CLAY BRICK WALLS THERMAL PROPERTIES

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Abstract: Today we deal with increasing requirements for quality of brick products, particularly in terms of thermal properties. These characteristics of products depend on many factors, such as configuration, that is, the number, arrangement and the void fraction.
This paper presents results of studying the thermal properties of heavy clay products, sampled at six different factories in Serbia. Thermal properties are accompanied by material and wall thermal conductivity coefficients. Characterization of block properties is done on the basis of volume mass, water absorption, void fraction and wall thickness. The results can be of help to optimize raw material mixture and to manage the production process in order to obtain the better thermal properties of heavy clay products.
Key words: clay brick walls, thermal properties.

1. INTRODUCTION

Hollow clay bricks used as building materials have obvious economicaly advantages, in improving thermal insulation performance of building walls and as well as reducing building wall loads. Thermal insulation performance of the hollow clay brick mainly depends on many factors, such as configuration, that is, the number, arrangement and the void fraction. Voids configuration effect is of great significance to improve its thermal insulation performance (Li et al., 2008, *Energy and Buildings*).
Knowledge of the mechanical and thermal properties of materials is essential for civil engeneering, guiding material choice for specific functions. Such materials exhibit complex microstructures consisting of a mixture of different solid phases in granular form, interfaces, eventually cracks and pores. In essence this can be considered as a two-phase mixture problem where the solid phase and the pore and voids phases are each characterized by constant, but strongly different, values of thermal conductivity (Grandjean et al., 2006).
Apart from surface radiation the heat transport process in the hollow brick is conduction and laminar flow in nature and this is a typical case that numerical simulation can play a great role. This is probably the main reason that most related literatures are of numerical study (Li et al., 2008, *Energy and Buildings*).
The development and increased capacity of computers with their associated software packages over the last 30 years open up an alternative approach. Finite element analyses are very wide used in such analysis. Long term systematic studies are done in order to highlight the influence of the structural morphology of a material (the shape and size of the grains and pores, connectivity of the solid and pore phases) on the value of thermal conductivity (Grandjean et al., 2006).
Some studies have identified to a marked degree those factors which singly or in combination are of the greatest significance in the improvement of the overall thermal insulation capacity of a wall constructed from hollow bricks by increasing the cavity height in respect to its width (Bouchar, 2008 and Li et al., 2008, *International Journal of Heat and Mass Transfer*).
Worldwide it has already been studied the possibility of improving block wall insulation by increasing porosity of bulk material or by addition of different ceilings into block voids. The aim of this paper was preliminary analysis of geometry impact on block wall insulaton properties, regarding to volume mass, water absorption, voids fraction (Standard EN 771) and wall thickness. The reason for this research is the energy efficiency of built structures usage in terms of thermal insulation, during both winter and summer. Heavy clay blocks are one of the most frequently the basic materials for construction in Serbia as well as world wide, so concerning the increasing tendency to reduce costs production and installation, and at the same time to achieve better insulating properties, it is necessary to come to new solutions, which would then be presented to the producers. Existing solutions to this problem are different systems of walls as well as layers addition like sandwich panels, polystyrene, thermal insulation mortars, etc., but it significantly increases the cost of objects construction. If we use clay as the basic material, further research should be more based on the geometry of products, primarily on the thickness of the walls and the number of cavities, and also possibilities of different secondary raw materials usage, which again decreases industry waste quantities and primary raw materials consumption.
The study has been carried out using samples from six different masonry factories in Serbia. Hollow

blocks with vertical voids (250mmx190mmx190mm) are studied on the basis of calculated thermal properties according to standard EN 1745:2002,

2. ANALYSIS AND DISCUSSION

Standard EN 1745:2002 provides rules for the determination of design values for thermal conductivity and thermal resistance of masonry and masonry products. It is connected with Specification of building elements, Standard EN 771 (parts 1 to 6). A specific building product can have different design thermal values according to the intended application. Computational value for a property of the product is one that determines its planned application.
Equivalent coefficient of thermal conductivity (primary material) presents a value that is obtained by dividing the thickness of the elements for building construction and measured thermal resistance.
Various numerical methods are in use (e.g. finite differences method, finite elements method) to calculate thermal properties of hollow or composite elements for building. Coefficients of thermal conductivity materials are required input parameters for such calculations. Geometry of elements for building is defined by the number of rows of holes and number of holes in a row. As additional information, part of cross-connections is necessary to define (the sum of the thickness of cross-links divided by length of the block, given in %) (Drpic et al., 2007).
Table 1 shows some of characteristic properties of hollow blocks analyzed, sorted by increasing percentage of voids and marked regarding to the producer. For comparisons, typical λ for honeycomb blocks is 0.10 W/(mK).

Table 1. Properties of hollow block with vertical voids

Smpl. mark	Vol. mass gross kg/m^3	Vol. mass net kg/m^3	λ_{mat}* W/(mK)	λ_{wall}** W/(mK)	W. a.*** (%)
II-1	869.4	1912.2	0.641	0.280	10.87
III-1	868.5	1953.2	0.651	0.347	11.70
II-2	845.1	1901.0	0.600	0.308	10.80
IV-1	708.3	1648.9	0.515	0.258	18.10
I-1	788.6	1828.7	0.581	0.294	14.50
I-2	726.5	1830.5	0.581	0.206	14.90
V-1	817.2	2059.8	0.686	0.304	9.30
VI-1	784.1	1984.1	0.665	0.354	9.5
VI-2	764.9	1984.3	0.675	0.326	9.4

*λ_{mat} - Primary material thermal conductivity
** λ_{wall} - Wall thermal conductivity
***W. a. – Water absorption

According to the literature data, expected thermal conductivity coefficient of some building materials at working conditions and 20˚C is given at Table 2. According to these data, it can be concluded that all the analyzed block samples are much better then it was expected (Recknagel et al., 1985).

Table 2. Properties of hollow block with vertical voids [7]

Subject matter	Gross volume mass (kg/m^3)	λ_{wall} W/(mK)
Hollow block wall	800 1600	0.35...0.52 0.52...0.76

A lower percentage of voids follow higher volume mass and therefore higher λ (clay material shows higher λ in relation to air). This primarily refers to the structural layout of a block (wall thickness, the arrangement of voids), because it does not depend so much on the material itself. For example - thicker walls and smaller cavities follow less plastic raw materials in order to preserve the mechanical characteristic.
Figures 1 and 2 show geometry characteristics of samples with and without thermal bridges. Samples III-1, VI-1 and VI-2 are those who have thermal bridges in the geometry, which explains the highest values of wall thermal conductivities, because in such cases isolation effect is worse. Equivalent coefficient of thermal conductivity (λ_{wall}) is there among highest. Sample VI-2 shows the best thermal properties of the three, beacuse it has two wider holes in the center, while the rest have only one.

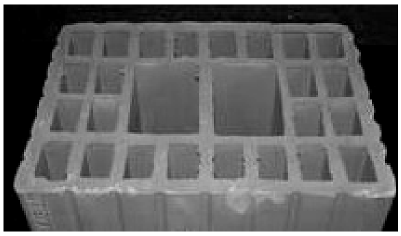

Fig. 1. Holow block with thermal bridges (sample VI-2)

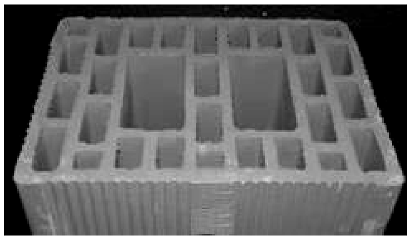

Fig. 2. Holow block without thermal bridges (sample I-2)

Sample V-1 showed the lowest water absorption, so it is expected to obtain also the highest λ_{mat} value. It is obvious that primary material developed very low bulk porosity during firing, so that volume mass is the highest, no matter that voids part relatively high.The reason can be that this block is fired more then necessary. Consistent to 18.10% water abosption on the case of sample IV-1 is the best bulk porosity, so λ_{wall} is one of the lowest. Nowing that fly ash is used as secondary raw material in this case explains such results.
Water absorption is very important when embedment is concerned; if it is about 10% mortar slowly dries and the association with the block is harder, but when

higher then 17% water from mortar is rapidly absorbed, which also obstructs binding.

Samples I-1 and I-2 show low net volume mass and high part of voids (high water absorption), so what is expected are among the best insulation properties above all the tested samples.

Figure 3 shows primary material thermal conductivity regarding to net volume, while Figure 4 show wall thermal conductivity on the basis of gross volume mass. Logical and expected results are obtained – with volume mass increasing, thermal conductivity coefficient also increases. Deviations from linear laws obtained by the method of least squares arise due to many factors.

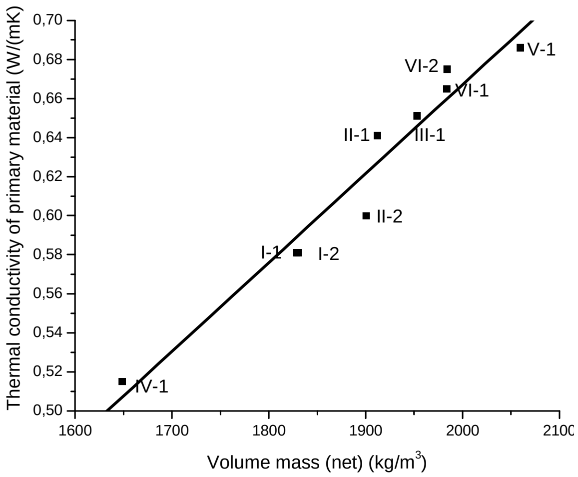

Fig. 3. Primary material thermal conductivity as a function of net volume mass

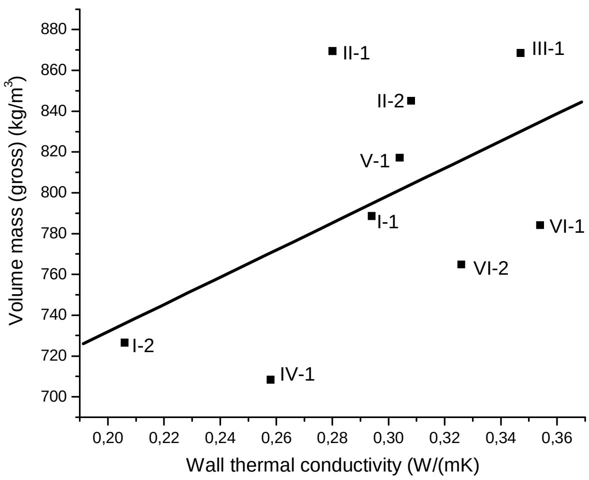

Fig. 4. Wall thermal conductivity as a function of gross volume mass

Besides the material characteristics, i.e. net volume mass and water absorption (porosity) there are elements related to the geometry of block (percentage of voids, thermo bridges, cavity layout, the size and number of the middle voids and wall thickness which are different in each block analyzed.

Similar conclusions are drawn by analysing Figures 5 and 6. Water absorption indicates the porosity of basic materials, and so greater absorption means better insulation, i.e. lower coefficient of thermal conductivity. Again there is dispersion of the results, when what is considered is the blocks wall, not just fired ceramic material.

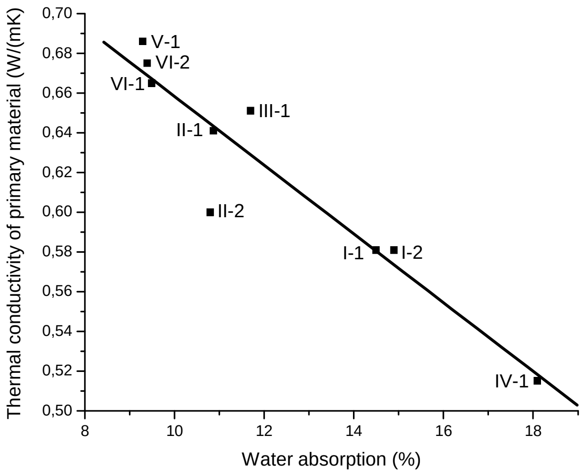

Fig. 5. Primary material thermal conductivity as a function of water absorption

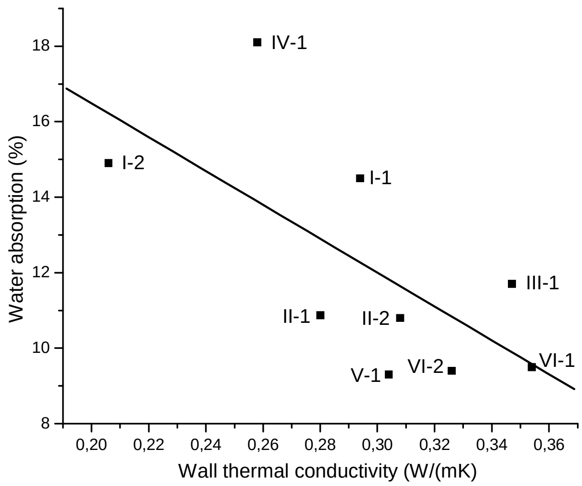

Fig. 6. Wall thermal conductivity as a function of water absorption

Table 3 shows thickness sum of individual walls within the block, together with the external walls (% part of 250 mm), number of these walls per length and also thermal relation between material itself and built wall characteristics.

Table 3. Geometry and thermal relation characteristics

Sample mark	Voids %	Total walls thickness (%)	Number of walls per length	λ_{mat}/ λ_{wall}
II-1	55	34.0	11	2.289
III-1	55	21.1	7	1.876
II-2	56	36.2	11	1.948
IV-1	57	30.6	10	1.996
I-1	57	27.8	10	1.976
I-2	60	27.3	10	2.820
V-1	60	23.7	10	2.256
VI-1	61	23.5	7	1.878
VI-2	62	22.0	9	2.070

Figures 7 and 8 show some characteristic relations between these parameters.

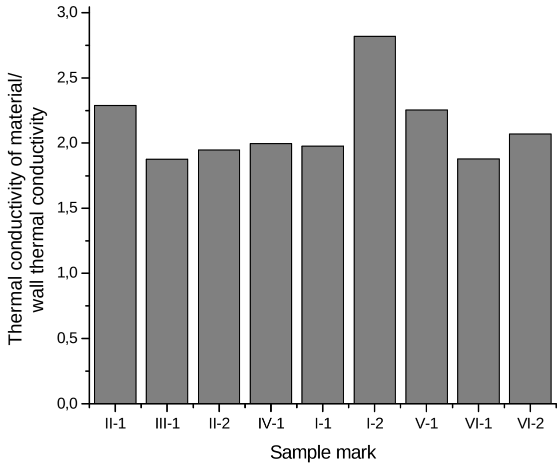

Fig. 7. λ_{mat}/ λ_{wall} relation of analyzed samples

Mathematicaly observed, with lower λ of the wall - this ratio is higher, and because geometry of block has the greatest impact the value of λ of the wall. Higher relation of these two thermal parameters shows greater influence of the geometry of the block. It is obvious if we notice that the highest value is for sample I -2 (two large voids in the middle), and then II-1 (no thermal bridges, similar voids arrangement), while the lowest ratio observed in the case of III-1 and VI-1 is due to the presence of thermal bridges. Since the sample VI-2 has two major voids in the middle, thus there is greater geometry influence then for III-1 and VI-1.

Sum of individual walls thickness depends on the voids fraction. More ceramic material means less voids.

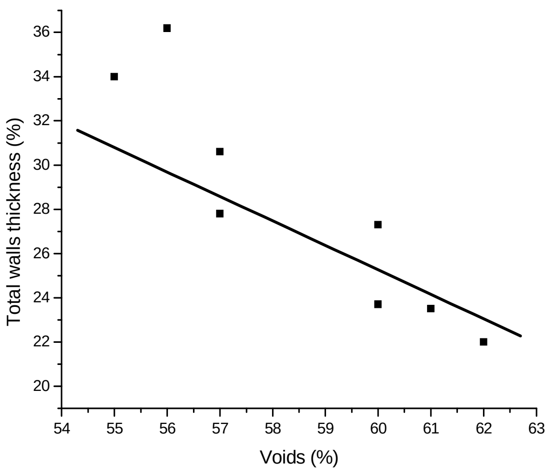

Fig. 8. Relation between total wall thickness and voids fraction

3. CONCLUSIONS

This paper presents primary results of the first thermal analysis of bricks. The idea is to include secondary raw materials in some factories, and to compare those results with the ones here given. Thermal properties are studied using two parameters: thermal conductivity of primary material and wall thermal conductivity.

Known effects of the characteristics of raw materials are confirmed, by volume mass and total voids fraction monitoring, but these could be improved in the future by mixing the clay with combustible or light-weighted materials or more plastic clay should be used (lower volume mass). Also what can improve thermal properties of blocks is setting optimum firing temperature in the kiln.

These analysis and mutual comparison of the results point and confirm a practical knowledge of the new influences of the aforementioned properties.

First of all it refers to the influence of products geometry on its thermal properties which opened the way for further variety (multidisciplinary) research.

4. ACKNOWLEDGEMENTS

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