D	Mass heat capacity, c
	AAC block	kg/m^3	W/(m.K)	W/(m^2. K)	–	J/(kg.K)
1.	GBC – 50	750	0.28	3.57	4.2	
2.	GBN – 50	700	0.27	3.39	4.2	
3.	GBN – 35	600	0.24	2.96	3.7	
4.	GBN – T and GBC – T	550	0.22	2.71	3.5	
5.	Bricks masonry	1,800	0.80	9.51	6.1	87
6.	AAC masonry					
6a.	with thin joints GBN 35	675	0.27	3.38	3.8	
6b.	with thin joints GBN 50	775	0.30	3.82	4.3	
6c.	with usual joints GBN 35	725	0.30	3.70	3.9	
6d.	with usual joints GBN 50	825	0.34	4.20	4.4	

Thermally, load-bearing or non load-bearing AAC walls are defined by distributed thermal insulation. The types of materials used and theirs characteristics are presented in Table 1.

Used for load-bearing or non load-bearing walls, these blocks are viable and durable alternatives.

3. Samples Analysis and Numerical Simulations for a Masonry Panel

With the specific intention of place them in thermal insulation category (referred to their density below 500 kg/m^3 and thermal conductivity below 0.1 W/m.K) new AAC blocks was manufactured, which are lighter than the ones presented in Table 1 and are designed to be bulk-production manufactured. For evaluating the thermal properties of the blocks and walls a set of experimental measurements war taken regarding:

a) dry density of the block and walls;

b) thermal conductivity for AAC blocks and equivalent thermal conductivity of the AAC masonry;

c) the behaviour on mass transfer.

The research involved the use of a Twin Climate Chamber manufactured by Feutron Klimasimulation GmbH, Germaniy, comm. – no. 9004 2861 and a heat flux-meter for the determination of the AAC blocks thermal conductivity. Furthermore, the numerical simulation used for the determination of equivalent thermal conductivity of the AAC masonry was taken in the ANSYS® Workbench 12.0 software.

3.1. The AAC Blocks Thermal Conductivity Determination

The Twin Climate Chamber (Fig. 1) create two different environments (warm and cold), defined by relative humidity (RH) and temperature. In the warm chamber the RH and the temperature varies between 10%…95% respectively 5%…100ºC and in the cold chamber the RH and the temperature varies between 15%…95%, respectively, 45%…100ºC.

The measurements method uses SR EN ISO 8990:2002 and SR EN 1946-3:2004.

For measuring the heat flow intensity and the surface temperature was used a TRSYS01 Hukseflux heatflux meter and a Testo 616 electric humidity meter. The AAC blocks, with de dimension 600 × 150 × 250 mm, category I, GBN 25 (SR EN 771-4/2004; SR EN 771-4/2004/A1-2005) were placed in the space between the two climate chambers using a guard ring. The position of the heat flux plates and of the thermocouples is shown in Fig. 2.

In order to drying them, the AAC blocks were placed in the climate chamber at a temperature of 80°C and relative humidity of 10% for 72 h. The resulting RH of the blocks was 5.5% as determined using the electrical humidity meter Testo 616.

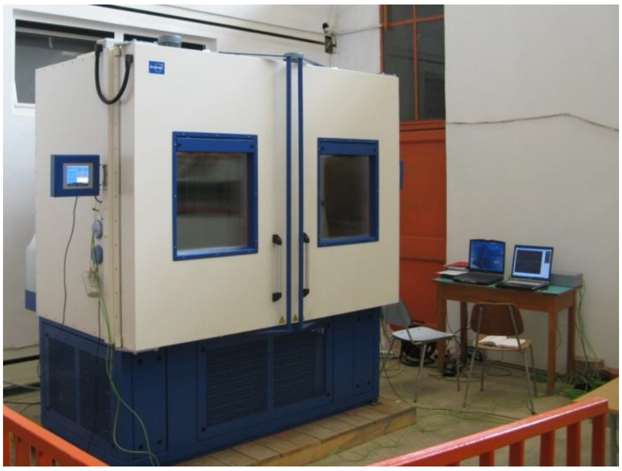


Fig.1 – Twin Climate Chamber.

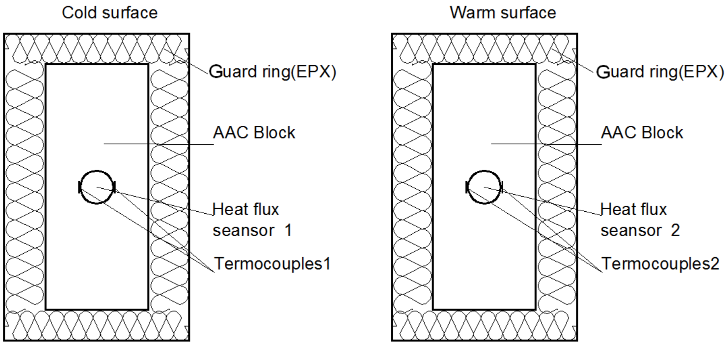


Fig. 2 – The heat flux sensors and the thermocouples position.

After that, the dried blocks were placed in the space between the chambers and the heat flux sensors and the thermocouples war installed. As is known, the thermal conductivity of the blocks can be determined, knowing the intensity of the heat flux crossing the specimen, the surface temperatures, as well as the thickness of the specimen.

Test duration was of 20 h for the following parameters:

a) warm chamber air temperature was 40ºC and relative humidity 10%;

b) cool chamber air temperature was 20ºC and relative humidity 10%;

and of 20 h for following parameters:

c) warm chamber air temperature was 40ºC and relative humidity 60%;

d) cold chamber air temperature was 30ºC and 60% relative humidity.

Heat flow direction was perpendicular to the surface of the blocks from the hot face to the cold one.

The test results are shown in Table 2.

Table 2
Thermophysical Characteristics of the Tested AAC Blocks

Dual climate chamber parameters	Relative humidity 10%, T_i – warm chamber = 40ºC, T_i – cold chamber = 20ºC			Relative humidity 60% T_i – warm chamber = 40ºC, T_i – cold chamber = 30ºC		
Tested block	E1	E2	E3	E1	E2	E3
d – blocks thickness, [m]	0.15	0.15	0.15	0.15	0.15	0.15
The RH of the AAC blocks, [%]	5.5	5.7	5.7	5.5	5.7	5.7
Average temperature of warm surface, [ºC]	39.81	40.46	39.65	39.81	40.62	40.26
Average temperature of cold surface, [ºC]	21.20	22.05	21.18	21.05	31.11	30.81
φ – the heat flow, [W]	13.82	12.97	12.62	17.36	8.22	8.356
ΔT – the difference between the tested block surface temperatures, [K]	18.92	18.41	18.46	18.77	9.4	9.456
R – the thermal permeability resistance of the tested AAC blocks, [$m^2 \cdot K/W$]	1.3688	1.4192	1.4624	1.081	1.155	1.1475
$\lambda_{average}$ – thermal conductivity of the AAC blocks, [W/m·K]*	0.109*	0.1057*	0.103*	0.1387*	0.1311*	0.1325*
Measuring errors	±10%	±10%	±10%	±10%	±10%	±10%

*The thermal conductivity values of the AAC blocks presented in Table 2, are obtained using weighted average of the measurements during the steady–state heat flux.

The values determined during steady heat flow are shown in the graphs in Figs. 3,...,6.

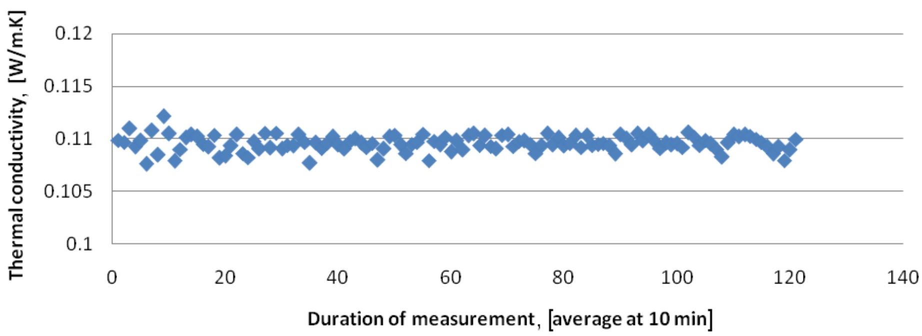


Fig. 3 – Variation of the thermal conductivity of the AAC block E1, at RH of 10% and temperatures of T_i – warm chamber = 40ºC, T_i – cold chamber = 20ºC.

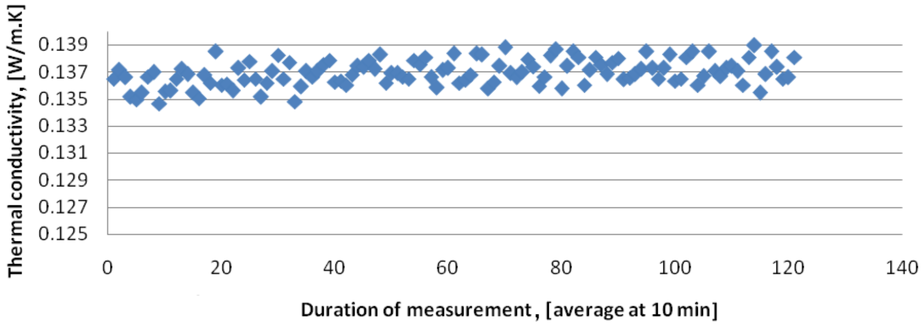
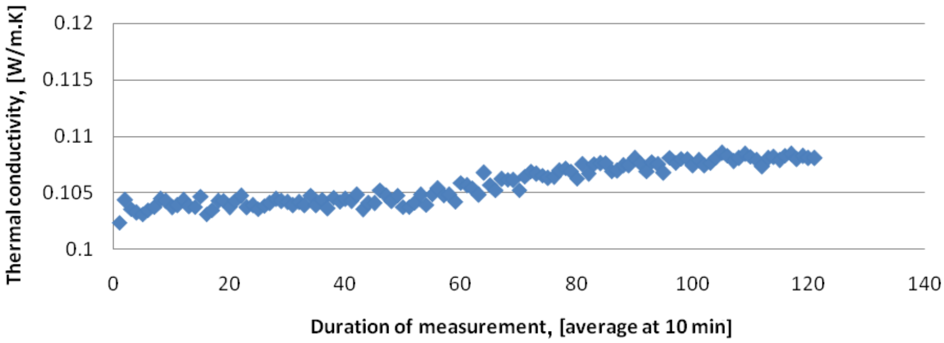


Fig. 4 – Variation of the thermal conductivity of the AAC block E1, at RH of 60% and temperatures of T_i – warm chamber = 40ºC, T_i – cold chamber = 30ºC.



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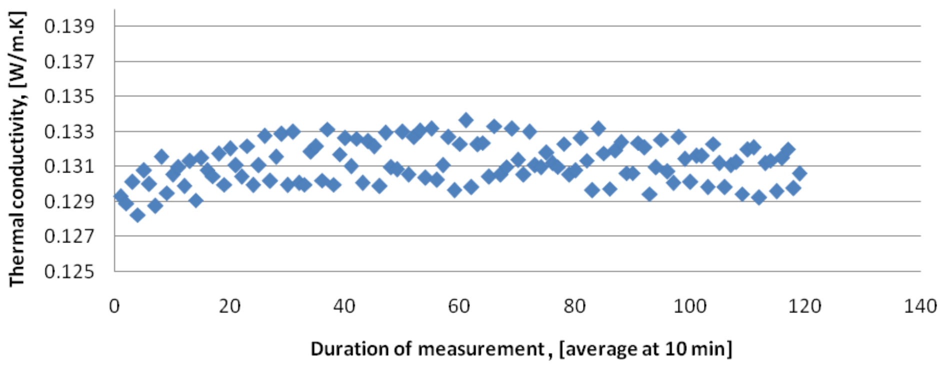

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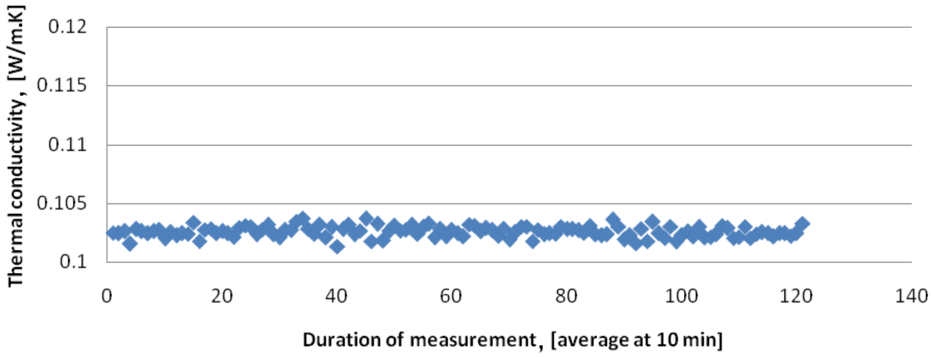
Fig. 5. Variation of the thermal conductivity of the AAC block E2, at:
a – RH of 10%, temperatures of T_i – warm chamber = 40ºC, T_i – cold chamber = 20ºC;
b – RH of 60 %, temperatures of T_i – warm chamber = 40ºC, T_i – cold chamber = 30ºC.



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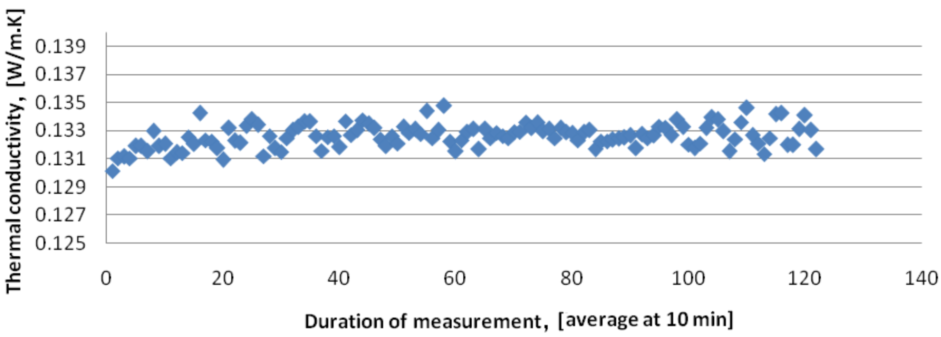

b

Fig. 6 – Variation of the thermal conductivity of the AAC block E3, at:
a – RH of 10 %, temperatures of T_i – warm chamber = 40ºC, T_i – cold chamber = 20ºC;
b – RH of 60 %, temperatures of T_i – warm chamber = 40ºC, T_i – cold chamber = 30ºC.

The characteristics of the AAC blocks have the following weighted averages:

a) dry bulk density: 390.0 kg/m^3;

b) pore volume: 39.5% vol.;

c) thermal conductivity (at own RH around 5.5% and RH of the chamber environments 10%): 0.11 W/m.K;

d) thermal conductivity (at own RH around 5.5% and RH of the chamber environments 60%): 0.135 W/m.K.

3.2. The Determination of Equivalent Thermal Conductivity of the AAC Masonry

Numerical simulation was performed using the program ANSYS® Workbench 12.0. Characteristics of the AAC blocks are presented above.

To build masonry panels it was used a mortar for joints type M5 having thermal conductivity of 0.87 W/m.K. There was two variants studied, refering to the thickness of the horizontal and vertical joints, respectively, 3 and 5 mm. The configuration of the AAC masonry panel is shown in Fig. 7.

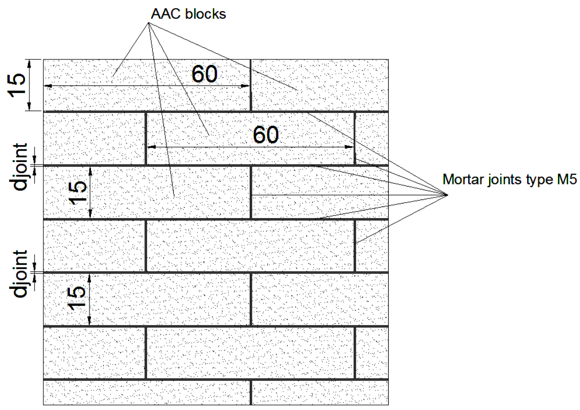

Fig. 7 – AAC masonry panel.

Table 3

The Equivalent Thermal Conductivity of the AAC Masonry Panel, λ_{zid}

No.	Thermal conductivity of AAC blocks $\lambda_{average}$, [W/m.K]	Thermal conductivity of the mortar $\lambda_{average}$, [W/m.K]	The thickness of the mortar joints d_{rost}, [mm]	Equivalent thermal conductivity of the AAC masonry λ_{zid}, [W/m.K]
1.	φ_i = 10%; λ = 0.11	0.87	3	0.12695
			5	0.13820
2.	φ_i = 60%; λ = 0.135		3	0.15153
			5	0.16256

It can be noticed a negative effect of the mortar joint on the thermal conductivity of the masonry panel when its thickness and its length increase. Therefore, the conductivity of the panel is increased from 0.127 to 0.138 W/m.K and from 0.152 to 0.163 W/m·K (Table 3), with the increase of the mortar joint thickness.

4. The Determination of the AAC Masonry Wall Thermal Inertia

The thermal inertia coefficient of a building element is determined by the following relation:

$$D = \sum_j \frac{d_j}{\lambda_j} s_j , \tag{1}$$

where: D is the index of the thermal inertia of a building element; d_j – the thickness of the building element or of one material layer from the building element structure, [m]; λ_j – rander thermal conductivity of the material, [W/m.K]; s_j – thermal assimilation coefficient of material, [W/m^2.K]; the value of this parameter is s = 3.4 W/m^2.K.

The results are shown in Table 4.

Table 4

Thermal Inertia of the AAC Masonry Walls

Joints thickness, d, [mm]	RH φ_i, [%]	Equivalent thermal conductivity of the AAC masonry λ_{zid}, [W/m.K]	$D = \sum_j \frac{d_j}{\lambda_j} s_j$
3	10	0.12695	6.7
5	10	0.13820	6.16
3	60	0.15153	5.60
5	60	0.16256	5.20

The obtained values classify the AAC masonry walls in buildings element with average thermal massivity, as D is ranged between 4 and 7.

5. Conclusions

The experimental measurements conducted of AAC blocks and masonry walls have highlighted a number of issues on the thermal performance of the material. Dry density of the blocks (390 kg/m^3) and its thermal conductivity (0.11...0.135 W/m.K) are characteristics superior than the one of the common AAC blocks and recommend the tested blocks for exterior walls with good hygrothermal behavior. Dry density of the masonry wall determined is 440 kg/m^3 for mortar joints of 3 mm thickness and 488 kg/m^3 for mortar joints of 5 mm thickness, with 34.8%…27.7% lower than the values of common AAC blocks presented in Table 1 (C 107/0 – 2002).

Thermal conductivity of the AAC masonry walls is direct influenced by the mortar joints thickness, the volume occupied by the mortar and the thermal conductivity of the mortar. The obtained values by numerical simulation indicate that the tested AAC masonry walls have an increase thermal resistance, thereby the thickness of additional thermal insulations, necessary to obtain the minimum global resistance, $R'_{\text{min.nec.}}$, is lower than in common external walls.

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DETERMINAREA CONDUCTIVITĂȚII TERMICE A ELEMENTELOR DIN B.C.A. UTILIZATE LA ZIDĂRII

(Rezumat)

În contextul actual, în care efectele schimbărilor climatice se manifestă în mod continuu, cu o intensificare permanentă, eficiența energetică a clădirilor a devenit un punct de plecare în proiectarea curentă. Eficiența energetică a unei clădiri este direct influențată de performanțele termice ale anvelopei. Astfel, proiectarea unor elemente de anvelopă ale căror rezistențe termice corectate să depășească valorile minime necesare, este o măsură impusă. Creşterea performanţelor termice ale pereților de închidere din zidărie se poate realiza prin izolare termică sau prin utilizarea unor blocuri pentru zidărie a căror conductivitate termică este scăzută. Din această categorie de materiale fac parte şi blocurile pentru zidărie din b.c.a.

Se prezintă o serie de determinări experimentale ale conductivității termice pentru blocuri din b.c.a. produse în țara noastră. Măsurătorile au fost realizate în Laboratorul de Fizica Construcțiilor al Facultății de Construcții din Iaşi. De asemenea, utilizând un program de modelare numerică precum şi pe baza unui calcul matematic a fost determinată şi conductivitatea termică echivalentă a zidăriei realizată din blocurile analizate.