Influence of large and highly perforated fired-clay bricks in the improvement of the equivalent thermal transmittance of single-leaf masonry walls

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3.1 Introduction

Current buildings are not ecologically sustainable. They are not environmentally friendly and damage the environment due to the high consumption of energy resources, which carries a large amount of harmful emissions (Theodosiou & Papadopoulos, 2007).

Buildings are great consumers of thermal energy. In fact, the residential sector demands about 25% of the total energy consumed in the EU-28, which is equivalent to 275 Mtoe (million tonnes of oil equivalent) (Eurostat, 2013). A large part of this energy is used in the air conditioning of buildings.

Sustainability in global energy generation depends mainly on three lines of action: the use of renewable energy sources (López González, Sala Lizarraga, La Peña Aranguren, & Míguez Tabarés, 2000; López González, Sala Lizarraga, Míguez Tabarés, & López Ochoa, 2007), energy saving and the energy efficiency of machinery and buildings.

Regarding this last line of action, the building sector has had to improve the techniques and properties of the materials used in the construction of enclosure walls so as to minimize energy loss and reduce energy requirements.

Low-density, large and highly perforated materials are now being used. Recent studies have shown the influence that the cladding materials used in building walls have on CO₂ emissions and energy consumption (Raimondo, Dondi, Mazzanti, Stefanizzi, & Bondi, 2005). Seeking to explore further improvements in wall construction materials, other studies have shown how the porous nature of fired-clay bricks can improve thermal performance (Antar, 2010; Morales, Juárez, López-Ochoa, & Doménech, 2010).

Large and highly perforated fired-clay bricks in single-leaf walls (García, 2003) meet these new requirements well. Masonry walls built with such bricks combine good sound insulation, high mechanical strength, exceptional fire resistance and high levels of heat insulation and comfort (thermal inertia).
The advantages of these walls, which are usually built with large format pieces, are evident from the point of view of labour requirements and even of costs in building the house. The walls are built with a single layer, eliminating the need for labour and stocks of materials on the site.

The first of these materials for single-layer walls that appear in our market was the Termoarcilla® brick, which, despite its advantages compared to conventional solutions within the framework of current legislation, encountered and continues to encounter great difficulties to find an entry in the market. The Termoarcilla® brick is a voided brick with a great macroscopic porosity (about 50% of voids) with air cells between layers of ceramic material that prevents its convective movements, to which a porosity on a smaller scale is added, formed by air bubbles within the material itself, generated during firing by the volatizing of other materials mixed with the clay for this purpose. Additionally, in the arrangement of these bricks on the site, the vertical joints of mortar are eliminated and the horizontal ones are arranged discontinuously, leaving an air gap between them. Thus low thermal conductivity is achieved using the high thermal resistance of air in any thermal transfer path through the brick.

Of all the different construction solutions for enclosures or envelopes, we focus on the single leaf with no inner cavity, characterized by large-format bricks with appropriate interior and exterior cladding. There are three sections in these single-leaf walls that can affect their thermal performance: the cross-section of the bricks with their air-filled voids (the “clay/air cross-section”), where the geometry of voids and the type of tongue and groove system are influential; the cross-section of the bricks with the voids filled with bonding mortar (the “clay/mortar cross-section”); and the cross-section of the layer of bonding mortar itself (the “bed joint cross-section”).

Researchers have recently increased interest in all the components of these sections. The resulting papers have individually characterized the influence of the type of internal void of the large-format brick (Termoarcilla & Tecnalia, 2005; Del Coz Diaz, Neto, Sierra, & Biempica, 2008; Li et al., 2008a,b; Lourenco, Vasconcelos, Medeiros, & Gouveia, 2010; Morales, Juárez, Muñoz, & Gómez, 2011; Sastre, 2008) and the type of tongue and groove arrangement (Ghazi Wakili & Tanner, 2003; Morales, Juárez, López-Ochoa, & Muñoz, 2012) in the clay/air cross-section and clay/mortar cross-section and, finally, the influence of the horizontal joint on the bed joint (Juárez, Morales, Muñoz, & Gómez, 2012).

Other research has sought to reduce the fired-clay thermal conductivity by including additives, and has shown that this decreases thermal conductivity by generating gas micropores in the volume of clay (Alonso-Santurde, Coz, Viguri, & Andrés, 2012; Bilgin et al., 2012; Luciana et al., 2012; Muñoz, Juárez, Morales, & Mendivil, 2013; Raut, Ralegaonkar, & Mandavgane, 2011). These researchers have also studied variations of the mechanical properties (bulk density, water absorption, compressive strength, etc.) versus clay thermal conductivity.

This work seeks to analyse comprehensively the influence of all these factors so that it can be decided which parameter to act on to reduce the equivalent thermal transmittance of the wall.

Finally, an attempt is made to find a relationship between the equivalent thermal transmittance of a wall and the fired-clay thermal conductivity used, since this is a
parameter on which it is possible to act easily by using a dispenser to add suitable quantities of pore-forming additive to the clay during the manufacturing process, prior to the extrusion of the clay.

Single-leaf walls with large and highly perforated fired-clay bricks were chosen for this study.


In this work, the mechanical properties of the bricks (bulk density, water absorption, compressive strength, etc.) are not studied, but only the influence of the thermal conductivity of clay in the equivalent thermal transmittance of the wall is studied. Once the improvement in thermal aspects is studied, it should be checked that the bricks and the wall meet all the requirements required by current legislation.

### 3.2 Materials and methods

Figure 3.1 shows, on a perforated ceramic brick, all elements on which we can act to reduce the equivalent transmittance of an enclosure:

- Internal geometry of voids
- Vertical joint (tongue and groove)

![Figure 3.1](image-url)  
**Figure 3.1** Factors influencing the thermal transmittance of a wall.
In the following sections, two types of internal and external geometries of the bricks, as well as three types of horizontal joints, are proposed. For each case, the dependence of the equivalent thermal transmittance of the wall regarding the fired-clay thermal conductivity is studied.

### 3.2.1 Bricks to study

Figure 3.2 shows the large brick model to be studied, which has the following specifications:

1. Brick dimensions: 300 × 290 × 250 mm.
2. Interior wall thickness: 5 mm.
3. Exterior wall thickness: 8 mm.
4. Length of tongue and groove arrangement: 16 mm, avoiding a vertical joint in the wall.

Two different types of brick are considered:

1. The first (block a) with rectangular internal voids consists of 17 rows perpendicular to the heat flow, in a quincunx, and with a voided tongue and groove arrangement, since this is the layout most widely used commercially and it has been studied previously (Antar, 2010; Termoarcilla & Tecnalia, 2005; García, 2003; Sastre, 2008; Li et al., 2008a; Morales et al., 2010, 2011). The cross-section of this brick is shown in Figure 3.3(a).
2. The second (block b) with rhomboidal internal voids, consists of 25 rows perpendicular to the heat flow and a simple tongue and groove arrangement. This brick has recently begun to appear on the market after several studies (Del Coz et al., 2008; Juárez et al., 2012; Li et al., 2008b; Lourenco et al., 2010; Morales et al., 2012). The cross-section of this brick is shown in Figure 3.3(b).

![Figure 3.2](image)
3.2.2 Horizontal joint in brickwork wall

The bricks described are examined with three different types of horizontal joint:

1. A horizontal joint made with standard mortar (Spanish Standard, 2008) and penetration, called a *full-bed joint*.
2. A discontinuous joint with an air chamber (this type of arrangement is the one most widely used in building), called a *furrowed-bed joint*.
3. A thin horizontal joint that uses a type of mortar grip that does not penetrate the junction bricks of consecutive rows, called a *thin joint*.

In this last arrangement, the clays used in the brick should allow easy grinding, as the bonding mortar is applied in very thin layers of 3 mm, according to the standard (Spanish Standard, 2013). This arrangement requires proper alignment of the bricks, suitable flatness between them and precision workmanship.

Each wall was built as follows:

1. Normal arrangement using standard mortar \((\lambda_m = 1.3 \text{ W/m-K})\), with 10-mm bed joint thickness and 10 mm of penetration in each brick. Two different horizontal joints were assessed:
   a. Full-bed joint
   b. Furrowed-bed with a 30-mm gap
2. Assembly with a thin horizontal joint made of bonding mortar \((\lambda_m = 0.83 \text{ W/m-K})\), with 3-mm bed joint thickness and no penetration.

3.2.3 Fired-clay thermal conductivity

As mentioned above, clays today are lightened with various materials in order to reduce their thermal conductivity. Several studies have been conducted on this matter (Demir, 2006; Sutcu & Akkurt, 2010), but they are all based on a clay with a specific composition and a given thermal conductivity.

A recent study (Muñoz et al., 2013) has shown that adding up to 15\% additive to a clay with no additive and \(\lambda = 0.745 \text{ W/m-K}\) can reduce its thermal conductivity to \(\lambda = 0.445 \text{ W/m-K}\), i.e. by 40\%.

![Cross-sections of the bricks studied](image-url)
Considering this background of studies, we set out to check for a relationship between the thermal conductivity of fired-clay bricks (regardless of how they were made) and the equivalent thermal transmittance of a wall, built using the bricks and arrangement proposed above.

The starting point for the study was a clay with a thermal conductivity of $\lambda = 0.600 \text{ W/m-K}$, decreasing in steps of 0.05 W/m-K to thermal conductivity values of 50%, that is, to a figure of $\lambda = 0.300 \text{ W/m-K}$.

### 3.2.4 Boundary conditions for solving by finite element method

The model analysed by numerical methods is the part of the wall represented by the assembly of two bricks, as is shown in Figure 3.4.

In this figure can be observed the three characteristic sections of the assembly and the heights of each one of them: the cross-section of the bricks with their air-filled voids (the “clay/air cross-section”), height $h_1$; the cross-section of the bricks with the voids filled with bonding mortar (the “clay/mortar cross-section”), height $h_2$; and the cross-section of the layer of bonding mortar itself (the “bed joint cross-section”), height $h_3$. These indicated heights relate to a standard type of assembly with gripping mortar and penetration into the bricks.

### 3.2.5 Thermal calculations

The finite elements method (COMSOL 4.2a; ANSYS 14.0) was used to obtain the heat fluxes for the boundary conditions as per the standards, thus enabling the equivalent thermal transmittance of the envelope wall to be calculated.

The finite elements method was used to solve each of the first two characteristic sections of the wall (the “clay/air cross-section” and the “clay/mortar cross-section”)

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**Figure 3.4** Part of the wall representing the assembly of two bricks and the three heights of characteristic sections.
with the boundary conditions specified by the aforementioned standards, as shown in Figure 3.5. The heat flow through each characteristic section, $Q_i$, was obtained.

Once the heat flow, $Q_i$, was calculated, the thermal resistance, $R_i$, was obtained via the following expression:

$$R_i = \frac{L \cdot \Delta T}{Q_i} - R_{ic} - R_{ec}$$

Where $R_{ic}$ and $R_{ec}$ are the resistances of the interior and exterior cladding, respectively.

This gave the thermal resistances for the clay/air cross-section ($R_1$) and for the clay/mortar cross-section ($R_2$).

The thermal resistance of the horizontal joint (the “bed joint cross-section”) can be calculated straightforwardly, since the conductivity of the bonding mortar and the size of the air gap are known:

1. For a horizontal joint with standard mortar furrowed with a 30-mm air gap

$$R_3 = \frac{e - 0,03}{\lambda_m} + \frac{0,03}{\lambda_{air}}$$

2. For a thin horizontal joint

$$R_3 = \frac{e}{\lambda_m}$$
Once the resistance of each characteristic section has been found, the total resistance of the unclad wall can be determined as follows:

\[ R_{uw} = \frac{h_1 + h_2 + h_3}{\frac{h_1}{R_1} + \frac{h_2}{R_2} + \frac{h_3}{R_3}} \]

where \( h_1 \), \( h_2 \) and \( h_3 \) are the heights of the aforementioned sections.

Finally, the equivalent thermal transmittance of the entire wall was calculated:

\[ U_i = \frac{1}{R_T} = \frac{1}{R_{ic} + R_{ec} + R_{uw}} \]

For the sake of clarity, a schematic layout of the thermal network is shown in Figure 3.6.

3.3 Results

3.3.1 Equivalent transmittance of the wall made of bricks with rectangular voids (block a) and the three types of horizontal joint

Table 3.1 shows the equivalent thermal transmittance of the wall made using “block a” for different fired-clay conductivities and for the three types of assembly.

As expected, the better the assembly system, the lower the thermal transmittance: in other words, the lower the thermal conductivity of the mortar used, the lower the height of the joint.

Data from Table 3.1 enable builders to choose the most appropriate method of assembly according to the remaining parameters.

For example, a “good” large and highly perforated fired clay with low thermal conductivity (0.300 W/m-K) with a “bad” assembly system (continuous-type assembly using mortar with high thermal conductivity) would yield a thermal transmittance of

![Figure 3.6 Thermal network.](image-url)
the wall of 0.6211 W/m²-K. However, a “good” assembly system (thin bonding mortar joint) with a “bad” fired clay with high thermal conductivity (0.600 W/m-K) would give a thermal transmittance of 0.5425 W/m²-K.

A plot of the values of Table 3.1 (Figure 3.7) shows a decreasing linear trend in thermal transmittance in all cases. This clearly shows the importance of the type of assembly, an aspect that has been studied in earlier papers (Juárez et al., 2012).

Both the table and the graph give an idea of the range of thermal transmittance values depending on the fired-clay thermal conductivity and the type of assembly. We believe that this may prove to be a useful tool for the prior design of walls.

### 3.3.2 Equivalent transmittance of the wall made of bricks with rhomboidal voids (block b) and the three types of horizontal joint

Table 3.2 shows the equivalent thermal transmittance of the wall made using “block b” for different fired-clay conductivities and for the three types of assembly.

It is worth noting that the thermal transmittance values for brick b were found to be very low at 0.3546 W/m²-K in the best case, i.e. the fired clay with the lowest thermal conductivity and a horizontal bonding mortar joint (a thin layer of mortar with low thermal conductivity).

It is also noteworthy that relatively low thermal transmittance levels are recorded for the wall in this case (0.5478 W/m²-K) with a continuous joint made of standard
Figure 3.7  Fired-clay thermal conductivity vs. wall thermal transmittance for a brick with rectangular voids.

Table 3.2  Table comparing equivalent thermal transmittance levels using bricks with rhomboidal voids, depending on the type of horizontal joint

<table>
<thead>
<tr>
<th>Block b</th>
<th>$U_{eq}$ (W/m²-K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fired clay</td>
<td>Joint with standard mortar $\lambda_m = 1.3$ (W/m-K)</td>
</tr>
<tr>
<td>$\lambda$ (W/m-K)</td>
<td>Full-bed joint</td>
</tr>
<tr>
<td>0.600</td>
<td>0.6782</td>
</tr>
<tr>
<td>0.550</td>
<td>0.6595</td>
</tr>
<tr>
<td>0.500</td>
<td>0.6399</td>
</tr>
<tr>
<td>0.450</td>
<td>0.6192</td>
</tr>
<tr>
<td>0.400</td>
<td>0.5972</td>
</tr>
<tr>
<td>0.350</td>
<td>0.5735</td>
</tr>
<tr>
<td>0.300</td>
<td>0.5478</td>
</tr>
</tbody>
</table>
mortar and lightened low fired-clay thermal conductivity due to the good geometrical configuration of the brick.

As in the previous case, the table enables the parameters that are to be adjusted to be chosen with a view to obtaining a specific wall thermal transmittance.

The values plotted in Table 3.2 (Figure 3.8) once again record a linear trend for each type of assembly.

Like the previous brick, this gives the range of wall thermal transmittance values depending on the fired-clay thermal conductivity and the type of assembly.

### 3.4 Comparative analysis

Combining Tables 3.1 and 3.2 for the different bricks and plotting them together (Figure 3.9) reveals a pronounced linear trend regardless of the type of brick or assembly.

The aforementioned graph reveals that the equivalent thermal transmittance of the wall depends largely on the type of brick and the type of assembly, as shown previously (Juárez et al., 2012; Morales et al., 2011, 2012).

As expected, the lowest equivalent thermal transmittance levels for the wall are obtained using the best brick with the best assembly, and the highest with the worst brick and the worst assembly. However, in the intermediate zones, any of the parameters could be changed when a particular thermal transmittance is required. It should be noted there are other parameters that influence the design of a wall, e.g. mechanical strength limits and the density of the bricks (which prevent the conductance of the fired-

![Figure 3.8](image_url) Fired-clay thermal conductivity vs. wall thermal transmittance for a brick with rhomboidal voids.
clay from being reduced), manufacturing processes that require using a particular brick type, difficulties in ensuring thin joint assembly and financial considerations.

Here is an example. A manufacturer has a clay with a thermal conductivity of 0.600 W/m·K and produces a rectangular brick, without grinding (i.e. the brick is not suitable for assembly with a thin horizontal joint). The best equivalent thermal transmittance that can be obtained for the wall under these conditions is 0.6654 W/m²·K (point 1 in Figure 3.9). There are three options for improving the equivalent thermal transmittance of the wall:

1. Grinding the brick surface to enable wall assembly with a thin horizontal joint. This gives an equivalent thermal transmittance of 0.5425 W/m²·K (point 2 in Figure 3.9). The grinding of the bricks may require considerable investment in machinery and a significant modification of the manufacturing process.

2. Changing the geometry of the brick from a rectangular to a rhomboid shape. This would give an equivalent thermal transmittance of the wall of 0.5594 W/m²·K (point 3 in Figure 3.9) with a horizontal furrowed joint with a 30-mm air gap, i.e. with no grinding required. This modification would involve changing the extrusion mold on the machinery and the production of a different brick, which would also require major investment.

3. Increasing the proportion of the pore-forming additive, reducing the thermal conductivity of the clay to 0.400 W/m·K. This would lead to an equivalent thermal transmittance of the wall of 0.5797 W/m²·K (Point 4 in Figure 3.9) with a horizontal furrowed joint with a 30-mm air gap. In this case, the manufacturer would only have to check whether the brick complies with the mechanical requirements, and no major investment would be necessary.

In view of the similarity of the slopes, we considered studying the quantities expressed as percentages in order to compare the percentage decrease in the fired-clay thermal transmittance of the wall:

![Figure 3.9 Wall thermal transmittance vs. fired-clay thermal conductivity.](image-url)

- **Block b-full bed joint**
- **Block b-furrowed bed joint**
- **Block b-thin joint**
- **Block a-full bed joint**
- **Block a-furrowed bed joint**
- **Block a-thin joint**

<table>
<thead>
<tr>
<th>Fired clay conductivity λ (W/m-K)</th>
<th>0.000</th>
<th>0.001</th>
<th>0.001</th>
<th>0.001</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal transmittance Ueq (W/m²-K)</td>
<td>0.500</td>
<td>0.550</td>
<td>0.600</td>
<td>0.650</td>
</tr>
<tr>
<td>0.700</td>
<td>0.750</td>
<td>0.800</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

0.000 0.000 0.000 0.000

Fired clay conductivity λ (W/m-K)

0.001 0.001 0.001

0.3000 0.3500 0.4000 0.4500

0.5000 0.5500 0.6000 0.6500

0.7000 0.7500 0.8000

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conductivity with the percentage decrease in the thermal transmittance of the wall depending on the type of brick and joint executed. The resulting values are shown in Tables 3.3 and 3.4.

From these values it can be deduced that the improvement in the equivalent thermal transmittance resulting from the decrease in fired-clay thermal conductivity ranges between 2.9% and 22% for bricks with rectangular voids, regardless of the type of assembly. For bricks with rhomboidal voids, the decreases are very similar, ranging between 2.6% and 19.2%, also regardless of the type of assembly.

The plot of the results from Tables 3.3 and 3.4 (Figure 3.10) shows that the trend line is reliably close to the results of the thermal calculations, with an error of ±3%. The trend line corresponds to the equation:

$$\Delta U_{eq} = 0.4040 \cdot \Delta \lambda_{clay} - 0.008$$

This equation, with a Pearson’s correlation coefficient of 0.98 (Lehmann & Romero, 2008), enables a rapid estimate to be made of the thermal transmittance of a wall once the variation in the fired-clay thermal conductivity is known and the brick and assembly types have been selected. In other words, if the thermal transmittance value of a wall for a given brick is known and the specifications of the clay and the specific assembly type are factored in, the variation in thermal transmittance based on the variation in fired-clay thermal conductivity can be estimated, maintaining the same brick and type of assembly, and builders can proceed accordingly by lightening the clay as much as possible.

| Table 3.3 Percentage improvement in the equivalent thermal transmittance of the wall according to the decrease in fired-clay thermal conductivity for bricks with rectangular voids |
|---------------------------------|---------------------------------|-----------------|-----------------|
| **Joint with standard mortar** | **% Improvement in $U_{eq}$ for “block a”** | **Joint of bonding mortar $\lambda_m = 0.83$ (W/m-K)** |
| Full-bed joint | 30-mm furrowed-bed joint | Thin joint |
| Decrease $\lambda_{clay}$ (%) | | | |
| 8.33% | 2.89% | 3.01% | 3.32% |
| 16.67% | 5.92% | 6.14% | 6.75% |
| 25.00% | 9.13% | 9.42% | 10.29% |
| 33.33% | 12.55% | 12.88% | 13.98% |
| 41.67% | 16.22% | 16.58% | 17.86% |
| 50.00% | 20.20% | 20.56% | 21.99% |
Table 3.4 Percentage improvement in the equivalent thermal transmittance of the wall according to the decrease in fired-clay thermal conductivity for bricks with rhomboidal voids

<table>
<thead>
<tr>
<th>Decreased $\lambda_{clay}$ (%)</th>
<th>% Improvement in $U_{eq}$ for “block b”</th>
<th>Joint with standard mortar $\lambda_m = 1.3$ (W/m-K)</th>
<th>Joint of bonding mortar $\lambda_m = 0.83$ (W/m-K)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full-bed joint</td>
<td>2.75%</td>
<td>2.65%</td>
<td>2.72%</td>
</tr>
<tr>
<td>30-mm furrowed-bed joint</td>
<td>5.64%</td>
<td>5.43%</td>
<td>5.53%</td>
</tr>
<tr>
<td>Thin joint</td>
<td>8.69%</td>
<td>8.35%</td>
<td>8.46%</td>
</tr>
<tr>
<td>Joint with standard mortar</td>
<td>11.94%</td>
<td>11.45%</td>
<td>11.54%</td>
</tr>
<tr>
<td>33.33%</td>
<td>15.43%</td>
<td>14.78%</td>
<td>14.81%</td>
</tr>
<tr>
<td>41.67%</td>
<td>19.22%</td>
<td>18.42%</td>
<td>18.36%</td>
</tr>
<tr>
<td>50.00%</td>
<td>25.00%</td>
<td>19.22%</td>
<td>18.36%</td>
</tr>
</tbody>
</table>

Figure 3.10 Percentage decrease of $U_{eq}$ versus percentage decrease in fired-clay thermal conductivity.
3.5 Conclusions and future trends

The equivalent thermal transmittance of a wall depends on several parameters: the type of brick used (including the specific type of internal void and the type of tongue and groove arrangement), the type of assembly (horizontal joint type and thermal conductivity of its materials), and the type of clay used to make the brick.

Obviously, the lower the thermal conductivity of the materials the lower the equivalent thermal transmittance of the whole wall will be. However, for a given type of brick and assembly, the thermal transmittance of the wall depends linearly on fired-clay thermal conductivity.

The best thermal performance is obtained in walls that use a geometrically optimized brick and are assembled with bonding mortar and a thin joint. Nevertheless, using either of these solutions (or indeed both of them together) entails significant investment in the brick manufacturing process and the wall building process.

The equivalent thermal transmittance of a wall can be decreased by up to 20% by reducing the conductivity of the clay by up to 50% without changing the type of brick or the type of wall assembly. All that is required is to ensure that the mechanical parameters (density and compressive strength) are fulfilled.

This study has found that the percentage improvement in the thermal transmittance of walls depends linearly on the percentage improvement in the fired-clay thermal conductivity, regardless of the type of brick and assembly.

An equation is obtained for estimating the percentage improvement in the thermal transmittance of a wall in terms of the percentage improvement in the thermal conductivity of the clay with an error of less than 3% in all cases—a figure that can be considered negligible in the range of values in which the trade usually works.

As previously mentioned, the mechanical parameters (bulk density, water absorption, compressive strength, etc.) have not been considered in this study. It would be desirable to relate the thermal conductivity of the clay with the mechanical parameters, which are those that limit the reduction in thermal conductivity, making it impossible to improve on the equivalent thermal transmittance. This study is not elementary since it depends on the type of clay used and the pore-forming additives employed.

Moreover, the use of additives in the clays increases water absorption and the block requires the use of external cladding.

Other lines of work may include repeating this study in other types of wall assemblies, as multilayer walls, ventilated facades, etc.

References


