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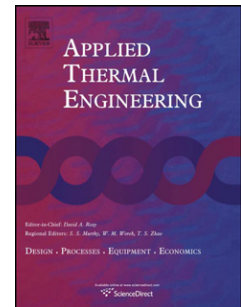


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# Study of the geometry of a voided clay brick using rectangular perforations to optimize its thermal properties

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## Abstract

This study was undertaken to optimize the equivalent transmittance of a wall consisting of voided clay bricks using ceramic material Termoarcilla<sup>®</sup> 29 ECO, complying with the Spanish UNE [1], European EN [2] and international ISO [3], [4], [5], [6], [7] standards.

Various geometries were investigated for the bricks' cross sections, starting from a commercialized block and improvements in its thermal conductivity were studied by varying parameters such as a number of rows in the brick, the type of tongue and grooving and the alternation between contiguous rows in the brick. Simulations were made using a finite elements application [9].

The conclusions of the study were that the thermal properties of a brick are improved by placing the perforations of the voids in a quincunx (in parallel rows, so that every hole is placed between those of the immediate rows, forming equilateral triangles) and that the greater the number of rows, the better the thermal behaviour. Further, if these perforations are extended to the tongue and groove area and a certain clearance is left between the tongue and groove of each brick, the wall's equivalent transmittance is reduced.

**Keywords:** Voided clay brick; energy saving; thermal properties; optimisation.

## 1. Introduction

The properties of the materials that form building walls are of vital importance since they enclose the buildings and separate and protect them from the exterior, thus determining the thermal comfort of the working area. Their properties will determine the building's bioclimatic functioning and, as a result, the thermal comfort of its interior.

With the coming into force of the Technical Building Code [1], an attempt is made to adapt legislation to the requirements of the Community Directives in matters of energy efficiency in building and to bring it into line with legislations in other member states.

Compliance with the TBC [1] requires a minimum average overall heat transfer coefficient for the wall  $U$  ( $\text{W}/\text{m}^2\text{K}$ ), depending on the severity of the climate in the location [8].

There appears as line of investigation the search of a new geometry that allows to comply with the new thermal requirements raised by the CTE [1] in voided clay bricks, according to the climatic zones of Spain, minimizing the transmittance of the block.

## 2. Starting data

The study started with the Termoarcilla brick<sup>®</sup> 29 ECO, whose manufacturing conditions are:

1. Brick dimensions  $30 \times 29 \times 19 \text{ cm}^3$ .
2. Thickness of interior partition 5 mm, and exterior 8 mm.
3. Tongue and groove length 16 mm.
4. Percentage of perforations  $< 55\%$ .

### INSERT FIGURE 1

### 2.1. Calculation parameters

We started with the properties of the clay that the company could supply and with the most usual building lining conditions, which are:

1. Conductivity of the clay  $0.5 \text{ W}/\text{m-K}$ , with a density of  $1740 \text{ kg}/\text{m}^3$ .
2. Interior lining of plaster, thickness 15 mm and conductivity  $0.57 \text{ W}/\text{m-K}$ .
3. Exterior lining of standard mortar, thickness 15 mm and conductivity  $1.3 \text{ W}/\text{m-K}$ .
4. Horizontal joint of mortar, studying two types:
  - a. Standard mortar with a conductivity of  $1.3 \text{ W}/\text{m-K}$ .
  - b. Insulating mortar with a conductivity of  $0.47 \text{ W}/\text{m-K}$ .
5. Horizontal joint (tilt), 10 mm thick, was studied with two types of laying:
  - a. With a discontinuous air joint, that is, the joint is of mortar with an air chamber in the centre.
  - b. With discontinuous joint of expanded polystyrene (EPS) with a conductivity of  $0.04 \text{ W}/\text{m-K}$ , that is, the joint of mortar with a expanded polystyrene (EPS) joint in the centre.
6. The penetration of the joint mortar into the brick was taken as 10 mm in each brick in contact with the joint.

## 2.2. Resolution of the Termoarcilla Brick® 29 ECO

The brick was studied on the basis of the above parameters. The following results for conductivity were obtained, depending on the type of mortar and type of joint.

### INSERT TABLE 1

Figure 2 shows the heat flow diagram for the clay section with voids filled with air in which the greater heat loss in the tongue and grooving and ribs directly connecting with the interior and exterior faces of the brick, called thermal bridges, can be seen. The purpose is to reduce this heat loss, improve the brick's conductivity and, with this, the equivalent wall's transmittance.

### INSERT FIGURE 2

## 3. Alternatives to the Termoarcilla Brick® 29 ECO

Based on the thermal behaviour of the original brick, a large loss can be seen in the tongue and grooving and in the thermal bridge in the interior partitions. The first study would therefore be to eliminate these interior continuous partitions in the brick and replace them with quincunx rows. A second study attempted to improve the type of tongue and grooving, always maintaining the type of perforation of the starting brick.

The following alternatives have been studied, initially, and the following results have been obtained:

### INSERT TABLE 2

It can be seen that there was an improvement with the latest geometry, with a horizontal discontinuous 30 mm to 20 mm expanded polystyrene (EPS) joint with standard mortar. The improvement in the equivalent wall's transmittance compared to the original one, for a horizontal joint with standard mortar with thermal bridge, was 12%.

All of this leads us to think of continuing to increase the number of rows but here we met a building problem, that the perforation cannot be less than 6 mm and the interior partition in the brick cannot be less than 5 mm, so the number of rows cannot be increased to try to comply with standard mortar and a discontinuous air joint, given that the perforation is already at 6 mm. This leads to the following alternative, in which the width of the brick was increased from 290 mm to 300 mm, allowing the number of perforations is to be increased.

### 3.1. Alternative 6

In this Alternative 6 the number of rows was 26 and the constructional limit of the thickness of the rectangular perforation void was 6 mm. For building reasons and to maintain symmetry, the extensions of the rectangles were modified, alternating 2 and 3 rows, which also maintained the gap in the tongue and grooving.

This section increased the percentage of voids to 47.18%. Given that the size of the brick increased from 290 mm wide to 300 mm, this gave a brick weight of 16.1 kg, perfectly allowable for handling by a mason.

The results for the equivalent wall's transmittance were improved, combined with the most restrictive climatic zone with a discontinuous air joint of 40 mm and standard mortar, as shown in the following table.

### INSERT TABLE 3

The heat flow diagram is shown in figure 3

### INSERT FIGURE 3

## 4. Conclusions

To minimize the brick's thermal transmittance, it can be concluded that:

1. Thermal bridges must be avoided in the brick, requiring the void perforations to be arranged in a quincunx.
2. It can be seen that by not having a higher percentage of voids, the brick's behaviour is improved. It can be seen that with a larger number of rows, causing a lower percentage of voids in the brick, there is a better thermal behaviour.
3. To avoid the thermal bridge in the tongue and grooving, it can be seen that this is broken by extending the perforations of the voids in this tongue and grooved area, greatly improving its thermal behaviour.
4. A small gap in the assembly of the brick also notably improves the brick's conductivity; the greater the number of rows, the greater this improvement.
5. We obtained a geometry of rectangles arranged in a quincunx with 26 rows in a brick 300 mm wide and tongue and grooved with the rectangles extended, with alternation and with a small gap in the assembly that gave an improvement of almost 16% compared to the original 29 ECO and complies with all areas of Spain, that is,  $U_{eq} < 0.57 \text{ W/m}^2\text{-K}$ , with a horizontal discontinuous joint with standard mortar and 40 mm air joint.

## 5. References

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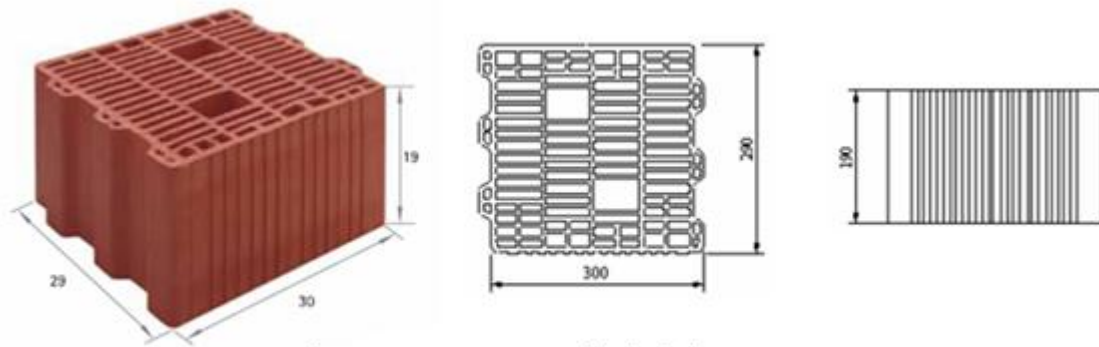


Figure 1. Termoarcilla brick® 29 ECO

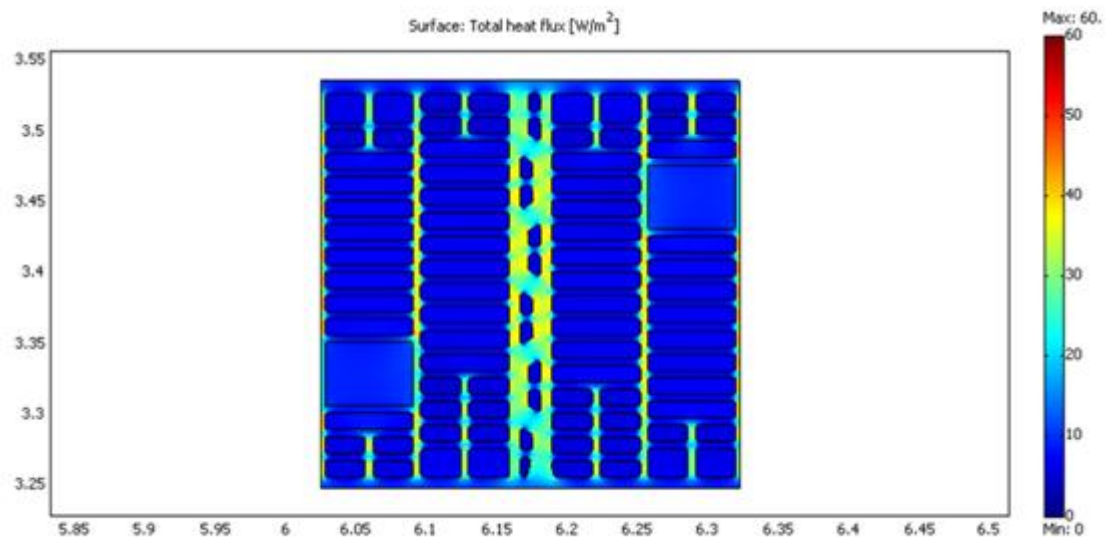


Figure 2. Heat flow diagram for the clay section

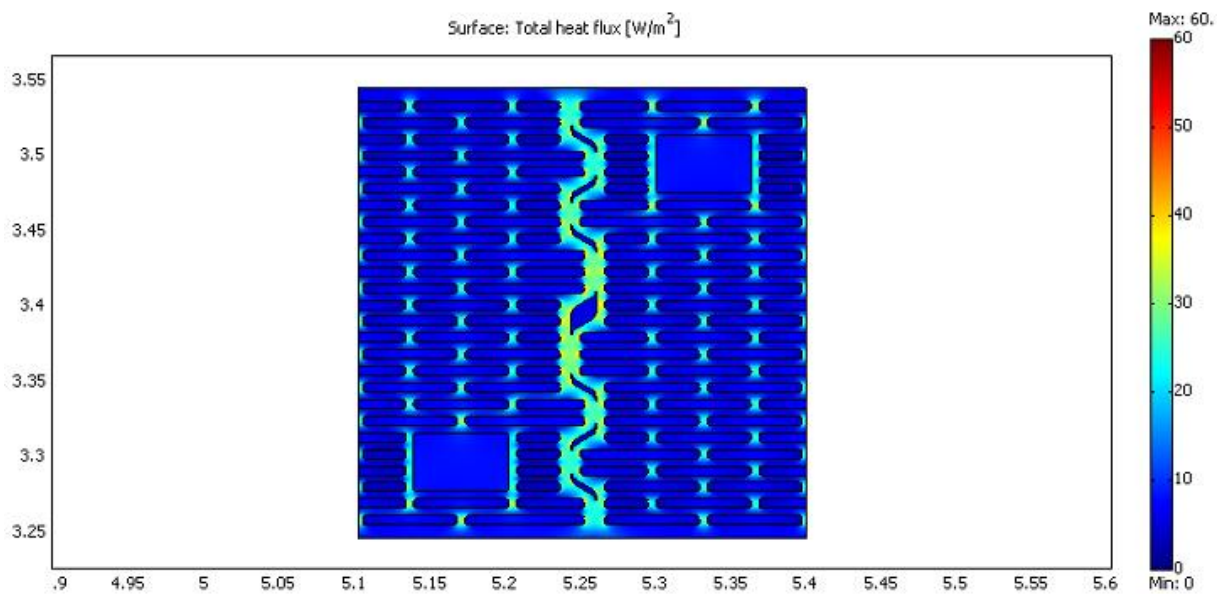


Figure 3. Heat flow diagram for the clay section



Table 1. Results for conductivity obtained for the Termoarcilla Brick® 29 ECO

ECO29-16F						
Mortar	Standard		Insulating		Haga	
Discontinuous joint	Air	EPS	Air	EPS	Air	EPS
Thickness (mm)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)
0	0,829	0,829	0,746	0,746	0,680	0,680
10	0,737	0,716	0,672	0,650	0,613	0,590
20	0,706	0,664	0,656	0,613	0,605	0,561
30	0,693	0,635	0,652	0,593	0,606	0,546
40	0,681	0,612	0,648	0,578	0,608	0,537

Table 2. Results obtained for alternatives 1 to 5

Alternative	Rows	Characteristics	Percentage of voids (%)	Percentage of improvement compared with the original with standard mortar (%)
1	17	Rectangular perforations in a quincunx	55	3
2	17	Extended rectangular perforations to the tongue	55	5
3	17	Extended rectangular perforations to the tongue with a certain clearance	55	6
4	21	Extended rectangular perforations to the tongue with a certain clearance	52,4	10
5	25	Extended rectangular perforations to the tongue with a certain clearance	46,44	12

Table 3. Results for conductivity obtained for the Alternative 6

ECO30-26F			Alternative 6			
Mortar	Standard		Insulating		Haga	
Discontinuous joint	Air	EPS	Air	EPS	Air	EPS
Thickness (mm)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)	Ueq (W/m <sup>2</sup> -K)
<b>0</b>	<b>0,717</b>	0,717	0,657	0,657	0,593	0,593
10	0,625	0,602	0,579	0,556	0,522	0,499
20	0,596	0,551	0,561	0,516	0,513	0,467
30	0,587	0,526	0,557	0,495	0,514	0,451
<b>40</b>	<b>0,570</b>	0,497	0,548	0,475	0,514	0,439

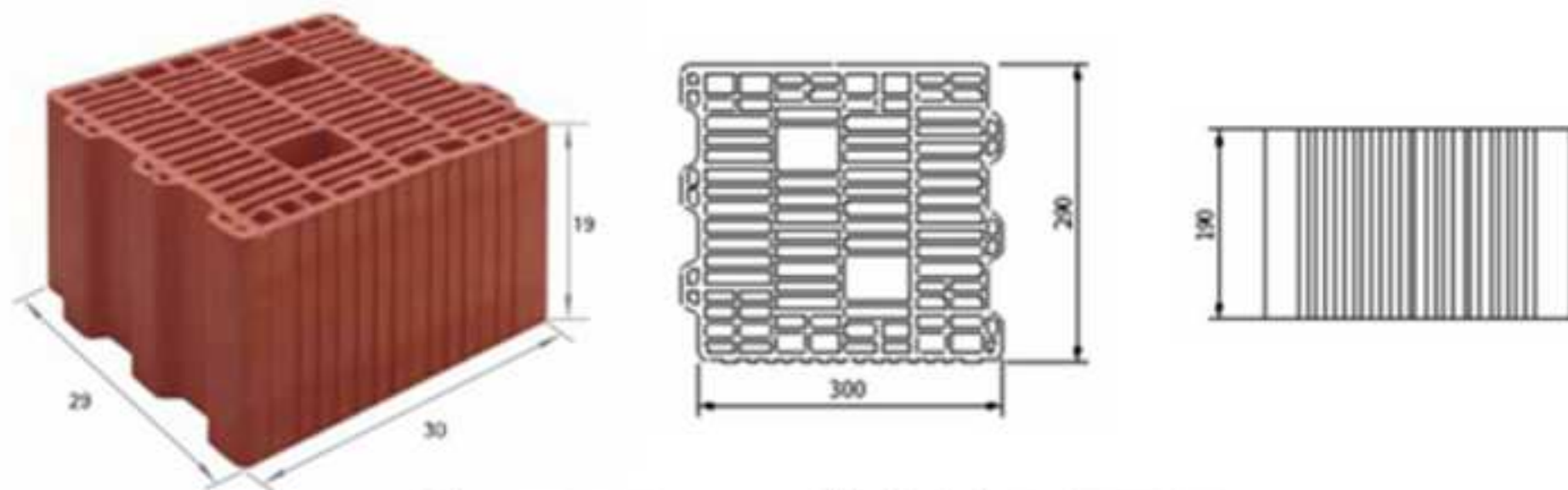


Figure 1. Termoarcilla brick® 29 ECO

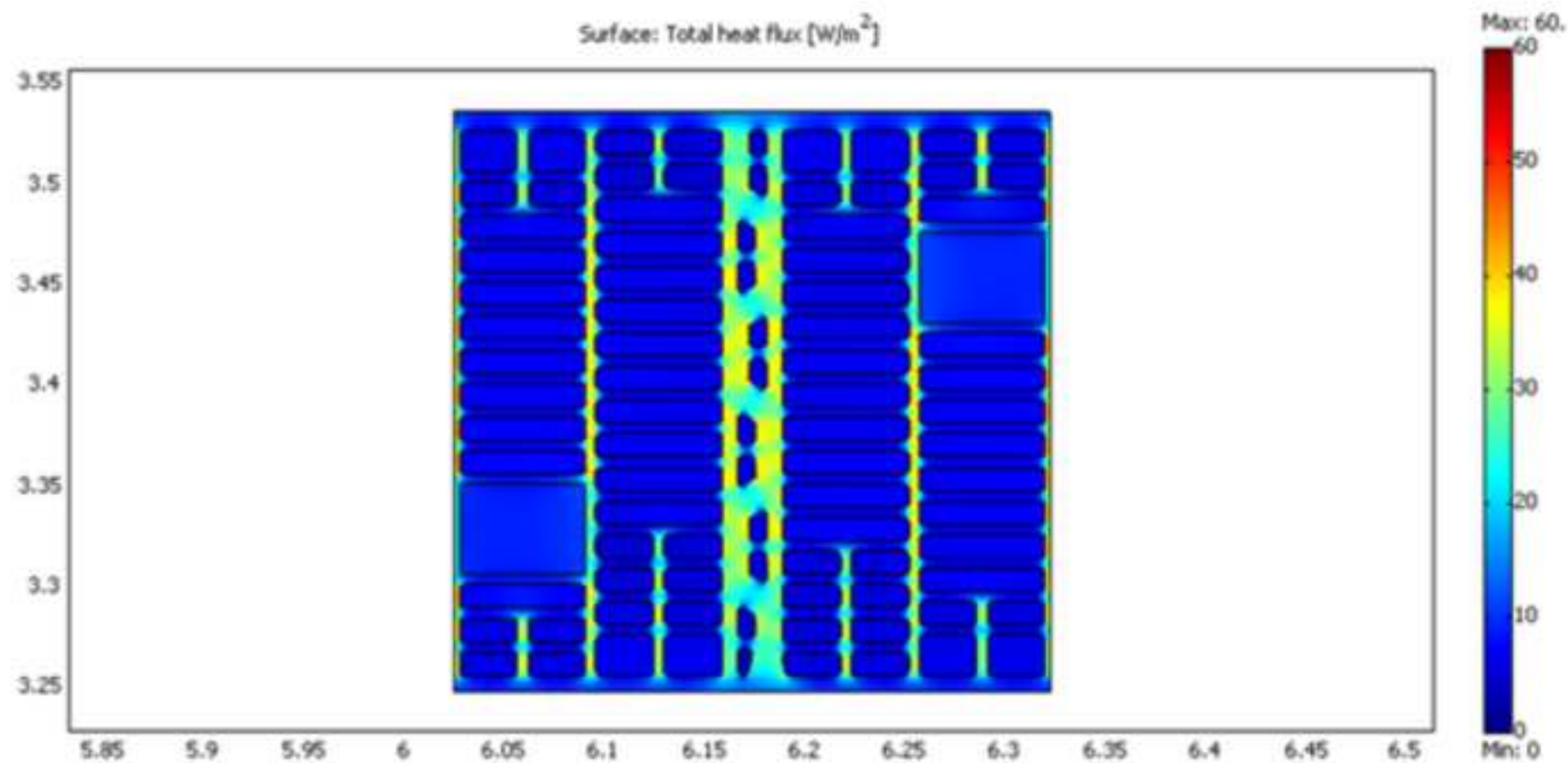


Figure 2. Heat flow diagram for the clay section

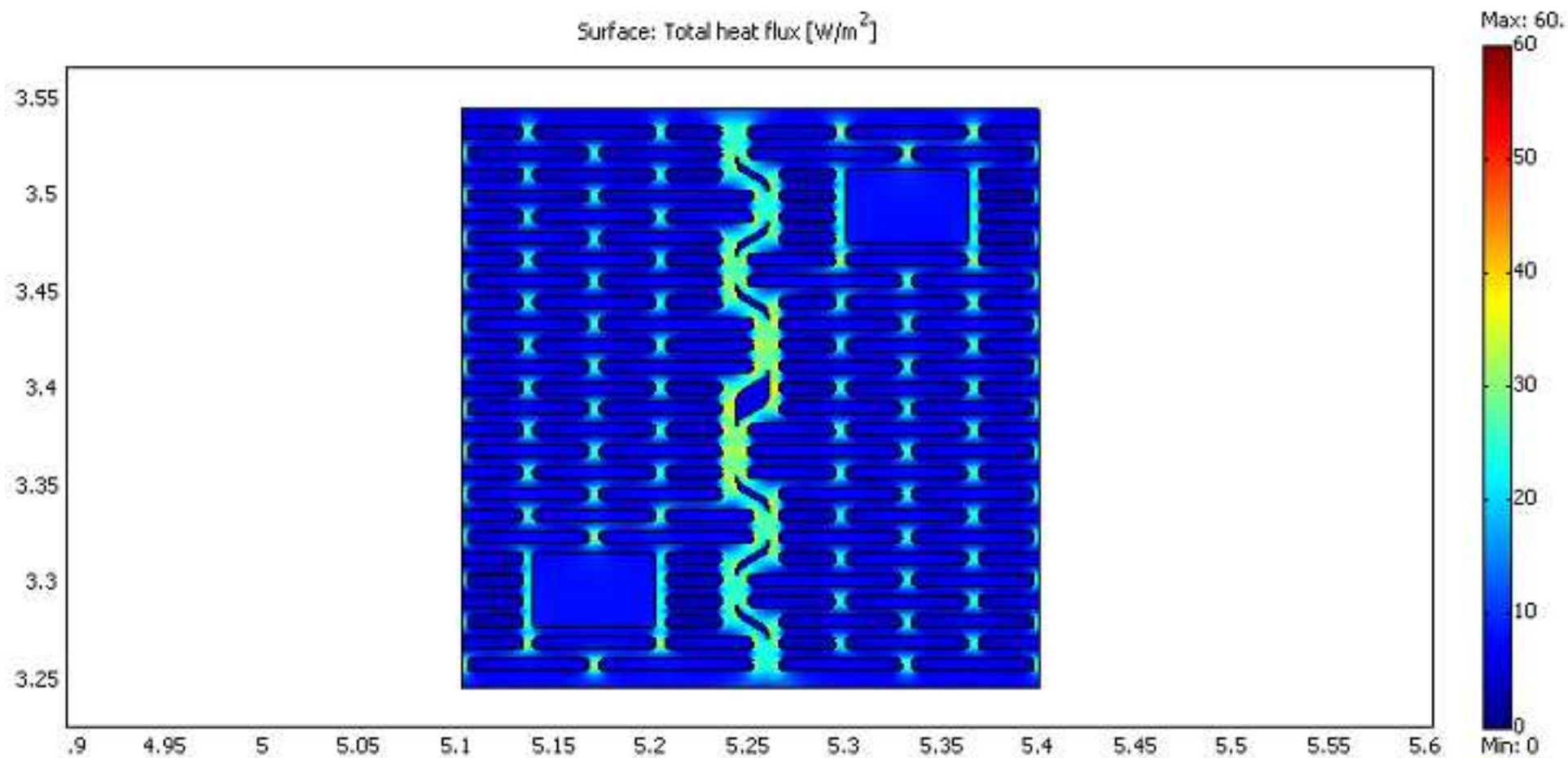


Figure 3. Heat flow diagram for the clay section