TEST REPORT

SQM_639_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K250

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/15/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_638_2023, 09/15/2023 - Determination of the equivalent thermal conductivity of the block K250 and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

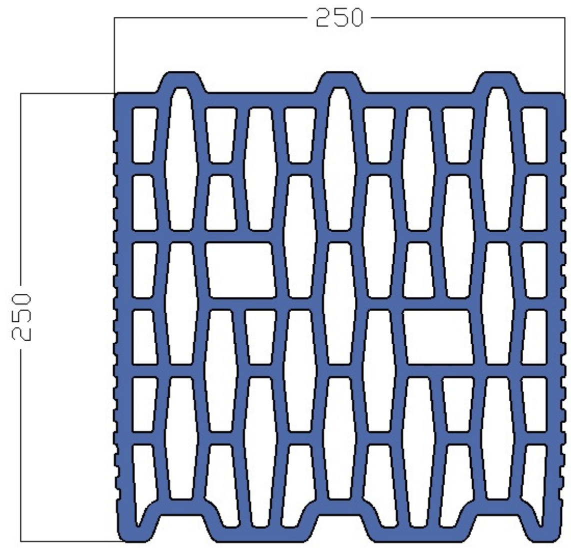

Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report K250	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.9962	0.1498	0.5992	1.6688	1.4988	0.1668

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	1.4588
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.2056
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	1.6288
Thermal transmittance **U** (W/m²K)	0.6139

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Masonry n. 2	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.6850
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1780
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.8550
Thermal transmittance **U** (W/m²K)	0.5391

Masonry n. 3	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.4014
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1784
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.5714
Thermal transmittance **U** (W/m²K)	0.6364

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block K250	**0.1668**	**0.5992**
Masonry n. 1	**0.2056**	**0.6139**
Masonry n. 2	**0.1780**	**0.5391**
Masonry n. 3	**0.1784**	**0.6364**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_638_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K250

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

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Report issued 09/15/2023
Revision n° 00

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Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

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This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

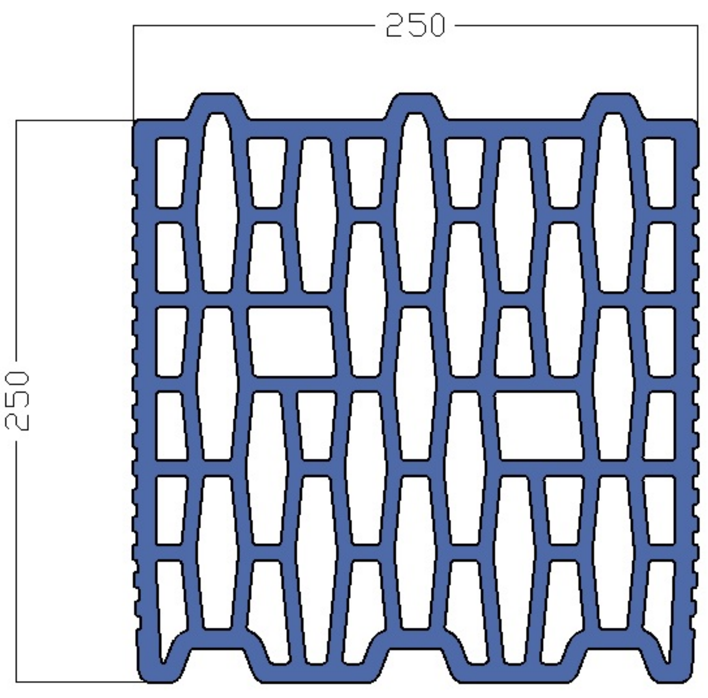
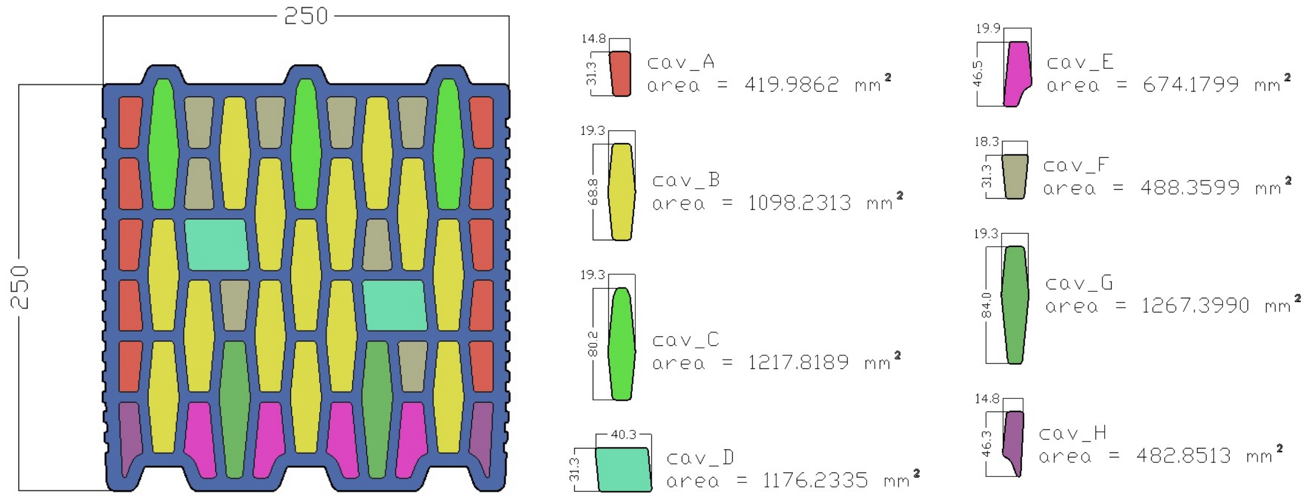


Table 1. Input data

Physical quantity	**Nominal value**	**Ref.**
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-a and 2-c., approximating convective and radiative heat transfer inside the void (Figure 2).

Figure 2. Cross section of the block and air voids data



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m^2K]	**Total thermal resistance** R_T [m^2K/W]	**True thermal resistance of the masonry unit** R_t [m^2K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2,8615	0.1431	0.5723	1.7473	1.5773	0.1585

Figure 3. Distribution of isotherms in the block [°C]

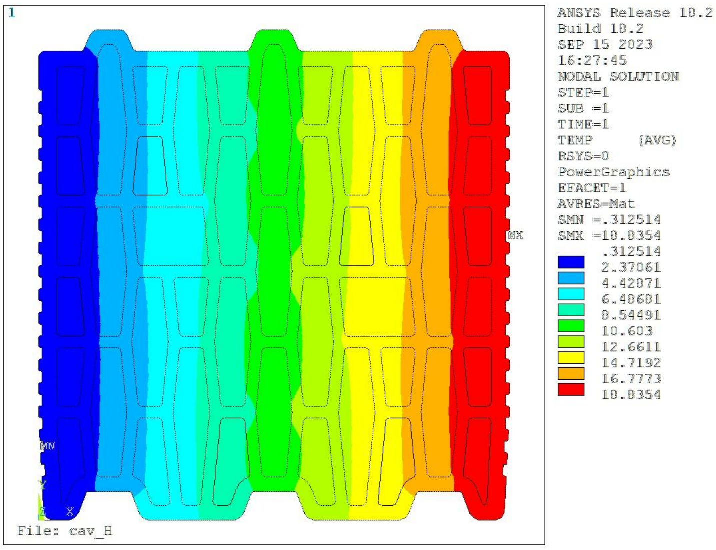
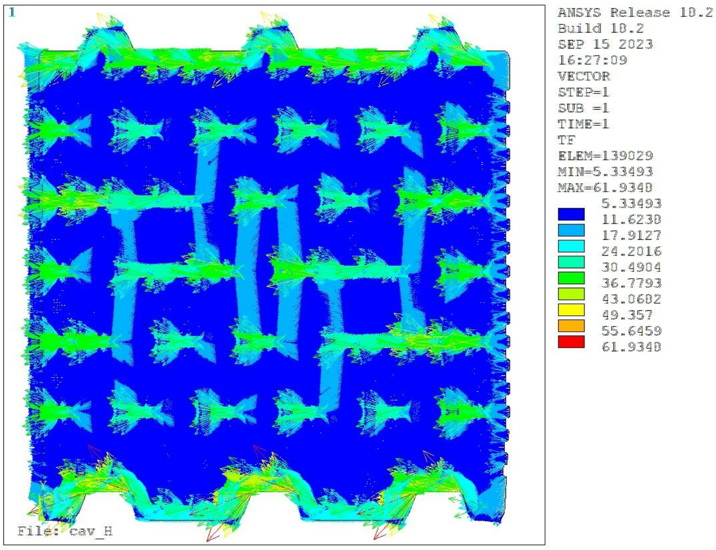


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.5607
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1922
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.7307
Thermal transmittance **U** (W/m²K)	0.5778

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.8482
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1623
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.0182
Thermal transmittance **U** (W/m²K)	0.4955

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.4945
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1673
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m²K/W]	1.6645
Thermal transmittance **U** [W/m²K]	0.6008

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block K250	0.1585	0.5723
Masonry no. 1	0.1922	0.5778
Masonry no. 2	0.1623	0.4955
Masonry no. 3	0.1673	0.6008

6. List of distribution

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Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

TEST REPORT

SQM_649_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K250PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

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Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
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Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

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Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_648_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block K250PLUS and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

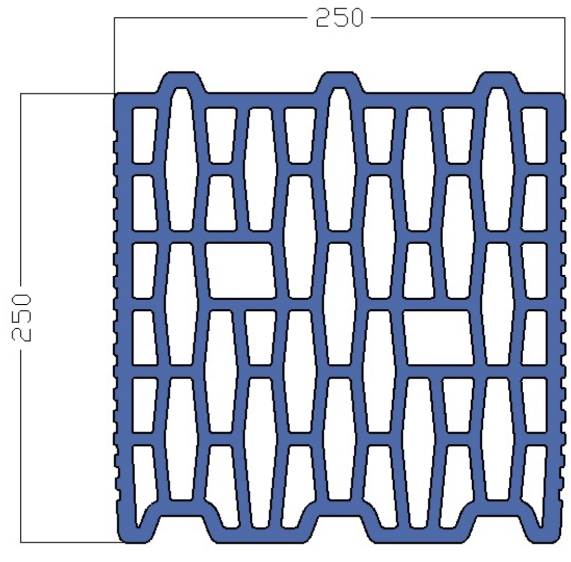

Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report K250PLUS	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.8182	0.0909	0.3636	2.7499	2.5799	0.0969

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	2.3739
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1264
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	2.5439
Thermal transmittance **U** (W/m²K)	0.3931

Masonry n. 2	Result
Thermal resistance only of the layer R_t [m²K/W]	2.6001
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1154
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	2.7701
Thermal transmittance **U** (W/m²K)	0.3610

Masonry n. 3	Result
Thermal resistance only of the layer R_t [m²K/W]	2.2860
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1094
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	2.4560
Thermal transmittance **U** (W/m²K)	0.4072

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block K250PLUS	**0.0969**	**0.3636**
Masonry n. 1	**0.1264**	**0.3931**
Masonry n. 2	**0.1154**	**0.3610**
Masonry n. 3	**0.1094**	**0.4072**

6. List of distribution

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In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

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Commissione Europea 2006/C 323/01

TEST REPORT

SQM_648_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K250PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

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3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

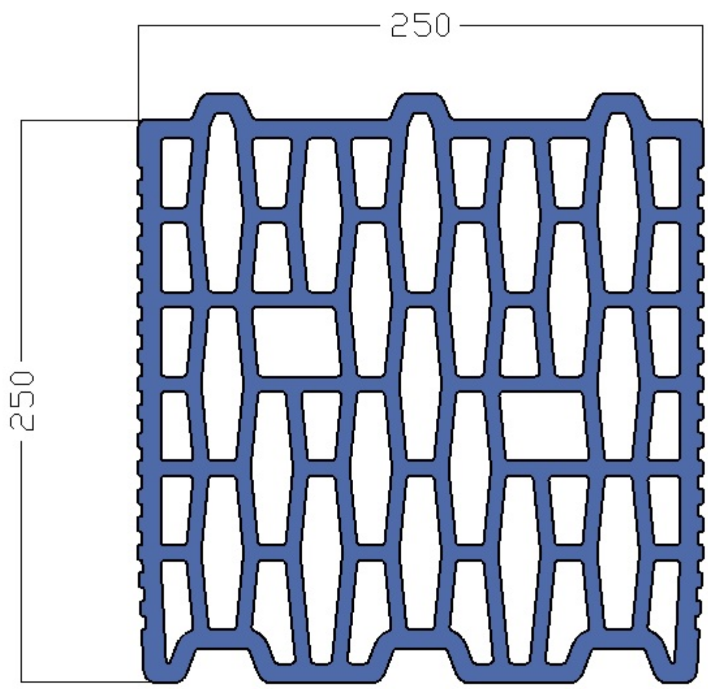

Table 1. Input data

Physical quantity	**Nominal value**	**Ref.**
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

All cavities are filled with NEOCOAT EPS 100 PLUS, whose conductivity is declared in the technical data sheet equal to 0.030 W/mK (Figure 2).

Figure 2. Cross section of the block

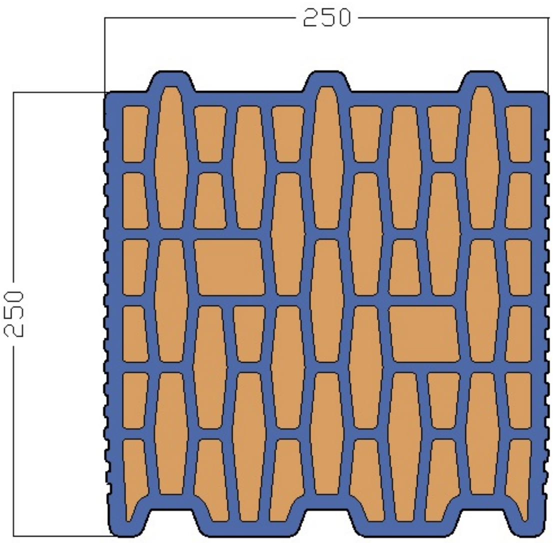

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Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.6986	0.0849	0.3397	2.9437	2.7737	0.0901

Figure 3. Distribution of isotherms in the block [°C]

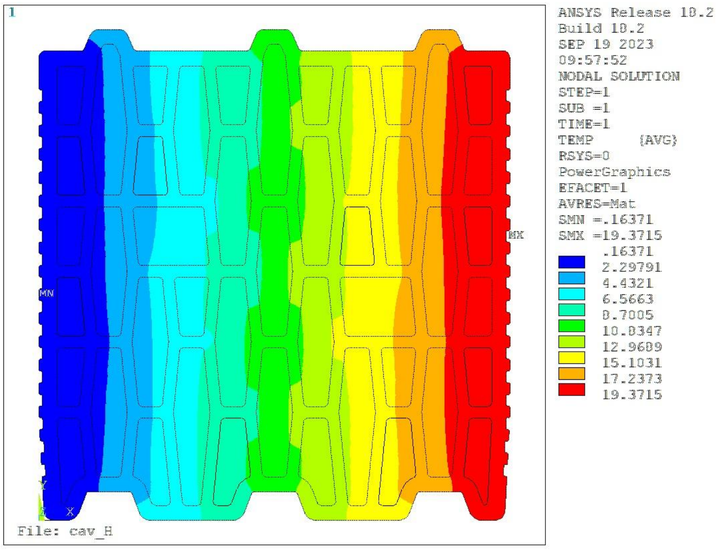
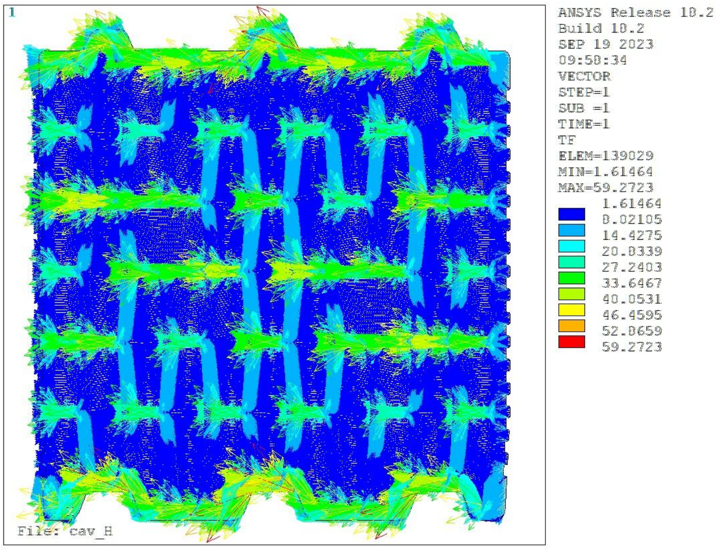


Figure 4. Average heat flow vectors [W/m²]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	2.6018
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1153
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^{2}K/W)	2.7718
Thermal transmittance **U** (W/m^{2}K)	0.3608

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	2.8893
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1038
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^{2}K/W)	3.0593
Thermal transmittance **U** (W/m^{2}K)	0.3269

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	2.5060
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.0998
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m^{2}K/W]	2.6760
Thermal transmittance **U** [W/m^{2}K]	0.3737

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block K250PLUS	0.0901	0.3397
Masonry no. 1	0.1153	0.3608
Masonry no. 2	0.1038	0.3269
Masonry no. 3	0.0998	0.3737

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

TEST REPORT

SQM_641_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K300

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_640_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block K300 and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

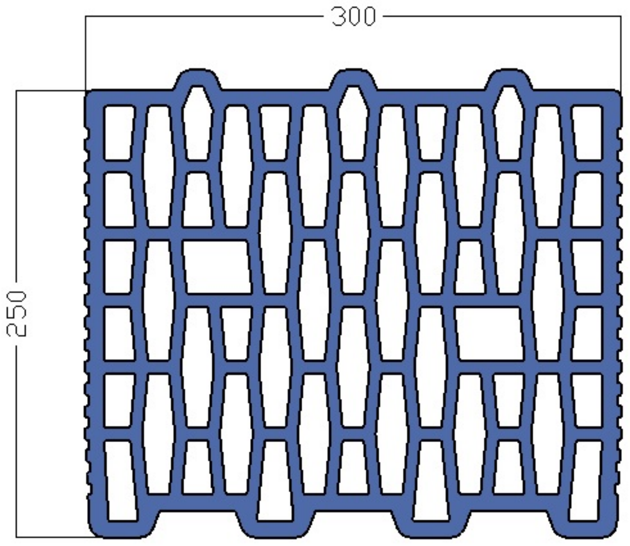


Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report K300	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2-\psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m^{2}K]	**Total thermal resistance** R_T [m^{2}K/W]	**True thermal resistance of the masonry unit** R_t [m^{2}K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.5178	0.1259	0.5036	1.9859	1.8159	0.1652

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m^{2}K/W]	1.7549
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1994
Thermal resistance of the masonry including superficial thermal resistances R_T (m^{2}K/W)	1.9249
Thermal transmittance **U** (W/m^{2}K)	0.5195

Masonry n. 2	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.9810
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1767
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.1510
Thermal transmittance **U** (W/m²K)	0.4649

Masonry n. 3	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.6966
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1768
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.8666
Thermal transmittance **U** (W/m²K)	0.5357

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block K300	**0.1652**	**0.5036**
Masonry n. 1	**0.1994**	**0.5195**
Masonry n. 2	**0.1767**	**0.4649**
Masonry n. 3	**0.1768**	**0.5357**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_640_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K300

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

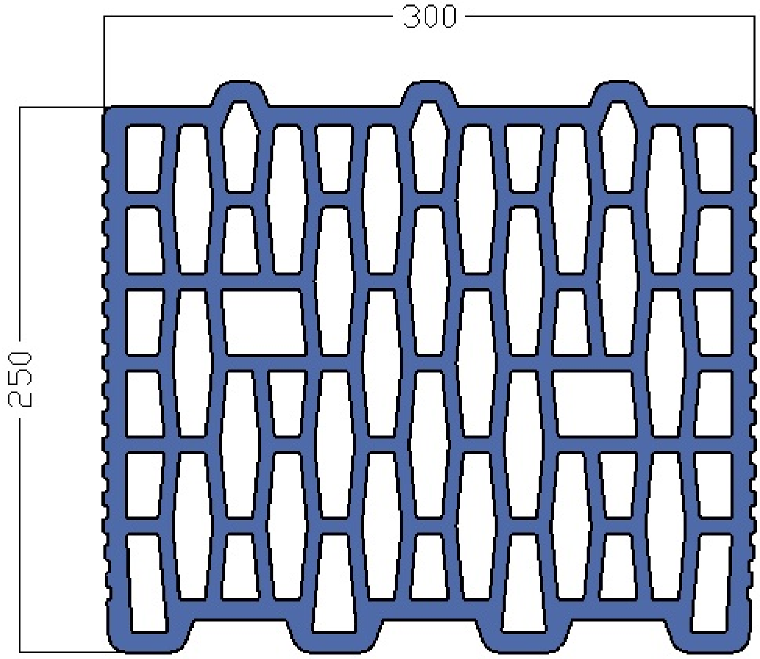
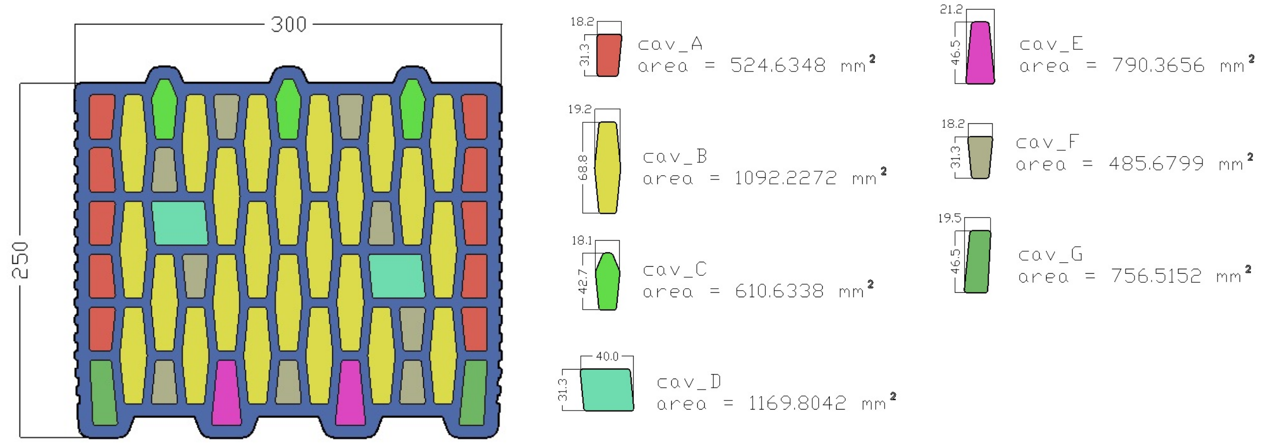


Table 1. Input data

Physical quantity	Nominal value	Ref.
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m²K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m²K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-a and 2-c., approximating convective and radiative heat transfer inside the void (Figure 2).

Figure 2. Cross section of the block and air voids data



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.4032	0.1202	0.4806	2.0805	1.9105	0.1570

Figure 3. Distribution of isotherms in the block [°C]

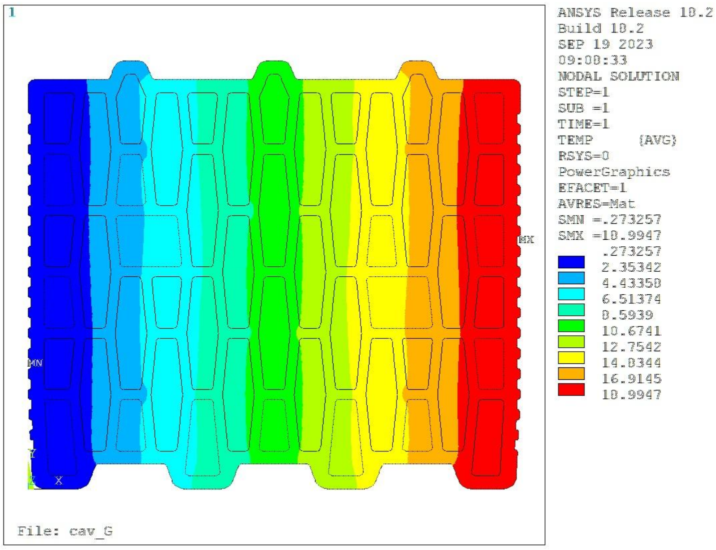
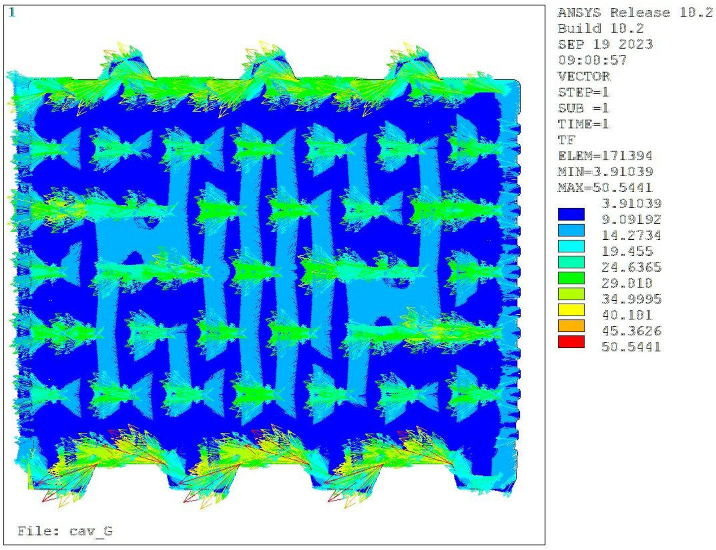


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	**Nominal value**	**Ref.**
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	**Nominal value**	**Ref.**
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	**Nominal value**	**Ref.**
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	1.8760
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1866
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^{2}K/W)	2.0460
Thermal transmittance **U** (W/m^{2}K)	0.4888

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	2.1635
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1618
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^{2}K/W)	2.3335
Thermal transmittance **U** (W/m^{2}K)	0.4285

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	1.8091
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1658
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m^{2}K/W]	1.9791
Thermal transmittance **U** [W/m^{2}K]	0.5053

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block K300	0.1570	0.4806
Masonry no. 1	0.1866	0.4888
Masonry no. 2	0.1618	0.4285
Masonry no. 3	0.1658	0.5053

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_651_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K300PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_650_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block K300PLUS and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

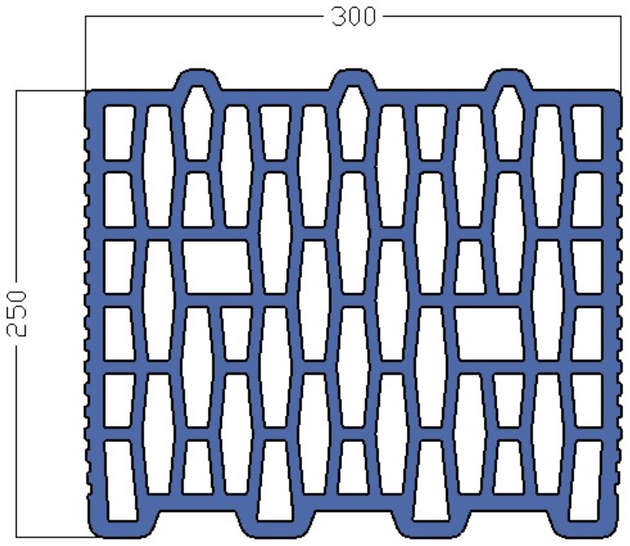


Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report K300PLUS	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.5198	0.0760	0.3040	3.2900	3.1200	0.0962

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	2.8517
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1227
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	3.0217
Thermal transmittance **U** (W/m²K)	0.3309

Masonry n. 2	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	3.0779
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1137
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	3.2479
Thermal transmittance **U** (W/m²K)	0.3079

Masonry n. 3	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.7619
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1086
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.9319
Thermal transmittance **U** (W/m²K)	0.3411

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block K300PLUS	**0.0962**	**0.3040**
Masonry n. 1	**0.1227**	**0.3309**
Masonry n. 2	**0.1137**	**0.3079**
Masonry n. 3	**0.1086**	**0.3411**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_650_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

K300PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

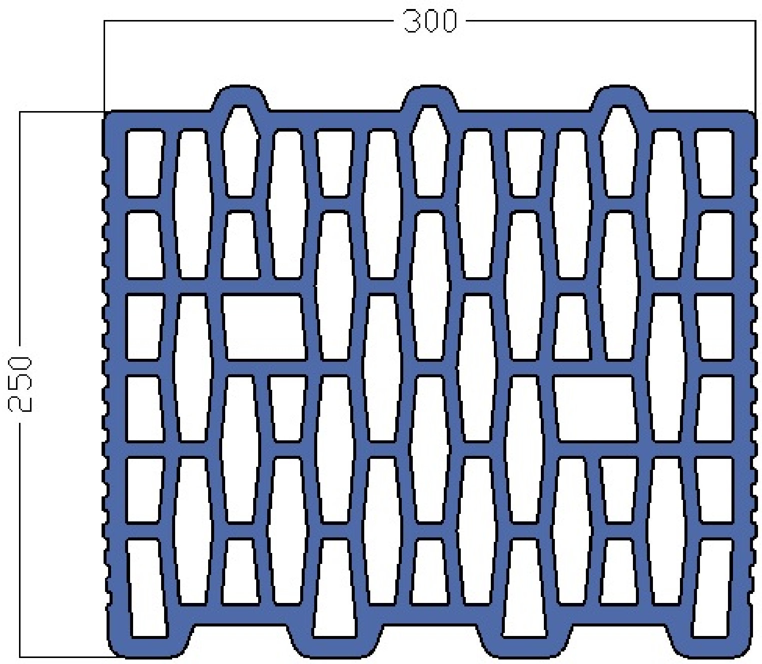
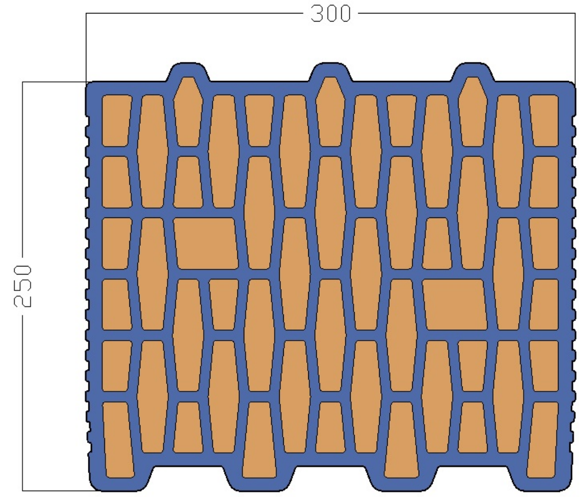


Table 1. Input data

Physical quantity	Nominal value	Ref.
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

All cavities are filled with NEOCOAT EPS 100 PLUS, whose conductivity is declared in the technical data sheet equal to 0.030 W/mK (Figure 2).

Figure 2. Cross section of the block



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m^2K]	**Total thermal resistance** R_T [m^2K/W]	**True thermal resistance of the masonry unit** R_t [m^2K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.4173	0.0709	0.2835	3.5278	3.3578	0.0893

Figure 3. Distribution of isotherms in the block [°C]

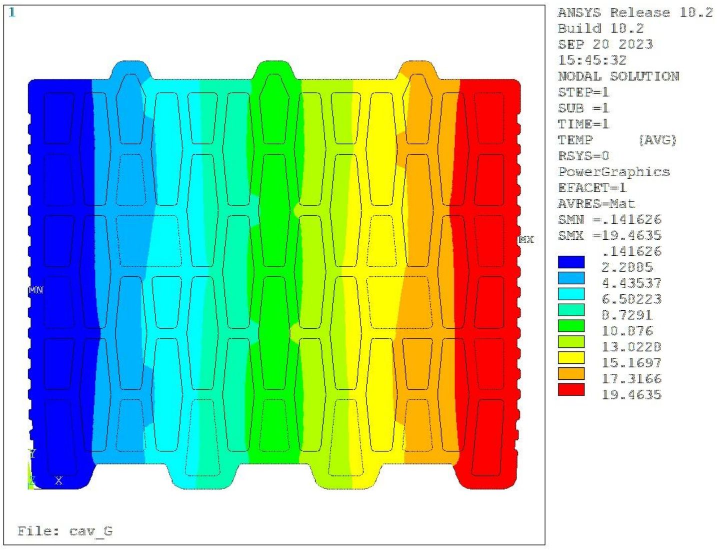
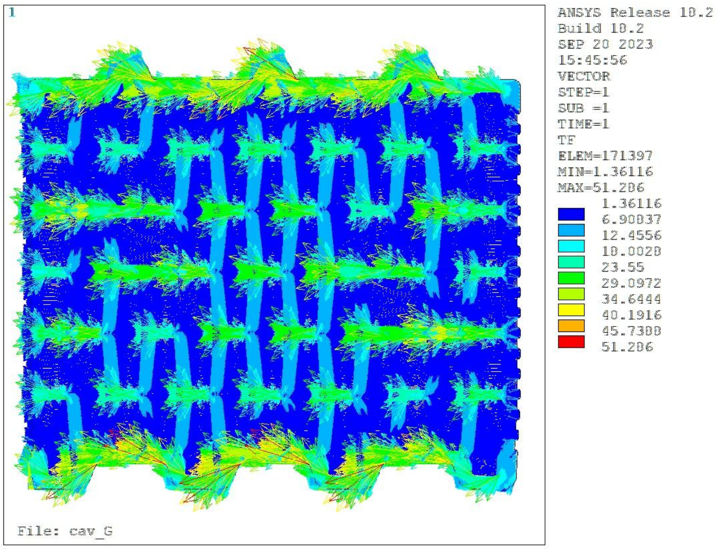


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	3.1286
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1119
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^2K/W)	3.2986
Thermal transmittance **U** (W/m^2K)	0.3032

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	3.4161
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1025
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^2K/W)	3.5861
Thermal transmittance **U** (W/m^2K)	0.2789

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	3.0309
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.0990
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m^2K/W]	3.2009
Thermal transmittance **U** [W/m^2K]	0.3124

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block K300PLUS	0.0893	0.2835
Masonry no. 1	0.1119	0.3032
Masonry no. 2	0.1025	0.2789
Masonry no. 3	0.0990	0.3124

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

TEST REPORT

SQM_643_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK250

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

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This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_642_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block NK250 and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

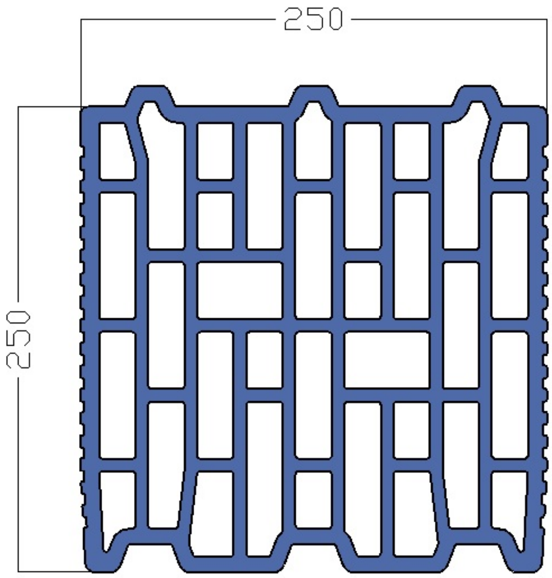

Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report NK250	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
3.1176	0.1559	0.6235	1.6038	1.4338	0.1744

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	1.4011
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.2141
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	1.5711
Thermal transmittance **U** (W/m²K)	0.6365

Masonry n. 2	Result
Thermal resistance only of the layer R_t [m²K/W]	1.6272
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1844
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	1.7972
Thermal transmittance **U** (W/m²K)	0.5564

Masonry n. 3	Result
Thermal resistance only of the layer R_t [m²K/W]	1.3451
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1859
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	1.5151
Thermal transmittance **U** (W/m²K)	0.6600

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block NK250	**0.1744**	**0.6235**
Masonry n. 1	**0.2141**	**0.6365**
Masonry n. 2	**0.1844**	**0.5564**
Masonry n. 3	**0.1859**	**0.6600**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_642_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK250

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
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Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

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Chief Technical Officer
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1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

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3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

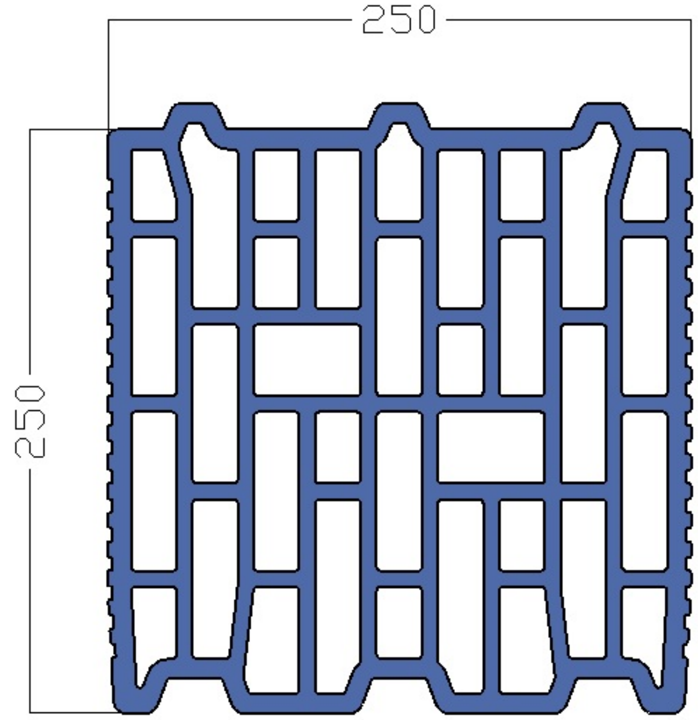
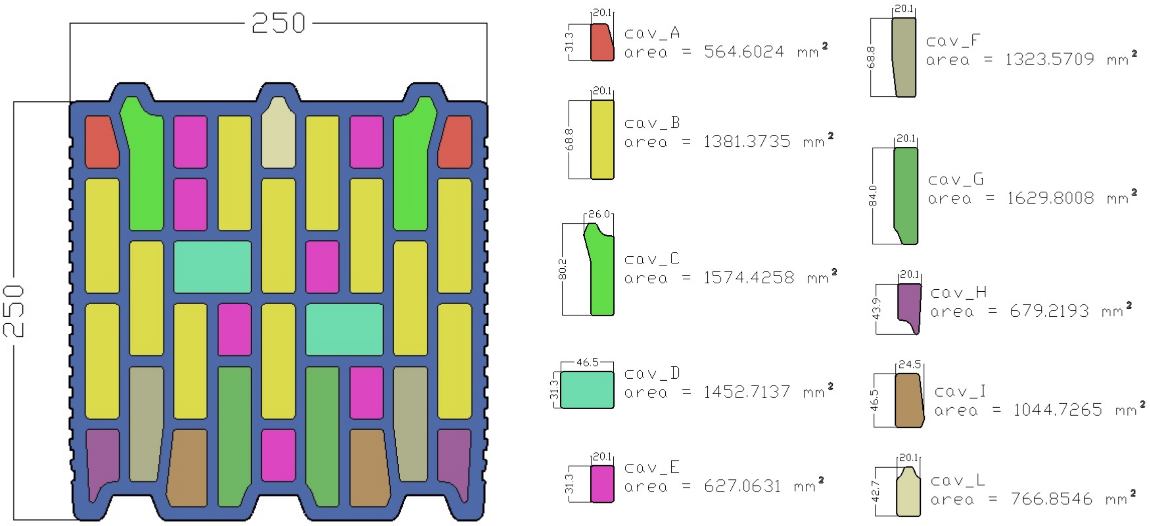


Table 1. Input data

Physical quantity	**Nominal value**	**Ref.**
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-a and 2-c., approximating convective and radiative heat transfer inside the void (Figure 2).

Figure 2. Cross section of the block and air voids data



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m^2K]	**Total thermal resistance** R_T [m^2K/W]	**True thermal resistance of the masonry unit** R_t [m^2K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.9891	0.1495	0.5978	1.6727	1.5027	0.1664

Figure 3. Distribution of isotherms in the block [°C]

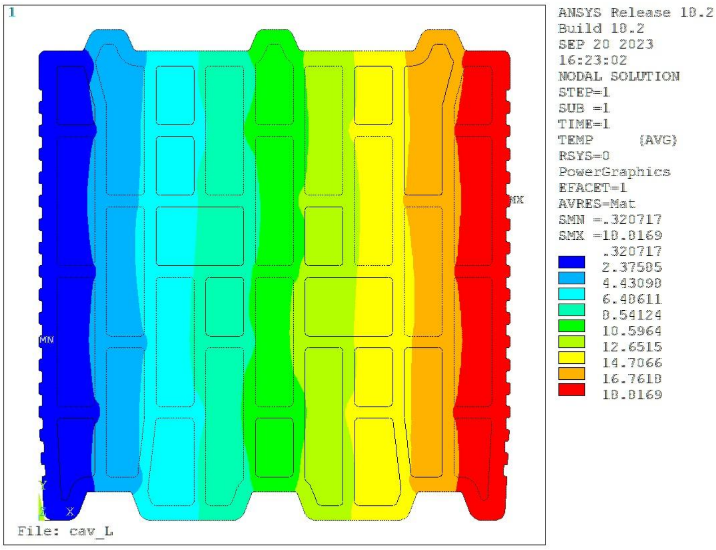
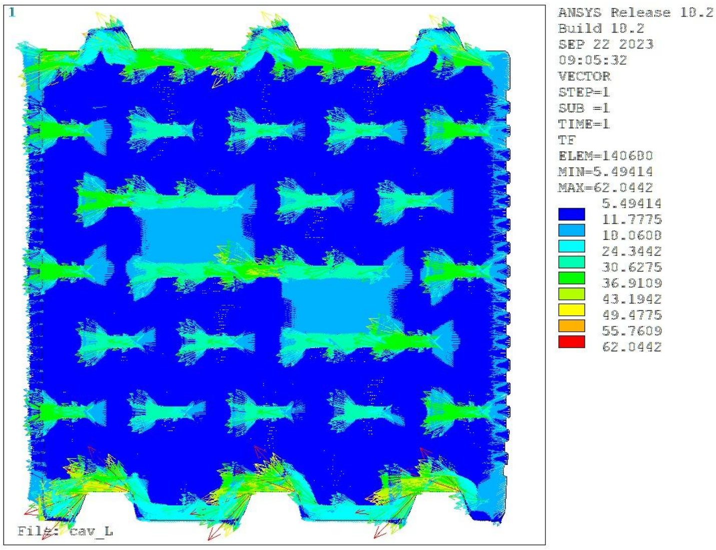


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.4929
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.2009
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.6629
Thermal transmittance **U** (W/m²K)	0.6013

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.7804
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1685
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.9504
Thermal transmittance **U** (W/m²K)	0.5127

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.4282
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1750
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m²K/W]	1.5982
Thermal transmittance **U** [W/m²K]	0.6257

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block NK250	0.1664	0.5978
Masonry no. 1	0.2009	0.6013
Masonry no. 2	0.1685	0.5127
Masonry no. 3	0.1750	0.6257

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_653_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK250PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format
digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

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via Granarolo, 62 | 48018 Faenza (RA) - ITALY
Test Laboratory: via Ravegnana 186 - Faenza (RA) - ITALY
+39 0546 678578 - laboratorio@certimac.it | www.certimac.it

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_652_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block NK250PLUS and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

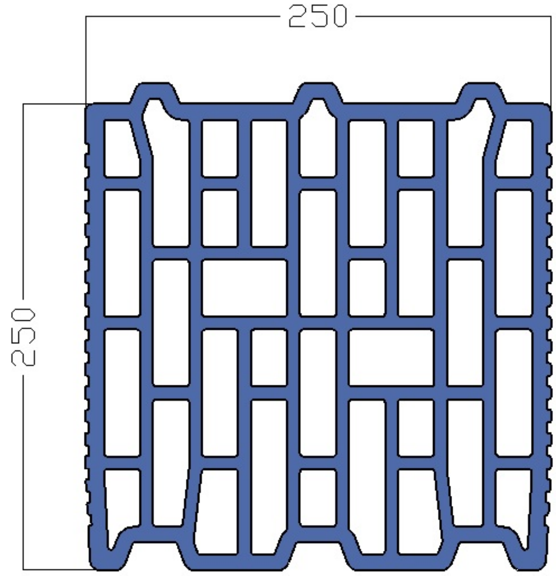


Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report NK250PLUS	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.7305	0.0865	0.3461	2.8893	2.7193	0.0919

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	2.4860
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1207
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	2.6560
Thermal transmittance **U** (W/m²K)	0.3765

Masonry n. 2	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.7122
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1106
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.8822
Thermal transmittance **U** (W/m²K)	0.3470

Masonry n. 3	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.3934
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1045
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.5634
Thermal transmittance **U** (W/m²K)	0.3901

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block NK250PLUS	**0.0919**	**0.3461**
Masonry n. 1	**0.1207**	**0.3765**
Masonry n. 2	**0.1106**	**0.3470**
Masonry n. 3	**0.1045**	**0.3901**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	**In charged of technical report drafting**	**Technical director Approval**
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

TEST REPORT

SQM_652_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK250PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

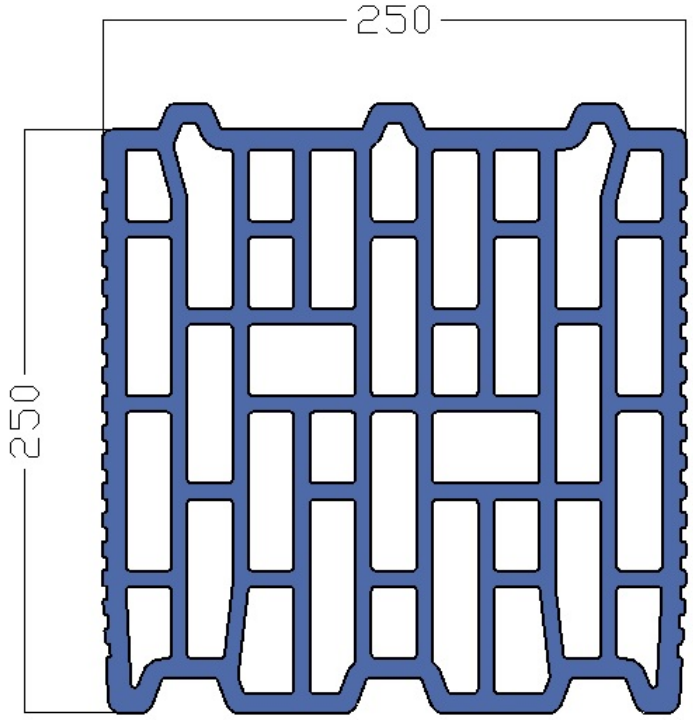
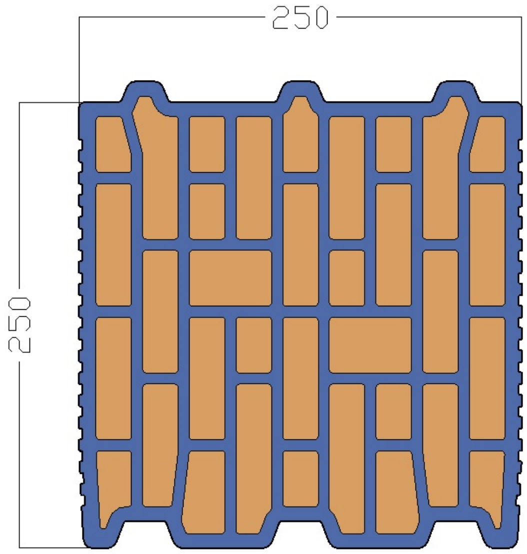


Table 1. Input data

Physical quantity	Nominal value	Ref.
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

All cavities are filled with NEOCOAT EPS 100 PLUS, whose conductivity is declared in the technical data sheet equal to 0.030 W/mK (Figure 2).

Figure 2. Cross section of the block



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m^2K]	**Total thermal resistance** R_T [m^2K/W]	**True thermal resistance of the masonry unit** R_t [m^2K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.6185	0.0809	0.3237	3.0893	2.9193	0.0856

Figure 3. Distribution of isotherms in the block [°C]

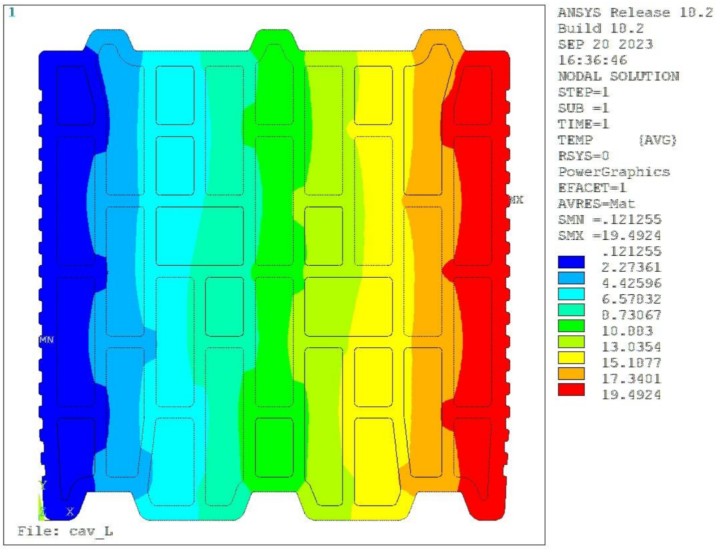
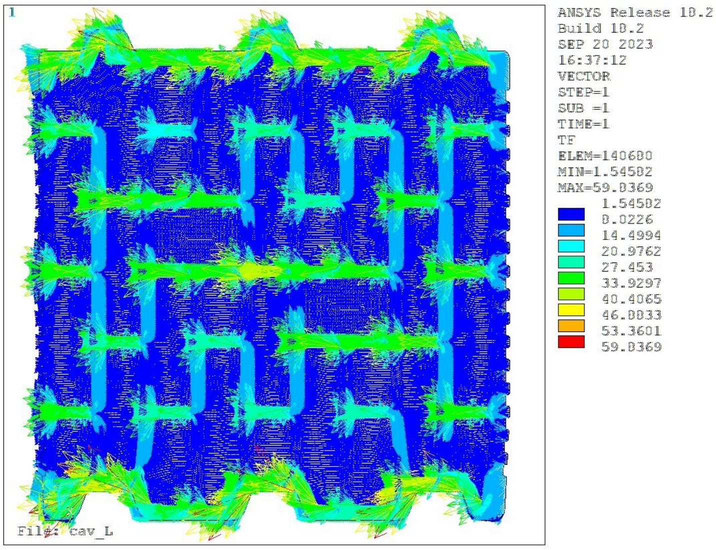


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.7229
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1102
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.8929
Thermal transmittance **U** (W/m²K)	0.3457

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	3.0104
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.0997
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	3.1804
Thermal transmittance **U** (W/m²K)	0.3144

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.6227
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.0953
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m²K/W]	2.7927
Thermal transmittance **U** [W/m²K]	0.3581

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block NK250PLUS	**0.0856**	**0.3237**
Masonry no. 1	**0.1102**	**0.3457**
Masonry no. 2	**0.0997**	**0.3144**
Masonry no. 3	**0.0953**	**0.3581**

6. List of distribution

ENEA	Archive	1 copy
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Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_645_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK300

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_644_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block NK300 and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

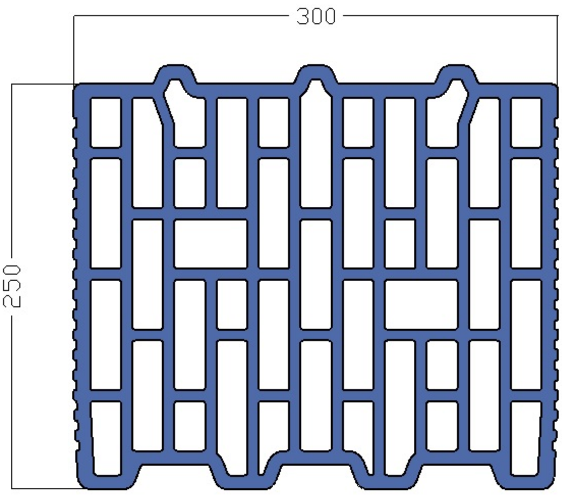


Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report NK300	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.5584	0.1279	0.5117	1.9543	1.7843	0.1681

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	1.7270
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.2027
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	1.8970
Thermal transmittance **U** (W/m²K)	0.5271

Masonry n. 2	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.9532
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1792
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.1232
Thermal transmittance **U** (W/m²K)	0.4710

Masonry n. 3	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	1.6694
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1797
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	1.8394
Thermal transmittance **U** (W/m²K)	0.5437

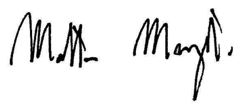
SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block NK300	**0.1681**	**0.5117**
Masonry n. 1	**0.2027**	**0.5271**
Masonry n. 2	**0.1792**	**0.4710**
Masonry n. 3	**0.1797**	**0.5437**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
		

-------- End of the Test Report ------

TEST REPORT

SQM_644_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK300

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

---

Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

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This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

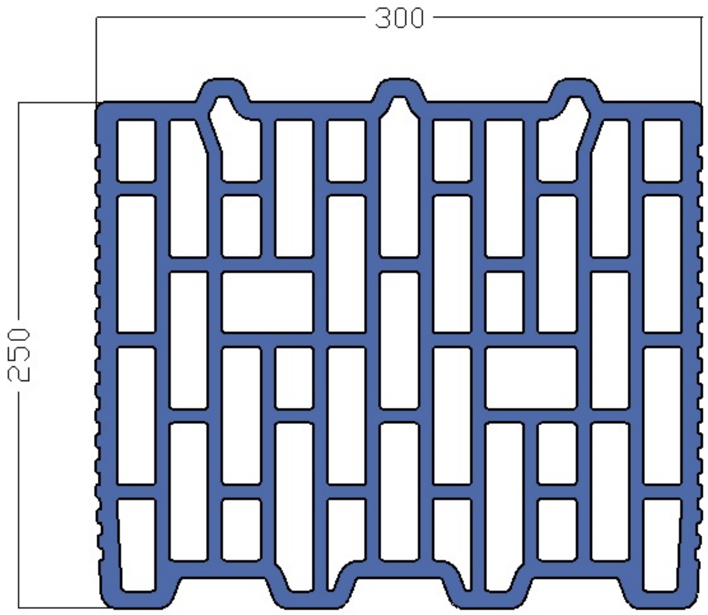
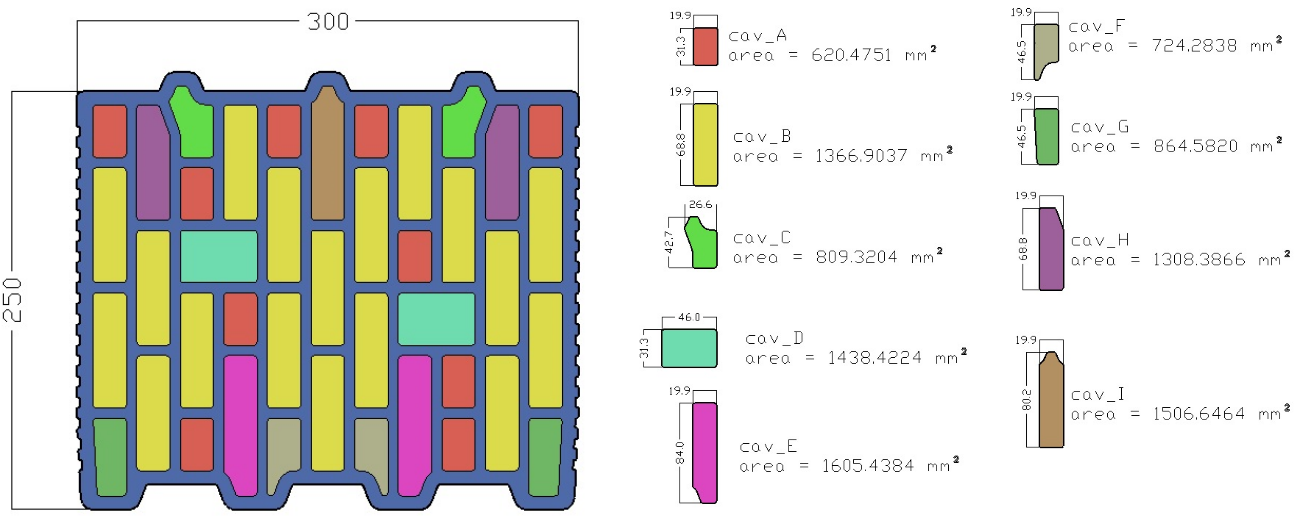


Table 1. Input data

Physical quantity	Nominal value	Ref.
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-a and 2-c., approximating convective and radiative heat transfer inside the void (Figure 2).

Figure 2. Cross section of the block and air voids data



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance U** [W/m^2K]	**Total thermal resistance** R_T [m^2K/W]	**True thermal resistance of the masonry unit** R_t [m^2K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.4517	0.1226	0.4903	2.0394	1.8694	0.1605

Figure 3. Distribution of isotherms in the block [°C]

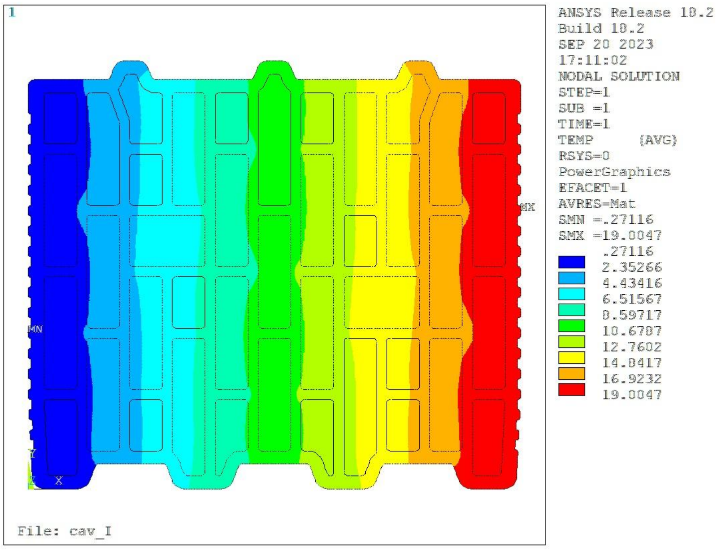
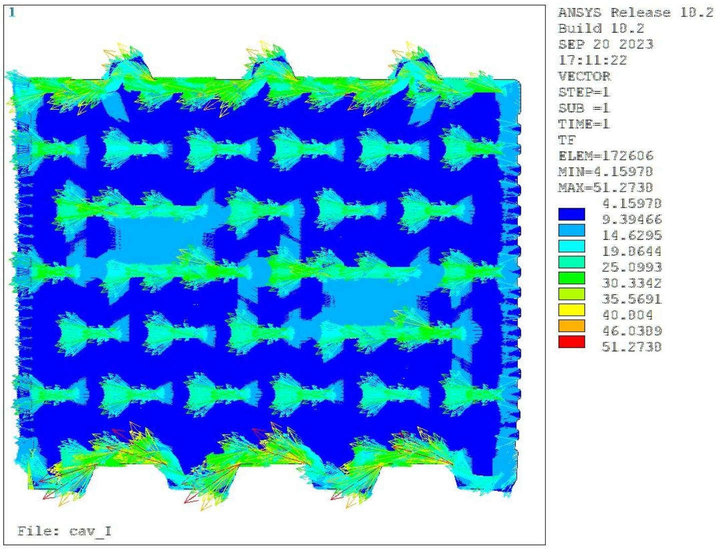


Figure 4. Average heat flow vectors [W/m²]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	1.8389
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1903
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^{2}K/W)	2.0089
Thermal transmittance **U** (W/m^{2}K)	0.4978

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	2.1264
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1646
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^{2}K/W)	2.2964
Thermal transmittance **U** (W/m^{2}K)	0.4355

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m^{2}K/W]	1.7726
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1692
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m^{2}K/W]	1.9426
Thermal transmittance **U** [W/m^{2}K]	0.5148

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block NK300	**0.1605**	**0.4903**
Masonry no. 1	**0.1903**	**0.4978**
Masonry no. 2	**0.1646**	**0.4355**
Masonry no. 3	**0.1692**	**0.5148**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_655_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK300PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

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Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_654_2023, 09/22/2023 - Determination of the equivalent thermal conductivity of the block NK300PLUS and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Tables 1 and 2.

Figure 1. Geometry of the block

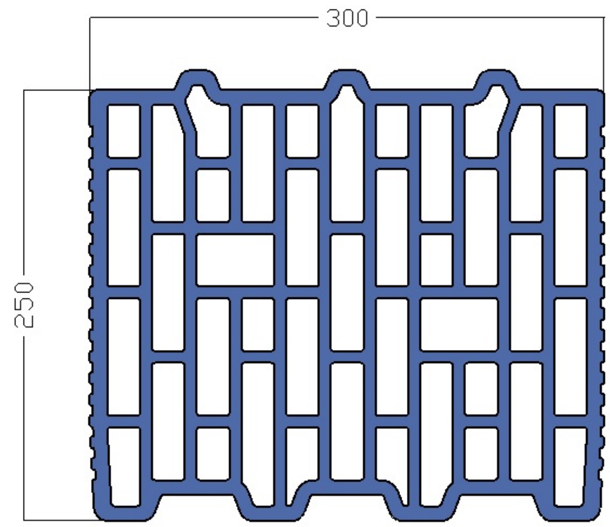

Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report NK300PLUS	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 °C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 °C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.4281	0.0714	0.2856	3.5013	3.3313	0.0901

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the three configurations described above, taking into account the effect of humidity.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	3.0200
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1159
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	3.1900
Thermal transmittance **U** (W/m²K)	0.3135

Masonry n. 2	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	3.2462
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1078
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	3.4162
Thermal transmittance **U** (W/m²K)	0.2927

Masonry n. 3	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.9240
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1026
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	3.0940
Thermal transmittance **U** (W/m²K)	0.3232

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results, taking into account the effect of humidity:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block NK300PLUS	**0.0901**	**0.2856**
Masonry n. 1	**0.1159**	**0.3135**
Masonry n. 2	**0.1078**	**0.2927**
Masonry n. 3	**0.1026**	**0.3232**

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi

-------- End of the Test Report ------

TEST REPORT

SQM_654_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK300PLUS

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

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Ordering Kebe S.A.
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Data related to the sample examined Masonry unit
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Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23436/lab of 09/01/2023
Order confirmation email of 09/01/2023
Receipt of the samples -
Test execution September 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 09/22/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

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Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

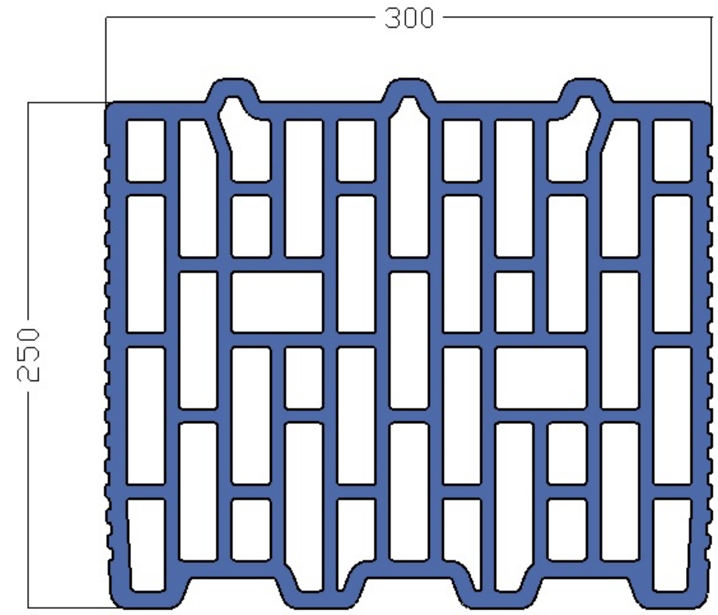
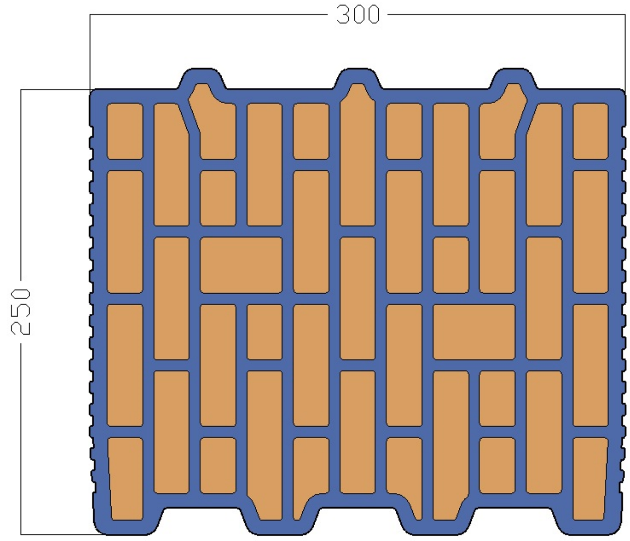


Table 1. Input data

Physical quantity	**Nominal value**	**Ref.**
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m^2K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m^2K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.401 W/mK	Provided by the Customer

All cavities are filled with NEOCOAT EPS 100 PLUS, whose conductivity is declared in the technical data sheet equal to 0.030 W/mK (Figure 2).

Figure 2. Cross section of the block



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m^2K]	**Total thermal resistance** R_T [m^2K/W]	**True thermal resistance of the masonry unit** R_t [m^2K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
1.3351	0.668	0.2670	3.7451	3.5751	0.0839

Figure 3. Distribution of isotherms in the block [°C]

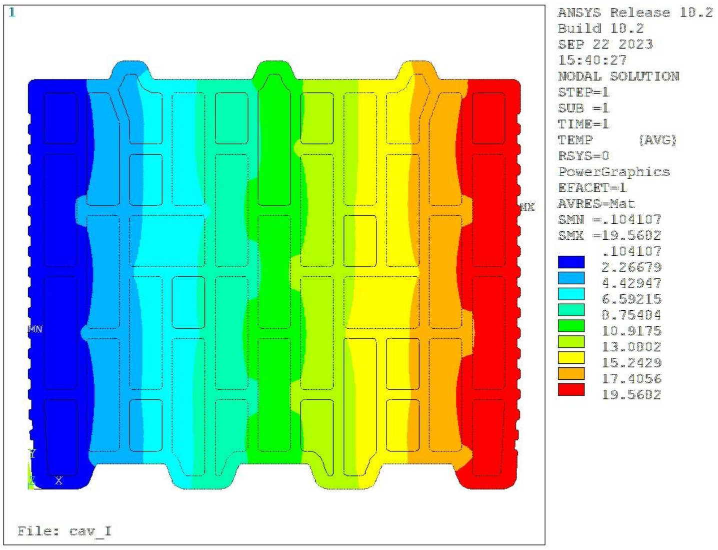
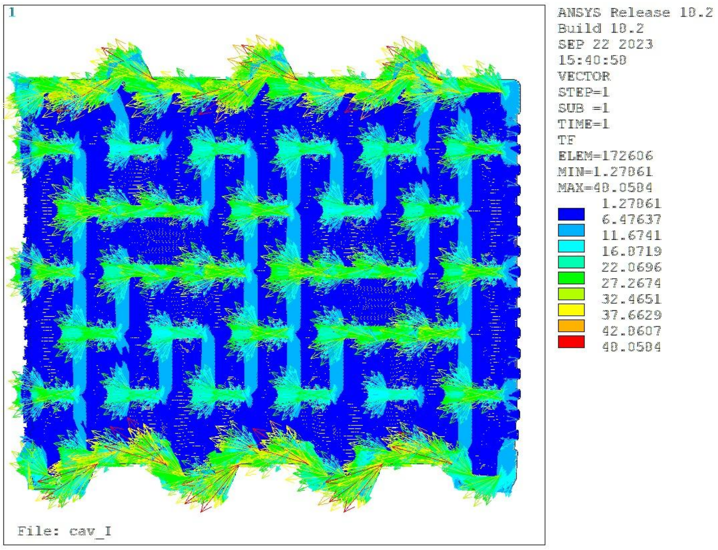


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

Because of the interlocking block geometry, only horizontal mortar joints were considered. For the evaluation of the thermal values of the masonry, three different configurations were studied. The input data for the definition of the configurations are indicated in table 3.

Table 3. Input data of the masonry

Masonry n. 1	**Nominal value**	**Ref.**
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	**Nominal value**	**Ref.**
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	**Nominal value**	**Ref.**
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Tables 4, 5 and 6 show the thermal values of the masonry, in the three configurations described above.

Table 4. Results of the calculation for the masonry no. 1

Physical quantity	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	3.3079
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1058
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	3.4779
Thermal transmittance **U** (W/m²K)	0.2875

Table 5. Results of the calculation for the masonry no. 2

Physical quantity	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	3.5954
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.0973
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	3.7654
Thermal transmittance **U** (W/m²K)	0.2656

Table 6. Results of the calculation for the masonry no. 3

Physical quantity	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	3.2045
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	00.0936
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m²K/W]	3.3745
Thermal transmittance **U** [W/m²K]	0.2963

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m²K]
block NK300PLUS	0.0839	0.2670
Masonry no. 1	0.1058	0.2875
Masonry no. 2	0.0973	0.2656
Masonry no. 3	0.0936	0.2963

6. List of distribution

ENEA	Archive	1 copy
Certimac	Archive	1 copy
Kebe S.A.	Archive	1 copy

In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

TEST REPORT

SQM_799_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK380

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the thermal design conductivity of the block and of masonry made with it

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Ordering Kebe S.A.
Product placed on the market from Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE
Data related to the sample examined Masonry unit
Sample origin sampled and provided from the Customer
Manufacturing plant Kebe S.A. - 61100 Nea Santa - Kilkis - GREECE

Estimate prot. 23545/lab of 10/18/2023
Order confirmation email of 10/18/2023
Receipt of the samples 10/18/2023
Test execution November 2023
Laboratory and location of test execution Certimac - via Ravegnana, 186 - Faenza (RA)

Report issued 11/24/2023
Revision n° 00

Test executed by: Eng. Mattia Morganti
Report drafted by: Eng. Mattia Morganti
Approval: Technical director Eng. L. Laghi

This test report is part of a file in PDF format digitally signed by Luca Laghi

Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of thermal design values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux. In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-a.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007)
b. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.
c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.
d. Test report SQM_798_2023, 11/24/2023 - Determination of the equivalent thermal conductivity of the block NK380 and of masonry made with it.

3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1-2.

Figure 1. Geometry of the block

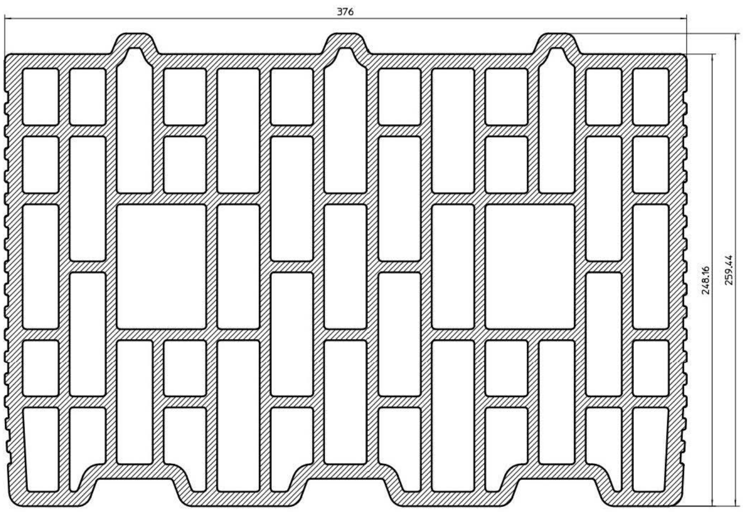

Table 1. Input data

Physical quantity	Nominal value	Ref.
Material thermal conductivity $\lambda_{10,dry,mat}$	0.373 W/mK	Provided by the Customer
Equivalent thermal conductivity of voids	Test Report NK380	Ref. 2-d

Table 2. Input data of the masonry

Masonry n. 1	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer

Masonry n. 2	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 30 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 3	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Not present	Provided by the Customer
External plaster	Not present	Provided by the Customer

Masonry n. 4	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 31 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 5	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 32 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

Masonry n. 6	Nominal value	Ref.
Horizontal mortar joints	Thickness = 3 mm λ_{mortar} = 0.87 W/mK	Provided by the Customer
Internal plaster	Thickness = 25 mm λ_{mortar} = 1.0 W/mK	Provided by the Customer
External plaster	Thickness = 33 mm λ_{mortar} = 0.08 W/mK	Provided by the Customer

4. Determination of the thermal design values

Thermal design values of the masonry are determined as defined by the standards at Ref. 2-a and 2-c, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (moisture content volume by volume):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)}$$

The standard sets as operating conditions a temperature of 23 ° C and a relative humidity of 80% (precautionary hypothesis), which is related to the test condition at 10 ° C, dry.

4. Results

Table 3 shows the results of the Finite Elements Analysis performed with design thermal values at Ref. 2-a.

Table 3. FEM results

Heat flow [W/m]	**Thermal coupling coefficient** L^{2D} [W/mK]	**Thermal transmittance** **U** [W/m²K]	**Total thermal resistance** R_T [m²K/W]	**True thermal resistance of the masonry unit** R_t [m²K/W]	**Equivalent thermal conductivity** $\lambda_{10,dry,unit}$ [W/mK]
2.1485	0.1074	0.4329	2.3101	2.1401	0.1757

5. Determination of thermal values of the masonry

Table 4 shows the thermal values of the masonry, in the six configurations described above.

Table 4. Results of the calculation for the masonry

Masonry n. 1	**Result**
Thermal resistance only of the layer R_t [m²K/W]	2.0654
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.2063
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	2.2354
Thermal transmittance **U** (W/m²K)	0.4473

Masonry n. 2	**Result**
Thermal resistance only of the layer R_t [m²K/W]	2.3423
Equivalent thermal conductivity of the masonry λ_{equ} [W/mK]	0.1840
Thermal resistance of the masonry including superficial thermal resistances R_T (m²K/W)	2.5123
Thermal transmittance **U** (W/m²K)	0.3980

Masonry n. 3	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	2.0088
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda}_{\mathbf{equ}}$ [W/mK]	0.1872
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^2K/W)	2.1788
Thermal transmittance **U** (W/m^2K)	0.4590

Masonry n. 4	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	2.3524
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda}_{\mathbf{equ}}$ [W/mK]	0.1836
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^2K/W)	2.5224
Thermal transmittance **U** (W/m^2K)	0.3964

Masonry n. 5	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	2.3626
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda}_{\mathbf{equ}}$ [W/mK]	0.1833
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^2K/W)	2.5326
Thermal transmittance **U** (W/m^2K)	0.3949

Masonry n. 6	**Result**
Thermal resistance only of the layer $\mathbf{R_t}$ [m^2K/W]	2.3727
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda}_{\mathbf{equ}}$ [W/mK]	0.1829
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m^2K/W)	2.5427
Thermal transmittance **U** (W/m^2K)	0.3933

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Thermal design conductivity λ_{equ} [W/mK]	Thermal design transmittance U [W/m²K]
block NK380	0.1757	0.4329
Masonry n. 1	0.2063	0.4473
Masonry n. 2	0.1840	0.3980
Masonry n. 3	0.1872	0.4590
Masonry n. 4	0.1836	0.3964
Masonry n. 5	0.1833	0.3949
Masonry n. 6	0.1829	0.3933

6. List of distribution

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In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

TEST REPORT

SQM_798_2023

CUSTOMER

Kebe S.A.

PRODUCT NAME

NK380

TYPE OF PRODUCT

Masonry unit

TYPE OF TEST

Determination of the equivalent thermal conductivity of the block and of masonry made with it

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Chief Technical Officer
(Eng. Luca Laghi)

1. Object of the test

The following test report describes the determination of the equivalent thermal values of a masonry brick. The calculations were performed by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-b), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux.

2. Reference standards and documents

The tests have been executed according to the methods defined in the following documentations and reference standards:

a. EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.
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3. Input data

The technical drawing of the block and the thermal conductivity of fired clay were supplied by the client (Figure 1). All input data used for the calculation are shown in Table 1.

Figure 1. Geometry of the block

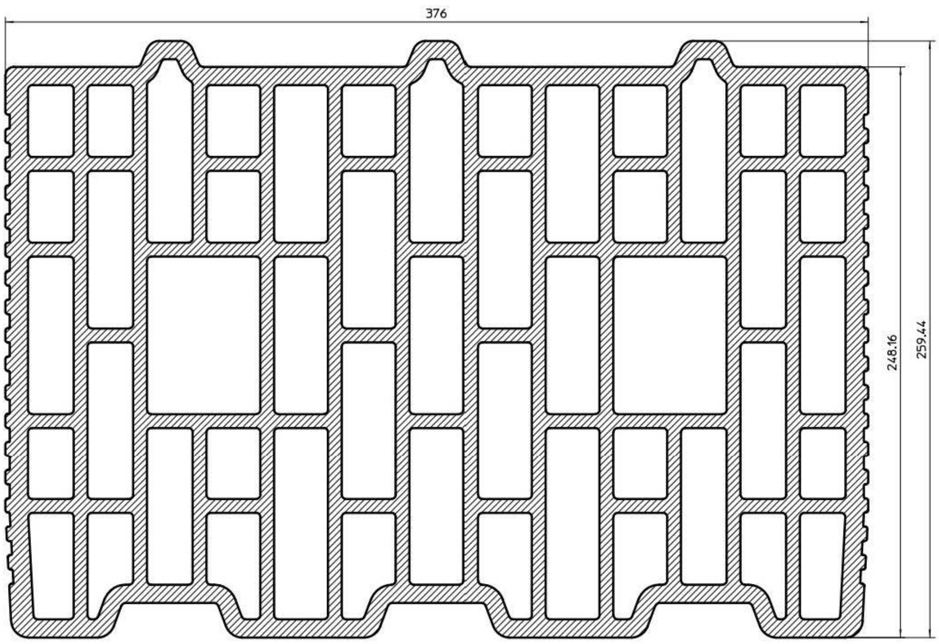
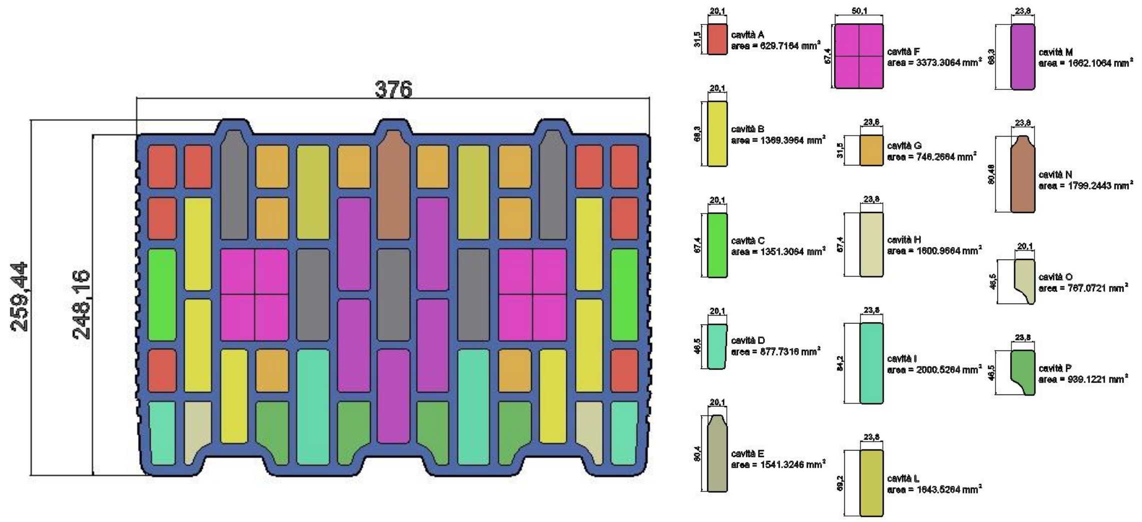


Table 1. Input data

Physical quantity	Nominal value	Ref.
Internal temperature Ti	20 °C = 293.15 K	Ref. 2-a and 2-c
External temperature Te	0 °C = 273.15 K	Ref. 2-a and 2-c
Internal superficial resistance Rsi	0.13 m²K/W	Ref. 2-a and 2-c
External superficial resistance Rse	0.04 m²K/W	Ref. 2-a and 2-c
Material thermal conductivity $\lambda_{10,dry,mat}$	0.373 W/mK	Provided by the Customer

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-a and 2-f., approximating convective and radiative heat transfer inside the void (Figure 2).

Figure 2. Cross section of the block and air voids data



4. Results

Table 2 shows the results of the Finite Elements Analysis; Figures 3 and 4 graphically show the distribution of the isotherms and the vector state of the heat flow.

Table 2. FEM results

Heat flow [W/m]	Thermal coupling coefficient L^{2D} [W/mK]	Thermal transmittance U [W/m²K]	Total thermal resistance R_T [m²K/W]	True thermal resistance of the masonry unit R_t [m²K/W]	Equivalent thermal conductivity $\lambda_{10,dry,unit}$ [W/mK]
2,0619	0.1031	0.4154	2.4071	2.2371	0.1681

Figure 3. Distribution of isotherms in the block [°C]

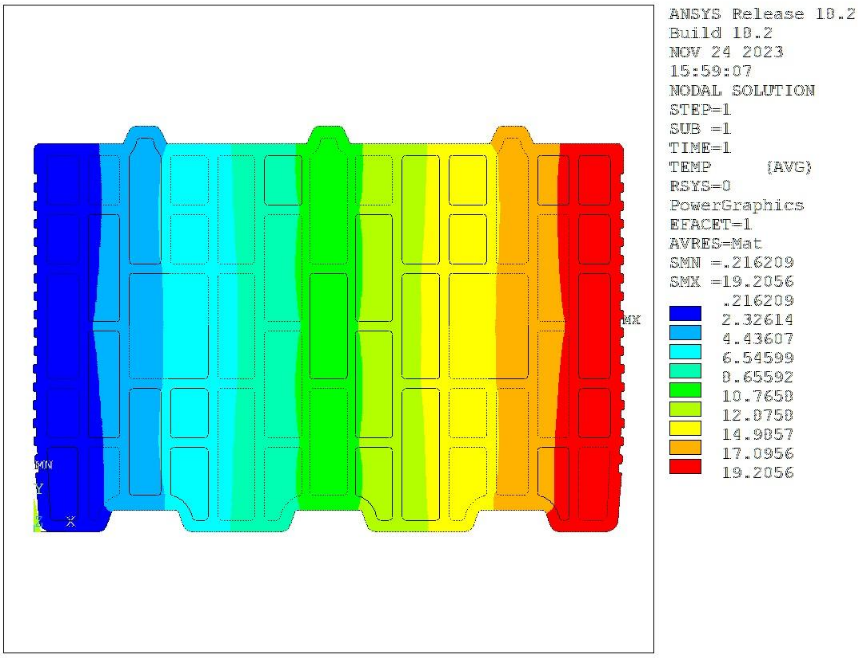
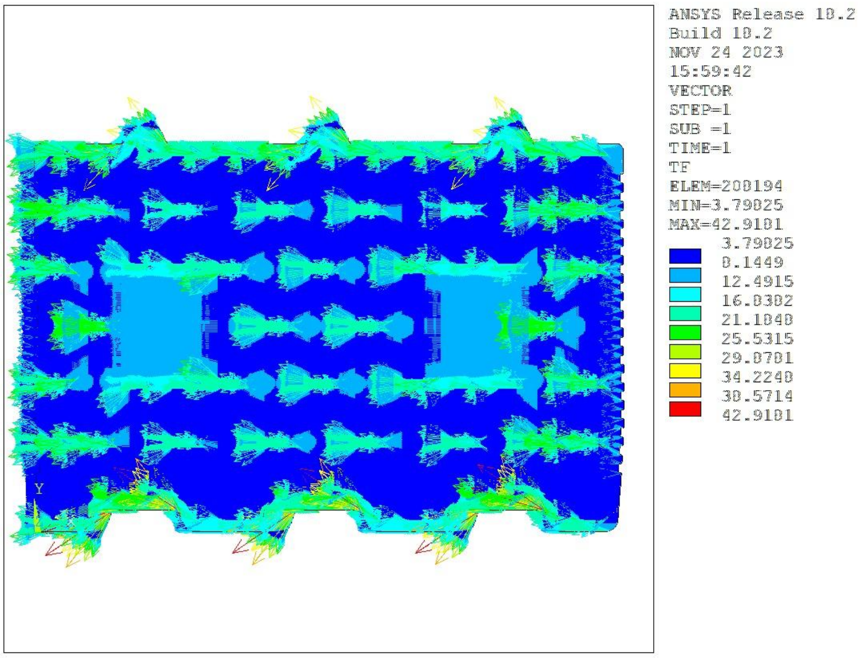


Figure 4. Average heat flow vectors [W/m^2]



5. Determination of thermal values of the masonry

In order to evaluate the thermal values of the masonry, only horizontal mortar joints were considered, without plaster layers. Because of the interlocking block geometry, the vertical joint was not considered. For the evaluation of the thermal values of the masonry, two different configurations were studied:

- 3 mm thick horizontal joints,
- no horizontal joints.

Table 3 shows the input data used for the masonry calculations.

Table 3. Input data for masonry calculations

Material	Dimensions [mm]	Thermal conductivity [W/mK]
Masonry unit	376 x 248.16 x 240	0.1681
Horizontal traditional mortar joints	Thickness = 3 – 0	0.900

Tables 4 and 5 show the thermal values of the masonry, in the two configurations described above.

Table 4. Results of the calculation for the masonry with 3 mm thick horizontal joints

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.1230
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1771
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ (m²K/W)	2.2930
Thermal transmittance **U** (W/m²K)	0.4361

Table 5. Results of the calculation for the masonry without mortar joints

Physical quantity	Result
Thermal resistance only of the layer $\mathbf{R_t}$ [m²K/W]	2.2371
Equivalent thermal conductivity of the masonry $\boldsymbol{\lambda_{equ}}$ [W/mK]	0.1681
Thermal resistance of the masonry including superficial thermal resistances $\mathbf{R_T}$ [m²K/W]	2.4071
Thermal transmittance **U** [W/m²K]	0.4154

SUMMARY TABLE OF RESULTS

The tests previously described gave the following results:

Product	Equivalent thermal conductivity λ_{equ} [W/mK]	Thermal transmittance U [W/m^{2}K]
block NK380	0.1681	0.4154
Masonry with 3 mm thick horizontal joints	0.1771	0.4361
Masonry without mortar joints	0.1681	0.4154

6. List of distribution

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In charged of technical test execution	In charged of technical report drafting	Technical director Approval
Eng. Mattia Morganti	Eng. Mattia Morganti	Ing. Luca Laghi
[signature]	[signature]	[signature]

-------- End of the Test Report ------

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TEST REPORT

|SQM_470_2022|

NUMERICAL EVALUATION OF THE THERMAL DESIGN VALUE OF A PRODUCT NAMED “ORTHOBLOCK MK 200” AND OF THREE TYPES OF MASONRY COMPOSED OF IT, PRODUCED BY “KEBE S.A.”, KILKIS (GREECE).

PLACE AND DATE OF ISSUE:	Faenza, 28th October 2022
COMPANY:	**Kebe S.A.**
ADDRESS:	Nea Santa – 61100 Kilkis, Greece
TYPE OF PRODUCT:	*Extruded Masonry Units*
STANDARD APPLIED:	EN ISO 6946, EN ISO 10456
DATE OF RECEIPT IN LABORATORY:	-
TESTS EXECUTED:	October 2022
TESTS EXECUTED BY:	CertiMaC, Faenza

NOTE: Results contained in the present test report are exclusively referred to the samples subjected to the tests described hereafter. Moreover, this report is for the exclusive use of the Customer, within the limits set by mandatory legislation and cannot be reproduced, totally or partially (in digital or paper form), without a written approval of the Laboratory.

Test executed	Written	Approved
Eng. Mattia Morganti	_Eng. Mattia Morganti_	_Eng. Luca Laghi_
Revision – 00 –		Page 1 of 7

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1 Introduction

This Test Report describes the numerical evaluation of thermal design values of a fired clay brick requested to CertiMaC Laboratory in Faenza by the Customer "Kebe S.A.", Kilkis, Greece (Ref. 2-a, 2-b).

Thermal design values were determined from what was measured in the document at Ref. 2-e and applying the instructions given in the standards at Ref. 2-c and 2-d.

2 References

a. Estimate: Reference Number 22389/lab dated 29th July 2022.

b. Order Confirmation: Mail dated 02nd August 2022.

c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

d. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007).

e. Test report SQM_243_2019 – 23rd July 2019: Determination of the equivalent thermal conductivity $\lambda_{10,dry,unit}$ of a product named "Orthoblock MK200" and of a masonry composed of it, produced by "Kebe S.A.", Kilkis (Greece).

f. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.

3 Description of calculation model of the design value of the masonry unit

The calculation model to determine the design value is the same used in the test report in Ref. 2-e: a Finite Element Model implemented in Ansys 18.2 (Ref. 2-f), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux (Figure 1). In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-d.

In addition to the block, the thermal design parameters were also calculated on three types of masonry, considering horizontal mortar joints and plasters and a configuration without any external/internal plaster.

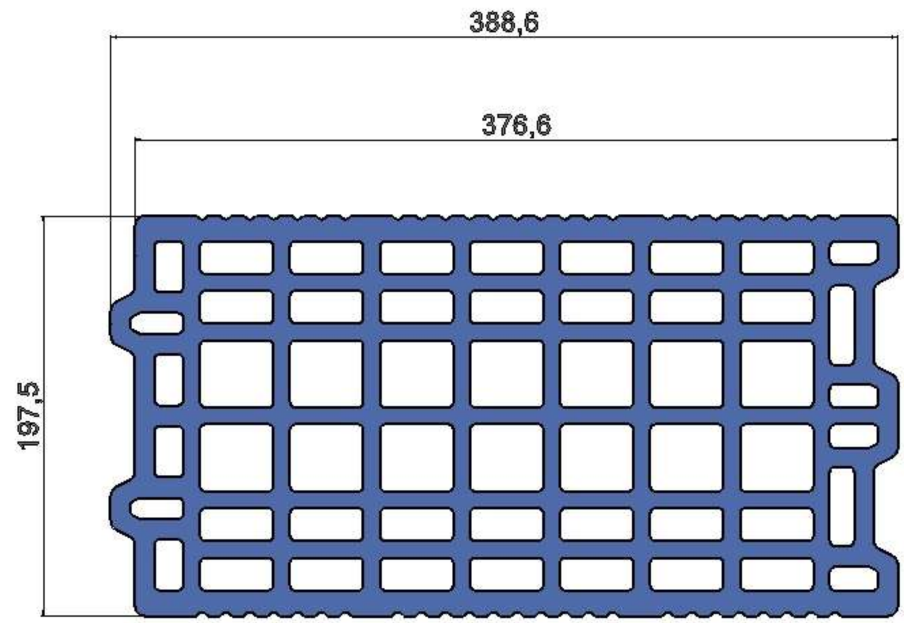

Figure 1. Geometry of the cross section employed for the calculation

4 Input data

The input data of the unit are taken from the test report at Ref. 2-e, while the masonry parameters are provided by the Client. Table 1 shows all the input data.

Input data (masonry unit)	
Physical quantity	**Nominal value**
Thermal conductivity of the fired clay	$\lambda_{10,dry,mat}$ **= 0.376 W/mK**
Equivalent thermal conductivity of voids	**See Test Report at Ref. 2-e**

Input data (masonry n. 1)	
Physical quantity	**Nominal value**
Horizontal mortar joints	Thickness = **3 mm** λ_{mortar} **= 0.87 W/mK**
Internal plaster	Thickness = **25 mm** λ_{mortar} **= 1.0 W/mK**
External plaster	Thickness = **25 mm** λ_{mortar} **= 1.0 W/mK**

Input data (masonry n. 2)	
Physical quantity	**Nominal value**
Horizontal mortar joints	Thickness = **3 mm** **λ_{mortar} = 0.87 W/mK**
Internal plaster	Thickness = **25 mm** **λ_{mortar} = 1.0 W/mK**
External plaster	Thickness = **30 mm** **λ_{mortar} = 0.08 W/mK**

Table 1. Input data

5 Determination of the Design Thermal Values

Thermal design values of the masonry are determined as defined by the standard of Ref. 2-d in accordance with the 2-c standard, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (1):

$$F_m = e^{f_\psi(\psi_2 - \psi_1)} \quad (1)$$

(for moisture content volume by volume). The standard sets as operating conditions a temperature of 23 ° C and a relative humidity of 80% (precautionary hypothesis), which is related (1) to the test condition at 10 ° C, dry. This translates into an increase in the thermal conductivities of masonry units, mortar joints and internal/external plasters (Table 2):

Design Conditions - Thermal Conductivity corrective Factors		
Element	**F_m conversion factor (m^3/ m^3)**	**Design Thermal Conductivity λ_U (W/mK)**
Masonry unit (fired clay)	**1.127**	**0.424**
Horizontal mortar joints	**1.271**	**1.106**
Internal plaster	**1.271**	**1.271**
External plaster (Masonry n. 1)	**1.271**	**1.271**
External plaster (Masonry n. 2)	**1.271**	**0.102**

Table 2. Moisture Conversion Factors for calculation under design conditions

5.1 Calculation results on the masonry unit

The determination of equivalent thermal conductivity of the masonry unit, performed with design thermal values reported in Table 2, gave the following results, determined through Ansys output, which is heat flow (W/m) (Table 3).

RESULTS OF FEM CALCULATION					
Heat Flow (W/m)	**Thermal coupling coefficient (W/mK)**	**Thermal Transmittance (W/m²K)**	**Total Thermal Resistance (m²K/W)**	**True Thermal Resistance of the masonry unit (m²K/W)**	**Equivalent thermal conductivity (W/mK)**
Φ	$L^{2D}=\Phi/\Delta T$	$U= L^{2D}/w$	$R_T=1/U$	$R_t=R_T-R_{si}-R_{se}$	$\lambda_{10,dry,unit}=d/R_t$
6.7957	0.3398	0.9022	1.1083	0.9383	**0.2105**

Table 3. Results

5.2 Calculation scenarios

Table 4 summarizes the conditions of the three different configurations:

Calculation scenarios		
Configuration	**Element**	**Design Thermal Conductivity λ_U (W/mK)**
Masonry n. 1	Masonry Unit	**0.2105** (see Table 3)
	Horizontal Joints (3 mm)	**1.106**
	Vertical Joints	**Not present**
	Internal Plaster (25 mm)	**1.271**
	External Plaster (25 mm)	**1.271**
Masonry n. 2	Masonry Unit	**0.2105** (see Table 3)
	Horizontal Joints (3 mm)	**1.106**
	Vertical Joints	**Not present**
	Internal Plaster (25 mm)	**1.271**
	External Plaster (25 mm)	**0.102**
Masonry n. 3	Masonry Unit	**0.2105** (see Table 3)
	Horizontal Joints (3 mm)	**1.106**
	Vertical Joints	**Not present**
	Internal Plaster (25 mm)	**Not present**
	External Plaster (25 mm)	**Not present**

Table 4. Calculation scenarios

5.3 Calculation results on the three types of masonry

The thermal design values of the masonry are reported below (Table 5 and Table 6):

Results for Masonry n. 1	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**0.9333**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2652**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.1033**
Thermal transmittance **U** (W/m^2K)	**0.9064**

Table 5. Results of the calculation for the masonry n. 1

Results for Masonry n. 2	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**1.2097**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2087**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.3797**
Thermal transmittance **U** (W/m^2K)	**0.7248**

Table 6. Results of the calculation for the masonry n. 2

Results for Masonry n. 3	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**0.8801**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2244**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.0501**
Thermal transmittance **U** (W/m^2K)	**0.9523**

Table 7. Results of the calculation for the masonry n. 3

6 Conclusions

On the basis of performed calculations, the product named "Orthoblock MK200" provided an equivalent design conductivity value of **0.2105 W/mK**. Calculations performed on the three types of masonry gave the results reported in Table 5 - Table 7.

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TEST REPORT

|SQM_243_2019|

DETERMINATION OF THE EQUIVALENT THERMAL CONDUCTIVITY $\lambda_{10,dry,unit}$ OF A PRODUCT NAMED "ORTHOBLOCK MK 200" AND OF A MASONRY COMPOSED OF IT, PRODUCED BY "KEBE S.A.", KILKIS (GREECE).

PLACE AND DATE OF ISSUE:	Faenza, 23 July 2019
COMPANY:	**Kebe S.A.**
ADDRESS:	Nea Santa – 61100 Kilkis, Greece
TYPE OF PRODUCT:	*Extruded Masonry Units*
STANDARD APPLIED:	UNI EN 1745, UNI EN ISO 6946
DATE OF RECEIPT IN LABORATORY:	17 June 2019
TESTS EXECUTED:	July 2019
TESTS EXECUTED BY:	CertiMaC, Faenza

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Test executed	Written	Approved
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Revision -		Page 1 of 11

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1 Introduction

This Test Report describes the determination of thermal design values of the product "Orthoblock MK 200" requested to CertiMaC Laboratory in Faenza by the Customer "Kebe S.A.", Kilkis, Greece (Ref. 2-a, 2-b). Figure 1 reports a unit sent by the Customer.

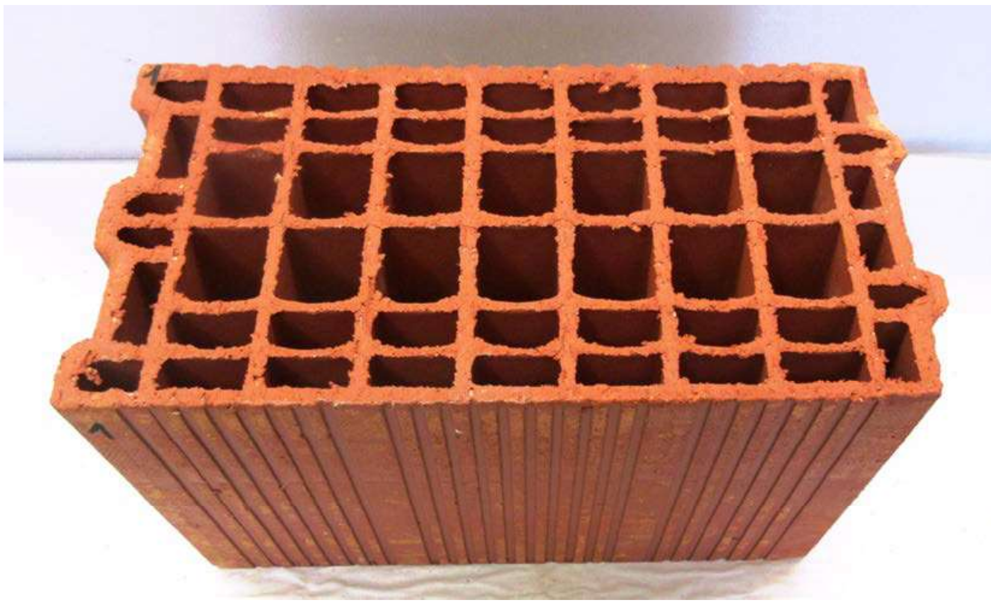


Figure 1. Example of the product

Thermal values for the type of product here described have been determined using the calculation methodology defined in Ref. 2-c, starting from the thermal conductivity and density values of the material determined experimentally (Ref. 2-d). The calculations were performed considering the thermal flow perpendicular to the longitudinal dimension of the block.

2 References

a. Estimate: Reference Number 19176/lab dated 20 June 2019.

b. Order Confirmation: Mail dated 17 July 2019.

c. UNI EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.

d. Test report SQM_241_2019 – 23 July 2019: Experimental determination of thermal conductivity and Test report SQM_242_2019 Determination of the $\lambda_{10,dry,mat}$ of a product named "Orthoblock MK 200", produced by "Kebe S.A.", Kilkis (Greece).

e. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.

f. UNI EN 772-13:2002. Methods of test for masonry units - Determination of net and gross dry density of masonry units (except for natural stone).

g. UNI EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3 Description of calculation model of the equivalent conductivity of the masonry unit

The equivalent thermal conductivity of the masonry unit $\lambda_{10,dry,unit}$ have been determined according to Ref. 2-c, by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-e), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux (Figure 2).

4 Input data for the determination of the equivalent thermal conductivity of the unit

4.1 Geometry

In the absence of a reference drawing to obtain geometrical data to use for the implementation of the Finite Element Model, the following procedure was applied:

- Determination of the dimensions of the units sent to the Laboratory (Ref. 2-f) in order to determine the average dimensions typical of the examined product;
- Grinding of the masonry unit presenting the closest dimensions to the average values in order to even the surface. Grinding is necessary to remove burrs resulting from cutting during the extrusion procedure;
- Scanner acquisition of the cross section of the unit and conversion of the image in .jpg format. The geometry chosen to represent the product and to be used for the implementation of the calculation was rectified in order to respect the symmetry of the product resulting from the extrusion process.
- Measurement of the dimensions of voids (shape and interaxis) and of external profiles on the basis of average dimensions determined on the sampling set. Measures were performed using a centesimal caliper.
- Definition, based on aforementioned values, of average geometric dimensions of the product type to employ in the calculation (Figure 2).

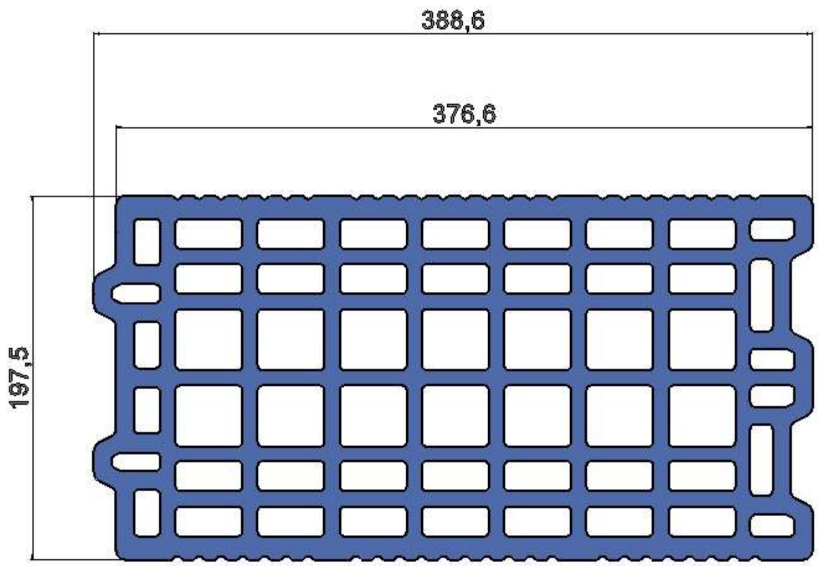


Figure 2. Geometry of the cross section employed for the calculation

4.2 Thermal conductivity of fired clay

Thermal conductivity $\lambda_{10,dry,mat}$ of fired clay was measured experimentally and then the value corresponding to the average density was determined, as described in Ref. 2-d. Hence, based on such elaborations, the following value was used to represent fired clay:

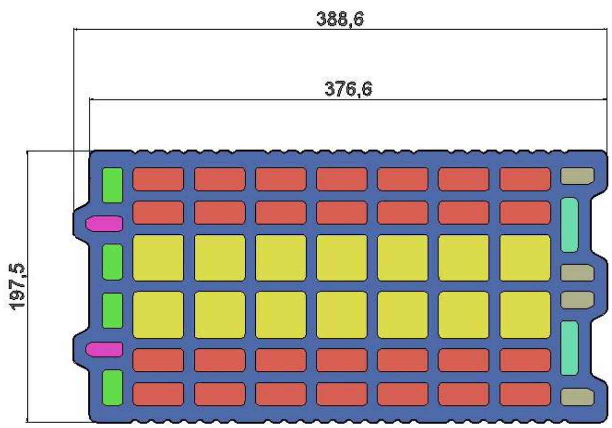
$$\lambda_{10,dry,mat} = \mathbf{0.376\ [W/mK]}$$

4.3 Equivalent thermal conductivity of voids

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-c and reported in Appendix B of Ref. 2-g, approximating convective and radiative heat transfer inside the void.

The calculation was performed for the only installation mode possible for this product, i.e. with holes axis in vertical position and with the longest sides exposed on the inside and on the outside of the masonry. Air conductivity within voids was referred to 10 °C.

All data related to voids are shown in Figure 3.



Voids	λ_{voids} (W/mk)
A	0,085
B	0,150
C	0,108
D	0,063
E	0,153
F	0,068

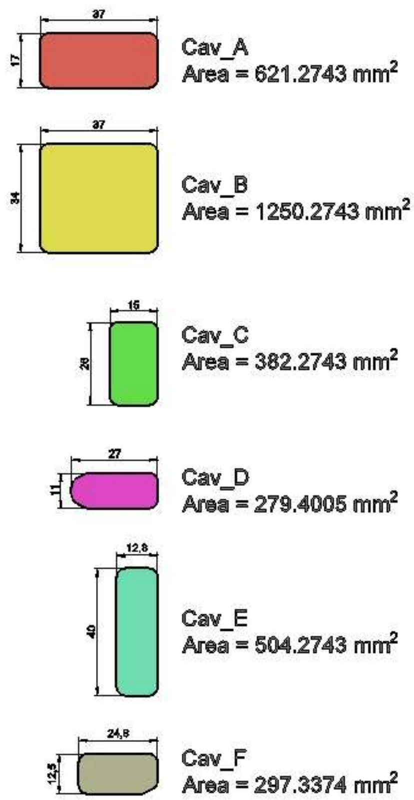


Figure 3. Cross section of the block and air voids data

4.4 Boundary conditions

Ref. 2-c sets boundary conditions for the definition of the model. In particular, it refers to internal and external temperatures and to internal and external superficial thermal resistances. These latter refer to convection and radiation phenomena occurring on the surfaces of the masonry unit and are evaluated in par. 5.2 of Ref. 2-g as follows:

BOUNDARY conditions	
Physical quantity	**Nominal value**
Internal temperature T_i	**20 °C = 293.15 K**
External temperature T_e	**0°C = 273.15 K**
Internal superficial resistance R_{si}	**0.13 m²K/W**
External superficial resistance R_{se}	**0.04 m²K/W**

Table 1. Applied boundary conditions

Boundary conditions were applied considering the longest sides exposed to internal and external environments.

4.5 Type of element and mesh

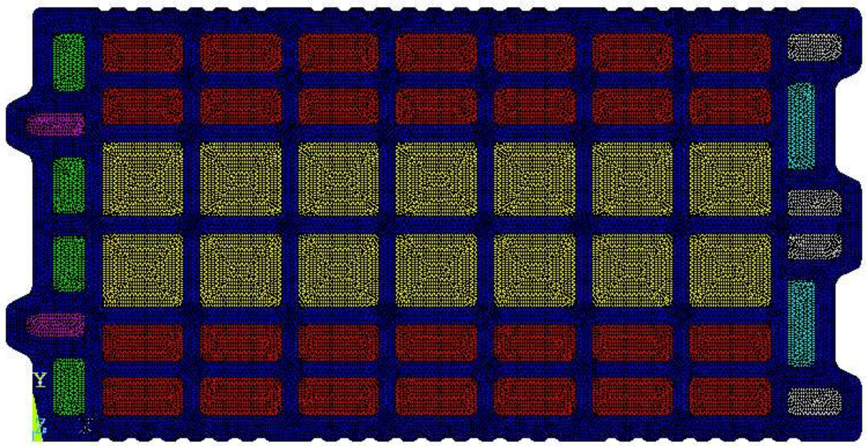


Figure 4. Meshed block

Considering the geometry of the block, the evaluation of its equivalent thermal conductivity by means of FEM was performed using triangular planar elements (plane 55 elements in Ansys 18.2). Mesh refinement (dimensions and distribution of elements) was defined, through the developed method of calculation certification, according to specifications regarding results accuracy reported in Ref. 2-c. Mesh discretization was performed with Ansys 18.2 (Ref. 2-e).

In order to guarantee an accuracy significantly lower than 2%, as required in Ref. 2-c a mesh for the masonry unit model was considered, according to specifications of Ref. 2-d, composed of 172474 elements and 86947 nodes (1 mm long edges on average) (Figure 4).

4.6 Results

The determination of equivalent thermal conductivity of the masonry unit $\lambda_{10,dry,unit}$, performed with thermal conductivity values of the fired clay $\lambda_{10,dry,mat}$ reported in par. 4.2, gave the following results, determined through Ansys output, which is heat flow (W/m) (Table 2).

RESULTS OF FEM CALCULATION					
Heat Flow (W/m)	**Thermal coupling coefficient (W/mK)**	**Thermal Transmittance (W/m²K)**	**Total Thermal Resistance (m²K/W)**	**True Thermal Resistance of the masonry unit (m²K/W)**	**Equivalent thermal conductivity (W/mK)**
Φ	$L^{2D}=\Phi/\Delta T$	$U= L^{2D}/w$	$R_T=1/U$	$R_t=R_T-R_{si}-R_{se}$	$\lambda_{10,dry,unit}=d/R_t$
6.42751	0.3214	0.8534	1.1718	1.0018	**0.1971**

Table 2. Results

Considering the installation of the units described, in the cross sections of the brick perpendicular to the direction of the thermal flow (1 unit thickness), the value of thermal flux resulting from the finite element model is Φ = 6.42751 W/m.

The entire series of calculations leading to the determination of equivalent conductivity is reported in Table 2. Dividing the heat flow that passes through aforementioned cross sections by the difference in temperature across the masonry (ΔT = 20°C), the thermal coupling coefficient is determined. In turn, dividing this coefficient by the masonry unit length leads to the determination of thermal resistance. Its inverse is the total thermal resistance, which, freed from the contribution of superficial resistances, gives the true thermal resistance of the masonry without convection and radiation. Considering the thickness (Figure 2), the equivalent dry thermal conductivity of the masonry unit can be determined $\lambda_{10,dry,unit}$ = 0.1971 W/mK (Table 2). A comparison between the thermal conductivity of the masonry unit with the one of the fired clay of which it is composed, reported in par. 4.2, it follows that the adopted layout allows reducing the equivalent conductivity of the masonry unit of 47.6%.

Obtained results are reported below, regarding the distribution of isotherms and of average heat flow vectors (Figure 5 and Figure 6).

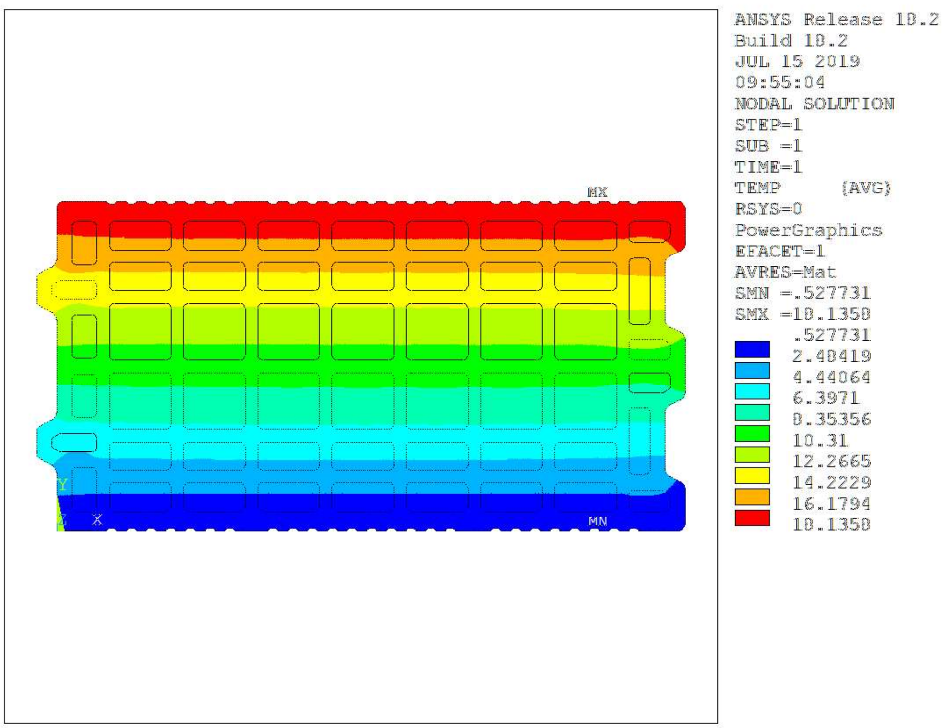


Figure 5. Distribution of isotherms in the block [°C]

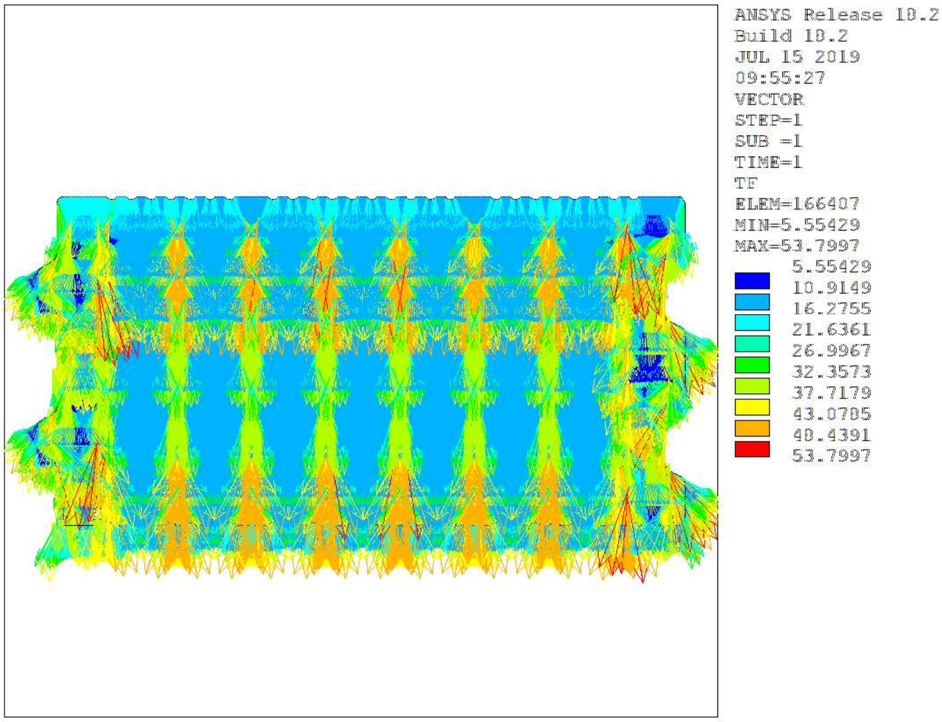


Figure 6. Average heat flow vectors [W/m²]

The calculation outlines an actual improvement of thermal characteristics of the block compared to the constituting material.

5 Determination of thermal values of the masonry

In order to evaluate the thermal values of the masonry, only horizontal mortar joints were considered, without plaster layers. Because of the interlocking block geometry, the vertical joint was not considered. For the evaluation of the thermal values of the masonry, three different configurations were studied:

- 12 mm thick horizontal joints,
- 3 mm thick horizontal joints,
- no horizontal joints.

In all configurations, a traditional mortar with thermal conductivity of 0.9 W/mK was considered.

The masonry was considered as presented in Figure 7.

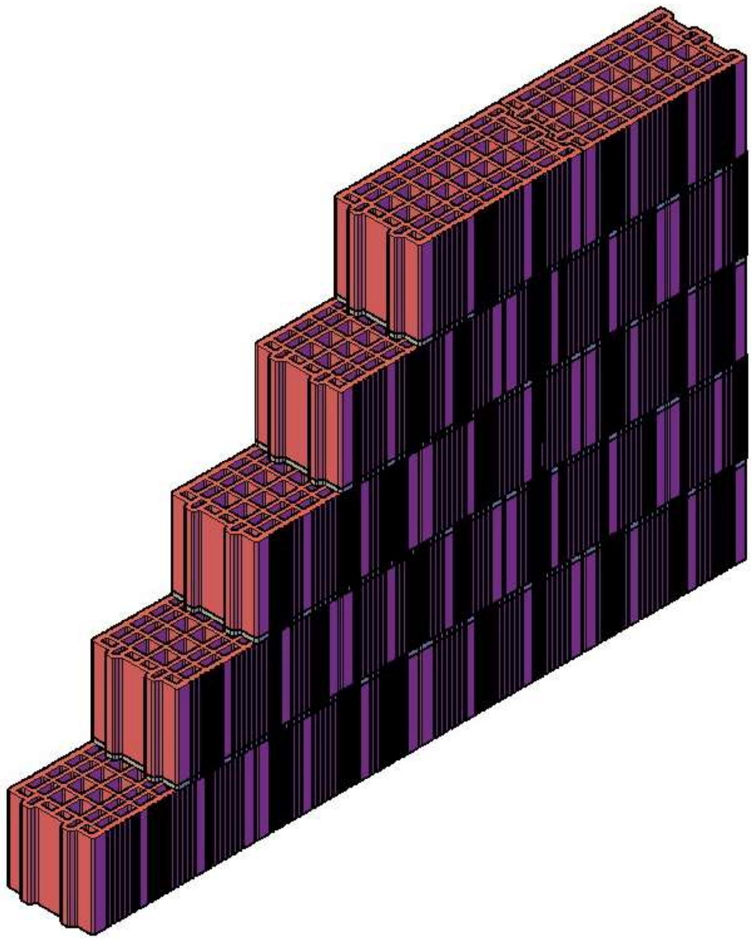


Figure 7. 3D composite masonry considered in the calculation

5.1 Input data

Based on the results of previous paragraphs, a calculation was performed starting from input data about the masonry:

Input data		
	Dimensions (mm)	**Thermal conductivity (W/mK)**
Masonry unit	**376.6 x 197.5 x 190**	**0.1971**
Horizontal traditional mortar joints	Thickness = **12 – 3 – 0**	**0.900**

Table 3. Input data for the calculation

5.2 Results of the calculation

the thermal values of the masonry, in the three configurations described above, are shown below.

a) Traditional configuration: (12 mm thick horizontal joints)

Results for the traditional configuration	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**0.8269**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2389**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**0.9969**
Thermal transmittance **U** (W/m^2K)	**1.0032**

Table 4. Results of the calculation for the masonry with 12 mm thick horizontal joints

b) Thin bed mortar configuration (3 mm thick horizontal joints)

Results for the traditional configuration	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**0.9494**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2080**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.1194**
Thermal transmittance **U** (W/m^2K)	**0.8933**

Table 5. Results of the calculation for the masonry with 3 mm thick horizontal joints

c) No joints configuration

Results for the traditional configuration	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**1.0020**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.1971**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.1720**
Thermal transmittance **U** (W/m^2K)	**0.8532**

Table 6. Results of the calculation for the masonry without mortar joints

6 Conclusions

On the basis of performed calculations, an equivalent value of thermal conductivity for the masonry unite equal to **0.1971 W/mK** was obtained. Calculations performed on the masonry gave a transmittance value of **1.0032 W/m²K** using 12 mm thick horizontal joints, **0.8933 W/m²K** with 3 mm thick horizontal joints and **0.8532 W/m²K** without mortar joints.

7 Distribution list

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TEST REPORT

|SQM_471_2022|

NUMERICAL EVALUATION OF THE THERMAL DESIGN VALUE OF A PRODUCT NAMED "ORTHOBLOCK MK 250" AND OF THREE TYPES OF MASONRY COMPOSED OF IT, PRODUCED BY "KEBE S.A.", KILKIS (GREECE).

PLACE AND DATE OF ISSUE:	Faenza, 28th October 2022
COMPANY:	**Kebe S.A.**
ADDRESS:	Nea Santa – 61100 Kilkis, Greece
TYPE OF PRODUCT:	*Extruded Masonry Units*
STANDARD APPLIED:	EN ISO 6946, EN ISO 10456
DATE OF RECEIPT IN LABORATORY:	-
TESTS EXECUTED:	October 2022
TESTS EXECUTED BY:	CertiMaC, Faenza

Test executed	Written	Approved
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Shareholders ENEA Italian National Agency for New Technologies, Energy and Sustainable Economic Development | National Research Council of Italy

1 Introduction

This Test Report describes the numerical evaluation of thermal design values of a fired clay brick requested to CertiMaC Laboratory in Faenza by the Customer "Kebe S.A.", Kilkis, Greece (Ref. 2-a, 2-b).

Thermal design values were determined from what was measured in the document at Ref. 2-e and applying the instructions given in the standards at Ref. 2-c and 2-d.

2 References

a. Estimate: Reference Number 22389/lab dated 29th July 2022.

b. Order Confirmation: Mail dated 02nd August 2022.

c. EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

d. EN ISO 10456:2007. Building materials and products - Hygrothermal properties -Tabulated design values and procedures for determining declared and design thermal values (ISO 10456:2007).

e. Test report SQM_246_2019 – 23rd July 2019: Determination of the equivalent thermal conductivity $\lambda_{10,dry,unit}$ of a product named "Orthoblock MK250" and of a masonry composed of it, produced by "Kebe S.A.", Kilkis (Greece).

f. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.

3 Description of calculation model of the design value of the masonry unit

The calculation model to determine the design value is the same used in the test report in Ref. 2-e: a Finite Element Model implemented in Ansys 18.2 (Ref. 2-f), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux (Figure 1). In this calculation, the input data have been modified taking into account the effect of humidity as indicated by the technical standard in Ref. 2-d.

In addition to the block, the thermal design parameters were also calculated on three types of masonry, considering horizontal mortar joints and plasters and a configuration without any external/internal plaster.

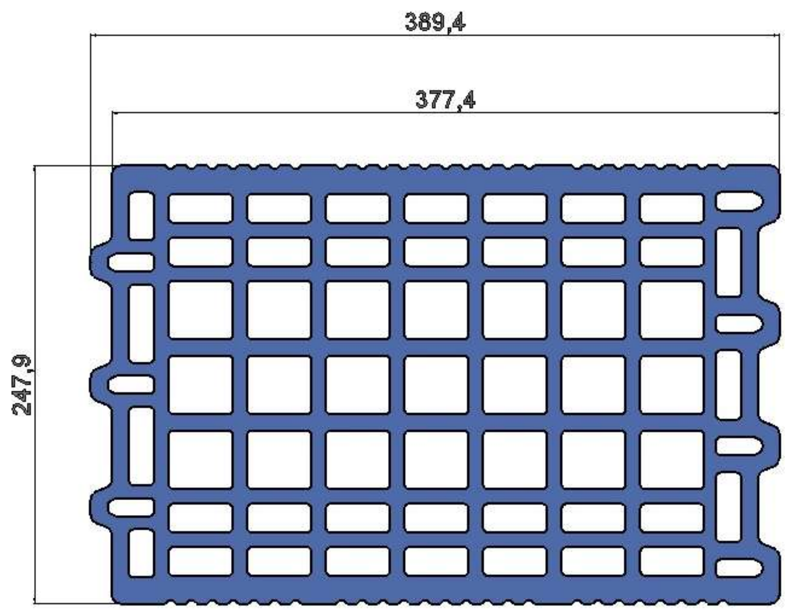

Figure 1. Geometry of the cross section employed for the calculation

4 Input data

The input data of the unit are taken from the test report at Ref. 2-e, while the masonry parameters are provided by the Client. Table 1 shows all the input data.

Input data (masonry unit)	
Physical quantity	**Nominal value**
Thermal conductivity of the fired clay	$\lambda_{10,dry,mat}$ **= 0.395 W/mK**
Equivalent thermal conductivity of voids	**See Test Report at Ref. 2-e**

Input data (masonry n. 1)	
Physical quantity	**Nominal value**
Horizontal mortar joints	Thickness = **3 mm** λ_{mortar} **= 0.87 W/mK**
Internal plaster	Thickness = **25 mm** λ_{mortar} **= 1.0 W/mK**
External plaster	Thickness = **25 mm** λ_{mortar} **= 1.0 W/mK**

Input data (masonry n. 2)	
Physical quantity	**Nominal value**
Horizontal mortar joints	Thickness = **3 mm** **λ_{mortar} = 0.87 W/mK**
Internal plaster	Thickness = **25 mm** **λ_{mortar} = 1.0 W/mK**
External plaster	Thickness = **30 mm** **λ_{mortar} = 0.08 W/mK**

Table 1. Input data

5 Determination of the Design Thermal Values

Thermal design values of the masonry are determined as defined by the standard of Ref. 2-d in accordance with the 2-c standard, increasing the thermal conductivity of the materials in relation to the moisture content, using the following conversion coefficient (1):

$$F_m = e^{f_\psi(\psi_2-\psi_1)} \quad (1)$$

(for moisture content volume by volume). The standard sets as operating conditions a temperature of 23 ° C and a relative humidity of 80% (precautionary hypothesis), which is related (1) to the test condition at 10 ° C, dry. This translates into an increase in the thermal conductivities of masonry units, mortar joints and internal/external plasters (Table 2):

Design Conditions - Thermal Conductivity corrective Factors		
Element	**F_m conversion factor (m^3/ m^3)**	**Design Thermal Conductivity λ_U (W/mK)**
Masonry unit (fired clay)	**1.127**	**0.445**
Horizontal mortar joints	**1.271**	**1.106**
Internal plaster	**1.271**	**1.271**
External plaster (Masonry n. 1)	**1.271**	**1.271**
External plaster (Masonry n. 2)	**1.271**	**0.102**

Table 2. Moisture Conversion Factors for calculation under design conditions

5.1 Calculation results on the masonry unit

The determination of equivalent thermal conductivity of the masonry unit, performed with design thermal values reported in Table 2, gave the following results, determined through Ansys output, which is heat flow (W/m) (Table 3).

RESULTS OF FEM CALCULATION					
Heat Flow (W/m)	**Thermal coupling coefficient (W/mK)**	**Thermal Transmittance (W/m²K)**	**Total Thermal Resistance (m²K/W)**	**True Thermal Resistance of the masonry unit (m²K/W)**	**Equivalent thermal conductivity (W/mK)**
Φ	$L^{2D}=\Phi/\Delta T$	$U= L^{2D}/w$	$R_T=1/U$	$R_t=R_T-R_{si}-R_{se}$	$\lambda_{10,dry,unit}=d/R_t$
5.8140	0.2907	0.7703	1.2982	1.1282	**0.2197**

Table 3. Results

5.2 Calculation scenarios

Table 4 summarizes the conditions of the three different configurations:

Calculation scenarios		
Configuration	**Element**	**Design Thermal Conductivity λ_U (W/mK)**
Masonry n. 1	Masonry Unit	**0.2197** (see Table 3)
	Horizontal Joints (3 mm)	**1.106**
	Vertical Joints	**Not present**
	Internal Plaster (25 mm)	**1.271**
	External Plaster (25 mm)	**1.271**
Masonry n. 2	Masonry Unit	**0.2197** (see Table 3)
	Horizontal Joints (3 mm)	**1.106**
	Vertical Joints	**Not present**
	Internal Plaster (25 mm)	**1.271**
	External Plaster (25 mm)	**0.102**
Masonry n. 3	Masonry Unit	**0.2197** (see Table 3)
	Horizontal Joints (3 mm)	**1.106**
	Vertical Joints	**Not present**
	Internal Plaster (25 mm)	**Not present**
	External Plaster (25 mm)	**Not present**

Table 4. Calculation scenarios

5.3 Calculation results on the three types of masonry

The thermal design values of the masonry are reported below (Table 5 and Table 6):

Results for Masonry n. 1	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**1.1143**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2673**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.2843**
Thermal transmittance **U** (W/m^2K)	**0.7786**

Table 5. Results of the calculation for the masonry n. 1

Results for Masonry n. 2	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**1.3907**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2178**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.5607**
Thermal transmittance **U** (W/m^2K)	**0.6407**

Table 6. Results of the calculation for the masonry n. 2

Results for Masonry n. 3	
Physical quantity	**Results**
Thermal resistance only of the layer **R_t** (m^2K/W)	**1.0617**
Equivalent thermal conductivity of the masonry **λ_{equ}** (W/mK)	**0.2335**
Thermal resistance of the masonry including superficial thermal resistances **R_T** (m^2K/W)	**1.2317**
Thermal transmittance **U** (W/m^2K)	**0.8119**

Table 7. Results of the calculation for the masonry n. 3

6 Conclusions

On the basis of performed calculations, the product named "Orthoblock MK250" provided an equivalent design conductivity value of **0.2197 W/mK**. Calculations performed on the three types of masonry gave the results reported in Table 5 - Table 7.

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TEST REPORT

|SQM_246_2019|

DETERMINATION OF THE EQUIVALENT THERMAL CONDUCTIVITY $\lambda_{10,dry,unit}$ OF A PRODUCT NAMED "ORTHOBLOCK MK 250" AND OF A MASONRY COMPOSED OF IT, PRODUCED BY "KEBE S.A.", KILKIS (GREECE).

PLACE AND DATE OF ISSUE:	Faenza, 23 July 2019
COMPANY:	**Kebe S.A.**
ADDRESS:	Nea Santa – 61100 Kilkis, Greece
TYPE OF PRODUCT:	*Extruded Masonry Units*
STANDARD APPLIED:	UNI EN 1745, UNI EN ISO 6946
DATE OF RECEIPT IN LABORATORY:	24 June 2019
TESTS EXECUTED:	July 2019
TESTS EXECUTED BY:	CertiMaC, Faenza

NOTE: Results contained in the present test report are exclusively referred to the samples subjected to the tests described hereafter. Moreover, this report is for the exclusive use of the Customer, within the limits set by mandatory legislation and cannot be reproduced, totally or partially (in digital or paper form), without a written approval of the Laboratory.

Test executed	**Written**	**Approved**
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Revision -		Page 1 of 11

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1 Introduction

This Test Report describes the determination of thermal design values of the product "Orthoblock MK 250" requested to CertiMaC Laboratory in Faenza by the Customer "Kebe S.A.", Kilkis, Greece (Ref. 2-a, 2-b). Figure 1 reports a unit sent by the Customer.

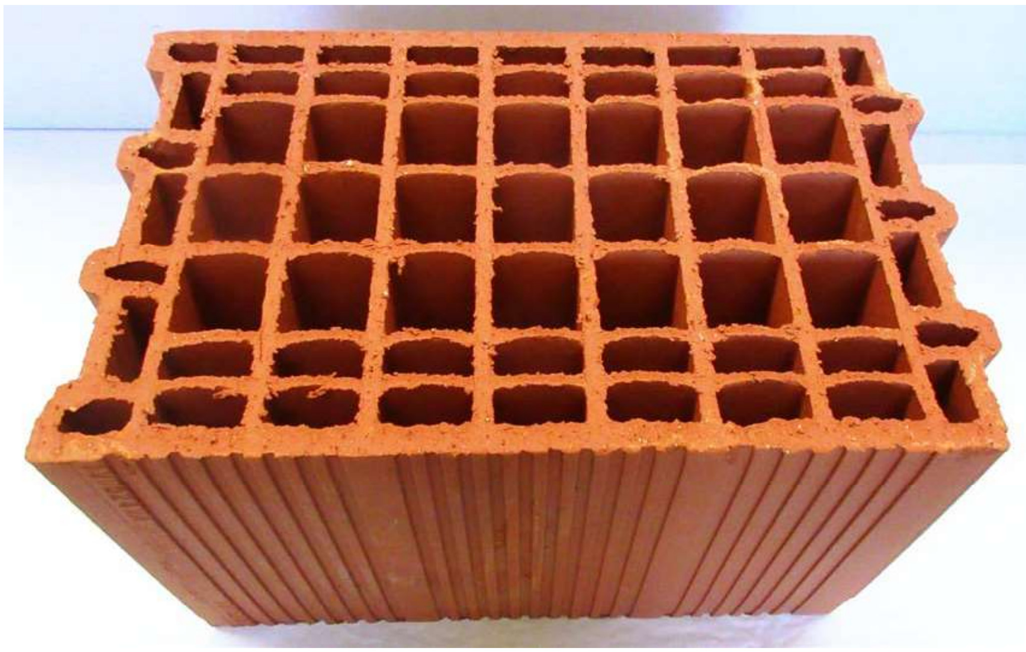


Figure 1. Example of the product

Thermal values for the type of product here described have been determined using the calculation methodology defined in Ref. 2-c, starting from the thermal conductivity and density values of the material determined experimentally (Ref. 2-d). The calculations were performed considering the thermal flow perpendicular to the longitudinal dimension of the block.

2 References

a. Estimate: Reference Number 19176/lab dated 20 June 2019.

b. Order Confirmation: Mail dated 17 July 2019.

c. UNI EN 1745:2012. Masonry and masonry products – Methods for determining thermal properties.

d. Test report SQM_244_2019 – 23 July 2019: Experimental determination of thermal conductivity and Test report SQM_245_2019 Determination of the $\lambda_{10,dry,mat}$ of a product named "Orthoblock MK 250", produced by "Kebe S.A.", Kilkis (Greece).

e. CertiMaC calibration report 040219-C-17/Rev01. Calibration of a two-dimensional model for the calculation of the equivalent thermal conductivity of a masonry unit.

f. UNI EN 772-13:2002. Methods of test for masonry units - Determination of net and gross dry density of masonry units (except for natural stone).

g. UNI EN 6946:2008. Building components and building elements – Thermal resistance and thermal transmittance – Calculation method.

3 Description of calculation model of the equivalent conductivity of the masonry unit

The equivalent thermal conductivity of the masonry unit $\lambda_{10,dry,unit}$ have been determined according to Ref. 2-c, by means of a Finite Element Model implemented in Ansys 18.2 (Ref. 2-e), applied to a planar cross section (unit length), perpendicular to the holes axis and parallel to the thermal flux (Figure 2).

4 Input data for the determination of the equivalent thermal conductivity of the unit

4.1 Geometry

In the absence of a reference drawing to obtain geometrical data to use for the implementation of the Finite Element Model, the following procedure was applied:

- Determination of the dimensions of the units sent to the Laboratory (Ref. 2-f) in order to determine the average dimensions typical of the examined product;
- Grinding of the masonry unit presenting the closest dimensions to the average values in order to even the surface. Grinding is necessary to remove burrs resulting from cutting during the extrusion procedure;
- Scanner acquisition of the cross section of the unit and conversion of the image in .jpg format. The geometry chosen to represent the product and to be used for the implementation of the calculation was rectified in order to respect the symmetry of the product resulting from the extrusion process.
- Measurement of the dimensions of voids (shape and interaxis) and of external profiles on the basis of average dimensions determined on the sampling set. Measures were performed using a centesimal caliper.
- Definition, based on aforementioned values, of average geometric dimensions of the product type to employ in the calculation (Figure 2).

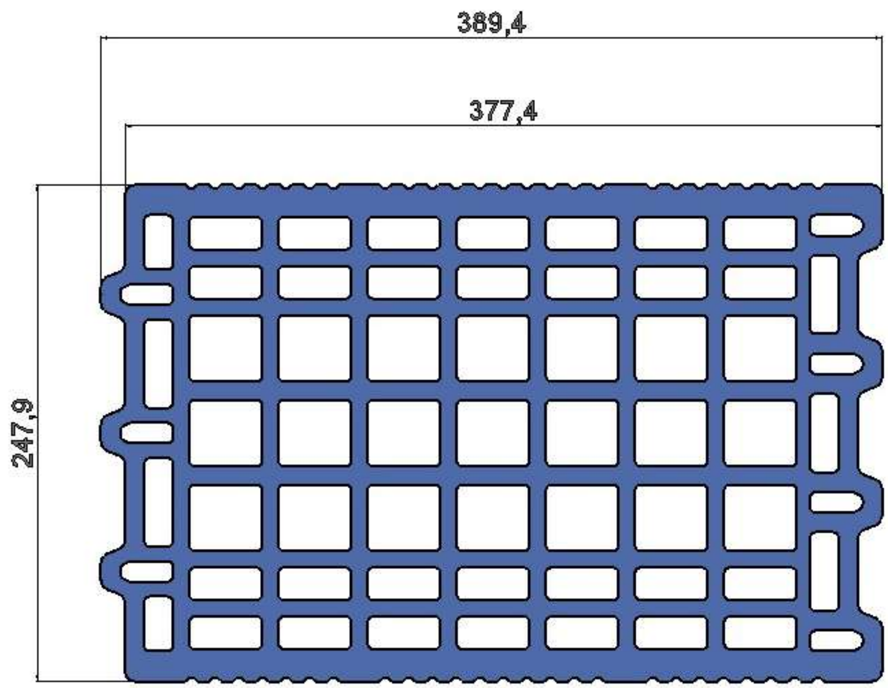


Figure 2. Geometry of the cross section employed for the calculation

4.2 Thermal conductivity of fired clay

Thermal conductivity $\lambda_{10,dry,mat}$ of fired clay was measured experimentally and then the value corresponding to the average density was determined, as described in Ref. 2-d. Hence, based on such elaborations, the following value was used to represent fired clay:

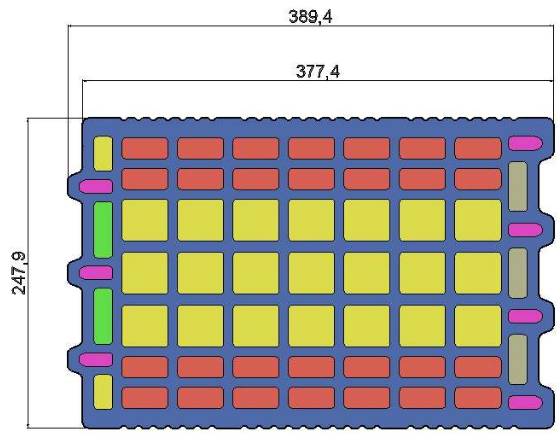
$\lambda_{10,dry,mat}$ = **0.395 [W/mK]**

4.3 Equivalent thermal conductivity of voids

Equivalent thermal conductivity values of air voids were determined according to the methodology outlined in Ref. 2-c and reported in Appendix B of Ref. 2-g, approximating convective and radiative heat transfer inside the void.

The calculation was performed for the only installation mode possible for this product, i.e. with holes axis in vertical position and with the longest sides exposed on the inside and on the outside of the masonry. Air conductivity within voids was referred to 10 °C.

All data related to voids are shown in Figure 3.



Voids	λ_{voids} (W/mk)
A	0,085
B	0,150
C	0,174
D	0,063
E	0,112
F	0,156

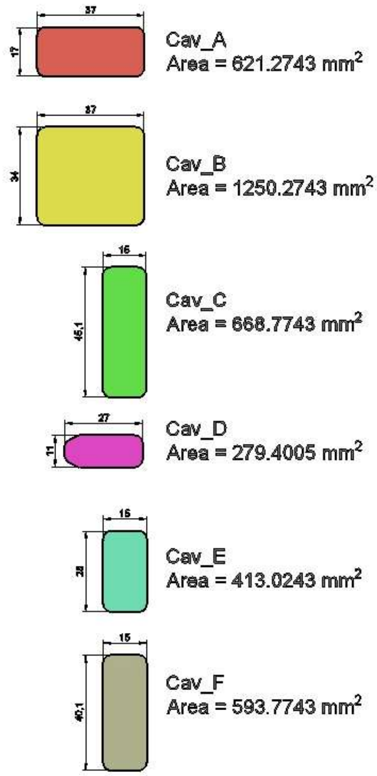


Figure 3. Cross section of the block and air voids data

4.4 Boundary conditions

Ref. 2-c sets boundary conditions for the definition of the model. In particular, it refers to internal and external temperatures and to internal and external superficial thermal resistances. These latter refer to convection and radiation phenomena occurring on the surfaces of the masonry unit and are evaluated in par. 5.2 of Ref. 2-g as follows:

BOUNDARY conditions	
Physical quantity	**Nominal value**
Internal temperature T_i	**20 °C = 293.15 K**
External temperature T_e	**0°C = 273.15 K**
Internal superficial resistance R_{si}	**0.13 m²K/W**
External superficial resistance R_{se}	**0.04 m²K/W**

Table 1. Applied boundary conditions

Boundary conditions were applied considering the longest sides exposed to internal and external environments.

4.5 Type of element and mesh

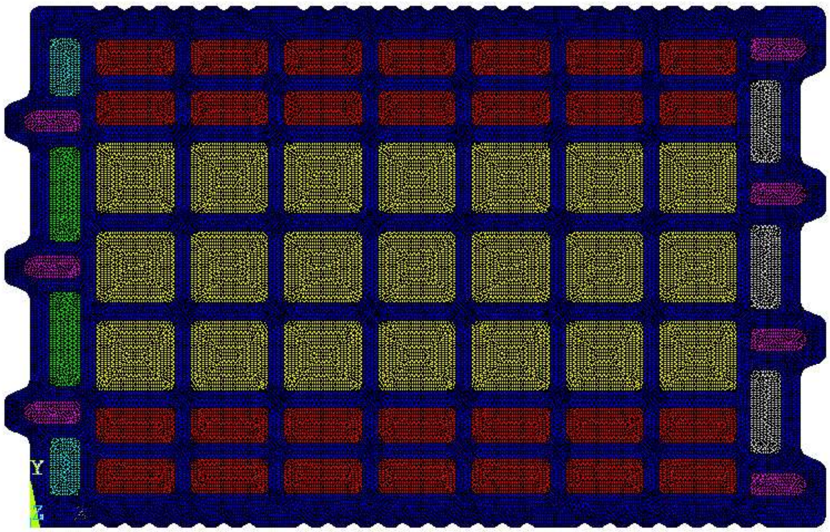


Figure 4. Meshed block

Considering the geometry of the block, the evaluation of its equivalent thermal conductivity by means of FEM was performed using triangular planar elements (plane 55 elements in Ansys 18.2). Mesh refinement (dimensions and distribution of elements) was defined, through the developed method of calculation certification, according to specifications regarding results accuracy reported in Ref. 2-c. Mesh discretization was performed with Ansys 18.2 (Ref. 2-e).

In order to guarantee an accuracy significantly lower than 2%, as required in Ref. 2-c a mesh for the masonry unit model was considered, according to specifications of Ref. 2-d, composed of 217815 elements and 109693 nodes (1 mm long edges on average) (Figure 4).

4.6 Results

The determination of equivalent thermal conductivity of the masonry unit $\lambda_{10,dry,unit}$, performed with thermal conductivity values of the fired clay $\lambda_{10,dry,mat}$ reported in par. 4.2, gave the following results, determined through Ansys output, which is heat flow (W/m) (Table 2).

RESULTS OF FEM CALCULATION					
Heat Flow (W/m)	**Thermal coupling coefficient (W/mK)**	**Thermal Transmittance (W/m²K)**	**Total Thermal Resistance (m²K/W)**	**True Thermal Resistance of the masonry unit (m²K/W)**	**Equivalent thermal conductivity (W/mK)**
Φ	$L^{2D}=\Phi/\Delta T$	$U= L^{2D}/w$	$R_T=1/U$	$R_t=R_T-R_{si}-R_{se}$	$\lambda_{10,dry,unit}=d/ R_t$
5.49835	0.2749	0.7285	1.3728	1.2028	**0.2061**

Table 2. Results

Considering the installation of the units described, in the cross sections of the brick perpendicular to the direction of the thermal flow (1 unit thickness), the value of thermal flux resulting from the finite element model is Φ = 5.49835 W/m.

The entire series of calculations leading to the determination of equivalent conductivity is reported in Table 2. Dividing the heat flow that passes through aforementioned cross sections by the difference in temperature across the masonry (ΔT = 20°C), the thermal coupling coefficient is determined. In turn, dividing this coefficient by the masonry unit length leads to the determination of thermal resistance. Its inverse is the total thermal resistance, which, freed from the contribution of superficial resistances, gives the true thermal resistance of the masonry without convection and radiation. Considering the thickness (Figure 2), the equivalent dry thermal conductivity of the masonry unit can be determined $\lambda_{10,dry,unit}$ = 0.2061 W/mK (Table 2). A comparison between the thermal conductivity of the masonry unit with the one of the fired clay of which it is composed, reported in par. 4.2, it follows that the adopted layout allows reducing the equivalent conductivity of the masonry unit of 47.8%.

Obtained results are reported below, regarding the distribution of isotherms and of average heat flow vectors (Figure 5 and Figure 6).

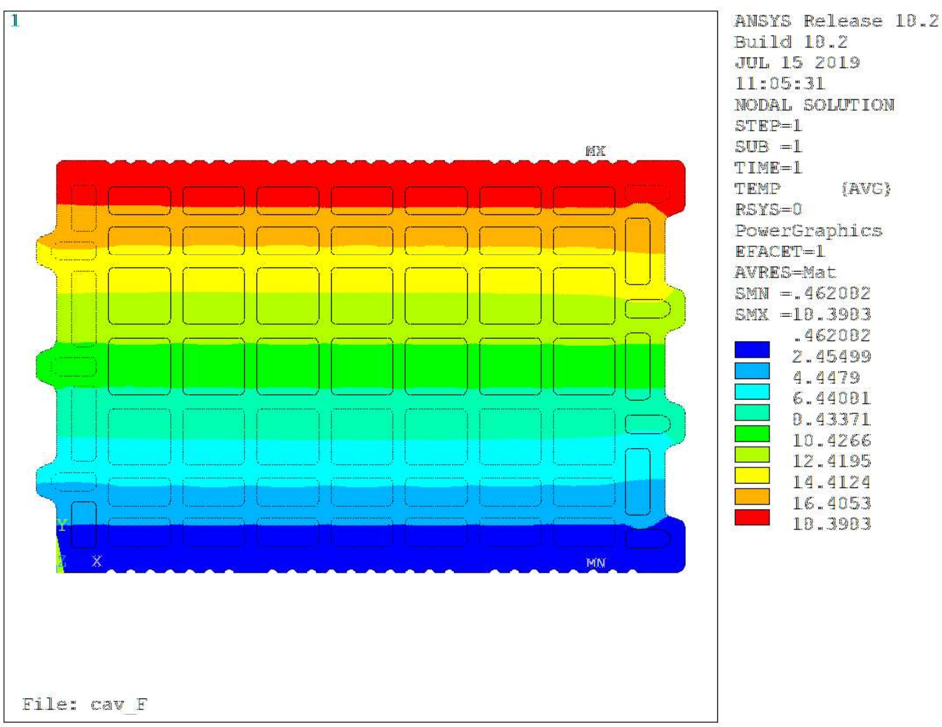


Figure 5. Distribution of isotherms in the block [°C]

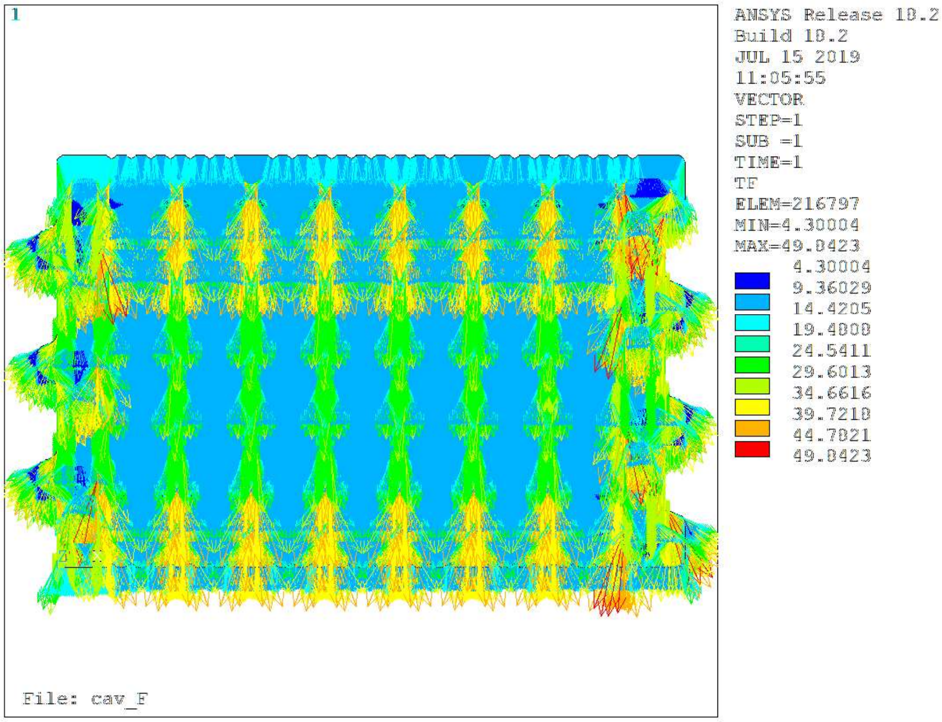


Figure 6. Average heat flow vectors [W/m²]

The calculation outlines an actual improvement of thermal characteristics of the block compared to the constituting material.

5 Determination of thermal values of the masonry

In order to evaluate the thermal values of the masonry, only horizontal mortar joints were considered, without plaster layers. Because of the interlocking block geometry, the vertical joint was not considered. For the evaluation of the thermal values of the masonry, three different configurations were studied:

- 12 mm thick horizontal joints,
- 3 mm thick horizontal joints,
- no horizontal joints.

In all configurations, a traditional mortar with thermal conductivity of 0.9 W/mK was considered.

The masonry was considered as presented in Figure 7.

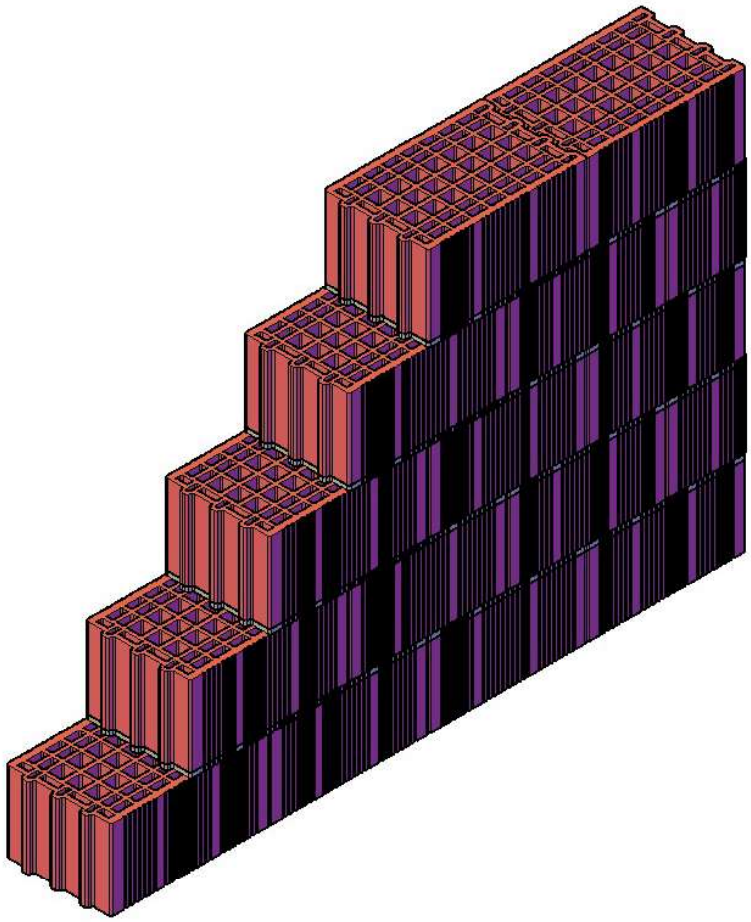


Figure 7. 3D composite masonry considered in the calculation

5.1 Input data

Based on the results of previous paragraphs, a calculation was performed starting from input data about the masonry:

Input data		
	Dimensions (mm)	**Thermal conductivity (W/mK)**
Masonry unit	**377.4 x 247.9 x 190**	**0.2061**
Horizontal traditional mortar joints	Thickness = **12 – 3 – 0**	**0.900**

Table 3. Input data for the calculation

5.2 Results of the calculation

the thermal values of the masonry, in the three configurations described above, are shown below.

a) Traditional configuration: (12 mm thick horizontal joints)

Results for the traditional configuration	
Physical quantity	**Results**
Thermal resistance only of the layer R_t (m^2K/W)	**1.0023**
Equivalent thermal conductivity of the masonry λ_{equ} (W/mK)	**0.2473**
Thermal resistance of the masonry including superficial thermal resistances R_T (m^2K/W)	**1.1723**
Thermal transmittance **U** (W/m^2K)	**0.8530**

Table 4. Results of the calculation for the masonry with 12 mm thick horizontal joints

b) Thin bed mortar configuration (3 mm thick horizontal joints)

Results for the traditional configuration	
Physical quantity	**Results**
Thermal resistance only of the layer R_t (m^2K/W)	**1.1430**
Equivalent thermal conductivity of the masonry λ_{equ} (W/mK)	**0.2169**
Thermal resistance of the masonry including superficial thermal resistances R_T (m^2K/W)	**1.3130**
Thermal transmittance **U** (W/m^2K)	**0.7616**

Table 5. Results of the calculation for the masonry with 3 mm thick horizontal joints

c) No joints configuration

Results for the traditional configuration	
Physical quantity	**Results**
Thermal resistance only of the layer R_t (m^2K/W)	**1.2028**
Equivalent thermal conductivity of the masonry λ_{equ} (W/mK)	**0.2061**
Thermal resistance of the masonry including superficial thermal resistances R_T (m^2K/W)	**1.3728**
Thermal transmittance **U** (W/m^2K)	**0.7284**

Table 6. Results of the calculation for the masonry without mortar joints

6 Conclusions

On the basis of performed calculations, an equivalent value of thermal conductivity for the masonry unit equal to **0.2061 W/mK** was obtained. Calculations performed on the masonry gave a transmittance value of **0.8530 W/m²K** using 12 mm thick horizontal joints, **0.7616 W/m²K** with 3 mm thick horizontal joints and **0.7284 W/m²K** without mortar joints.

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