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CALCULATION REPORT No. 324722

Place and date of issue: Bellaria-Igea Marina - Italy, 21/05/2015

Customer: S.A.C.M.E. SERVICE S.r.l. - Via Primo Maggio, 85 - 33082 AZZANO DECIMO (PN) - Italia

Date calculation requested: 23/04/2015

Order number and date: 66368, 27/04/2015

Date sample received: 05/05/2015

Date drawing received: 24/04/2015

Date calculation performed: from 27/04/2015 to 12/05/2015

Purpose of calculation: determination of thermal properties of masonries and masonry units in accordance with standard UNI EN 1745:2012 using the finite-element calculation method and of dynamic thermal characteristics of masonries in accordance with standard UNI EN ISO 13786:2008

Calculation venue: Istituto Giordano S.p.A. - Blocco 2 - Via Rossini, 2 - 47814 Bellaria-Igea Marina (RN) - Italy

Sample origin: sampled and supplied by STANTAR BETON E.P.E. Kranidi - Argolidas - Greece

Identification of sample received sample: No. 2015/0927

Sample name*

The test sample is called "THERMOBLOCCO DA mm 250-H170-400 A 4 FORI CHIUSI (thickness 250 mm)".

(*) according to that stated by the Customer.

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Description of sample*

The test sample consist of a masonry unit made of concrete with no other aggregate than pumice, nominal dimensions 398 mm × 250 mm × 170 mm, with a shaped panel made of EPS with graphite (maximum thickness 90 mm).

Note: the nominal dimensions are given in length × width × height order, as foreseen by standard UNI EN 771-3§5.2.1 "Dimensions", as a result the second dimension given is the thickness of the masonry without masonry renderings.

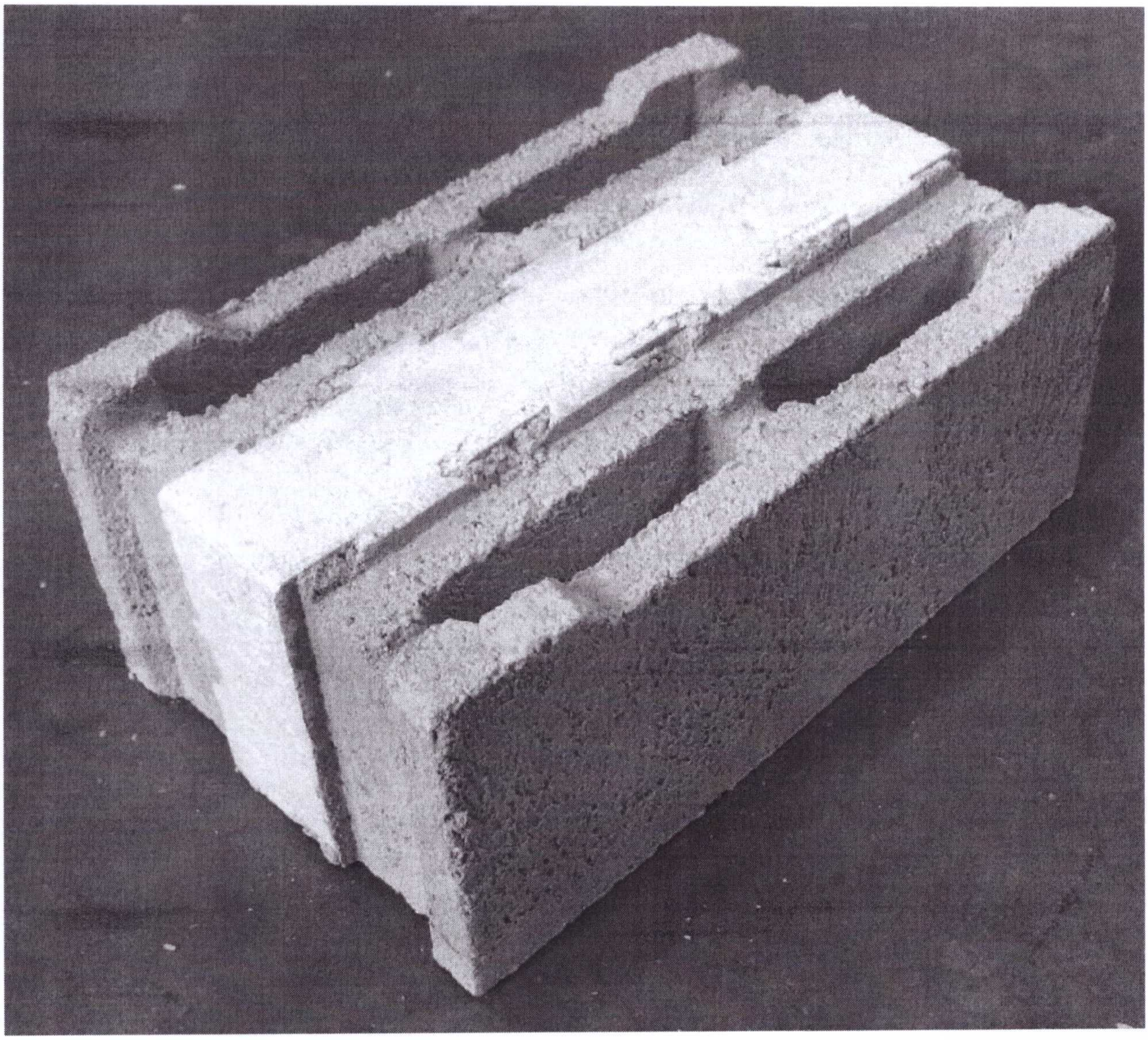

Photo of masonry unit.

(*)according to that stated by the Customer.

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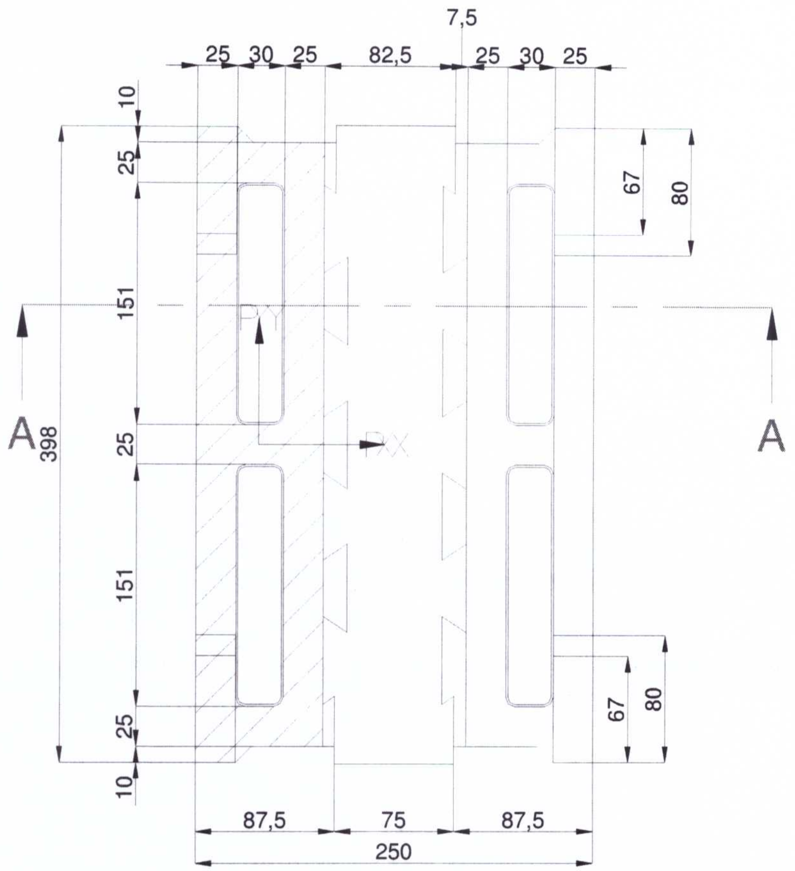
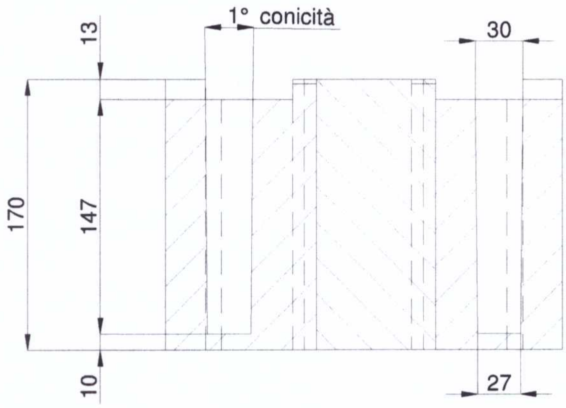
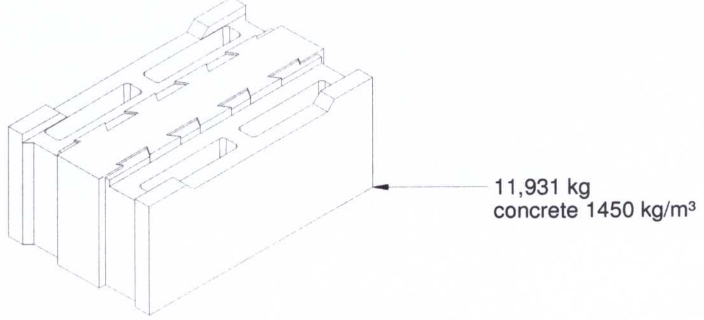
DRAWING OF MASONRY UNIT





SECTION A-A



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Customer-declared data

Masonry unit	**Net dry density (of material) "$\rho_{n,dry}$" and tolerance**	1450 kg/m³	+ 3 % - 0 %
EPS with graphite panel	**Declared thermal conductivity "λ_D" (according to documentation provided by the Customer)**	0,035 W/(m · K)	
	Density	21 kg/m³	

Data obtained from sample

Length "h_{unit}"	398 mm
Width "w" (matches masonry thickness without rendering mortar)	250 mm
Heigth "l" (including upper spacers)	170 mm
Mass of dried masonry unit	11,633 kg
Net dry density (of material) "$\rho_{n,dry}$"*	1442 kg/m³
Gross dry density of masonry unit "$\rho_{g,dry}$"	688 kg/m³

(*) the net dry density was determined as the ratio of the mass of the dried masonry unit to its net volume determined in accordance with subclause 7.2 of standard UNI EN 772-13:2002 dated 01/10/2002 "Metodi di prova per elementi di muratura. Determinazione della massa volumica a secco assoluta e della massa volumica a secco apparente degli elementi di muratura (ad eccezione della pietra naturale)" *("Methods of test for masonry units. Determination of net and gross dry density of masonry units (except for natural stone)")*.

Normative references

The analysis was performed in accordance with the requirements of the following standards:

- UNI EN 771-3:2011 dated 16/06/2011 "Specifica per elementi per muratura. Parte 3: Elementi di calcestruzzo vibrocompresso (aggregati pesanti e leggeri) per muratura" *("Specification for masonry units. Part 3: Aggregate concrete masonry units (Dense and lightweight aggregates)")*;
- UNI EN 1745:2012 dated 14/06/2012 "Muratura e prodotti per muratura. Metodi per determinare i valori termici" *("Masonry and masonry products. Methods for determining design thermal values")*, subclauses 5 "Procedures to determine equivalent $\lambda_{10,dry,unit}$ values for masonry units with formed voids and composite masonry units", 5.2 "Calculation method" and 7.2.2 "$R_{design,mas}$ or $\lambda_{design,mas}$ values using a numerical calculation method based on the design thermal conductivity of the material used";

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- UNI EN ISO 13786:2008 dated 22/05/2008 "Prestazione termica dei componenti per edilizia. Caratteristiche termiche dinamiche. Metodi di calcolo" *("Thermal performance of building components. Dynamic thermal characteristics. Calculation methods");*
- UNI EN ISO 6946:2008 dated 17/07/2008 "Componenti ed elementi per edilizia. Resistenza termica e trasmittanza termica. Metodo di calcolo" *("Building components and building elements. Thermal resistance and thermal transmittance. Calculation method");*
- UNI EN ISO 10456:2008 dated 22/05/2008"Materiali e prodotti per edilizia. Proprietà igrotermiche. Valori tabulati di progetto e procedimenti per la determinazione dei valori termici dichiarati e di progetto" *("Building materials and products. Hygrothermal properties. Tabulated design values and procedures for determining declared and design thermal values").*

Calculation method and conditions

Calculation of (steady-state) thermal characteristics of masonry units and masonries.

The calculation was performed on the basis of the sample supplied by the Customer, under dry conditions and without masonry mortar joints or rendering mortar.

The calculation of the (steady-state) thermal characteristics was performed either on the masonry unit alone, either on the masonry.

The thermal analysis has the purpose of determining the "declared thermal properties" of the masonry unit and of the masonry, under reference conditions.

The analysis concerning the masonry unit is made under dry conditions without masonry mortar joints or rendering mortar, while that of masonry is made considering also the masonry mortar joints, the rendering mortar and the influence of moisture content in standard equilibrium conditions.

The analysis was performed in accordance with the requirements of subclauses 5.3.2.3 "Model P4. Determination of $\lambda_{10,dry,unit}$ values using tabulated value from Annex A" and 7.2.2 "$R_{design,mas}$ or $\lambda_{design,mas}$ values using a numerical calculation method based on the design thermal conductivity of the material used" by applying the finite-element method to 2-dimensinal plane sections of the masonry unit and the masonry, using a calculation programme meeting the requirements of Annex D "Requirements for appropriate calculation procedures" of standard UNI EN 1745.

Voids were assessed by calculating the corresponding equivalent thermal conductivity value in accordance with the provisions of Annex B "Thermal resistance of airspaces" of standard UNI EN ISO 6946.

Conditions used for masonry unit thermal analysis.

Steady-state thermal performance of the masonry unit (thermal resistance and equivalent thermal conductivity) was assessed under the conditions specified in Table 1 "Declared value conditions" of standard UNI EN ISO 10456, for the set of conditions "Ia":

- reference temperature: 10 °C;
- moisture: "u_{dry}" (dried material).

The thermal conductivity of the masonry unit's constituent material was determined in accordance with subclause 5.3.2.3 of standard UNI EN 1745, by interpolating the data provided by TableA.9 "Concrete units with other lightweight aggregates" with the net dry density supplied by the Customer.

Finite-element thermal analysis was performed on a 2-dimensional section parallel to the heat flow and perpendicular to the unit's perforation direction.

Conditions used for masonry thermal analysis.

The masonry hypothesized in the calculations consists of the masonry units under examination with vertical voids, masonry mortar joints interrupted near the EPS with graphite panel, of which the horizontal of thickness of 13 mm (imposed by 4 upper spacers) and the vertical inside the perimeter pockets.

Steady-state thermal performance of the masonry was assessed under the conditions specified in Table 1 "Declared value conditions" of standard UNI EN ISO 10456, for the set of conditions "Ib":

- reference temperature: 10 °C;
- moisture: "$u_{23,50}$" (moisture content in equilibrium with air at 23 °C and relative humidity of 50 %).

The thermal conductivity value of the material constituting the masonry unit was calculated by applying the formulas for calculating the design thermal conductivity of clause 6 "Moisture conversion" of standard UNI EN 1745, to the thermal conductivity value previously used for calculating the thermal characteristics of the masonry unit, with the moisture content of Table 4 "Moisture properties and specific heat capacity of thermal insulation materials and masonry materials" of standard UNI EN ISO 10456.

The thermal conductivity of the masonry mortar and rendering mortar was determined by interpolating the data provided by Table A.12 "Mortar (masonry mortar and rendering mortar)" for the fractile P = 50% and applying the formulas for calculating the design thermal conductivity of clause 6 of standard UNI EN 1745, with the moisture content of Table 4 of the UNI EN ISO 10456.

Finite-element thermal analysis was performed on a 2-dimensional section parallel to the heat flow direction and perpendicular to the unit's perforation direction.

To take into account the horizontal masonry mortar, a finite-element thermal analysis was performed on a section parallel to the direction of heat flow and perpendicular to the section previously considered.

To take account of masonry mortar penetration into the voids, the thickness of the masonry mortar perpendicular to the voids axis has been increased by 5 mm.

To take into account of the filling concrete a finite-element thermal analysis was performed on a section parallel to the first one in correspondence of the filling concrete.

The thermal transmittance value of the masonry was calculated according to clause 8 "Determination of the thermal transmittance of masonry" considering the masonry with rendering mortar of thickness 20 mm applied on both sides.

Calculation of dynamic thermal characteristics of masonries.

The calculation was performed on the basis of the sample supplied by the Customer.

The masonry hypothesised and the conditions used in the calculations are the same used for the steady-state thermal analysis of the masonry.

The analysis was carried out considering the masonry consisting of homogeneous layers parallel to the masonry surfaces and perpendicular to the heat flow, ignoring the influence of thermal bridges as provided in subclause 6.1 of standard UNI EN ISO 13786.

The non-homogeneous layers made of concrete, voids and masonry mortars joints (horizontal and vertical) have been described with a homogeneous equivalent material (referred to as "equivalent concrete"), whose equivalent density and equivalent specific heat capacity values were determined as weighted average (of the concrete, voids and masonry mortars) and equivalent thermal conductivity value was determined in order to find the same steady-state thermal transmittance value.

As specific heat capacity of the material constituting the masonry unit, the rendering mortars (inside and outside) and the masonry mortar, the value of 1000 J/(kg · K) was used, obtained from tables A.4 and A.12 of standard UNI EN 1745.

The value of 1450 J/(kg · K) was used for the EPS with graphite panel, obtained from Table 4 of standard UNI EN ISO 10456.

All dynamic thermal characteristics have been calculated for thermal variations with a period of the variations "T" of 24 h.

Calculation data

Data for determining thermal characteristics of masonry units.

<table>
<tr><td rowspan="6">Masonry unit</td><td>Voids</td><td colspan="2">vertical non completely passing</td></tr>
<tr><td>Material</td><td colspan="2">concrete with no other aggregate than pumice</td></tr>
<tr><td>Net dry density (of material)
(value measured on masonry unit supplied by the Customer)</td><td colspan="2">1442 kg/m³</td></tr>
<tr><td rowspan="2">Net dry density (of material)
(data provided by the Customer)</td><td rowspan="2">1450 kg/m³</td><td>+ 3 %</td></tr>
<tr><td>- 0 %</td></tr>
<tr><td>Net dry density (of material) used for calculations “$\rho_{n,dry}$”</td><td colspan="2">1450 kg/m³</td></tr>
<tr><td></td><td>Thermal conductivity of dried material “$\lambda_{10,dry,mat}$”
(UNI EN 1745 - Table A.9 “Concrete units with other light-weight aggregates”)</td><td colspan="2">0,700 W/(m · K)</td></tr>
<tr><td>EPS with graphite panel</td><td>Declared thermal conductivity “λ_D”
(according to documentation provided by the Customer)</td><td colspan="2">0,035 W/(m · K)</td></tr>
<tr><td colspan="2">Internal environment temperature “T_i”</td><td colspan="2">20 °C</td></tr>
<tr><td colspan="2">External environment temperature “T_e”</td><td colspan="2">0 °C</td></tr>
<tr><td colspan="2">Internal surface resistance “R_{si}”
(UNI EN ISO 6946 § Table 1 “Conventional surface resistances - Direction of heat flow downwards”)</td><td colspan="2">0,13 m² · K/W</td></tr>
<tr><td colspan="2">External surface resistance “R_{se}”
UNI EN ISO 6946 § Table 1 “Conventional surface resistances - Direction of heat flow downwards”)</td><td colspan="2">0,04 m² · K/W</td></tr>
</table>

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Data for determining thermal characteristics of masonries.

MASONRY UNIT		
Voids	vertical non completely passing	
Material	concrete with no other aggregate than pumice	
Net dry density (of material) (value measured on masonry units supplied by the Customer)	1442 kg/m³	
Net dry density (of material) (data provided by the Customer)	1450 kg/m³	+ 3 % - 0 %
Net dry density (of material) used for calculations "$\rho_{n,dry}$"	1450 kg/m³	
Thermal conductivity of dried material "$\lambda_{10,dry,mat}$" (UNI EN 1745 - Table A.9 "Concrete units with other lightweight aggregates")	0,700 W/(m · K)	
Moisture conversion coefficient "f_ψ" (UNI EN 1745 - Table A.9)	4	
Moisture content by volume of material "Ψ"(UNI EN ISO 10456 - Table 4 "Concrete units with other lightweight aggregates", at T = 23 °C and UR = 50 %)	0,030 m³/m³	
Moisture conversion factor "F_m" of thermal conductivity of material	1,127	
Thermal conductivity of material "$\lambda_{design,mat}$" at set of conditions "Ib"	0,789 W/(m · K)	
Specific heat capacity "c_p" (UNI EN 1745 - Table A.4) (UNI EN 1745 - Table A.9)	1000 J/(kg · K)	

EPS WITH GRAPHITE PANEL	
Density (data provided by the Customer)	21 kg/m³
Declared thermal conductivity "λ_D" (according to documentation provided by the Customer)	0,035 W/(m · K)
Specific heat capacity "c_p" (UNI EN ISO 10456 - Table 4 "Expanded polystyrene")	1450 J/(kg · K)

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MASONRY MORTAR	
Description	Vertical: inside perimeter pockets and interrupted near the EPS with graphite panel. Horizontal: interrupted near the EPS with graphite panel.
Dry density	1700 kg/m³
Thermal conductivity in dry state "$\lambda_{10,dry,mor}$" (UNI EN 1745 - Table A.12 "Mortar (masonry mortar and rendering mortar))	0,715 W/(m · K)
Moisture conversion coefficient "f_Ψ" (UNI EN 1745 - Table A.12)	4
Moisture content by volume "Ψ" (UNI EN ISO 10456 - Table 4 "Mortar (masonry mortar and rendering mortar)", at T = 23 °C and UR = 50 %)	0,04 m³/m³
Moisture conversion factor "F_m" of thermal conductivity	1,174
Thermal conductivity "$\lambda_{design,mor}$" at set of conditions "Ib"	0,839 W/(m · K)
Specific heat capacity "c_p" (UNI EN 1745 - Table A.12)	1000 J/(kg · K)
Thickness of vertical joints "h_{mor}"	20 mm
Thickness of horizontal joints "h_{mor}"	(13 + 5 *) mm

(*) Increase which takes account of the masonry mortar penetration into the voids.

RENDERING MORTARS	
Moisture conversion coefficient "f_Ψ" (UNI EN 1745 - Table A.12)	4
Moisture content by volume "Ψ" (UNI EN ISO 10456 - Table 4 "Mortar (masonry mortar and rendering mortar)", at T = 23 °C and UR = 50 %)	0,04 m³/m³
Moisture conversion factor "F_m" of thermal conductivity	1,174
Dry density	1400 kg/m³
Thermal conductivity in dry state "$\lambda_{10,dry,mor}$" (UNI EN 1745 - Table A.12)	0,450 W/(m · K)
Thermal conductivity "$\lambda_{design,mor}$" at set of conditions "Ib"	0,528 W/(m · K)
Specific heat capacity "c_p" (UNI EN 1745 - Table A.12)	1000 J/(kg · K)
Thickness	20 mm

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Internal environment temperature "T_i"	20 °C
External environment temperature "T_e"	0 °C
Internal surface resistance "R_{si}" (UNI EN ISO 6946 § Table 1 "Conventional surface resistances - Direction of heat flow downwards")	0,13 m² · K/W
External surface resistance "R_{se}" (UNI EN ISO 6946 § Table 1 "Conventional surface resistances - Direction of heat flow downwards")	0,04 m² · K/W

Masonry schematisation for calculation of dynamic thermal characteristics.

The masonry has been described by the following layers:

MASONRY LAYERS				
Material	**Thickness "d"** [mm]	**Thermal conductivity "λ"** [W/(m · K)]	**Density "ρ"** [kg/m³]	**Specific heat capacity "c_p"** [J/(kg · K)]
Inside rendering mortar	20	0,528	1400	1000
Inside equivalent concrete	87,5	0,849	1130	1000
EPS with graphite panel	75	0,035	21	1450
Outside equivalent concrete	87,5	0,849	1130	1000
Outside rendering mortar	20	0,839	1700	1000

Mass per unit area of masonry without rendering mortars	200 kg/m²
Mass per unit area of masonry with rendering mortars	264 kg/m²

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Calculation result

The thermal properties, calculated using the thermal conductivity data of masonry unit material of standard UNI EN 1745 - Table A.9 "Concrete units with other lightweight aggregates", are as follows:

Steady-state thermal characteristics of masonry unit.

Thickness of masonry unit "w"	250 mm	
Mass of dried masonry unit	11,445 kg	
Net dry density (of material) (value measured on masonry unit supplied by the Customer)	1442 kg/m³	
Net dry density (of material) (data provided by the Customer)	1450 kg/m³	+ 3 %
		- 0 %
Net dry density (of material) used for calculations "$\rho_{n,dry}$"	1450 kg/m³	
Masonry unit equivalent thermal conductivity in dry state "$\lambda_{10,dry,unit}$" (Set of conditions "Ia" *)	**0,104 W/(m · K)**	

(*) Set of conditions "Ia" - UNI EN ISO 10456 - Table 1:

- reference temperature: 10 °C;
- low moisture content reached by drying material.

Steady-state thermal characteristics of masonry.

The masonry defined in the previous clauses provides the following characteristics:

Thickness of masonry without rendering mortars "w"	250 mm	
Net dry density (of material) (value measured on masonry unit supplied by the Customer)	1442 kg/m³	
Net dry density (of material) (data provided by the Customer)	1450 kg/m³	+ 3 %
		- 0 %
Net dry density (of material) used for calculations "$\rho_{n,dry}$"	1450 kg/m³	
Thermal resistance of masonry without rendering mortars "$R_{design,mas}$" (Set of conditions "Ib" **)	**2,35 m² · K/W**	
Thermal transmittance of masonry with rendering mortars "$U_{design,mas}$" (Set of conditions "Ib" **)	**0,388 W/(m² · K)**	

(**) Set of conditions "Ib" - UNI EN ISO 10456 - Table 1:

- reference temperature: 10 °C;
- moisture content in equilibrium with air at 23 °C and relative humidity of 50 %.

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Dynamic thermal characteristics of masonry.

The masonry defined in the previous clauses provides the following characteristics:

TRANSFER MATRIX		
Matrix elements	**Modulus**	**Argument**
Z_{11}	28,0	2,61 rad
Z_{12}	6,08 m² · K/W	-1,08 rad
Z_{21}	210 W/(m² · K)	0,39 rad
Z_{22}	45,6	2,98 rad

DYNAMIC THERMAL CHARACTERISTICS OF MASONRY		
	Modulus	**Time shift**
Internal thermal admittances "Y_{11}"	4,60 W/(m² · K)	2,10 h
External thermal admittance "Y_{22}"	7,51 W/(m² · K)	3,52 h
Internal areal heat capacity "k_1"	65,2 kJ/(m² · K)	-
External areal heat capacity "k_2"	106 kJ/(m² · K)	-
Steady-state thermal transmittance "U_0"*	**0,388 W/(m² · K)**	**-**
Periodic thermal transmittance "Y_{12}"	**0,165 W/(m² · K)**	**-7,88 h**
Decrement factor "f"	**0,425**	-

(*) The steady-state thermal transmittance "U_0" does not consider the effects of thermal bridges, so it may not be used to assess masonry's heat loss.

The above characteristics have been calculated for a period of the variations "T" of 24 h.

Note: – the masonry unit's thermal properties calculated with material in dry state may be used for the declaration of the unit's thermal properties, but may not be used "as is" to determine heat loss of the masonry built from such units, since they do not take account of masonry mortar joints and of moisture content;

– the masonry's thermal properties "$R_{design,mas}$" and "$U_{design,mas}$" may be used to determine heat loss of the masonry provided that the conditions assumed in the calculation correspond to the operating conditions. If moisture contents are different from those assumed for this calculation, the thermal properties should be corrected as prescribed by standard UNI EN 1745;

– masonry unit and of the masonry's thermal properties may be compared with those of other products only if they have been determined with the same procedure, in the same conditions and for the same fractile and confidence level.

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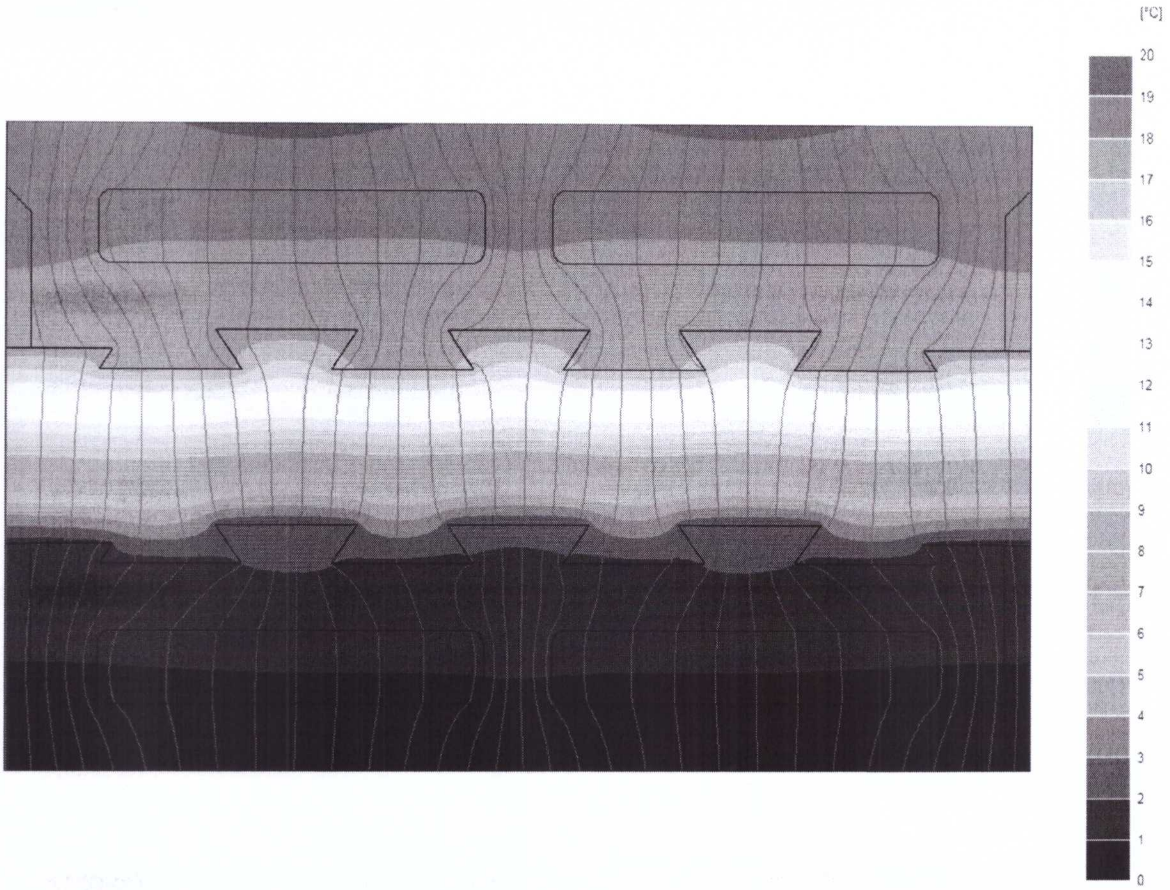
ISOTHERMS AND FLOW LINES FOR THE SECTION OF MASONRY CONSIDERED



Test Technician	Head of Heat Transfer Laboratory	Chief Executive Officer
(Dott. Ing. Paolo Ricci)	(Dott. Floriano Tamanti)	(Dott. Arch. Sara Lorenza Giordano)

Firmato digitalmente da GIORDANO SARA LORENZA